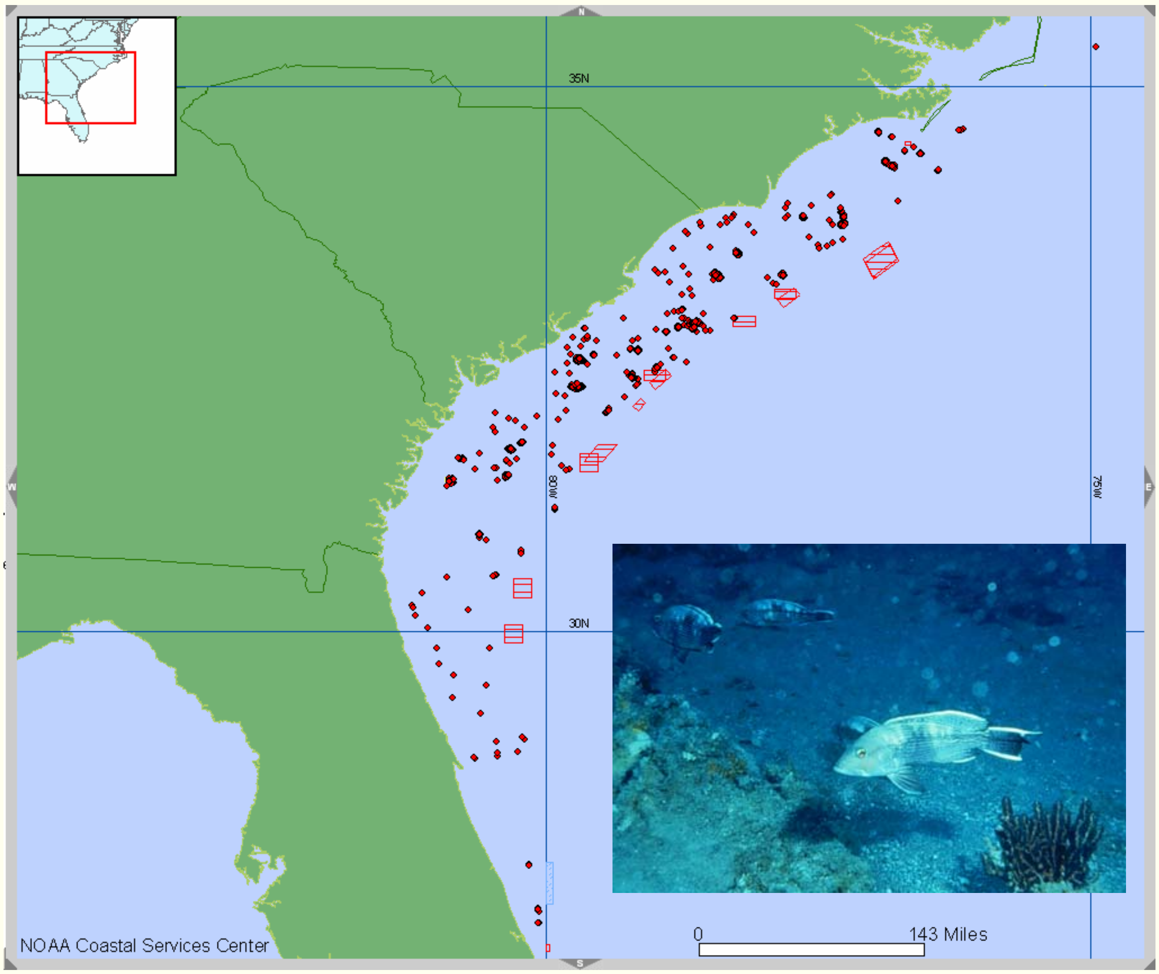
GIS Analysis of Fishery-Independent Data in Relation to Definition of Essential Fish Habitat, Habitat Areas of Particular Concern, and Marine Protected Areas in the South Atlantic Bight

Final Project Report

by

G.R. Sedberry, P. Weinbach, J.A. Stephen, D.J. Machowski, J.K. Loefer, D. dosReis, K. Draganov and S.B. Griffin



Prepared By:
South Carolina Department of Natural Resources
Marine Resources Research Institute
P.O. Box 12559
Charleston, South Carolina 29422-2559
Project Number NA17FF2874

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George R. Sedberry, Principal Investigator
Philip Weinbach, Co-Principal Investigator
Jessica A. Stephen
Daniel J. Machowski
Joshua K. Loefer
David dosReis
Kyle Draganov
Sarah B. Griffin

Principal Investigator Affiliation:
South Carolina Department of Natural Resources
P.O. Box 12559
Charleston SC 29412

Grant Number NA17FF2874

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ABSTRACT

This document describes the results of a project aimed at building a readily accessible database that includes data collected during a regional (North Carolina to Florida) multi-gear fishery-independent survey of a variety of fish habitats on the continental shelf and upper slope. Data were collected with a variety of fisheries and oceanographic sampling gear from 1973 to 2004 and incorporated into a relational database (Microsoft Access) with a user-friendly interface. A subset of the data, that includes all station data and data for some economically valuable and ecologically dominant species, has been included in an internet map server called the SEA-GEOFISH (SouthEAst GEOgraphic Fishery-Independent Survey and Historical) Database (http://www.csc.noaa.gov/seageofish/) and on a CD-ROM that accompanies this report.

EXECUTIVE SUMMARY

This project utilized data collected during a fishery-independent survey of the continental shelf from southern North Carolina to southern Florida. Most sampling effort concentrated off South Carolina and Georgia and used fishing gear such as trawls, baited traps and baited hooks, as well as oceanographic and plankton sampling gear. Over 29,000 collections were made between 1973 and 2004. Data from 2601 bottom trawl collections (years 1973-1987), 11,639 fish trap collections (1977-2004), 2240 baited hook collections (1977-2004), 2521 plankton collections (1973-1986), 6247 hydrographic stations (1973-2004) and other collections and observations were compiled into the database. The goal of the project was developing a Geographic Information System (GIS) to allow the presentation of fishery-independent survey data and fishery-dependent data in maps and data layers that can enable users to determine areas that might contain Essential Fish Habitat (EFH) or Habitat Areas of Particular Concern (HAPC), such as spawning locations or areas of high fish diversity. The database and GIS that were developed can be used to describe and visualize distribution, abundance, biomass, diversity and spawning locations for priority fishery species and other fishes. The project has pinpointed locations that were historically (or currently are) above average in biomass and diversity of fish assemblages, and may constitute areas for consideration as Marine Protected Areas (MPAs). The database also contains information on hydrographic conditions and bottom type (including some bottom images). Much of the database was incorporated into an Internet Map Server (IMS) built with ArcIMS software, and housed at the National Oceanic and Atmospheric Administration's Coastal Services Center (CSC). The ArcIMS site is called the SEA-GEOFISH (SouthEAst GEOgraphic Fishery-Independent Survey and Historical) Database, and can be accessed at http://www.csc.noaa.gov/seageofish/.

To accomplish the goal, we formatted data collected during the cooperative Marine Resources Monitoring, Assessment and Prediction (MARMAP) program of the NOAA Fisheries Service (National Marine Fisheries Service) and the South Carolina Department of Natural Resources (SCDNR) into a relational database (Microsoft Access). Data from additional fisheries projects (e.g., Marine Fisheries Initiative, Saltenstall-Kennedy Act) were incorporated into the database so that the data could be queried to build shapefiles and a GIS. The fishery-independent data, some fishery-dependent data (and metadata) were used with the existing Southeast Area Monitoring and Assessment Program-South Atlantic (SEAMAP-SA) bottom mapping database in order to correlate fish distribution data with habitat type. Some limited bottom images were also incorporated, so that habitat at several important fishing and fish spawning areas can be viewed. The project also integrated MARMAP and other hydrographic databases into the GIS so that users can correlate fish distribution with hydrographic parameters.

Spatial analyses that were performed included mapping of sampling sites for all fishing and hydrographic gears and distribution maps of ecologically dominant or economically valuable fishes, including forage species. For some species or higher taxa, this included maps of distribution of larval, juvenile, adult and spawning fish, along with documentation of bottom and hydrographic features. Length frequency data were incorporated into the database and can be accessed at the ArcIMS site. Overall biomass, abundance (based on catch per unit of effort) and diversity were also mapped.

The GIS and database were incorporated into a web-based framework made available to scientists, resource managers and the general public, to more effectively plan future mapping, exploration, and management in the South Atlantic Bight.

PURPOSE

In the re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act, through the Sustainable Fisheries Act, the U.S. Congress included provisions that required regional Fishery Management Councils (FMCs) to identify essential fish habitat (EFH). Such EFH should include "those waters and substrate necessary to fish for spawning, feeding or growth to maturity" (MSFMCA 1996; Schmitten 1999). While the definition is broad in scope, and perhaps includes most aquatic habitats, it is important to identify those regions and habitats that are essential for various life history stages of fishes of economic importance. Such essential areas could include specific substrates (e.g., reefs), hydrographic regimes (e.g., upwelling zones), species associations (e.g., sponge and/or coral) and unknown factors that result in high abundance, biomass, diversity or spawning potential of fishes. The Magnuson Act re-authorization also provided for recognition of Habitat Areas of Particular Concern (HAPC) for various fish stocks or assemblages (e.g., Murawski et al. 2000; Reed 2000). HAPC are locations where some user activities (e.g., trawling, bottom longlining) are banned because of particularly sensitive habitats or species assemblages such as ivory tree coral (*Oculina varicosa*) and associated organisms (Reed 2000). The National Oceanic and Atmospheric Administration (NOAA) Marine Protected Areas Center defines HAPC as "a habitat area designated by an FMC under the Magnuson-Stevens Fishery Conservation and Management Act of 1976 to help focus conservation efforts on localized areas that are vulnerable to degradation or are especially important ecologically". HAPCs can be designated by the regional FMCs to provide a mechanism to acknowledge areas where more is known about the ecological function and/or vulnerability of portions of EFH (Federal Register 2002). HAPCs are areas designated by regional FMCs as EFH that plays an especially important role in the life history of managed species, or which may be vulnerable to degradation as a result of human activities. EFH regulations [Section 600.815(a)(9)] encourage the FMCs to identify HAPCs based on one or more of the following considerations (Federal Register 2002):

1. The importance of the ecological function provided by the habitat.
2. The extent to which the habitat is sensitive to human-induced environmental degradation.
3. Whether, and to what extent, development activities are, or will be, stressing the habitat type.

4. The rarity of the habitat type.

In order to manage fisheries under EFH and HAPC provisions, it is necessary to recognize and map EFH and HAPC, and to more clearly define it in relation to the fishery management unit [e.g., the Snapper/Grouper Management Unit of the South Atlantic Fishery Management Council (SAFMC)]. As a first step, it is essential to map distributions of fishery species of concern. Additional mapping is needed of important spawning and nursery areas, substrates occupied by priority species, and areas of particularly high biomass, abundance and diversity of priority species, forage fishes and other fishes in the ecosystem. Because many snappers (Lutjanidae), groupers (Serranidae) and other species of the SAFMC management units are piscivores (Parrish 1987), the locations of high biomass of forage species [e.g., herrings (Clupeidae), anchovies (Engraulidae), scads (Carangidae)] might also constitute EFH or HAPC. Knowledge of distribution and abundance of concentrations of forage species is needed to develop ecosystem-based fishery management plans (EPAP 1998; Okey and Pauly 1999; Pauly et al. 2000).

Off the southeastern United States, priority species and habitats for EFH and HAPC consideration include the 73 species of the Snapper/Grouper Management Unit (e.g., snappers, groupers, porgies, grunts, tilefishes) and their hard-bottom and sponge-coral habitats (Coleman et al. 2000). This project primarily addressed EFH and HAPC issues in the Snapper/Grouper fishery, but includes data on adults and larvae of coastal pelagic species (e.g., mackerels, herrings) and some highly migratory species (e.g., billfishes).

The South Carolina Department of Natural Resources (SCDNR) and its predecessor agency has conducted research since 1973 on the continental shelf and slope off the southeastern U.S., in an area often referred to as the South Atlantic Bight (SAB), from Cape Hatteras to Cape Canaveral. Some surveys have extended south to about Palm Beach FL, and offshore to the Blake Plateau and Charleston Bump (Sedberry et al. 2001). Through cooperative programs with federal agencies such as the NOAA National Marine Fisheries Service (NMFS or NOAA Fisheries or NOAA Fisheries Service) and the Minerals Management Service (MMS), the SCDNR has conducted basic descriptive faunal surveys, fishery assessment surveys, monitoring surveys, and studies directed at specific resource management problems. Surveys have included trawl, trap, longline, hydrographic, benthic and ichthyoplankton sampling (e.g., Wenner 1983; Wenner et al. 1983; Mathews and Pashuk 1986; Collins and Stender 1987; McGovern, Sedberry and Harris 1998; Harris et al. 2001). Various cooperative state-federal projects (e.g., MARMAP, MARFIN) at SCDNR have conducted detailed life history studies of many fishes. These have included descriptions of age and growth (e.g., White et al. 1998; Loefer and Sedberry 2003), reproduction (e.g., McGovern et al. 1998; Sedberry et al. in press), feeding habits (e.g., Sedberry and Cuellar 1993; Weaver and Sedberry 2001), early life history (e.g., Olney and Sedberry 1983; Keener et al. 1988), movements determined by tagging (Loefer and Sedberry 2005; McGovern et al. 2005), and population genetics (e.g., Sedberry et al. 1996; Zatcoff et al. 2004). Ichthyoplankton (1973-1984), trawl (1973-1987) and trap (1978-2004) studies have included region-wide annual (or more frequent) sampling cruises. Studies of reproductive biology of reef fishes have included determination of spawning times and frequencies (e.g., Harris et al. 2004; Sedberry et al. in press). Tagging studies have indicated movements to locations suspected to be spawning grounds (McGovern et al. 2005).

Data collected from the above published studies and a substantial database on other species of the region, collected from 1973 through 2004, were used for additional analysis with the goal of using recently developed spatial and geographic analysis tools unavailable or not considered when the original data analyses were performed. Spatial analysis tools such as GIS can be used on these databases to determine areas that support greater abundance, biomass and/or diversity of fishes. The databases can also be examined to describe distribution of individual species in relation to bottom and hydrographic features, where those features have been mapped. The databases can be queried for locations of fish in spawning condition, locations where large numbers of juveniles are found (recruitment areas) and locations where early larvae of priority species are found (spawning areas). We proposed to conduct such analyses, with the goal of determining locations of EFH and HAPC, and sensitive areas that might need intensive management in the form of Marine Protected Areas (MPAs). Such MPAs could include areas where bottom fishing is prohibited (SAFMC 2004). It is thought that such MPAs are needed to restore declining stocks of reef fishes in the SAB (PDT 1990).

Mapping of EFH and HAPC for reef fishes off the southeastern U.S. Atlantic coast is of particular importance at this time. 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 (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 SAB appear to be particularly at risk, and many species are severely overfished or in danger of being so (e.g., Coleman et al. 2000; Musick et al. 2000; Wyanski et al. 2000; Harris et al. 2001; NMFS 2005). Goliath grouper and Nassau grouper, while uncommon in the SAB, have been so heavily overfished in the southeastern U.S. that they have been considered for Endangered Species Act listing (Sadovy and Eklund 1999). Warsaw grouper and speckled hind, formerly common groupers of the SAB, may soon follow (Huntsman 1996a; Huntsman 1996b; Coleman et al. 2000). The fishery for red porgy 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.

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, Sedberry and Harris 1998). 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 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 such as gag. Circumstantial evidence includes long-distance migrations that 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. 2005). Additional circumstantial evidence for spawning aggregations of gag in the SAB includes capture of fish in spawning condition (presence of hydrated oocytes or post-ovulatory folicles) at specific depths such as deep shelf-edge reefs (see below). Such capture might represent spawning aggregations from traditional spawning sites that should certainly be classified as EFH. If fishermen target these aggregations, additional HAPC consideration should be given so that such spawning sites can be protected during the spawning season. If such spawning sites are used for many species for much of the year, additional protection should be provided in the form of no-take MPA designation.

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 (e.g., 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 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; Paffenhöffer et al. 1984; Mathews and Pashuk 1986). Small and 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 (the "Daytona upwelling") 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 (Sedberry et al. 2001; Govoni and Hare 2001). It is likely that spawning of gag 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 31°N to 33°N (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. Such areas might be considered EFH or HAPC, and it is important to map prominent and persistent hydrographic features in relation to distribution of fish larvae, juveniles and adults to determine the spatial relationships among life history stages and hydrographic features.

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, Sedberry and Harris 1998). As a result of this overfishing and the inability of traditional methods to reverse this trend, the 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 siting MPAs that included obtaining input from user groups, interested parties, and the general public, along with some review of existing biological and habitat data (SAFMC 2004). Of prime concern is protecting those habitats and locations that are essential to completing the life cycles of overfished species. This SAFMC siting process highlighted some significant problems with gaps in knowledge of distribution of habitat, species and spawning locations (see also Sale et al. 2005). These gaps include knowledge of community structure, benthic food webs, oceanographic processes that affect recruitment to and from reefs, and placement of MPA networks to maximize resource protection and production of surplus fish biomass that might spill over into adjacent fished areas. High fish biomass is known to be associated with hard bottom vs. sand bottom habitat (Wenner 1983), but additional study of distribution of individual reef fish species and spawning sites in relation to bottom habitats and faunas, and the relationship of bottom features to hydrographic features and proposed MPA sites, is needed. Oceanographic conditions, circulation patterns, chlorophyll-a concentrations, and locations of upwelling need to be mapped 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 commercial and recreational reef fish 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 and summarize such biological and oceanographic data, particularly data on spawning locations and recruitment pathways.

We proposed research to use historical and recent fishery-independent databases to build a GIS that will map and describe distributions of species, and their abundance, biomass and diversity in relation to each other and to bottom and oceanographic features. We examined the MARMAP life history databases for spawning locations of priority species to determine areas that might be spawning aggregation sites. The overall goal was to identify areas as EFH or HAPC for economically valuable reef fishes. Objectives included the following:

1. Format existing MARMAP fishery-independent trawl, trap, longline and ichthyoplankton data into an Access database that can be incorporated into a GIS.
2. Integrate the fishery-independent data (and metadata) with the existing SEAMAP-SA bottom mapping database in order to correlate fish distribution data with habitat type.

3. Integrate MARMAP and other hydrographic databases into the GIS to correlate fish distribution with hydrographic parameters.
4. Perform spatial analyses to determine the relationships among distribution of larval, juvenile, adult and spawning fish with bottom and hydrographic features.
5. Incorporate the GIS and database into a web-based framework made available to scientists, resource managers and the general public, to more effectively plan future mapping, exploration, and management in the South Atlantic Bight.

This project will provide a summary of data on fish distribution and abundance, prior to any MPA designation in the SAB. These data will provide a baseline for determination of any effects of subsequent MPA designation. This project will provide readily accessible and simple visualizations (maps) of the distribution, abundance, biomass and diversity of species of the SAMFC Snapper/Grouper Management Unit, and other species in this important ecosystem. In addition to simple distribution maps, the analysis will provide maps of areas of above average fish abundance, biomass and diversity. It will provide maps and locations of capture of priority reef fishes in spawning condition. These maps will provide essential basic information on fishes needed to develop ecosystem-based management plans. In addition to simple visualizations, the database and GIS structure will enable users to easily access data on species composition, relative abundance, spawning condition and other important fishery data by "point and click" in latitude-longitude cells on GIS maps on an Internet map server. Having the MARMAP database in such a readily accessible form will benefit management agencies. Although the investigators will summarize the database and maps in relation to EFH, HAPC and potential MPAs, the entire GIS will be made available for management agencies to apply their own search criteria. There will be benefits provided to other natural resource researchers by having the GIS available on the web, similar to the NOAA Ocean Planning Information System-OPIS (www.csc.noaa.gov/opis/) and NOAA Biogeography Program South Atlantic EFH (biogeo.nos.noaa.gov/projects/efh/sa-efh/) web sites. Note that the proposed project will complement existing databases on OPIS on which it will be based, and will provide a substantial improvement in content and accessibility over the current South Atlantic EFH web site. Links can also be made to ocean education web sites (e.g., Project Oceanica, www.cofc.edu/oceanica). By linking research, management and education, the project will benefit fish and fisheries by integrating conservation of managed species and fisheries management, resulting in improved conservation and management of reef fishes in the region.

APPROACH

Methods

Sampling Programs and Data Sources

The database and GIS constructed during this project was built from fishery-independent survey data collected since 1973. Some fishery-dependent data (primarily spawning locations) were also used. Most of the data came from the MARMAP program, a cooperative program between NOAA Fisheries Service and the SCDNR. The MARMAP program has been conducting fishery-independent surveys between Cape Hatteras and Cape Canaveral since 1973. Most sampling occurred with a variety of fishing gear deployed on the continental shelf and upper slope.

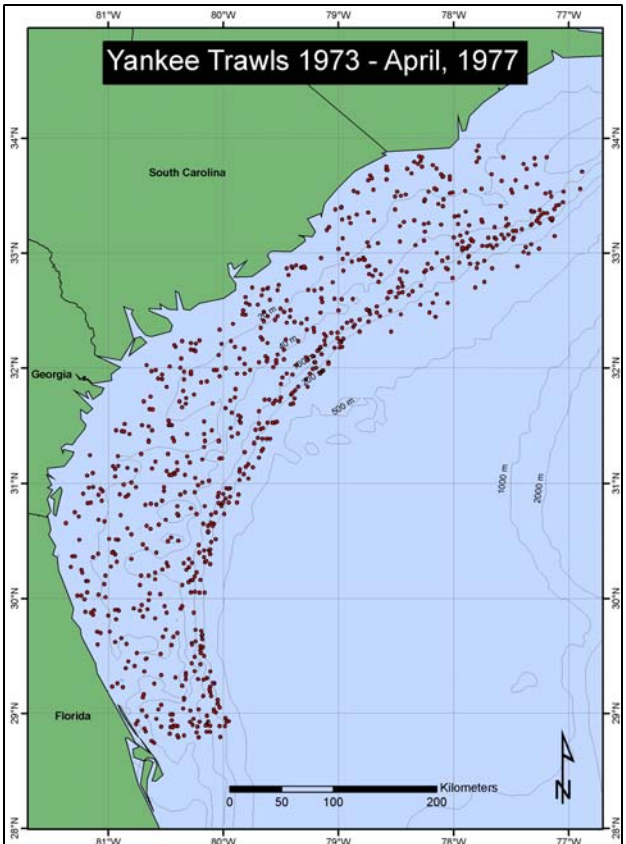

Fig. 1. Locations of 739 trawl stations sampled with the Yankee Trawl during the Stratified Random Groundfish Trawl Survey, at depths from 9-338 m. Points are "trawl set" positions, at the beginning of each 30-min tow.

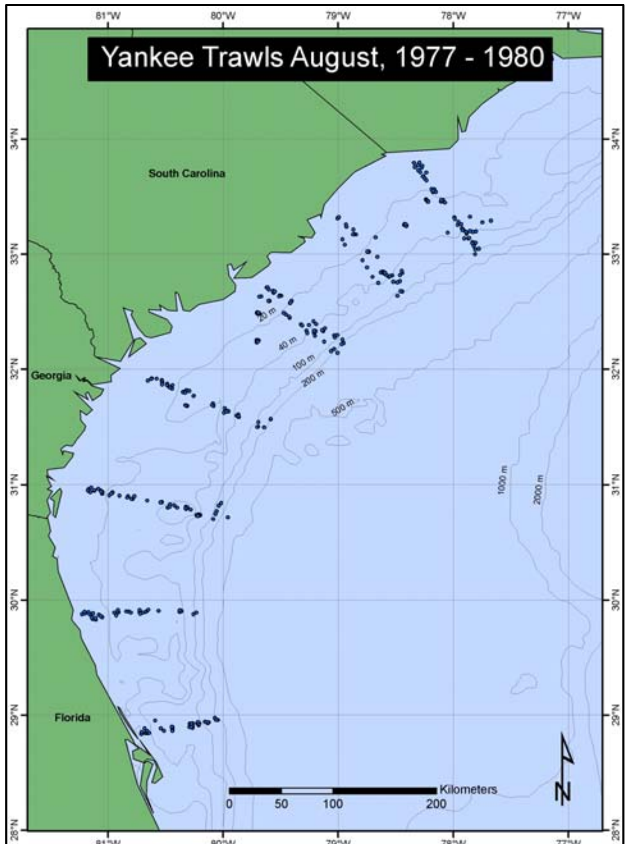

Fig. 2. Locations of 284 trawl stations sampled with the Yankee Trawl during the Transect Groundfish Trawl Survey, at depths from 12-223 m. Points are "trawl set" positions, at the beginning of each 30-min tow.

The MARMAP database consists of several demersal fish surveys. Each fish survey was accompanied by a hydrographic survey. Sampling stations were located using Long Range Navigation or LORAN-A from 1973-1975 and LORAN-C from 1976-1987. Global Positioning System (GPS) was used from 1988-2004. The best available navigation technology was used at the time of fishery-independent sampling. Details of each survey and sampling gear are available as metadata in the database and ArcIMS described below. Details are also available in publications based on the data, which are cited as needed. Brief descriptions will be given here.

Trawl Surveys

From 1973-1980, the MARMAP program performed a trawl survey (the Groundfish Trawl Survey), which consisted of two sampling designs (Fig. 1; Fig. 2) that covered the continental shelf from Cape Fear, North Carolina to Cape Canaveral, Florida (Barans and Burrell 1976; Wenner et al. 1979a,b,c,d; Wenner et al. 1980; Wenner and Read 1981). Trawl surveys were conducted at least once annually, and were focused on trawlable bottom, primarily sandy shelf and muddy upper slope habitats. The surveys, conducted from the 32.6m RV *Dolphin*, utilized one of two sampling strategies. The Stratified Random Groundfish Trawl Survey from

1973 through the winter cruise of 1977 consisted of a stratified random sampling design (Grosslein 1969; Wenner et al. 1979a) that designated stations within specified depth and latitudinal zones (Fig. 1). The six depth zones were: 9-18 m, 19-27 m, 28-55 m, 56-110 m, 111-183 m, 184-366 m, and 739 trawl collections were made during all seasons of the year, but primarily in summer. A Transect Groundfish Trawl Survey was conducted from the summer of 1977 through 1980, and consisted of a systematic sampling plan with 180 pre-selected stations positioned along seven transects (Fig. 2). Transects were spaced within a fairly equal distance along the coast and were oriented perpendicular to the coastline from 9 –183 m depth, and 284 trawl collections were made in summer (primarily) and winter along the transects (Table 1).

A single trawl, the ¾ scale version of a No. 36 Yankee Trawl (Wilk and Silverman 1976), was used for the two Groundfish Trawl Surveys. The Yankee Trawl was a bottom trawl made with #72 flat nylon thread, a 16.5-m footrope sweep, #500 New England otter trawl doors, and 11 aluminum floats (20.3 cm diameter) spaced equally along the 11.9-m headrope. The footrope was equipped with 9-cm (3.5-inch) rubber rollers ("cookies"). The net had the following stretched mesh dimensions: 11.4 cm in the wings, 10.2 cm then to 8.9 cm in the body, 5.1 cm in the cod end, and 1.3 cm in the cod end liner. The net was towed behind the R/V *Dolphin* at a vessel speed of 6.5 km hr^{-1} (3.5 knots). For this survey, tows were 30 min in duration, and distance varied but was not measured. The sweep of the Yankee Trawl was 8.748 m, and 3.241 km was the distance covered during a standard tow (Wenner et al. 1979a), resulting in a swept area of 2.835 ha/tow. Only successful tows that caught demersal finfish or benthic invertebrates were included in database. Their presence indicated bottom contact by the open trawl.

Table 1. Number of collections, by cruise, during the Groundfish Trawl Surveys. Total trawl collections = 1023.

Year	Months	Cruise	Number of Random Tows	Number of Transect Tows
1973	Oct-Nov	DP-7305	87	
1974	Apr-May	DP-7402	116	
1974	Aug-Sep	DP-7403	88	
1975	Jan-Apr	DP-7501	92	
1975	Aug-Sep	DP-7503	87	
1976	Jan-Feb	DP-7601	87	
1976	Aug-Sep	DP-7603	89	
1977	Jan-Mar	DP-7701	93	
1977	Aug-Sep	DP-7703		50
1978	Jan	DP-7801		54
1978	Sep	DP-7807		60
1979	Aug	DP-7904		58
1980	Jul	DP-8004		62
TOTAL			**739**	**284**

Beginning in 1977, MARMAP shifted its sampling from sand-bottom habitats to hard-bottom reef habitat throughout the SAB using a variety of gear types, including trawls, fish traps, hook and line, longlines and underwater television (Barans and Powles 1977; Wenner 1983; Wenner et al. 1986; Collins 1990). Hard bottom, or "live bottom" (Struhsaker 1969) reef locations were selected from analysis of the MARMAP Groundfish Trawl Surveys and existing sonar data to determine locations of reef fishes or hard bottom with vertical relief. Simultaneous sonar recorder tracings and bottom observations made with a Hydro Products TC-125 SDA3 low-light level underwater television system in conjunction with LORAN-C positions were used to produce maps of several index stations that included extensive hard bottom (Wenner 1983). Observations of bottom type (reef vs. non-reef) and the distribution and abundance of reef invertebrates and fishes were recorded. The hard bottom reef habitat was defined by the presence of rocky bottom, sometimes with attached invertebrate growth. The resulting reef area maps were used to direct removal sampling with trawls and other fishing gear.

The Live Bottom Trawl Survey and other sampling that attempted to target known reef areas was generally restricted to spring and summer months. Trawl sampling was conducted annually between April and July from 1978 to 1987, however, two separate cruises (April and September) were conducted in 1979 (Table 2). In 1978 and 1979 the Live Bottom Trawl Survey (Fig. 3) was conducted using the ¾-scale Yankee Trawl (Wilk and Silverman 1976) towed from the R\V *Dolphin* at the mapped index stations (Fig. 3). In the late seventies, the "URI High-Rise" trawl (Hillier 1974) was introduced to commercial fisherman in the SAB (Smith 1977). This trawl was equipped with rollers on the footrope, and was designed to collect fishes on moderate relief bottom. It provided a greater vertical opening and was considered more effective at catching reef fishes congregating in schools over reefs. This second trawl design, used at the index stations between 1980 and 1987 (Fig. 3), was a smaller scale (approximately 2/3 scale) version of the "URI High-Rise", and was referred to as the "40/54 Fly Net" or the Fly Net. The Fly Net had a 16.5-m footrope, 12.2-m headrope and 3.8-cm stretched mesh cod end with 1.3-cm stretched mesh knotless nylon liner. The 16.5-m sweep footrope was equipped with 9-cm rubber rollers ("cookies"), 45-cm bobbins and Chinese "V" doors (1.8 X 1.2 m; 249.5 kg each). Plastic or aluminum floats (20.3 cm diameter) were equally spaced every ~ 0.6 m on the headrope. For trawls on these live-bottom sampling cruises, 1-km tows (from end of wire pay out to beginning of wire haul back) were conducted aboard the R\V *Dolphin* (1978-1980) or the 33.5 m R\V *Oregon* (1981-1987).

Additional trawl surveys sampled the coastal habitat (Struhsaker 1969; Collins and Wenner 1988; Wenner and Sedberry 1989) in depths from 3 to 20 m (Table 3; Fig. 4). Two different trawl configurations were towed from three different research vessels in the Coastal Trawl Survey. During the summers of 1980-1982, Semi-balloon Otter Trawls were towed from the R/V *Atlantic Sun* (Wenner and Sedberry 1989). During the summers of 1982 and 1985, this same trawl configuration was towed from the R/V *Lady Lisa*. The NOAA Ship *Oregon II* was used to tow this trawl during the summer of 1987. During the summers of 1986 and 1987, Falcon Trawls were towed from the R/V *Lady Lisa* (Collins and Wenner 1988). All three research vessels were rigged for paired trawling, towing one trawl from each of the two outriggers (port and starboard) simultaneously for 20-60 min. Most trawl tows were 20 min.

Table 2. Number of collections, by cruise, during the Live Bottom Trawl Survey. Total trawl collections = 304.

Year	Months	Cruise	Number of Yankee Trawl Tows	Number of Fly Net Tows
1978	Jun-Jul	DP-7805	86	
1979	Apr-May	DP-7903	57	
1979	Sep	DP-7905	28	
1980	May-Jun	DP-8003		32
1981	Jun-Sep	OE-8105		28
1982	Jun-Nov	OE-8203		14
1984	Jul-Aug	OE-8403		15
1985	May-Jun	OE-8501		20
1986	Apr-May	OE-8601		12
1987	May-Jun	OE-8702		12
TOTAL			**171**	**133**

Table 3. Number of collections, by cruise, during the Coastal Trawl Survey. Total trawl collections = 1274.

Year	Months	Cruise	Number of Semi-balloon Otter Trawl Tows	Number of Falcon Trawl Tows
1980	Jul-Sep	AS-8006	346	
1981	Apr-Jun	AS-8102	230	
1982	Jan	AS-8201	124	
1982	Oct-Dec	LL-8201	230	
1985	Aug-Sep	LL-8501	88	
1986	Aug-Sep	LL-8601		82
1986	Oct	LL-8602		110
1987	Apr	LL-8701		32
1987	Apr	O2-8701	32	
TOTAL			**1050**	**224**

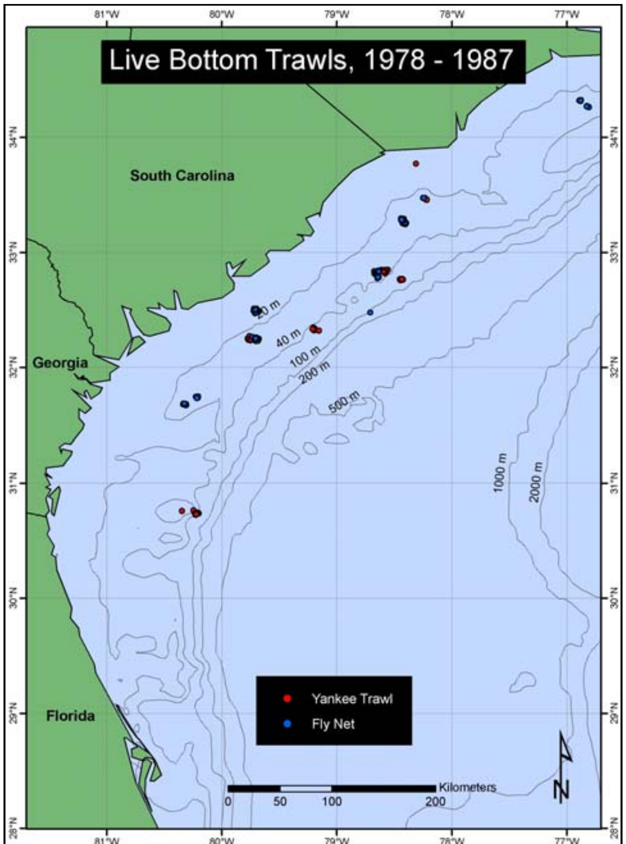

Fig. 3. Locations of 317 trawl stations sampled with the Yankee Trawl (1978-1979, red dots) or Fly Net (1980-1987, blue dots) at reef sites during the Live Bottom Trawl Survey, at depths from 15-48 m. Points are "trawl set" positions, at the beginning of each 1-km tow.

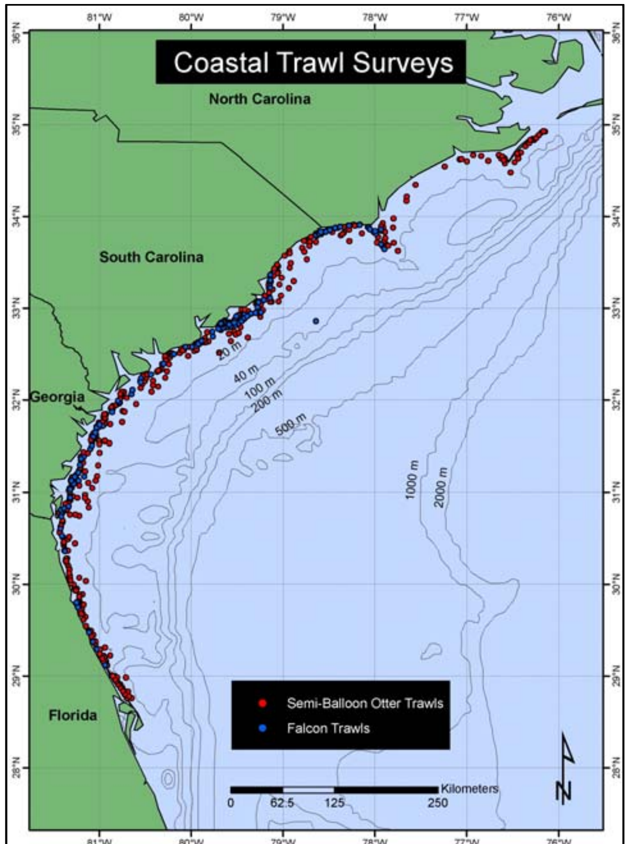

Fig. 4. Locations of 1274 trawl stations sampled with the Semi-balloon Otter Trawl (1980-1982, 1985, 1987; 4-20 m depth; 1050 red dots) or Falcon Trawl (1986-1987; 3-13 m; 224 blue dots) along the coast of the SAB the Coastal Trawl Survey, at depths from 3-18 m. Points are "trawl set" positions, at the beginning of each tow.

Semi-balloon Otter Trawls were 40/60 four-seam Gulf of Mexico semi-balloon shrimp trawls, with a 12.8-m headrope and 15.8-m footrope (Wenner and Sedberry 1989). Each trawl was equipped with 1.5 x 0.8 m wooden and chain doors attached with 61-m bridles to a single tow warp. Semi-balloon Otter Trawls had stretch mesh sizes of 5.1 cm in the wings, 4.4 cm in the body and 4.1 cm in the cod end. A tickler chain was attached between the doors and adjusted to drag on the bottom 0.6 m in front of the net. Falcon Trawls were "tongue" trawls that a 22.9-m footrope, 4.1 cm mesh and 3.0 x 1.0 m wooden doors (Collins and Wenner 1988). The Falcon Trawl had larger panels sewn into the sides and a third bridle leg to the "tongue" on the headrope, which was equipped with a single 60-cm polyball float. This net had a greater vertical opening than the Semi-balloon Otter Trawl. In 1986, some Falcon Trawls were equipped with a NMFS Trawling Efficiency Device (TED) or a Georgia TED (Collins and Wenner 1988). A tickler chain was also used with Falcon Trawls.

For all trawl surveys, actual fishing time of trawls can be influenced by depth. However, this could not be quantified, and differences were considered insignificant for much of the depth range sampled. Therefore, there was no attempt made to adjust tow time or distance for depth. Set time and position was the end of paying out wire from the trawl winch. Haul time was the beginning of wire haul back.

Fish Traps

As part of the focus on live-bottom reef habitats that began in 1977, the MARMAP program evaluated and deployed several different fish trap designs to sample reef fishes (Table 4). As trawls were found to be ineffective in sampling reef fishes and had the potential for damaging the habitat (Wenner 1983; Van Dolah et al. 1987), the program began to focus on more efficient gear for sampling reef fishes (Powles and Barans 1980). Several fish trap designs were tested briefly (Fig. 5 and Table 4) or used for several years (Fig. 6-8) before the program settled on using a chevron-shaped Antillean fish trap (Chevron Trap). All traps were baited with herrings (Clupeidae), usually menhaden (*Brevoortia* spp. or *Alosa* spp.).

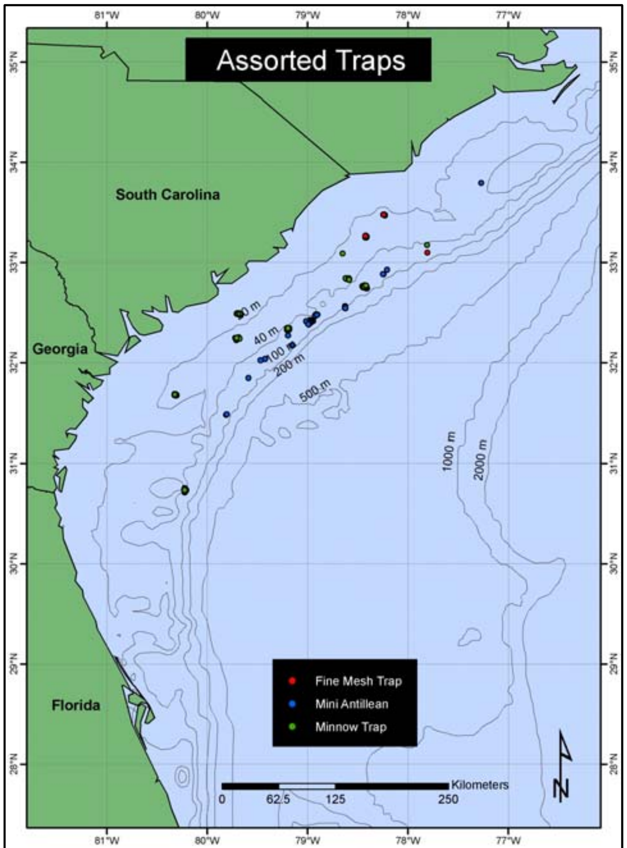

Fig. 5. Locations of 439 fish trap stations on live bottom, sampled with several experimental trap designs that were tried by the MARMAP program, but not used for fish abundance estimates. Trap designs included Fine Mesh Traps (1978-1979; 120 red dots), Mini-Antillean S Traps (1977-1980; 157 blue dots) and Minnow Traps (1978; 162 green dots).

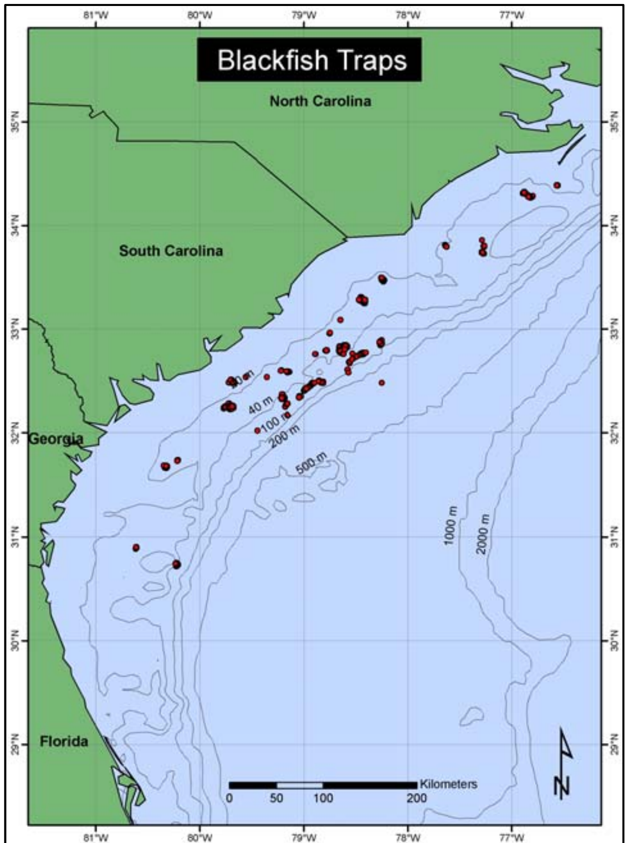

Fig. 6. Sampling locations of 3186 Blackfish Traps deployed on live bottom, 1979-1989.

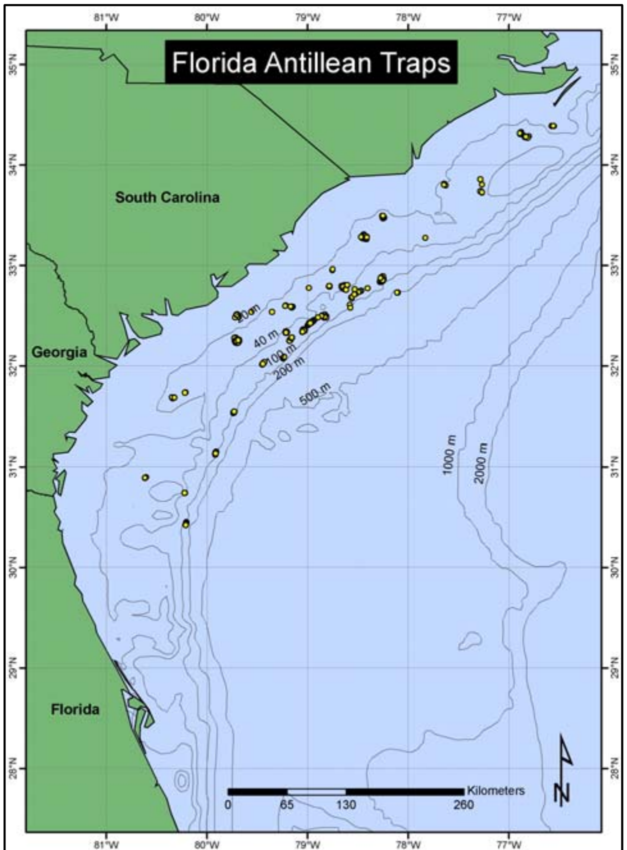

Fig. 7. Sampling locations of 1637 Florida Antillean Traps deployed on live bottom, 1980-1989.

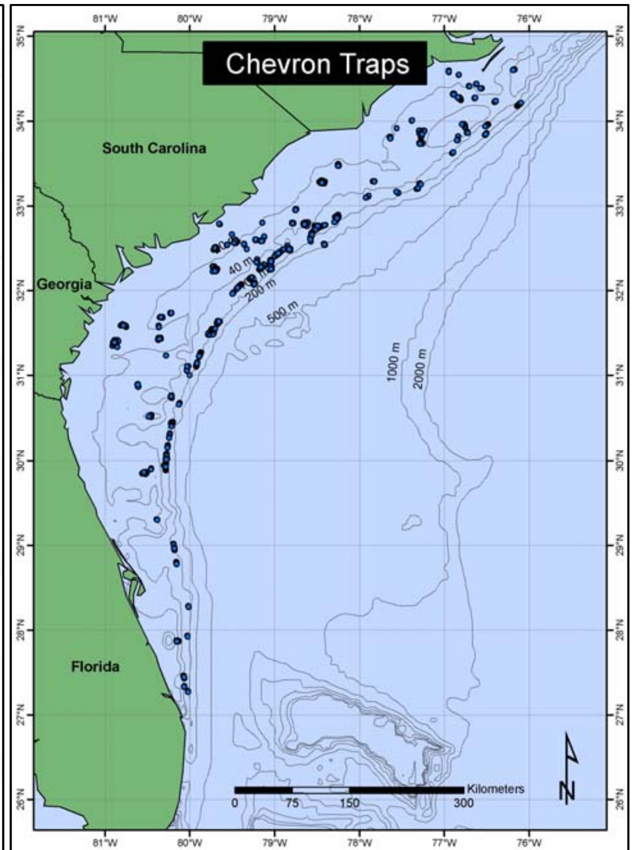

Fig. 8. Sampling locations of 6377 Chevron Traps deployed on live bottom, 1988-2004.

Traps were usually set for 90 min, although some experimental traps were fished for varying amounts of time, and mechanical or other problems sometimes caused delays in retrieving traps. Traps here hauled using a high-speed hydraulic pot hauler.

From 1978 through 1980, MARMAP deployed the Antillean Mini-S Trap on buoyed lines (Fig. 5). From 1978 to 1987, Blackfish Traps and Florida Antillean Traps (Powles and Barans1980; Collins 1990) were set from the R\Vs *Dolphin, Oregon* or *Palmetto,* on buoyed lines at index stations (Fig. 6, Fig. 7). In 1988 and 1989, those traps were deployed from the vessel as it anchored over reef habitat. During those years, the Chevron Trap (Fig. 8) was also deployed, and the three traps were fished simultaneously on individual lines tied to the anchored vessel. From 1990 to 2004, Chevron Traps were deployed on buoyed lines, using the R/V *Palmetto*.

Blackfish Traps were nearly cubic (0.6 m x 0.6 m x 0.5 m; 0.16 m^3 volume) and constructed of 38-mm octagonal plastic-coated wire mesh ("chicken wire"). Each trap consisted of two entrances (0.13 m diameter, 0.09 m length) and one bait well (0.10 m diameter, 0.25 m length). Blackfish traps were deployed on buoyed lines (usually two traps separated by 30.5-m line), but individually in the early years. Blackfish Traps were generally set on live-bottom reef areas that were less than 50 m in depth (Fig. 6).

Florida Antillean traps were rectangular (0.9 m x 1.1 m x 0.6 m; 0.59 m^3 volume) and constructed of 38 x 51 mm plastic-coated wire mesh. Each trap had one entrance and one bait well (0.13-m diameter, 0.6-m length). Florida Antillean Traps were generally set on the same live-bottom reef areas on the continental shelf where Blackfish Traps were set. The standard deployment consisted of 10 Blackfish Traps (five buoys with two traps each) and two Florida Antillean Traps set individually on buoyed lines. There was much variation, however in how the traps were set. Florida Antillean Traps were the only traps deployed at deeper shelf-edge reef sites (45-60 m) from 1980-1987.

Chevron Traps were chevron- or arrowhead-shaped (1.5 m x 1.7 m.; 0.91 m^3 volume) and constructed of 35 x 35-mm rectangular mesh plastic-coated wire. Chevron Traps had one entrance funnel (“horseneck”). They did not have a bait well and bait was suspended on four stringers within the trap and placed loosely in the trap. The traps were tethered individually on buoyed lines, except in 1988 and 1989 when they were tethered to the anchored vessel. Traps were generally set on live-bottom reef areas on the continental shelf and upper slope. Up to six traps were fished at the same time.

Other trap designs included standard Minnow Traps (bait traps) and blackfish traps covered with 12.7-mm plastic mesh (Fine Mesh Traps). These were occasionally deployed to collect juvenile fishes (Table 4; Fig. 5).

Table 4. Number of trap collections, by cruise, during the Live Bottom Reef Surveys. Total trap collections = 11,639.

Year	Months	Cruise	Antillean Mini-S	Black Fish	Florida Antillean	Chevron	Minnow	Fine Mesh
1977	May	DP-7702	23					
1977	Sep	DP-7704	7					
1978	Jan-Feb	DP-7802	8					
1978	Jun-Jul	DP-7805	90	90			161	60
1978	Jul-Aug	AS-7801	18					
1978	Sep	DP-7808					1	
1979	Feb	DP-7901	6					
1979	Apr-May	DP-7903		130				58
1979	Sep	DP-7905		182				
1979	Sep	AS-7910						2
1980	May-Jun	DP-8003	5	298	7			
1981	Jun-Sep	OE-8105		348	121			
1982	Jun-Nov	OE-8203		259	130			
1983	Apr-May	OE-8302		432	78			
1983	Aug	OE-8303			86			
1984	May-Jun	OE-8401			96			
1984	Jul-Aug	OE-8403		530	164			
1985	May-Sep	OE-8501		300	100			
1985	Jun	OE-8502			88			

Table 4. Continued.

Year	Months	Cruise	Antillean Mini-S	Black Fish	Florida Antillean	Chevron	Minnow	Fine Mesh
1986	Apr-May	OE-8601		252	84			
1986	Jun	OE-8603			144			
1987	Feb-Mar	OE-8701			126			
1987	Apr	OE-8702		180	60			
1987	Aug	OE-8703			168			
1988	May-Sep	OE-8802		105	105	105		
1989	May-Sep	PO-8901		80	80	80		
1990	May-Aug	PO-9002				354		
1991	Jun-Sep	PO-9101				305		
1992	Mar-Aug	PO-9201				324		
1993	May-Aug	PO-9301				414		
1993	Jul; Oct	PO-9302				128		
1994	May-Aug	PO-9401				405		
1994	Oct	PO-9402				62		
1995	Apr	FE-9501				33		
1995	May-Sep	PO-9502				328		
1995	Jul; Sep; Oct	PO-9503				184		
1996	Apr-Sep	PO-9602				515		
1996	May-Jun; Sep-Oct	PO-9603				127		
1997	Apr-Sep	PO-9702				24		
1997	May-Sep	PO-9703				508		
1998	Mar; May-Aug; Oct	PO-9801				38		
1998	May-Aug	PO-9802				485		
1999	Feb-Mar; May-Oct	PO-9901				75		
1999	Jun-Sep	PO-9902				272		
2000	Mar-Apr; Aug-Oct	PO-0001				26		
2000	May-Oct	PO-0002				357		
2001	Aug-Oct	PO-0101				32		
2001	May-Sep	PO-0102				293		
2002	Jun-Sep	PO-0202				298		
2003	Jun-Sep	PO-0302				286		
2004	May-Sep	PO-0401				308		
2004	Oct	PO-0404				11		
TOTAL			**157**	**3186**	**1637**	**6377**	**162**	**120**

Baited Hooks

In order to sample deepwater members of the Snapper-Grouper Complex such as snowy grouper (*Epinephelus niveatus*) and tilefish (*Lopholatilus chamaeleonticeps*), the MARMAP program has employed experimental longline gear (Table 5). Longline sampling has been directed at two habitat types: upper continental slope reefs and mud bottom tilefish grounds. Both habitats are centered around the 183-m depth contour on the upper continental slope (Fig. 9). Tilefish grounds were sampled with Bottom Longlines; slope reefs were sampled with off-bottom Kali Pole Longlines or Short Longlines (Fig 9). Longlines were equipped with monofilament gangions, comprising an AK snap, approximately 0.5 m of 90-kg test monofilament and a #6 or #7 tuna circle hook baited with squid. Longlines were soaked for about 90 min and retrieved using a high-speed hydraulic pot hauler.

From 1982-1986, Bottom Longlines (Table 5) deployed on the tilefish grounds were constructed of treated cotton line (~914 m) deployed from galvanized tubs (Barans and Stender 1993). The groundline had a single buoy line to the surface. This was similar to commercial "tub trawl" gear, but retrieved with a hydraulic pot hauler. From 1996 to 2004, bottom longlines

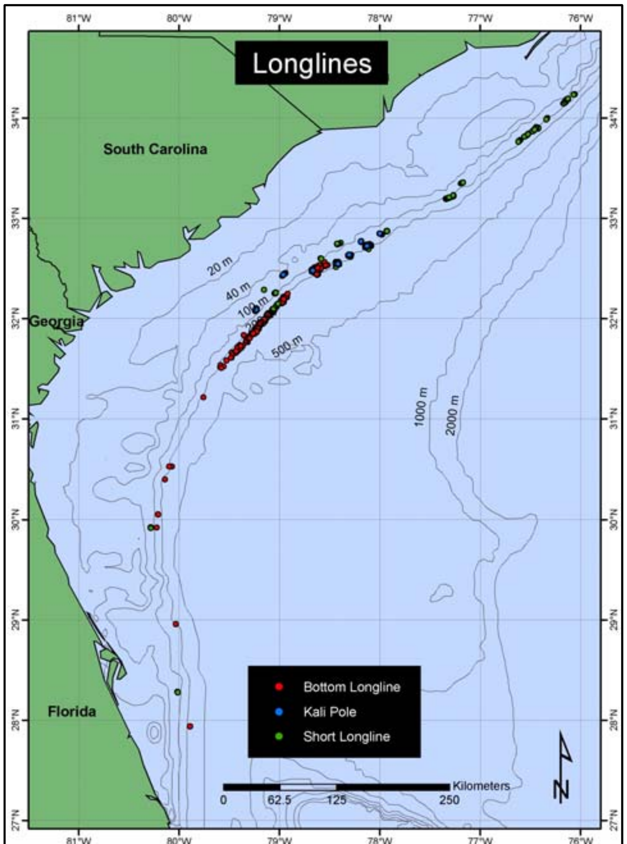

Fig. 9. Sampling locations of 875 Longlines deployed from on live bottom, 1979-2004. These include 335 Bottom Longlines (red dots) set on tilefish grounds; and 199 Kali Pole Longlines (blue dots) and 341 Short Longlines (green dots) set on upper slope reefs.

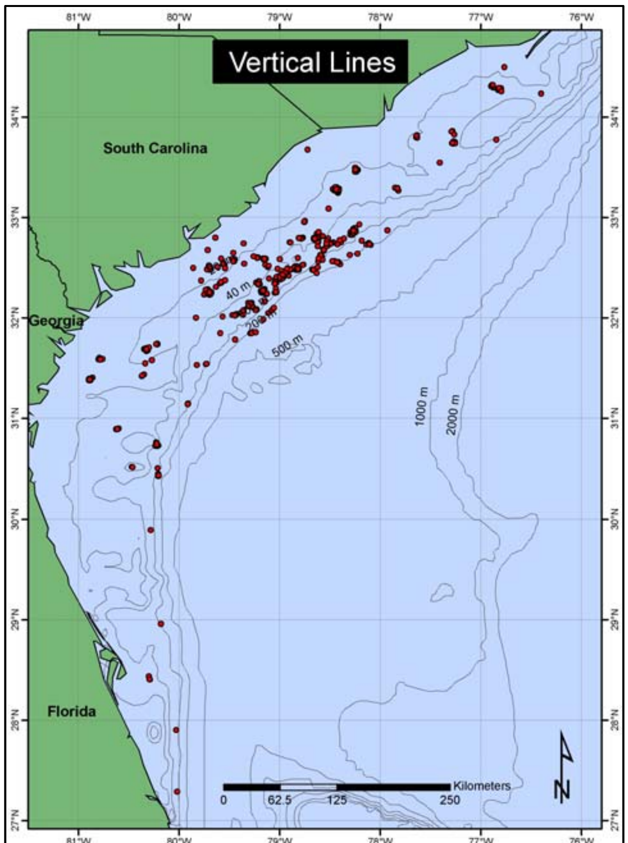

Fig. 10. Locations of 1365 Vertical Lines deployed from anchored or drifting vessels. For drifting vessels, location is start of drift. Vertical Line collections include rod-and-reel (electric or manual) and commercial-type snapper reels (electric, hydraulic or manual).

were constructed of 3.2-mm galvanized cable (1525 m long), deployed from a longline reel with 1220 m of cable used as groundline and the remaining 305 m buoyed to the surface. The groundline on both types of Bottom Longline consisted of an ~11-kg weight attached to the terminal end, 100 gangions (at 12-m intervals) attached to the groundline, and another weight at the other end, which was connected to the surface buoy. Bottom longlines were generally deployed in areas of smooth mud (e.g., tilefish grounds).

Kali Pole Longlines (Russel et al. 1988) were "off-bottom" longlines, designed to place a large number of baited hooks in close proximity to rugged rocky bottom, while minimizing hang-ups of the gear in the rocks. The poles were attached to a 91-m polypropylene groundline (6.4 mm diameter). Each pole was 3-m long PVC plastic pipe (25-mm diameter, schedule 80) and had 10 hooks. Each groundline had 20 poles. The groundline was buoyed to the surface at each end. Kali Pole Longlines were deployed from 1982-1986 (Table 5) at rocky reefs on the upper continental slope (Fig. 9).

Short Bottom Longlines consisted of 25.6 m of 6.4-mm treated solid braid dacron groundline with 20 gangions placed 1.2 m apart on the groundline, with a single buoy line to the surface. The gear was deployed by stretching the groundline along the vessel's gunwale with ~11-kg weights attached at the ends of the groundline. This gear was deployed in areas with rough bottom contours in order to follow the bottom profile, generally at depths > 165 m on the upper continental slope (Fig. 9). This gear was used in 1979 and 1987 and replaced the Kali Pole Longline for sampling slope reefs from 1996-2004 (Table 5).

Baited hooks were also deployed from 1977-2003, with a variety of recreational- and commercial-type gear designed to fish Vertical Lines from an anchored or drifting vessel, and using relatively few hooks (3-10) of various designs and sizes (Table 5, Fig. 10). Vertical Lines included manual, electric or hydraulic heavy-duty reels (Snapper Reels, sometime called Bandit Reels) and manual or electric rod-and-reel. Snapper Reels had a 30 cm diameter reel spooled with 3.2-mm stainless steel cable. Terminal tackle usually consisted of a 2.2-kg weight and two or three 4/0 hooks baited with squid, round scad (*Decapterus punctatus*) and/or cut fish. There was much variation in fishing times, number of anglers (1-3) per collection number and configuration of terminal tackle and bait used. Rod-and-reel collections used 6/0 Penn Senator high speed reels, sometimes equipped with Electramate electric motors on 1.83-m boat rods and 23-kg test monofilament line. Terminal tackle consisted of three 4/0 or 5/0 non-offset “J” hooks on 23-kg or 36-kg test monofilament leaders 0.25 m long and 0.3 to 0.5 m apart, above one or two 0.5 kg lead sinkers. Hooks were baited with cut squid and/or round scad. Hook and line collections were often made at dusk and dawn with the vessel either anchored or drifting. There was much variation in fishing times, number of anglers per collection number (1-3), configuration of terminal tackle and bait used.

Processing of Fish Catches and Data

The fish from catches from all fishing gear were sorted to species, counted and weighed. Large catches of abundant species were subsampled by weight for abundance estimates. Fish size was recorded to the nearest cm as total length (TL), fork length (FL), or disc width (DW) for batoid fishes. Sampling durations (spatial and temporal) were recorded during collection so that catches could be converted to various measures of catch per-unit-effort (CPUE). CPUE units included catch per tow, catch per trap, catch per 100 hooks, catch per ha of swept area (trawl tows), catch per unit volume filtered (plankton tows, see below), etc.

Table 5. Number of collections made with fishing gear that comprised baited hooks, by cruise, during the Live Bottom Reef, Slope Reef and Tilefish Grounds Surveys. Total number of collections = 2240.

Year	Months	Cruise	Bottom Longline	Kali Pole Longline	Short Longline	Vertical Line
1977	May	DP-7702				39
1977	Sep	DP-7704				2
1978	Jan-Feb	DP-7802				9
1978	Jul	DP-7806				1
1978	Jul-Aug	AS-7801				10
1979	Feb	DP-7901			8	3
1979	Apr-May	DP-7903				16
1979	Sep	DP-7905				10
1980	May-Jun	DP-8003				30
1981	Jun-Sep	OE-8105				36
1982	Mar-Apr	OE-8201				1
1982	Apr	OE-8202				1
1982	Jun-Nov	OE-8203	34	34		20
1983	Apr-May	OE-8302				23
1983	Aug	OE-8303		18		12
1983	Sep	OE-8304	34	37		3
1984	May-Jun	OE-8401				8
1984	May-Jun; Sep	OE-8402	57	33		21
1984	Jul-Aug	OE-8403				26
1985	May-Sep	OE-8501				26
1985	Jun	OE-8502				12
1985	Jun-Sep	OE-8503	45	45		9
1986	Apr-May	OE-8601				15
1986	May-Jun	OE-8602	21	32		
1986	Jun	OE-8603				11
1987	Feb-Mar	OE-8701			2	12
1987	Apr	OE-8702				10
1987	Aug	OE-8703				13
1988	May-Sep	OE-8802				322
1989	May-Sep	PO-8901				241
1990	May-Aug	PO-9002				124
1991	Jun-Sep	PO-9101				41
1992	Mar-Aug	PO-9201				25
1993	May-Aug	PO-9301				52
1993	Jul; Oct	PO-9302				17
1994	May-Aug	PO-9401				41
1994	Oct	PO-9402				25

Table 5. Continued.

Year	Months	Cruise	Bottom Longline	Kali Pole Longline	Short Longline	Vertical Line
1995	May-Sep	PO-9502				20
1995	Jul; Sep; Oct	PO-9503				10
1996	Apr-Sep	PO-9602	17		20	18
1996	May-Jun; Sep-Oct	PO-9603				16
1997	Apr-Sep	PO-9702				17
1997	May-Sep	PO-9703	21		34	3
1998	May-Aug	PO-9802	10		33	6
1999	Jun-Sep	PO-9902	30		44	0
2000	May-Oct	PO-0002	11		40	1
2001	May-Sep	PO-0102	14		36	5
2002	Jun-Sep	PO-0202	4		22	
2002	Sep	LL-0201	16			
2003	Jun-Sep	PO-0302			54	1
2003	Sep	LL-0301	16			1
2004	May-Sep	PO-0401	5		48	
TOTAL			**335**	**199**	**341**	**1365**

Plankton Sampling

From 1973-1984 the MARMAP program conducted ichthyoplankton surveys of the SAB (Table 6, Fig. 11). Sampling was conducted at 1,163 randomly-selected stations, with some effort directed at areas where random sampling indicated a high incidence of grouper larvae near the Charleston Gyre between 32° and 33°N (Collins and Stender 1987; Collins and Stender 1989; Sedberry et al. 2001; Govoni and Hare 2001). Several types of plankton gear equipped with Nitex netting were deployed to sample fish larvae:

1. 1.0 x 0.5-m neuston net with 303- or 505-µm mesh, towed half submerged:
2. 2.0 x 1.0-m neuston net (4.9- or 8.5-m length) with 947-µm mesh towed half submerged;
3. bongo frame equipped with 60-cm diameter nets of 505-µm and 333-µm mesh towed in double-oblique fashion from the surface to the bottom (or to 200 m if depth > 200 m).
4. Isaacs-Kidd Midwater Trawl (IKMT) equipped 1.8- x 1.8-m mouth opening and 1.050-mm mesh netting.

All nets were equipped with calibrated flowmeters to measure volume of water strained. Samples were sieved and preserved at sea in 10% buffered formalin. Some special bongo collections were preserved in 100% ethanol so that otoliths of larval fishes would be preserved for ageing. In the laboratory, fish larvae were sorted from all samples, excluding the 333-µm bongo net, and identified to the lowest possible taxon, using literature available at the time. Larvae were counted and the longest and shortest in a sample measured (notochord length or standard length). Data on abundance were standardized to number per m^3 of water strained by the nets.

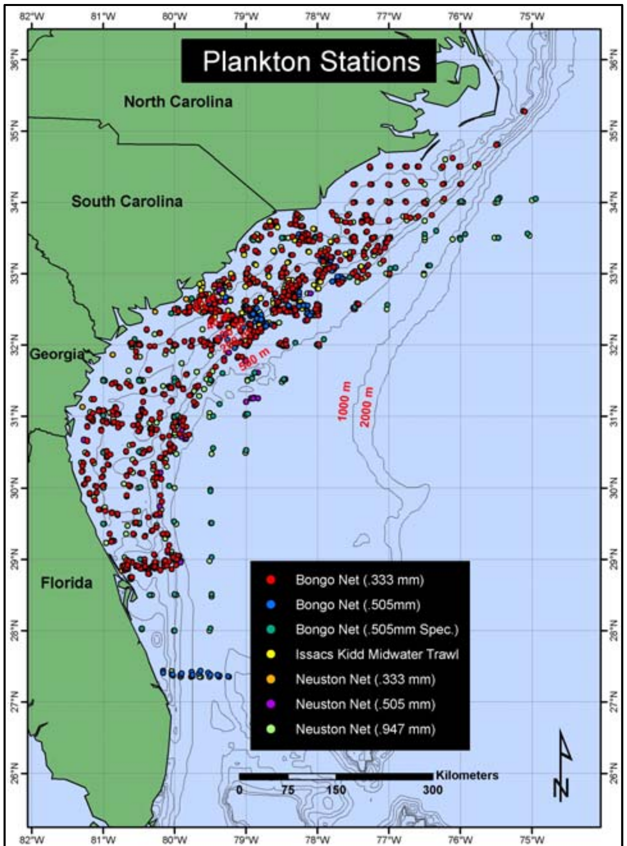

Fig. 11. Locations of 2521 plankton collections, 1973-1986.

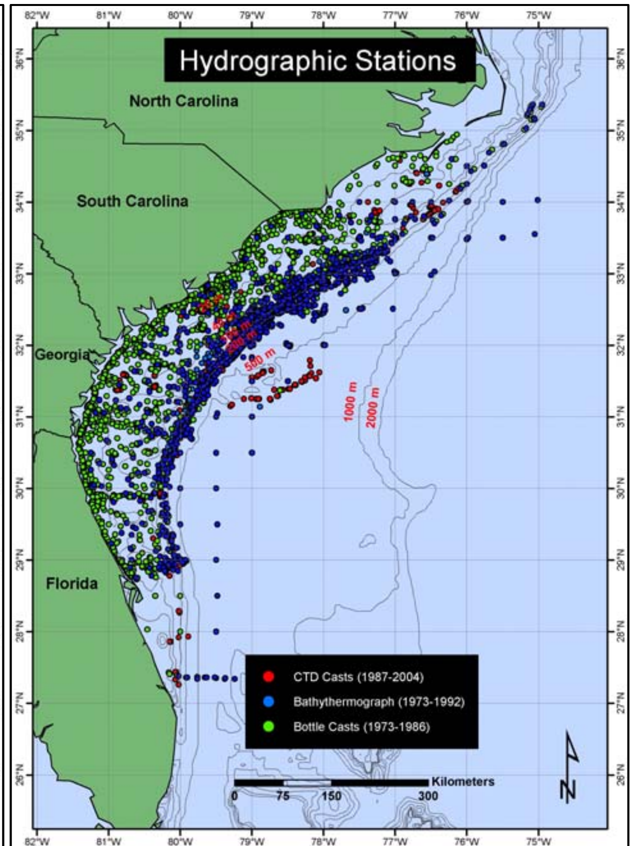

Fig. 12. Locations of 6247 hydrographic samples, 1973-2004.

Hydrographic Sampling

Hydrographic data, including bottom temperature, salinity and depth, were initially (1973-1986) collected via bottle casts and sonar at each trawl station, at index reef stations or at clusters of random trap stations (Table 7, Fig. 12). Salinity was measured from water samples taken by Niskin bottle, and temperatures were measured using reversing thermometers or stem thermometers. Samples included surface bucket, surface and bottom Niskin bottles, and Niskin bottles deployed at standard hydrographic depths (McLellan 1965): 0, 10, 20, 30, 40, 50, 75, 100 150, 200, 300, 400, 500 m. Drift bottles were occasionally deployed to track surface currents and expendable bathythermographs (XBT) or mechanical bathythermographs (MBT) were used to record temperature-depth profiles. Beginning in 1987, a CTD (conductivity-temperature-depth probe) was used to measure hydrographic parameters. Hydrographic data included depth, temperature and salinity. During some surveys, dissolved oxygen, nutrients and chlorophyll-a were measured.

Table 6. Number of plankton collections, by cruise and net, 1973-1986. Total number of plankton net collections = 2521.

			Bongo			Neuston				
Year	Months	Cruise	333	505	505 special	333	505	947 4.9 m	947 8.5 m	IKMT
1973	Feb-Mar	DP-7302		67					67	
1973	May	DP-7303		44					44	
1973	Oct-Nov	DP-7305	27	27				41		
1974	Apr-May	DP-7402	42	42				56		
1974	Aug-Sep	DP-7403	38	38				38		
1975	Jan-Apr	DP-7501	77	77				79		
1975	Aug-Sep	DP-7503	41	41			41			
1976	Jan-Feb	DP-7601	40	40			40			
1976	Aug-Sep	DP-7603	42	42			42			
1977	Jan-Mar	DP-7701	44	44			44			
1977	Aug-Sep	DP-7703	21	36	15		21	15		
1978	Jan	DP-7801	21	21			21			
1978	Apr	DP-7803	14	14					14	
1978	Sep	DP-7807	27	27			27			
1978	Sep	DP-7808					15	25		
1979	Feb	AS-7901		4	4			4		4
1979	Feb	AS-7902		4	4			5		4
1979	Mar	AS-7903		11	11			11		11
1979	Mar	DP-7902		11	11			11		11
1979	Apr	AS-7904		6	6			6		7
1979	Apr	AS-7905		11	11			11		11
1979	Apr-May	AS-7906		11	11			11		17
1979	May	AS-7907		7	7			7		9
1979	Jun	AS-7908		11	11			11		2
1979	Jun-Jul	AS-7909		4	4			4		3
1979	Aug	DP-7904	27	38	11		27	11		11
1980	Apr	AS-8001						7		7
1980	May	AS-8002						7		11
1980	May	AS-8003						7		14
1980	May	AS-8004						7		11
1980	May	AS-8005						8		8
1980	Jul	DP-8004	27	27			28			
1981	Mar	AS-8101					1	2		
1981	Apr	OE-8102						34		37
1982	Mar-Apr	OE-8201		7			7	7		4
1982	Apr	OE-8202	8	8			8	4		8
1982	May	CP-8201	5	5			5	5		
1985	Jun-Sep	OE-8503		11	11		14	14		
1985	Aug-Sep	LL-8501				5				
1986	May-Jun	OE-8602	14		14		15	15		
TOTAL:			**515**	**736**	**131**	**5**	**356**	**463**	**125**	**190**

Table 7. Number of hydrographic sample collections, by cruise and gear, 1973-2004. Total number of collections = 6247. Niskin bottles were deployed at surface and bottom only, or at standard hydrographic depths, and were equipped with reversing thermometers.

Year	Months	Cruise	CTD	Surface Bucket	S&B Niskin Bottle	Std Hyd Niskin Bottle	Drift Bottle	XBT	MBT
1973	Feb-Mar	DP-7302			67			37	30
1973	May	DP-7303			44			14	30
1973	Oct-Nov	DP-7305			27	62		5	84
1974	Apr-May	DP-7402			21	103		21	105
1974	Aug-Sep	DP-7403			37	56		51	42
1975	Jan-Apr	DP-7501			79	53	37	79	53
1975	Aug-Sep	DP-7503			41	51	61	68	24
1976	Jan-Feb	DP-7601			40	53		47	46
1976	Aug-Sep	DP-7603			55	40		76	19
1977	Jan-Mar	DP-7701			44	54		57	41
1977	May	DP-7702			8				39
1977	Aug-Sep	DP-7703			29	41		35	35
1977	Sep	DP-7704						14	56
1978	Jan	DP-7801			23	32		39	16
1978	Jan-Feb	DP-7802						37	50
1978	Apr	DP-7803			14			10	4
1978	Jun-Jul	DP-7805			29	1		23	7
1978	Jul	DP-7806						98	62
1978	Jul-Aug	AS-7801						6	
1978	Sep	DP-7807			27	38		48	17
1978	Sep	DP-7808			7	1		18	1
1979	Feb	DP-7901						6	71
1979	Feb	AS-7901		4					4
1979	Feb	AS-7902		5					5
1979	Mar	AS-7903		11					11
1979	Mar	DP-7902		11					11
1979	Apr	AS-7904		7				3	4
1979	Apr	AS-7905		11					11
1979	Apr-May	AS-7906		11					11
1979	Apr-May	DP-7903			19			19	
1979	May	AS-7907		7					7
1979	Jun	AS-7908		11					11
1979	Jun-Jul	AS-7909		4					4
1979	Aug	DP-7904		11	27	36		50	24
1979	Sep	DP-7905			13			13	
1980	Apr	AS-8001		7					7
1980	May	AS-8002		7				1	7
1980	May	AS-8003		8					8

Table 7. Continued.

Year	Months	Cruise	CTD	Surface Bucket	S&B Niskin Bottle	Std Hyd Niskin Bottle	Drift Bottle	XBT	MBT
1980	May	AS-8004		7				3	4
1980	May	AS-8005		8				8	
1980	May-Jun	DP-8003			28			36	
1980	Jul	DP-8004			28	34		42	25
1980	Jul-Sep	AS-8006				172			
1981	Apr	OE-8102			37			26	11
1981	Apr-Jun	AS-8102				115			
1981	Jun-Sep	OE-8105			28			45	
1982	Jan	AS-8201				62			
1982	Mar-Apr	OE-8201			3		1		10
1982	Apr	OE-8202		8			1	3	5
1982	May	CP-8201		5			1		5
1982	Jun-Aug	OE-8203			14			16	
1983	Apr-May	OE-8302			30			31	
1983	Aug	OE-8303						10	3
1983	Sep	OE-8304							17
1984	May	OE-8401			5				5
1984	May-Jun; Sep	OE-8402							28
1984	Jul-Aug	OE-8403			40			42	
1985	May-Jun	OE-8501			32			32	
1985	June	OE-8502			8			8	
1985	Jun-Sep	OE-8503		7				3	23
1985	Aug-Sep	LL-8501				87			
1986	Apr-May	OE-8601			26			26	
1986	May-Jun	OE-8602		22					30
1986	June	OE-8603			12			12	
1986	Aug-Sep	LL-8601				41			
1986	Oct	LL-8602				54			
1987	Feb-Mar	OE-8701			12			12	
1987	Apr	LL-8701				15			
1987	Apr	O2-8701				15			
1987	Apr	OE-8702			20			20	
1987	Aug	OE-8703	16		2			2	
1988	May-Sep	OE-8802	102						
1989	May-Sep	PO-8901	78						
1990	May-Aug	PO-9002	79						
1991	Jun-Sep	PO-9101	62						
1992	Mar-Aug	PO-9201	59		1			1	
1993	May-Aug	PO-9301	87						
1993	Jul; Oct	PO-9302	12						

Table 7. Continued.

Year	Months	Cruise	CTD	Surface Bucket	S&B Niskin Bottle	Std Hyd Niskin Bottle	Drift Bottle	XBT	MBT
1994	May-Aug	PO-9401	70						
1994	Oct	PO-9402	3						
1995	May-Sep	PO-9502	56						
1995	Jul; Sep; Oct	PO-9503	14						
1996	Apr-Sep	PO-9602	104						
1996	May-Jun; Sep-Oct	PO-9603	9						
1997	Apr-Sep	PO-9702	4						
1997	May-Sep	PO-9703	103						
1998	Mar; May-Aug; Oct	PO-9801	4						
1998	May-Aug	PO-9802	103						
1999	Feb-Mar; May-Oct	PO-9901	5						
1999	Jun-Sep	PO-9902	82						
2000	Mar-Apr; Aug-Oct	PO-0001	2						
2000	May-Oct	PO-0002	80						
2001	May-Sep	PO-0102	66						
2001	Aug-Oct	PO-0101	2						
2002	Jun-Sep	PO-0202	58						
2002	Sep	LL-0201	11						
2003	Jun-Sep	PO-0302	59						
2003	Sep	LL-0301	6						
2004	May-Sep	PO-0401	66						
2004	Oct	PO-0404	3						
TOTAL:			**1405**	**172**	**977**	**1216**	**101**	**1253**	**1123**

Determination of Spawning Condition and Locations

An important part of EFH and HAPC includes spawning grounds. This is particularly important on SAB live-bottom reefs, as many species of reef fish are known to migrate to specific sites at specific times of the year for spawning (Coleman et al. 1996; Domeier and Colin 1997; Sedberry et al. in press). Such sites are particularly favored by fisherman, resulting in vulnerability of fishes at a critical life history stage. There is particular interest in designing MPAs to incorporate spawning sites as EFH or HAPC (R. Pugliese, SAFMC, pers. comm., June 2004).

During fishery-independent surveys of the MARMAP Program (and associated projects funded by NOAA Fisheries Service) described above, all specimens of economically valuable reef fishes (or subsamples of large catches) were dissected to obtain samples for study of feeding, age/growth and reproductive biology. Data collected for each dissected specimen included capture location, hydrographic parameters, lengths (total, fork and standard, as appropriate), fish weight, and gonad weight. Gonads were fixed in the field in 10% seawater formalin solution. All fish samples from fishery-independent sampling that were processed for reproductive studies were obtained using LORAN-C or differential GPS navigation.

In addition to samples collected during the fishery-independent surveys, we sampled commercial (and, rarely, recreational) catches to obtain a full size range of specimens or to obtain samples outside of the months (generally May through September) that fishery-independent sampling occurred. Fishery-dependent samples were processed in the field and lab in the same manner as those collected during fishery-independent surveys; however, precise catch time and location were not always available. Commercial catch location was often reported as a NOAA Fisheries Service (NMFS) Reef Fish Logbook statistical grid cell number. Those cells are one degree of latitude by one degree of longitude or about 10,440 km^2 for this region. Deficiencies in time and location data were noted in the data analysis, and fishery-dependent samples were plotted differently on spawning location maps.

Reproductive tissues were processed in the laboratory, using standard MARMAP techniques (Wenner et al. 1986; Harris and McGovern 1997; McGovern et al. 1998; Harris et al. 2004; Sedberry et al. in press). For this project, analysis was limited to females, as males are in spawning condition for much longer periods and the presence of ripe testes was not considered evidence of imminent spawning. Females of all species were considered to be imminent spawners if migratory-nucleus oocytes or hydrated oocytes were present in histological sections of the ovary. The presence of postovulatory follicles in histological sections was considered indicative of recent spawning (<36 h ago). The presence of these three stages in histological sections of ovaries, along with time and location of capture was considered to be evidence of a spawning site for a particular species. Capture, fish length/weight, and gonad condition data were incorporated into the database for GIS analysis. The database also included hydrographic measurements taken by CTD deployed at the same time as the fish collections (± 2 h), and within one kilometer of the fish collection sites. We queried the database for the priority species for which we had reproductive data (Table 8) and exported the data to ESRI ArcInfo ArcMap 9.0 (ESRI 2005) for spatial analysis.

Table 8. Species from which SCDNR has collected life history samples for spatial and temporal analysis of sex and reproductive state.

Family	Scientific Name	Common Name
Berycidae	*Beryx decadactylus*	red bream
Scorpaenidae	*Helicolenus dactylopterus*	blackbelly rosefish
Polyprionidae	*Polyprion americanus*	wreckfish
Serranidae	*Centropristis ocyurus*	bank sea bass
	Centropristis striata	black sea bass
	Cephalopholis cruentata	graysby
	Cephalopholis fulva	coney
	Diplectrum formosum	sand perch
	Epinephelus adscensionis	rock hind
	Epinephelus drummondhayi	speckled hind
	Epinephelus flavolimbatus	yellowedge grouper

Table 8. Continued.

Family	Scientific Name	Common Name
Serranidae	*Epinephelus morio*	red grouper
	Epinephelus nigritus	warsaw grouper
	Epinephelus niveatus	snowy grouper
	Mycteroperca interstitialis	yellowmouth grouper
	Mycteroperca microlepis	gag
	Mycteroperca phenax	scamp
Malacanthidae	*Caulolatilus microps*	blueline tilefish
	Lopholatilus chamaeleonticeps	tilefish
Carangidae	*Seriola dumerili*	greater amberjack
Lutjanidae	*Lutjanus campechanus*	red snapper
	Rhomboplites aurorubens	vermilion snapper
Haemulidae	*Haemulon aurolineatum*	tomtate
	Haemulon plumieri	white grunt
Sparidae	*Calamus nodosus*	knobbed porgy
	Pagrus pagrus	red porgy
Centrolophidae	*Hyperoglyphe perciformis*	barrelfish
Balistidae	*Balistes capriscus*	gray triggerfish

Additional Data and Materials

An ancillary objective of this project was to contribute video clips and other bottom images from submersible video cameras and other bottom cameras to the ArcIMS web site, so that some habitats where some species were collected could be viewed on the Internet. Submersible transect start and end points (N=244) with reliable coordinates from 2001, 2002 and 2003 NOAA Ocean Exploration cruises conducted by SCDNR were chosen to be included in the GIS. Short segments of 10-15 sec of video were clipped as Audio Video Interleaved (AVI) files using Roxio DVD Builder v1.1. The video clips show representative reef morphology and general bottom characteristics from each selected transect start and end point. The AVI files were converted to MPEG (Motion Picture Experts Group) format using Cleaner v6.0 to reduce file size (*.mpg files) and allow them to load and play more smoothly across the Internet. The video clips were stored on the SCDNR Yellowfin server in Columbia, SC. A shapefile of the 244 transect coordinates, associated dive number, tape number and file path of the clipped video was created in ArcGIS v8.3 ™. This point file was transferred to the NOAA Coastal Services Center staff and added to the GIS project on the ArcIMS server.

Constructing the SEA-GEOFISH Database

<u>Data Collection and Quality Assurance</u>

The Southeast Geographic Fishery-Independent Survey and Historical database (SEA-GEOFISH) was built from many data sources and formats that required standardization, and quality assurance. All fishery-independent data collected on research vessels were initially recorded on paper logs and key-entered to American Standard Code for Information Interchange

(ASCII) files with an 80-character limit per keypunched (punch card) record. Data collected since 1989 follow the original paper log layout, but were recorded electronically from sensors and devices (weather, CTD data, GPS coordinates) or digital measuring devices (digital scales, electronic fish measuring boards, field computers). Site information (e.g., location, date, time, etc.) collected electronically (i.e., since 1987) were recorded into a Microsoft (MS) Access database. This was a combination of user-entered data and direct data inputs from sensors and electronic measuring devices aboard the vessel. Sample data for each species collected (e.g., species collected, total abundance, total weight, etc.) and life history data (individual specimen length and weight data) were entered through an electronic fish measuring board and recorded in data files (*.DAT) in ASCII characters. CTD data were recorded in hexadecimal files (*.HEX) in ASCII characters. In addition to the electronic data collected, several paper logbooks were used to record ancillary data, and were used to clarify inconsistencies, errors or other problems in the data. The project data manager and the chief scientists on each sampling cruise initially reviewed and corrected all data after each cruise.

Quality control checks included comparing electronic sampling location data to the chief scientists' logbook to double-check locations, dates and times. Sample data for all species collected were sorted by collection number and matched to the site information based on collection number and gear code. Any noted errors were corrected. Unidentified specimens brought back to the lab for confirmation were identified and the data entered. Life history data were sorted by collection number and matched to paper logs, with any noted errors corrected. Length-weight regressions were performed to check for outliers for which a measurement may have been incorrectly recorded. Any outlier was noted, investigated and corrected as needed. CTD HEX files were converted into CNV (also ASCII) files, using the SEABIRD (SBE) Data Processing Program. All files were then stored as final raw data.

Fishery-dependent data were collected from various commercial fishermen throughout the region. Commercial catches were sampled to obtain specimens that were caught outside the months that fishery-dependent cruises occurred, or to obtain species and sizes not frequently collected during research cruises. Those samples were used to complement fishery-independent samples obtained for life history studies. Data were collected in a similar fashion as the fishery-independent data, except that there was often no detailed data on catch location or other species caught. Fishery-dependent data were collected using paper logs or electronic fish measuring board when available. Fishery-dependent data recorded on paper were manually entered into text files. All files were then proofed against the original paper copies to capture typographical errors.

MS Access Importation and Secondary Quality Checks

Raw data files (ASCII, DAT, CNV, XLS) were converted into simple text files (delimited or fixed width). Converted files were then imported into Microsoft Access using the Import Wizard and Specification Rules. After importation, the tables were corrected for normalization. Normalization is a required structure format in any relational database, and aids in establishing an organized database that is easily maintained and updated, and normalization reduces disk space use by eliminating redundant data storage. In raw data files, short-hand codes were substituted for lengthy data descriptions of some data collection conditions (e.g., light phase, measurement units used for length or weight, type of balance used to weight fish). For each set of codes, separate code tables were established using the code as the primary (unique) key. These tables were then linked in a one-to-many relationship, with enforced referential integrity and cascading update/delete options, to the main data tables within the database (Appendix A and C).

Since fishery-dependent and fishery-independent sampling collected different additional sampling site information, the site information was distributed into three site tables: *tbl_SamlogMain*, t*bl_Samlog_FD*, and *tbl_Samlog_FI*. *Tbl_SamlogMain* contains data that are contained in both data types, while *tbl_Samlog_FD* contains additional fishery-dependent data and the remaining table contains additional fishery-independent data (Appendix B.1).

Because raw table imports did not follow normalization rules, the data were manipulated for normalization and ease of use within the database. A primary (unique) key was established for the site information tables, which consisted of a combination of three main fields: *Project ID, Collection Number* and *Gear Code*. A combination was required because historical data collection had collection number repetition within a project and there were multiple projects within the database. *Project ID*s (3-character SCDNR code) in raw data files were recorded as 2-character codes (to save space in the old 80-column format), therefore the third letter for the 3-character code needed to be identified and added to the field. *Collection Numbers* (6 characters, beginning with the last two digits of the year of capture), which were a numeric text field, were double checked for dropped leading zeros. Leading zeros were often dropped if the data had been placed in a program, such as MS Excel, which read the data as numeric instead of text. In raw files, minutes of latitude and longitude were recorded with an implied decimal place between the second and third digit (again to save space in the old 80-column format). Within MS Access, the location minutes were divided by 10 to adjust for the implied decimal. Beginning in the late 1990s coordinates were recorded in an MS Access system to the nearest .001minute. Data for these collections were standardized as needed. *Time* (Greenwich Mean Time, time zone Z) was recorded in decimal hours from 1973 through 1980 and in hours and minutes from 1981 on. All *Time*s were converted to international (24-hr) GMT. Additional fields were added to the tables to promote user-friendly queries. These were *Date*, *Year*, *Location* (latitude and longitude as decimal degrees) and quality codes. *Year* and *Date* fields were created out of the existing data contained within the database (*Day*, *Month* and *Collection Number* fields). *Location* fields were calculated from the latitude/longitude degree and decimal minutes fields. Once the information was updated it was checked for normalization by establishing *Project ID*, *Collection Number* and *Gear Code* (PCG) as the primary key field. Any records that had duplicate values were investigated and corrected as necessary. Another normalization check required validating all code fields within the table to the related code tables. Any erroneous code was investigated and corrected as necessary.

Sample information for fishery-independent data collected on research cruises contained overall data about the species within each collection. It listed the species, the total weight, subsampled weight, total number caught, and lengths with corresponding frequencies (number of fish of that species at that length within the collection (Appendix B.2). Basic sample information was placed in the *tbl_SpeciesData* table, while length-frequency data were placed in the *tbl_LengthData* table. First, the PCG field was added to the raw table and updated with the correct values. The PCG was then compared to the *tbl_SamlogMain* table to ensure that site information existed for that collection. If site information did not exist, the data was double-checked for typographical errors and corrected as necessary. A primary key was then established for this table. The primary key, PCGSQE, is a combination of the PCG (*Project ID*, *Collection Number*, and *Gear Code*), *Species Codes*, *Questionable Identification* value, and *Estimated Sample* code (indicating a subsample was measured and used to calculate the number of fish in the sample by multiplying the sample weight by the number of lengths (i.e. measured fish) in the subsample weight). The primary key was based on historical data that required this combination, where the PCG and *Species Code* were not unique due to questionable identifications that were later correctly identified and because of the subsample procedure. The QID (*Questionable Identification* value) field was converted from a text field to a Boolean Yes/No field. A final abundance field was added to the table, which reflects the calculated abundance for subsampled records (based on the weight and subsampled weight and number of fish measured in the subsample), and the actual abundance for complete (not subsampled) collections. All coded fields (e.g., balance equipment, measurement unit) were validated against the code tables. Any erroneous information was corrected as necessary.

Finally the table was split into the two MS Access tables (*tbl_SpeciesData* and *tbl_LengthData*), utilizing append queries. The length-frequency data were linked to the species data through the PCGSQE field, and the species data were linked to the site information table (*tbl_SamlogMain*) through the PCG field. Both of these links were one-to-many relationships with enforced referential integrity with cascading update/deletions options.

Life history data were gathered in various stages. Field length and weight values were captured in a text file key-entered from paper logs or from electronic logging equipment used on research cruises or when sampling commercial catches at the dock or in the laboratory. After analysis of the gonad samples in the laboratory (see above), codes for sex and reproductive state were added to this file. Additional detailed age and life history data were stored in separate files that varied in format according to the primary data collectors. Field life-history data were imported into the database and the table was modified for normalization (Appendix B.5). A primary key combination, PCGSS (*Project ID*, *Collection Number*, *Gear Code*, *Species Code* and *Specimen Number*) was created. Additionally the PCG field was created to link the table to the site information table in a one-to-many relationship with referential integrity and cascade update/delete options. Several YES/NO fields were converted to Boolean data format. Species codes were validated and any erroneous entry was investigated and updated accordingly.

Ichthyoplankton collection data were imported into Access and the table was modified according to normality rules. A combination primary key field, PCGSQ (*Project ID*, *Collection Number*, *Gear Code*, *Species Code* and *Questionable ID*) was created as well as the PCG field (Appendix B.4). The PCG field allowed the table to be related to the site information table in a one-to-many relationship with referential integrity and cascade update/delete options. Missing minimum or maximum lengths per collection were populated according to the data at hand (the original paper log sheets from laboratory analysis of the samples) when appropriate. Code fields were verified through relationships to the code tables.

Hydrographic information came from a variety of equipment (e.g., Niskin Bottles, CTD) and data files throughout the years. All electronic CTD data files (.HEX or .CNV) were uploaded into an MS Access table. The equipment type and data file source were added to each collection. Older hydrographic files had been compiled into one Excel file. Many records in this file were missing pertinent information (e.g., *Collection Number*, *Gear Code*). Almost all missing information was available by investigating the site information logs and was added to the file. Any information that was inconsistent or unable to be resolved was deleted from the dataset. The older hydrographic files were then uploaded to the MS Access system. For all hydrographic collections, a PCG field was established in order to relate to the site information table (Appendix B.3). Any discrepancies between the hydrographic collections and the site information were investigated. Errors were corrected in either the site information or the hydrographic files as necessary.

<u>MS Access Entry and Tertiary Quality Checks</u>

Secondary quality checks were used to establish format and normalization of the data, while tertiary quality check validated the actual data contained within the tables. Tertiary checks of the site information looked specifically at the *Location* fields, *Date/Time* fields, and *Depth* fields. Each record was mapped using the ArcGIS. Any locations that mapped outside the general collection region were investigated for erroneous data entry and corrected as necessary. Any record that had missing *Location* information received a quality code indicating that the information was not available. *Date* and *Time* fields were verified against *Collection Number* (year of collection, sequence of collection number) for any transposed data. These fields were also verified against the *Light Phase* code (e.g., day, night, dawn, dusk) and corrected as necessary. Dawn and dusk times were one hour on either side of local sunrise and sunset, determined from the Nautical Almanac. Any record missing a date and/or time was coded with an appropriate quality code. *Sample Depth* (depth of gear deployment) and *Station Depth* (depth of bottom) were verified against each other and with mapped records for any outliers or erroneous entries. Erroneous entries were corrected as necessary.

Tertiary checks of the species data looked for errors in weights and abundances. Weights were checked so that the subsample weight never exceeded the total weight. Final abundances were checked to see that they matched total abundances for non-subsampled data and were greater than the number measured for subsampled data. The *Quality* field was used to mark any records missing weights and/or measurement data.

Tertiary checks for length-frequency data looked for any duplicate length measurements for the same PCGSQE record. Any duplicates were investigated and either deleted (if true duplicate), combined with existing data, or checked for erroneous sample information (e.g., wrong species, collection or gear).

Tertiary checks for the life history data looked for incongruent measurements. Length data were validated so that total length was greater than fork length, which was greater than standard length. Weight data were validated so that total weight was greater than gutted weight, which was greater than gonad weight. Any discrepancy was investigated for conversion, typographical or other errors and corrected as necessary. When inconsistent data could not be verified the outlying value was deleted from the database. Additional data checks concentrated on length-weight and length-length regressions to look for outliers. Any outlying point was investigated and corrected or deleted as necessary.

Tertiary quality checks of hydrographic data investigated discrepancies in *Sample Depth, Station Depth, Location* and other hydrographic data collected (e.g., temperature, salinity). Any error that could not be resolved was deleted from that file.

<u>MS Access Structure</u>

The MARFIN database system was split into two databases, consisting of a front-end and back-end database. The back-end database contained all the tables, while the front-end database contained the forms, queries and reports, with the tables linked in a read-only mode. The database was split so that individual users could download the front-end database to their computer where they could change, edit or add queries and reports. Splitting the database also reduces the amount of memory required on each machine to access the front-end database because the tables are not stored within that database. Front-end users cannot change any of the actual data, but can create or modify queries. The back-end of the database has restricted access, with only a select user group, which can change, edit, delete or add information to the tables. All table relationships were created and stored in the relationships window (Appendix C). Individual table structures can be viewed through the back-end database in design mode (Appendix B).

Forms and queries were constructed to allow front-end users who had limited to no knowledge of MS Access to view the data in preset layouts with variable options for selecting data to be viewed or analyzed. Initial data questions and layouts were identified. Queries were then created to display these results with appropriate table linkages and field identifiers. Next, unbound forms were created to allow users to select criteria for the predefined queries. Field selections were added as either checkboxes, drop down selections or freeform text fields. Finally, visual basic code was written to run the behind-the-scenes actions that created the final results. Visual basic coding functions were: 1) interpret field selections; 2) converted query language; 3) supply actions to command buttons; and 4) supply error messages. Forms were then grouped according to data categories (e.g., demersal fish surveys, life-history data, ichthyoplankton surveys, etc.). Switchboard menus were then created to allow a user to navigate to the selected dataset and view the predefined queries/forms. The switchboard menu also gave the user the opportunity to view the code tables used within the database (but not change the values) and to hyperlink to the SEA-GEOFISH ArcIMS website (see below). Additional coding created toolbars and menu options specific to the SEA-GEOFISH database.

Final preparation for the front-end database required coding to depict the database's starting options. Starting options hid the actual database from view, made all tables and forms read-only, opened the switchboard automatically and allowed only the SEA-GEOFISH menu and toolbars to appear.

Building the GIS

Queries were performed in the SEA-GEOFISH MS Access database to acquire the appropriate data sets (species, abundance, biomass, reproductive state, etc.). These queries were exported as text files in a GIS-compatible format. Individual text files were created for each of the desired species, species groups, life history stages and/or gear types. All of these text files were imported into an ArcGIS 9.0 ArcMap document (ESRI 2005). The "display XY data" tool was then used to display the spatial distribution of the data points. The longitude field was assigned as the X, while the latitude field was assigned as the Y. This process resulted in event themes. Once plotted, the point data were visually error-checked to ensure that all data points fall within the study area of the project that collected the data, as a further quality control/quality assurance measure. These point data files were exported as shapefiles and delivered to the NOAA Coastal Services Center (CSC) for incorporation into the Internet Map Server (IMS).

To look for spatial patterns in abundance, biomass and diversity of selected taxa or life history stages, collections were pooled by latitude-longitude cell and mean catch calculated for each cell. CPUE output was generated for any specific gear with optional date ranges and species selections. The first step generated a table (*CPUE_Data*) that listed all valid collections. Valid collections were collections that were fished properly without any damage to the gear or loss of specimens (based on *Catch Codes* assigned to each collection in the field). Another query generated a list of all the collections where the desired species (or multiple species) and gears occurred and from which abundances and biomass were calculated; this list was appended to the collection table (*CPUE_Data*). All locations were placed within a 1-min latitude x 1-min longitude grid designation. For example, a location of 32º29.130'N / 78º 49.370'W, would be placed within the grid 32º39'N/78º49'W. Each grid started at the full minute (x.000) and went to the 999th decimal point (x.999). For example, grid 32º39'N/78º49'W would run from 32º39.000'N to 32º39.999'N and from 78º49.000'W to 78º49.999'W. Once collections were assigned to grids, total, mean, standard deviation and standard error were calculated for biomass and abundance within grid cells. Total number of valid collections were calculated for each grid cell and CPUE was calculated for each grid cell by dividing the total abundance or biomass values by the total valid collections (e.g., mean biomass per trap collection). The same procedure for mapping abundance and biomass by latitude/longitude cell was used for spatial analysis of trends in fish abundance and biomass from Yankee Trawl and Chevron Trap collections, because they had the greatest geographic coverage of all sampling gears. Diversity values were mapped in a similar fashion for Yankee Trawls.

For mapping diversity, Yankee Trawl data were pooled into the 1-min latitude/longitude grids to calculate four diversity indices: number of species per tow; species richness (Margalef 1958); Shannon-Wiener Index, H' (Shannon and Weaver 1949; Margalef 1958); and Pielou's (1975) Evenness Measure (J'). Two of these, number of species per tow and H' were used to map species diversity from Yankee Trawl catches. Analysis was limited to Yankee Trawl catches because they caught the most number of species and had the greatest geographic coverage. Diversity was mapped to visually determine areas with high diversity of fishes.

For mapping abundance, biomass and diversity by latitude/longitude cell, data as text files were imported into ArcGIS 9x. The text file was plotted using the display XY data function. The plotted data were visually error checked for accuracy to insure all points fell within the MARMAP sampling area and then exported to a shapefile. The shapefile was displayed using a graduated color scheme to cover the range of abundance, biomass or diversity values. The value ranges were manually edited to reflect appropriate data groupings.

Fish abundance data, consisting of mean catch per tow (trawls), abundance per cubic meter (plankton), mean catch per trap and mean catch per 100 hooks were calculated and mapped for some gears and species using the 1-minute latitude/longitude cells. In addition, these CPUE measures can be calculated from the ArcIMS web site (described below), using any unit of area.

To map spawning sites, the SEA-GEOFISH Database was queried for species identification, collection data, sex and reproductive state, and bottom temperature (collected ± 2 h, and within one kilometer of the fish spawning site). We queried the database for the priority species for which we had reproductive data (Table 8) and exported the data to ESRI ArcInfo ArcMap 9.0 for spatial analysis. We plotted location of capture of all specimens of each species, and overlaid location of capture of spawning females (as defined above) on the same map. Where relevant, we included on each map the location of proposed no-take (no bottom fishing) MPAs that are currently under consideration by the SAFMC (SAFMC 2004). We also analyzed occurrence of spawning females by month to define spawning season and temporal peaks in spawning activity. We calculated mean (± one standard deviation) and range of bottom temperatures recorded when spawning females of each species were collected. Sampling data reported in tables (below) were from fishery-independent sampling only, and depth, location, time and temperature data were accurate. Maps generated from the GIS analysis included approximate locations from some fishery-dependent samples, and those are differentiated on the maps.

Metadata records were created using ArcInfo ArcCatalog 9.0. The Federal Geographic Data Committee (FGDC) Environmental Systems Research Institute (ESRI) stylesheet was used as the template (http://www.fgdc.gov/metadata/metadata.html). Metadata was created for all gear-type and species shapefiles used on the IMS site (http://www.csc.noaa.gov/seageofish/). All metadata records were delivered to CSC for inclusion on the ArcIMS site, and can be viewed at the site (see below).

Because of the goal of mapping fishes in relation to EFH, HAPC and MPAs, we created data layers that included the *Oculina* HAPC (Reed 2002), the proposed MPA sites under consideration by the SAFMC (SAFMC 2004) and Gray's Reef National Marine Sanctuary (Sedberry et al. 1998). The SAFMC considers spawning locations of managed species to be HAPC (Roger Pugliese, SAFMC, pers. comm, June 2004) and we made mapped those areas as well (see above).

All static maps for reports were created using ArcGIS 9.0 ArcMap. The maps were exported as .PDF and .jpg files for use in this report and an accompanying CD-ROM.

The ArcIMS Web Site

The ArcIMS web site (http://www.csc.noaa.gov/seageofish/) was built in cooperation with CSC and its contractors at Perot Systems Government Services (PSGS) and I.M. Systems Group (IMSG). Because of CSC's interest in the project and in adding data and information that fit the mission of CSC and its web sites, the CSC did this work at no cost to the project.

The first step in building the IMS web site was the Software Development Plan (Appendix D), which is summarized here. The software plan included a description of the ArcIMS site; all necessary data required for the product (including the expected source, format, attributes, scale, and extent); software system diagrams that defined and described custom functions and functional coding units; estimates of programming, tester, and support staff time requirements and activities needed to complete the project; a definition of the alpha and beta product draft versions and a description of planned alpha and beta reviews; a production timeline which estimated alpha, beta, and final review periods, change control periods, quality control/testing periods, and delivery dates; a user interface approved by the PI; a quality assurance plan describing coding units and unit clusters and how each will be tested and each containing review and testing protocols for the alpha and beta product versions; and a change control plan specifying opportunities for changes that deviate from the plan as well as a protocol for addressing unexpected change requests. Quality assurance and control of all phases of building the ArcIMS followed the PSGS Quality Assurance Plan and was further defined in the PSGS Overview of the Software Development Process.

Staff at CSC were asked by the project PI to create an Internet-based mapping application that allows any user with an Internet connection and capable browsing software to visualize, identify, and conduct basic queries of the fisheries database described above. It was determined that an ArcIMS site would be the ideal vehicle to "incorporate the GIS and database into a web-based framework made available to scientists, resource managers and the general public, to more effectively plan future mapping, exploration, and management in the South Atlantic Bight", as we proposed. The ArcIMS site was designed to provide stakeholders with the ability to access the necessary information for sustainability of the resources, including maps and locations of the resource species' distributions, and analysis tools to help support management of the resource.

The primary intended audience when designing the ArcIMS site was members of the scientific community and resource managers within the South Atlantic Bight. However, there are a number of other agencies, organizations, academic institutions, as well as the general public that will potentially have interest in this application. As a result, the user interface was designed to be as easy to navigate and operate as possible.

The Internet mapping application was developed using ESRI's ArcIMS, version 4.01 software package and was designed to be viewed with a standard Web browser without the need for additional user software. Requirements for the backwards compatibility of this product were developed from CSC standard practices and were based on previous user characterizations generated from the past three years of documented user trends. The code that was written to enact the specified functionality relies on Java scripts that are proprietary to the ArcIMS HTML Viewer software package. Therefore, the code can only be implemented in web pages that have been developed specifically for use with this software and will not function in a stand-alone web environment.

The data and map view were assembled by SCDNR staff using ArcGIS and provided to CSC to be incorporated into the Center's ArcIMS template. The graphical user interface used was very similar to existing Center products, with some additional functionality (buttons). All input data were in a common folder and hosted on the Center's ArcIMS server. To limit the complexity associated with on-line map interaction, multiple data frames were used to group similar data sets. Because this product involves the use of the CSC IMS template, much of the design elements and tools were standard within the product. For example, standard code already existed to execute the "Pan, Zoom", and "Identify" functions. For this reason, many of these tools are listed as a "Predefined Process or Tool".

The mapping tool was developed as an ArcIMS site, built with a single *.MXD file that contains multiple data frames. Designers at CSC adhered to established system architecture for IMS projects, including a Web server, ArcIMS 4.01 (w/ ArcMap Server), Java Servlet Container, CSCCommon JAR Library, and Struts 1.1.

Because the ArcIMS site will use an MXD to reference the data layers, the file structure was based on the requirements as set forth in the ArcIMS 4.01 documentation. However, the ArcIMS Web site does not include successive queries and, thus, will not store any intermediary or queried data sets on the Center server for future use.

A prototype interface was developed that documented the Graphical User Interface (GUI) and features of the mapping tool. The prototype interface essentially looked like the final product, but did incorporate functionality to store or process information.

Nearly all of the required functionalities for the SEA-GEOFISH ArcIMS site were already available within the CSC template. Based on the interface for the "Coastal Storms Initiative: Risk and Vulnerability Assessment Tool" (http://www.csc.noaa.gov/rvat/), the only elements that required custom coding were the "Zoom to x/y", "Multiple Selection/Drill Down Identify", and "Summarize" functions. These queries required an additional distinct icon within the interface in order to maintain their prominence and visibility to the user. The "Zoom to x/y" function was designed to allow the user the ability to center the map on a specific geographic coordinate location by either entering the x/y coordinates into a text box or by clicking on the map. The "Multiple Selection/Drill Down Identify" tool was designed to identify multiple layers in the active data frame, and calculate user-defined statistical analyses (descriptive statistics such as biomass per unit area from a specific sampling gear and/or species, or CPUE for a selected area/gear/species combination). A "Summarize" function was designed to be similar to the "Multiple Selection/Drill Down Identify" tool, but allows the user to calculate user-defined statistics for one layer at a time. Output from both functions consists of a table, with summary statistics at the top, and the accompanying record files. The site was designed to deliver final products as an image service, functioning within the Web browser to return an image based on the request that is submitted.

The IMS site was also set up to provide a data download function. All data sets provided within the IMS site have a corresponding PkZip file, including the shapefile and its corresponding FGDC-compliant metadata. The download function will provide the user with more flexibility than the existing Web page. No data were made available for download at the time of this report, but will be made available as requests are evaluated.

Product Design began in May 2004 and was completed by the end of the year. The draft ArcIMS site was made accessible to all parties with Internet access. As development progressed, the PI and CSC partners made decisions regarding changes after a fully (or nearly fully) functional Alpha 1.0 version was completed and tested by the project team, then reviewed by SCDNR staff. Additional data uploads, minor text corrections, and other changes have been added, based on preliminary user comments. Modifications have been, and will continue to be made to the existing center ArcIMS template Viewer, in order to include the necessary functionality.

In order to get the site up and running for testing, we incorporated shapefiles of distribution of fish species, rather than all the raw data. To determine "Important Species" for inclusion into the initial shapefile transfer, we analyzed the SEA-GEOFISH data and included the species that ranked among the top ten by abundance within any one fish sampling gear described above. This resulted in 37 "Important Species" included in the IMS as of 1 January 2005. All species will be added in the future.

Project Management:

Personnel:

George R. Sedberry, Principal Investigator. Marine Resources Research Institute (MRRI), SCDNR.
John C. McGovern, Co-Principal Investigator. MRRI, SCDNR.
Philip R. Weinbach, Co-Principal Investigator and GIS Manager. Marine Resources Division (MRD), SCDNR.
Joshua K. Loefer, Biologist II. Research Assistant. MRRI, SCDNR.
Daniel J. Machowski, Biologist II, Research Assistant. MRRI, SCDNR.
Jessica A. Stephen, Biologist II, Research Assistant. MRRI, SCDNR.
David M. Wyanski, Biologist III, Research Assistant. MRRI, SCDNR.
Athan M. Barkoukis, Graduate Research Assistant. College of Charleston and MRRI, SCDNR.
Sarah B. Griffin, Graduate Research Assistant. College of Charleston and MRRI, SCDNR.
Christina Ralph Schobernd, Graduate Research Assistant. College of Charleston and MRRI, SCDNR.
David dosReis-PSGS Project Leader. Perot Systems Government Services (PSGS), CSC.
Kyle Draganov-IMSG Lead Programmer. I.M. Systems Group, CSC.
Hamilton Smillie, NOAA Project Leader. NOAA Coastal Services Center (CSC).

Dr. Sedberry was responsible for overall project management, and ensured that tasks were completed according to schedule as outlined in the proposal. Dr. McGovern was Principal

Investigator on the MARMAP Program and several other NOAA Fisheries Service projects that supplied data for this project. He left SCDNR several months after the project began, but was instrumental in initial coordination of databases. Mr. Weinbach oversaw construction of GIS data layers, files and maps, and integration of datasets into a comprehensive GIS. He coordinated building of the ArcIMS site with from CSC and transfer of files. Mr. Loefer and Mr. Machowski assisted in data reduction and quality control. Mr. Machowski's considerable experience with the MARMAP database solved many problems with old data. Ms. Stephen built the MS Access database from scratch, using 30+ years of data in various formats in raw text files. She completed this monumental task in spite of having little experience collecting the data, and she and Mr. Machowski assured that the data were checked and are as error-free as is humanly possible. Mr. Wyanski provided the data from over two decades of MARMAP studies of reproductive biology of reef fishes; he also assured those data were clean. Mr. Barkoukis compiled data from Gray's Reef National Marine Sanctuary and Ms. Griffin and Ms. Schobernd assisted in data reduction and bringing imagery into the database and ArcIMS site. Mr. dosReis and Mr. Draganov built the ArcIMS site, made it visually pleasing and easy to use, and made it work, and Mr. Smillie was the NOAA Project Leader at CSC for the ArcIMS site.

This project benefited from the professional experience and advice of several people familiar with the data and the fishes and fisheries of the South Atlantic Bight. Charlie Barans and Oleg Pashuk provided advice on fish and hydrographic sampling, respectively, from the early days of the MARMAP program. Charlie Wenner and Bill Roumillat, former investigators on the MARMAP project, also provided advice on the historical data. Geno Olmi and Lori Cary-Kothera, CSC, were instrumental in forming the partnership between SCDNR and CSC for this project. Roger Pugliese and Myra Brouwer (SAFMC) provided advice and data on proposed MPAs, HAPC and other fishery habitat issues.

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Special thanks are extended to all current and past scientists, vessel crews and NMFS technical monitors of the cooperative SC-MARMAP program, for careful collection, editing and processing of mountains of data.

FINDINGS

Accomplishments and Findings

Data Collected and Processed

For this project, data from 2601 bottom trawl collections (years 1973-1987), 11,639 fish trap collections (1977-2004), 2240 baited hook collections (1977-2004), 2521 plankton collections (1973-1986) and 6247 hydrographic stations (1973-2004) were compiled into the database. Collections occurred mainly from Cape Hatteras, North Carolina through south Florida. Most of the collections were from the waters off South Carolina (coastline from 32°02'N to 33°49'N) and Georgia (coastline from 30°42' to 32°02'N), and 65.0% were collected from 31°00.00'-32°59.99'N latitude. An additional 21.3% were collected from 33°00.00'-34°59.99'N latitude. Many collections (10.6%) were from 29°00.00'N-30°59.99'N. Off south Florida, 2.7% of collections came from 27°00.00'N-28°59.99'N. Less than 0.3% of collections came from latitudes lower than 27°N or from 35°N or higher. Fishery-independent samples were collected from 18°05.20'N (off of Puerto Rico) up to 35°22.00'N (off of Cape Hatteras, North Carolina) and from the coast (1-m depth) out to the "Charleston Bump" (Sedberry et al. 2001) on the Blake Plateau (686 m depth). Fishery-dependent samples were collected from 18°14.33'N (off Puerto Rico) up to 40°40.90'N (off New York), and from 2-697 m depth. Fishery-dependent samples were collected from as far east at the mid-Atlantic ridge (28°56'W).

Fishery-independent gear that sampled demersal fishes (trawls, traps, hooks) caught 1,221,324 specimens representing 126 families and 583 species. Of these specimens, 553,062 were measured and 145,031 were dissected to obtain life history samples, including 43,475 specimens that were aged from otoliths or other hard parts and 109,073 that were classified by reproductive state (sex, maturity, condition) based on gonad histology.

Plankton-sampling gear caught 243,693 larval fishes identified to 705 unique taxa (species, genus, subfamily or family) representing 146 families.

The database comprised 89.4 mb of general back-end data (groundfish catch data, hydrographic and plankton data), 65.1 mb of life history backend data and 30.8 mb of front-end data (forms, codes). It included 33,315 sample records (station data), 58,596 groundfish species data records (a record of a species occurring in a collection), 201,446 groundfish length frequency records (a record of a length and its frequency for a particular species in a particular collection). The database also contained 23,270 plankton records (a record of a species in a plankton collection, including its abundance and minimum and maximum lengths in the collection). Records containing hydrographic data [a record may be a surface and/or bottom measurement or a water column profile (standard hydrographic depths or continuous)] totaled 164,046. There were 156,031 records containing life history information (individual specimen lengths and weights, plus ages and/or reproductive state.

SEA-GEOFISH Database

At the time of this report, the Access database contained approximately 45 tables, 23 forms, 49 queries, 37 function modules, 22 switchboard modules and six reports. Users can access the database to extract complete datasets based on user-selected criteria (e.g., species, depths, locations, gears (e.g., Fig. 13). After selecting data to be analyzed, users can generate simple calculated datasets (e.g., total abundance), or more complex calculations such as CPUE (e.g., Fig. 14). The user can extract hydrographic data related (spatially and temporally) to each fish collection (Fig. 15), and similar queries can be made for the plankton data (Fig. 16). Following selection of data, summaries and descriptive statistics, users can create reports based on query outputs and view metadata relating to coded fields. Extracted data can be printed, exported to Excel, text or rich text format files, imported into ArcGIS for mapping or imported into Statistical Analysis Systems (SAS 2004) or other statistical and ecological software packages for statistical analysis and calculation of ecological indices (e.g., diversity, similarity).

Length frequency from catch data can be extracted based on selection criteria, and can include simple descriptive statistics (Fig. 17). Additional detailed life history information can also be obtained, including detailed lengths and weight and gonad condition (Fig. 18).

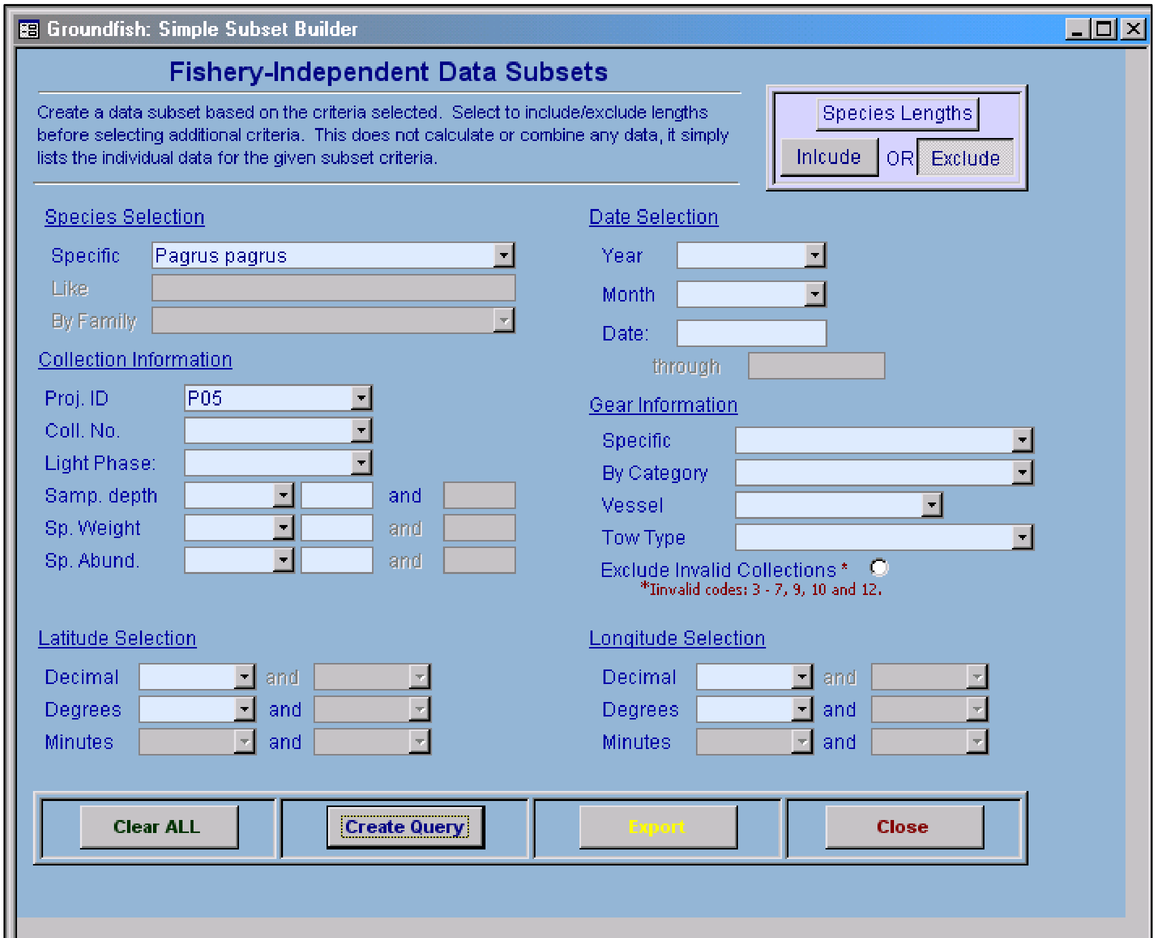
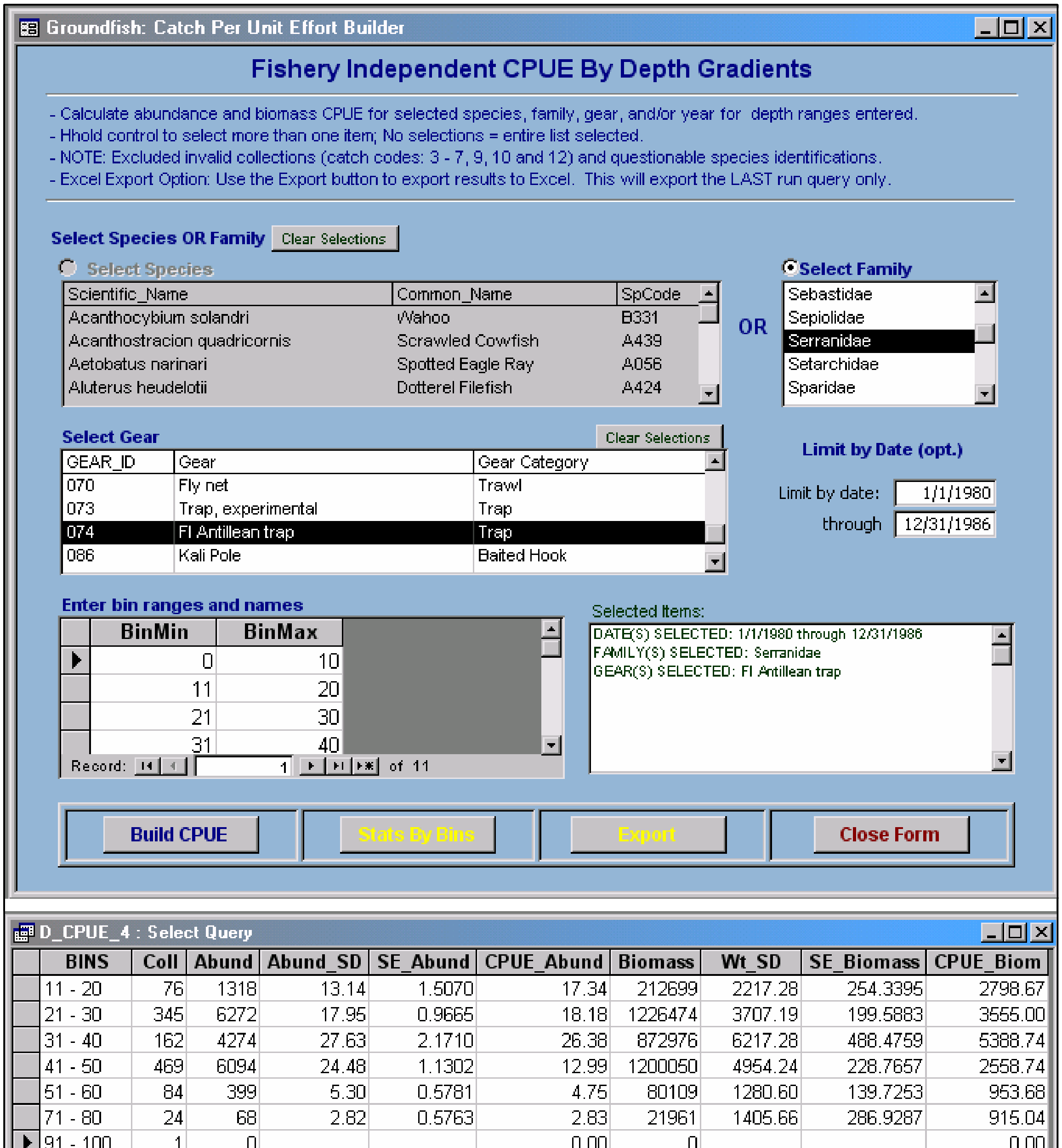
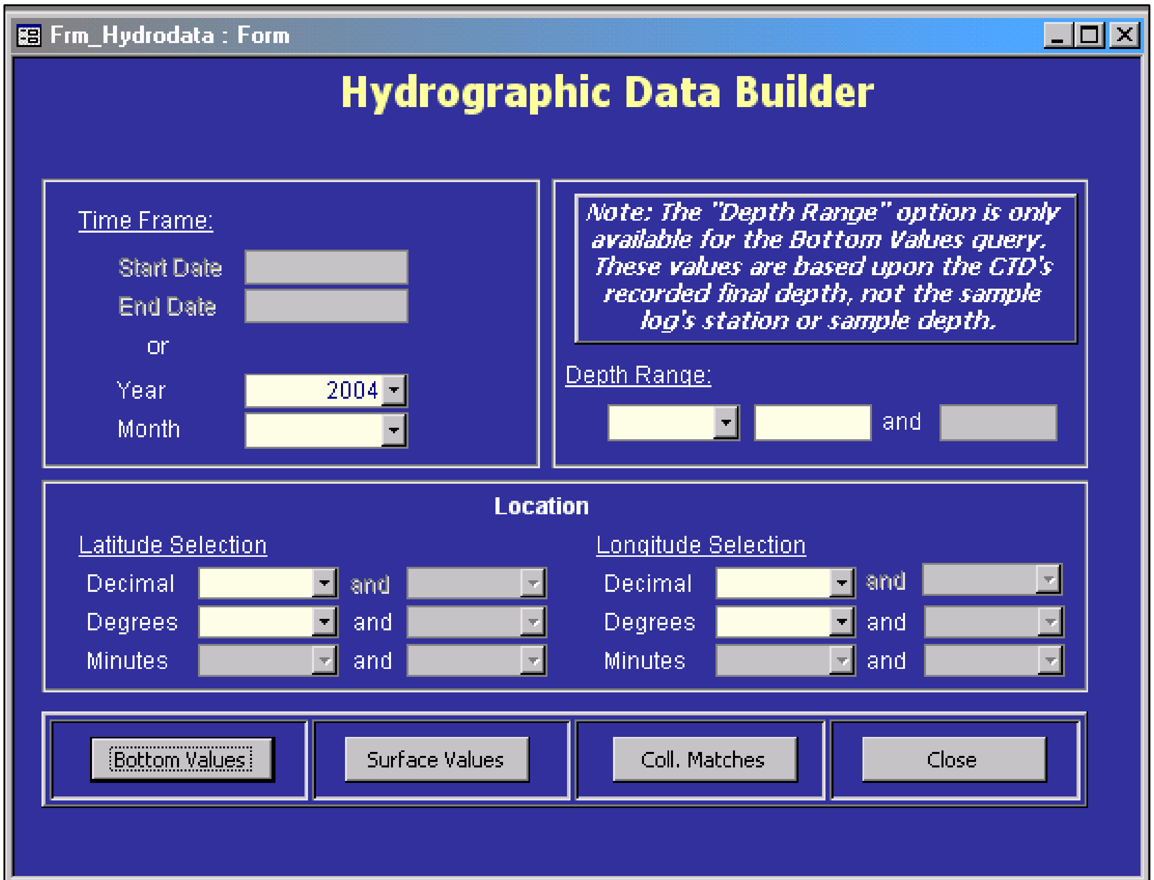


Fig. 13. Screen capture from SEA-GEOFISH database, showing query set up to extract data for a single species (*Pagrus pagrus)* and showing various selection criteria.



BINS	Coll	Abund	Abund_SD	SE_Abund	CPUE_Abund	Biomass	Wt_SD	SE_Biomass	CPUE_Biom
11 - 20	76	1318	13.14	1.5070	17.34	212699	2217.28	254.3395	2798.67
21 - 30	345	6272	17.95	0.9665	18.18	1226474	3707.19	199.5883	3555.00
31 - 40	162	4274	27.63	2.1710	26.38	872976	6217.28	488.4759	5388.74
41 - 50	469	6094	24.48	1.1302	12.99	1200050	4954.24	228.7657	2558.74
51 - 60	84	399	5.30	0.5781	4.75	80109	1280.60	139.7253	953.68
71 - 80	24	68	2.82	0.5763	2.83	21961	1405.66	286.9287	915.04
91 - 100	1	0			0.00	0			0.00

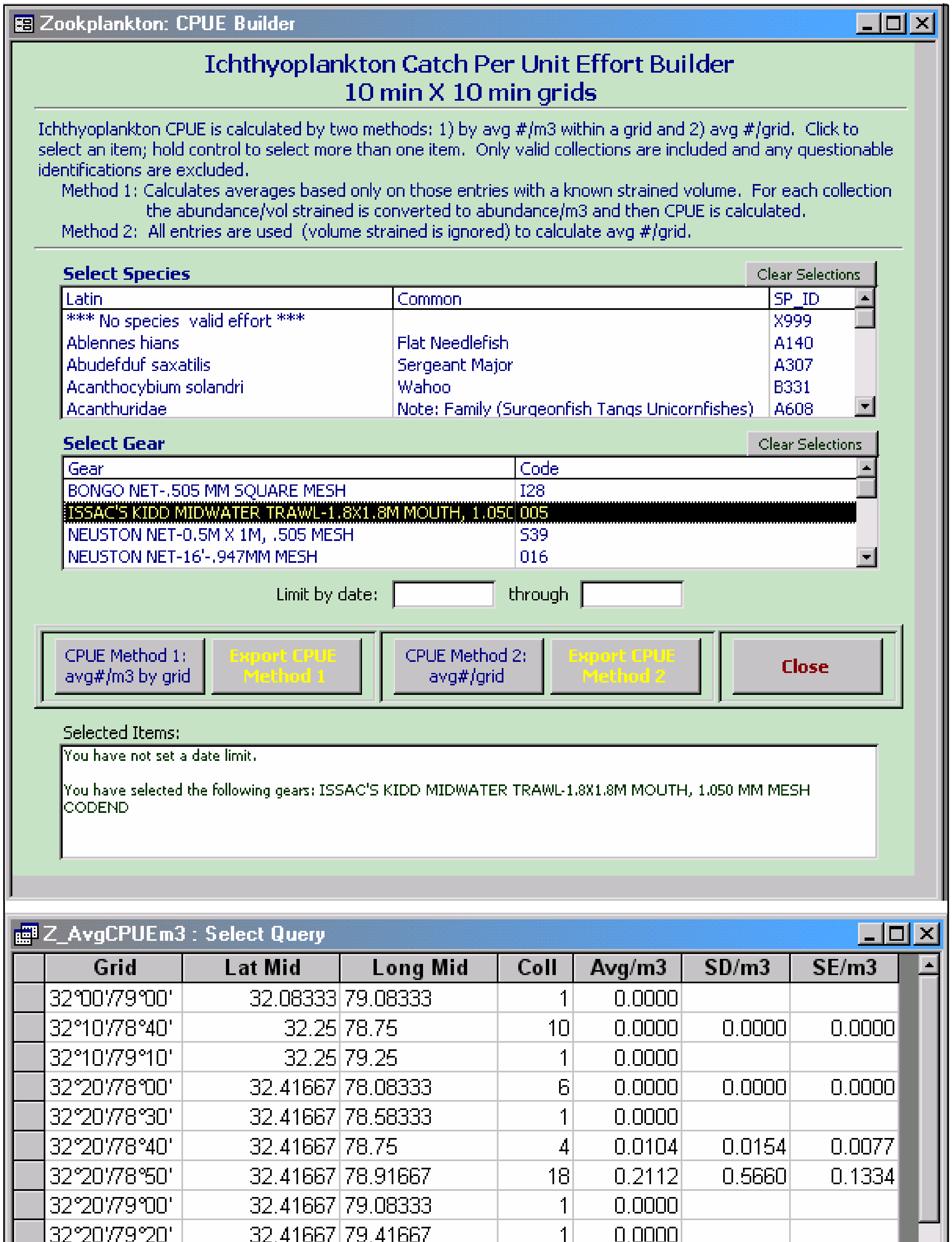
Fig. 14. Screen captures from SEA-GEOFISH database, showing setup to calculate CPUE by family (Serranidae), gear (Florida Antillean Trap) and depth interval (10-m), for dates from 1 Jan 1980 through 31 Dec 1986. The results of the query are shown in the table below (separate screen). The resulting table shows each depth interval (BINS), number of collections that met the selection criteria, total number of fish (Abund), total weight in grams (Biomass). Also included are CPUE and measures of variance (SD and SE) for mean abundance and biomass.



qry_hydrobottom : Select Query

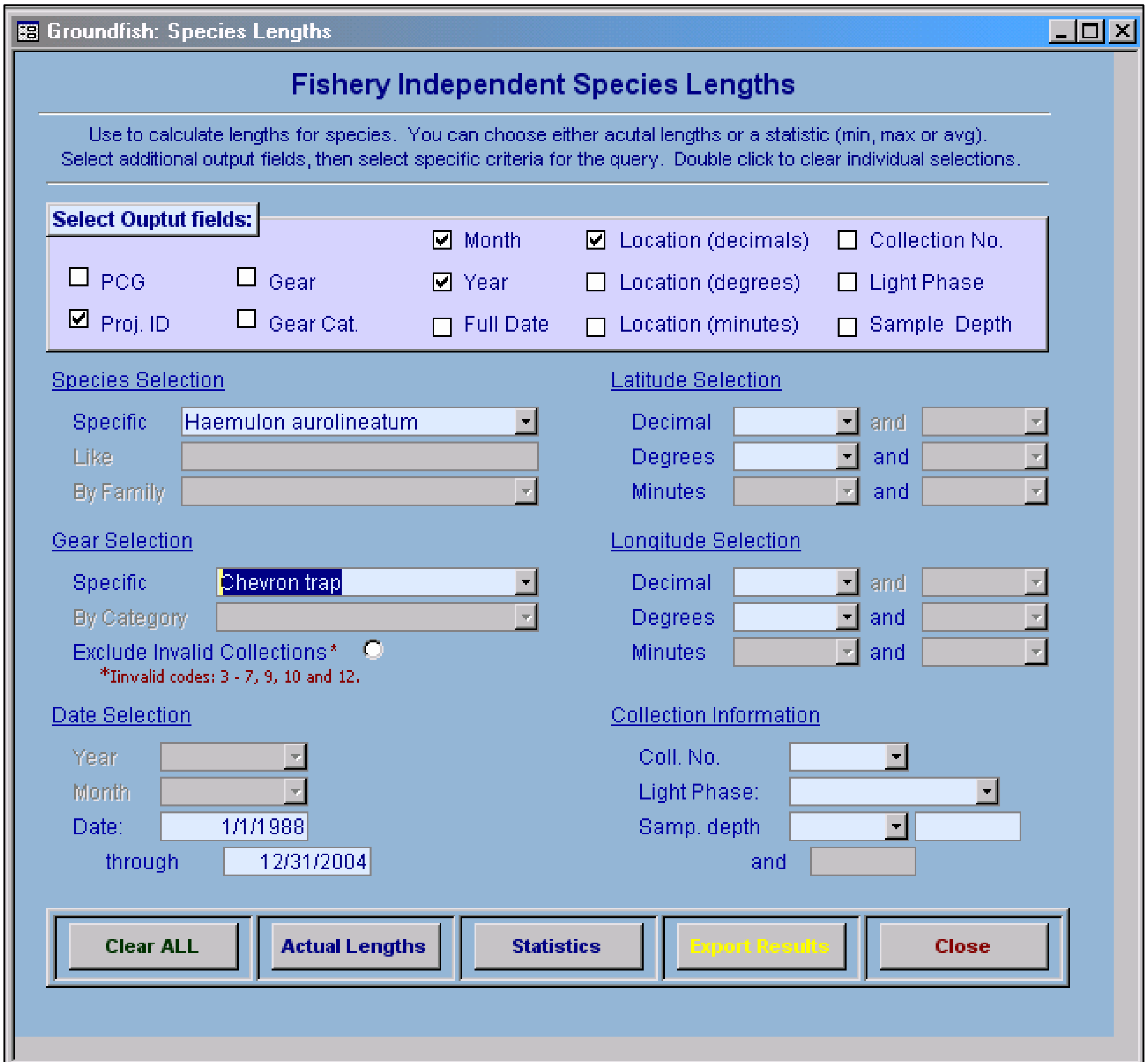
PCG	Gear_abbr	Pressure	Depth	Temp	Salinity	Oxygen	CHLA	Date	Latitude	Longitude	OffBottom
P05040329298	CTD	40.275	39.990	21.70	36.438	4.55667	0.2615	7/21/2004	33.92167	-76.75500	☐
P05040122298	CTD	46.990	46.657	19.55	36.440	3.68690	0.6593	6/2/2004	32.83333	-78.27167	☐
P05040241298	CTD	25.547	25.367	0.00	36.281	4.58110	0.3580	6/22/2004	33.27500	-78.45000	☐
P05040021298	CTD	55.311	54.919	0.00	36.414	3.73142	0.1816	5/5/2004	32.35667	-79.04166	☐
P05040129298	CTD	194.713	193.265	0.00	35.934	3.07709	-0.0628	6/2/2004	32.73000	-78.10000	☐
P05040150298	CTD	43.734	43.424	0.00	36.418	3.52483	0.2852	6/3/2004	32.70667	-78.54166	☐
P05040227298	CTD	66.975	66.498	16.71	36.148	3.08340	0.3083	6/10/2004	31.62333	-79.66833	☐
P05040348298	CTD	32.244	32.016	25.75	36.358	4.67055	0.2313	7/22/2004	33.83500	-77.26500	☐
P05040322298	CTD	42.072	41.775	20.43	36.398	4.34408	2.1779	7/21/2004	33.93667	-76.52167	☐
P05040103298	CTD	29.983	29.771	22.80	36.387	4.71212	0.1164	5/26/2004	32.23333	-79.70167	☐
P05040303298	CTD	25.426	25.249	23.35	36.409	4.53776	0.5685	7/20/2004	33.27000	-78.45834	☐
P05040136298	CTD	55.480	55.086	0.00	36.403	3.21828	0.0922	6/3/2004	32.76000	-78.43500	☐
P05040014298	CTD	53.033	52.656	18.57	36.404	3.43689	0.1173	5/5/2004	32.28167	-79.15833	☐
P05040341298	CTD	41.917	41.621	0.00	36.466	4.84147	3.5638	7/21/2004	33.77500	-76.85500	☐
P05040171298	CTD	54.723	54.335	19.84	36.273	3.92609	0.4297	6/8/2004	31.10500	-79.92333	☐
P05040440298	CTD	17.196	17.075	23.47	35.046			10/28/2004	31.40333	-80.84666	☐
P05040336298	CTD	37.948	37.680	23.95	36.396	4.62133	0.3365	7/21/2004	33.96333	-76.79333	☐
P05040297298	CTD	26.638	26.452	23.46	36.409	4.51760	0.4862	7/20/2004	33.27167	-78.45500	☐
P05040388298	CTD	198.813	197.332	12.08	35.563	2.79293	-0.0558	8/5/2004	32.10167	-79.05666	☐
P05040028298	CTD	97.499	96.796	18.08	36.376	3.22436	-0.0280	5/6/2004	32.25500	-79.03333	☐
P05040096298	CTD	27.666	27.471	0.00	36.383	4.73316	0.1355	5/26/2004	32.25500	-79.71667	☐

Fig. 15. Screen captures from SEA-GEOFISH database, showing screen to extract hydrographic data (top) and example results (below) from bottom measurements taken using a CTD equipped with DO probe and fluorometer.



Grid	Lat Mid	Long Mid	Coll	Avg/m3	SD/m3	SE/m3
32°00'/79°00'	32.08333	79.08333	1	0.0000		
32°10'/78°40'	32.25	78.75	10	0.0000	0.0000	0.0000
32°10'/79°10'	32.25	79.25	1	0.0000		
32°20'/78°00'	32.41667	78.08333	6	0.0000	0.0000	0.0000
32°20'/78°30'	32.41667	78.58333	1	0.0000		
32°20'/78°40'	32.41667	78.75	4	0.0104	0.0154	0.0077
32°20'/78°50'	32.41667	78.91667	18	0.2112	0.5660	0.1334
32°20'/79°00'	32.41667	79.08333	1	0.0000		
32°20'/79°20'	32.41667	79.41667	1	0.0000		

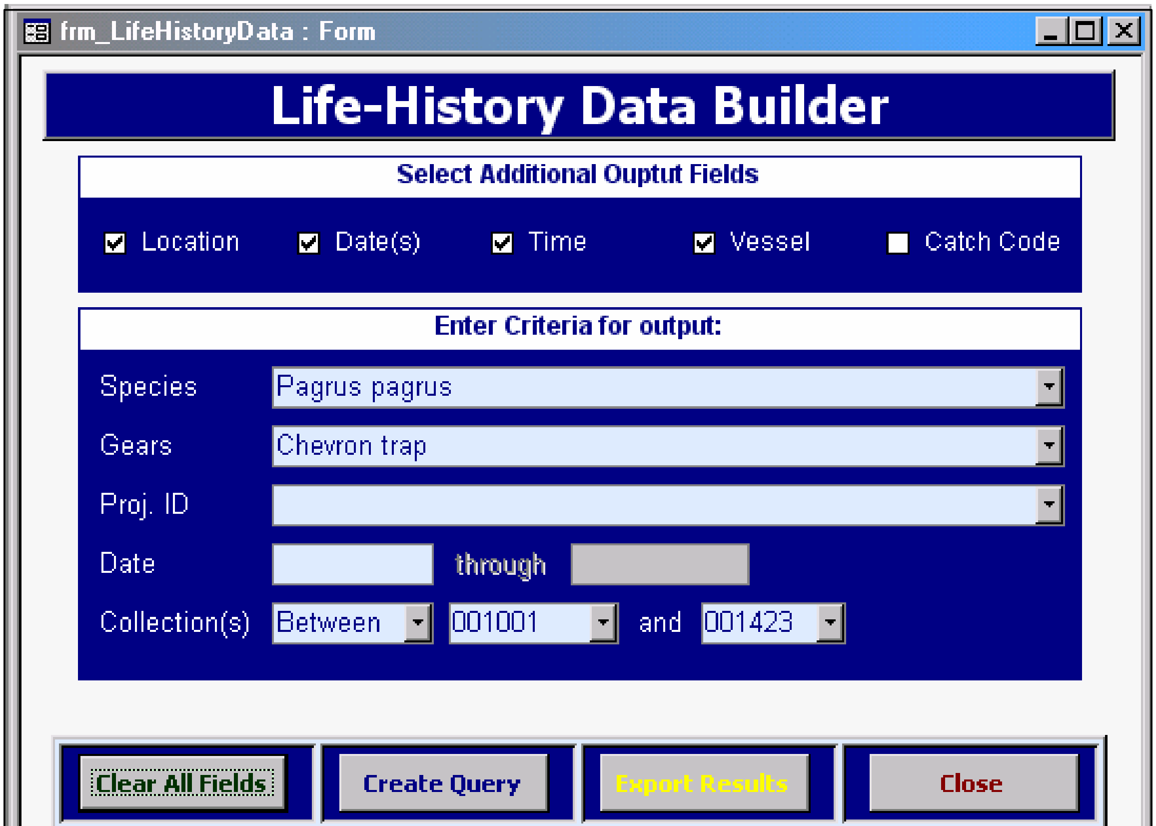
Fig. 16. Screen captures from SEA-GEOFISH database, showing screen to extract plankton data for 10- x 10-min latitude/longitude cells (top), and example results (below).



qrySpListing : Select Query

SP_ID	Scientific_Name	Min Length	Max Length	Avg Length	PID	Month	Year	Latitude	Longitude
A258	Haemulon aurolineatum	16	21	18.63	P05	4	1990	32.23565	-79.69624
A258	Haemulon aurolineatum	16	20	17.64	P05	4	1990	32.23678	-79.69370
A258	Haemulon aurolineatum	16	19	17.00	P05	4	1990	32.23829	-79.69043
A258	Haemulon aurolineatum	15	21	17.52	P05	4	1990	32.23883	-79.69800
A258	Haemulon aurolineatum	14	18	16.27	P05	4	1990	32.23985	-79.70509
A258	Haemulon aurolineatum	16	17	16.50	P05	4	1990	32.24002	-79.69470
A258	Haemulon aurolineatum	16	19	17.05	P05	4	1990	32.24033	-79.69614
A258	Haemulon aurolineatum	15	20	17.21	P05	4	1990	32.24053	-79.69489
A258	Haemulon aurolineatum	15	18	16.40	P05	4	1990	32.24067	-79.69756
A258	Haemulon aurolineatum	16	19	17.71	P05	4	1990	32.24165	-79.68460
A258	Haemulon aurolineatum	16	18	17.00	P05	4	1990	32.24170	-79.70290
A258	Haemulon aurolineatum	16	22	17.35	P05	4	1990	32.24237	-79.70081
A258	Haemulon aurolineatum	16	19	17.57	P05	4	1990	32.24423	-79.70635
A258	Haemulon aurolineatum	16	20	16.88	P05	4	1990	32.24598	-79.70567

Fig. 17. Screen captures from SEA-GEOFISH database, showing screen to extract length frequency data (cm) for tomtate (above) and example results (below).



qry_LifeHistory : Select Query

PCG	SP_ID	SPEC	Age	TL	FL	SL	FISH_WT	SEX	Sex_text	MATURITY	Maturity General	Mat_Male
P05001001324	A272	1		335	289	259	562	5	Hermaphroditic female	6	Transitional	Protogyny: testicular pro
P05001001324	A272	2		310	263	246	422	5	Hermaphroditic female	5	Resting	Larger transverse section
P05001001324	A272	3		272	236	204	283	5	Hermaphroditic female	0	Uncertain maturity	Inactive testes; unable to
P05001001324	A272	4		261	225	196	272	5	Hermaphroditic female	1	Immature (virgin)	Small transverse section
P05001002324	A272	1		329	279	245	501	5	Hermaphroditic female	6	Transitional	Protogyny: testicular pro
P05001002324	A272	10		395	345	300	787	4	Hermaphroditic male	3	Running Ripe	Predominance of spermat
P05001002324	A272	11		358	317	263	689	4	Hermaphroditic male	3	Running Ripe	Predominance of spermat
P05001002324	A272	12		365	313	267	692	4	Hermaphroditic male	3	Running Ripe	Predominance of spermat
P05001002324	A272	13		328	292	239	495	5	Hermaphroditic female	6	Transitional	Protogyny: testicular pro

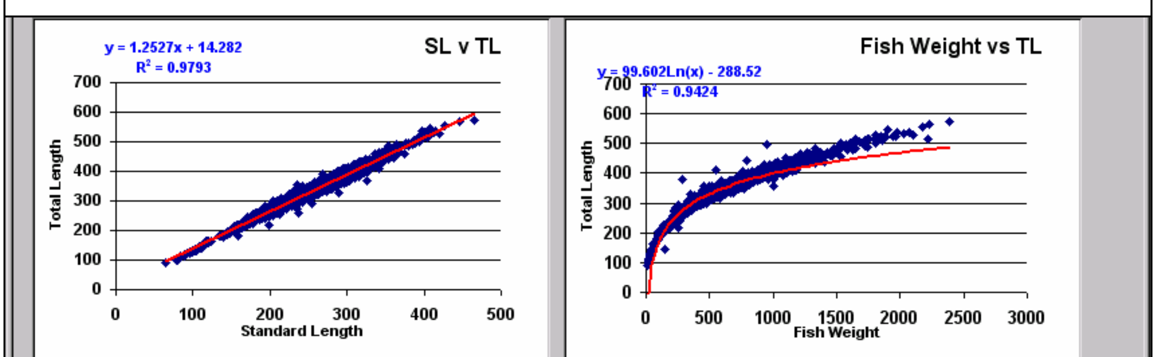


Fig. 18. Screen captures from SEA-GEOFISH database, showing screen to extract life history data for red porgy (top), example data showing sex and maturity (middle), and example length-length (mm) and length-weight (g) relationships (bottom left and right).

GIS and the ArcIMS Website

Building the MS Access database has enabled us to construct maps and visualize patterns of species' distributions, abundance, diversity and CPUE. All maps illustrated in this report were generated from the SEA-GEOFISH database and demonstrate the mapping capabilities of the database. In addition to the sampling location maps previously shown (Figs. 1-12), we can map any number of parameters in the SEA-GEOFISH database. We can also map relevant data and images that have been imported from other sources (not SCDNR sampling), such as sea surface temperature images. One such database that is very important to this project is the location of designated or proposed HAPC and MPAs. Coordinates for existing HAPC (consisting of the *Oculina* HAPC) and offshore MPAs (Gray's Reef National Marine Sanctuary), as well as proposed MPAs (SAFMC 2004) were incorporated into the GIS (Fig. 19). Distribution and abundance of individual species can be mapped in relation to existing or proposed marine managed areas (Fig. 20). Existing or proposed MPA sites or other kinds of Marine Managed Areas (MMAs) can be examined to determine the extent of knowledge of fish assemblages occurring there by looking initially to see if there has been any sampling in the proposed sites (Fig. 20-23). Some sites have been intensively sampled as part of MARMAP reef fish sampling (Fig. 21-22), whereas others have not (Fig. 23). This may be an indication of the amount of reef fish habitat in each proposed MPA.

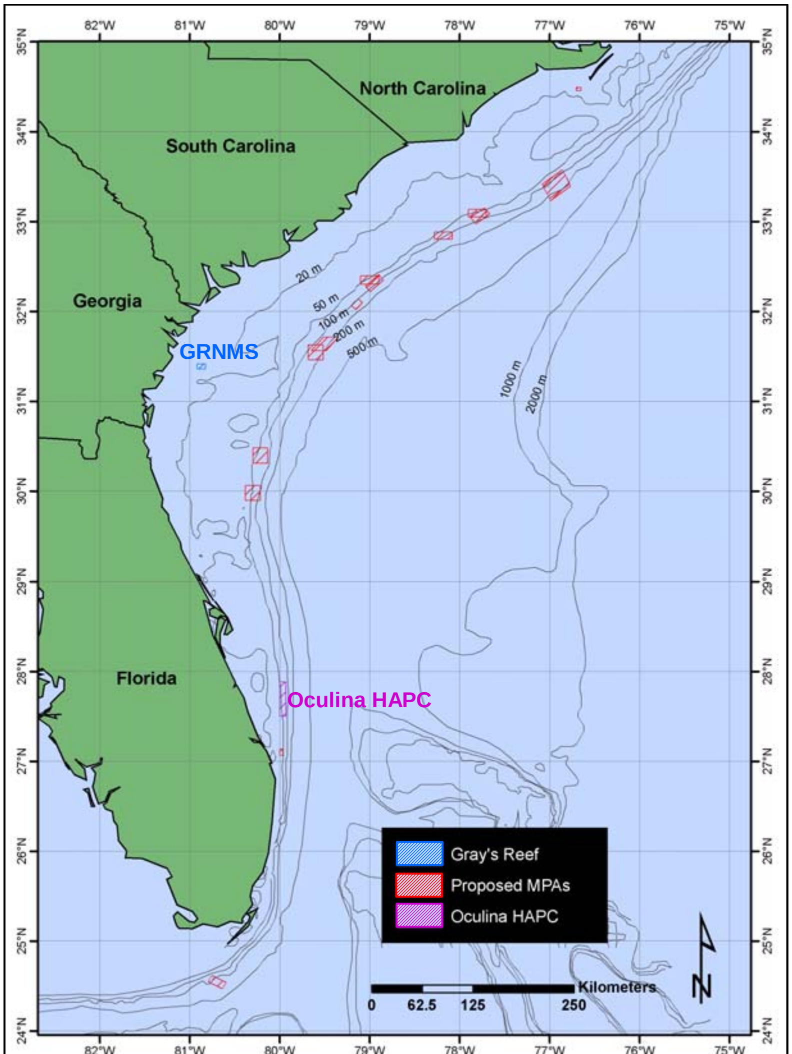


Fig. 19. Location of designated HAPC and proposed (N=15)and existing (GRNMS) MPAs in the southeast Atlantic region.

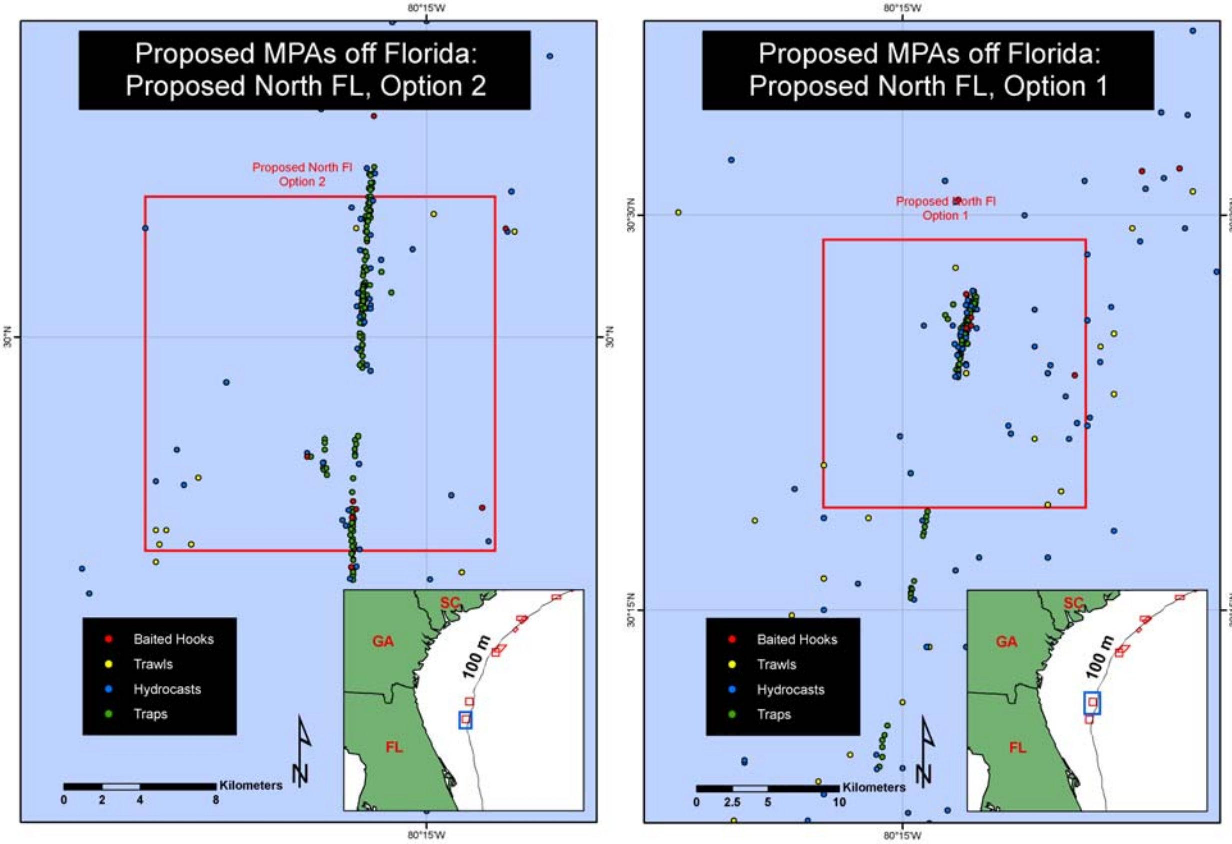


Fig. 20. Location of demersal fish and hydrographic collections in relation to proposed MPA sites off Florida. Other proposed MPA sites and the *Oculina* HAPC off Florida (all south of Cape Canaveral) had no samples in the database.

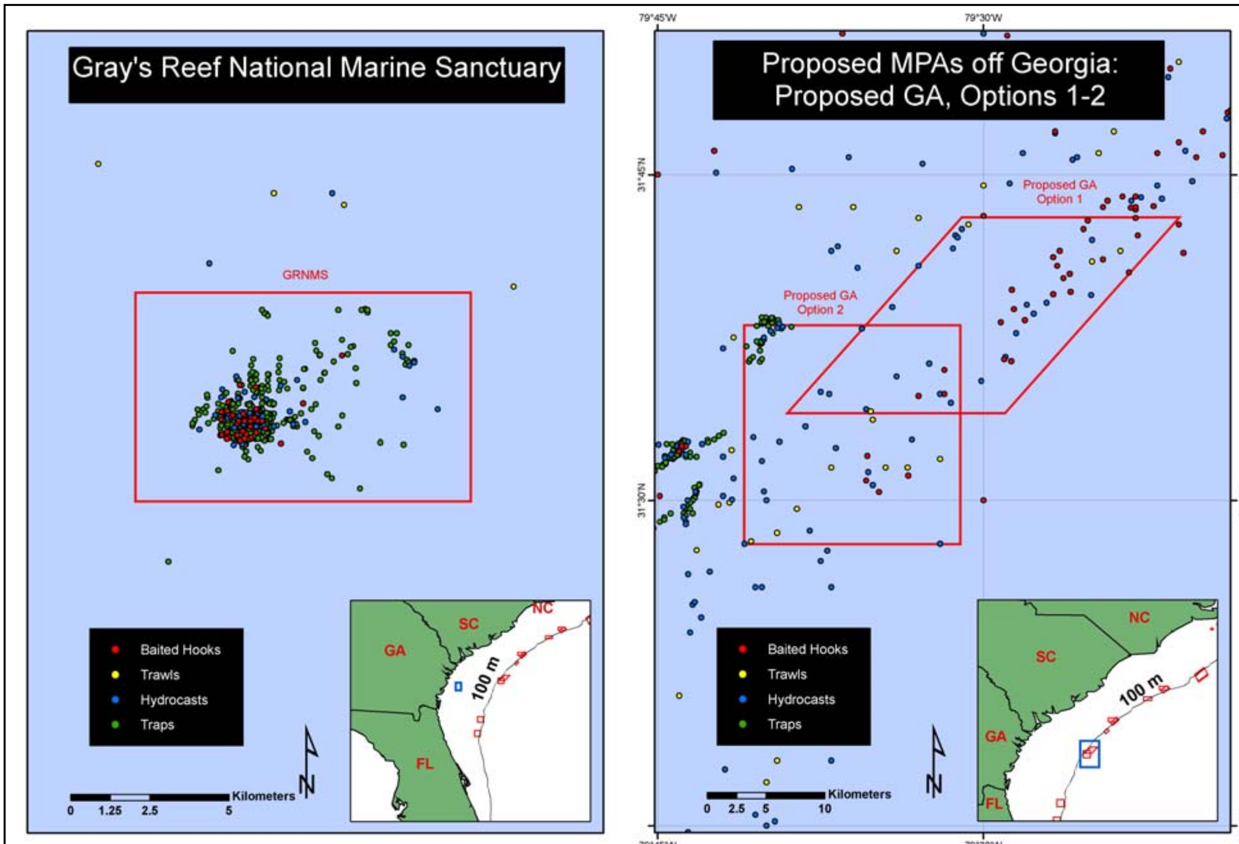


Fig. 21. Location of demersal fish and hydrographic collections in relation to Gray's Reef National Marine Sanctuary and proposed MPA sites off Georgia.

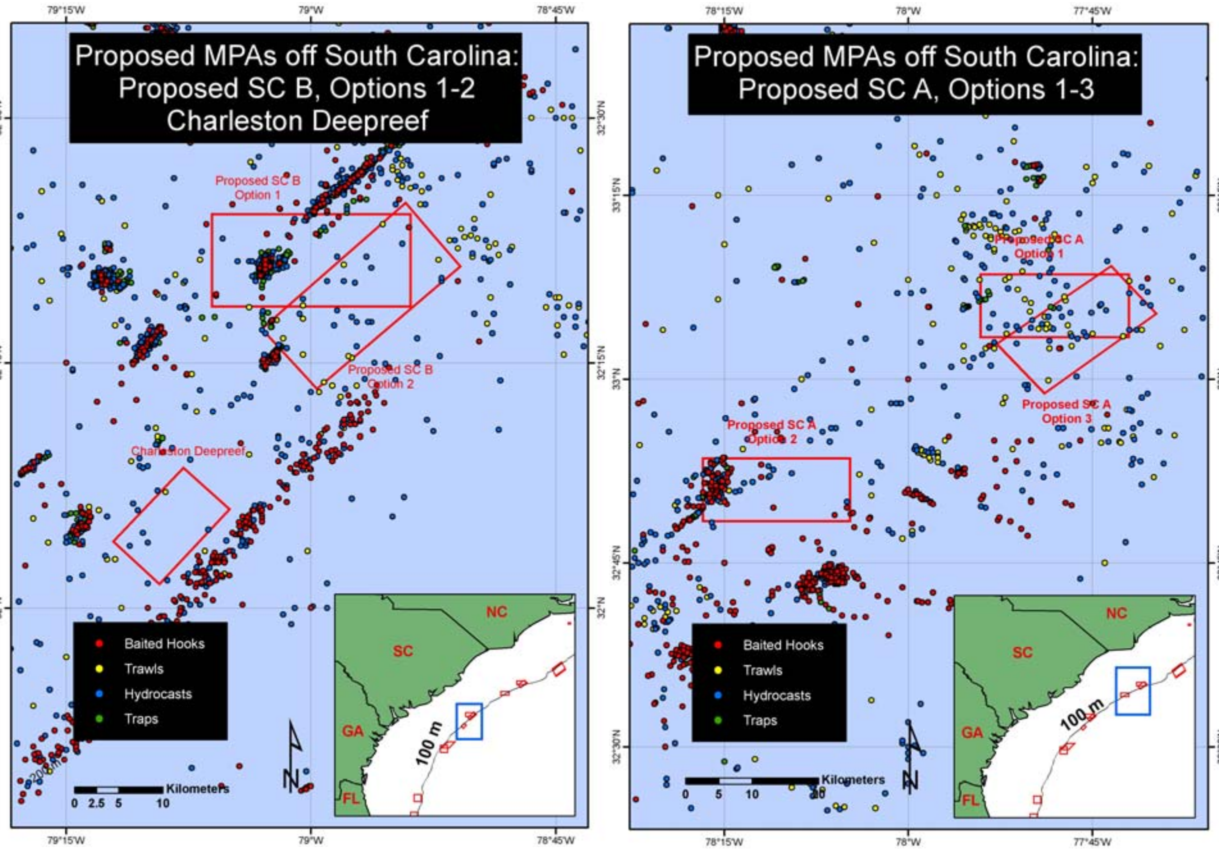


Fig. 22. Location of demersal fish and hydrographic collections in relation to proposed MPA sites off South Carolina.

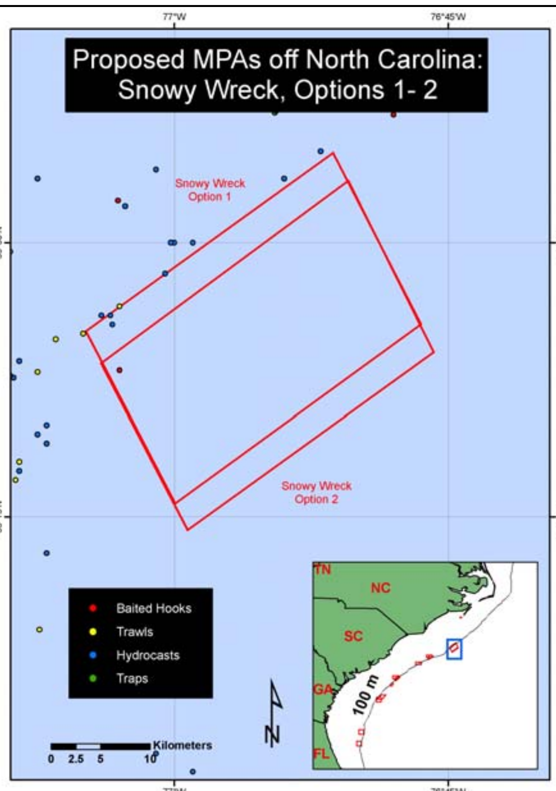


Fig. 23. Location of demersal fish and hydrographic collections in relation to proposed MPA sites off North Carolina. The small proposed nearshore MPA off North Carolina contained no samples.

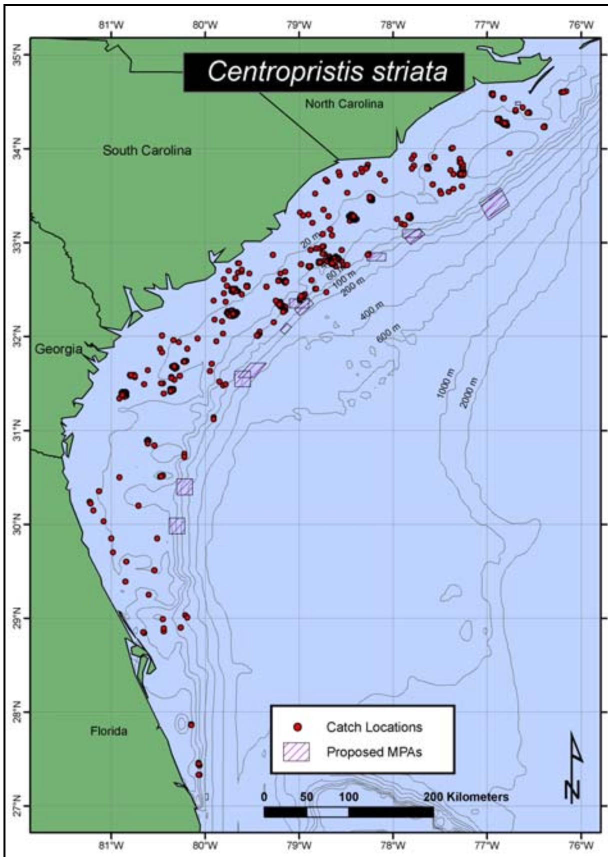


Fig. 24. Capture locations of black sea bass, in relation to proposed MPA sites.

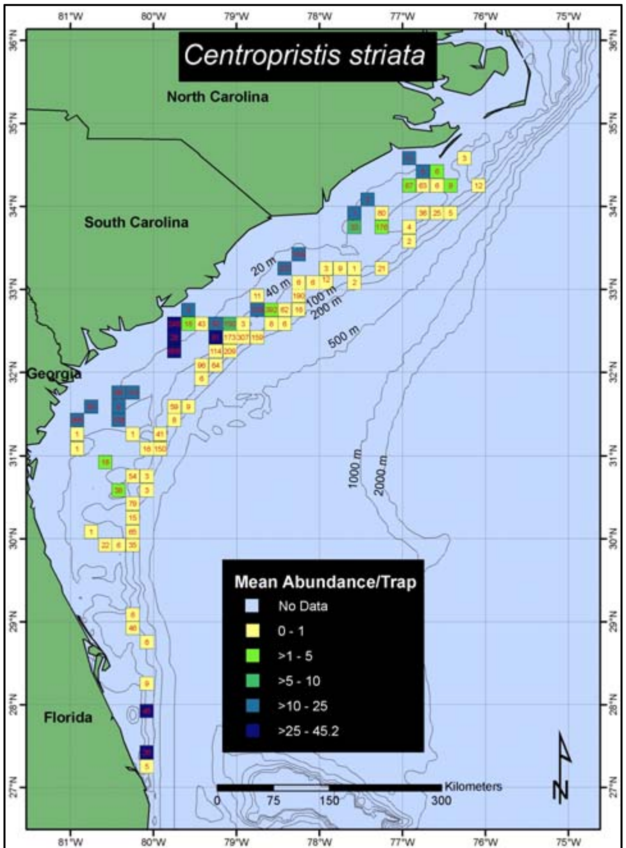


Fig. 25. Density of black sea bass, as estimated from catch per unit of effort (mean number per Chevron Trap) within 1 x 1-min latitude/longitude grid cells), 1988-2004. Numbers within cells show the number of traps fished within cells.

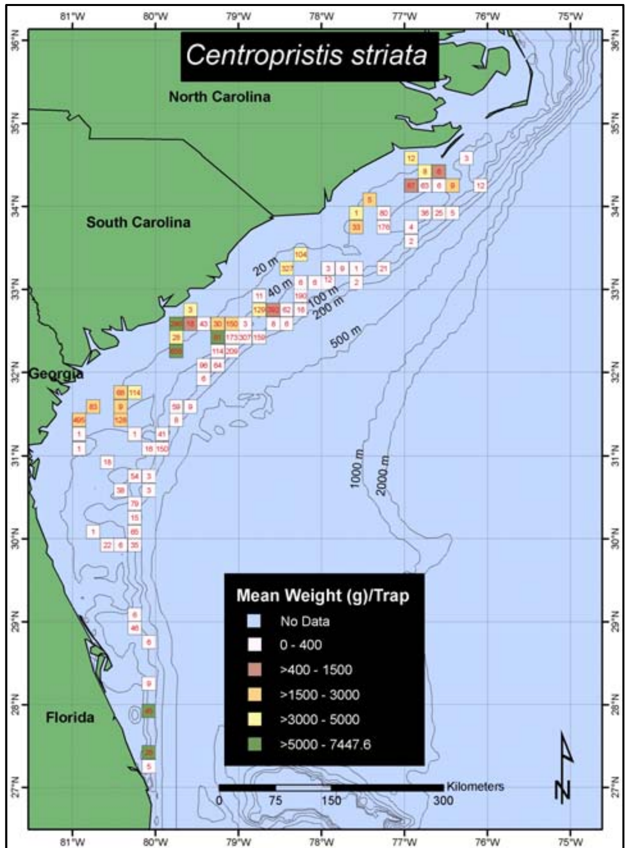


Fig. 26. Density of black sea bass, as estimated from catch per unit of effort (mean biomass (g) per Chevron Trap) within 1 x 1-min latitude/longitude grid cells), 1988-2004. Numbers within cells show the number of traps fished within cells.

In addition to determining sample locations with respect to management areas, the SEA-GEOFISH database and GIS can be used to examine distribution, abundance and life history of priority fishery species in relation to proposed MPAs or other habitat features. Using black sea bass (*Centropristis striata*) as an example, it can be seen that proposed MPA sites at shelf-edge reefs and at deeper sites will not afford much protection to black sea bass, which is distributed mainly across the shelf (Fig. 24). In addition to looking at simple point distribution, the database can be used to examine density of fish populations, as estimated by CPUE (Fig. 25-26). For black sea bass, highest abundance and biomass CPUE was on inner shelf (<20 m deep) reefs, although biomass is quite high on deeper (>20<40 m) reefs.

Because black sea bass is an economically valuable species, catches were often subsampled for life history information (age, growth, reproduction). Examination of the database shows that black sea bass were sampled throughout the region, but that few life history samples were obtained from proposed MPA sites (Fig. 27), because black sea bass are rare at those depths (Fig. 25-26).

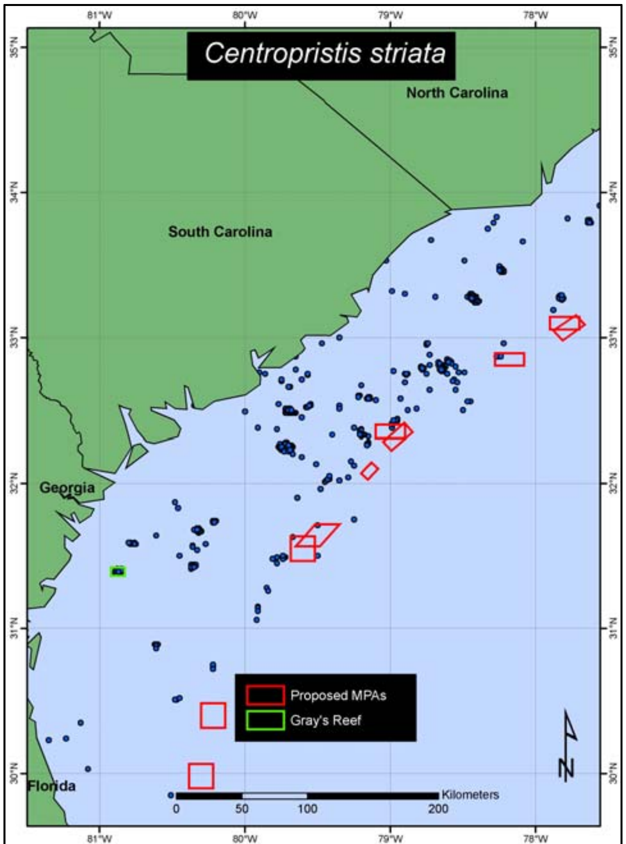


Fig. 27. Map showing locations off South Carolina and Georgia where black sea bass were sampled for life history studies, in relation to MPA locations. Samples were also obtained off North Carolina and Florida, but none were obtained in the vicinity of proposed or actual MPAs or HAPC.

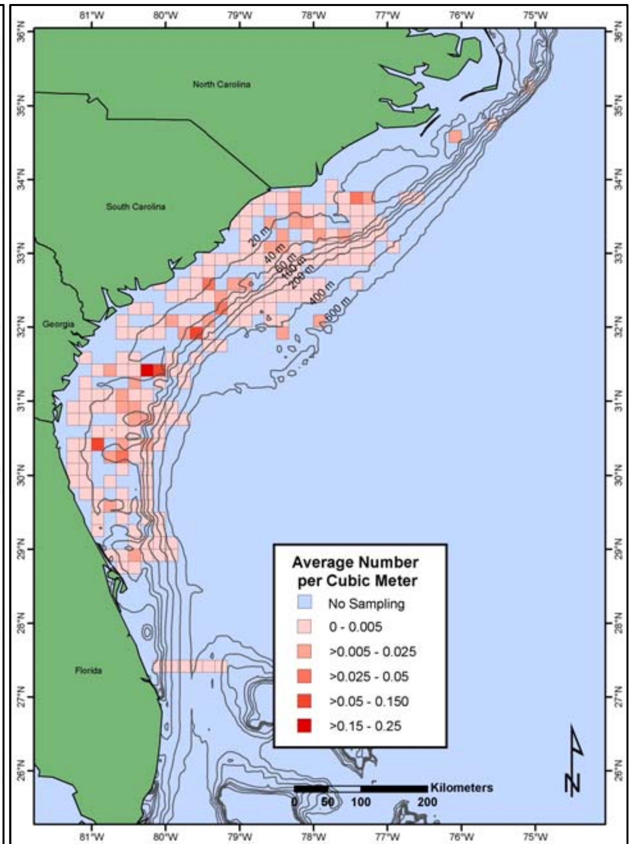


Fig. 28. Density of *Centropristis* spp. larvae in Bongo 505 µm mesh samples. The database was searched for all species of *Centropristis*, plus *Centropristis* spp. Collections likely contain more than one species, with *C. striata* as the dominant species.

The plankton survey data can also be examined for the density of larval fishes that might indicate EFH, such as upwelling zones for enhanced feeding of early life history stages. For example, density of *Centropristis* spp. larvae was greatest on middle-shelf depths, indicating these may be important spawning grounds (Fig. 28). This was confirmed by life history samples collected from spawning adult sea basses (see below).

In addition to visualizing distribution and abundance of individual species, the database can be used to determine locations of particularly high fish abundance, biomass or diversity of all species or particular species groups (e.g., forage species). In Yankee Trawl catches (Fig. 29-30), areas of high total fish abundance and biomass (all species combined) were noted in the area of the Daytona upwelling north of Cape Canaveral and in the Charleston Gyre off the South Carolina-North Carolina border. Upwelling in these two areas is caused by diverging isobaths north of Cape Canaveral and by deflection of the Gulf Stream at the Charleston Bump off South Carolina (Paffenhöfer et al. 1984; Bane et al. 2001; Sedberry et al. 2001). The upwelling off the narrower Florida shelf brings cooler productive water closer to shore; whereas, the Charleston

Gyre upwelling, which is farther offshore, affects mainly the outer and middle shelf, and this is reflected in spatial distribution of fish abundance (Fig. 29).

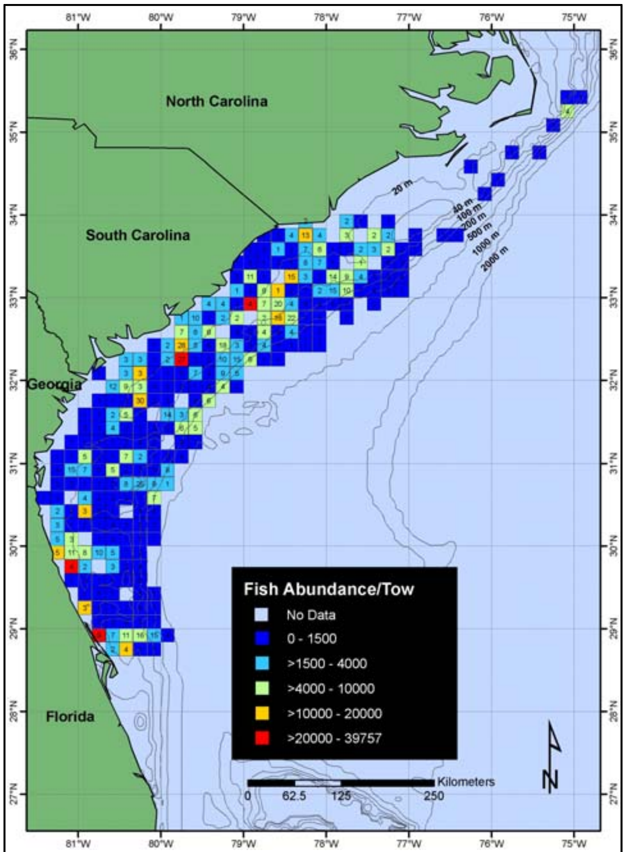


Fig. 29. Mean catch per Yankee Trawl tow for total fish abundance. Numbers in cells indicate the number of tows in that cell, 1973-1980. Noteworthy features include areas of high fish abundance just north of Cape Canaveral (29°N) in the Daytona upwelling, and also near the Charleston Gyre upwelling (32°-33°)N. The Daytona upwelling brings productive water close to shore across the narrow Florida Shelf and the Charleston Gyre influences shelf-edge and mid-shelf depths near the North Carolina-South Carolina border.

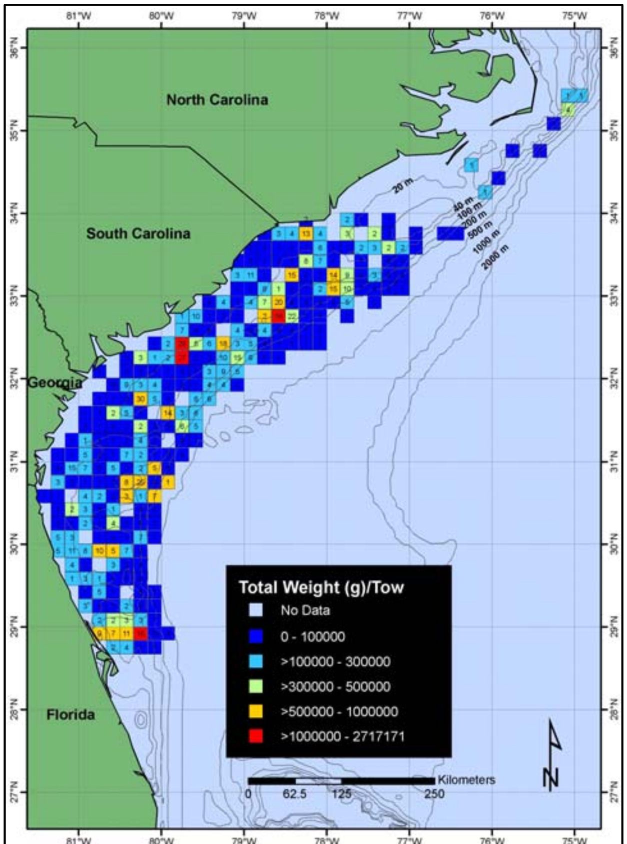


Fig. 30. Mean catch per Yankee Trawl tow for total fish biomass. Numbers in cells indicate the number of tows in that cell, 1973-1980. Noteworthy features include areas of high fish biomass just north of Cape Canaveral (29°N) in the Daytona upwelling, and also near the Charleston Gyre upwelling (32°-33°)N. The Daytona upwelling brings productive water close to shore across the narrow Florida Shelf and the Charleston Gyre influences shelf-edge and mid-shelf depths near the North Carolina-South Carolina border.

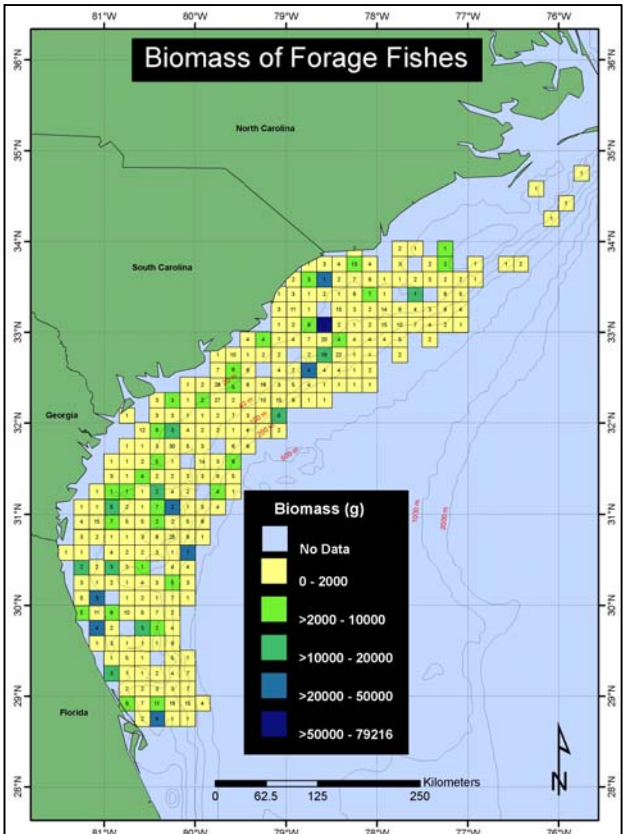


Fig. 31. Mean catch per Yankee Trawl tow for biomass of forage fishes that may be important prey for economically valuable piscivorous fishes such as snappers, groupers and mackerels. Numbers in cells indicate the number of tows in that cell, 1973-1980. Noteworthy features include areas of high biomass of forage fishes in the Daytona upwelling, and also near the Charleston Gyre upwelling. Taxa included in the analysis were Ammodytidae (sand lances), Argentinidae (argentines), Branchiostomatidae (lancelets), Clupeidae (herrings), Engraulidae (anchovies), Mugilidae (mullets), Myctophidae (lanternfishes), and *Decapterus* spp. (scads).

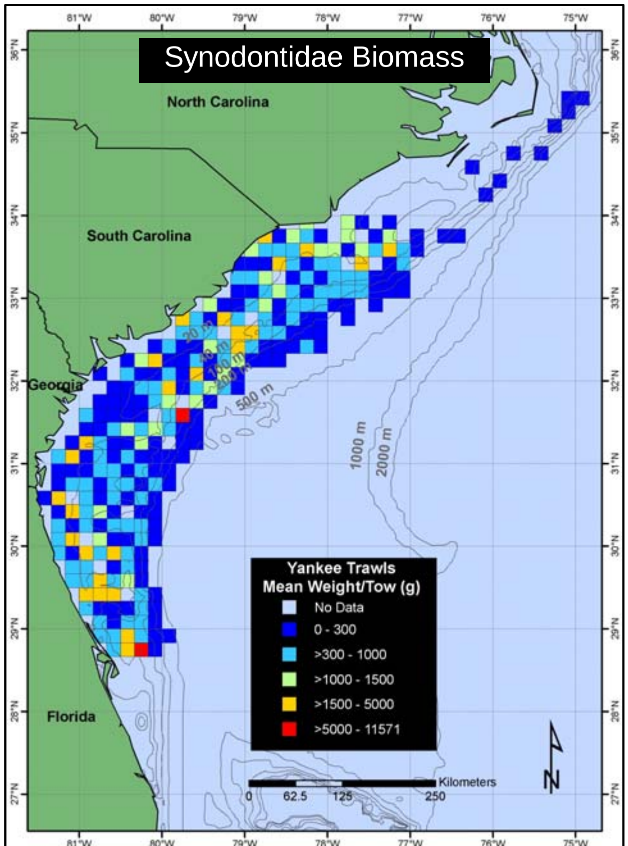


Fig. 32. Mean catch per Yankee Trawl tow for biomass of lizardfishes, including *Saurida* spp. (*S. brasiliensis, S. caribbaea, S. normani*), *Synodus* spp. (*S. foetens, S. intermedius, S. poeyi, S. synodus*) and *Trachinocephalus myops*. Lizardfishes are abundant and widespread fish predators on the continental shelf and slope. Note high biomass (light green-orange) near the Daytona and Charleston Gyre upwellings, where prey is abundant (Fig. 30).

Much of the biomass noted in the upwelling area (Fig. 30) came from high biomass of small forage fishes such as anchovies, herrings, sardines and scads caught in Yankee Trawls (Fig. 31). Feeding grounds are considered EFH, and concentrations of forage species near the bottom (catches were in bottom trawls) indicate areas that may be important feeding grounds for top-level predators.

Lizardfishes (Synodontidae) are common to abundant piscivorous benthic fishes that occupy a variety of habitats in the SAB (Wenner et al. 1979a; Sedberry and Van Dolah 1984; Wenner 1983), and ranked fifth in biomass and 11th in abundance out of 121 families of fishes taken during regional trawl surveys on the shelf and upper slope (e.g., Wenner 1979a). In all, at least eight species occur in the region and occupy a wide range of habitats and depths. Lizardfish biomass is highest on the middle and outer shelf (Fig 32). Among the most abundant demersal fishes in these habitats, lizardfishes are noteworthy because they are piscivorous (Sulak et al. 1985; Sweatman 1984; Thresher et al. 1986), whereas most other dominant species [e.g., *S. chrysops, M. hispidus, U. regia, H. aurolineatum, R. aurorubens* (Wenner et al. 1979a)] feed on macrobenthic or planktonic invertebrates (Sedberry 1983; Sedberry 1985; Sedberry 1987; Sedberry 1988; Sedberry and Cuellar 1993). High piscivory rates (feeding attacks every 35 min; consuming an average of 1.8 fish per day and 12% of their own body weight) and high population densities of lizardfish are thought to have a major influence on evolution, feeding, spawning, daily activity and structure of some fish communities (Sweatman 1984; Thresher et al. 1986). It is noteworthy that their spatial biomass distribution is similar to that of the forage species (Fig. 31-32). Such important forage areas for economically valuable piscivores such as snappers, groupers and mackerels can be determined from additional analyses of feeding habits of fishes and examination of the SEA-GEOFISH database for occurrence of prey fishes. Such areas would be EFH for the predators, and might be considered as HAPC or MPAs for economically valuable species.

Examination of distribution of larvae of a particularly abundant taxon, the Clupeidae (herrings and sardines) indicated that upwelling areas may be important in the early life history of these abundant forage fishes and other species (Fig. 33). Although larvae are more ephemeral in their occupancy of pelagic habitats, it appears that there are patches of high density of larval clupeids near the Daytona and Charleston Gyre upwellings (Fig. 33). Such productive areas might be considered EFH, but they may be ephemeral and may vary in location from one spawning season to the next.

Productivity and upwelling, along with bottom type and other habitat features, may also affect diversity of fish assemblages in the region. Sites or areas of particularly high biodiversity, including fish diversity, may warrant particular consideration as protected areas to conserve biodiversity (Malakoff 2004). Such biodiversity "hot spots" (Malakoff 2004) can be mapped from the Groundfish Trawl Survey. Using Yankee Trawl data (considered to be the most

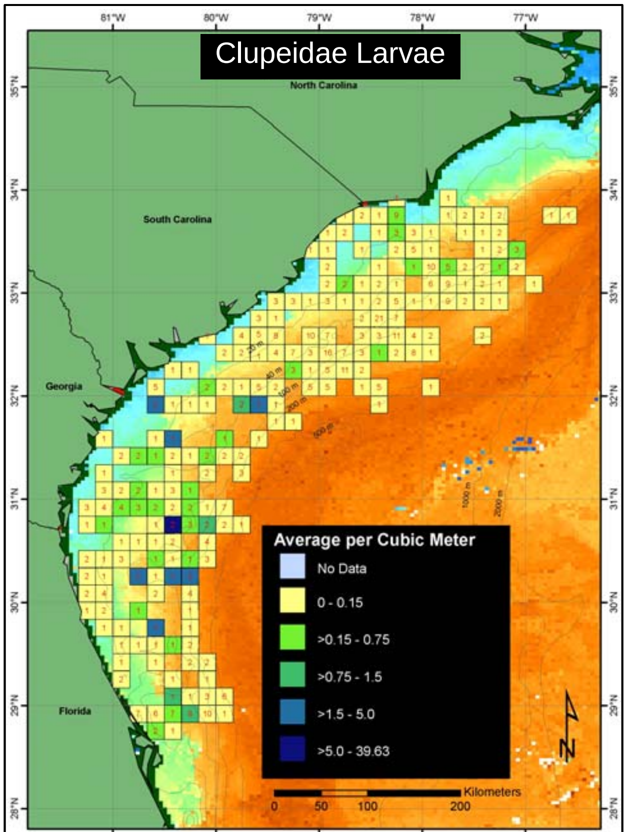


Fig. 33. Mean catch per m^3 for clupeid larvae in 505 µm bongo tows, in relation to winter (December 1997) sea surface temperature satellite imagery. Numbers in cells indicate the number of tows in that cell, 1973-1985. Noteworthy are concentrations of larvae near fronts and meanders associated with the Daytona upwelling at about 29°N and with the Charleston Gyre at 33-34°N.

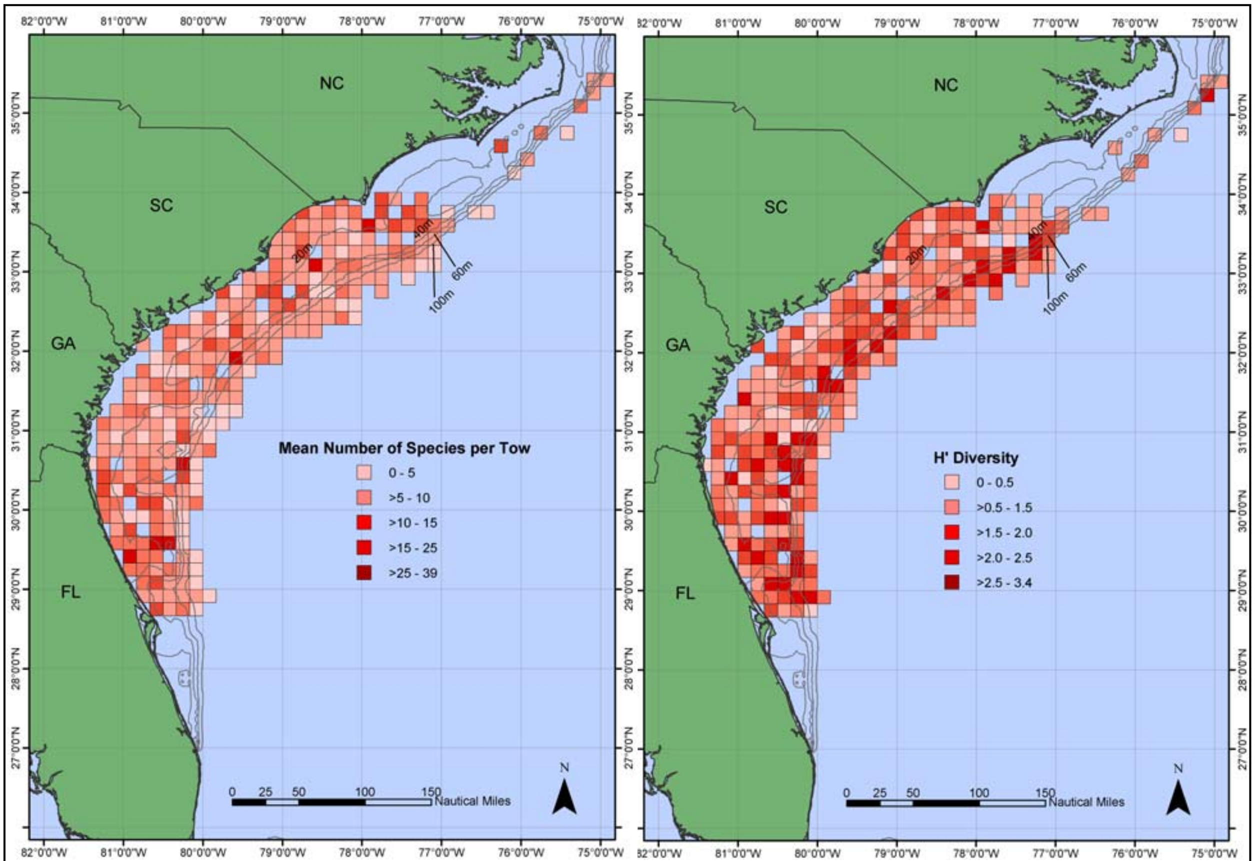


Fig. 34. Mean number of species per tow per latitude/longitude cell, and H' diversity for tows pooled by cell, from Yankee Trawls.

geographically comprehensive, with the least selective fishing gear) and SEAMAP bottom mapping data (SEAMAP-SA 2001), GIS mapping indicated hot spots of fish diversity associated with the shelf-edge and middle shelf, and with high-productivity upwelling areas north of Cape Canaveral and in the Charleston Gyre (Fig. 34). Such areas have hard-bottom reefs and stable thermal regimes (see Fig. 47, below) that support diverse fish populations (Miller and Richards 1980; Sedberry and Van Dolah 1984). Mapping simple diversity (mean number of species per Yankee Trawl tow) in relation to known hard bottom indicates that areas without hard bottom have low diversity and that cells containing hard bottom have high fish diversity (Fig. 35). Because thermal stability and warm water such as that found on the middle shelf contributes to high diversity (Sedberry and Van Dolah 1984), high diversity may also be associated with warm waters (Fig. 35; Fig. 49). There is likely a combination of factors that can be examined to find areas of particularly high fish diversity. If fishery ecosystem plans are to include conservation of biodiversity, such areas that appear to contain a high diversity of fishes should be considered for protective management.

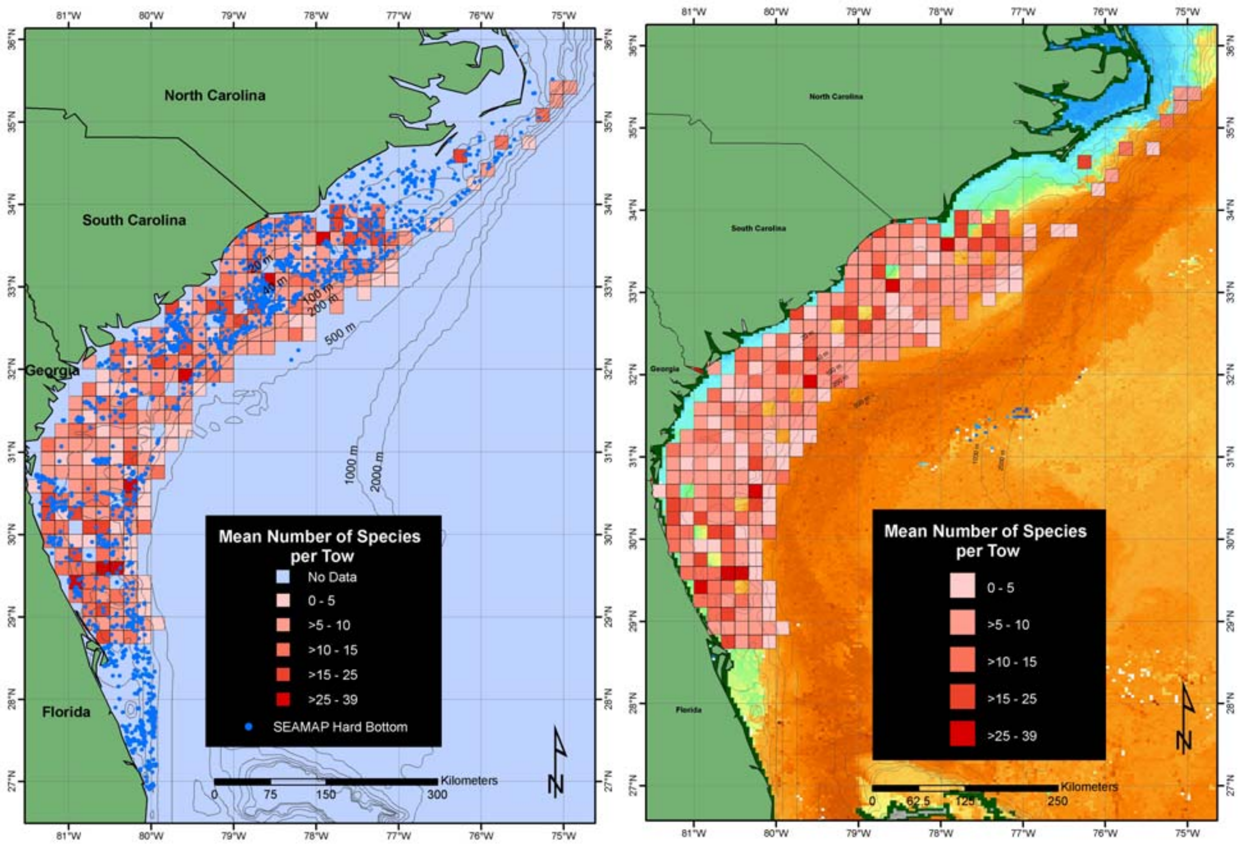


Fig. 35. Mean number of species per tow per latitude/longitude cell, from Yankee Trawls. Blue dot on map at left are points where definite hard bottom was mapped by the SEAMAP-SA (2001) bottom mapping project. Map of same data on right is overlain on a sea surface temperature satellite image (25 Dec 1997). High numbers of species are associated with hard bottom and warm and stable mid-and outer-shelf waters.

Spawning Times and Locations for Reef Fishes

All reef fish spawning locations are considered to be HAPC for the SAFMC Snapper-Grouper Management Unit (R. Pugliese, SAFMC, pers. comm, June 2004). In addition, there are several options being considered as no-bottom-fishing MPAs, and special consideration should be given to those proposed sites that are spawning grounds, since they also contain EFH and HAPC. For this reason, special effort was given to looking for spawning locations of reef fishes (SAFMC Snapper/Grouper Management Unit) by examining life history tables in the SEA-GEOFISH database, in order to map spawning sites and determine spawning times. Fishery-independent sampling effort was not equally distributed, either spatially or temporally (e.g., Fig. 8, Table 9), and was concentrated from May through September and in the middle of the region (South Carolina and Georgia). Fishery-dependent samples provided accurate temporal information (± 5 days) on spawning times for those months not sampled during fishery-independent surveys, but location data, particularly those collected by NOAA Fisheries Service, were often "rounded" to the nearest degree of latitude and longitude. In all, 28 species were examined for spawning locations, but not all maps will be presented. Additional details can be found in Sedberry et al. (in press) or at the SEA-GEOFISH web site.

In spite of some temporal and spatial sampling limitations, we found that fish species examined exhibited a variety of spatial patterns of spawning activity, with respect to their general distribution, habitat features and in relation to other species. Several species such as small serranids (sea basses), haemulids (grunts), sparids (porgies) and lutjanids (snappers) spawned over protracted periods and throughout the region (Table 9).

Black sea bass (*C. striata*), a small serranid, was distributed across the continental shelf throughout the region, generally in depths less than 60 m (range: 2-130 m). Of 30,170 examined to determine sex and reproductive state, 2251 were spawning females (Table 9). Spawning sites were located throughout the region in depths of 15-56 m (Fig. 36), although most were found mainly in the middle of the SAB. Spawning females were collected during most months of the year (Table 10), with a major spawning period of February through April. Bottom water temperatures where spawning females were collected ranged from 11.45 to 26.57°C (Table 9, N = 898 independent measurements). Bank sea bass (*C. ocyurus*) were also broadly distributed across the shelf throughout the region (map not presented), but appeared to prefer deeper waters than black sea bass (range 1-146 m). Of 2402 examined for sex and reproductive state, only 52 were spawning females, and all of those were collected in depths of 27-57 m off South Carolina in October through May (Tables 9-10). The major spawning period was February through April. Spawning females were collected in water temperatures that ranged from 16.24 to 18.63°C (N = 21). Sand perch (*D. formosum*) were also widely distributed across the shelf (map not presented), generally in depths less than 60 m (range 9-84 m). The sand perch appears to be much less dependent on reef habitat, and was often taken in trawl collections over sandy bottom (e.g., Wenner et al. 1979a). More than 80% of the female sand perch examined were in spawning condition. Spawning females (n = 634) were collected throughout the region from May through September at depths of 17-47 m (Tables 9-10). Bottom temperatures at spawning sites ranged from 14.03 to 28.50°C (N = 596). Like sand perch, tomtate (*H. aurolineatum*) were found across the shelf throughout the region. Spawning females (n = 238 of 2412 examined) occurred on middle and outer-shelf reefs (map not presented) and were collected from May through July in depths from 15-54 m (Tables 9-10). Bottom temperatures at spawning sites ranged from 20.16 to 28.04°C (N = 232).

Red snapper (*L. campechanus*) were also widely distributed across the shelf (Fig. 37, Table 9), but appeared to spawn at mid- to outer-shelf depths (24-67 m). Of 778 red snapper examined for sex and reproductive state, 80 were spawning females. Spawning females were collected in January and May through October in the waters off South Carolina to Florida (Table 10). The major spawning period was June through September. Red snapper spawned at temperatures ranging from 18.05 to 27.59°C (Table 9; N = 41).

Vermilion snapper (*R. aurorubens*) were ubiquitous in collections on the middle and outer shelf, and were found in depths from 14-163 m (Fig. 38, Table 9). Spawning females (n = 3280 of 11,798 fish examined) were found at nearly all depths and latitudes where vermilion snapper occurred. Vermilion snapper spawned in depths from 18 to 97 m and at temperatures from 16.01 to 28.09°C (N = 2511). Spawning occurred from April through September, with a major spawning period of May through September (Table 10).

Table 9. Collection data for species examined for spawning activity. Data include total number of specimens collected, number examined to determine sex and reproductive state, and number found to be spawning females; depth of capture of all specimens and of spawning females; latitude range (°N) of collections of spawning females; and bottom temperatures (mean, standard deviation and range) where spawning females were collected. Depth, latitude, and temperature data were from fishery-independent sampling. In some cases (-), data were not available.

	Total Specimens			Capture Deptt	Spawning Depth	Spawning Latitude	Spawning Temperatures (°C)		
Species	Collected	Exam	Spawning	(m)	(m)	(°N)	Mean	sd	Range
B. capriscus	7582	4349	141	13-128	20-75	27-33	22.41	1.96	18.87-27.42
B. decadactylus	17	16	8	-	-	-	-	-	-
C. nodosus	3210	1181	88	21-155	45-60	31-32	21.92	0.68	20.10-22.67
C. microps	1344	1112	514	46-256	48-234	32-32	14.91	2.12	8.87-16.28
C. ocyurus	20754	2402	52	1-146	27-57	32-32	16.81	0.63	16.24-18.63
C. striata	118059	30170	2251	2-130	15-56	27-34	18.88	2.68	11.45-26.57
C. cruentata	11	7	0	30-50	-	-	-	-	-
C. fulva	24	18	1	39-58	39	33	23.80	-	23.80-23.80
D. formosum	12830	780	634	9-84	17-47	27-34	23.55	3.09	14.03-28.50
E. adscensionis	43	34	5	33-83	37-53	32-32	21.75	1.51	20.05-23.96
E. drummondhayi	427	274	5	28-114	-	32-32	-	-	-
E. flavolimbatus	1000	73	6	31-205	160-194	32-32	14.47	-	14.47-14.47
E. morio	2390	2223	46	22-95	30-90	32-34	21.01	2.09	16.97-24.08
E. nigritus	21	12	1	48-168	168	-	-	-	-
E. niveatus	3437	649	96	18-302	187-302	32-33	-	-	-
H. aurolineatum	115969	2412	238	13-97	15-54	27-33	23.66	2.41	20.16-28.04
H. plumieri	6073	2255	151	15-75	22-51	32-33	24.96	2.35	18.92-27.42
H. dactylopterus	4280	1381	138	38-686	229-238	32-32	-	-	-
H. perciformis	353	102	12	181-520	-	-	-	-	-
L. chamaeleonticeps	3552	2431	324	62-311	190-300	31-32	13.02	1.96	10.16-14.90
L. campechanus	1225	778	80	7-240	24-67	27-33	23.16	2.02	18.05-27.59

Table 9. Continued.

Species	Total Specimens			Capture Deptt (m)	Spawning Depth (m)	Spawning Latitude (°N)	Spawning Temperatures (°C)		
	Collected	Exam	Spawning				Mean	sd	Range
M. interstitialis	29	18	9	27-84	49-51	32-32	-	-	-
M. microlepis	7329	5363	1848	15-117	24-117	26-33	17.26	-	17.26-17.26
M. phenax	3759	2467	351	17-113	33-93	29-32	21.18	1.84	15.60-24.08
P. pagrus	22732	15687	457	9-307	26-57	30-32	16.88	0.89	16.24-18.99
P. americanus	2067	1466	55	44-653	433-595	31-31	-	-	-
R. aurorubens	41455	11798	3280	14-163	18-97	27-34	23.37	2.01	16.01-28.09
S. dumerili	2797	2498	250	15-216	45-122	24-33	23.71	0.00	23.71-23.71

Table 10. Spawning periods for fishes examined. Spawning percentage = percent of female specimens in spawning condition. Dark gray indicates major spawning period. Light gray indicates months of spawning activity.

Species	# Females	Spawning Percentage	Percentage in spawning condition by month											
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
B. capriscus	2259	6.24	0.0	0.0	0.0	0.0	2.7	10.0	13.0	2.4	0.0	0.0	0.0	0.0
B. decadactylus	11	72.73	-	-	-	0.0	0.0	100.0	100.0	100.0	100.0	-	0.0	0.0
C. nodosus	752	11.70	0.0	0.0	2.6	55.4	76.5	2.2	2.8	0.0	0.0	0.0	-	0.0
C. microps	619	83.04	0.0	100.0	66.7	68.8	89.4	84.2	92.7	75.7	91.1	86.4	-	-
C. ocyurus	1267	4.10	13.6	45.0	26.1	29.6	0.2	0.0	0.0	0.0	0.0	15.4	14.8	0.0
C. striata	19740	11.40	0.0	31.5	79.9	35.6	20.5	0.6	6.4	0.2	2.9	0.0	15.1	0.0
C. cruentata	4	0.00	-	-	0.0	-	-	-	0.0	-	-	-	-	-
C. fulva	8	12.50	-	-	-	-	-	100.0	0.0	0.0	-	-	-	-
D. formosum	779	81.39	-	-	-	-	100.0	95.8	78.4	77.0	64.1	-	-	-
E. adscensionis	12	41.67	-	-	100.0	-	100.0	20.0	0.0	-	-	-	-	-
E. drummondhayi	169	2.96	-	0.0	0.0	0.0	2.5	6.8	0.0	2.9	0.0	-	-	0.0
E. flavolimbatus	52	11.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	27.8	-	-	-
E. morio	2058	2.24	0.0	2.8	3.5	13.3	2.3	3.6	0.0	0.0	0.0	0.0	0.0	0.0
E. nigritus	9	11.11	-	0.0	-	-	50.0	0.0	0.0	-	-	-	-	0.0
E. niveatus	533	18.01	0.0	0.0	0.0	3.1	28.7	7.1	19.0	31.3	15.0	-	-	0.0
H. aurolineatum	925	25.73	-	0.0	-	0.0	58.1	31.3	31.1	0.0	0.0	-	-	-
H. plumieri	1227	12.31	0.0	0.0	2.4	10.8	23.4	26.4	1.1	0.9	3.9	0.0	0.0	0.0
H. dactylopterus	548	25.18	38.5	57.8	77.1	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
H. perciformis	68	17.65	14.3	-	-	-	50.0	-	0.0	-	-	0.0	21.4	22.2
L. chamaeleonticeps	1161	27.91	1.4	1.3	40.0	76.2	85.6	66.1	18.8	1.7	0.7	0.0	1.3	0.0
L. campechanus	402	19.90	8.7	0.0	0.0	0.0	15.2	27.3	56.0	28.1	41.2	18.2	0.0	0.0
M. interstitialis	12	75.00	-	50.0	100.0	0.0	-	0.0	-	100.0	-	-	-	-
M. microlepis	4872	37.93	11.8	39.6	57.3	50.2	3.6	0.0	0.0	0.0	0.0	0.0	0.0	1.2
M. phenax	1988	17.66	0.0	1.1	39.2	53.0	64.1	8.8	3.6	0.4	0.0	0.0	0.0	0.0
P. pagrus	10870	4.20	88.5	64.0	33.3	3.5	0.1	0.0	0.0	0.0	0.1	0.0	48.0	43.5
P. americanus	793	6.94	14.7	77.8	92.9	16.4	1.7	0.0	0.0	0.0	0.0	0.0	1.0	3.1
R. aurorubens	8666	37.85	0.0	0.0	0.0	8.6	24.0	41.9	59.7	40.2	34.6	0.0	0.0	0.0
S. dumerili	1363	18.34	1.9	5.7	14.1	49.1	53.5	4.4	0.0	0.0	0.0	0.0	0.0	0.0

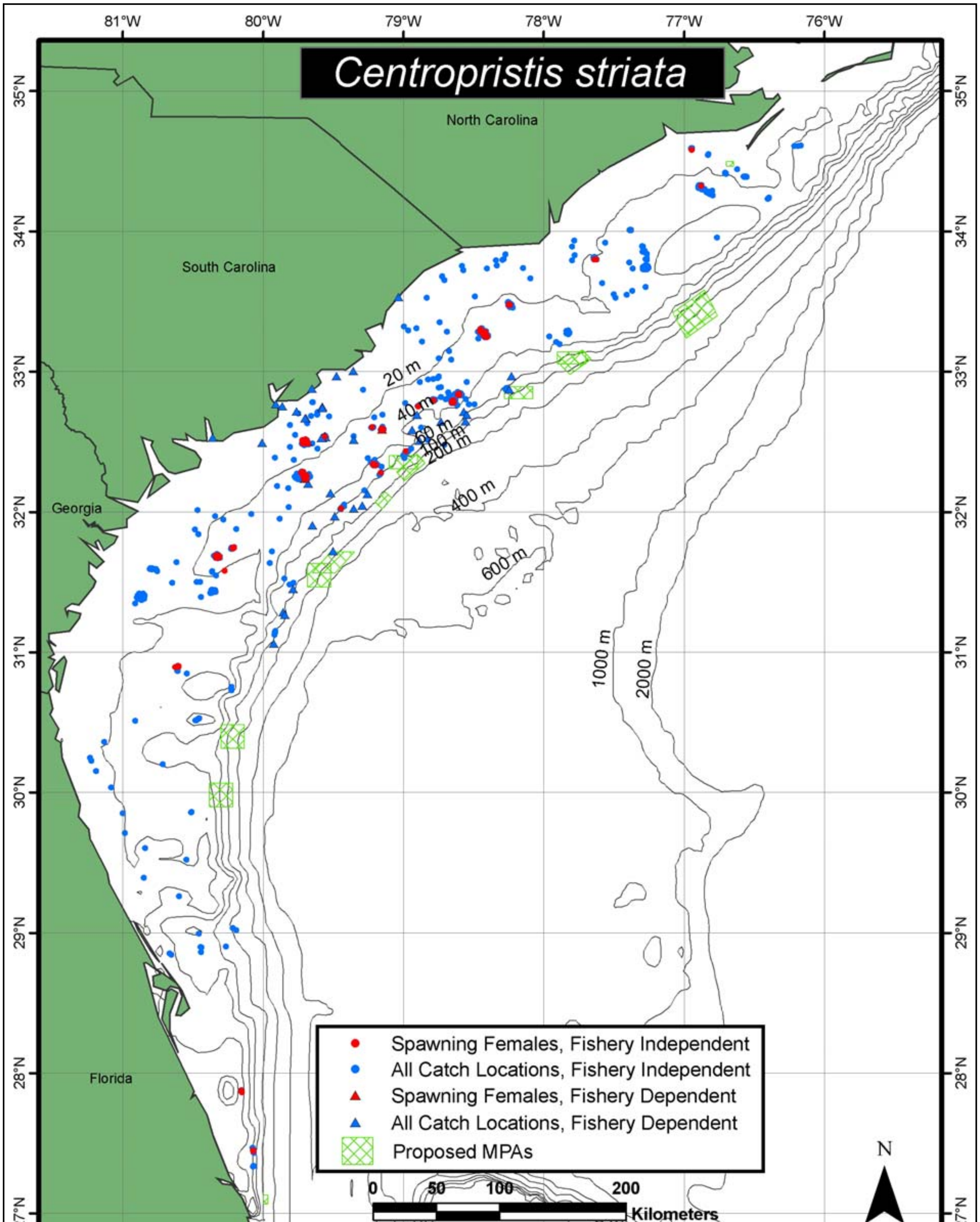


Fig. 36. Locations of capture of black sea bass, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

Several species (*Mycteroperca microlepis, M. phenax, Balistes capriscus, Calamus nodosus, Pagrus pagrus and Seriola dumerili*) appeared to spawn at specific shelf-edge reef sites (50-100 m depth) in spite of being generally distributed across the shelf. Gag (*M. microlepis*) were caught throughout the region (15- 17 m) during fishery-independent sampling (Table 9, Fig. 39). Because gag are winter-early spring spawners (from December through May), few were collected during research cruises that sampled mainly from May through September. However, fishery-dependent sampling yielded many female gag in spawning condition from throughout the region. Of 5363 gag obtained from all sampling, 1848 were spawning females. Most fishery-dependent samples were landed under an emergency rule that required fishermen to land gag with the gonads intact so that researchers could determine sex ratios and other aspects of reproduction (McGovern et al. 1998). Unfortunately, the emergency rule did not require accurate location data and catch locations were often reported in NMFS sampling grid cells (Fig. 39). In spite of the inaccuracy in location, it appears that gag spawn at shelf-edge reefs, in depths from 24-117 m, primarily from February through April (Table 10), at a bottom temperature of 17.26°C (only one measurement).

Scamp (*M. phenax*) were found mainly on middle- and outer-shelf reefs throughout the region (Table 9, Figure 40). Spawning females (n = 351 of 2467 examined) were found at shelf-edge reefs from northern Florida to South Carolina from February to August (Table 10), with a major spawning period of March through May. Spawning females were collected at depths of 33-93 m and water temperatures from 15.60-24.08°C (Table 9; N = 131). We observed scamp engaged in courtship behavior like that described by Gilmore and Jones (1992) at shelf-edge reefs off northern Florida (St. Augustine and Jacksonville) and South Carolina (Charleston) in July or August of 2002 and 2004. These observations involved one gray-head (apparent) male scamp and one to a few apparent females. Courtship behavior was observed, but not any spawning. Video clips of the observations are included in the SEA-GEOFISH database (see below). 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. These behaviors were observed in the morning and late afternoon. Spawning was not observed, but as in other groupers (Carter et al. 1994) that may occur after sunset (Harris et al. 2002), when we were not making observations.

Greater amberjack (*S. dumerili*) occurred on middle- and outer-shelf and upper-slope reefs throughout the region and were captured at depths of 15-216 m (Table 9; map not shown). We examined 2498 gonads, 250 of which were from spawning females. Spawning females were collected from depths of 45 to 122 m. Only two spawning specimens were obtained from research cruises, and they were collected at a water temperature of 23.71°C. Spawning females were collected from January through June, with a major spawning period in April and May (Table 10). Most (88%) spawning greater amberjack were collected by commercial fishermen in the Florida Keys during a special effort aimed at obtaining gonads for determining fecundity, sex ratios and spawning season. Most (95%) spawning females were collected from waters south of 30°N latitude, although there is evidence for spawning off the Carolinas and Georgia too.

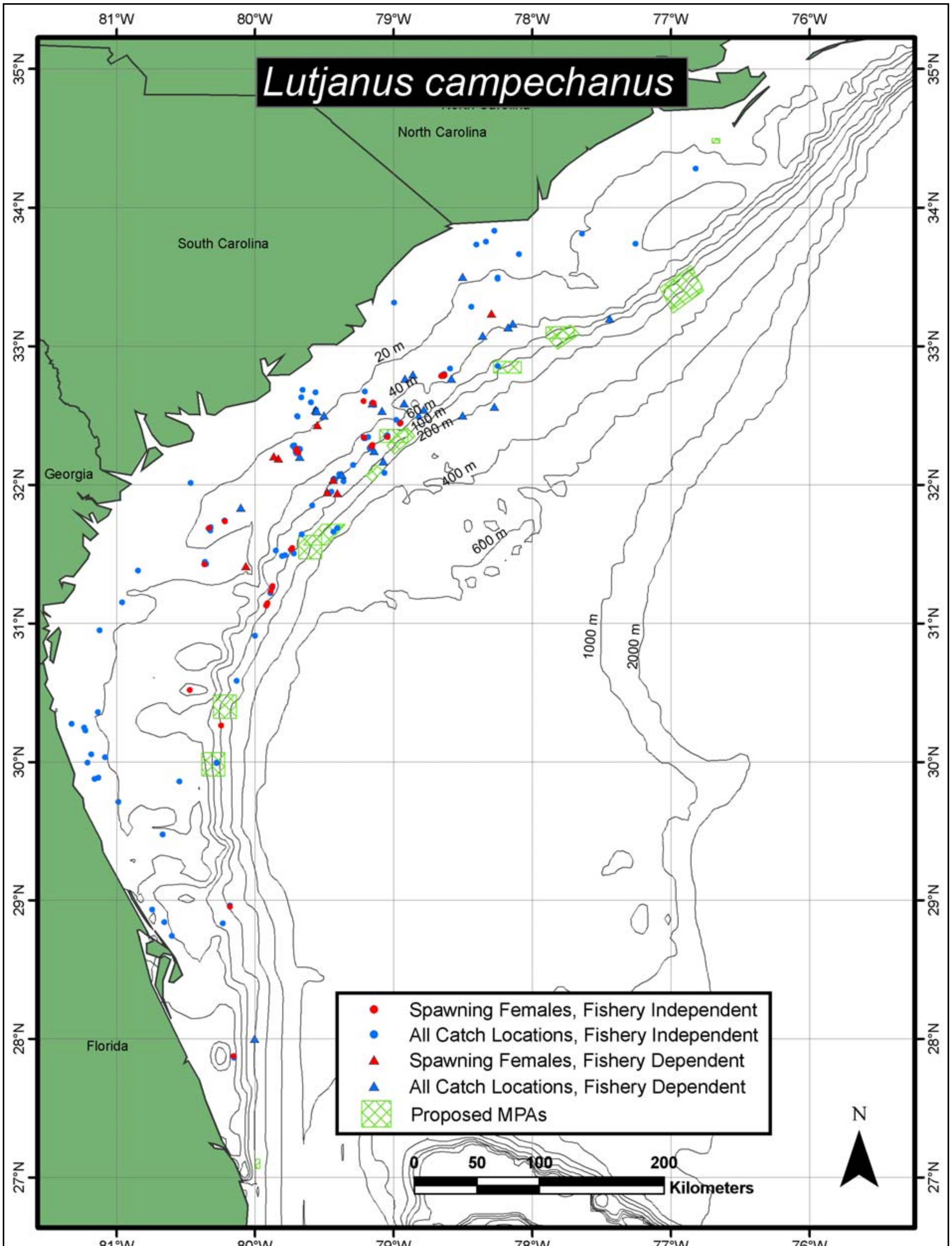


Fig. 37. Locations of capture of red snapper, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

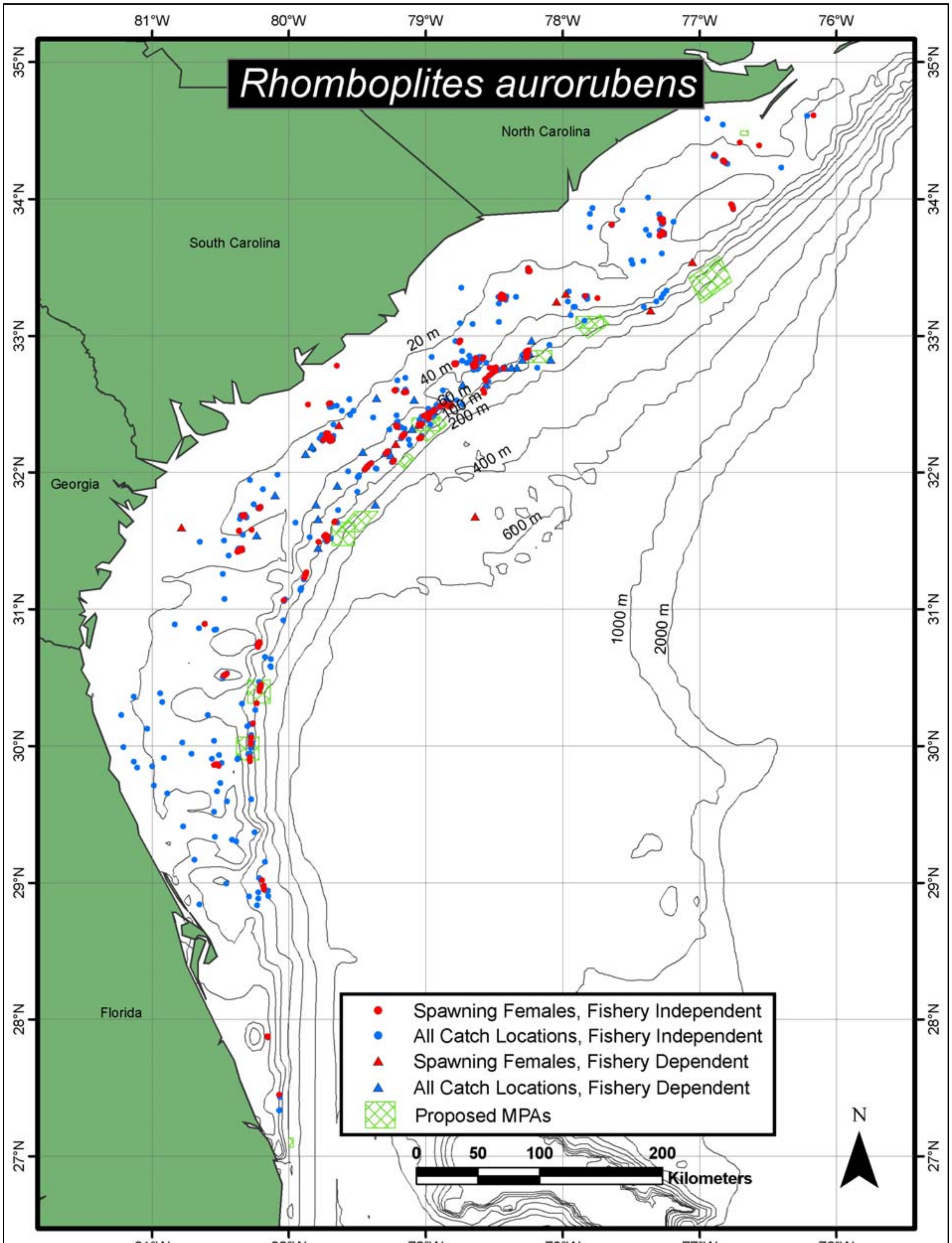


Fig. 38. Locations of capture of vermilion snapper, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

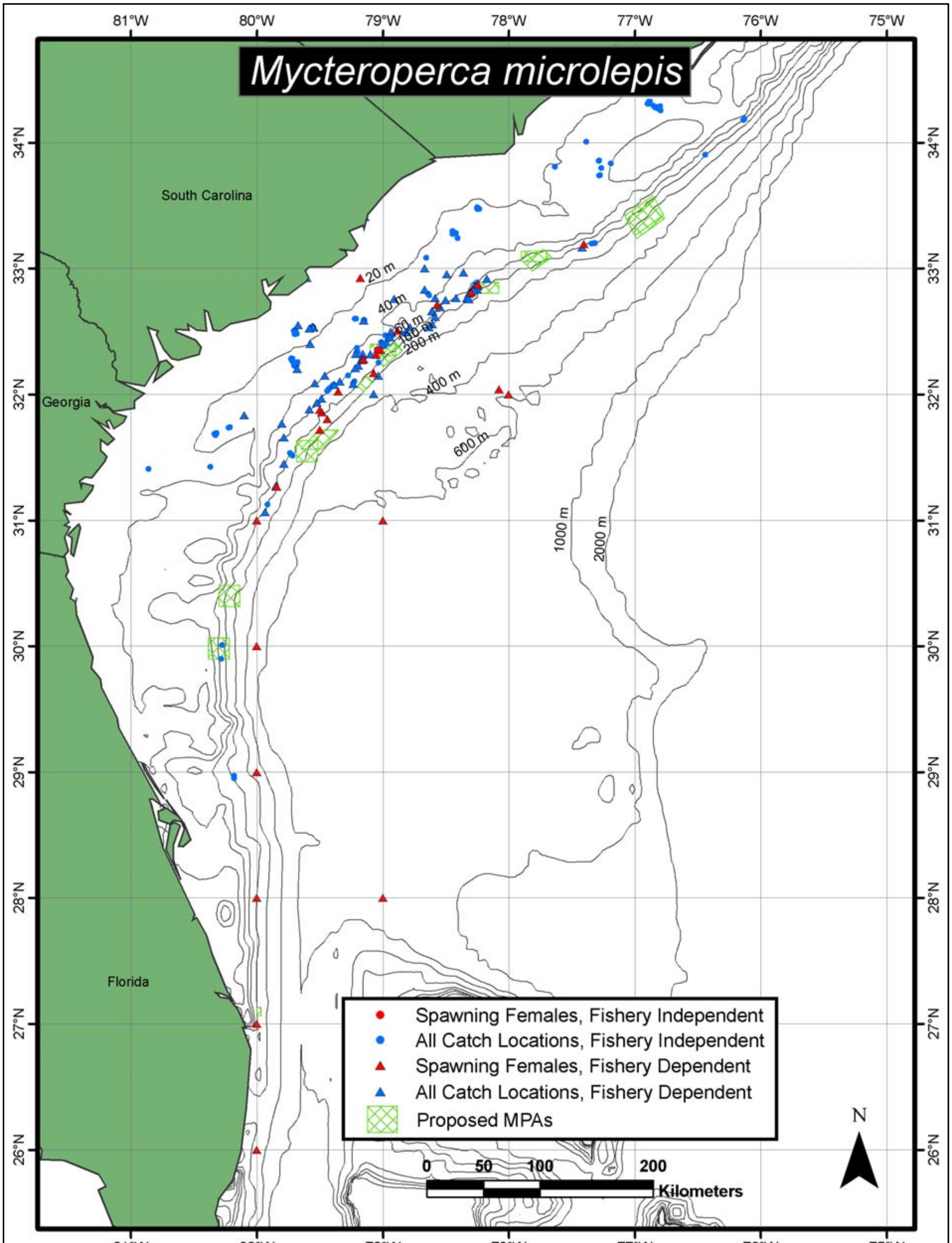


Fig. 39. Locations of capture of gag, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also

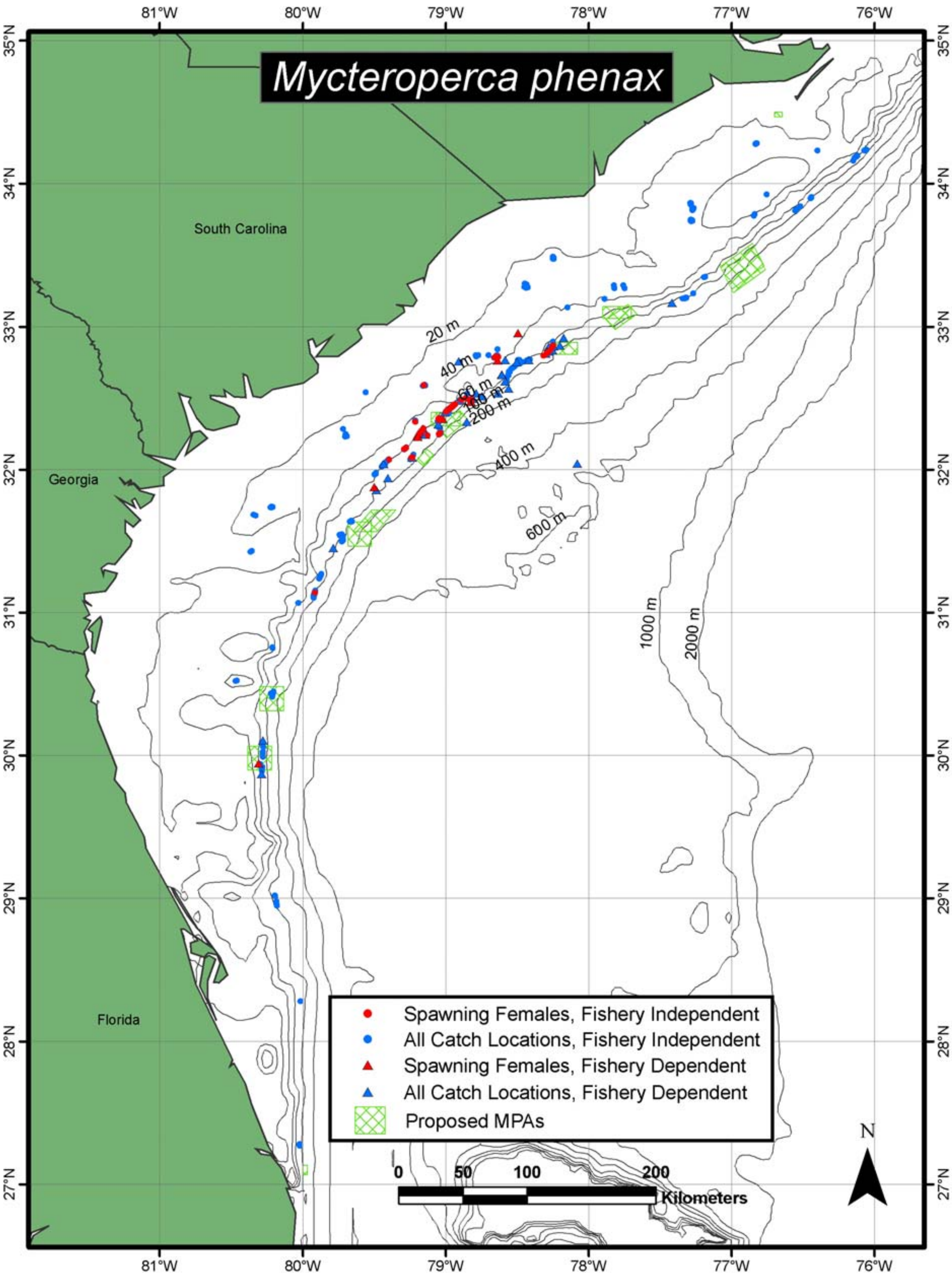


Fig. 40. Locations of capture of scamp, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also

Knobbed porgy (*C. nodosus*) were more restricted to mid- and outer-shelf reefs off the Carolinas and Georgia (21-155 m, map not shown). Spawning females were found almost exclusively at outer-shelf reefs and occurred at depths of 45 to 60 m (Table 9). Of 1181 specimens examined for sex and reproductive state, 88 were spawning females (Table 9). Knobbed porgy spawned over a narrow temperature range (49 measurements; range = 20.10-22.67°C). Spawning occurred from February through July, with a major spawning period of April through May (Table 10).

Red porgy (*P. pagrus*) were also distributed across the middle and outer shelf throughout the region, and spawning females were collected in depths from 26-57 m (Table 9, Fig. 41). Of 15,687 examined for sex and reproductive state, 457 were spawning females. Females in spawning condition were found from September through May at bottom temperatures of 16.24 to 18.99°C (N = 18); however, the major spawning period was November through March (Table 10).

Gray triggerfish (*B. capriscus*) were broadly distributed across the shelf (13-128 m) throughout the region (map not shown), but appear to concentrate spawning on middle-shelf to shelf-edge reefs (20-75 m). Of 4349 examined for sex and reproductive state, 141 were spawning females (Table 9). Gray triggerfish and other balistids construct nests by creating a shallow cleared depression on the bottom. These nests are guarded by either parent for 24-48 h after spawning (Fricke 1980, Lobel and Johannes 1980). On 4 August 2002 (32.8°N, 78.3°W; 54 m; 20.58°C) we observed and videotaped a large (~30 cm TL) gray triggerfish hovering over a cleared depression about 75 cm in diameter (video clip included in database). An apparent egg mass could be observed in the bottom of the depression. Gray triggerfish spawned from May through August, with a major spawning period of June and July (Table 10), at temperatures of 18.87-27.42°C (N = 148).

White grunt (*H. plumieri*) and red grouper (*E. morio*) had distributions that differed from most shelf species (e.g., Fig. 42). Both species were caught on the middle and outer shelf, mainly in the northern part of the SAB, and apparently have a disjunct distribution (Zatcoff et al. 2004, Chapman et al. in prep.). They are abundant in the Caribbean and southern Florida, but are not common off northern Florida or Georgia. They appear to be more tropical species that are found only in the waters of the northern SAB, which are under the influence of the Charleston Gyre (see additional discussion below).

Of the 2256 white grunt examined, 151 were spawning females. Spawning females were collected from March through September at most locations where white grunt occurred, with a major spawning period of April through June (Table 10; map not shown). Spawning occurred in depths from 22 to 51 m (Table 9). White grunt spawned in warmer waters (20.23-27.42°C; N = 123) than other species examined, reflecting its preference for warmer waters.

Red grouper (*E. morio*) have a distribution similar to that of white grunt, although spawning is generally restricted to depths greater than 40 m (Fig. 42). Spawning females (n = 46) represented 2.1% of the 2223 red grouper examined for sex and reproductive state (Table 9). Red grouper spawn in late winter and spring (February through June with a peak in April; Table 10) in depths from 30 to 90 m.

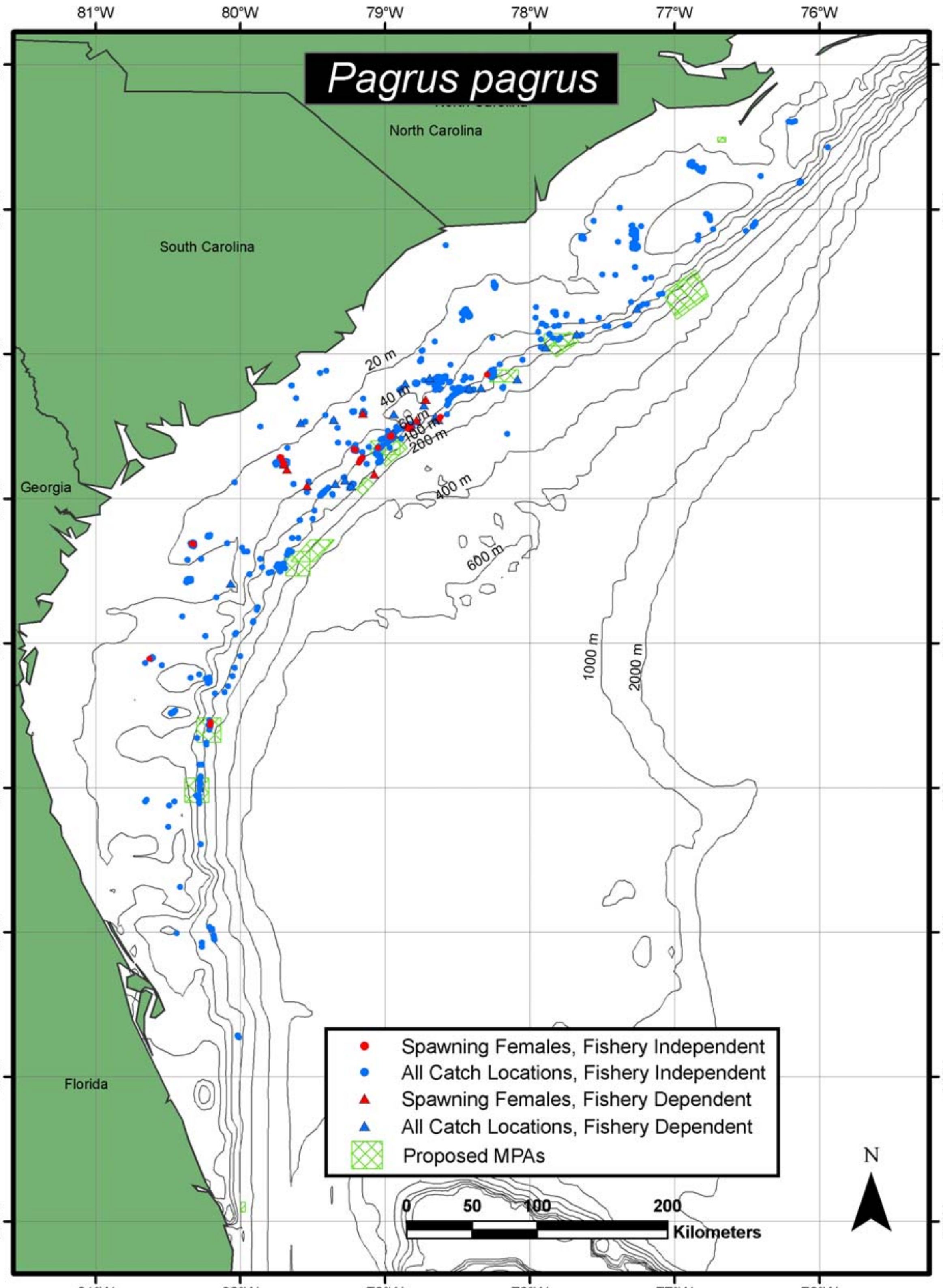


Fig. 41. Locations of capture of red porgy, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

Several species such as *Caulolatilus microps, Lopholatilus chamaeleonticeps, Epinephelus flavolimbatus, E. niveatus, Helicolenus dactylopterus, Polyprion americanus, Hyperoglyphe perciformis* and *Beryx decadactylus* have specific habitat requirements and were therefore collected and found in spawning condition in very restricted areas. They generally exhibited protracted spawning periods. Blueline tilefish (*C. microps*) were collected only off of South Carolina on shelf-edge and upper slope reefs between 46 and 256 m (Fig. 43). Blueline tilefish (N = 1112 examined for sex and reproductive state) were found associated with hard bottom that occurs in that area (Sedberry et al. 2004). Females in spawning condition (n = 514) were collected from February through October, with a major spawning period of March through September (Table 10). Spawning females were collected at a temperature range of 8.87-16.28°C (N = 32).

Tilefish (*L. chamaeleonticeps*) also had a restricted depth and latitude range (Table 9, Fig. 44); however, tilefish are found on soft-bottom habitat on the upper slope, where they construct burrows (Harris et al. 2001). Most tilefish were collected off South Carolina and Georgia, and spawning females were found in those areas. Spawning females (324 of 2431 fish examined) were collected in all months except October and December (Table 10), in depths from 190 to 300 m, at temperatures from 10.16 to 14.90°C (N = 9). The major spawning period was March through July.

Yellowedge grouper (*E. flavolimbatus*), like blueline tilefish, had a restricted depth distribution (map not shown) and were also found mainly on shelf-edge and upper-slope reefs off of the Carolinas at depths of 31 to 205 m. Spawning females (six of 73 fish examined) were collected in August and September in depths from 160 to 194 m, at a temperature of 14.47°C (one measurement) (Tables 9-10).

Snowy grouper (*E. niveatus*) were collected on shelf-edge and upper-slope reefs, mainly off the Carolinas (Fig. 45). Spawning females (96 of 649 fish examined) were collected from April through September, in depths from 187 to 302 m (Tables 9-10). The major spawning period was May through August. No bottom temperature data were available for collections of spawning snowy grouper. During a submersible dive on snowy grouper habitat in August (2002) off South Carolina, a bottom temperature of 13.27°C was measured, although no spawning snowy grouper were observed during that dive (Sedberry et al. 2004).

Blackbelly rosefish (*H. dactylopterus*) were also found over a relatively restricted depth range over hard bottom, and were often caught along with snowy grouper (map not shown). Blackbelly rosefish were collected between 38 and 686 m and spawning females were caught in depths from 229 to 238 m (Table 9). Of 1381 specimens examined, 138 were spawning females. Females were in spawning condition from December through April, with a major spawning period of January through April (Table 10). No bottom temperature data were available for collections of spawning blackbelly rosefish, and only one collection off South Carolina had location data.

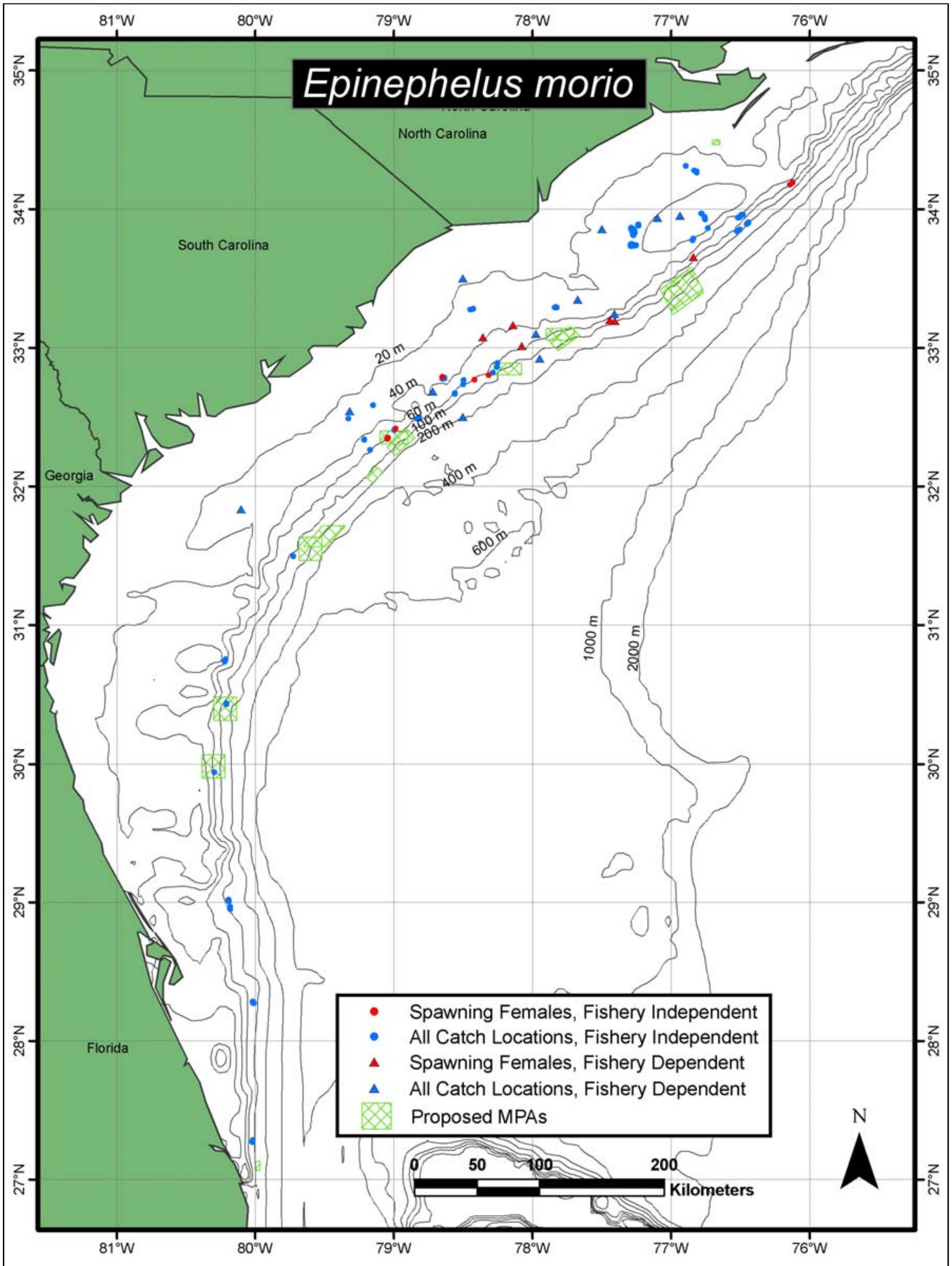


Fig. 42. Locations of capture of red grouper, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

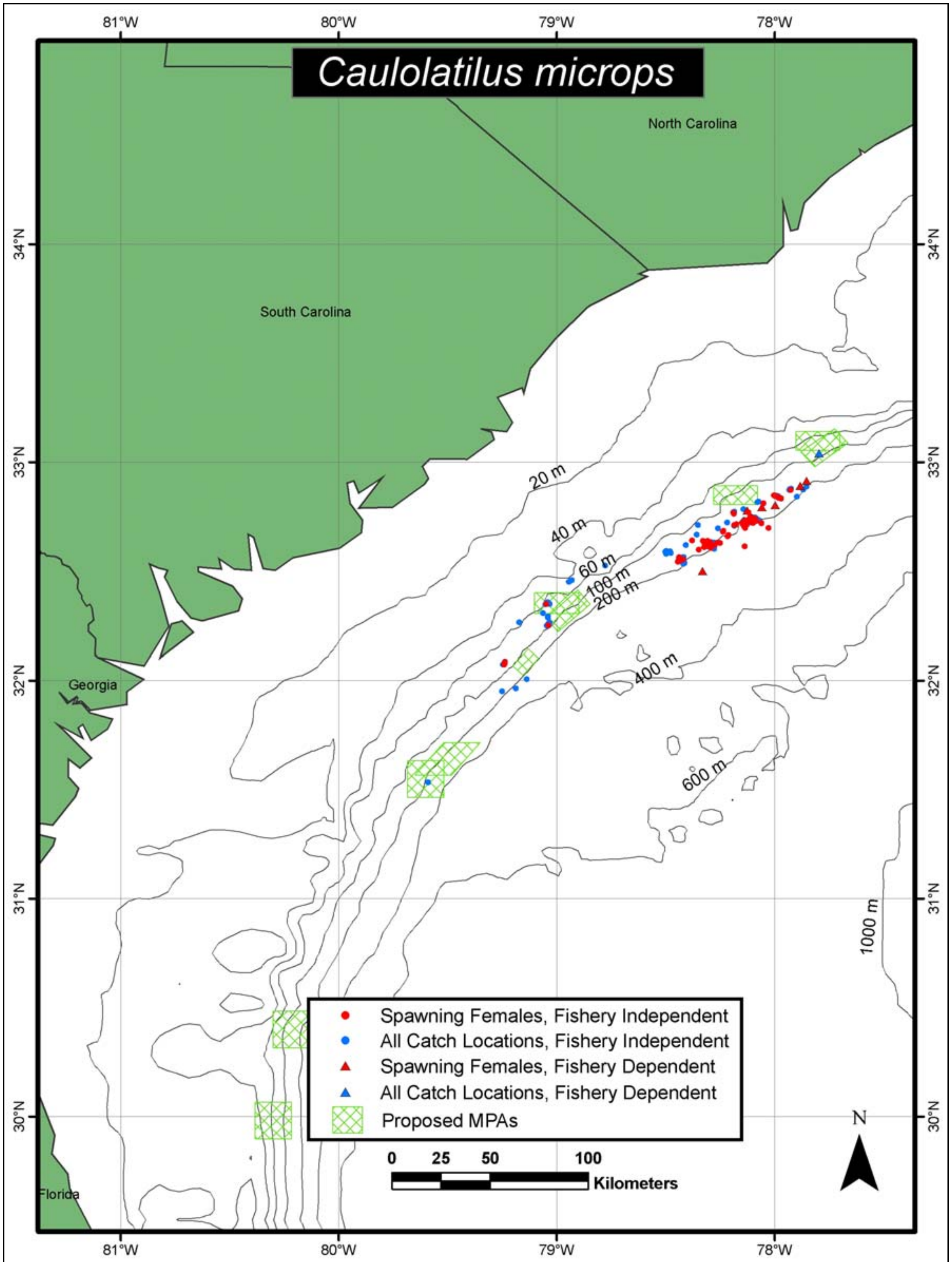


Fig. 43. Locations of capture of blueline tilefish, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

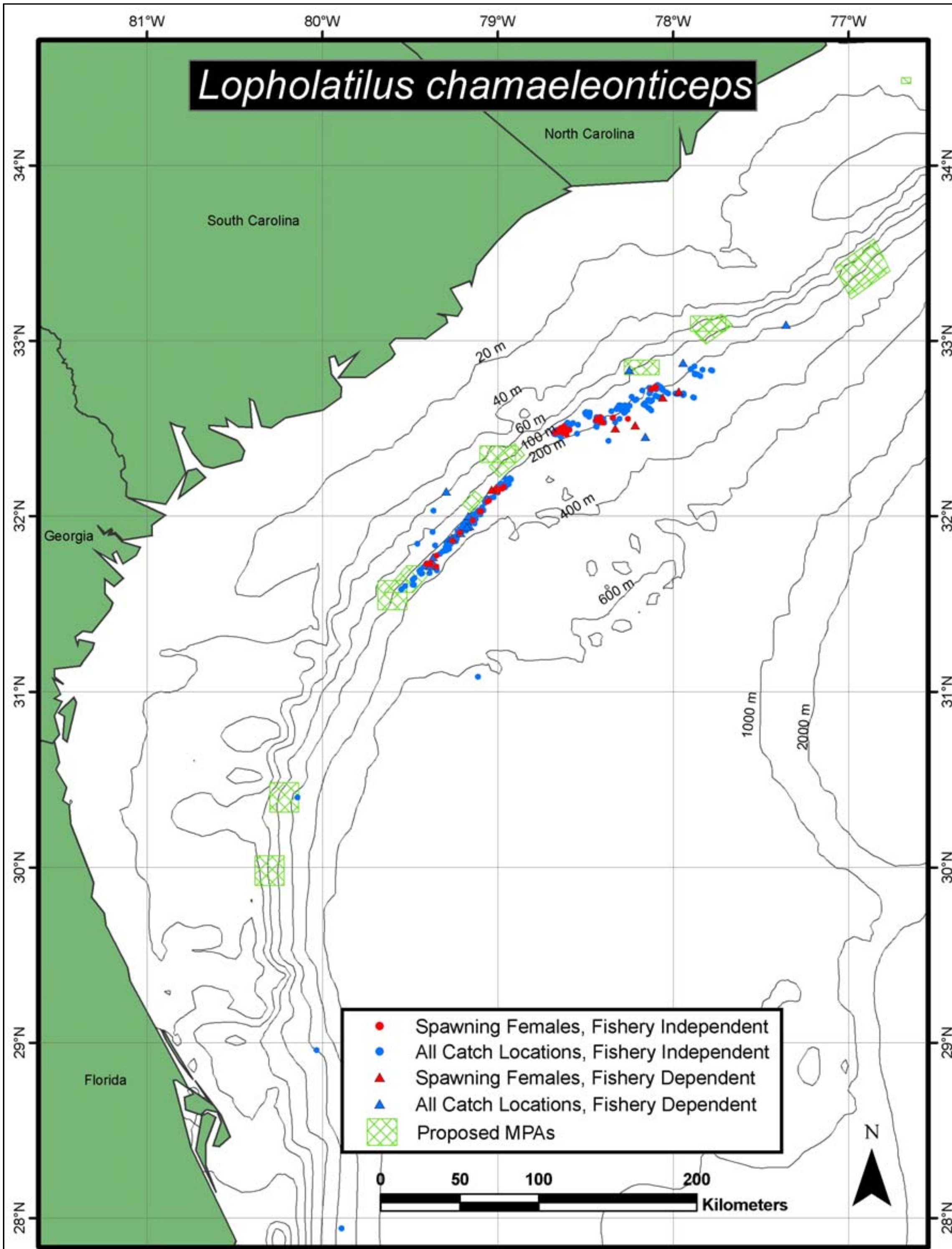


Fig. 44. Locations of capture of tilefish, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

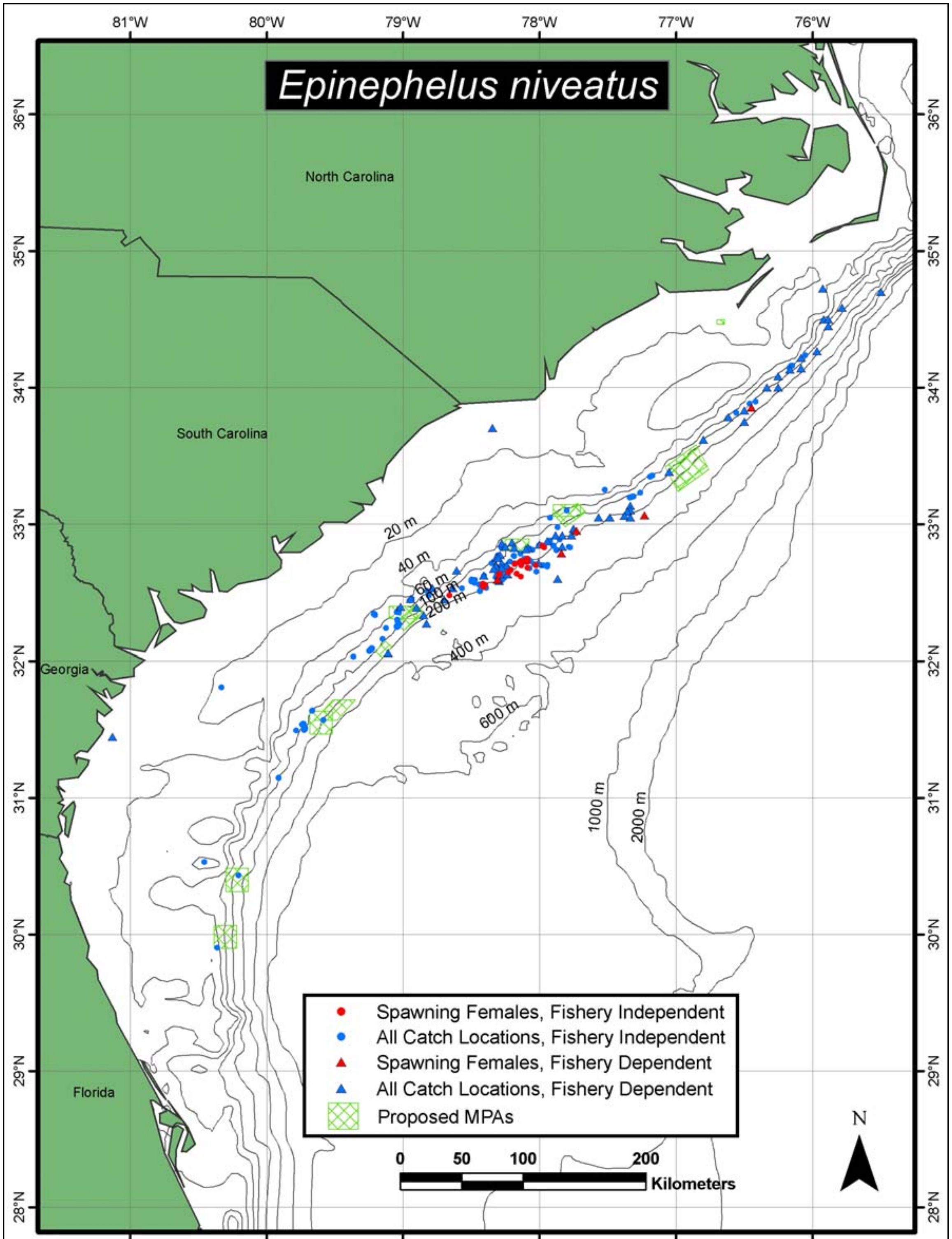


Fig. 45. Locations of capture of snowy grouper, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

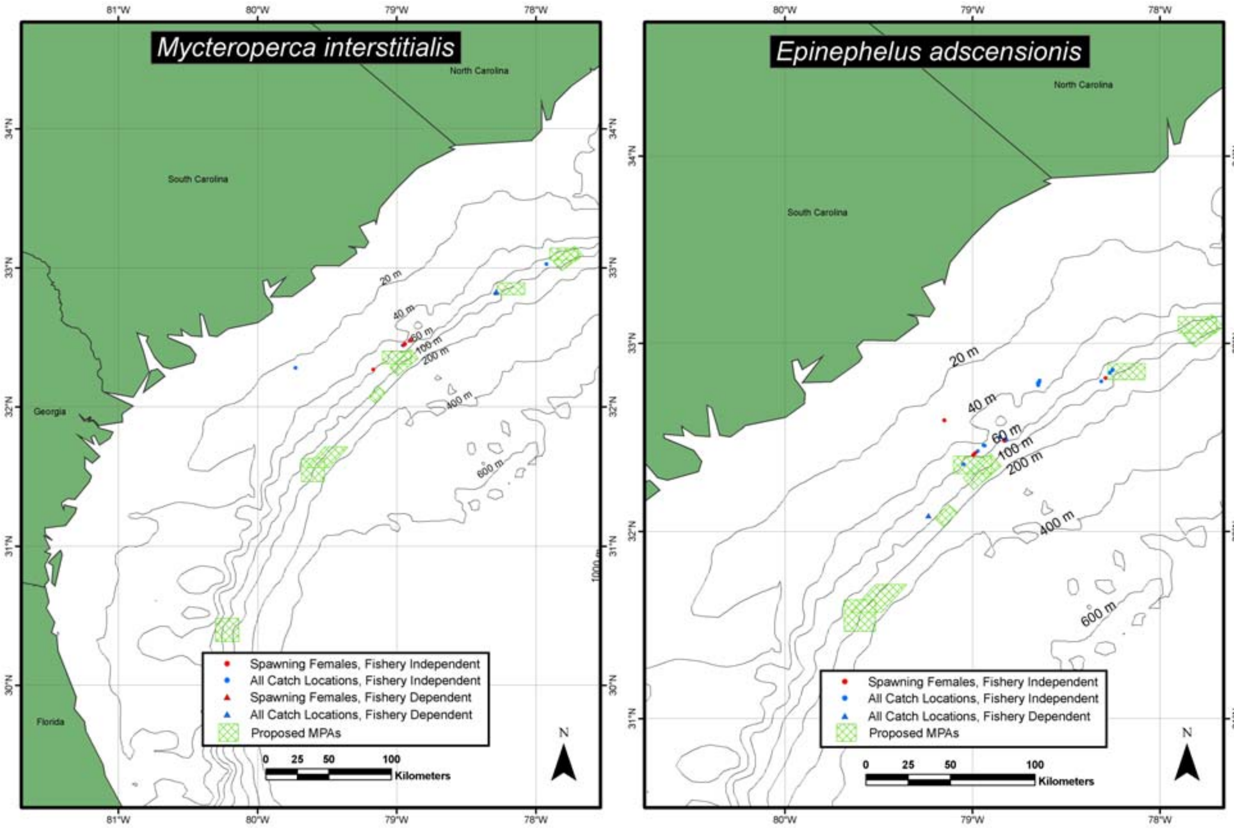
Wreckfish (*P. americanus*) occurred only on the continental slope, on a feature known as the Charleston Bump (Sedberry et al. 2001). Of 1466 wreckfish examined for sex and reproductive state, 55 were spawning females. Wreckfish were caught in depths from 44 to 653 m, and spawning females were caught in depths from 433 to 595 m (Table 9; map not shown). Wreckfish on the Charleston Bump have been collected at temperatures ranging from 6.2 to 16.3°C (Sedberry et al. 1999), and observed from submersibles (September 2001; August-September 2003) at temperatures of 8.4-16.7°C in depths from 430 to 570 m. Females in spawning condition were collected from November to May and were most prevalent in samples from February and March (Table 10). The Charleston Bump is the only known spawning area for wreckfish in the western North Atlantic (Sedberry et al. 1999).

We obtained 325 barrelfish (*H. perciformis*) from commercial wreckfish fishermen and conducted histological examination of 102 specimens. All samples, including spawning females, came from the Charleston Bump (Sedberry et al. 2001). The distribution of adult barrelfish is similar to that of adult wreckfish and spawning locations and times are about the same (map not shown). Of the 102 specimens examined, 12 were females in spawning condition (Table 9). Females in spawning condition were found from November through January and in May (Table 10).

Red bream (*B. decadactylus*), like wreckfish and barrelfish, were collected by wreckfish fishermen on the Charleston Bump. Of 16 specimens examined, eight were spawning females collected in June through September (Table 10). No spawning females were present in samples from April, May, November and December. No depth or temperature data were obtained from the fishermen, but location and temperatures were similar to wreckfish catch locations.

Three additional species of grouper were rarely collected in spawning condition. Yellowmouth grouper (*M. interstitialis*) was occasionally taken at middle- and outer-shelf reefs off of South Carolina (N = 18), where a few females (N = 9) were found in spawning condition in February, March and August off South Carolina at depths of 49-51 m (Tables 9-10, Fig. 46). Only one bottom temperature was recorded at one spawning location (14.47°C). Rock hind (*E. adscensionis*) were collected mainly at shelf-edge reefs off of South Carolina and, of 34 examined for sex and reproductive state, five were spawning females collected during March, May and June from depths of 37-53 m (Tables 9-10, Fig. 46). Bottom water temperatures for those collections were 20.05-23.96°C (N=6). Speckled hind (*E. drummondhayi*) were distributed throughout the region on outer-shelf to upper-slope reefs in depths from 28 to 114 m, and were collected more frequently (274 examined) than rock hind (Table 9, Fig. 46). Five spawning females were found off of South Carolina in May, June and September (Table 10).

In addition to the above species of grouper, we also examined gonads of seven graysby (*C. cruentata*), 18 coney (*C. fulva*) and 12 warsaw grouper (*E. nigritus*) collected throughout the region (Table 9). Several of the warsaw grouper were collected in proposed MPA sites off northern Florida and South Carolina. One spawning female was caught in May on the upper slope at a depth of 168 m (location unknown). An additional warsaw grouper examined from the database contained late vitellogenic oocytes, perhaps indicating potential spawning in the region. We collected one female coney in spawning condition in June (33.8°N, 76.8°N, 39 m), and one potential spawner in the same month with late vitellogenic oocytes. One female graysby examined also contained late vitellogenic oocytes, again indicating potential spawning in the region. We observed several running ripe male coney and graysby; however, male reef fishes are in spawning condition for much of the year and cannot be used to determine spawning location in the absence of females.



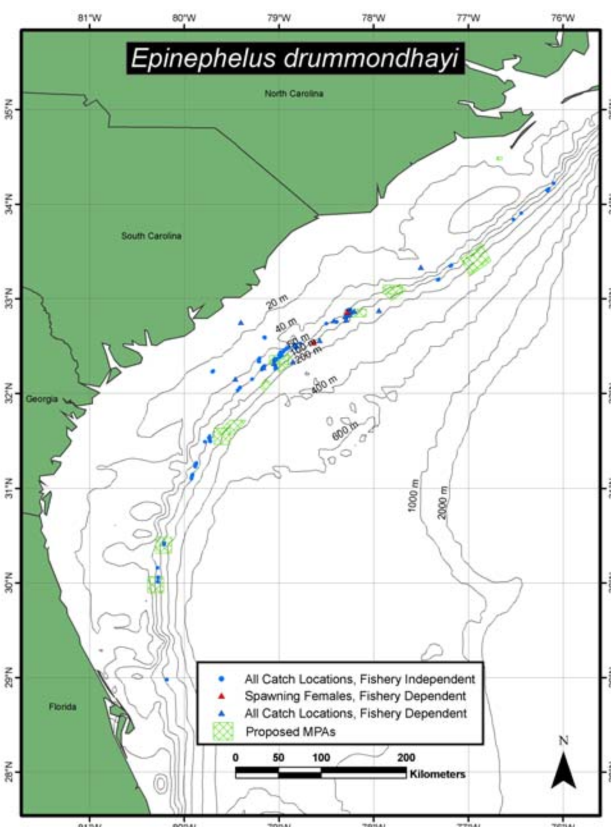


Fig. 46. Locations of capture of yellowmouth grouper, rock hind and speckled hind, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Proposed MPA sites are also shown.

In addition to the histological evidence of spawning cited above, we have observed courtship behavior in hogfish, *Lachnolaimus maximus*, at shelf-edge reef sites. Hogfish courtship was observed from submersible off Jacksonville, Florida on 30 July 2002 (30.4°N, 80.2°W, 56 m depth, 1846-1926 EDT) and off Charleston, South Carolina on 1 August 2002 (32.3°N, 79.0°W, 61 m depth, ~1000 EDT). Behavior was as described by Colin (1982), with the male displaying erect spines in the first dorsal fin, and rapid pelvic-fin agitations. This display was directed at one or two nearby females. Although Colin (1982) observed spawning from mid-afternoon to sunset, we did not observe actual spawning in hogfish during dives in morning and late afternoon. Bottom temperatures at the Florida site during the dive ranged from 20.90-20.94°C, considerably cooler than those reported by Colin (1982) in December to March in Puerto Rico (24-26°C). Bottom temperatures at the South Carolina site ranged from 20.47-22.03°C.

Spawning Sites as EFH, HAPC and MPAs

Spawning condition was determined for 28 species of reef fish at several phylogenetic levels, including Beryciformes (Berycidae), Scorpaeniformes (Scorpaenidae), Perciformes (Carangidae, Centrolophidae, Haemulidae, Lutjanidae, Malacanthidae, Polyprionidae, Serranidae, Sparidae) and Tetraodontiformes, and over a considerable depth and latitudinal range (Fig. 47). In spite of some temporal and spatial sampling limitations, we determined that the species examined fall into a few groups of life history and spawning strategies.

Several species such as small serranids, haemulids, sparids and lutjanids spawned over protracted periods and throughout the region. Black sea bass, sand perch, tomtate, red snapper and vermilion snapper were broadly distributed and spawned across the shelf, although vermilion snapper spawning activity seemed to be more concentrated at shelf-edge reefs than the other species in this group.

Red porgy and bank sea bass also had broad distributions throughout the region, but spawning appeared to be more narrowly focused on deeper sites in the middle of the region. In the case of bank sea bass, and to a lesser extent red porgy, this may reflect sampling limitations as these both spawn in winter, when sampling is more difficult and was subsequently more confined to the waters near our laboratory.

Gag, scamp, red grouper, knobbed porgy and gray triggerfish spawned mainly at shelf-edge reefs. Gag use shallow coastal or estuarine waters as nursery areas, but make either an ontogenetic shift or spawning migration to the outer shelf. Tagging of gag has indicated a spawning migration (Van Sant et al. 1994; McGovern et al. 2005). Gray triggerfish juveniles are pelagic or benthic in a variety of habitats (Martin and Drewry 1978), but apparently move to deep reefs with age and maturity. Knobbed porgy, red grouper and scamp appear to be more resident on outer-shelf reefs, where spawning occurs. Tilefish, blackbelly rosefish, blueline tilefish, snowy grouper and yellowedge grouper are resident, at least as adults, on the upper slope. Spawning is restricted to reef (or mud in the case of tilefish) habitats on the upper slope.

Barrelfish, wreckfish and red bream live on the Charleston Bump, mainly in depths from 500-600 m (Sedberry et al. 2001; Popenoe and Manheim 2001; Weaver and Sedberry 2001). Spawning also occurs there, under the main axis of the Gulf Stream. Eggs, larvae and juveniles of wreckfish and barrelfish are pelagic, perhaps living at the surface for several months (Sedberry et al. 1999; Martin and Drewry 1978). It is uncertain how these fishes are recruited back to the Charleston Bump. Juvenile wreckfish are very common at the surface in the eastern North Atlantic in the months following spawning on the Charleston Bump, and wreckfish from the eastern North Atlantic are genetically identical to those from the Charleston Bump (Sedberry et al. 1999; Ball et al. 2000), indicating substantial gene flow between the regions, mediated by Gulf Stream flow.

White grunt and, to a lesser extent, red grouper were collected in spawning condition primarily in the northern part of the study area and apparently have a disjunct distribution (Zatcoff et al. 2004; Chapman et al. in prep.). They are abundant in the Caribbean and southern Florida, but are not common off northern Florida or Georgia. They appear to be more tropical species that are found only in the waters of the northern SAB that are under the influence of the Charleston Gyre. Because of the influence of Gulf Stream waters being transported onto shelf waters off northern South Carolina and southern North Carolina via the Charleston Gyre, many tropical species are recruited to this area (Powell et al. 2000).

Gag and greater amberjack appear to undertake spawning migrations to the south, with most spawning in greater amberjack apparently occurring off of southern Florida. Tagging of these species off South Carolina has indicated substantial movement to south Florida of large fish during the spawning season (Van Sant et al. 1994; McGovern et al. 2005; Meister et al. in prep.).

Several rare tropical groupers (yellowmouth grouper, rock hind, speckled hind, graysby, coney, warsaw grouper) occur in the region, but it remains uncertain if spawning in most of these is occurring here or if recruitment of these fish comes from southern spawning locations. Groupers generally have long-lived larvae [31-66 d (Lindeman et al. 2000)] and it is certainly possible that periodic recruitment of these tropical species occurs. Some females examined appeared to be in, or approaching, spawning condition; however, it is unknown if population densities are high enough to induce spawning behavior (aggregation, harem formation) that often accompanies spawning in these tropical groupers (Jimenez and Fernandez 2001).

Although influenced by sampling limitations, there did appear to be areas within the region that are spawning grounds for several species. Shelf-edge reefs (40-60 m) in the middle of the SAB appeared to be particularly important (Fig. 47). Some of these reefs coincide with areas proposed by the SAFMC as MPAs (Fig. 47) that will prohibit bottom fishing (SAFMC 2004). Proposed MPAs that encompass shelf-edge reefs off Charleston, South Carolina [SAFMC Proposed South Carolina-B MPA, Option 1 at about 32.3°N (SAFMC 2004)] included spawning grounds for bank sea bass, red grouper, gag, scamp, knobbed porgy, red porgy, vermilion snapper and gray triggerfish (Fig. 47B). Blueline tilefish were also caught in spawning condition in this proposed MPA site, but most were caught deeper, on upper slope reefs. Red snapper were also found spawning in this proposed MPA, but extensive spawning was found scattered across the shelf. Black sea bass and sand perch spawned near the South Carolina B sites, but most spawning in those two species was at scattered middle-shelf reefs. Rock hind spawned near this site and occurred in the proposed SC-B Option 1 MPA (Fig. 47B). Spawning in rock hind also occurred near Proposed South Carolina-A MPA, Option 2 at about 32.8°N, and rock hind were collected at that proposed shelf-edge MPA site. The two instances of courtship behavior observed in hogfish also took place in proposed MPA sites, one of which was South Carolina B (the other was Florida Option 1 off Jacksonville). The proposed MPA sites off South Carolina appear to be particularly important as spawning grounds for several species (Fig. 47). Spawning occurred at one proposed South Carolina site (South Carolina-B Option 1) during all months of the year.

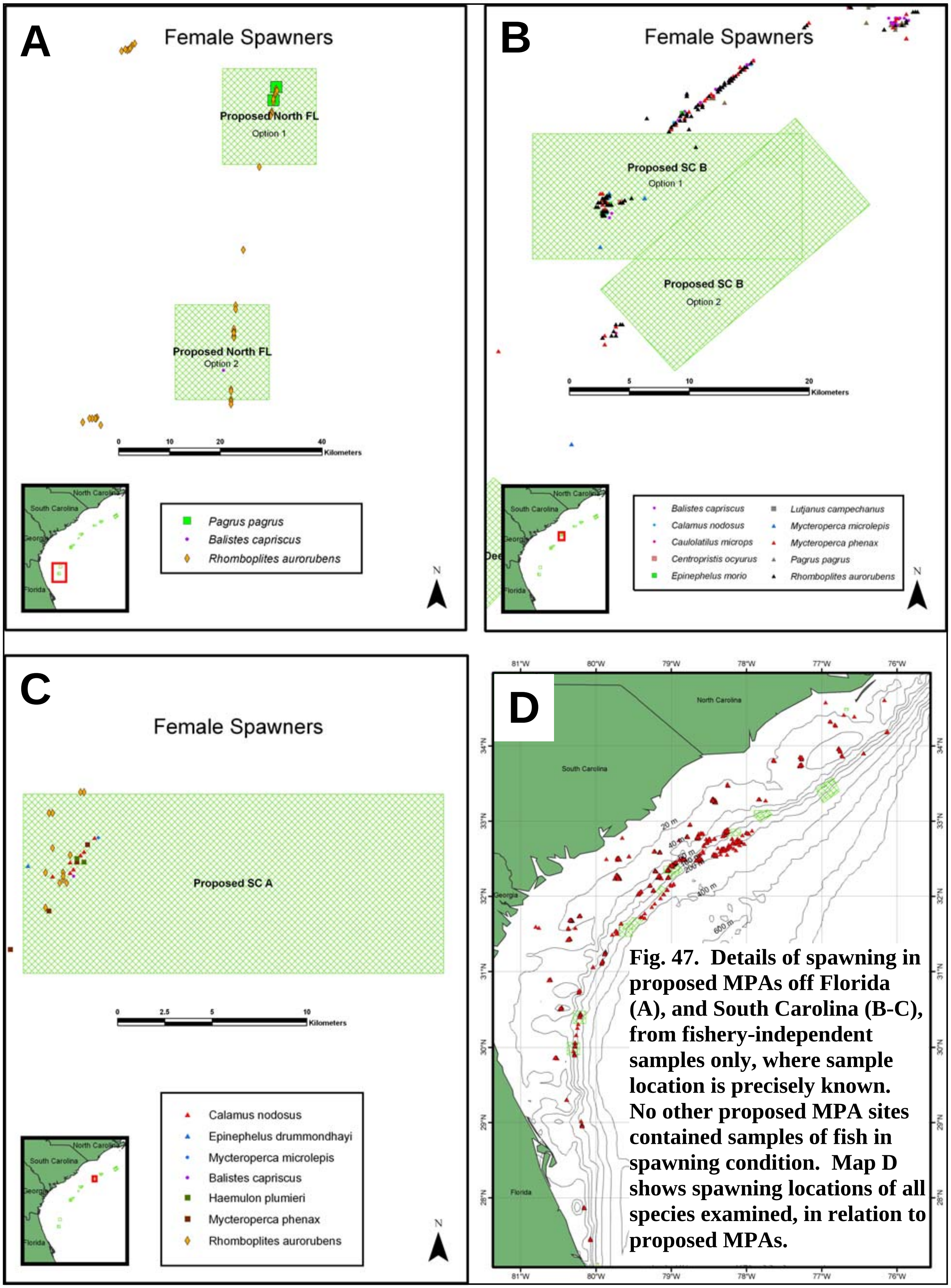


Fig. 47. Details of spawning in proposed MPAs off Florida (A), and South Carolina (B-C), from fishery-independent samples only, where sample location is precisely known. No other proposed MPA sites contained samples of fish in spawning condition. Map D shows spawning locations of all species examined, in relation to proposed MPAs.

Gag and scamp spawning occurred in more than one proposed MPA site off South Carolina, and spawning scamp were caught in proposed MPA sites off Florida too (SAFMC Proposed North Florida MPA Option 2 at 30°N). Tomtate were found spawning at many mid- to outer-shelf sites, but only one proposed MPA site (the North Florida Option 2 site) had spawning tomtate. Vermilion snapper were found spawning in almost all of the proposed sites, the exceptions being deep (> 200 m) sites off North Carolina and Georgia.

Several species spawned mainly on upper-slope habitats. Blackbelly rosefish, snowy grouper, yellowedge grouper and tilefish spawned on reef or mud habitat centered around 200 m. Although tilefish spawned near one of the proposed Georgia MPAs (SAFMC Proposed Georgia MPA Option 1), no spawning in any of these deepwater species was detected within the proposed MPA sites. Because protection and management of deepwater species is one of the primary objectives of the proposed MPA sites (SAFMC 2004), consideration should be given to locating a deepwater site to coincide with known spawning areas in deepwater species.

No spawning sites of greater amberjack coincided with proposed SAFMC MPA sites. However, two spawning locations were within the Florida Keys National Marine Sanctuary, but not within no-take zones in the Sanctuary. Tagging data (Meister et al. in prep.) indicate substantial movement of greater amberjack from the Carolinas to southern Florida during the spawning season. The commercial fishery for greater amberjack is closed in April (see SAFMC web site for regulations: www.safmc.net) and 56% of spawning fish were collected in April (most of those from southern Florida). This probably affords considerable protection to spawning greater amberjack.

Gag and red porgy are managed, in part, by a spawning season closure, with commercial catches limited to the recreational bag limit for gag in March and April (when 76% of spawning females were collected). Among several other restrictions, sale of red porgy is prohibited from January through April, when 88% of spawning females were collected. These closures during the peak spawning season probably afford some protection to spawning gag and red porgy.

Many species of reef fish spawn at shelf-edge sites that are under the influence of the Charleston Gyre. Eggs and larvae of these species are probably entrained in this gyre. Gag larvae are most often collected in the Charleston Gyre, often several tens of kilometers offshore and over much deeper water (>600 m) than their preferred (<50 m) habitat (Sedberry et al. 2004). Spawning in the Charleston Gyre probably results in better survival, as early life history stages are carried off the shelf with its associated predators, and are retained in a cyclonic circulation (with upwelling at its core) that provides nutrients and eventual transported back onto the shelf toward shallow nursery areas. Such a strategy seems to be associated with the long larval period found in groupers that spawn at shelf-edge sites (Lindeman et al. 2000) and that helps them utilize large gyres such as the Charleston Gyre.

Deep reef fishes of the Charleston Bump and Blake Plateau live and spawn in areas beyond those currently proposed as MPAs where bottom fishing would be prohibited. Wreckfish, however, are managed with gear restrictions (no longlines), an individual transferable quota with total allowable catch, and a spawning season closure (15 January through 15 April). Because barrelfish spawn at about the same place, and their spawning season extends into January (no data were available from February), it is likely that they are afforded some protection during spawning by regulations imposed on the wreckfish fishery. Red bream, however, spawn in summer on the Charleston Bump, when the wreckfish fishery is open and they are caught as bycatch. There is no evidence that the apparently small (but undocumented) bycatch is having a negative effect on spawning red bream, but this deserves further investigation. In addition to spawning demersal fishes on the Charleston Bump, there is some evidence that this is a spawning site for pelagic dolphin (*Coryphaena hippurus*) and swordfish (*Xiphias gladius*) as well (Govoni and Hare 2001, Sedberry et al. 2004).

Although many reef fishes important in commercial and recreational fisheries off the southeastern U.S. spawn across broad shelf areas, it is evident that some spawning is localized. Often, local spawning grounds are utilized by several species. In deciding among options for final MPA sites, consideration should be given to sites that are used as spawning grounds by several species. It is obvious that some options among the MPA sites proposed by the SAFMC contain more spawning sites for more species than do some of the other sites, and that by minor shifts in location or even orientation of the proposed closed areas, more spawning fishes could be protected. Consideration of known spawning areas and times should be an important criterion when planning time or area closures to ensure sustained fisheries.

Hydrographic Data

The database contains hydrographic data from 6247observations. Bottom temperature data have been related to spawning times and places (see above) and are available for additional analyses (Fig. 48). Distribution, abundance, biomass and diversity of fishes can be examined in relation to bottom temperatures (e.g., Fig. 49). Generally, the data show the expected great seasonal differences in temperature, which affect assemblages of fishes. In the summer, bottom

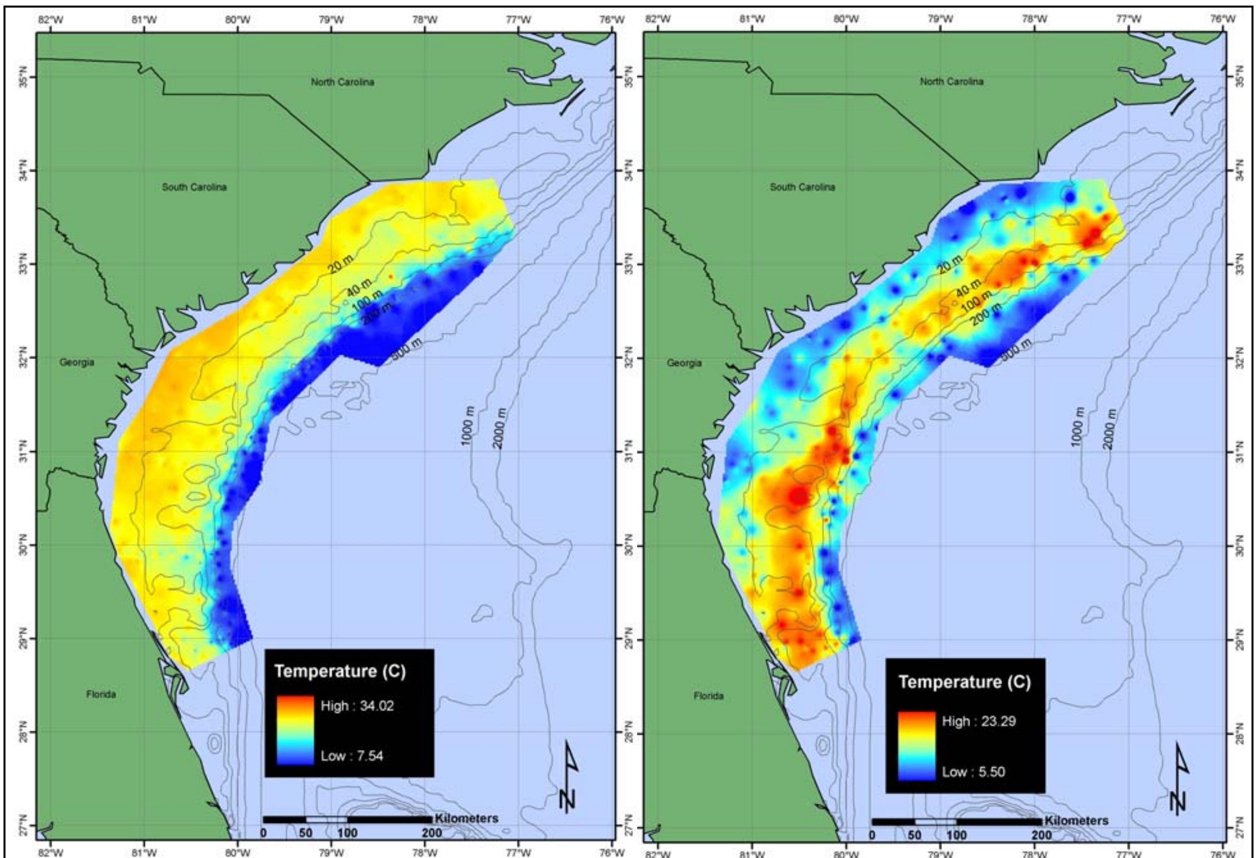


Fig. 48. Bottom temperatures measured during fishery survey cruises, 1978-2004. Plots are for all summer (Jul-Sep; on left) winter (Dec-Mar; on right) measurements combined. Note changing color scale between seasons.

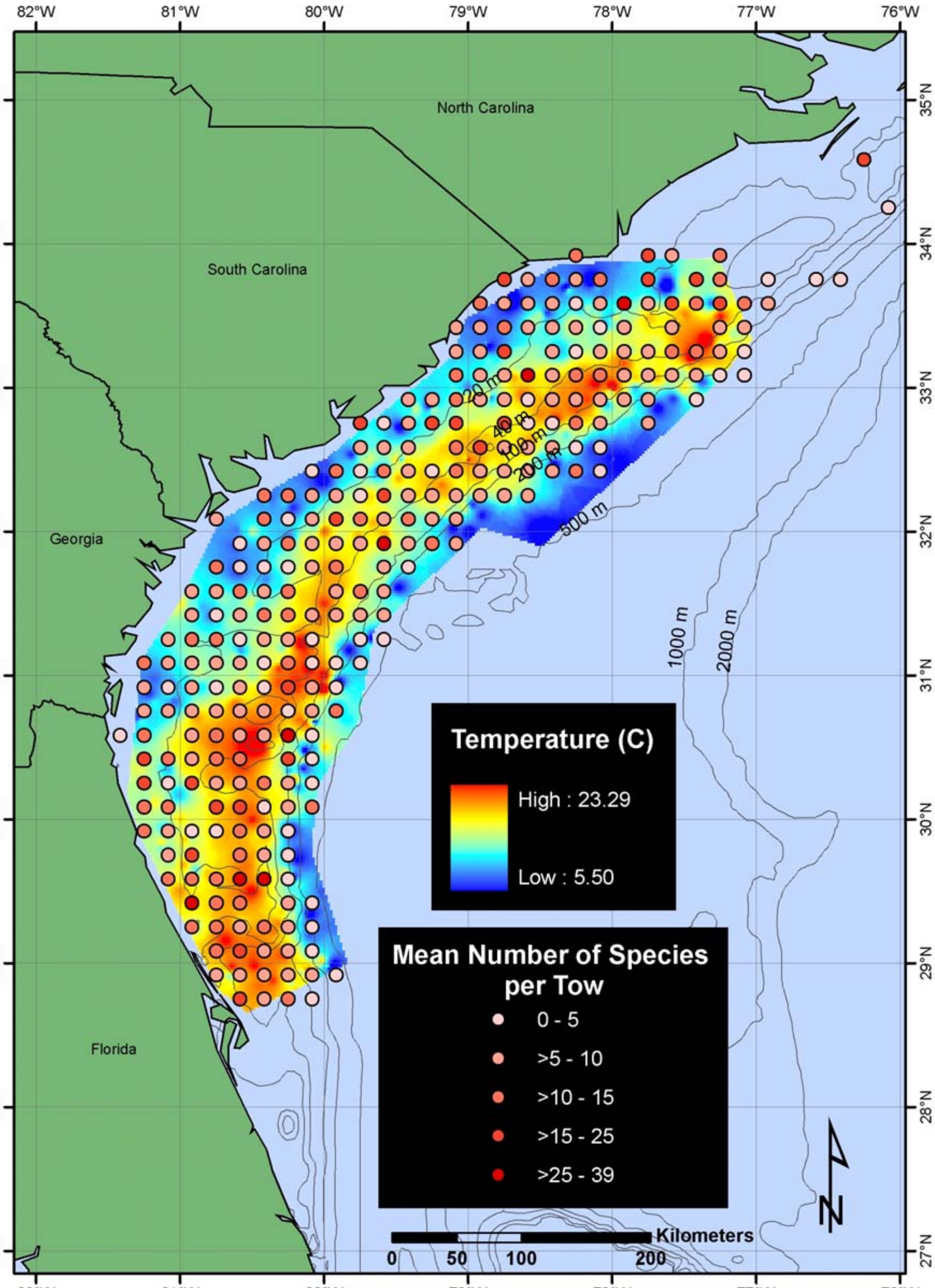


Fig. 49. Winter bottom temperatures (from Fig. 47) in relation to fish diversity (mean number of species per tow; same data as Fig. 34-36). High diversity is associated with warmer waters of the middle shelf and southern part of the SAB.

temperatures are relatively warm across the shelf and decline with increasing depth beyond the shelf edge. Areas of intrusion of upwelled water can be seen along the shelf edge and on to the middle shelf in summer. In winter, seasonal atmospheric cooling affects shallow bottom waters, but a band of warm water persists and mid-shelf depths, where it supports populations of warm-temperate and tropical reef fishes (Miller and Richards 1980; Sedberry and Van Dolah 1984).

Internet Map Server

The SEA-GEOFISH Internet Map Server (http://www.csc.noaa.gov/seageofish/) is housed at the CSC, and is an Internet-based mapping application that allows any user with an Internet connection and capable browsing software to visualize, identify, and conduct basic queries of the SEA-GEOFISH database described above (Fig. 50). Maps and descriptive statistics such as those described in this report can be accessed from the web site. The web site has two main Map Displays: "Important Species" (with 36 layers) and "Gear" (with 15 layers). There are three supporting Data Layers that are "Important Species, "Hotlink Layers, "Managed Areas" and "Base Layers (isobaths, etc.). The main pages include click-on tools that includes "Zooms" (In, Out, Full Extent, Active Layer, Lat/Long). Other tools can select data output by measurements, rectangle, or polygon. Miscellaneous tools allow finding locations, panning across maps, linking to other data layers (e.g., video clips of the bottom at some sites) and printing of each view. By pointing and clicking, one can plot multiple species or gears, or query for specific information on a layer (e.g., location, year, depth). The IMS will display known marine management zones (e.g., existing National Marine Sanctuaries and designated HAPCs, artificial reef Special Management Zones, jurisdictions and various economic, state, federal and military zones.

In addition to the types of maps and data presented thus far in this report, the web site contains video clips (1-2 mb files in mpg format) of the bottom, taken by submersible during NOAA Ocean Exploration cruises (G. Sedberry, Chief Scientist) to deep reef habitats from Florida to South Carolina. Some clips include observations of spawning fishes, but were chosen primarily to show bottom habitat features at a particular location. Video clips (N=242) of bottom type from transect start and end points were cut from dive tapes, resulting in approximately 60 min of short segments. A server at the SCDNR in Columbia hosts the video files; however, they may be accessed from the SEA-GEOFISH website. Transect points are listed as Sea Floor Video under the "Hotlink Layers" item on the main page. When the Sea Floor Video file data layer is active, the points appear on the map as icons placed according to their latitude and longitude coordinates (Fig. 51). Tools previously described allow the viewer to zoom in and out and pan as well as select points or polygons on the map and open tables of data. The viewer can click on one of the Sea Floor Video icons and the hyperlink opens a media player and plays the video clip from the SCDNR server. Using the "Identify All" button, the user can highlight Sea Floor Video points and a table will display information about the points below the map. The table includes dive number, tape number, gear identification number, type of gear, date, latitude, longitude, general location, transect and the file path of the video clip. The SEA-GEOFISH map allows the user to view the relative locations of transect points within a dive, relative location of all submersible dives, in relation to other sampling points and data available at the site.

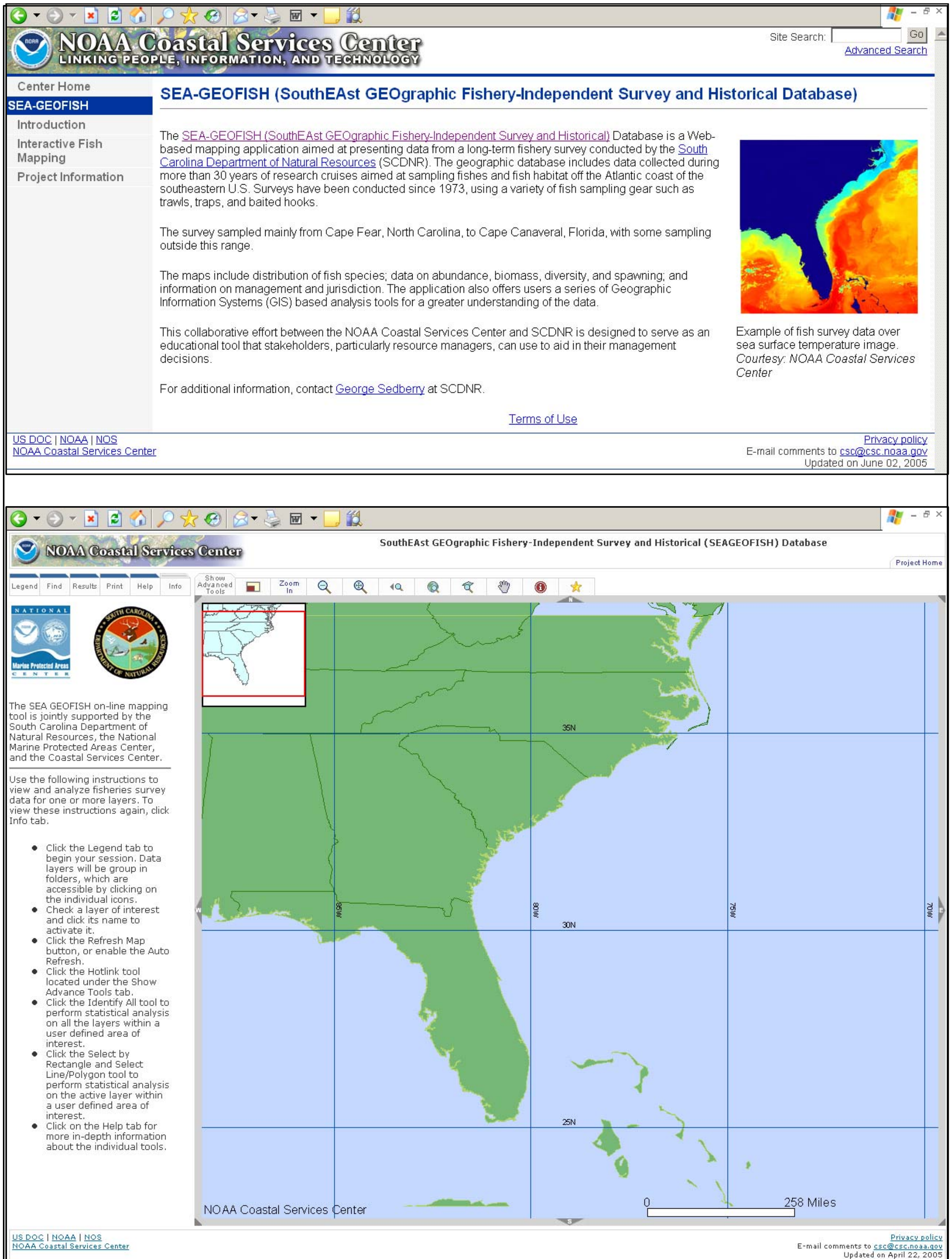


Fig. 50. Screen captures of opening page (above) and interactive mapping page (below) of the SEA-GEOFISH internet map server web site.

Additional imagery exists that will eventually be loaded onto the web site. The PI has over 1500 bottom color bottom photographs taken from cameras attached to the Chevron Traps during routine deployment through the region in 1987-1989. Negatives have been scanned and the images will be added to the web site as clickable icons that will display a bottom photograph.

The primary intended audience for the ArcIMS site is members of the scientific community and resource managers within the South Atlantic Bight. However, there are a number of other agencies, organizations, academic institutions, as well as the general public that will potentially have interest in this application. As with many other online mapping sites based on ArcIMS, it will be assumed that the user's experience will vary from novice to experienced GIS user. As a result, the user interface is as easy to navigate and operate as possible, and can generate maps such as those presented in this report. The ArcIMS also provides a data download function, but which is not yet functional. All data sets provided within the IMS

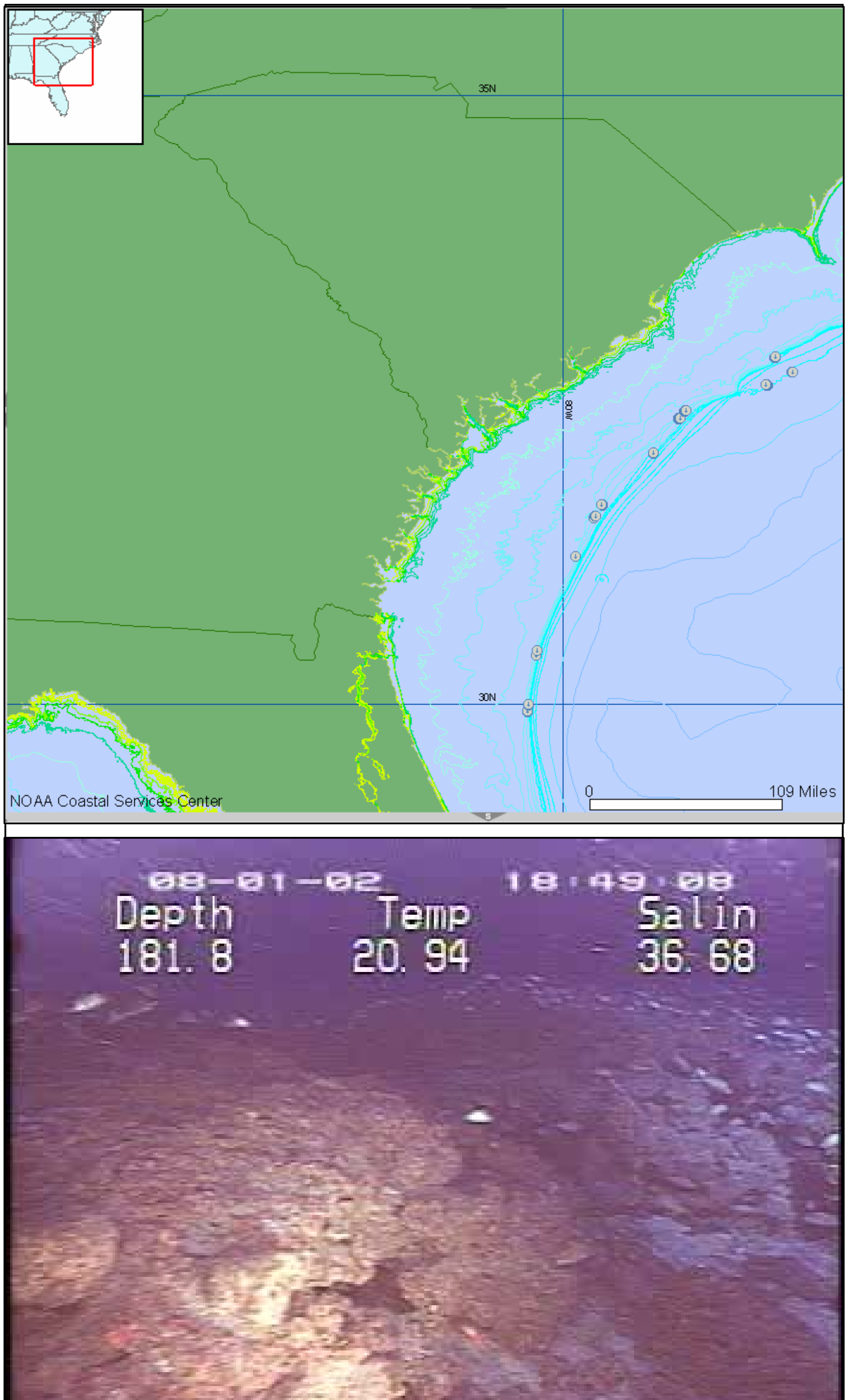


Fig. 51. Top: screen capture from SEA-GEOFISH web site showing hotlink icons (gray circles) for location of video clips in the database. Bottom: Frame captures from a video clip take off South Carolina. Depth in ft., temperature in °C and salinity in psu. Shown are large broken rocks at the shelf break . Deeper sediments were observed offshore (to the right in the image), and sediments were often seen on inshore and offshore sides of the ridge.

site will have a corresponding PkZip file, including the shapefile and its corresponding FGDC-compliant metadata. The download function provides the user with more flexibility than the existing Web page. As the site becomes better known and user needs are assessed, SCDNR will determine which data layers will be made available for download based on demand and potential sensitivity issues. The user will be able to choose among the available layers for download, based on the active layers in the current data frame. The spatial extent of the downloaded data will correspond directly with the map extent at the time of download.

Significant Problems

No significant problems have been encountered. The amount and variety of data presented problems in making it all available at the SEA-GEOFISH web site, especially considering the number of species involved. However, all the various types of data are presented on the web site, and it will be modified as users request additional information or modification. Not all raw data have been put on the web site, and not all data are viewable or downloadable. The investigators felt that access to detailed information on fish locations or spawning sites could result in adverse effects on the fishery; however the data are available and can be added. Such additions may be warranted as additional protective management is employed in the fishery.

Need For Additional Work

The database is being continuously updated and added to. For example, annual MARMAP monitoring cruises add collection data, and laboratory analysis of life history samples add additional data on spawning locations, nursery areas and other important data. Additional bottom imagery is available (still images and video) that can be eventually added to the database. In addition, the list of “Important Species” needs to be expanded to include all species. This will entail uploading raw data (rather than shapefiles) to the ArcIMS site, and project personnel will be working on this as additional data and updates are added.

EVALUATION

Extent To Which The Project Goals And Objectives Were Attained

Project goals were attained. Some additional data not available when the study was proposed (e.g., OE bottom video; 2004 MARMAP data) were added to the database. Although all data are in the database, as noted above, only Important Species have been included on the web site. Because of the large number of species involved, we chose the most abundant species to set up and demonstrate the web site. All species will be added eventually.

The major modification made to the project was extending it beyond the end date. This was partially caused by a delay in the ability to hire staff, but was also requested to enable us to incorporate additional data and to update the database through 2004, as those data became available at the end of the year. The extension also allowed us to test and modify the ArcIMS web site based on preliminary user comments.

A measure of the extent to which the project meets the objective of providing data to evaluate MPA sites (that include EFH and HAPC) can be obtained by evaluating the project in relation to MPA selection criteria. The SAFMC, in its review and deliberation process for establishing MPAs for reef fish management in the SAB, proposed several criteria for the establishment of MPAs that are relevant to the goals and objectives of this project (SAFMC

2001; Hare et. al. 2001). A review of the criteria is useful in determining how the project objectives were met in terms of evaluating proposed MPA sites. The 16 MPA siting criteria developed by the SAFMC are:

1. Are there sites that are regionally representative?

This project has generated species distribution maps (e.g., Fig. 24) that enable managers to locate reef sites that contain species that are generally representative of hard-bottom habitats from North Carolina to Florida, particularly within the SAFMC area of interest off southern North Carolina to Cape Canaveral.

2. Are there sites or habitats that are not conserved elsewhere?

Because there are no areas of hard-bottom that are currently classified as MPAs as defined by the SAFMC, this question is answered for MPAs. However, the only existing HAPC (i.e. the *Oculina* HAPC) appears to be a unique habitat, but may not support unique fishery species. We have mapped spawning locations for species in the SAFMC Snapper/Grouper Management Unit that have restricted spawning habitats, such as wreckfish, blueline tilefish (Fig. 43) and tilefish (Fig. 44). Such habitats and spawning sites are not conserved elsewhere, and MPA designation for them would conserve known spawning sites for these species. The project has identified locations that warrant consideration as MPAs to protect these spawning fishes. Some of the proposed MPAs contain spawning sites for these restricted species (e.g., Fig. 43).

3. Are there areas of high habitat diversity?

The databases available to this project contained no data on habitat diversity. However, fish species diversity can serve as a proxy for habitat diversity, because diverse habitats create diverse niches that support diverse fish assemblages. The database can be queried to determine if there are areas of high species diversity, and GIS analysis of the MARMAP Groundfish Trawl Survey data indicated that such areas exist. They appear to be correlated with stable warm bottom temperatures (Fig. 49) and hard bottom (Fig. 35). Such habitats might be considered as areas to protect and conserve high biodiversity.

4. Are there unique habitats in the database?

Existing databases contained little specific information about habitats, other than general indications of soft versus hard bottom (SEAMAP-SA 2001). The SEA-GEOFISH database now contains limited imagery of bottom habitats at the shelf edge and upper slope (e.g., Fig. 51), but these do not appear to be unique. However, areas that contain unique fish species might contain unique fish habitats. The database can be examined for occurrences of species that have restricted distribution that might indicate unique habitats (e.g., Fig. 44 for tilefish). The database can be analyzed to determine locations that contain fish species that are unique to some areas.

5. Are there fragile habitats in the region?

Existing databases on fishes did not provide this information. However it may be possible in the future to add distribution data on fragile sponges and corals (e.g., Wenner et al. 1983; Van Dolah et al. 1987). The investigators have additional video from deepwater coral habitats on the Charleston Bump, as well as still images taken with trap cameras. Such imagery can be added to the database in the future, and can be used to locate areas that contain fragile sponge and coral assemblages that, in turn, serve as habitat for fishes.

6. Are there areas containing vulnerable species?

The database and GIS can be examined to find locations for overfished species (NMFS 2005). Such species include red snapper (Fig. 37), snowy grouper (Fig. 45), red grouper (Fig. 42), black sea bass (Fig. 36), speckled hind (Fig. 46), warsaw grouper, and red porgy (Fig. 41).

In addition, locations and spawning sites can be determined for species undergoing overfishing (NMFS 2005), such as vermilion snapper (Fig. 38), gag (Fig. 39) and tilefish (Fig. 44). Warsaw grouper and speckled hind (Fig. 46) have been listed by IUCN (International Union for the Conservation of Nature) as Critically Endangered (Huntsman 1996a Huntsman 1996b), and several other reef fishes occur on the IUCN Red List as being severely impacted. Some of the proposed MPAs contain these listed species and should be given consideration for restoring stocks of these severely reduced species.

7. Are there areas that include vulnerable or rare stages?

The database includes the MARMAP ichthyoplankton and trawl surveys that can be queried for location of vulnerable early life history stages (e.g., Fig. 28, Fig. 33). The database can also show locations of spawning fishes, many of which spawn in proposed MPA sites (e.g., Fig. 47). Species such as groupers that form spawning aggregations are particularly vulnerable to fishing during the spawning season, and such seasons and locations can be determined for all economically valuable groupers in the region (e.g., Fig. 40).

8. Are there areas that support exploited species?

Many species of the SAFMC Snapper/Grouper Management Unit and Coastal Pelagics Management Unit have been found in the region, and distribution maps of priority species was one of the first products generated. Distribution maps can be made for all managed species (e.g., Fig. 24), as well as forage species and other species important in the ecosystem (e.g., Fig. 31).

9. Are there areas that supply recruits to adjacent areas?

The MARMAP tagging database (mainly on gag and greater amberjack) is being formatted to be incorporated into SEA-GEOFISH, and will be able to be used to examine movements of fishes from one area to another. A preliminary analysis of that subset of the data is being used to examine movements into and out of Gray's Reef National Marine Sanctuary, as a follow-up to the work of Sedberry et al. (1998). Spawning locations of fishery species have already been mapped and hydrographic data can be examined to describe dominant circulation patterns (e.g., Mathews and Pashuk 1986) that might carry larvae from documented spawning areas to "downstream" recruitment areas. Although not yet in the database, a separate SCDNR-NOAA Fisheries Service project is deploying satellite-tracked drifters and drift bottles on the spawning locations mapped in this study, during the spawning seasons. Data from those drifters will be available in early 2006 to be added to the database after analysis. Drifter tracks will be able to be visualized in relation to known spawning sites.

10. Is the area large enough?

There are many unknown factors regarding the size of MPAs for reef fishes (Botsford et al. 2003). The SEA-GEOFISH database can be used to examine different sizes and locations to determine species that occur there, their relative abundance and where and when they spawn there. The GIS enables users to examine different-sized areas for MPA consideration, and then see how size affects the species composition, biomass, abundance, diversity and spawning of fishes included in the MPA under consideration. The database can be used to examine MPA location in relation to specific hydrographic regimes. The GIS will also enable managers to look at known spawning locations of select species to determine how large an area should be incorporated to include spawners.

11. Are adjacent coastal areas supportive?

This criterion cannot be addressed with the ArcIMS site and database we have constructed; however, the mapping tools and maps generated can be used for educational materials to inform coastal residents of MPA considerations, such as location in relation to ports, cities, and fish locations.

12. Are there areas that are aesthetically appealing?

This may not be as big a consideration for locating MPAs in the SAB as it is in tropical coral reef areas. In fact, most of the proposed MPA sites are beyond observing by most recreational divers. Still, locations where aesthetically pleasing colorful reef fish species and the habitats with which they associate can be determined from the database.

13. Are potential MPAs, EFH, HAPC or other fish habitats accessible to user groups?

As managed areas or habitats of concern are debated or determined by management agencies, the distributions of fish species of concern can be examined in relation to nearby human population centers and ports. In addition, some fishery-dependent data are available on areas used by recreational headboats and charter boats (SAFMC 2004). Such data layers can be eventually added to the SEA-GEOFISH database, or the SEA-GEOFISH data can be downloaded to be used in fishery-dependent or socio-economic databases.

14. Can enforcement provide support?

Maps of potential MPA sites and habitats of concern will help in enforcement planning. MPAs can be based on biological data contained in the SEA-GEOFISH database, and potential sites selected according to those criteria can be refined based on ease of enforcement (e.g., distance offshore and from major ports).

15. Is there effective management?

Availability of the database and maps will assist in management of HAPC and MPAs. To date, data and shapefiles have been transferred to staff of NOAA's Gray's Reef National Marine Sanctuary, NOAA's National Centers for Coastal Ocean Science (M. Kendall) and the SAFMC Habitat and Ecosystem Management program for use in developing management plans. The SAFMC is using data from the project to develop effective Fisheries Ecosystem Plans.

16. Will a proposed MPA satisfy socio-cultural needs?

This project did not address this question directly, but the database should assist in analysis of socio-cultural factors in relation to fish and habitat distribution.

17. Does a proposed MPA preserve historical sites?

The project did not address this aspect of MPA planning. There are currently no data in the SEA-GEOFISH database regarding historical sites.

Dissemination of Project Results

Data, maps, images and shapefiles have been distributed from the project to the SAFMC, other investigators from The Nature Conservancy, and various universities and marine labs. Project staff have made several presentations regarding the project, and several papers have been published or are in progress, that have used the database.

Presentations Incorporating Project Data, Maps and Images

Bubley, W. 2004. Life history of sand perch, *Diplectrum formosum*, in the Atlantic waters of the southeastern United States with an emphasis on reproduction. South Carolina Chapter, American Fisheries Society.

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

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

Loefer, J.K. and G.R. Sedberry. 2003. A second year of satellite telemetry tagging of swordfish, *Xiphias gladius*, off the Southeastern United States. ARGOS Users Conference, Annapolis MD.

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

Loefer, J.K. and G.R. Sedberry. 2005. Satellite pop-up tagging provides a first look into the diel migration patterns of the night shark, *Carcharhinus signatus*. American Society of Ichthyologists and Herpetologists, St. Petersburg FL.

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.

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

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APPENDICES

APPENDIX A

Microsoft Access Database Objects

Appendix A. Database Objects

Name	Object Type	Location	Description
1_MinGrids	Table	Back-end	Stores conversions from decimal degree locations to 1 min grids for mapping
10_MinGrids	Table	Back-end	Stores conversions from decimal degree locations to 10 min grids for mapping
Cd_bal	Table	Back-end	Lists and describes the balance codes
Cd_bins	Table	Front-end	Stores user-inputed depth bins for depth CPUE queries
Cd_Catch	Table	Back-end	Lists and describes the catch codes
Cd_CatchAmt	Table	Back-end	Lists and describes the cathc amount codes
Cd_Est	Table	Back-end	Lists and describes the estimates codes
Cd_gear	Table	Back-end	Lists and describes the gear codes
Cd_Ltphase	Table	Back-end	Lists and describes the light phases codes
Cd_Lunar	Table	Back-end	Lists and describes the lunar phases codes
Cd_Maturity	Table	Back-end	Lists and describes the maturity codes
Cd_Sex	Table	Back-end	Lists and describes the sex codes
Tbl_ProposedMPAs	Table	Back-end	Proposed MPA locations
Cd_Meas	Table	Back-end	Lists and describes the measurement codes
Cd_PID	Table	Back-end	Lists and describes the Project ID codes
Cd_Quality	Table	Back-end	Lists and describes the quality codes
Cd_TowType	Table	Back-end	Lists and describes the towing codes
Cd_Unit	Table	Back-end	Lists and describes the measurement unit codes
Cd_Vessels	Table	Back-end	Lists and describes the vessel codes
Cd_VesselType	Table	Back-end	Lists and describes the vessel type codes
CPUE	Table	Front-end	Used in groundfish location CPUE queries
CPUE_SpeciesHold	Table	Front-end	Used in ichtyoplankton location CPUE queries
D_CPUE	Table	Front-end	Used in groundfish depth CPUE queries
D_CPUE_Sp	Table	Front-end	Used in groundfish depth CPUE queries
LAT_CPUE	Table	Front-end	Used in groundfish latitude CPUE queries
LAT_CPUE_Sp	Table	Front-end	Used in groundfish latitude CPUE queries
MRD_SpeciesCode	Table	Back-end	Lists and describes the species codes; based on MRD codes
SwitchboardItems	Table	Front-end	Data needed to run the switchboard form
Tbl_Bottom	Table	Back-end	Stores bottom values for hydrographic samples
Tbl_HydroData	Table	Back-end	Stores hydrographic data
Tbl_LengthData	Table	Back-end	Stores Length-frequency data for groundfish surveys
Tbl_PFSM	Table	Back-end	Stores the final life-history data
Tbl_Samlog_FD	Table	Back-end	Stores the additional sample log information for fishery-dependent data

Tbl_Samlog_FI	Table	Back-end	Stores the additional sample log information for fishery-independent data
Tbl_Samlog_Main	Table	Back-end	Stores the sample log (site) information
Tbl_SpeciesData	Table	Back-end	Stores the collection data by species for groundfish surveys
Tbl_Zooplankton	Table	Back-end	Stores the ichthyoplankton data
Z_CPUE	Table	Front-end	Used in ichthyoplankton location CPUE queries
Z_CPUE_SpeciesHold	Table	Front-end	Used in ichtyoplankton location CPUE queries
AvgCPUEbyGrid	Query	Front-end	Used in groundfish location CPUE queries
CPUE_AbundBiom	Update Query	Front-end	Used in groundfish location CPUE queries
CPUE_Append	Append Query	Front-end	Used in groundfish location CPUE queries
CPUE_Delete	Delete Query	Front-end	Used in groundfish location CPUE queries
CPUE_Species	Make-table Query	Front-end	Used in groundfish location CPUE queries
D_CPUE_1	Make-table Query	Front-end	Used in groundfish depth CPUE queries
D_CPUE_2	Make-table Query	Front-end	Used in groundfish depth CPUE queries
D_CPUE_3	Update Query	Front-end	Used in groundfish depth CPUE queries
D_CPUE_4	Query	Front-end	Used in groundfish depth CPUE queries
D_CPUE_W_YR_Loc	Query	Front-end	Used in groundfish depth CPUE queries
Hydro_matches	Query	Front-end	Matches Collections with bottom hydrographic values
Lat_CPUE_1	Make-table Query	Front-end	Used in groundfish latitude CPUE queries
Lat_CPUE_2	Make-table Query	Front-end	Used in groundfish latitude CPUE queries
Lat_CPUE_3	Update Query	Front-end	Used in groundfish latitude CPUE queries
Lat_CPUE_Final	Query	Front-end	Used in groundfish latitude CPUE queries
Qry_BinnedDepths	Query	Front-end	Used with Hydrographic Depths Form
Qry_BottomSamlog	Query	Front-end	Used to match collections to hydrographic values
Qry_Dmax_Order	Query	Front-end	Used to create bottom hydrographic values
Qry_FITotals	Query	Front-end	Used with Fishery-Independent Totals Form
Qry_GraphData	Query	Front-End	Used with graphing QA form
Qry_HydroBottom	Query	Front-End	Used with hydrographic form
Qry_HydroDateMatches	Query	Front-End	Used to match collections to hydrographic values
Qry_HydroMatches	Query	Front-End	Used to match collections to hydrographic values
Qry_HydroSurface	Query	Front-End	Used with hydrographic form
Qry_LifeHistory	Query	Front-End	Used with Life-history form

Qry_Surface	Query	Front-End	Used with hydrographic form
Qry_z_lengths	Query	Front-end	Used with ichthyoplankton Length Form
Qry_z_SpAbund	Query	Front-end	Used with ichthyoplankton Totals Form
Qry_Z_uniqspecies	Query	Front-end	Used with ichthyoplankton Species Form
Qry_z_UniqSpList	Query	Front-end	Used with ichthyoplankton Species Form
Qry_zoosub	Query	Front-end	Used with ichthyoplankton Subset Form
QryCollCounts	Query	Front-end	Used with Collections form
QryGears	Query	Front-end	Used with the Gears Form
QryMulti	Query	Front-end	Used with groundfish Complext subset form
QryRounding	Query	Front-end	Used with Hydrographic Depths Form
QrySpListing	Query	Front-end	Used with groundfish length form
QryStatic	Query	Front-end	Used with Groundfish Simple Subset Form
Z_avgCPUEbyGrid	Query	Front-end	Used in ichtyoplankton location CPUE queries
Z_avgCPUEm3	Query	Front-end	Used in ichtyoplankton location CPUE queries
Z_CPUE_#m3	Update Query	Front-end	Used in ichtyoplankton location CPUE queries
Z_CPUE_Abund	Update Query	Front-end	Used in ichtyoplankton location CPUE queries
Z_CPUE_Append	Append Query	Front-end	Used in ichtyoplankton location CPUE queries
Z_CPUE_Delete	Delete Query	Front-end	Used in ichtyoplankton location CPUE queries
Z_CPUE_Species	Make-table Query	Front-end	Used in ichtyoplankton location CPUE queries
Frm_Collections	Form	Front-end	Form used to query collection records
Frm_FI_CPUE	Form	Front-end	Form used to calculate location CPUE from fishery-independent groundfish surveys
Frm_FI_CPUE_Depths	Form	Front-end	Form used to calculate depth CPUE from fishery-independent groundfish surveys
Frm_FI_Lengths	Form	Front-end	Form used to query species length data from fishery-independent groundfish surveys
Frm_FI_MultiSub	Form	Front-end	Form used to create complex subsets from fishery-independent groundfish surveys
Frm_FI_Subset	Form	Front-end	Form used to create simple subsets from fishery-independent groundfish surveys
Frm_FI_Totals	Form	Front-end	Form used to calculate total abundance and/or biomass by species from fishery-independent groundfish surveys
Frm_Gears	Form	Front-end	Form depicting gear descriptions
Frm_Graphs	Form	Front-end	Form used to graph length-length and length-weight data from life-history datasets based on species selection

Frm_graphSpecies	Form	Front-end	Form used to graph length-length and length-weight data from life-history datasets based on species selection
Frm_HydroByDepths	Form	Front-end	Form used to query hydrographic data by depths
Frm_HydroData	Form	Front-end	Form used to query hydrographic data
Frm_LifeHistoryData	Form	Front-end	Form used to query lifehistory data
Frm_SampleLog	Form	Front-end	Form used to view all sample (site) information
Frm_SpeciesList	Form	Front-end	Form used to view all species code information
Frm_ZooCPUE	Form	Front-end	Form used to calculate location CPUE from ichthyoplankton surveys
Frm_ZooLengths	Form	Front-end	Form used to query ichthyoplankton data for species length information
Frm_ZooMulti	Form	Front-end	Form used to create complex subsets from ichthyoplankton surveys
Frm_ZooSpTotals	Form	Front-end	Form used to calculate total abundance by species from ichthyoplankton surveys
Frm_ZooStatic	Form	Front-end	Form used to create simple subsets from ichthyoplankton surveys
Frm_ZooUSp	Form	Front-end	Form used to calculate species richness from ichthyoplankton surveys
Sfrm_Bins	Subform	Front-end	Subform that populates depth ranges for the Depth CPUE from fishery-independent surveys
Sfrm_samlog_FD	Subform	Front-end	Subform used with the sample log form
Sfrm_Samlog_FI	Form	Front-end	Subform used with the sample log form
Switchboard	Switchboard Form	Front-end	Switchboard form used to navigate within the database
Rpt_SummaryYear	Report	Front-end	Report containing end of the year information
Srpt_Days	Report	Front-end	Subreport used in the summary year end report
Srpt_GearSummary	Report	Front-end	Subreport used in the summary year end report
Srpt_Species	Report	Front-end	Subreport used in the summary year end report
Srpt_Species_Sum	Report	Front-end	Subreport used in the summary year end report

APPENDIX B

Table Layouts

Appendix B. Table Layouts

B.1. Site Information: tbl_Samlog_Main, tbl_Samlog_FD, and tbl_Samlog_FI

B.1.a: Tbl_Samlog_Main

Field	Type	Size	Description
Source	Text	1	For fishery-dependent data: Source of sample
PCG	Text	12	Primary Key: Project ID, Collection Number and Gear Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
GMT	Date/Time	8	Start Time in Greenwich Mean Time
Day	Integer	2	Sample Day
Month	Integer	2	Sample Month
Year	Integer	2	Sample Year
Date	Date/Time	8	Sample Date
Latitude	Single	4	Sample Latitude in decimal degrees
Longitude	Single	4	Sample Longitude in decimal degrees
Lat_Deg	Integer	2	Sample Latitude Degrees
Lat_Min	Single	4	Sample Latitude Minutes (XX.X)
Long_Deg	Integer	2	Sample Longitude Degrees
Long_Min	Single	4	Sample Longitude Minutes (XX.X)
Stat_Depth	Integer	2	Station Depth (m)
Samp_Depth	Integer	2	Sample Depth (m)
Samp_Dur	Integer	2	Sample Duration (min)
Tow_ID	Text	50	Tow Code (nets only)
LP_ID	Text	50	Light Phase Code
Catch_ID	Integer	2	Catch Code
Vessel	Text	2	Vessel Code
Speed	Single	4	Speed (knots)
10G	Text	50	10 Minute Grid Value
1G	Text	50	1 Minute Grid Value
Quality	Text	1	Quality Code

B.1.b: Tbl_Samlog_FD

Field	Type	Size	Description
PCG	Text	12	Primary Key: Project ID, Collection Number and Gear Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
Source	Text	1	For fishery-dependent data: Source of sample
CatchAmt	Text	1	Catch Amount Code
FedTripNo	Text	10	Federal Trip Indentification Number (NMFS Samples)
Lunar_ID	Integer	2	Lunar Phase Code
VT_ID	Integer	2	Vessel Type Code

B.1.c: Tbl_Samlog_FI

Field	Type	Size	Description
PCG	Text	12	Primary Key: Project ID, Collection Number and Gear Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
Strata	Text	4	Strata Code
WO	Integer	2	Wire Out amount (m)
WA	Integer	2	Wire Angle (Deg)
Vol_Str	Integer	2	Volume Strained (m^3)

B.2. Groundfish Surveys (Fishery-Independent): tbl_SpeciesData and tbl_LengthData

B.2.a: tbl_SpeciesData

Field	**Type**	**Size**	**Description**
PCG	Text	12	Related Key: Project ID, Collection Number and Gear Code Combination
PCGSQE	Text	20	Primary Key: Project ID, Collection Number, Gear Code, Species Code, Questionable ID Code, and Estimate Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
SP_ID	Text	4	Species Code
QID	Yes/No	1	Questionable ID Code
Est_ID	Text	1	Estimated Sample Code
Bal_ID	Integer	2	Balance Code
Unit_ID	Text	1	Measurement Unit Code
Total_Wt	Long Integer	4	Total Weight (kg)
Sub_Wt	Long Integer	4	Subsample Weight (kg)
Num_Measured	Long Integer	4	Number Actually Measured
Abundance	Long Integer	4	Total Abundance
Quality	Text	1	Quality Code

B.2.b: tbl_LengthData

Field	**Type**	**Size**	**Description**
PCG	Text	12	Related Key: Project ID, Collection Number and Gear Code Combination
PCGSQE	Text	20	Primary Key: Project ID, Collection Number, Gear Code, Species Code, Questionable ID Code, and Estimate Code Combination
Meas_ID	Text	2	Measurement Code
Unit_ID	Text	1	Measurement Unit Code
Len	Integer	2	Length of Specimen (cm)
Freq_Org	Integer	2	Original Frequency
Freq_Exp	Long Integer	4	Frequency expanded due to subsampling
Len_X_Freq	Long Integer	4	Length multiplied by frequency expected

B.3. Hydrographic Information: tbl_Hydrographic and tbl_Bottom

B.3.a: tbl_Hydrographic

Field	Type	Size	Description
PCG	Text	12	Related Key: Project ID, Collection Number and Gear Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
Order	Long Integer	4	Order of recordings
Type	Text	10	Type of Equipment
Year	Long Integer	4	Year sample was taken
Pressure	Single	4	Pressure readings (milibars)
Temp	Single	4	Temperature (ºC)
Salinity	Single	4	Salinity (PSU or ppt)
Depth	Single	4	Depth (m)
Oxygen	Single	4	Dissolved Oxygen (1987-1992: mg/l; =>2004: ml/l)
CHLa	Single	4	Chlorophyll a (micrograms/l)
PO4	Single	4	Phosphate (microgram atoms/l)
NO2	Single	4	Nitrites (microgram atoms/l)
NO3	Single	4	Nitrates (microgram atoms/l)
Instrument	Text	25	Particular instrument documentation
File Type	Text	10	Raw storage file type

B.3.a: tbl_Bottom

Field	Type	Size	Description
PCG	Text	12	Related Key: Project ID, Collection Number and Gear Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
Pressure	Single	4	Pressure readings (milibars)
Depth	Single	4	Depth (m) derived from pressure readings
Temp	Single	4	Temperature (ºC)
Salinity	Single	4	Salinity (PSU or ppt)
Depth	Single	4	Depth (m)
Oxygen	Single	4	Dissolved Oxygen (1987-1992: mg/l; =>2004: ml/l)
CHLa	Single	4	Chlorophyll a (micrograms/l)
PO4	Single	4	Phosphate (microgram atoms/l)
NO2	Single	4	Nitrites (microgram atoms/l)
NO3	Single	4	Nitrates (microgram atoms/l)
Order	Long Integer	4	Order of data recording
Flag	Yes/No	1	Flagged if “Bad” reading

B.4. Ichthyoplankton Surveys: tbl_Zooplankton

Field	Type	Size	Description
PCG	Text	12	Related Key: Project ID, Collection Number and Gear Code Combination
PCGSQE	Text	20	Primary Key: Project ID, Collection Number, Gear Code, Species Code, Questionable ID Code, and Estimate Code Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
SP_ID	Text	4	Species Code
QID	Yes/No	1	Questionable ID Code
QIDMemo	Text	15	Notes about any QID
Number_of_Splits	Long Integer	4	Number of splits for subsamples
Number_In_Splits	Long Integer	4	Number of specimens in split by species
Number_In_Sample	Long Integer	4	Total Abundance
Meas_ID	Text	2	Measurement Code
Min_Length	Long Integer	4	Minimum length measured in sample (mm)
Max_Length	Long Integer	4	Maximum length measured in sample (mm)

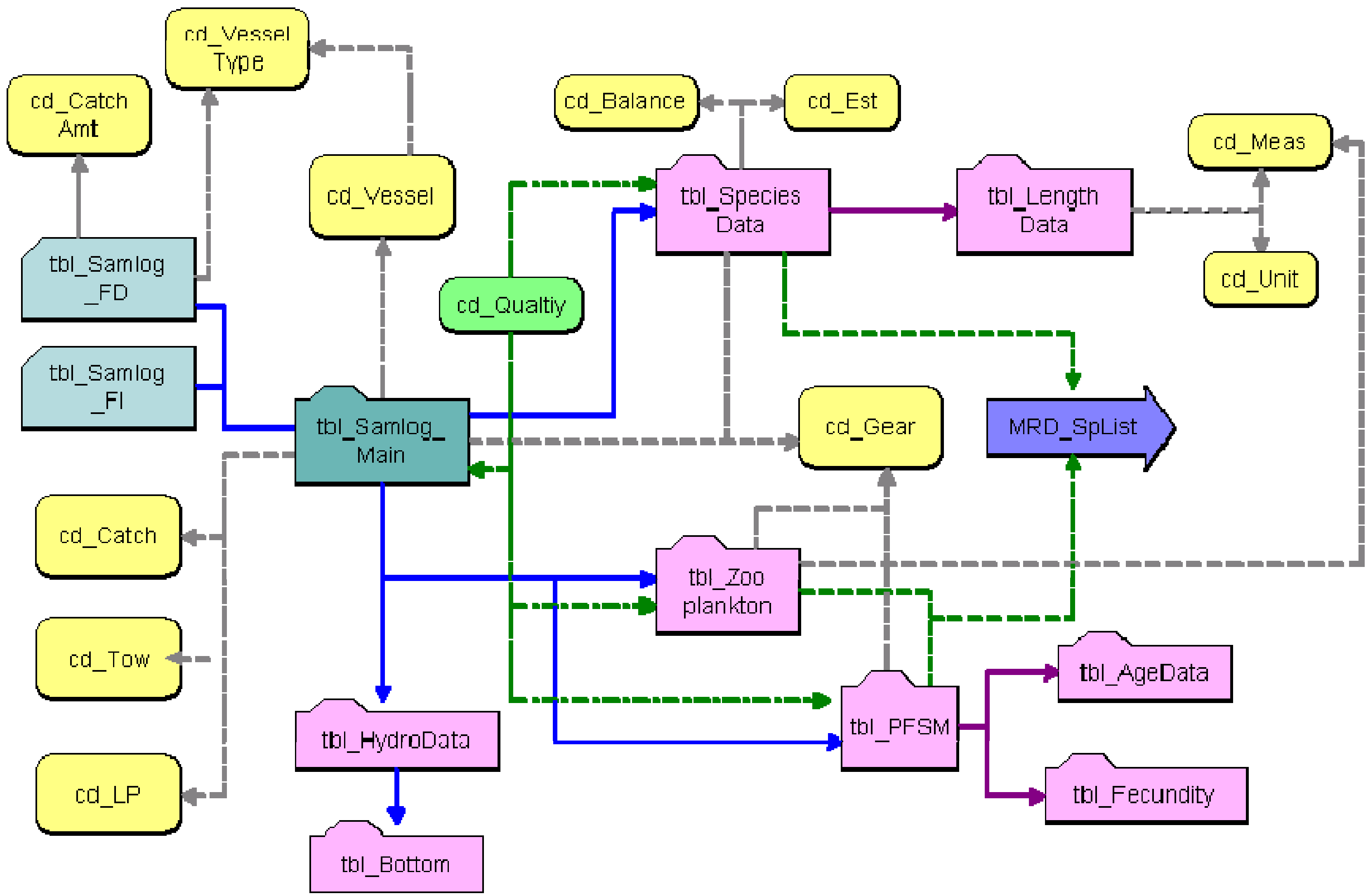
B.5. Life-History Surveys: tbl_PFSM

Field	Type	Size	Description
Source	Text	1	For fishery-dependent data: Source of sample
PCG	Text	12	Related Key: Project ID, Collection Number and Gear Code Combination
PCGSS	Text	25	Primary Key: Project ID, Collection Number, Gear Code, Species Code and Specimen Number Combination
PID	Text	3	Project ID
Coll	Text	6	Collection Number
Gear_ID	Text	3	Gear Code
SP_ID	Text	4	Species Code
Specimen	Integer	2	Specimen Number
Age	Single	4	Final Age
TL	Integer	2	Total Length (mm)
FL	Integer	2	Fork Length (mm)
SL	Integer	2	Standard Length (mm)
Fish_Wt	Single	4	Whole Fish Weight (kg)
Gonad_Wt	Single	4	Gonad Weight (g)
Sex	Text	1	Sex Code
Maturity	Text	1	Maturity Code
Gutted_Wt	Single	4	Gutted Weight (kg)
Scales	Yes/No	1	Scales Taken
L_Otolith	Yes/No	1	Left Otolith Taken
R_Otolith	Yes/No	1	Right Otolith Taken
Histology	Yes/No	1	Histology Sample Taken
Fecundity	Yes/No	1	Fecundity Sample Taken
Stomach	Yes/No	1	Stomach Contents Taken
Remarks	Text	50	Remarks and Scientific Staff Intitials
Quality	Text	1	Quality Code

APPENDIX C

Database Relationships

Appendix C. Database Relationships



Appendix D

Software Development Plan

SEA-GeoFISH Database ArcIMS Site: Software Development Plan

Written by:
David dosReis

Project Team:
David dosReis
Kyle Draganov

May 21, 2004

South Carolina Department of Natural Resources Internet Mapping Sever Application

PIP 67, Deliverable 1.01

Perot Systems Government Servi

2234 South Hobson Avenue	Tel:	(843) 740-1187
Charleston, SC 29405-2413	Fax:	(843) 740-1290

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Project Scope

Staff at the Coastal Services Center (CSC) were asked by officials at the South Carolina Department of Natural Resources (SC DNR) to create an Internet-based mapping application that allows any user with an Internet connection and capable browsing software to visualize, identify, and conduct basic queries with fisheries data for the South Atlantic Bight (SAB). The fisheries data will consist of spatial data on fish assemblages, distributions, abundance, reproduction, etc. The extensive fisheries database that will be utilized for this project was developed through various cooperative state-federal projects (e.g., MARFIN, MARMAP).

It was determined that an ArcIMS site would be the ideal vehicle to "incorporate the GIS and database into a web-based framework made available to scientists, resource managers and the general public, to more effectively plan future mapping, exploration, and management in the South Atlantic Bight." The ArcIMS site is one component of a broader vision of the SCDNR to provide stakeholders with the ability to access the necessary information for sustainability of the resources. The project will not only provide maps and locations of the resource distribution, but it will also provide analysis tools to help support management of the resource.

The development of the ArcIMS site will be a collaborative effort between CSC and SCDNR. The two parties will work together in designing the user interface, establishing a list of data layers to be made available, and creating an extensible product that will serve as a platform to access fisheries data for the area of interest. In addition to the joint development of the site, each of the groups will also be responsible for specific components of the product. Staff at SCDNR will focus on the data development, while PSGS will concentrate on the development of the interface and any customization of the application.

1 MARMAP Reef Fish Survey Internet Mapping Application Software Development Plan

This document was prepared in accordance with the *PSGS Overview of the Software Development Process* document and accompanying flow diagram, which can be found on PSGS's internal Web site.

1.1 Functional Specifications

1.1.1 User Requirements

The primary intended audience for the ArcIMS site will be members of the scientific community and resource managers within the South Atlantic Bight. However, there are a number of other agencies, organizations, academic institutions, as well as the general public that will potentially have interest in this application. As with many other online mapping sites based on ArcIMS, it will be assumed that the user's experience will vary from novice to experienced GIS user. As a result, the user interface has been created to be as easy to navigate and operate as possible.

1.1.2 System Requirements

The MARMAP Reef Fish Survey Internet Mapping Application will be developed using ESRI's ArcIMS, version 4.01 software package. Aside from a standard Web browser, no additional software will be required of the user. Requirements for the backwards compatibility of this product will be based on the standard Center practice, while considering the user characterization generated from the past three years of documented user trends. The code that will be written to enact the specified functionality will rely on Java scripts that are proprietary to the ArcIMS HTML Viewer software package. Therefore, the code can only be implemented in web pages that have been developed specifically for use with this software and will not function in a stand-alone web environment.

The data and map view will be assembled by SCDNR representatives in ArcGIS and provided to CSC to be incorporated into the Center's ArcIMS template. The graphical user interface will be very similar to existing Center products, with some additional functionality (buttons). All input data will be stored in a common folder and hosted on the Center's ArcIMS server. To limit the complexity associated with on-line map interaction, multiple data frames will be used to group like data sets. In this way, the team is able to limit the total number of datasets displayed within any given map.

1.2 PSGS Software Engineering Data Flow Diagram

The MARMAP Reef Fish Survey Tool ArcIMS Data Flow Diagram (DFD) (Appendix A) provides the conceptual design of the system, illustrating the flow of the application as a user selects map functions and analysis tools. Because this product involves the use of the Center IMS template, much of the design elements and tools are standard within the product. For example, standard code already exists to execute the "Pan, Zoom", and "Identify" functions. For this reason, many of these tools are listed as a "Predefined Process or Tool". The project team felt that it would be unnecessary to elaborate further for such out-of-the-box functionality. It should be noted that the final version of the DFD (Appendix A) has been reviewed and approved by SCDNR representatives.

1.3 Technical Specifications

1.3.1 Structural Design

1.3.1.1 System Architecture

The tool will be developed as an ArcIMS site, built with a single .mxd file that contains multiple data frames. The ArcIMS site will support all the functionality identified within the Data Flow Diagram (Appendix A). The Coastal Services Center adheres to established system architecture for IMS projects, including a Web server, ArcIMS 4.01 (w/ ArcMap Server), Java Servlet Container, CSCCommon JAR Library, and Struts 1.1.

1.3.2 Data Storage Structure

Due to the fact that the ArcIMS site will use an mxd to reference the data layers, the file structure will be based on the requirements as set forth in the ArcIMS 4.01 documentation. However, this ArcIMS Web site does not include successive queries and, thus, will not store any intermediary or queried data sets on the Center server for future use.

1.3.3 Prototype Interface

The prototype interface for the MARMAP Reef Fish Survey Internet mapping application can be found in Appendix B. The prototype interface documents the Graphical User Interface (GUI) and features of the tool. The prototype interface essentially looks like the final product, but does not incorporate functionality to store or process information.

1.3.4 Map Functions

Nearly all of the required functionality for the MARMAP Reef Fish Survey ArcIMS site is already available within the Center template. Based on the interface for the “Coastal Storms Initiative: Risk and Vulnerability Assessment Tool”, the only elements that may require custom coding are the “Zoom to x/y”, “Multiple Selection/Drill Down Identify”, and “Summarize” functions. It is possible that, through a combination of the selection and identify functions, and basic statistic analysis, this process may be replicated with only a minimal level of custom coding. Both the System Architect and the Lead Programmer agreed with this assessment in terms of the level of effort. These queries require an additional, distinct icon within the interface in order to maintain their prominence and visibility to the user. However, it is likely that much of the code required to execute these queries is already available and will need to simply be linked to the newly created GUI element.

The “Zoom to x/y” function will allow the user the ability to center the map on a specific geographic coordinate location (the precision on the coordinates will be predetermined by SCDNR), by either entering the x/y coordinates into a text box or by clicking on the map. The “Multiple Selection/Drill Down Identify” tool will be used to identify multiple layers in the active data frame, and calculate user-defined statistic analyses. The output will be in tabular form with a summary listing of each selected layer. The “Summarize” function will be similar to the “Multiple Selection/Drill Down Identify” tool, but will only allow the user to calculate user-defined statistics for one layer at a time. The output will also consist of a table, with summary statistics at the top, and the accompanying record files.

The final product will be delivered as an image service. The IMS site will function within the Web browser and return an image based on the request that is submitted.

1.3.5 Data Download

The MARMAP Reef Fish Survey ArcIMS site will provide a data download function. All data sets provided within the IMS site will have a corresponding PkZip file, including the shapefile and its corresponding FGDC-compliant metadata. The download function will provide the user with more flexibility than the existing Web page.

SCDNR will determine which data layers will be made available for download based on potential sensitivity issues. The user will be able to choose among the available layers for download, based on the active layers in the current data frame. The spatial extent of the downloaded data will correspond directly with the map extent at the time of download.

1.4 Resource Estimation

1.4.1 Integrated Timeline

Due to the fact that the code for this project will only need to be modified and not developed in-house, it is envisioned that time requirements will be minimal for this project. All programming/code modification will be developed by the Lead Programmer and reviewed by a member of the Programming Staff by the middle of Quarter 1 in 2005 for delivery in Quarter 2 in 2005 . The timeline estimates are combined to form the integrated timeline contained in Appendix C.

Stage 1: Product Design – May 21, 2004

Stage 2: Initial Development – August 6, 2004

Stage 3: Review and Testing – October 1, 2004

Stage 4: Final Delivery – December 3, 2004

1.4.2 Staffing Requirements

Staffing requirements for the project will also be minimal and dependent on the stage of development.

		Required Percent of Time			
Title	**PSGS Staff**	**Stage 1: Product Design**	**Stage 2: Initial Dev.**	**Stage 3: Review**	**Stage 4: Final Delivery**
Project Leader	David dosReis	0.1	0.1	0.1	0.1
Customization/ Code Reviewer / Tester	Kyle Draganov	0.05	0.05	0.05	0

1.5 Change Control Process

The change control process has been outlined to provide a structured process for mitigating the effect of unplanned changes to product design throughout the development process. The process is designed to track and manage any change in the scope, timeline, and/or resources on the project. The current estimate of time and resources is based upon the assumption that the project will follow the design specifications described in this development plan. It is anticipated that as the project progresses, the project team and/or project partners may make decisions regarding the project that alter the design specifications required for completion. Certain times throughout the development process are designated as appropriate for change implementation. Due to the simplistic nature of the project, it is not envisioned that changes to the existing code will be required during the development process.

1.6 Code Review Process

The functional unit code will be reviewed in accordance with the ***PSGS Software Engineering Code Review Guidelines.*** This document specifies the characteristics against which the code will be measured. The code review process is detailed within Appendix D.

1.7 Quality Assurance Process

It is expected that Quality Assurance (QA) will be addressed in the four following stages:

Stage 1 – Product Design

- Develop an appropriate QA plan.

Stage 2 – Initial Development

- Modifications will be made to the existing center ArcIMS template Viewer, in order to include the necessary functionality, as requested by SCDNR. Upon completion of the modifications, the code will be designated as an alpha version of the final product and will be subject to review and testing in Stage 3.

Stage 3 – Review and Product Improvement

- Conduct alpha review and testing.
    - The initial review will consist of the Project Leader, representatives from SCDNR, and a member of the Center Programming Staff who is familiar with JavaScript code in the ArcIMS environment.
    - The alpha version will be tested for overall functionality according to the design specifications. Any changes and bugs found during the alpha review will be documented
    - Each bug identified in the alpha review must be resolved in order for alpha review QA to be completed. Any changes made to the alpha version will also be subject to review and testing before the code can be designated as a beta version of the final product.

- Conduct beta review and testing.
    - The beta product review team will also consist of the Project Leader, representatives from SCDNR, and additional members of the Center Staff. The code will be implemented and tested in the draft version of the site.
    - The beta review will be tested for bugs; no significant changes will be considered after this review unless the code is found to not be functioning properly.
- The final stage of the QA process is review of the code as a finished product.

Stage 4 – Finalization and Delivery

- All QA has occurred prior to this stage. Final QA and deliverable forms describe QA process throughout the entire development process.

1.8 Data Requirements

The data required for this ArcIMS site will be provided by the SCDNR in time for alpha development. SCDNR will provide PSGS with an ArcMap project file (MXD), and the associated data layers. The data layers and MXD will be hosted on the Center's ArcIMS server. The MXD will be referenced by the ArcIMS Viewer, and as a result SCDNR will have control over the design of the data displayed.

2 Documentation

2.1 Technical Documentation

Upon completion of the code review and testing process, technical documentation will be developed that will instruct the ArcIMS site developer on how to implement the code into the existing site. All JavaScript code produced for this project will be fully documented according to current Center standard