DISTRIBUTION OF SPECKLED HIND AND WARSAW GROUPER IN THE U.S. SOUTH ATLANTIC

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EXECUTIVE SUMMARY

The South Atlantic Fishery Management Council (SAFMC) manages speckled hind (*Epinephelus drummondhayi*) and warsaw grouper (*E. nigritus*) from federal waters at the Virginia/North Carolina border through the Atlantic side of the Florida Keys. Currently, these stocks are both formally designated as undergoing overfishing, with an unknown overfished status. Stock assessments and research studies of varying degrees of resolution and rigor have indicated a declining trend for both stocks. Harvest of these species is currently prohibited in federal waters of the South Atlantic and SAFMC is considering additional management measures intended to protect these stocks and reduce fishing mortality. This analysis uses a variety of fishery-dependent, fishery-independent, and anecdotal habitat, encounter, and landings data sources to evaluate the distribution of speckled hind and warsaw grouper, identify stocks caught in association with these species, and evaluate the impacts of existing and proposed no-take marine protected areas.

Available data indicated most encounters occurred inshore of 240 ft; however, statistical tests accounting for sampling and/or fishing effort by depth suggested the odds of encountering speckled hind and warsaw grouper were higher outside of 240 ft. Cluster analyses reflected the ontogenetic migration of these species and their vulnerability to fishing pressure at different life stages. Warsaw grouper were associated with speckled hind, misty grouper, shallow-water snappers and snowy grouper. Speckled hind were associated with warsaw grouper, red grouper, scamp, red porgy, and other grunts and porgies. Point observations of speckled hind and warsaw grouper indicated that the stocks were predominantly distributed on the shelf edge hardbottom habitats between 25-100 fathoms, with concentrations in certain locations in 30-45 fathoms. Logistic regression models for probability of detection for speckled hind and warsaw grouper found latitude, habitat type, and sampling gear to be important predictors of the probability of a positive observation. Speckled hind distributions appeared to be more shallow (e.g., 25-50 fathoms) and more northern (e.g., favoring SC and NC) relative to warsaw grouper, which

appeared to be more evenly distributed across the 25-100 fathom range with a higher probability of encounter between northeast Florida and Georgia. Warsaw grouper probability of encounter was substantially lower than that for speckled hind.

A total of 9 existing MPAs/MPA networks and 26 new MPAs were evaluated in this analysis. Existing and proposed MPAs varied in their predicted efficiency at protecting speckled hind and warsaw grouper. Efficiency was determined by a variety of methods including fishery-dependent and fishery-independent observation rates, the MPA's coverage of known and probable grouper preferred habitats, and the total weighted probability of encounter within the MPA from logistic model output. Of the existing reserves, the Edisto, Oculina ECA, North Florida, and Northern SC MPAs were estimated to overlap with estimated speckled hind and warsaw grouper relative abundances to the greatest extent. A total of 17.1% of known habitat for speckled hind and 10.9% for warsaw grouper is already contained within reserves, with substantially less known and probable habitats already protected (speckled hind: 8.3%, warsaw grouper: 8.1%). The most efficient proposed MPAs for speckled hind appeared to be various reorientations, reconfigurations, and extensions of existing shelf-edge MPAs (e.g., Edisto, Northern SC, Georgia, Snowy Wreck), along with the following newly proposed MPAs: 'Charleston Shelf MPA', the 'Daytona MPA', the 'Fernandina MPA', the 'First Devil's Hole MPA', the 'Georgetown Hole MPA', the 'Mid-SC MPA', the 'North Cape Lookout MPA' and 'North Cape Lookout 2 MPA', the 'South Cape Lookout MPA', and the 'St Simons MPA'. The maximum percent of known habitat between 25-100 fathoms covered by non-overlapping MPA alternatives for speckled hind was approximately 84%. The maximum percent of known and probable habitat between 25-100 fathoms covered by non-overlapping MPA alternatives for speckled hind was approximately 28%. The maximum summed probabilities of occurrence for speckled hind contained within non-overlapping MPA alternatives was approximately 24%. The most efficient proposed MPAs for warsaw grouper appeared to be various reorientations of the Edisto MPA, Georgia MPA, and Northern SC MPA, as well as the following newly proposed MPAs: the 'Daytona MPA', the 'St Augustine MPA' and 'St Augustine MPA Extension', and the 'St Simons MPA'. The 'Warsaw Hole 2 MPA' and the 'Georgetown MPA' protected believed spawning locations. The maximum percent of known habitat between 25-100 fathoms covered by non-overlapping MPA alternatives for warsaw grouper was approximately 74%. The maximum percent of known and probablehabitat between 25-100 fathoms covered by non-overlapping MPA alternatives for warsaw grouper was approximately 27%. The maximum summed probabilities of occurrence for warsaw grouper contained within non-overlapping MPA alternatives was approximately 24%.

The selection of MPA alternatives presented in this study will involve a tradeoff of predicted biological benefits and potential economic effects. In general, larger MPAs or MPAs closer to population centers are predicted to have the greatest economic impacts; however, these MPAs also provide the greatest proportional reduction in fishing pressure. Impacts of proposed MPAs for speckled hind and warsaw grouper upon commercial and recreational catches of associated stocks were determined by overlaying proposed MPAs on mean percent commercial and recreational catches (2009-2011) by logbook-reported spatial area and deducting the percent area overlap times the percent of catch from the total catch. For example, if a commercial logbook cell contained 10% of the mean commercial catch and was 50% covered by a proposed MPA, the total commercial catch could potentially be reduced by 5%. This method presumes that catches

are uniformly-distributed within the highest spatial resolution and that headboat catch locations are a reasonable proxy for other recreational catch. Our analyses suggested that none of the MPA alternatives would reduce snapper-grouper catches by more than 3% of historical averages for any given stock and the total reduction in snapper-grouper catches would be contingent on the range of MPA alternatives selected for management. Given that all exploited stocks in the SAFMC are managed by Annual Catch Limits (ACLs), effort shifting may allow fishermen to compensate for spatial closures, and actual reductions in harvest may be less than predicted unless the core site for the stock is below the resolution of the reported data and is located within the implemented MPA.

Conclusions regarding the status, distribution, and impacts of spatial protection for speckled hind and warsaw grouper are uncertain. This uncertainty stems from the rarity of the stocks and a variety of confounding factors that further limit the data available for drawing meaningful conclusions. Records of warsaw grouper and speckled hind in commonly used fishery-dependent and fishery-independent data sources were limited. When data were available, catch location was often unavailable or very coarse in resolution. Most of the more spatially-resolved data sources suffered from geographic bias in their sampling regime, particularly with sampling concentrated off South Carolina or in and around existing reserves. Prior to the early 1990s, speckled hind and warsaw grouper were not identified to species in the commercial logbooks, and a harvest prohibition began in 1994. As such, conclusions that might be drawn about the distribution of the stock from post-1994 data suffer from biases for under-representation due to the prohibition on retention of fish, and conclusions based exclusively on point data would be biased towards existing reserves and the shelf-edge off South Carolina.

Implementation of spatial closures for speckled hind and warsaw grouper should apply adaptive management principles when possible. Adaptive management modifies management practices and policies to be more successful when new science, socioeconomic information or lessons learned from previous management actions indicate that practices could be made more efficient. For spatial closures such as those discussed in this study, monitoring and evaluating, testing assumptions, and generating learning opportunities are important aspects of adaptive management. Research should be conducted to understand the level of protection afforded to the stocks by the reserves and to better describe stock status. As further information emerges regarding ecosystem conditions, fishing operations, community structures, or other social, ecological, or governance factors, MPAs could be modified, added, or removed to best address management needs. Dynamic MPA management would benefit most from improved resolution on hardbottom identification and increased fishery-independent sampling over a broader geographic range using appropriate gears.

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Figure 85. Three-dimensional image of shelf edge within Warsaw Hole proposed marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open)..... 135

INTRODUCTION

The South Atlantic Fishery Management Council (SAFMC) manages speckled hind (*Epinephelus drummondhayi*) and warsaw grouper (*E. nigritus*) from federal waters at the Virginia/North Carolina border through the Atlantic side of the Florida Keys. Currently, these stocks are both formally designated as undergoing overfishing, with an unknown overfished status. Stock assessments of varying degrees of resolution and rigor have indicated a declining trend for both stocks (Grimes et al. 1982, Tester et al. 1983, Staff 1991, Huntsman et al. 1992, Potts et al. 1998, Potts & Brennan 2001, Rudershausen et al. 2008, Ziskin 2008, Ziskin et al. 2011). Grimes et al. (1982) sampled reef and rock outcroppings along shelf edge and inshore live bottom habitats between NC-SC from 1972-1977 and encountered speckled hind in 58% of sets. Speckled hind were the fourth most common species on the shelf-edge behind red porgy, vermilion snapper, and blueline tilefish; warsaw grouper were the 19th most common, encountered in 8.5% of sets (Grimes et al. 1982). Tester et al. (1983) evaluated headboat catch data and concluded that speckled hind were broadly distributed along the NC-SC shelf edge, with higher catches off SC. Staff (1991), Huntsman et al. (1992), Potts et al. (1998), and Potts & Brennan (2001) were all considered in the first formal stock assessment of speckled hind and warsaw grouper (SEDAR-4 2004); these catch curve analyses concluded that static SPR for warsaw grouper increased from 0.2% to 6% between 1988 and 1990, whereas speckled hind SPR values declined from 25% (1988) to 12% (1990) to 8% (1996) to 5% (1999). Rudershausen et al. (2008) compared fishery-independent catch composition near Onslow Bay, NC, and found that speckled hind and warsaw grouper were observed in the 1970s but not in 2005-2006. Ziskin (2008) and Ziskin et al. (2011) sampled 1365 speckled hind (1977-2007) from NC to central FL and revealed trends suggesting speckled hind are overfished and undergoing overfishing—an increasing fishing mortality rate, decreasing size-at-age, and a loss of mature individuals.

Speckled hind and warsaw grouper have a complicated management history which makes any analysis of their distribution or current status from fishery-dependent data analytically challenging. Speckled hind and warsaw grouper regulations went from inclusion in the five grouper aggregate recreational bag limit in 1992 (56 FR 56016), to a commercial and recreational limit of one per vessel of each species with a commercial sale prohibition of these species in 1994 (59 FR 27242), to a complete harvest prohibition of both species in 2011 (75 FR 82280). Due to continuing concerns regarding the overfished status of these stocks, Amendment 17B to the SAFMC's Snapper-Grouper Fishery Management Plan (S-G FMP) established annual catch limits (ACLs) of zero pounds for speckled hind and warsaw grouper in January 2011. Due to concerns about bycatch of these species, Amendment 17B also prohibited harvest beyond a depth of 240 ft for snowy grouper, blueline tilefish, yellowedge grouper, misty grouper, queen snapper, and silk snapper in the U.S. South Atlantic. In May 2012, Regulatory Amendment 11 (Reg-11) to the S-G FMP removed the 240-ft closure imposed by Amendment 17B. Data indicated the closure may not significantly reduce bycatch of these species, while the socioeconomic impacts of the closure were significant in some areas. The SAFMC is currently developing Regulatory Amendment 17 (Reg-17), which proposes a variety of spatial closures to reduce bycatch mortality for these stocks. This analysis describes the landings, discards, and the species most commonly caught with speckled hind and warsaw grouper. It also assimilates all available fishery-dependent and fishery-independent data to describe the distribution of speckled

hind and warsaw grouper relative to depths and habitats. The analysis also summarizes available literature to provide guidance on what percentage of occurrence and/or habitat is "appropriate" to be closed for these stocks. Finally, several models are developed to quantify the impacts of no-take marine protected areas (MPAs) upon speckled hind and warsaw grouper populations and harvest of associated snapper-grouper stocks.

METHODS

Catch Data

Data from the Southeast Fisheries Science Center's (SEFSC) commercial logbook program, SEFSC's supplemental discard commercial logbook program, SEFSC's headboat survey (HBS), reef fish observer program (RFOP), Marine Resources Monitoring Assessment and Prediction (MARMAP) program, accumulated landings system (ALS), Florida, Georgia, South Carolina, and North Carolina trip tickets (TT), Deep-Water Remote-Operated Vehicle Survey (DW-ROV), the Southeast Fishery-Independent Survey (SEFIS), the REEF program (REEF), Oculina ROV (Oc-ROV), Manooch's Fishery Research Group (FRG), the collaborative NMFS/FWC/UMiami Reef Visual Census (RVC), Sedberry sub visual surveys (Sedberry), museum collection data and anecdotal fisher reports were evaluated to determine locations of warsaw grouper and speckled hind encounters and co-occurrence with other species (**Table 1**). Locations of catch were provided to the highest possible resolution.

Total recreational and commercial South Atlantic landings (1986-2011) for speckled hind and warsaw grouper were determined based on the SEFSC Annual Catch Limit (ACL) datasets (2011). Additional discard information was determined using the ACL datasets, SEFSC Headboat Survey expanded reported discard estimates, and SEFSC Commercial Logbook expanded reported discard estimates. Headboat discard estimates were expanded using proxy vessels to represent discards from non-reporting vessels (see Methods in SERO-LAPP-2012-01). Commercial discard estimates were expanded by establishing a discard rate per unit effort (hook-hours) from reported discard logbooks and expanding to the total effort in the Snapper-Grouper fishery (METHODS PER K. McCarthy, SEFSC, pers. comm.).

The SEFSC's commercial logbook program (accessed May 2012) consisted of self-reported landings on a trip level from commercial fishermen. This dataset provided species-specific landings (in lbs), primary gear used, primary area and depth of capture. The SEFSC's supplemental discard commercial logbook program began in 2001 and includes a random sample of 20% of commercial vessels. Commercial logbook and supplemental discard logbook data were merged into a combined dataset for the years 2001-2011. All trip records with a recorded landing or discard of warsaw grouper or speckled hind were retained. Area fished was based on reported 1° longitude by 1° latitude commercial logbook statistical areas. A single depth of fishing was reported in the commercial logbooks for each species per trip from 2005 onward, although they may be encountered at numerous depths during multiple sets. Very little depth of capture information was available prior to 2005, and no harvest information was available prior to the harvest prohibition in 1994.

In July 2006, NOAA Fisheries Service began a voluntary reef fish observer program (RFOP) to characterize fishery landings and bycatch in the southern U.S. Atlantic Ocean. This voluntary program suffers from spatial and sampling biases; however, it does provide accurate species identification and depth of capture at the gear set-level for species encountered using bottom longline, electric (bandit) reel, and hand lines. Depth fished was reported for each set.

The recreational headboat sector of the snapper-grouper fishery was evaluated using HBS logbook data (accessed 2 Feb 2011) reported by headboat operators. Headboats are large, for-hire vessels that typically accommodate 20 or more anglers on half- or full-day trips. HBS records contain trip-level information on number of anglers, trip duration, date, area fished, landings (number of fish), and releases (number of fish) of each species. Headboat encounters (landings plus releases) were summarized by species, year, month, and area fished for the years 1973-2011. Reporting of area fished has improved through time, with resolution ranging from state level to 0.17° by 0.17° grids. For cluster analysis, area fished was aggregated at the most common reporting level (1° latitude by 1° longitude). As with the commercial fishery data, area fished is self-reported and this could have introduced error into the analysis. Additionally, vessels fishing in multiple areas during a trip would be constrained by the current data form to select one area fished for the trip, which limits the spatial precision of the analysis. Depth fished was not reported.

For over thirty years, the Marine Resources Research Institute at the South Carolina Department of Natural Resources, through the MARMAP program, has conducted fisheries-independent research within the region between Cape Lookout, North Carolina, and Ft. Pierce, Florida. The overall mission of the program is to determine distribution, relative abundance, and critical habitat of economically and ecologically important fishes of the southeastern U.S., and to relate these features to environmental factors and exploitation activities. MARMAP survey work has provided a monitoring program that allowed standardized sampling of fish populations over time and development of a historical base for future comparisons of long-term trends. The gears (e.g., chevron trap, bottom longlines) and methodologies used have been consistent over the years to allow for long term analysis and comparisons. Historically, sampling effort for snapper-grouper has been concentrated off South Carolina using various trap gears. MARMAP samples accurately identify fish to species and also collect valuable information on undersized fish. MARMAP data for the years 1977-2011 were aggregated by individual gear (i.e., a single trap, or a single line), at the set level. Depth fished was reported for each set.

The accumulated landings system (ALS) is a general canvass landings data encompassing all landings statistics for the Southeast Region, including information on the quantity and value of seafood products caught by fishermen and sold to established seafood dealers or brokers, as reported to the fisheries agency in each state. The ALS data was filtered so only landings from states in the south Atlantic region remained (Florida, Georgia, South Carolina, and North Carolina), and only landings from the Atlantic side of Florida were included. The database began in 1962 but Florida was the only south Atlantic state that had records during this early period. ALS data was available in Georgia starting in 1979, South Carolina in 1980, and North Carolina in 1981. Catch location data did not begin until after 1992.

Each state of the south Atlantic region has a commercial trip ticket database. These databases provide information on catch (i.e. date, pounds and price) of fish species landed. This program began in Florida in 1986, followed by South Carolina in 1989, North Carolina in 1994, and then Georgia in 2004. In later years the states recorded general catch locations in one degree squares. Florida began providing general catch locations in 1992. Georgia recorded general catch locations for only 5% of the landings for all years of available data (2004-2009). South Carolina started reporting general catch locations in 2004, and North Carolina always recorded general locations of the catch since the beginning (1994).

Through public comment and a series of expert workshops, several recreational and commercial fishermen contributed catch location information to SAFMC staff. These data were incorporated into a Geographic Information System (GIS) map. An additional warsaw grouper site was identified from two complementary sources (Frost 2006, Maps Unique 2012).

Between 2004-2011, NMFS has conducted deep-water remote-operated vehicle (DW-ROV) surveys of the five natural bottom MPAs in the US South Atlantic between Jacksonville, FL and Cape Fear, NC. Based upon limited multibeam bathymetric maps and the local knowledge of other researchers, ROV transects are surveyed inside the MPAs and in adjacent open-to-fishing areas of similar depth and habitat type. Transects of roughly 1 km are followed and the resulting videotapes are analyzed for all detected fish and structure forming invertebrates. Distribution, abundance, habitat associations, and trends over time of dominant reef fish and species of particular interest (e.g., lionfish) are determined and reported. Observations of speckled hind and warsaw grouper were identified in a GIS map. Additional information using similar methods were collected in the Oculina Banks MPA between 2001-2005 (Oculina-ROV).

Since 2010, the SEFSC Laboratory in Beaufort, NC has conducted fishery independent video (SEFIS-V) and trap surveys (SEFIS-T). All point observations of speckled hind and warsaw grouper from these surveys were incorporated into GIS. Additional survey data from submersible dives on continental shelf edge habitats were also incorporated (http://www.sefsc.noaa.gov/labs/beaufort/ecosystems/sefis/).

Since 1990, the Reef Environmental Education Foundation (REEF) survey has collected standardized information from volunteer divers and snorkelers on marine fish populations. Using a roving diver technique, volunteers record the geographic location and approximate abundance of species sited (www.reef.org).

Between 1972-1979, scientists from NOAA's Beaufort, North Carolina, Fisheries Research Group (FRG) collected fish from offshore waters between Cape Lookout and Cape Fear, North Carolina. Numbers, size, and collection location were recorded by species at three primary sites in Onslow Bay, NC (Rudershausen et al. 2008).

In 1985 and 2002, Dr. George Sedberry participated in some research submarine dives on the South Atlantic Bight (Sedberry-Sub). Speckled hind and warsaw grouper were observed during some of these dives and the locations of the observations were recorded.

From 1979 to 2012, NOAA Fisheries Service and the University of Miami, in conjunction with various federal, state and academic partners, have conducted a reef fish visual census (RVC) in the Florida Keys and Dry Tortugas (Brandt et al. 2009). In this two-stage sampling design, trained divers conduct a stationary point count of all reef fish stocks within a given distance of the sampling site, and record species, abundance, and various size metrics.

Since 1884, various U.S. museums have maintained collections of speckled hind and warsaw grouper, including the Florida Museum of Natural History, Gainesville (www.flmnh.ufl.edu/scripts/dbs/fish_pub.asp), the North Carolina State Museum of Natural Sciences, Raleigh (www.naturalsciences.org), and Smithsonian National Museum of Natural History, Washington, DC (www.mnh.si.edu). Geographic coordinates for capture locations were either downloaded directly from online catalogs or specifically requested (W. Laney, USFWS, pers. comm.).

All available spatial data were incorporated into a Geographic Information System (GIS). Commercial landings and discards for speckled hind and warsaw grouper were plotted, as were commercial landings for several associated species. Commercial logbook data were plotted by joining reported depth of capture and statistical area of capture to statistical areas sliced by the Coastal Relief Model (www.ngdc.noaa.gov/mgg/coastal/startcrm.htm) in 5-fathom bins. Headboat logbook data were plotted in a similar fashion, by assigning landings to 1/36th of a statistical area when this resolution of reporting was available. Commercial and headboat landings were aggregated across years and presented as percentages of total landings in bins, so as to protect confidentiality. The distribution of observed catches of speckled hind and warsaw grouper were evaluated pre- and post-2000 to examine possible geographic shifts in the distribution of the stock.

Depth of Capture

All data with depth records were aggregated into 40-fathom bins and plotted as histograms. Depth of capture was compared within datasets for speckled hind, warsaw grouper, and the remaining species of the Snapper-Grouper FMP using Chi-Square and Fisher Exact tests. Available data regarding maturation status were plotted by depth to examine possible ontogenetic shifts in depth of preferred habitat. Gag grouper release mortality at depth was examined as a proxy for speckled hind and warsaw grouper.

Associations with Other Stocks

Dimension reduction and hierarchical cluster analyses were used to evaluate associations of speckled hind and warsaw grouper with other species in the catch. These analyses were performed upon fishery datasets containing ‘area-fished’ information (i.e., CLB, RFOP, HBS, and MARMAP). Each data set was formatted as a matrix, with columns representing species (*i*) and rows representing aggregation bins (*j*). Aggregation bins represented the highest resolution of data available for the dataset. Fishermen will typically make multiple sets on a trip, sometimes in geographically distant areas, targeting different species. Aggregating landings at the highest resolution reduced the probability of grouping species caught during the same time period that would likely not co-occur during any given set due to disparate geographic

distributions. For CLB, aggregation bins were *year-month-area* combinations. For the RFOP, aggregation bins were *set-level*. For HBS, aggregation bins were *year-month-area (1° latitude by 1° longitude)* combinations. For MARMAP, aggregation bins were *set-level*. Within each element of the matrix (c_{ij}) the presence or absence of a species (i) landed in a specific bin (j), was assigned a '1' when there was an encounter and assigned a '0' when there were no encounters. Whenever possible, discards were included in the aggregated catch, as they provide valuable information when determining species associations.

By restricting the analysis to bins where speckled hind or warsaw grouper were observed, we ensured that the resultant clusters would be representative of the co-occurrence of other species with these two species of concern. Because the fishing effort that generates the landings data does not represent a consistent sampling program, reported landings data might not be quantitatively comparable between collections. Additionally, due to the restrictions on harvest since 1994, for most of the data sources examined, the catch of warsaw grouper and speckled hind is incidental. Boesch (1977) suggested a binary index (e.g., 'presence-absence') may be a more appropriate measure of similarity for data collected with an inconsistent sampling framework (e.g., fishery-dependent data). A binary index applied to each fish record also reduces distortions caused by using fish weights which are influenced by super-abundant and heavier species.

Dimension reduction was conducted using PROC VARCLUS in SAS V9.2 (SAS Institute Inc., Cary, NC). PROC VARCLUS is a dimension reduction tool that clusters variables with the greatest correlation and minimized correlations with other clusters. The algorithm used by PROC VARCLUS is binary and divisive - all variables start in one cluster. A cluster is chosen and split into two clusters by performing an orthoblique rotation on the first two principal components. Each variable is assigned to the rotated component with which it has the higher squared correlation. The procedure is nonhierarchical; variables are iteratively reassigned to clusters to maximize the variance accounted for by the cluster components. Clusters are split until all variance is explained (i.e., 'proportion=1').

Hierarchical cluster analysis of species presence-absence data used average linkage between groups with a Sørenson measure of dissimilarity:

$$D_{ih} = \sum_{j=1}^{J} \frac{\left|c'_{ij} - c'_{hj}\right|}{\left|c'_{ij} - c'_{hj}\right|} \qquad (1)$$

where D_{ih} is the distance between species i and h, and j is the number of rows (bins). The Sørenson (e.g. 'Dice', 'Bray-Curtis', 'Czekanowski') measure is an index in which joint absences are excluded from consideration, and matches are double weighted. The Sørenson measure has been found to be robust in ecological studies (Beals 1973, Field et al. 1982, Faith et al. 1987), and is commonly used in studies of fish assemblages (e.g., Mueter & Norcross 2000, Gomes et al. 2001, Williams and Ralston 2002, Shertzer & Williams 2008, Shertzer et al. 2009).

The average linkage clustering function specified the distance between two clusters as the average distance between objects from the first cluster and objects from the second cluster. Averaging was performed over all pairs (x, y) of objects, where x is an object from the first

cluster and y is an object from the second cluster. The average linkage function was expressed as follows:

$$D(X,Y) = \frac{1}{N_X * N_Y} \sum_{i=1}^{N_X} \sum_{j=1}^{N_Y} d(x_i, y_i); \quad x_i \in X, y_i \in Y \tag{2}$$

where $d(x, y)$ was the distance between objects $x \in X$ and $y \in Y$; X and Y are two sets of objects (clusters), and N_X and N_Y are the numbers of objects in clusters X and Y, respectively. Average-link clustering is less sensitive to outliers than complete-link clustering, and less likely to form long chains than single-link clustering. This method is also known as the 'unweighted pair-group method using arithmetic averages' (UPGMA), and is widely used in ecology (see Boesch 1977, McGarigal et al. 2000). This method is a space-conserving strategy that introduces little distortion to the relationships expressed in the similarity matrix (Boesch 1977).

Dendrograms were generated for each cluster, based upon the agglomeration schedule. Dendrograms are read from left to right, with vertical lines indicating joined clusters. The position of the line on the scale indicates the distance at which clusters are joined. In SPSS, observed distances are rescaled to fall into the range of 1 to 25; the ratio of the rescaled distances within the dendrogram is the same as the ratio of the original distances. In SAS, Proc TREE was used to plot the dimension reductions with the proportion of variability explained as the height variable. Species joined closer to the left of the dendrogram would be considered more associated.

Habitat Suitability Analysis

A simple qualitative habitat suitability analysis was conducted as follows. Offshore habitats in the South Atlantic from NC to the FL Keys were gridded following the SEAMAP 1199 grid (FWC 2001). Each grid cell was one-minute latitude by one-minute longitude. The grid extended from the shoreline to approximately five nautical miles beyond the 200 m depth contour (roughly the continental shelf break). Each grid cell within the one-minute grid was coded to a bottom type of Hard Bottom (HB), Possible Hard Bottom (PH), or Not Hard Bottom (NH), based on the SEAMAP Bottom Mapping point, line, and polygon data that intersected the grid cell. If a cell had any HB data in it, it was coded to HB regardless of any NH data in the cell. If a cell had NH and no other type of data, it was coded to NH. If a cell was not sampled, it was coded as Unknown (UN). A variety of supplemental bathymetric layers were assimilated from NOAA, SEFIS, USGS, US Navy, and NCCOS (A. David, NOAA, pers. comm., G. Sedberry, NOAA, pers. comm.; NCCOS data available from: http://ccma.nos.noaa.gov/ecosystems/sanctuaries/south_atlantic/data/). Data were merged into a layer, clipped by the SEAMAP grid, and evaluated using surface statistics for maximum percent slope. The average maximum percent slope across SEAMAP cells categorized as HB was 1.45. SEAMAP cells categorized as UN were recategorized as PH if their max slope from the supplemental bathymetric sources was greater than 1.45. An extensive listing of shelf-edge wrecks and artificial reef was also assimilated from fishing, shipwreck, and state agency websites. Some artificial habitats are known to be important aggregation sites for speckled hind

and warsaw grouper; wreck locations were examined visually during reserve planning but not quantitatively incorporated into the analyses.

Using the Coastal Relief Model, the habitat categorization grids were clipped by 5-fathom bins, creating depth-grids. Information was projected as UTM NAD83 Zone 17N and areas (km^2) were assigned to clipped depth-grids using Hawth's Tools (Beyer, 2004). Point data were plotted at the set level for observations of speckled hind, warsaw grouper, and all sets. These data were counted within depth-grids. Analyses focused on the 30,275 depth-grids within the 25-100 fathom depth range; this encompassed the majority of observations of mature fish and was the primary area of concern with regards to barometric trauma and associated high release mortality.

Habitat suitability for speckled hind was qualitatively assigned to each SEAMAP depth-grid as follows: 'Known' – A speckled hind was observed by a data source other than HBS; 'No' – Habitat type was 'NH' if no speckled hind were observed and more than 5 samples were taken in a depth-grid; 'Probable' – A HBS observation fell within the depth-grid or the habitat type was 'HB' or 'PH'; 'Unknown' – Fewer than 5 negative samples and no identified habitat within the depth-grid. Plots were prepared for the offshore areas of NC, SC, GA, Northeast FL (NEFL), Southeast FL (SEFL), and the Florida Keys. The percentage of area falling into the various habitat suitability categories was computed, and the proportion of these categories already contained within currently established and proposed marine protected areas was determined. A similar process was followed for warsaw grouper.

Logistic regression analysis was used to develop a quantitative habitat suitability model for speckled hind. The logistic regression modeled the probability of detecting a speckled hind within a given depth-grid as a function of input variables in **Table 2** and their interaction terms. As speckled hind and warsaw grouper are known to exclusively inhabit hardbottom habitats (including wrecks), unknown habitat types were reassigned prior to input into the logistic model as follows: if a speckled hind or warsaw grouper were detected by a data source other than headboat, the habitat was reassigned as 'HB'; if they were only detected by headboat, the habitat was reassigned as 'PH'. The headboat reassignment reflected the lack of spatial precision in the headboat locations provided relative to the depth-grids. Logistic regression analysis using a logit link was implemented using SAS 'Proc Logistic' (SAS Institute, Cary, NC). Logistic regression model development proceeded in a stepwise fashion, with variables added in order of importance with respect to reduction in the AIC (Akaike 1974). Maps of habitat suitability were made by explicitly solving the logistic regression equation, ignoring the effects of gear, for each depth-grid. A similar process was followed for warsaw grouper. Because sampling in certain areas, especially southern Florida, was extremely limited, depth-grids with actual observations of speckled hind and warsaw grouper were reassigned the maximum observed probability for their respective stock. Quadratic terms for depth and latitude were incorporated to prevent overprediction of probabilities on the fringes of the distributions for these terms.

Impacts of Spatial Closures

Speckled Hind and Warsaw Grouper

A variety of no-fishing zones have been established in the SAFMC's jurisdiction (**Table 3**). Additional spatial closure alternatives were developed from recommendations made by the MPA Expert Workgroup (SAFMC 2012), realignments of existing MPAs, and additional MPAs to form a more efficient reserve network (**Table 4**). To evaluate the impacts of existing (**Table 3**) and proposed (**Table 4**) spatial closures, they were overlaid on speckled hind and warsaw grouper habitat suitability maps. For the qualitative habitat suitability analysis, the total area of each habitat categorization contained within each MPA was summed for each stock. This was subsequently expressed as a percentage of the total area of that habitat categorization within the entire SAFMC jurisdiction. For the quantitative habitat suitability analysis, the probability of detection weighted by area within each depth-grid within each MPA was tallied. This was subsequently expressed as a percentage of the total area-weighted probability of detection within the entire SAFMC jurisdiction.

To provide a proxy for the relative predicted efficiency of existing and proposed MPAs, CPUE indices were developed, expressing the ratio of positive observations relative to the number of observations (POGS: Positive Observations per Gear Sample). This computation was performed on a gear- and data-source-specific basis for all gears with underlying sampling regimes in which both positive and negative occurrences were recorded (see **Table 2**). Positive observations and total samples were summed across gears to develop aggregate fishery-independent (i.e., MARMAP, SEFIS, Oculina-ROV, DW-ROV) and fishery-dependent (i.e., HBS, FRG, RFOP) indices. Summing across gears functionally treated each gear as equally-weighted within the fishery-independent (FID) and fishery-dependent (FD) POGS.

Associated Stocks

The impacts of proposed spatial closures upon other stocks were evaluated by overlaying proposed MPAs upon commercial logbook and headboat logbook plots of landings for species associated with speckled hind and warsaw grouper. Commercial data were plotted in areas 1° tall by 5 fathoms wide. Headboat data were plotted in areas 1/36° square. The percentage of average landings (2009-2011) within each logbook-area was computed. The total area of each logbook-area and the sliced area contained within each MPA were computed. The potential percent reduction in landings that could occur due to MPA implementation, assuming no effort shifting, was computed as the ratio of the logbook area within the MPA relative to the total area of each logbook-area multiplied by the percentage of mean landings within each logbook-area *i*:

$$\%Impact_i = \overline{\%Landings_i}^{2009-2011} * \frac{area_i^{protected}}{area_i^{total}}$$

This approach assumes landings are distributed uniformly within the logbook-areas and fishermen do not redistribute effort to compensate for lost catches by fishing in other areas.

Spawning Locations

In addition to plotting known speckled hind and warsaw grouper spawning locations (see **Figs. 5-6** and **15-18**), efforts were made to infer likely spawning locations based upon known aggregations for proxy species and from biogeomorphology. Known aggregations for snapper-grouper stocks were identified for many proposed reserves in SAFMC (2012). Additionally, biogeomorphological studies (Kobara & Heyman 2010, Coleman et al. 2011, Heyman & Wright 2011) have suggested that fish spawning aggregations tend to form on concave hardbottom shelf-edge features. All proposed reserves were plotted relative to three-dimensional bathymetry from the Coastal Relief Model, SEAMAP habitat categorizations, and point observations of speckled hind and warsaw grouper to qualitatively assess likelihood of aggregation sites.

RESULTS

Catch Data

Commercial discard information was only available from 2002 on. Evaluation of temporal trends relative to management actions for speckled hind (**Fig. 1**) and warsaw grouper (**Fig. 2**) suggests a declining trend in landings through time. Discard levels for speckled hind appear to fluctuate through time but may indicate a fall-off since 2008 (**Fig. 1**). Discard levels for warsaw grouper appear to be very low for the last decade (**Fig. 2**).

Landings by data source are summarized in **Table 5**. Commercial logbooks (2005-2011) reported 13,515 lbs of landed and 437 discarded speckled hind and 696 lbs landed and 15 discarded warsaw grouper with area and depth. Most encounters with speckled hind were reported off Charleston, SC, Wilmington, NC and Cape Hatteras, NC (**Fig. 3**); most encounters with warsaw grouper were reported off St. Augustine, FL and South Carolina (**Fig. 4**).

Headboat logbooks (1973-2011) reported a total of 26,293 speckled hind encountered (i.e., landed or discarded) to 10 minute resolution, along with 4,178 warsaw grouper. Most encounters with speckled hind were reported off Charleston, SC (**Fig. 5**); most encounters with warsaw grouper were reported off Charleston, SC, St. Augustine, FL, and Cape Canaveral, FL (**Fig. 6**).

In all point-catch datasets except MARMAP, the primary gears catching warsaw grouper and speckled hind were vertical line and bandit gears, followed by longlines. Traps were the primary gear catching warsaw grouper and speckled hind during MARMAP sampling. A marked change in spatial distribution through time was not apparent (**Figs. 5-6**).

RFOP records (2006-2011) reported 339 caught speckled hind and 15 warsaw grouper. Most speckled hind encounters ranged from NC to mid-FL (**Fig. 5**); warsaw grouper ranged from SC to GA (**Fig. 6**).

MARMAP (1977-2011) reported catches of speckled hind in 189 sets and warsaw grouper in 11 sets. Most speckled hind and warsaw grouper encounters were centered off SC (**Figs. 5-6**).

Anecdotal reports from commercial fishermen from the Southeast Region indicate a historic area of warsaw grouper abundance in the Florida Keys known as the 'Warsaw Hole', consisting of numerous rock formations that rise up to about 250 feet from the bottom of about 320 feet (**Fig. 5**). A variety of ledges, holes, and rock formations in 100-260 feet of water off the Northeast Florida shelf were also identified as historically hosting at least some warsaw grouper and/or speckled hind (**Figs. 5-6**). These observations appear to indicate that speckled hind and warsaw grouper distributions overlap, but speckled hind range further inshore. Additional catch locations were reported for several wrecks along the South Atlantic Bight, near Western Dry Rocks in the Florida Keys, and near Devil's Hole and Georgetown Hole off SC (**Figs. 5-6**).

Speckled hind were observed on 9 of 107 deepwater MPA ROV (2005-2011) surveys (8%); of these, 5 (56%) were inside MPAs (**Fig. 5**). Warsaw grouper were observed on only 2 of 107 surveys (2%); both of these observations were outside of MPAs (**Fig. 6**). No clear trends in habitat selection could be determined from this limited suite of observations.

ALS (1962-2010) contained 2,145 records for speckled hind and 2,309 records for warsaw grouper. No specific catch location data were available prior to 1992; instead, catch location was listed merely as 'Southeast U.S.'. Since 1992, the majority of speckled hind and warsaw grouper catch reported to ALS originate from the Florida Keys (**Table 6**).

Florida Trip Tickets (1986-1992) reported 205 records for speckled hind and 1,731 records for warsaw grouper, with only general catch locations reported prior to 1992. After 1992, the majority of speckled hind catches originated from offshore Jacksonville, FL; most warsaw grouper catches originated from offshore Cape Canaveral and Jacksonville (**Table 6**). South Carolina Trip Tickets (1989-2009) did not report location of catch for most speckled hind and all warsaw grouper. When location information was available, it was not possible to determine the depth of the catch due to the coarse spatial resolution of the reported location. For speckled hind, there were 213 records from 1989-1992, and 137 records from 1993-2008. The 2004 to 2008 records had location grids off of Myrtle Beach and Charleston. It is not possible to determine the depth where these fish were caught because these two location codes include South Carolina's shoreline. For warsaw grouper, there were 48 records from 1989-1992, and 47 records from 1993-1996. There were no warsaw grouper records after 1996. Georgia Trip Tickets (2004-2009) reported only one speckled hind (2004), with no location data. No warsaw grouper catches were reported. North Carolina Trip Tickets (1994-2010) reported landing locations by state or federal waters, north or south of Cape Hatteras. Of the 38 records of speckled hind available (1994-1998), two were from federal waters north of Cape Hatteras, five were in federal waters south of Cape Hatteras, and 31 were in federal waters (>3 miles from shore, water zone 25) with no detail on whether the fish were caught north or south of Cape Hatteras. Of the five records of warsaw grouper (1994, 2001, 2010), one record was in state waters (within 3 miles from shore), another record was in federal waters south of Cape Hatteras, and the final three records were reported from federal waters (>3 miles from shore, water zone 25) with no detail on whether the fish were caught north or south of Cape Hatteras.

Depth of Capture

All data sources with depth records (i.e., Commercial Logbook, Discard Logbook, Reef Fish Observer Program, and MARMAP) were significantly biased towards fishing inshore of the 240 ft depth contour that was closed by Amendment 17B (**Fig. 7**). Coupled with the harvest prohibition and the rarity of speckled hind and warsaw grouper, this implies most speckled hind and warsaw grouper encounters would occur inshore of 240 ft, due to the substantially higher fishing pressure in this region. Although most encounters occurred inshore of 240 ft, Chi-square and Fisher Exact tests suggested the odds of encountering speckled hind and warsaw grouper were higher outside of 240 ft (SH: all $p<0.05$; WG: MARMAP $p<0.05$, all others insufficient samples). Gag release mortality studies (SEDAR-7 2007) suggested release mortality rates would be above 50% beyond 25 fathoms depth (**Fig. 8**).

Associations with Other Stocks

Speckled hind and warsaw grouper rarely co-occurred with snowy grouper, blueline tilefish, yellowedge grouper, misty grouper, queen snapper, or silk snapper (**Table 7**). Hierarchal cluster analyses of commercial logbook data indicated relatively low levels of association between warsaw grouper, speckled hind and other deep-water species (**Fig. 9**). Warsaw grouper was most closely associated with shallow-water groupers and speckled hind was most closely associated with vermilion snapper, red porgy, and scamp. Dimension reduction analyses of commercial logbook data showed warsaw grouper was closely associated with misty grouper and lightly associated with snowy grouper, but not other deep-water species. Speckled hind was closely associated with red grouper, scamp, and red porgy, but not other deep water species (**Fig. 10**). Hierarchal cluster analyses of headboat data indicated warsaw grouper most closely associated with shallow-water snappers and speckled hind were most closely associated with porgies and grunts (**Fig. 11**). Dimension reduction analyses of headboat data showed warsaw grouper and speckled hind were closely associated with each other. These species were also associated with grunts and porgies. Blueline tilefish was most closely associated with snowy grouper and yellowedge grouper (**Fig. 12**). Dimension reduction analyses of binary-transformed set-level RFOP and MARMAP data showed warsaw grouper and speckled hind were closely associated with each other (**Fig. 13-14**) and had low associations with other species.

Habitat Suitability Analysis

Plots of point observations of speckled hind and warsaw grouper indicated that the stocks were predominantly distributed on the shelf edge between 25-100 fathoms, with concentrations in certain locations in 30-45 fathoms (**Figs. 15-19**). Concentrations of observations visually corresponded to areas with hardbottom (**Figs. 20-24**). This trend was most obvious in areas with high-resolution habitat mapping (**Figs. 25-28**). Observations were heavily concentrated over hardbottom habitat features within and adjacent to the existing Northern South Carolina MPA (**Fig. 25**), Edisto MPA (**Fig. 26**), North Florida MPA (**Fig. 27**), and Oculina Experimental Closed Area (**Fig. 28**). Qualitative habitat suitability analysis identified known and probable speckled hind habitats following a consistent hardbottom ridge that moved between depth contours between 25-100 fathoms from NC to southeast Florida (**Figs. 29-31**). Warsaw grouper

were more rarely encountered, but their range also appeared to encompass more of the southern end of the SAFMC's jurisdiction (**Figs. 32-36**).

Logistic regression models for probability of detection for speckled hind and warsaw grouper both found linear and quadratic functions of latitude, habitat type, and sampling gear to be important predictors of the probability of a positive observation (**Table 8**). The inclusion of a quadratic function of depth also improved model fits for speckled hind (**Table 8A**). The speckled hind model explained a maximum-adjusted 45.46% and the warsaw grouper model explained a maximum-adjusted 20.47% of the variability in probability of detection, respectively. Quantitative habitat suitability analysis using logistic model fits to depth-grids indicated that speckled hind and warsaw grouper are rare south of Cape Canaveral, FL and north of Cape Hatteras, NC. Speckled hind distributions (**Figs. 37-40**) appeared to be more shallow (e.g., 25-50 fathoms) and more northern (e.g., favoring SC and NC) relative to warsaw grouper, which appeared to be more evenly distributed across the 25-100 fathom range with a higher probability of encounter between northeast Florida and Georgia (**Figs. 41-45**).

Impacts of Spatial Closures

Speckled Hind and Warsaw Grouper

Observation rates of speckled hind and warsaw grouper varied in existing and proposed MPAs (**Figs. 46-58**), as evidenced by the substantial differences in FD- and FID-POGS (**Table 9A**). The rarity of warsaw grouper was reflected in the substantially reduced scores across categories relative to speckled hind (**Table 9B**).

Of the existing reserves, the Edisto, Oculina ECA, North Florida, and Northern SC MPAs appeared to cover the highest percentage of the speckled hind and warsaw grouper populations (**Table 9**). A total of 17.1% of known habitat for speckled hind and 10.9% for warsaw grouper was already contained within reserves, with substantially less known and probable habitats already protected (speckled hind: 8.3%, warsaw grouper: 8.1%; **Table 9**). Fishery-independent POGS indicated the Oculina, Snowy Wreck, Edisto, Northern SC, and North Florida MPAs were the reserves which are predicted to cover the greatest amount of stock abundance per area (**Table 9**). Fishery-dependent POGS and quantitative habitat suitability models suggested the Northern SC, Snowy Grouper Wreck, and the Edisto MPA contained relatively high concentrations of speckled hind (**Table 9**).

Reserves predicted to cover the greatest amount of speckled hind abundance appeared to be the various reorientations, reconfigurations, and extensions of existing shelf-edge MPAs (e.g., Edisto, Northern SC, Georgia, Snowy Wreck), along with the following proposed MPAs: the 'Charleston Shelf MPA', the 'Daytona MPA', the 'Fernandina MPA', the 'First Devil's Hole MPA', the 'Georgetown Hole MPA', the 'Mid-SC MPA', the 'North Cape Lookout MPA' and 'North Cape Lookout 2 MPA', the 'South Cape Lookout MPA', and the 'St Simons MPA'(**Table 9A**). The 'Northern SC Reorient' MPA protected a few identified spawning locations. The 'Charleston Shelf' MPA was one of the smallest proposed MPAs, but had a relatively high fishery-independent POGS for speckled hind. The largest of the proposed reserves was the 'Daytona' MPA, which contained the highest percentage of known and probable speckled hind and warsaw grouper habitat, and had the highest probability for

containing warsaw grouper. The 'Edisto Reconfig 3 MPA' contained the highest number of observed points, the highest percentage of known habitat, and the highest score and probability of observing a speckled hind. The 'South Cape Lookout NC MPA' contained the highest fishery-independent POGS. The 'North Cape Lookout NC MPA' contained the highest fishery-dependent POGS. The 'Daytona MPA' contained the highest percentage of known and probable habitats for speckled hind. The maximum percent of known habitat between 25-100 fathoms covered by non-overlapping MPA alternatives for speckled hind was approximately 84%. The maximum percent of known and probable habitats between 25-100 fathoms covered by non-overlapping MPA alternatives for speckled hind was approximately 28%. The maximum summed probabilities of occurrence for speckled hind contained within non-overlapping MPA alternatives was approximately 24%.

Existing reserves predicted to cover the greatest amount of warsaw grouper abundance appeared to be the various reorientations of the Edisto MPA, Georgia MPA, and Northern SC MPA. Proposed reserves covering the greatest amount of warsaw grouper abundance included the 'Daytona MPA', the 'St Augustine MPA' and 'St Augustine MPA Extension', and the 'St Simons MPA' (**Table 9B**). The 'Warsaw Hole 2 MPA' and the 'Georgetown MPA' protected believed spawning locations. The 'St Augustine Extension' had the highest fishery-independent POGS. The 'St Augustine MPA' had the highest fishery-dependent POGS. The 'Georgia MPA Reconfiguration' had the highest percentage of known habitat. The 'Daytona MPA' contained the most point observations, had the highest percentage of known and probable habitats, and the highest scores and probabilities of encounter for warsaw grouper. The maximum percent of known habitat between 25-100 fathoms covered by non-overlapping MPA alternatives for warsaw grouper was approximately 74%. The maximum percent of known and probable habitats covered by non-overlapping MPA alternatives for warsaw grouper was approximately 27%. The maximum summed probabilities of occurrence for warsaw grouper contained within non-overlapping MPA alternatives was approximately 24%.

Associated Stocks

The impacts of proposed MPAs were evaluated for species associated with speckled hind and warsaw grouper in the catch data, including blueline tilefish (**Fig. 59**), gag (**Fig. 60**), red grouper (**Fig. 61**), red porgy (**Fig. 62**), scamp (**Fig. 63**), snowy grouper (**Fig. 64**), silk snapper (**Fig. 65**), vermilion snapper (**Fig. 66**), and yellowedge grouper (**Fig. 67**). Assuming landings were uniformly distributed within the highest resolution reported for catch and that no effort shifting took place to compensate for lost catch, the maximal predicted impacts from the establishment of individual no-take MPAs were relatively small (**Table 10**). The proposed 'Daytona MPA', 'Georgetown Hole MPA', and 'Devil's Hole 2 MPA' had the highest relative impacts, but no individual proposed MPA reduced landings by more than 3% from the historical (2009-2011) average for any given exploited stock when considered across the entire SAFMC jurisdiction. If the primary landings location were located within the MPA, the impact could be greater than predicted. If the fishermen redistribute their effort to land stocks in different areas, the impact could be less than predicted. Maximum landings reductions if all non-overlapping reserves were selected averaged 4.2% for commercial stocks (range 2.5%-6.8%) and 2.7% for recreational stocks (range 0.7%-8.0%). If all non-overlapping proposed reserves were selected, the maximum predicted reduction in commercial and recreational landings would be 6.8% and 8.0% for commercial and recreational scamp, respectively.

Spawning Locations

Table 11 summarizes what is known and might be inferred from anecdotal evidence and biogeomorphological characteristics with regards to spawning locations for speckled hind and warsaw grouper. Anecdotal evidence and fishery-independent observations suggested fisheries spawning aggregations were found within the existing Edisto MPA and Northern SC MPA and their proposed reconfigurations, as well as the proposed Georgetown, Devil's Hole, St. Lucie Extension, Western Dry Rocks, and Warsaw Hole MPAs. The St. Lucie Extension proposed MPA contains 'Push Button Hill' which contains an important reef fish spawning ground for multiple species (SAFMC 2012, p. 17).

Additionally, the proposed 'Western Dry Rocks' MPA contains a well-known and greatly exploited mutton snapper spawning aggregation, a permit spawning aggregation, and aggregations of gag, scamp, and black grouper, as well as gray and red snapper (SAFMC 2012). The proposed 'Warsaw Hole' MPA is believed to be a spawning aggregation site for warsaw grouper and possibly greater amberjack and red snapper (SAFMC 2012).

Hardbottom shelf-edge features were obvious at many existing and all proposed sites (**Figs. 70-85**). Concave hardbottom slope features were visually apparent at the existing Snowy Wreck MPA, the proposed Cape Lookout NC, Northern SC Reconfiguration, the various Georgetown Hole/Devil's Hole configurations, the St. Lucie Extension, the Western Dry Rocks, and the Warsaw Hole MPAs. Of these, the most obvious feature was a pronounced hump within the St. Lucie Hump Extension that corresponds to 'Push Button Hill' (described above).

DISCUSSION

Conclusions regarding the status, distribution, and impacts of spatial protection for speckled hind and warsaw grouper are uncertain. This uncertainty stems from the rarity of the stocks and a variety of confounding factors that further limit the data available for drawing meaningful conclusions. Records of warsaw grouper and speckled hind in commonly used fishery-dependent and fishery-independent data sources were limited. When data were available, catch location was often unavailable or very coarse in resolution. Prior to the early 1990s, speckled hind and warsaw grouper were not identified to species in the commercial logbooks, and a harvest prohibition began in 1994. As such, conclusions that might be drawn about the distribution of the stock from post-1994 data suffer from biases for under-representation due to the disincentive to retain the fish, and incentives to misidentify the fish if kept and sold. Depth was unavailable for most datasets. For data sources with depth, samples were most frequently from depths beyond 160 ft, but sampling/fishing pressure were much higher at shallower depths.

To control for all these confounding factors, we consolidated a broad variety of fishery-dependent, fishery-independent, and anecdotal data sources. All data sources appeared to tell a consistent story regarding the habitats, depths, and latitudinal distribution of speckled hind and warsaw grouper. Both stocks were heavily associated with the shelf-edge between 25-100 fathoms on hardbottom habitats. Neither species was found with any frequency in the mostly

mud-bottom habitats on the shelf-edge north of Cape Hatteras, NC. Speckled hind were most common south of Cape Hatteras, NC to northeast Florida. Warsaw grouper were most common from SC to the Florida Keys, with an apparent area of concentration off northeast Florida.

The cluster analyses displayed low association between warsaw grouper and speckled hind with blueline tilefish and snowy grouper. The low levels of association with blueline tilefish may be explained by the different habitat preferences of the species. Warsaw grouper inhabit steep cliffs, notches, and rocky ledges of the continental shelf break (Manooch and Mason 1987), and speckled hind inhabit high and low profile hard bottom (Huntsman and Dixon 1976). Blueline tilefish inhabit irregular bottoms comprised of troughs and terraces inter-mingled with sand, mud, or shell hash bottom where they live in burrows (Parker and Ross 1986; Parker and Mays 1998). Snowy grouper inhabit the upper continental slope, between 240 and 330 ft of depth, in habitats characterized by rocky ledges and swift currents (Matheson and Huntsman 1984). Although snowy grouper appear to occupy similar habitats to warsaw grouper and speckled hind, cluster analyses suggested co-occurrence of these species are rare.

The cluster analysis results could have been biased due to the overrepresentation of data from shelf edge and inshore habitats. Warsaw grouper and speckled hind undergo an ontogenetic migration; as they mature, they move into deeper waters (Heemstra and Randall 1993; Brule et al. 2000). Thus, the mature portion of the stock, which would suffer from higher release mortality due to deeper depth-at-encounter, is under-represented in the available data. The mature portion of the stock may also be under-represented relative to unfished conditions, as overfishing typically preferentially removes larger (e.g., older) individuals.

Spatial closures, such as no-take marine reserves (NTMRs), have been endorsed as fisheries management tools that, when used in conjunction with traditional management, may help ensure sustainability of intensely exploited regional fisheries resources (Bohnsack et al. 2004). Theory suggests that buildup of fish biomass, density, and average size in an NTMR due to reduced exploitation (e.g., Ault et al. 2006, 2007; Bartholomew et al. 2008) will result in density-dependent emigration of adult fish across reserve boundaries (Crowder et al. 2000). Additionally, larval production should be amplified by the larger, older population within the reserve due to its increased spawning stock biomass (Botsford et al. 2001, Lubchenco et al. 2003). The advection of these eggs and larvae by ocean currents may enhance recruitment in fishable areas (Crowder et al. 2000).

Over the past two decades, there has been much scientific discussion regarding the percent of the stock that should be protected by a no-take MPA to provide benefits such as reduced risk of overexploitation, restoration of natural community dynamics, increased spawning stock biomass, and maximization of yield through spillover of adult biomass and larval recruits. A meta-analysis of percent closure recommendations indicated a consensus that between 20-40% of the stock should be protected unless it is heavily exploited outside the MPA system (NRC 2000; **Fig. 69**). Obviously, the exact amount of area or stock that should be protected will depend on the specific objectives of the MPA, and will balance the biology and status of the stocks in need of protection with the regulations that exist outside of the MPA (FAO 2011). As such, there is no ‘one size fits all’ answer for the appropriate size, scale, or number of MPAs needed (FAO 2011).

For the specific case of speckled hind and warsaw grouper protections, a primary goal for spatial protection would be to supplement the existing prohibition of harvest with spatial closures to reduce bycatch mortality. As such, no-take MPAs would be most effective if located at sites where bycatch mortality has been highest. Those sites would be in deep water, at the intersection of relatively high stock concentrations and high fishing pressure for associated species. No-take MPAs would be most effective if scaled to the natural movements of the fish (Botsford et al. 2009, Farmer & Ault 2011), with a sufficient buffer to prevent the redistribution of fishing pressure on the edges of the reserve from offsetting the benefits of protection at the core. As the spillover of adults and juveniles across reserve boundaries increases, or reserve size decreases, reserves become less effective, with total population abundance eventually approaching that of a system with no reserves. Farmer & Ault (2011) documented home range sizes of 1.44 ± 1.04 and 2.09 ± 0.39 km^2 for black grouper (*Mycteroperca bonaci*) and red grouper (*Epinephelus morio*), respectively. Following Barrett (1995)'s suggestion that a reserve be an order of magnitude larger than the daily movements of the protected organisms, assuming speckled hind and warsaw grouper movements are comparable to black grouper and red grouper, no-take reserves for speckled hind and warsaw grouper should be at least 10-20 km^2 in size. A meta-analysis of reef fish home range sizes relative to body lengths (Botsford et al. 2009, Fig. 7) suggests that speckled hind (maximum length ~ 1100 mm) and warsaw grouper (maximum length ~ 2400 mm) may have much larger home range requirements. However, anecdotal information suggests that warsaw grouper may have extremely high site fidelity to certain reefs and wrecks (M. Barnette, pers. comm.; G. Gilmore, pers. comm.). Progressively larger reserves would be necessary to protect a larger percentage of the population, provide adequate buffers against redistributed fishing effort, and encompass key habitats (Botsford et al. 2009, Farmer & Ault 2011).

Under the naïve assumption that speckled hind and warsaw grouper are distributed uniformly throughout the 25-100 fathom depth range in the SAFMC jurisdiction, a closure of 20% of this habitat should protect 20% of the stock. However, fish stock spatial dynamics—including preferential habitat utilization, movements and migratory behaviors—play a critical role in determining how fishing pressure will impact the stock, and result in fish stocks being heterogeneously distributed throughout the oceans (Rothschild 1986, Longhurst & Pauly 1987, MacCall 1990, Mann & Lazier 1991, Bakun 1996, Humston et al. 2000). Our meta-analysis of available fishery-dependent, fishery-independent, and anecdotal data told a consistent story with regards to the hardbottom obligate habitat preferences of speckled hind and warsaw grouper. Coupling that information with available habitat mapping and depth-grid specific computations of POGS and probability of encounter, we have identified areas of higher concentration for these stocks. Assuming an MPA selection process preferentially closes habitat-areas with higher concentrations of the stocks, it is likely a safe assumption that a greater percentage of the stock will be protected than the proportion of the habitat closed. For example, a closure of 20% of the hardbottom habitats between 25-100 fathoms with the highest concentrations of speckled hind and warsaw grouper would likely protect over 20% of the actual stock. Covering 20% of the point observations for the stocks would not meet this objective, as the point sampling distributions are geographically and temporally biased, and most heavily concentrated off South Carolina (core of MARMAP and RFOP surveys) and around existing deepwater MPAs (due to allocation of special project funding for DW-ROV and Oculina-ROV surveys). Use of point observations alone to guide reserve selection could lead to overly optimistic conclusions

regarding the level of protection the stock is receiving. We have attempted to control for this bias using the qualitative and quantitative habitat suitability analyses described above.

Selection of MPAs protecting a reasonable percentage of depth-grids containing known and probable habitats for both speckled hind and warsaw grouper would be a reasonable approach towards enhancing the protection of these stocks from bycatch mortality. The most efficient closures would be those of reasonable size that are sited in areas with high POGS and a high probability of encounter for each stock. Within the effective domain of the logistic model (34° N to 26° S), the probability of detection with gear effects removed are proportional to abundances. Thus, the sum of depth-grid cell probabilities within a given MPA divided by the sum of all SAFMC depth-grid probabilities provides a reasonable estimate of the proportion of the population contained within the MPA (see 'Prob' in **Table 9**).

Less overall area would need to be closed to achieve the same level of protection if the spatial protections are preferentially selected based on their predicted efficiency. There will likely be tradeoffs between distributing the socioeconomic impacts of spatial protection among fishermen from various coastal states; however, the greatest reductions in bycatch mortality will be realized by closing where fishing pressure for associated stocks is highest, unless this causes redistribution of fishing pressure onto adjacent areas where concentrations of warsaw grouper and speckled hind are even higher.

The fishery benefits of an MPA will be most fully realized if the MPA contains spawning habitats. Unfortunately, little information exists regarding the spawning locations of speckled hind or warsaw grouper. Ziskin et al. (2011) describes the capture of 12 speckled hind in spawning condition between 24-100 fathoms (mean = 41 fathoms); most captures were between 32-33° latitude in 1979, with one in 2004. Some of these locations were in and around the proposed Georgetown Hole MPA and the existing Northern SC and Edisto MPAs, and are contained by the reorientations of these MPAs. Anecdotal information suggests Georgetown Hole (a.k.a. 'Devil's Hole') may have been an important spawning location for speckled hind (SAFMC 2012) and warsaw grouper (Frost 2006). The Oculina Experimental Closed Area once contained spawning aggregations of speckled hind and shelf-margin groups of warsaw grouper, but no mature speckled hind or warsaw grouper have been seen since 1985 despite surveys in 1995, 2001, 2005, and 2008. Anecdotal information also suggests the proposed 'St. Augustine' MPA may contain spawning locations for speckled hind (SAFMC 2012). Biogeomorphological features along with anecdotal information suggests the existing Edisto and Northern SC MPAs and their proposed reconfigurations as well as the proposed Georgetown Hole/Devil's Hole MPA configurations, St. Augustine Extension, and Western Dry Rocks, and Warsaw Hole MPAs are the most likely to contain fish spawning aggregations, including likely spawning aggregations for either speckled hind or warsaw grouper (see **Table 11**).

The selection of MPA alternatives presented in this study will involve a tradeoff of predicted biological benefits and potential economic effects. In general, larger MPAs or MPAs closer to population centers are predicted to have the greatest economic impacts; however, these MPAs also provide the greatest proportional reduction in fishing pressure. Our analyses suggested that none of the proposed MPA alternatives would reduce catches by more than 3% of historical averages for any given snapper-grouper stock. Given that all exploited stocks in the SAFMC are

managed by Annual Catch Limits (ACLs), effort shifting may allow fishermen to compensate for the spatial closure, and actual reductions in harvest may be less than predicted unless the core site for the stock is below the resolution of the reported data and is located within the implemented MPA.

Our analyses indicated that while there is some overlap, certain MPAs provide better protections for speckled hind and others provide better protections for warsaw grouper. The best performing reserves for both stocks were the existing 'Oculina ECA' and the proposed 'Daytona', 'Devil's Hole 2', 'Edisto Reconfig 3', 'Edisto S Ext', 'Fernandina', 'Georgia Reconfig', and 'St Simon' MPAs (**Table 9**). Additional high levels of protection for speckled hind would be provided by the 'N Cape Lookout NC', 'S Cape Lookout NC', and 'St Simon Extension' MPAs. High levels of protection for warsaw grouper would be provided by the 'St Lucie Ext', 'St Augustine' and 'St Augustine Ext' MPAs.

For a deep-water MPA to be effective when continuous enforcement is fiscally infeasible, it is important to have public support. MPA credibility is enhanced when the benefits of the MPA can be quantitatively demonstrated. A first step in this process is sampling the fish populations and habitats within the proposed closed areas. Sampling the fish populations establishes a baseline which may later be used for comparison; illustrating gains in mature fish biomass (see Ault et al. 2006). Sampling the habitats allows fine-tuning of the MPA configuration and helps ensure that important habitats for the stock are not located outside the MPA (see Eklund et al. 2000). A second step is evaluating the space use and movements of speckled hind and warsaw grouper in relation to MPA size and boundaries, to ensure there is an adequate buffer to protect the stocks from undesirable fishing pressure that would undermine the effectiveness of the MPA (see Babcock & MacCall 2011, Farmer & Ault 2011). Finally, a combination of follow-up monitoring and marine population dynamic simulation modeling should be used to evaluate the effectiveness of the MPA.

Enforcement is a critical ingredient towards MPA success, as even low-levels of poaching can rapidly erode MPA benefits (SERO-LAPP-2009-07-Rev). Configuring MPA boundaries so that they are easily interpreted and enforced is an important consideration. Simplifying regulatory language to make long-distance determination of illegal fishing activities reduces the need for enforcement to board vessels. Mandatory use of Vessel Monitoring Systems (VMS) would ease the burden on enforcement substantially (SAFMC 2012). Additional cost-effective enforcement may be achieved by the deployment of passive acoustic listening devices that could record the sounds of illegal fishing operations (SAFMC 2012).

Determining the stock status of speckled hind and warsaw grouper through traditional assessment methods will likely continue to be challenging due to the lack of fishery-dependent catch-per-unit-effort data and the limited spatial coverage of appropriate fishery-independent surveys. A recent study has suggested that the ratio of fish density outside to fish density inside reserves might be used as a proxy for biomass depletion (B/B_{target}) in control rules (Babcock & MacCall 2011). This would eliminate the need for a stock assessment to estimate depletion, which would be extremely useful for data-poor stocks such as speckled hind and warsaw grouper. Simulations suggest that a target density ratio of 60% of mature fish caused the spawning stock biomass to equilibrate around 40% of the unfished level (Babcock & MacCall

2011). This ratio would be relatively simple to determine with fishery-independent surveys inside and outside existing and newly-implemented no-take MPAs. The success of this target appeared to be mostly independent of the status of the population at the time of reserve establishment (Babcock & MacCall 2011). This approach is complicated by the various harvest control rules in effect on speckled hind and warsaw grouper outside the reserve, which would tend to depress the density ratio. Declines in the ratio would be a clear signal that the reserve is not operating efficiently; whereas a failure to detect increases in the ratio would not be a significant cause for concern. It would be additionally informative to examine the actual densities and length frequencies to infer population trends.

Implementation of spatial closures for speckled hind and warsaw grouper should apply adaptive management principles when possible (Stankey et al. 2005). Adaptive management modifies management practices and policies to be more successful when new science, socioeconomic information or lessons learned from previous management actions indicate that practices could be made more efficient. For spatial closures such as those discussed in this study, monitoring and evaluating, testing assumptions, and generating learning opportunities are important aspects of adaptive management. Any MPAs implemented will not exist in a vacuum, and research should be conducted to understand the level of protection afforded to the stocks by the reserves and to better describe stock status. As further information emerges regarding ecosystem conditions, fishing operations, community structures, or other social, ecological, or governance factors, MPAs could be modified, added, or removed to best address management needs. Dynamic MPA management would benefit most from improved resolution on hardbottom identification and increased fishery-independent sampling over a broader geographic range using appropriate gears. A special emphasis on building a long-term robust time series of population abundance data for both stocks to allow for an updated stock assessment is also recommended.

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Table 1. Data sources evaluated in meta-analysis.

Data Source	Years	Resolution	Discards?	Depth Info
Commercial Log	2001-2011	1° X 1° area	20% of records	2005-present
Headboat Log	1973-2011	Some 0.17° X 0.17°	2004-present	No
Reef Fish Obs.	2006-2011	Lat/Long	Yes	Yes
MARMAP	1977-2011	Lat/Long	Yes	Yes
ALS	1962-2009	State Sub-Regions	No	No
FL Trip Ticket	1986-1992	State Sub-Regions	No	No
GA & SC T. Ticket	1989-2009	State Sub-Regions	No	No
NC Trip Ticket	1994-2010	State Sub-Regions	No	No
DW ROV Survey	2004-2011	Lat/Long	Yes	Not provided
Fisher Reports	1960s-2011	Loran Lat/Long	Yes	Some
SEFIS	2010-2011	Lat/Long	Yes	Yes
REEF	1980s-2011	State Sub-Regions	Yes	No
Oculina ROV	2003-2005	Lat/Long	Yes	Yes
Manooch (FRG)	1972-1977	Lat/Long	Yes	Yes
Sedberry Sub	1985, 2002	Lat/Long	Yes	Yes
Museum Collections	1884-1991	Lat/Long	Yes	Yes

Table 2. Input variables considered in logistic regression model used to seed quantitative habitat suitability analysis.

VARIABLE	DESCRIPTION
latY	WGS Latitude, rounded to nearest tenth.
latYSq	Quadratic function of WGS Latitude
depthBeg	Beginning depth of 5-fathom depth bin
depthBegSq	Quadratic function of beginning depth
Agg_Hab	Habitat classification: ‘HB’- hardbottom, ‘PH’- possible hardbottom, ‘NH’- not hardbottom, ‘UN’- unknown
Gear	Gear classification*: MARMAP, HBS, FRG, SEFIS Trap, SEFIS Video, Oculina ROV, DW-ROV

*See text for description of data sources

Table 3. Existing no-take marine protected areas (MPAs) in SAFMC waters.

MPA Name	POINT	LATITUDE	LONGITUDE
Snowy Grouper Wreck	A	33.4167	-77.0792
Snowy Grouper Wreck	B	33.5792	-76.8550
Snowy Grouper Wreck	C	33.4250	-76.7750
Snowy Grouper Wreck	D	33.2625	-77.0000
Northern South Carolina	A	32.8917	-78.2792
Northern South Carolina	B	32.8917	-78.0792
Northern South Carolina	C	32.8083	-78.0792
Northern South Carolina	D	32.8083	-78.2792
Edisto	A	32.4000	-79.1000
Edisto	B	32.4000	-78.9000
Edisto	C	32.3083	-78.9000
Edisto	D	32.3083	-79.1000
Charleston Deep Artificial Reef	A	32.0667	-79.2000
Charleston Deep Artificial Reef	B	32.1417	-79.1250
Charleston Deep Artificial Reef	C	32.1000	-79.0833
Charleston Deep Artificial Reef	D	32.0250	-79.1550
Georgia	A	31.7167	-79.5167
Georgia	B	31.7167	-79.3500
Georgia	C	31.5667	-79.4833
Georgia	D	31.5667	-79.6500
North Florida MPA	A	30.4833	-80.2333
North Florida MPA	B	30.4833	-80.0333
North Florida MPA	C	30.3167	-80.0333
North Florida MPA	D	30.3167	-80.2333
St. Lucie Hump	A	27.1333	-80.0000
St. Lucie Hump	B	27.1333	-79.9667
St. Lucie Hump	C	27.0667	-79.9667
St. Lucie Hump	D	27.0667	-80.0000
East Hump	A	24.6083	-80.7583
East Hump	B	24.5333	-80.6000
East Hump	C	24.4583	-80.6417
East Hump	D	24.5417	-80.8000
Oculina Exp Closed Area	A	27.88333333	-80
Oculina Exp Closed Area	B	27.88333333	-79.93333333
Oculina Exp Closed Area	C	27.5	-79.93333333
Oculina Exp Closed Area	D	27.5	-80

Table 4. Proposed alternatives for no-take marine protected areas (MPAs) in SAFMC waters.

MPA	VERTEX	LAT	LONG	SOURCE
EDISTO RECONFIG 1	NW	32.39	-78.89	MPA EXPERT WG
EDISTO RECONFIG 1	NE	32.45	-78.97	MPA EXPERT WG
EDISTO RECONFIG 1	SE	32.32	-79.11	MPA EXPERT WG
EDISTO RECONFIG 1	SW	32.26	-79.03	MPA EXPERT WG
EDISTO RECONFIG 2	NW	32.45	-78.97	MPA EXPERT WG
EDISTO RECONFIG 2	NE	32.28	-78.89	MPA EXPERT WG
EDISTO RECONFIG 2	SE	32.26	-79.03	MPA EXPERT WG
EDISTO RECONFIG 2	SW	32.33	-79.11	MPA EXPERT WG
FIRST DEVILS HOLE	NW	32.6	-78.57	MPA EXPERT WG
FIRST DEVILS HOLE	NE	32.57	-78.54	MPA EXPERT WG
FIRST DEVILS HOLE	SE	32.51	-78.6	MPA EXPERT WG
FIRST DEVILS HOLE	SW	32.54	-78.63	MPA EXPERT WG
GEORGETOWN HOLE	NW	32.7	-78.48	MPA EXPERT WG
GEORGETOWN HOLE	NE	32.7	-78.64	MPA EXPERT WG
GEORGETOWN HOLE	SE	32.54	-78.64	MPA EXPERT WG
GEORGETOWN HOLE	SW	32.54	-78.48	MPA EXPERT WG
N CAPE LOOKOUT NC	NE	34.19	-76.11	MPA EXPERT WG
N CAPE LOOKOUT NC	NW	34.19	-76.23	MPA EXPERT WG
N CAPE LOOKOUT NC	SW	34.1	-76.23	MPA EXPERT WG
N CAPE LOOKOUT NC	SE	34.1	-76.11	MPA EXPERT WG
PUSH BUTTON HILL	NE	27.17	-79.94	MPA EXPERT WG
PUSH BUTTON HILL	SE	27.15	-79.94	MPA EXPERT WG
PUSH BUTTON HILL	SW	27.17	-79.94	MPA EXPERT WG
S CAPE LOOKOUT NC	NW	33.9	-76.45	MPA EXPERT WG
S CAPE LOOKOUT NC	NE	33.9	-76.59	MPA EXPERT WG
S CAPE LOOKOUT NC	SE	33.77	-76.59	MPA EXPERT WG
S CAPE LOOKOUT NC	SW	33.77	-76.45	MPA EXPERT WG
SNOWY WRECK EXTENSION	NW	33.31	-77.26	MPA EXPERT WG
SNOWY WRECK EXTENSION	NE	33.42	-77.08	MPA EXPERT WG
SNOWY WRECK EXTENSION	SE	33.26	-77	MPA EXPERT WG
ST AUGUSTINE MPA	NW	30.1	-80.22	MPA EXPERT WG
ST AUGUSTINE MPA	NE	30.1	-80.32	MPA EXPERT WG
ST AUGUSTINE MPA	SE	29.98	-80.32	MPA EXPERT WG
ST AUGUSTINE MPA	SW	29.98	-80.22	MPA EXPERT WG
ST SIMONS MPA	NW	31.22	-79.83	MPA EXPERT WG
ST SIMONS MPA	NE	31.22	-79.98	MPA EXPERT WG
ST SIMONS MPA	SE	31.07	-79.98	MPA EXPERT WG
ST SIMONS MPA	SW	31.07	-79.83	MPA EXPERT WG
WARSAW HOLE	NW	24.362	-82.334	MPA EXPERT WG
WARSAW HOLE	NE	24.362	-82.323	MPA EXPERT WG
WARSAW HOLE	SE	24.357	-82.323	MPA EXPERT WG
WARSAW HOLE	SW	24.357	-82.334	MPA EXPERT WG

MPA	VERTEX	LAT	LONG	SOURCE
WESTERN DRY ROCKS	NW	24.44166667	-81.95833333	MPA EXPERT WG
WESTERN DRY ROCKS	NE	24.44166667	-81.91666667	MPA EXPERT WG
WESTERN DRY ROCKS	SE	24.41666667	-81.91666667	MPA EXPERT WG
WESTERN DRY ROCKS	SW	24.41666667	-81.95833333	MPA EXPERT WG
NORTHERN SC REORIENT	NW	32.89166667	-78.31666667	SERO
NORTHERN SC REORIENT	NE	32.89166667	-78.21666667	SERO
NORTHERN SC REORIENT	SE	32.735	-78.21666667	SERO
NORTHERN SC REORIENT	SW	32.735	-78.31666667	SERO
MID SC MPA	NW	32.8	-78.51666667	SERO
MID SC MPA	NE	32.8	-78.38333333	SERO
MID SC MPA	SE	32.7	-78.38333333	SERO
MID SC MPA	SW	32.7	-78.51666667	SERO
EDISTO S EXT	NW	32.31666667	-79.13333333	SERO
EDISTO S EXT	NE	32.31666667	-78.98333333	SERO
EDISTO S EXT	SE	32.23333333	-79.07708333	SERO
EDISTO S EXT	SW	32.23333333	-79.22708333	SERO
FERNANDINA MPA	NW	30.83333333	-80.08333333	SERO
FERNANDINA MPA	NE	30.83333333	-80	SERO
FERNANDINA MPA	SE	30.58333333	-80.08333333	SERO
FERNANDINA MPA	SW	30.58333333	-80.16666667	SERO
DAYTONA MPA	NW	29.26666667	-80.25	SERO
DAYTONA MPA	NE	29.26666667	-80.08333333	SERO
DAYTONA MPA	SE	28.9	-80.08333333	SERO
DAYTONA MPA	SW	28.9	-80.25	SERO
WARSAW HOLE 2	NW	24.38333333	-82.35	SERO
WARSAW HOLE 2	NE	24.38333333	-82.31666667	SERO
WARSAW HOLE 2	SE	24.33333333	-82.31666667	SERO
WARSAW HOLE 2	SW	24.33333333	-82.35	SERO
ST LUCIE EXT	A	27.13333333	-80	SERO
ST LUCIE EXT	B	27.18333333	-80	SERO
ST LUCIE EXT	C	27.18333333	-79.925	SERO
ST LUCIE EXT	D	27.06666667	-79.925	SERO
ST LUCIE EXT	E	27.06666667	-79.96666667	SERO
ST LUCIE EXT	F	27.13333333	-79.96666667	SERO
ST AUGUSTINE EXT	NW	29.98	-80.22	SERO
ST AUGUSTINE EXT	NE	29.98	-80.32	SERO
ST AUGUSTINE EXT	SE	29.93333333	-80.32	SERO
ST AUGUSTINE EXT	SW	29.93333333	-80.22	SERO
ST SIMON EXT	NW	31.28333333	-79.98	SERO
ST SIMON EXT	NE	31.28333333	-79.83	SERO
ST SIMON EXT	SE	31.22	-79.83	SERO
ST SIMON EXT	SW	31.22	-79.98	SERO
GEORGIA MPA RECONFIG	NW	31.61666667	-79.71666667	SERO
GEORGIA MPA RECONFIG	NE	31.61666667	-79.6	SERO
GEORGIA MPA RECONFIG	SE	31.45	-79.71666667	SERO
GEORGIA MPA RECONFIG	SW	31.45	-79.83333333	SERO

MPA	VERTEX	LAT	LONG	SOURCE
N CAPE LOOKOUT 2	NW	34.1	-76.34166667	SERO
N CAPE LOOKOUT 2	NE	34.1	-76.23	SERO
N CAPE LOOKOUT 2	SE	34	-76.23	SERO
N CAPE LOOKOUT 2	SW	34	-76.34166667	SERO
DEVILS HOLE 2	NW	32.68333333	-78.56666667	SERO
DEVILS HOLE 2	NE	32.68333333	-78.43333333	SERO
DEVILS HOLE 2	SE	32.53333333	-78.56666667	SERO
DEVILS HOLE 2	SW	32.53333333	-78.7	SERO
CHARLESTON SHELF MPA	NW	32.51666667	-78.85	SERO
CHARLESTON SHELF MPA	NE	32.51666667	-78.78333333	SERO
CHARLESTON SHELF MPA	SE	32.46666667	-78.78333333	SERO
CHARLESTON SHELF MPA	SW	32.46666667	-78.85	SERO
EDISTO RECONFIG 3	NW	32.45	-78.98333333	SERO
EDISTO RECONFIG 3	NE	32.45	-78.83333333	SERO
EDISTO RECONFIG 3	SE	32.31666667	-78.98333333	SERO
EDISTO RECONFIG 3	SW	32.31666667	-79.13333333	SERO

Table 5. Summary of warsaw and speckled hind catches for all U.S. South Atlantic datasets. Values in parentheses are sample size.

Data	Years	Location of Majority of Catch (Samples)		Discard Info	Depth Info
		Warsaw Grouper	Speckled Hind		
Commercial Logbooks	2001-2011	St. Augustine, Offshore South Carolina (696 lbs, 15 discards)	Charleston SC, Wilmington NC, Cape Hatteras (13,515 lbs, 437 discards)	20% of Records	2005-present
Headboat Survey	1973-2011	Charleston SC, St. Augustine FL, Cape Canaveral FL (4,178 fish)	Charleston SC (29,293 fish)	2004-Present	None
RFOP	2006-2011	South Carolina and Georgia (15 fish)	South Carolina (339 fish)	Yes	Yes
MARMAP	1977-2011	South Carolina and Georgia (9 fish)	South Carolina (233 fish)	Yes	Yes
ALS	1962-2010	Florida Keys (2,309 records)	Florida Keys (2,145 records)	No	None
Georgia Trip Ticket	2004-2009	No Records	No location information (1 fish)	No	None
Florida Trip Ticket	1986-1992	Cape Canaveral (1,731 records)	Jacksonville (205 records)	No	None
South Carolina Trip Ticket	1989-2009	No location information (95 records)	No location information (350 records)	No	None
North Carolina Trip Ticket	1994-2010	Federal Waters (5 records)	Federal Waters (38 records)	No	None

Table 6. Percentage of catch by location from Florida trip ticket (FTT) and accumulated landings system (ALS) data. Catch is in pounds gutted weight.

Warsaw				Region			
% of landings	Time Period	Not Recorded	Jacksonville	Canaveral	West Palm	Miami	Keys
ALS	1992-2009	0.0	2.6	7.9	1.9	23.6	**64.1**
FTT	1986-1992	20.1	28.7	**32.1**	8.9	3.2	7.1
Speckled Hind				Region			
% of landings	Time Period	Not Recorded	Jacksonville	Canaveral	West Palm	Miami	Keys
ALS	1992-2009	0.0	3.8	11.9	4.9	7.8	**71.7**
FTT	1986-1992	**79.4**	18.2	0.0	0.5	1.9	0.0

Table 7. Top co-occurring species with warsaw grouper and speckled hind for the merged commercial logbooks (CLB) and headboat survey (HBS) datasets. Amendment 17B 'deep-water' species are in bold.

	With Speckled Hind		With Warsaw Grouper	
Rank	**Commercial**	**Headboat**	**Commercial**	**Headboat**
1	red porgy	vermilion snapper	red porgy	gray triggerfish
2	scamp	gray triggerfish	scamp	black sea bass
3	vermilion snapper	scamp	vermilion snapper	red snapper
4	greater amberjack	red porgy	greater amberjack	gag
5	red snapper	tomtate	**speckled hind**	gray snapper
6	gag	white grunt	red snapper	lane snapper
7	red grouper	knobbed porgy	gag	vermilion snapper
8	gray triggerfish	greater amberjack	gray triggerfish	tomtate
9	**warsaw grouper**	gag	red grouper	scamp
10	rock sea bass	red snapper	red hind	whitebone porgy
11	**snowy grouper**	black sea bass		greater amberjack
12	yellowtail snapper	whitebone porgy		red porgy
13	black grouper	almaco jack		red grouper
14	blue runner	bank sea bass		white grunt
15	crevalle jack	graysby		almaco jack
16	almaco jack	queen triggerfish		knobbed porgy
⋮	⋮	⋮	⋮	⋮
	blueline tilefish (#22)	***blueline tilefish (#32)***	***no blueline tilefish***	***blueline tilefish (#39)***

Table 8. Logistic regression model maximum likelihood parameter estimates for A) speckled hind and B) warsaw grouper probability of detection, with marginal variability explained (i.e. percent variability explained by inclusion of additional variable).

A) Speckled Hind

Analysis of Maximum Likelihood Estimates							
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq	Marginal Variability Explained
Intercept		1	-97.7162	6.2614	243.5513	<.0001	-
latYSq		1	-0.0877	0.00709	153.1521	<.0001	29.88%
gear	DWROV	1	0.4210	0.2695	2.4393	0.1183	10.63%
gear	FRG	1	2.4874	0.3183	61.0759	<.0001	-
gear	HBS	1	0.9792	0.1517	41.6907	<.0001	-
gear	MMAP	1	-1.5909	0.1572	102.4395	<.0001	-
gear	OCULINA	1	2.1723	0.3442	39.8333	<.0001	-
gear	REEF	1	1.3389	0.5440	6.0565	0.0139	-
gear	RFOP	1	-0.3154	0.1588	3.9439	0.0470	-
gear	SEFISt	1	-2.6889	0.5312	25.6222	<.0001	-
latY		1	5.7950	0.4221	188.4451	<.0001	3.21%
Agg_Hab	HB	1	0.8587	0.1441	35.5196	<.0001	1.47%
Agg_Hab	NH	1	0.0105	0.1637	0.0041	0.9489	-
Agg_Hab	PH	1	1.1512	0.1456	62.5291	<.0001	-
DepthBegSq		1	-0.00013	0.000027	23.7124	<.0001	0.27%

B) Warsaw Grouper

Analysis of Maximum Likelihood Estimates							
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq	Marginal Variability Explained
Intercept		1	-153.5	48.8213	9.8871	0.0017	-
latY		1	9.7189	1.1750	68.4184	<.0001	8.51%
gear	DWROV	1	1.6809	45.6030	0.0014	0.9706	5.14%
gear	FRG	1	4.2396	45.6029	0.0086	0.9259	-
gear	HBS	1	2.0493	45.6002	0.0020	0.9642	-
gear	MMAP	1	-0.7913	45.6009	0.0003	0.9862	-
gear	OCULINA	1	1.5921	45.6089	0.0012	0.9722	-
gear	REEF	1	-9.7530	364.8	0.0007	0.9787	-
gear	RFOP	1	0.7422	45.6007	0.0003	0.9870	-
gear	SEFISt	1	-0.1458	45.6030	0.0000	0.9974	-
latYSq		1	-0.1590	0.0197	65.1885	<.0001	6.03%
Agg_Hab	HB	1	0.4304	0.2842	2.2933	0.1299	0.79%
Agg_Hab	NH	1	0.8188	0.3053	7.1911	0.0073	-
Agg_Hab	PH	1	0.1356	0.2926	0.2148	0.6430	-

Table 9. Efficiency and predicted impacts of existing and proposed no-take marine protected areas (MPAs) for A) speckled hind and B) warsaw grouper relative to coverage of speckled hind and warsaw grouper habitats, positive observations per gear sample (POGS) for fishery-dependent (FD) and fishery-independent (FID) data sources, probability of observation as predicted by logistic habitat suitability models relative to area covered ('Score') and overall distribution ('Estimated % Stock Protected').

A) SPECKLED HIND				SPECKLED HIND						
					POGS		HABITAT SUITABILITY			
NAME	STATUS	AREA (km^2)	STATE	POINTS	FID	FD	Known	Known & Probable	Score	Estimated % Stock Protected
Charleston Deep	Existing	66.0	SC	0	no samp.	0.0%	0.0%	0.0%	4.8	0.3%
Edisto	Existing	185.6	SC	31	5.7%	23.1%	8.1%	1.6%	32.3	1.8%
Georgia	Existing	154.8	GA	0	0.0%	0.0%	0.0%	0.6%	13.9	0.8%
North Florida	Existing	152.3	FL	8	4.3%	0.1%	1.6%	1.2%	14.5	0.8%
Northern SC	Existing	171.7	SC	22	2.7%	30.3%	3.2%	1.1%	24.0	1.3%
Oculina ECA	Existing	279.2	FL	10	26.3%	no samp.	3.8%	3.1%	8.2	0.5%
Snowy G. Wreck	Existing	187.4	NC	2	9.1%	7.7%	0.4%	0.6%	16.7	0.9%
St. Lucie Hump	Existing	24.4	FL	0	no samp.	no samp.	0.0%	0.2%	0.2	0.0%
FKNMS SPAs & Ers	Existing	639.0	FL	0	0%	0%				
CHARLESTON SHELF MPA	*Proposed*	34.8	SC	33	10.4%	8.9%	3.6%	0.4%	8.3	0.5%
DAYTONA MPA	*Proposed*	659.0	FL	21	0.7%	2.2%	3.5%	4.4%	32.1	1.8%
DEVILS HOLE 2	*Proposed*	208.3	SC	204	1.4%	39.7%	5.5%	1.4%	28.1	1.6%
EDISTO RECONFIG 1	*Proposed*	196.3	SC	68	6.0%	23.2%	16.8%	2.0%	38.7	2.2%
EDISTO RECONFIG 2	*Proposed*	234.0	NC	57	5.6%	22.5%	14.1%	2.1%	42.0	2.4%
EDISTO RECONFIG 3	*Proposed*	208.7	SC	253	5.5%	41.0%	17.9%	2.3%	44.1	2.5%
EDISTO S EXT	*Proposed*	130.6	NC	189	3.8%	40.9%	9.8%	0.9%	22.7	1.3%
FERNANDINA MPA	*Proposed*	221.1	FL	8	0.0%	5.1%	1.1%	2.3%	28.6	1.6%
FIRST DEVILS HOLE	*Proposed*	37.5	FL	174	0.0%	43.7%	0.5%	0.4%	5.9	0.3%
GEORGETOWN HOLE	*Proposed*	266.6	GA	203	1.2%	39.5%	5.4%	1.3%	25.9	1.5%
GEORGIA MPA RECONFIG	*Proposed*	204.7	FL	14	3.1%	15.8%	4.9%	1.9%	37.2	2.1%
MID SC MPA	*Proposed*	138.7	FL	247	0.7%	55.4%	2.7%	0.7%	16.0	0.9%
N CAPE LOOKOUT 2	*Proposed*	114.8	NC	63	no samp.	41.4%	2.6%	0.7%	14.9	0.8%
N CAPE LOOKOUT NC	*Proposed*	110.9	NC	13	12.1%	75.0%	2.3%	1.0%	16.4	0.9%
NORTHERN SC REORIENT	*Proposed*	162.8	SC	112	2.6%	37.7%	6.1%	1.0%	21.0	1.2%
S CAPE LOOKOUT NC	*Proposed*	187.5	NC	21	25.7%	14.3%	1.8%	0.9%	20.1	1.1%
SNOWY WRECK EXTENSION	*Proposed*	194.6	NC	15	16.7%	15.7%	0.5%	0.7%	15.5	0.9%
ST AUGUSTINE EXT	*Proposed*	49.9	FL	0	0.0%	no samp.	0.0%	0.1%	3.1	0.2%
ST AUGUSTINE MPA	*Proposed*	128.2	FL	6	2.0%	0.0%	1.9%	0.8%	10.7	0.6%
ST LUCIE EXT	*Proposed*	71.7	FL	1	no samp.	no samp.	0.4%	0.2%	0.8	0.0%
ST SIMON EXT	*Proposed*	100.3	GA	15	7.1%	21.9%	3.1%	0.2%	9.5	0.5%
ST SIMONS MPA	*Proposed*	237.8	GA	34	6.5%	21.0%	5.4%	1.5%	30.3	1.7%
WARSAW HOLE	*Proposed*	0.6	FL	0	no samp.	no samp.				
WARSAW HOLE 2	*Proposed*	18.7	FL	0	no samp.	no samp.				
WESTERN DRY ROCKS	*Proposed*	11.7	FL		no samp.	no samp.	0.0%	0.1%		

B) WARSAW GROUPER				WARSAW GROUPER						
					POGS		HABITAT SUITABILITY			
NAME	STATUS	AREA (km^2)	STATE	POINTS	FID	FD	Known	Known & Probable	Score	Estimated % Stock Protected
Charleston Deep	Existing	66.0	SC	0	no samp.	0.0%	0.0%	0.0%	0.4	0.4%
Edisto	Existing	185.6	SC	1	0.3%	0.0%	1.2%	1.4%	1.2	1.2%
Georgia	Existing	154.8	GA	0	0.0%	0.0%	0.0%	0.6%	1.3	1.3%
North Florida	Existing	152.3	FL	11	1.8%	0.8%	4.5%	1.2%	1.7	1.7%
Northern SC	Existing	171.7	SC	1	0.0%	0.0%	2.5%	1.1%	0.8	0.8%
Oculina ECA	Existing	279.2	FL	1	2.6%	no samp.	2.6%	3.1%	0.9	0.9%
Snowy Grouper Wreck	Existing	187.4	NC	0	0.0%	0.0%	0.0%	0.5%	0.6	0.6%
St. Lucie Hump	Existing	24.4	FL	0	no samp.	no samp.	0.0%	0.2%	0.0	0.0%
FKNMS SPAs & Ers	Existing	639.0	FL	0	0%	0%				
CHARLESTON SHELF MPA	*Proposed*	34.8	SC	0	0.0%	0.0%	0.0%	0.3%	0.2	0.2%
DAYTONA MPA	*Proposed*	659.0	FL	18	0.0%	4.3%	2.3%	4.4%	4.8	5.0%
DEVILS HOLE 2	*Proposed*	208.3	SC	14	0.0%	2.3%	1.7%	1.3%	1.0	1.1%
EDISTO RECONFIG 1	*Proposed*	196.3	SC	1	0.1%	0.0%	1.2%	1.6%	1.3	1.3%
EDISTO RECONFIG 2	*Proposed*	234.0	NC	1	0.2%	0.0%	1.2%	1.8%	1.5	1.6%
EDISTO RECONFIG 3	*Proposed*	208.7	SC	12	0.1%	2.2%	2.4%	1.9%	1.3	1.4%
EDISTO S EXT	*Proposed*	130.6	NC	17	0.5%	3.5%	8.8%	0.7%	0.9	1.0%
FERNANDINA MPA	*Proposed*	221.1	FL	6	0.0%	4.3%	5.1%	2.4%	1.9	2.0%
FIRST DEVILS HOLE	*Proposed*	37.5	FL	12	0.0%	2.8%	0.7%	0.4%	0.2	0.2%
GEORGETOWN HOLE	*Proposed*	266.6	GA	14	0.0%	2.3%	1.8%	1.3%	0.9	1.0%
GEORGIA MPA RECONFIG	*Proposed*	204.7	FL	4	1.2%	2.6%	11.2%	1.9%	1.6	1.7%
MID SC MPA	*Proposed*	138.7	FL	10	0.7%	2.0%	0.1%	0.6%	0.4	0.4%
N CAPE LOOKOUT 2	*Proposed*	114.8	NC	6	no samp.	3.9%	2.4%	0.7%	0.2	0.2%
N CAPE LOOKOUT NC	*Proposed*	110.9	NC	0	0.0%	0.0%	0.0%	1.0%	0.1	0.1%
NORTHERN SC REORIENT	*Proposed*	162.8	SC	7	0.0%	2.3%	2.5%	0.8%	0.7	0.7%
S CAPE LOOKOUT NC	*Proposed*	187.5	NC	0	0.0%	0.0%	0.0%	0.9%	0.3	0.3%
SNOWY WRECK EXTENSION	*Proposed*	194.6	NC	0	0.0%	0.0%	0.0%	0.7%	0.6	0.6%
ST AUGUSTINE EXT	*Proposed*	49.9	FL	3	4.3%	no samp.	0.8%	0.1%	0.5	0.5%
ST AUGUSTINE MPA	*Proposed*	128.2	FL	6	1.0%	50.0%	9.4%	0.8%	1.2	1.2%
ST LUCIE EXT	*Proposed*	71.7	FL	6	no samp.	no samp.	6.5%	0.2%	0.2	0.2%
ST SIMON EXT	*Proposed*	100.3	GA	2	0.0%	6.3%	2.2%	0.1%	0.6	0.6%
ST SIMONS MPA	*Proposed*	237.8	GA	3	1.2%	1.0%	5.2%	1.4%	2.0	2.1%
WARSAW HOLE	*Proposed*	0.6	FL	3	no samp.	no samp.	0.8%	0.0%		
WARSAW HOLE 2	*Proposed*	18.7	FL	4	no samp.	no samp.	3.1%	0.0%		
WESTERN DRY ROCKS	*Proposed*	11.7	FL		no samp.	no samp.	0.0%	0.1%		

Table 10. Maximum percent reductions in catch of associated species possible given reserve implementation of proposed no-take marine protected areas (MPAs) relative to 2009-2011 average landings baseline from commercial and headboat logbooks, assuming uniform distribution of landings within highest resolution reported area of catch and no effort shifting. Final row sums maximum reductions if all non-overlapping MPAs were implemented.

			POTENTIAL REDUCED LANDINGS													
			Red Porgy		Vermilion		Scamp		Amberjack		Blueline		Gag		Red Grouper	
NAME	AREA (km^2)	STATE	Com	Hbt	Com	Hbt	Com	Hbt	Com	Hbt	Com	Hbt	Com	Hbt	Com	Hbt
CHARLESTON SHELF MPA	34.8	SC	0.1%	0.0%	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%
DAYTONA MPA	659.0	FL	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	2.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
DEVILS HOLE 2	208.3	SC	0.6%	0.4%	0.5%	0.4%	0.9%	2.8%	0.2%	0.3%	0.3%	0.0%	0.3%	0.8%	0.4%	0.1%
EDISTO RECONFIG 1	196.3	SC	0.3%	0.3%	0.3%	0.1%	0.6%	0.4%	0.2%	0.2%	0.1%	0.0%	0.2%	0.2%	0.1%	0.0%
EDISTO RECONFIG 2	234.0	NC	0.4%	0.3%	0.4%	0.1%	0.7%	0.4%	0.2%	0.2%	0.2%	0.0%	0.2%	0.2%	0.1%	0.0%
EDISTO RECONFIG 3	208.7	SC	0.5%	0.4%	0.6%	0.1%	0.9%	0.5%	0.3%	0.2%	0.2%	0.0%	0.3%	0.3%	0.2%	0.0%
EDISTO S EXT	130.6	NC	0.3%	0.0%	0.3%	0.0%	0.6%	0.1%	0.2%	0.0%	0.1%	0.0%	0.2%	0.0%	0.1%	0.0%
FERNANDINA MPA	221.1	FL	0.2%	0.0%	0.3%	0.1%	0.1%	0.0%	0.1%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
FIRST DEVILS HOLE	37.5	FL	0.0%	0.1%	0.0%	0.1%	0.0%	0.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
GEORGETOWN HOLE	266.6	GA	0.7%	0.4%	0.5%	0.4%	1.0%	3.2%	0.2%	0.4%	0.2%	0.0%	0.3%	0.9%	0.4%	0.1%
GEORGIA MPA RECONFIG	204.7	FL	0.2%	0.0%	0.3%	0.0%	0.3%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.2%	0.0%
MID SC MPA	138.7	FL	0.4%	0.0%	0.3%	0.0%	0.6%	0.5%	0.1%	0.1%	0.1%	0.0%	0.2%	0.1%	0.2%	0.0%
N CAPE LOOKOUT 2	114.8	NC	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%
N CAPE LOOKOUT NC	110.9	NC	0.1%	0.2%	0.1%	0.5%	0.0%	0.0%	0.0%	0.0%	0.1%	0.7%	0.0%	0.2%	0.2%	0.5%
NORTHERN SC REORIENT	162.8	SC	0.3%	0.1%	0.3%	0.1%	0.5%	0.1%	0.1%	0.2%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%
S CAPE LOOKOUT NC	187.5	NC	0.0%	0.6%	0.0%	0.4%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.3%	0.0%	0.7%
SNOWY WRECK EXTENSION	194.6	NC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ST AUGUSTINE EXT	49.9	FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ST AUGUSTINE MPA	128.2	FL	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
ST LUCIE EXT	71.7	FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ST SIMON EXT	100.3	GA	0.3%	0.0%	0.5%	0.0%	0.4%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%
ST SIMONS MPA	237.8	GA	0.5%	0.0%	0.9%	0.0%	0.9%	0.0%	0.4%	0.0%	0.4%	0.0%	0.3%	0.0%	0.3%	0.0%
WARSAW HOLE	0.6	FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WARSAW HOLE 2	18.7	FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WESTERN DRY ROCKS	11.7	FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Maximum Reduction for Non-Overlapping MPAs			**5.0%**	**2.2%**	**5.3%**	**2.1%**	**6.8%**	**8.0%**	**4.5%**	**1.7%**	**2.6%**	**0.7%**	**2.5%**	**2.8%**	**2.6%**	**1.5%**

Table 11. Comments on observed (this meta-analysis) and anecdotal (SAFMC 2012) spawning aggregations at existing and proposed (*italics*) marine protected area locations.

NAME	AREA (km^2)	STATE	FISH SPAWNING AGGREGATION SITE?			
			Speckled Hind	Warsaw Grouper	Snapper-Grouper	Biogeomorphology
Charleston Deep	66.0	SC				NOT LIKELY
Edisto	185.6	SC	OBSERVED		OBSERVED	POSSIBLE
Georgia	154.8	GA				NOT LIKELY
North Florida	152.3	FL				POSSIBLE
Northern SC	171.7	SC	OBSERVED		OBSERVED	POSSIBLE
Oculina ECA	279.2	FL				POSSIBLE
Snowy Grouper Wreck	187.4	NC				LIKELY
St. Lucie Hump	24.4	FL				POSSIBLE
FKNMS SPAs & Ers	639.0	FL			OBSERVED (Riley's Hump)	LIKELY (Riley's Hump)
CHARLESTON SHELF MPA	34.8	SC				POSSIBLE
DAYTONA MPA	659.0	FL				POSSIBLE
DEVILS HOLE 2	208.3	SC	OBSERVED	ANECDOTAL	OBSERVED	LIKELY
EDISTO RECONFIG 1	196.3	SC	OBSERVED		OBSERVED	POSSIBLE
EDISTO RECONFIG 2	234.0	NC	OBSERVED		OBSERVED	POSSIBLE
EDISTO RECONFIG 3	208.7	SC	OBSERVED		OBSERVED	POSSIBLE
EDISTO S EXT	130.6	NC				POSSIBLE
FERNANDINA MPA	221.1	FL				POSSIBLE
FIRST DEVILS HOLE	37.5	FL	OBSERVED	ANECDOTAL	OBSERVED	LIKELY
GEORGETOWN HOLE	266.6	GA	OBSERVED	ANECDOTAL	OBSERVED	LIKELY
GEORGIA MPA RECONFIG	204.7	FL				POSSIBLE
MID SC MPA	138.7	FL				LIKELY
N CAPE LOOKOUT 2	114.8	NC				POSSIBLE
N CAPE LOOKOUT NC	110.9	NC				LIKELY
NORTHERN SC REORIENT	162.8	SC	OBSERVED		OBSERVED	LIKELY
S CAPE LOOKOUT NC	187.5	NC				POSSIBLE
SNOWY WRECK EXTENSION	194.6	NC				POSSIBLE
ST AUGUSTINE EXT	49.9	FL	ANECDOTAL		ANECDOTAL	POSSIBLE
ST AUGUSTINE MPA	128.2	FL	ANECDOTAL		ANECDOTAL	POSSIBLE
ST LUCIE EXT	71.7	FL			ANECDOTAL	VERY LIKELY
ST SIMON EXT	100.3	GA				POSSIBLE
ST SIMONS MPA	237.8	GA				POSSIBLE
WARSAW HOLE	0.6	FL		ANECDOTAL	ANECDOTAL	LIKELY
WARSAW HOLE 2	18.7	FL		ANECDOTAL	ANECDOTAL	LIKELY
WESTERN DRY ROCKS	11.7	FL			ANECDOTAL	LIKELY

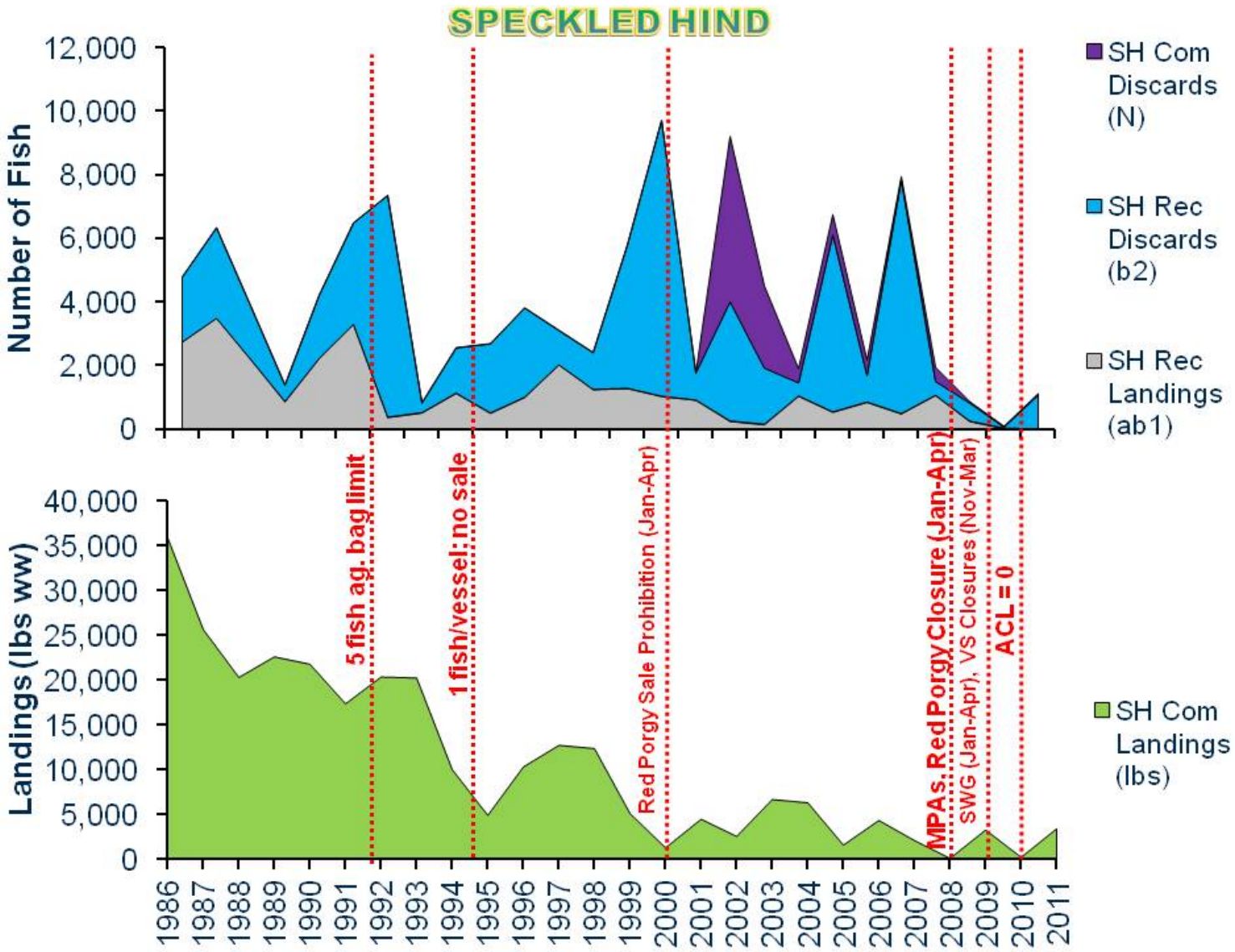

Figure 1. Speckled hind (A) recreational landings and discards in numbers (1986-2011), as well as commercial discards in numbers (2002-2011) and (B) commercial landings in pounds (1986-2011) relative to management actions.

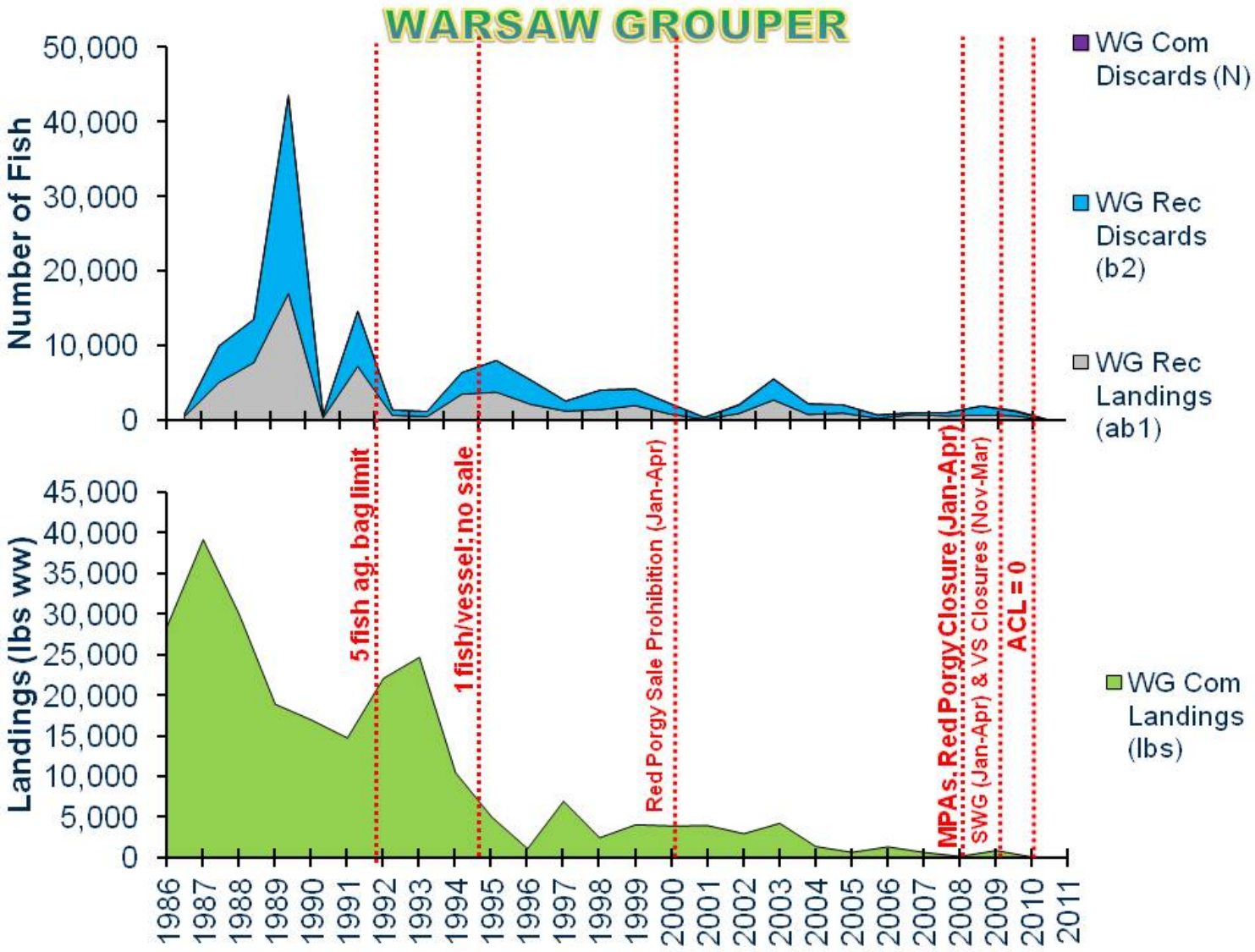

Figure 2. Warsaw grouper (A) recreational landings and discards in numbers (1986-2011), as well as commercial discards in numbers (2002-2011) and (B) commercial landings in pounds (1986-2011) relative to management actions.

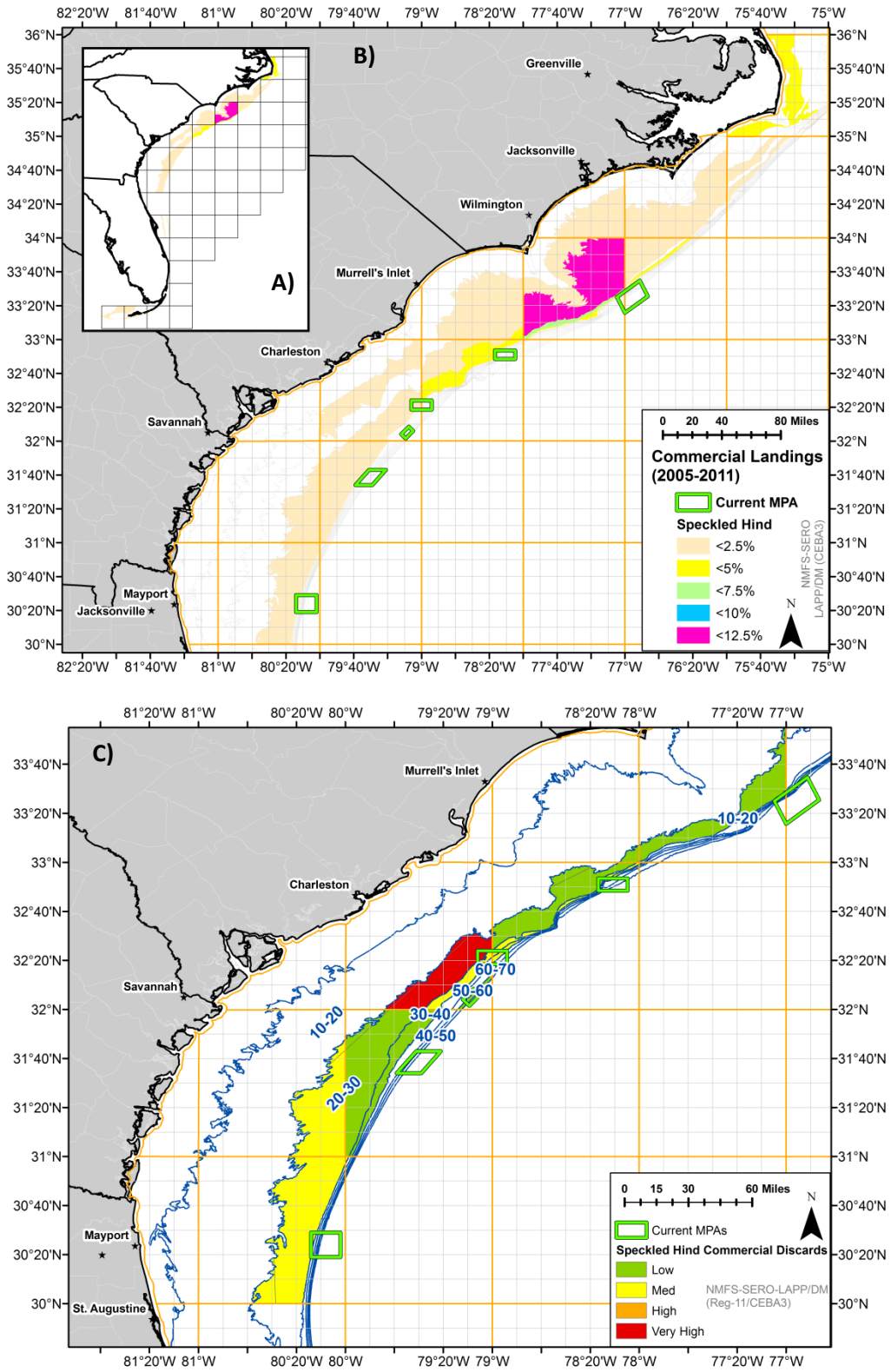

Figure 3. Commercial logbook reported distribution of speckled hind (A) landings, (B) core landings area, and (C) discards by depth and area.

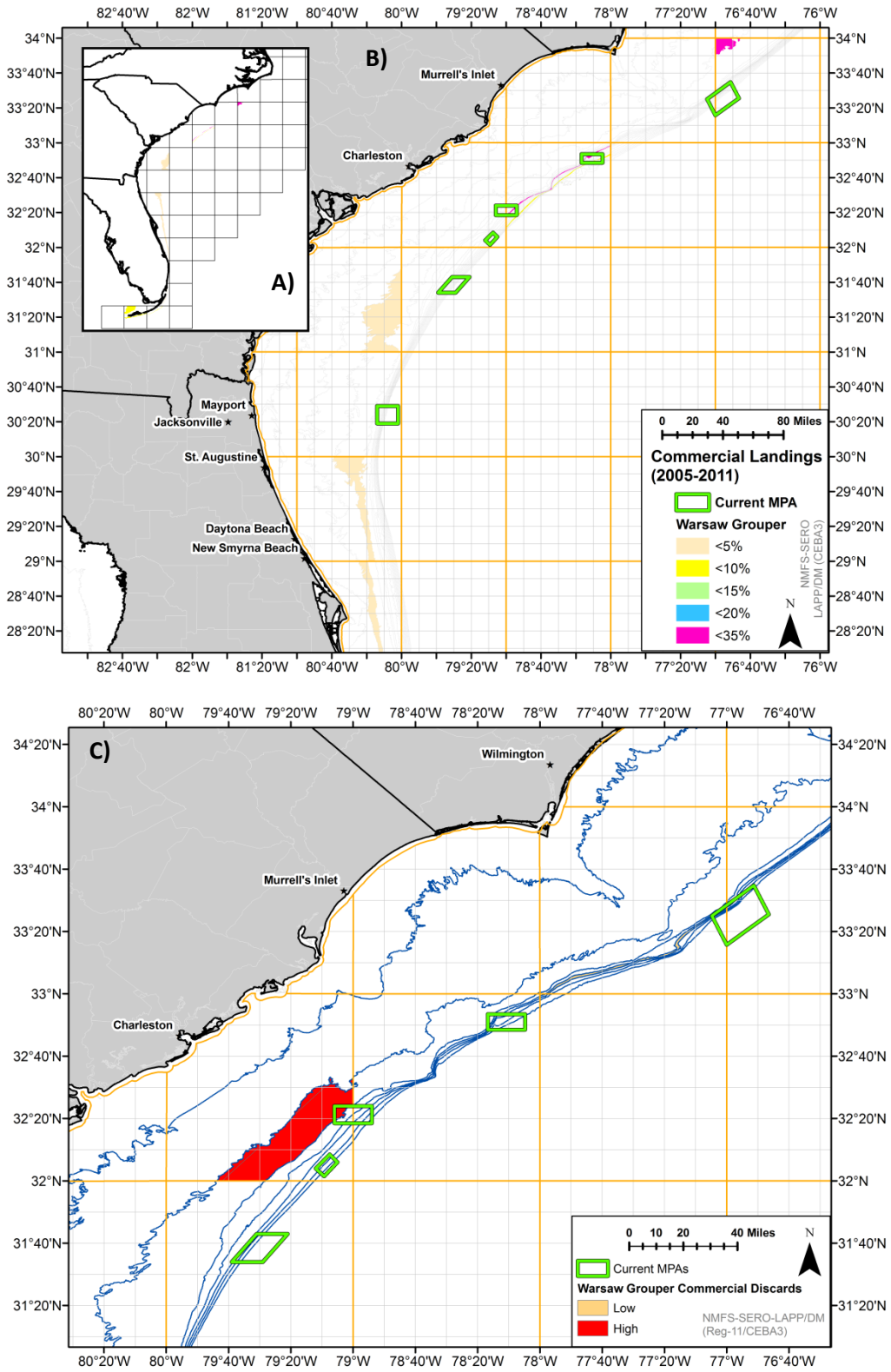

Figure 4. Commercial logbook reported distribution of warsaw grouper (A) landings, (B) core landings area, and (C) discards by depth and area.

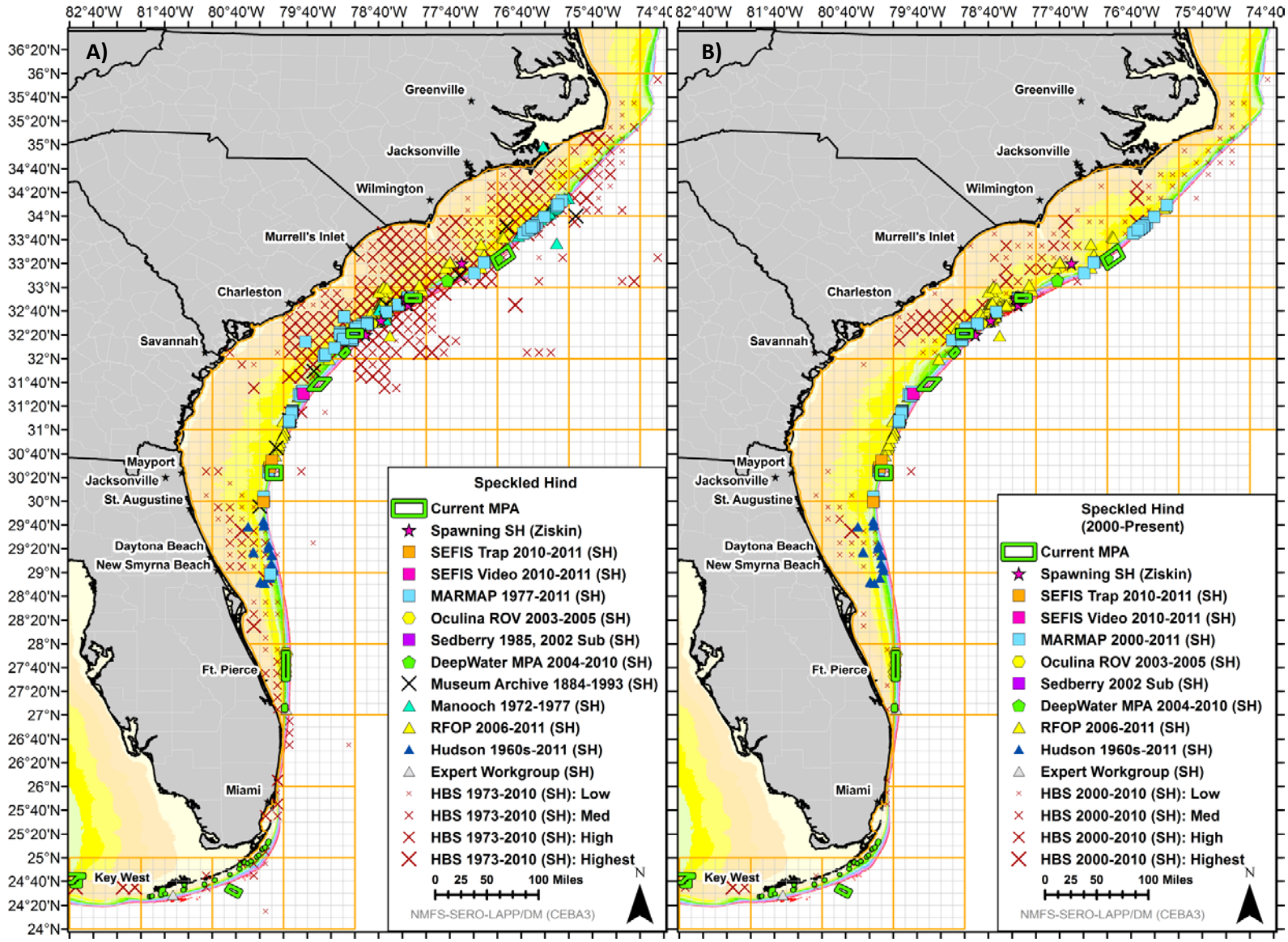

Figure 5. Speckled hind encounters reported by various data sources for (A) all available years and (B) 2000-2011.

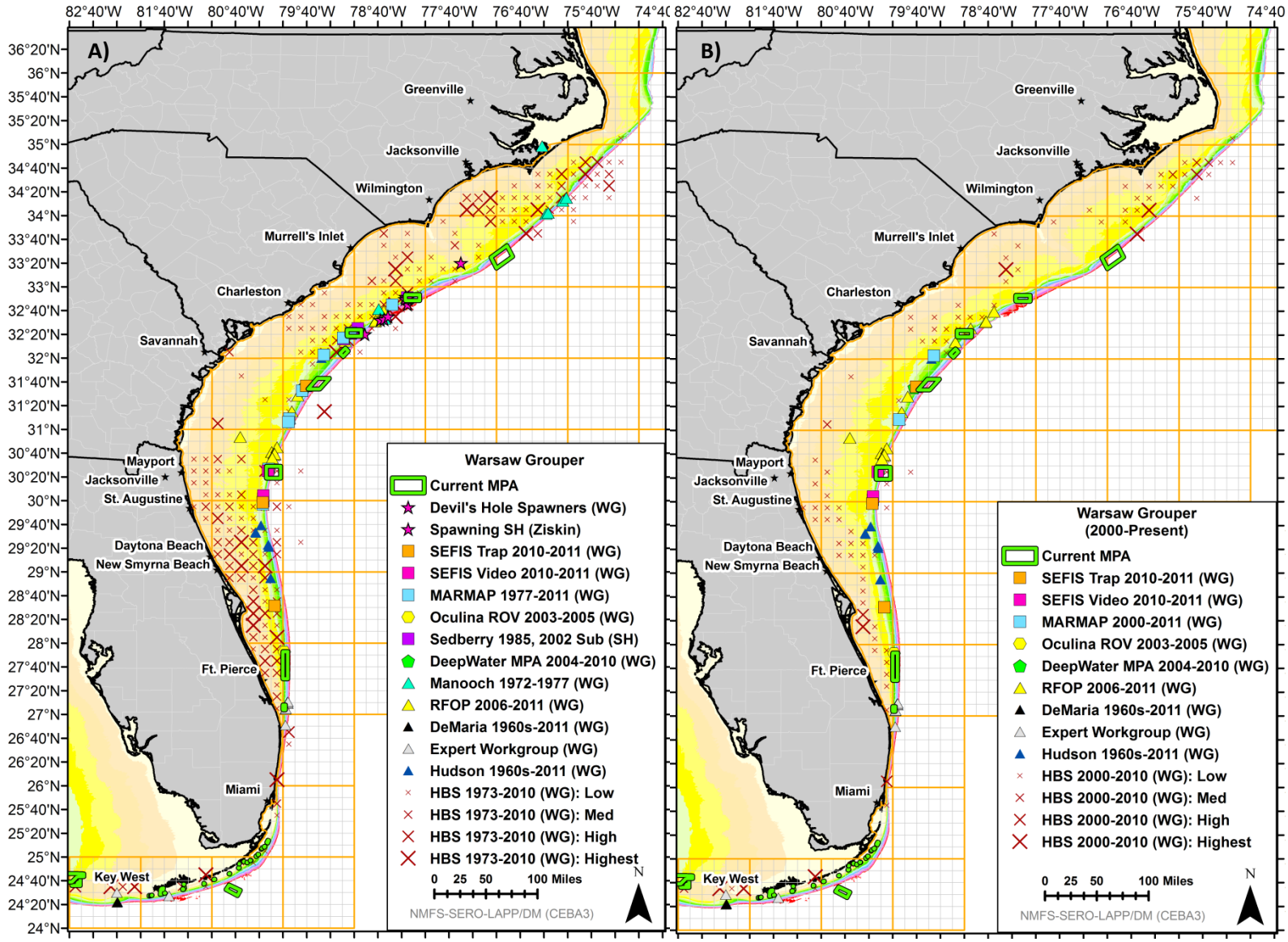

Figure 6. Warsaw grouper encounters reported by various data sources for (A) all available years and (B) 2000-2011.

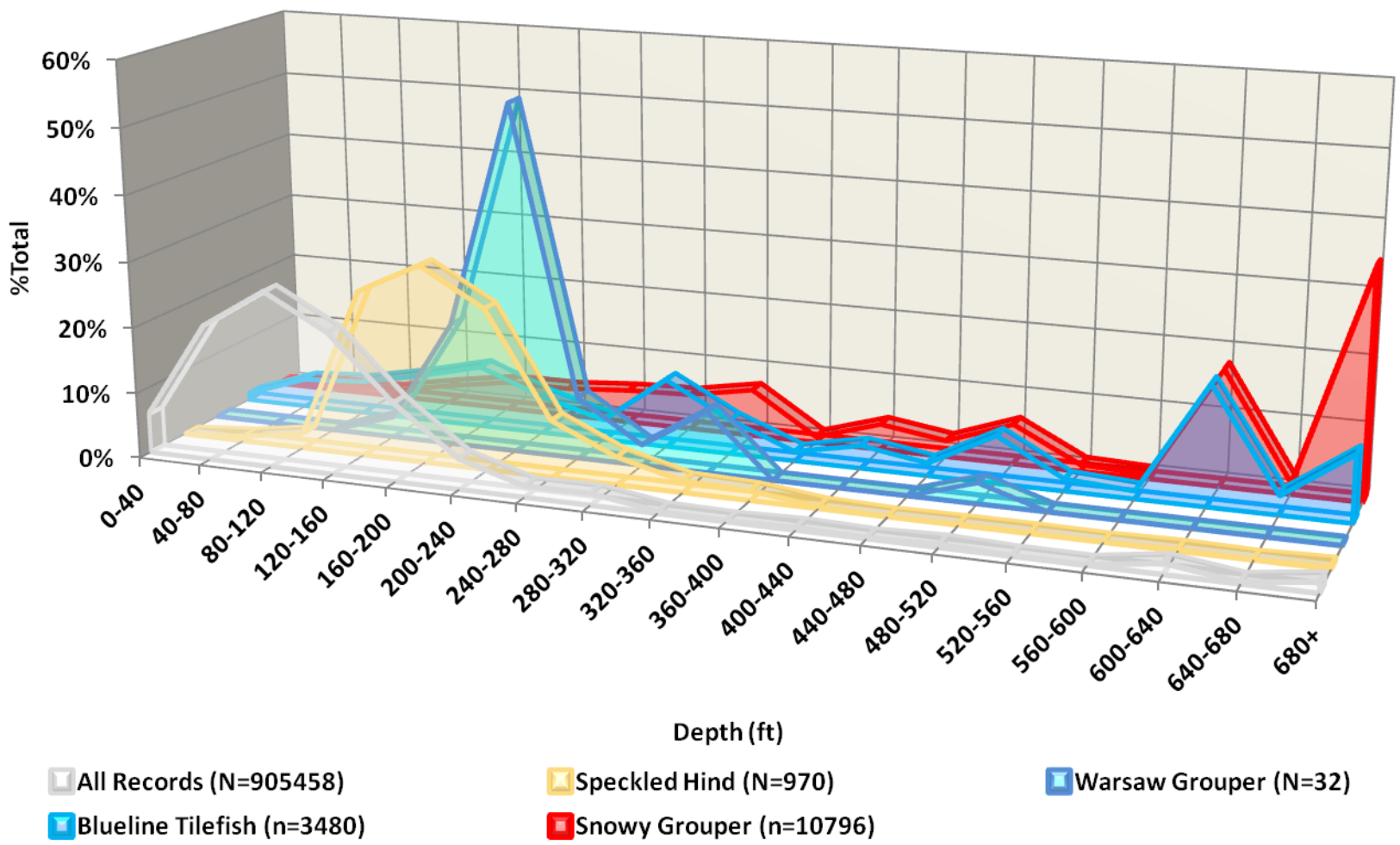

Figure 7. Percent frequency of all commercial logbook, headboat survey, reef fish observer, and MARMAP reported depth-of-capture observations, pooled across data sources, for managed stocks listed in Amendment 17B's 240-ft closure.

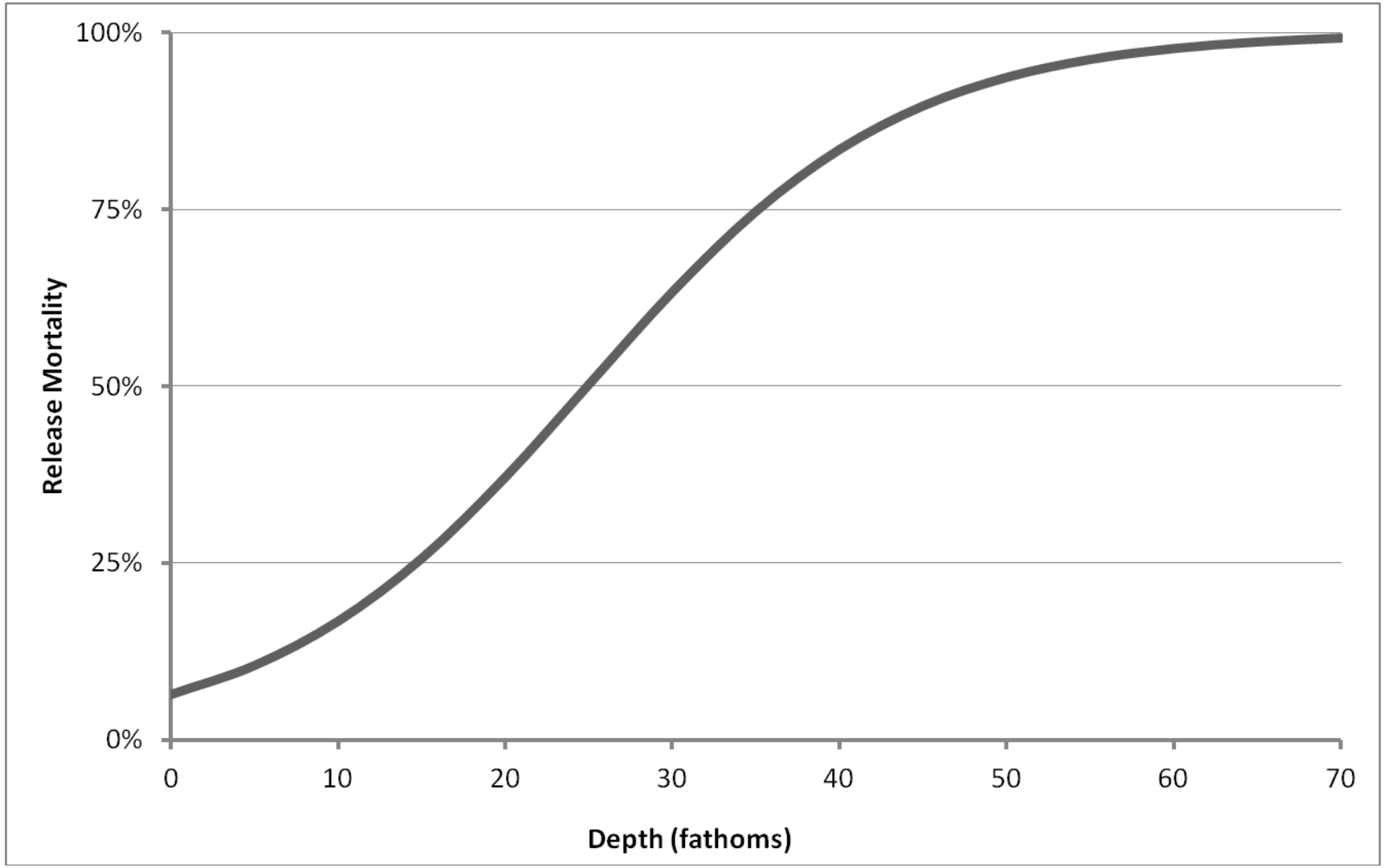

Figure 8. Release mortality rate for gag (*Mycteroperca microlepis*) from SEDAR-7 (2007).

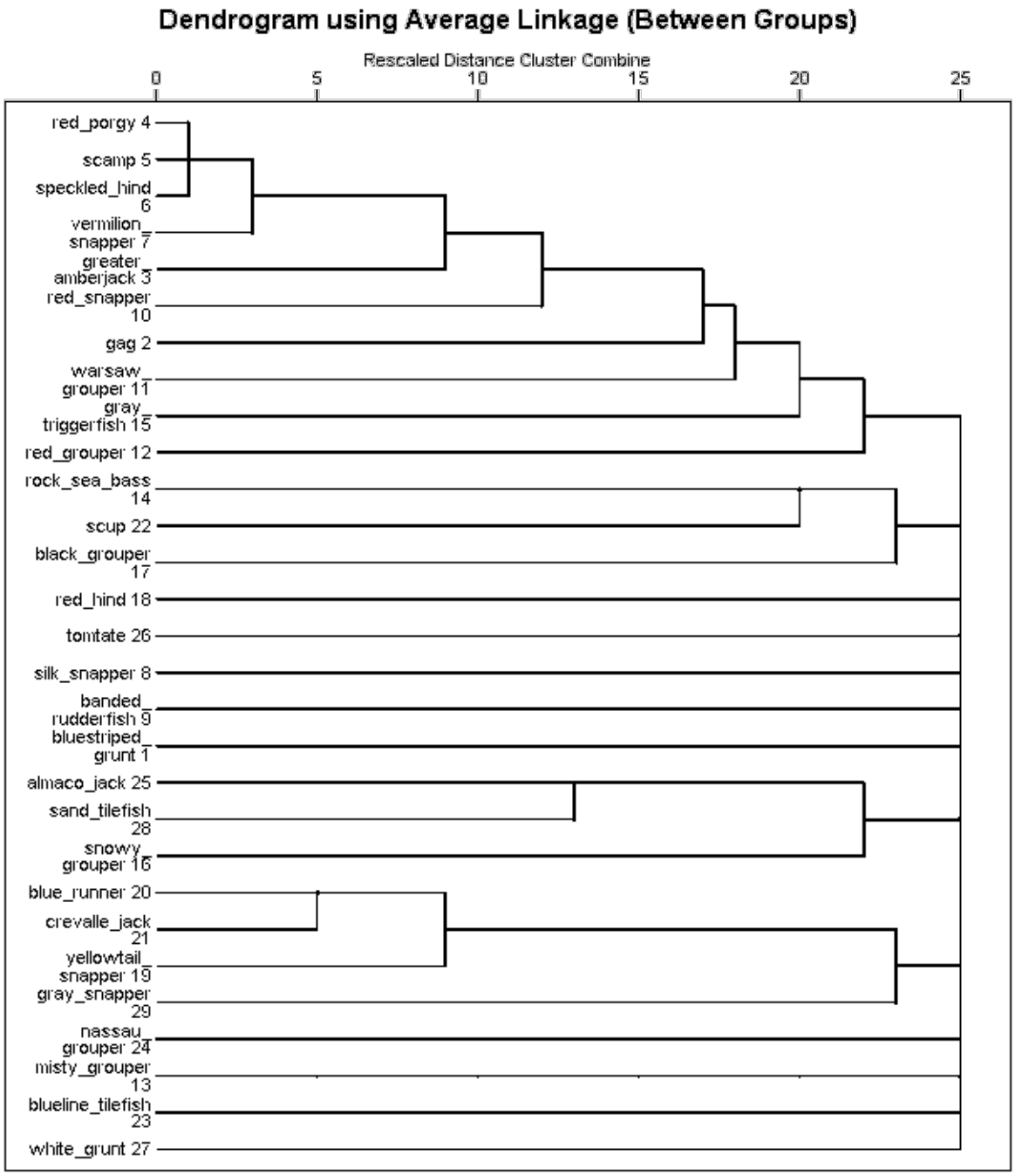

Figure 9. Hierarchical cluster analyses results for the commercial logbook dataset from 2001 to 2009 (warsaw grouper n=42; speckled hind n=255). Only includes trips where warsaw grouper or speckled hind were caught. Average linkage method was used with Sorenson similarity measure and binary transformation.

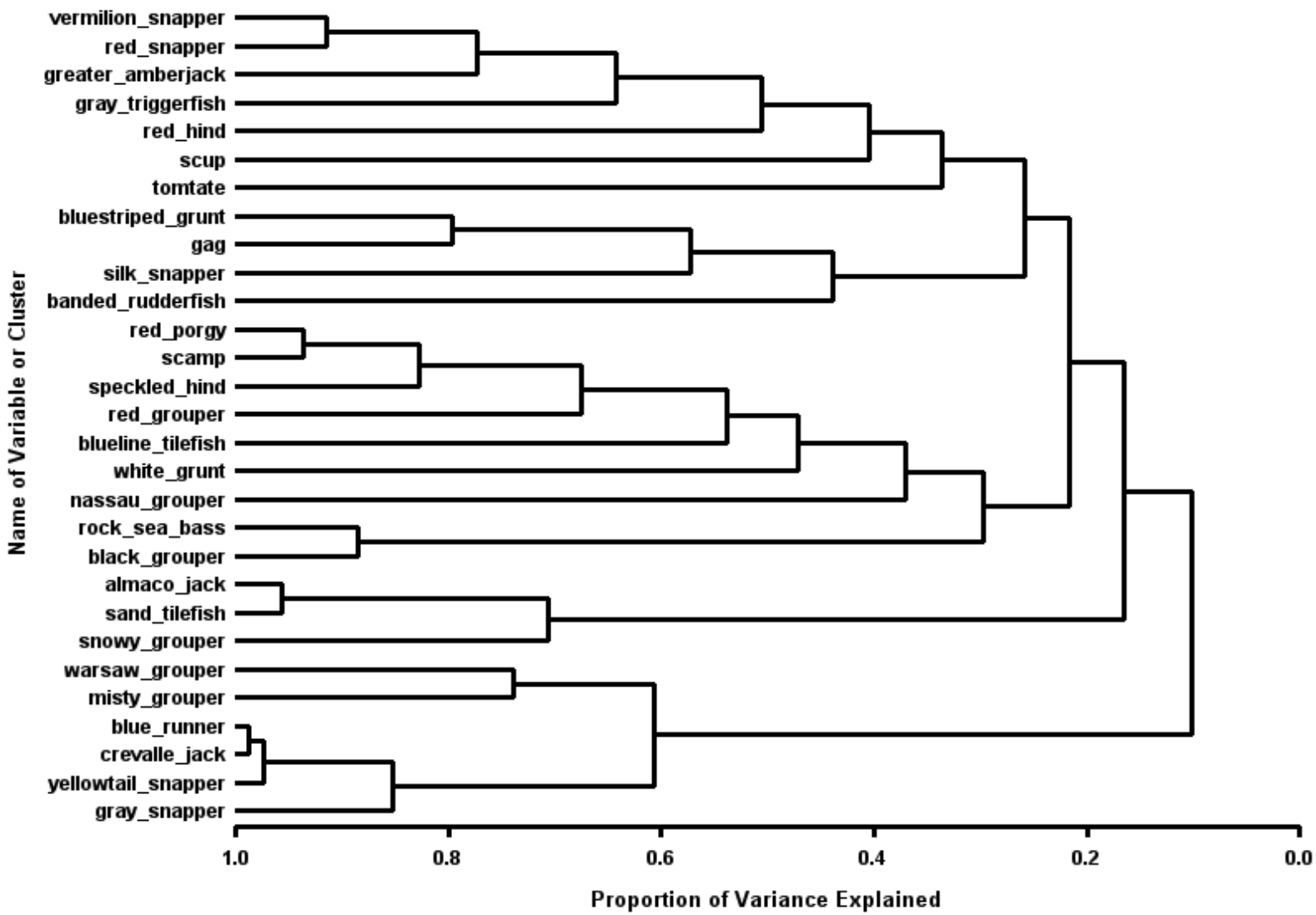

Figure 10. Dimension reduction analysis results for the binary-transformed commercial logbook dataset from 2001 to 2009 (warsaw grouper n=42; speckled hind n=255).

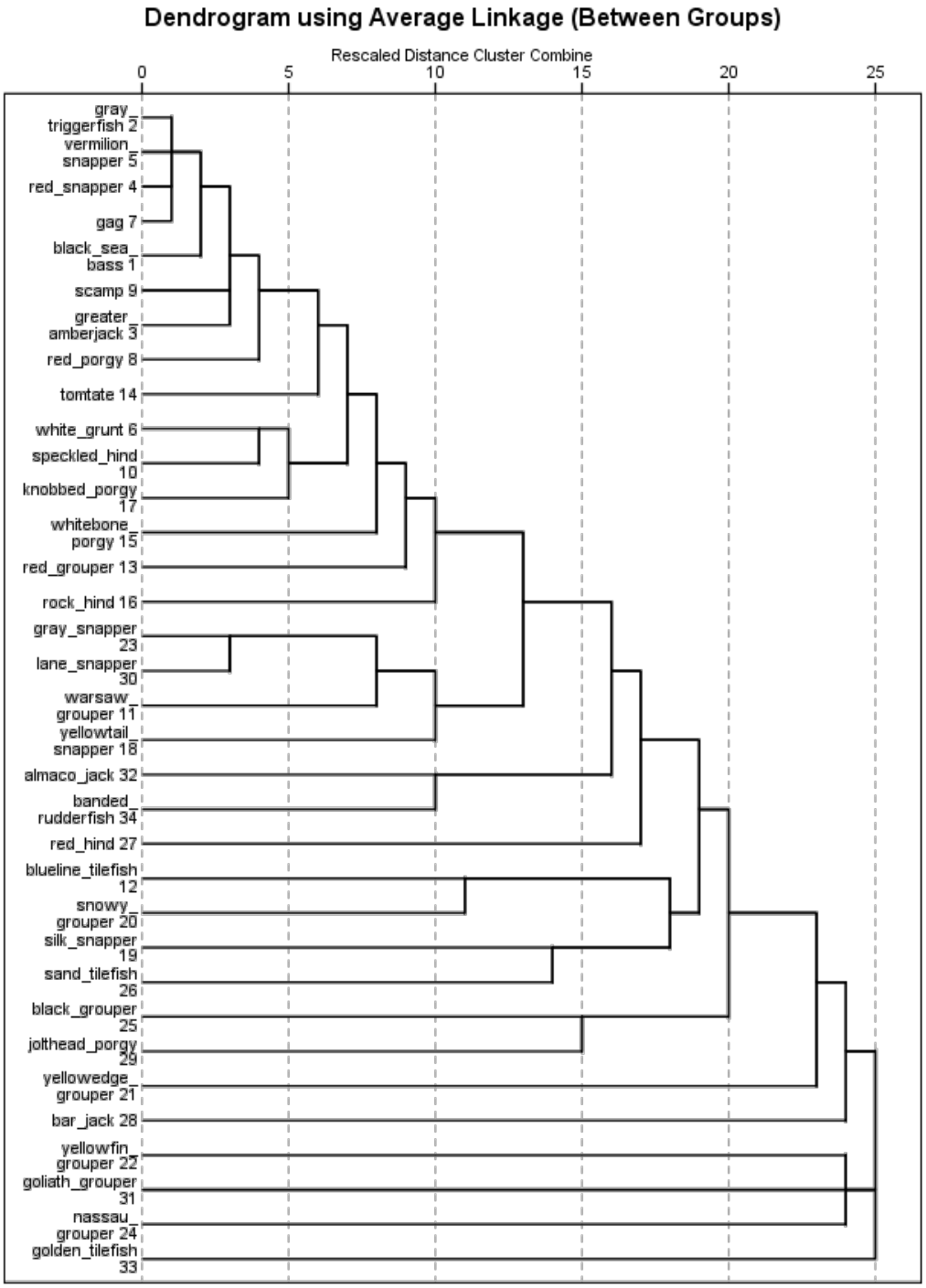

Figure 11. Hierarchical cluster analyses results for the headboat logbook dataset from 1973 to 2009 (warsaw grouper n=3,203; speckled hind n=26,650). Only includes trips where a warsaw grouper or speckled hind was caught. Average linkage method was used with Sorenson similarity measure and binary transformation.

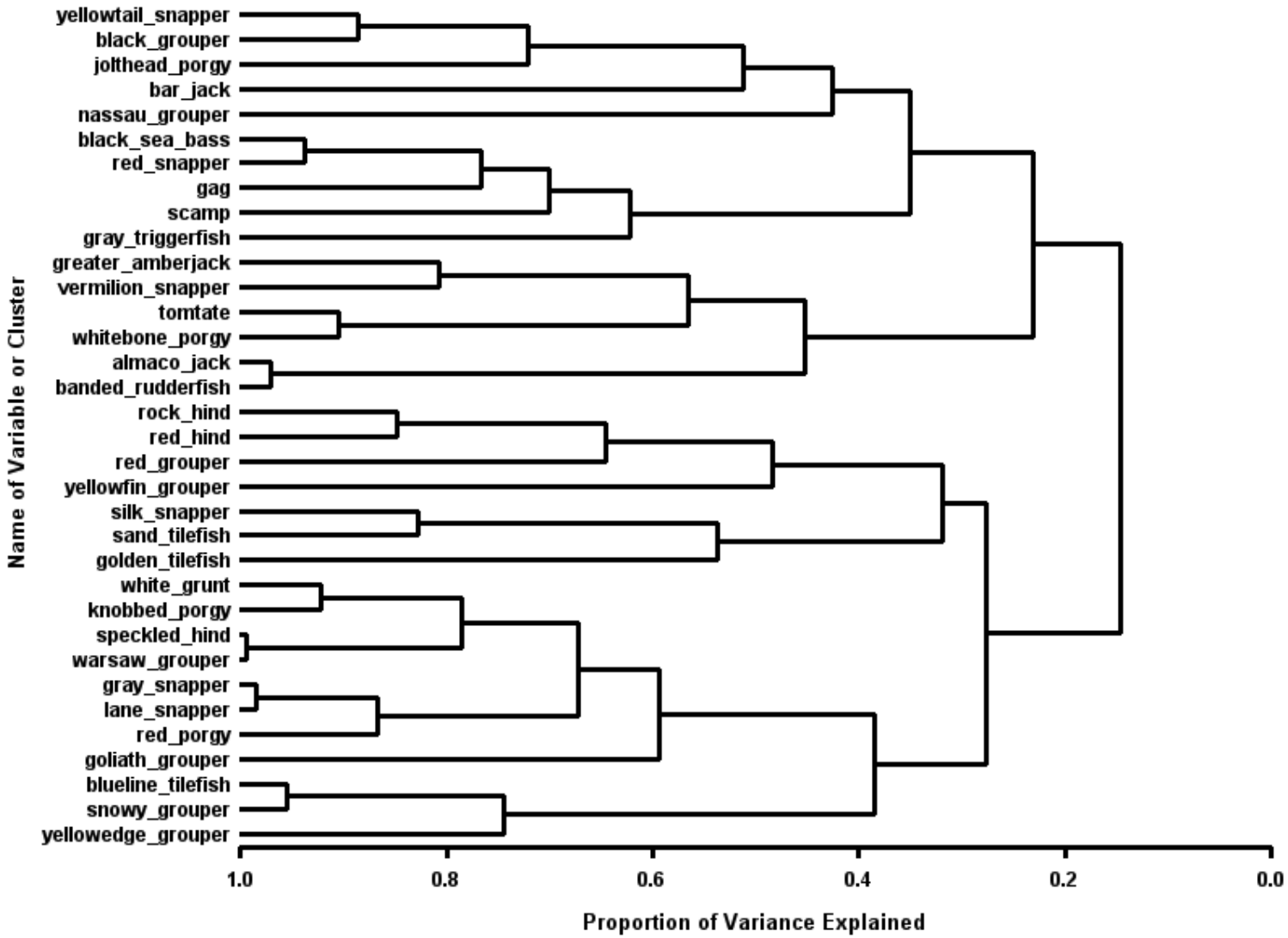

Figure 12. Dimension reduction analysis results for the binary-transformed headboat logbook dataset from 1973 to 2009 (warsaw grouper n=3,203; speckled hind n=26,650).

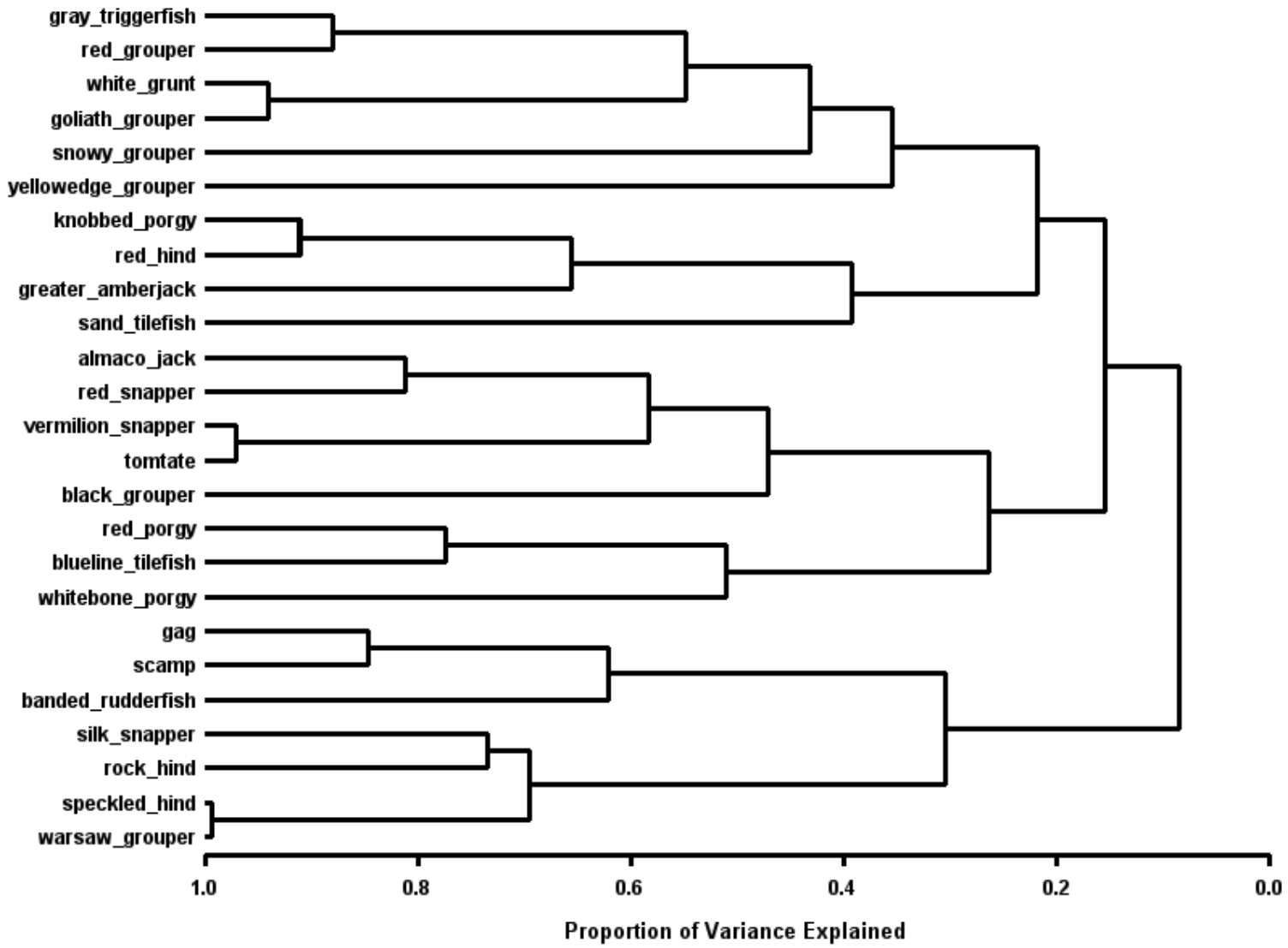

Figure 13. Dimension reduction analysis results for the binary-transformed reef fish observer dataset from 1973 to 2009 (warsaw grouper n=13; speckled hind n=182).

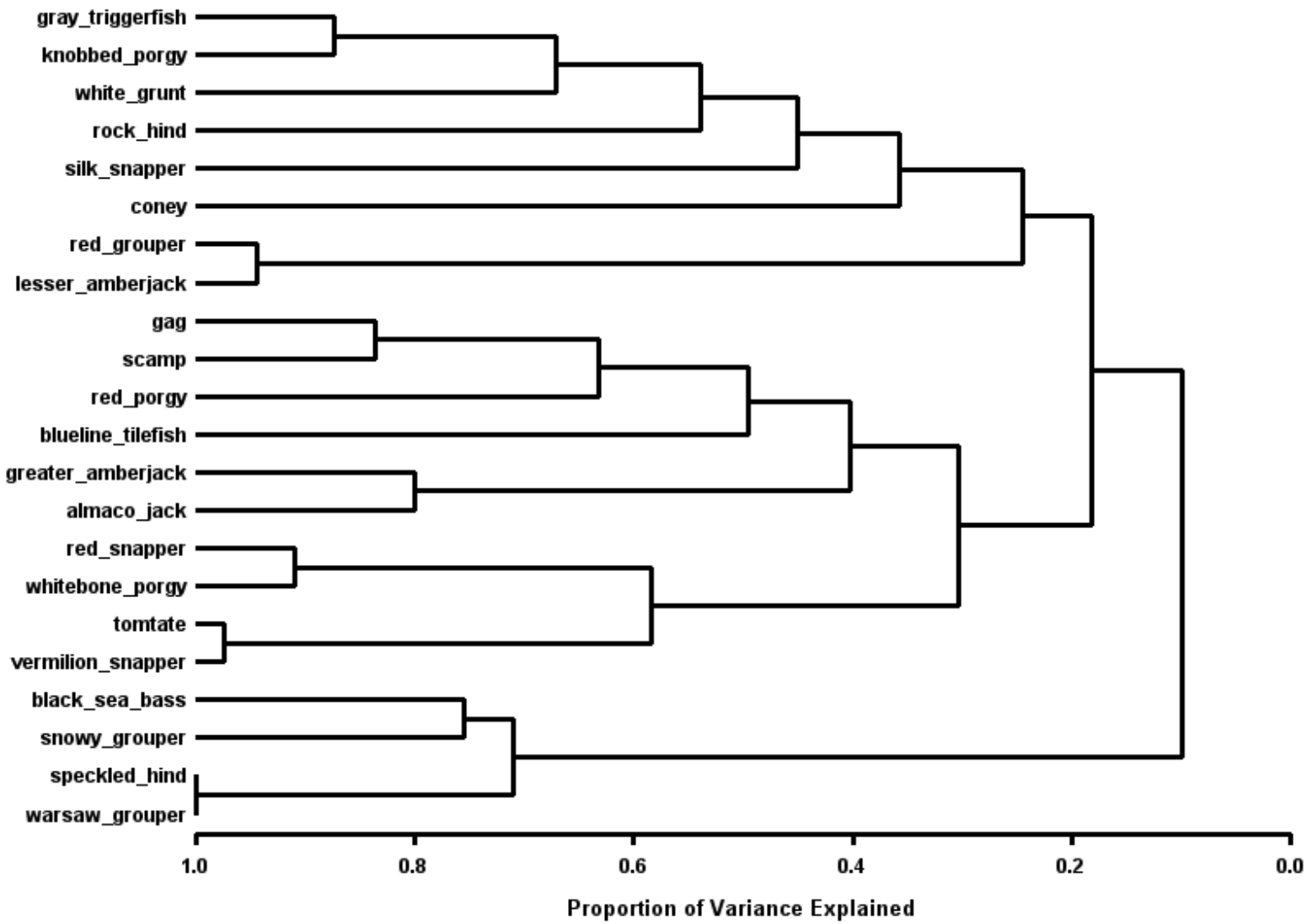

Figure 14. Dimension reduction analysis results for the binary-transformed MARMAP dataset from 1977 to 2011 (warsaw grouper n=14; speckled hind n=241).

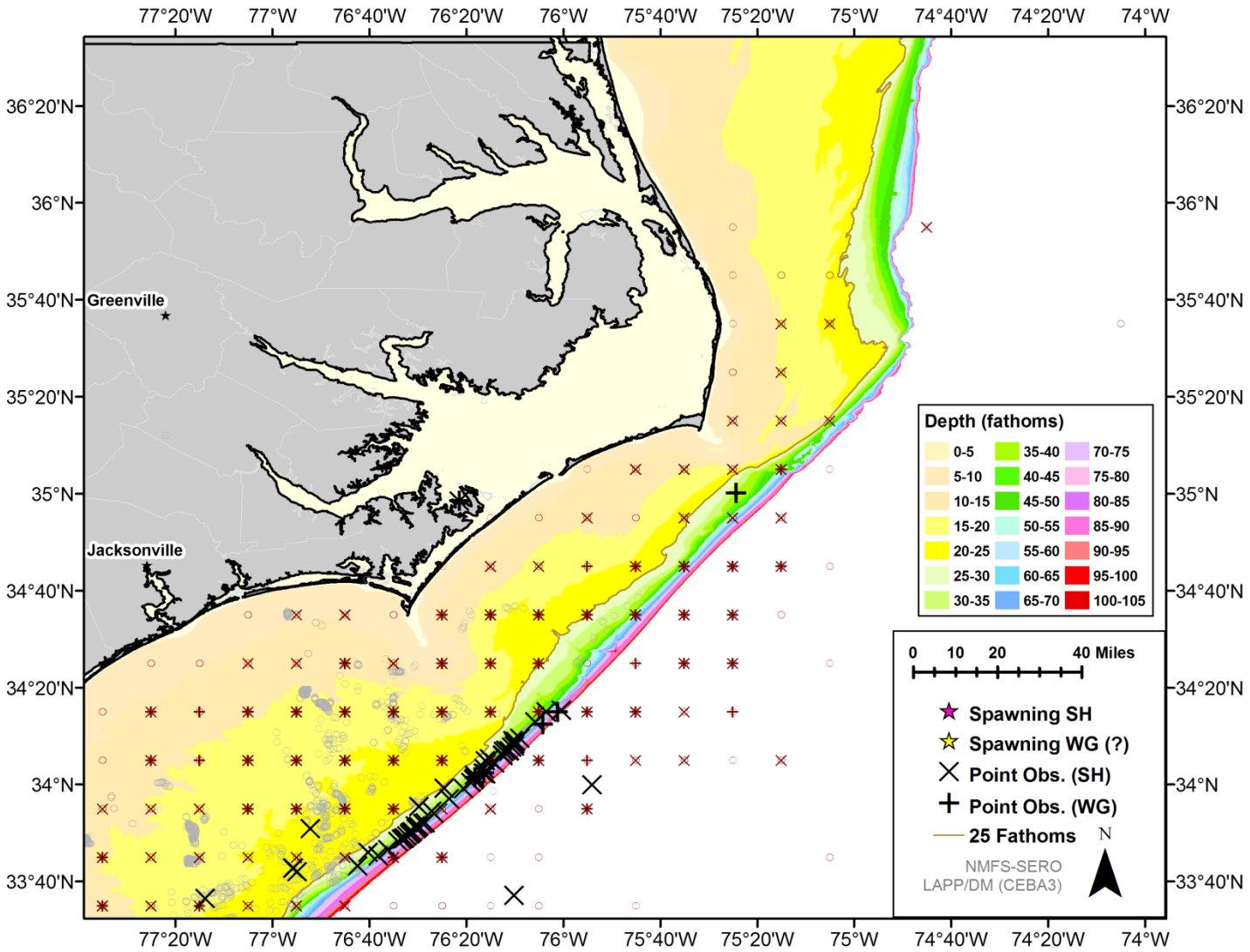

Figure 15. Point samples (O) and observations of speckled hind (X) and warsaw grouper (+) off North Carolina (HBS in red).

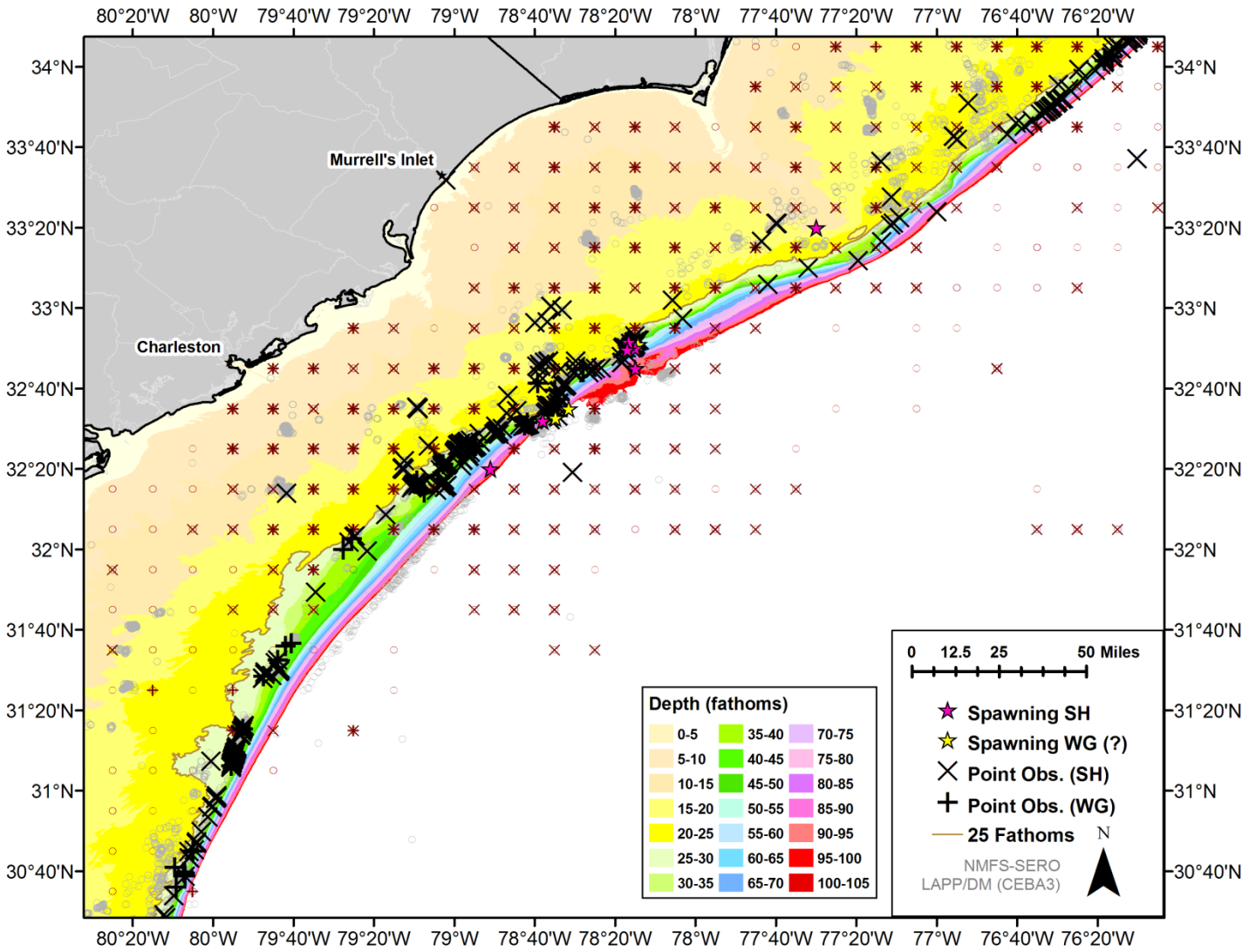

Figure 16. Point samples (O) and observations of speckled hind (X) and warsaw grouper (+) off South Carolina (HBS in red).

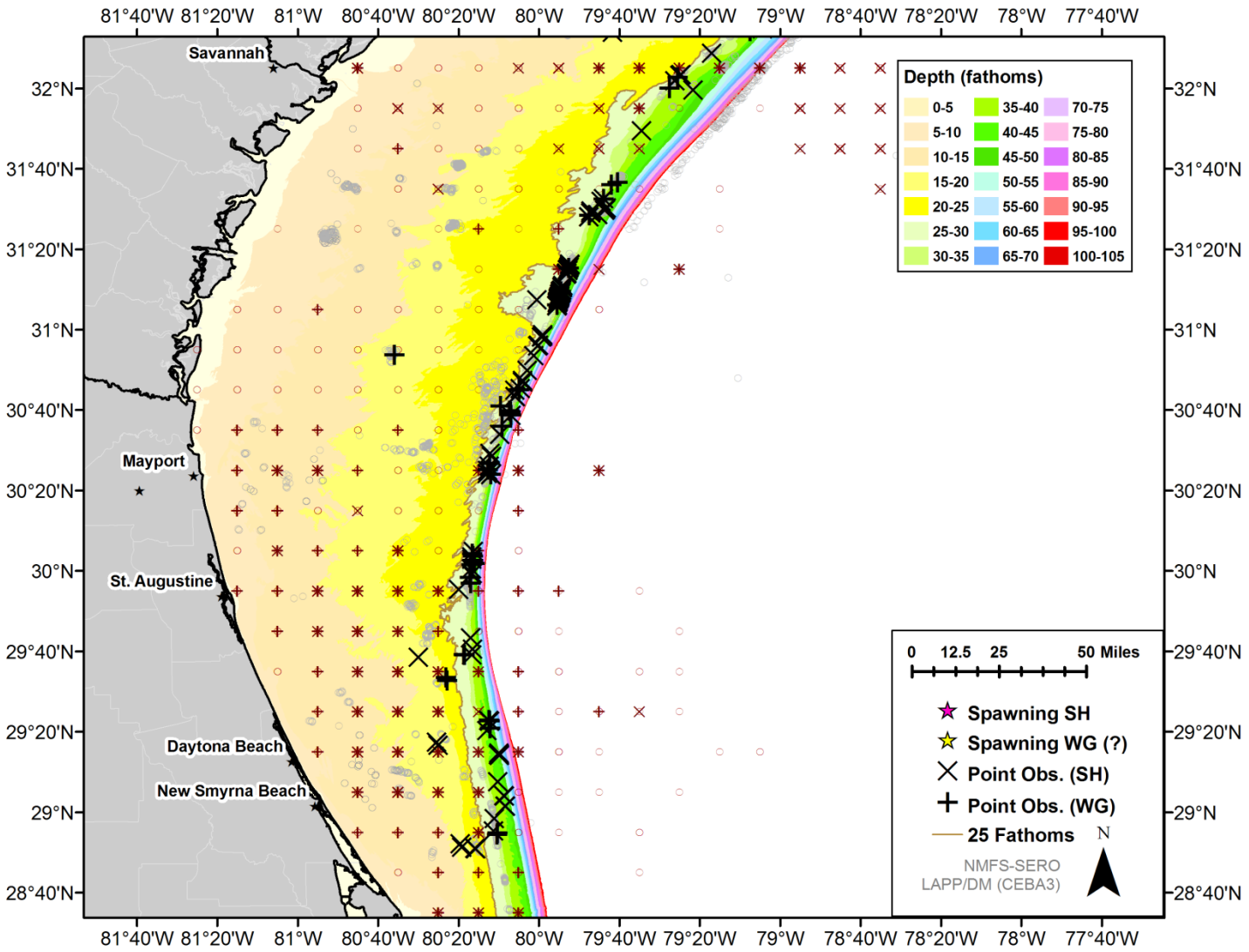

Figure 17. Point samples (O) and observations of speckled hind (X) and warsaw grouper (+) off Georgia and northeast Florida (HBS in red).

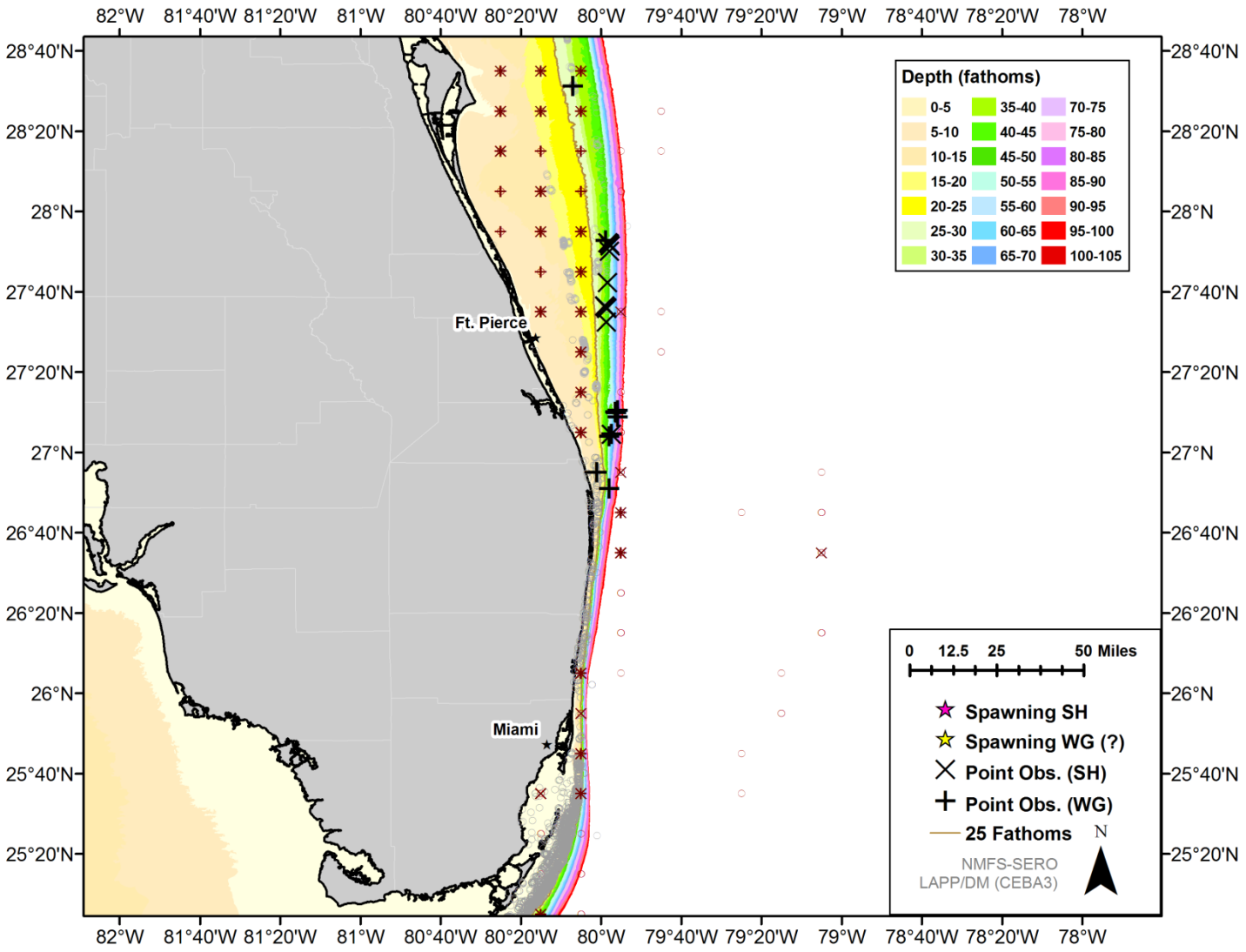

Figure 18. Point samples (O) and observations of speckled hind (X) and warsaw grouper (+) off southeast Florida (HBS in red).

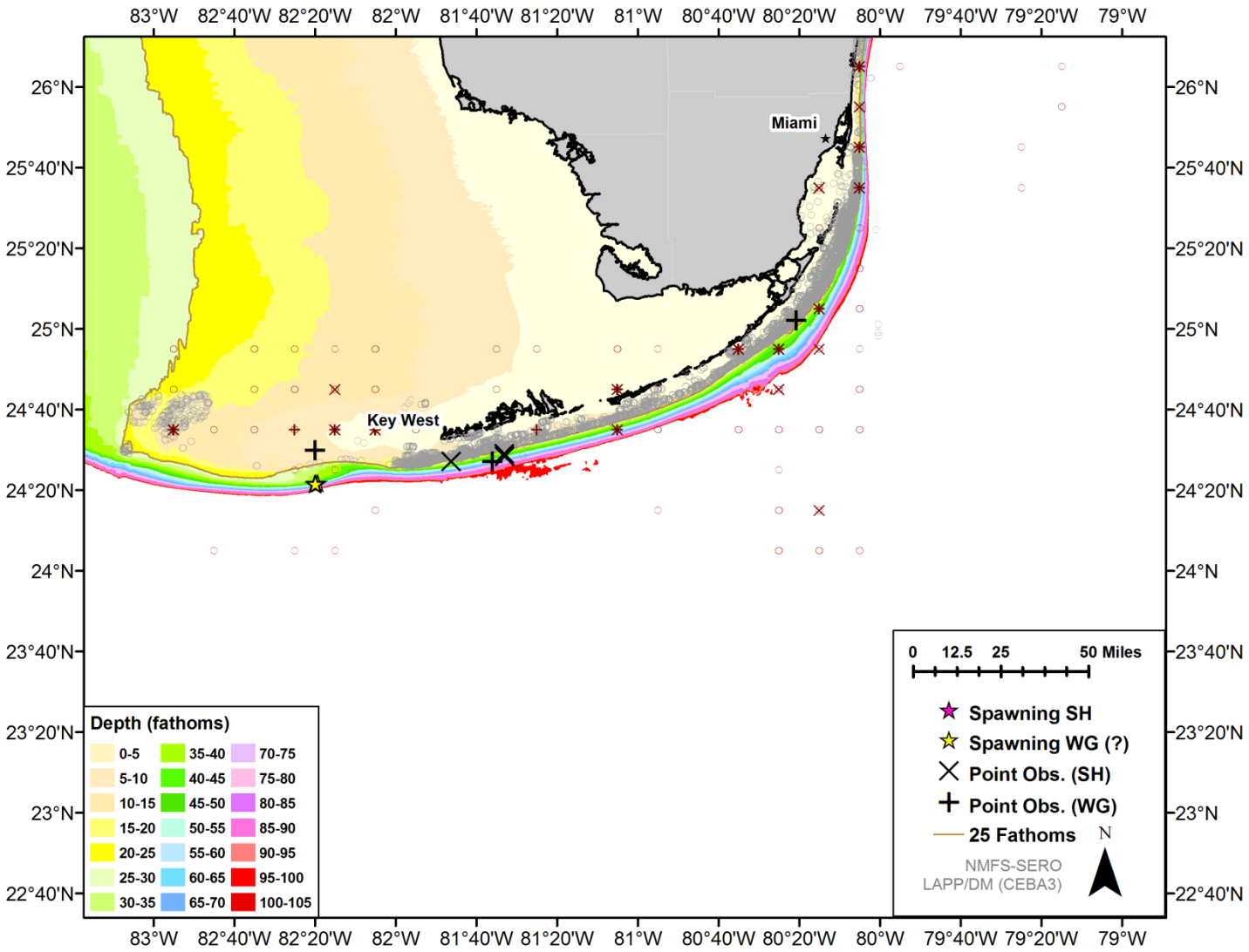

Figure 19. Point samples (O) and observations of speckled hind (X) and warsaw grouper (+) off the Florida Keys (HBS in red).

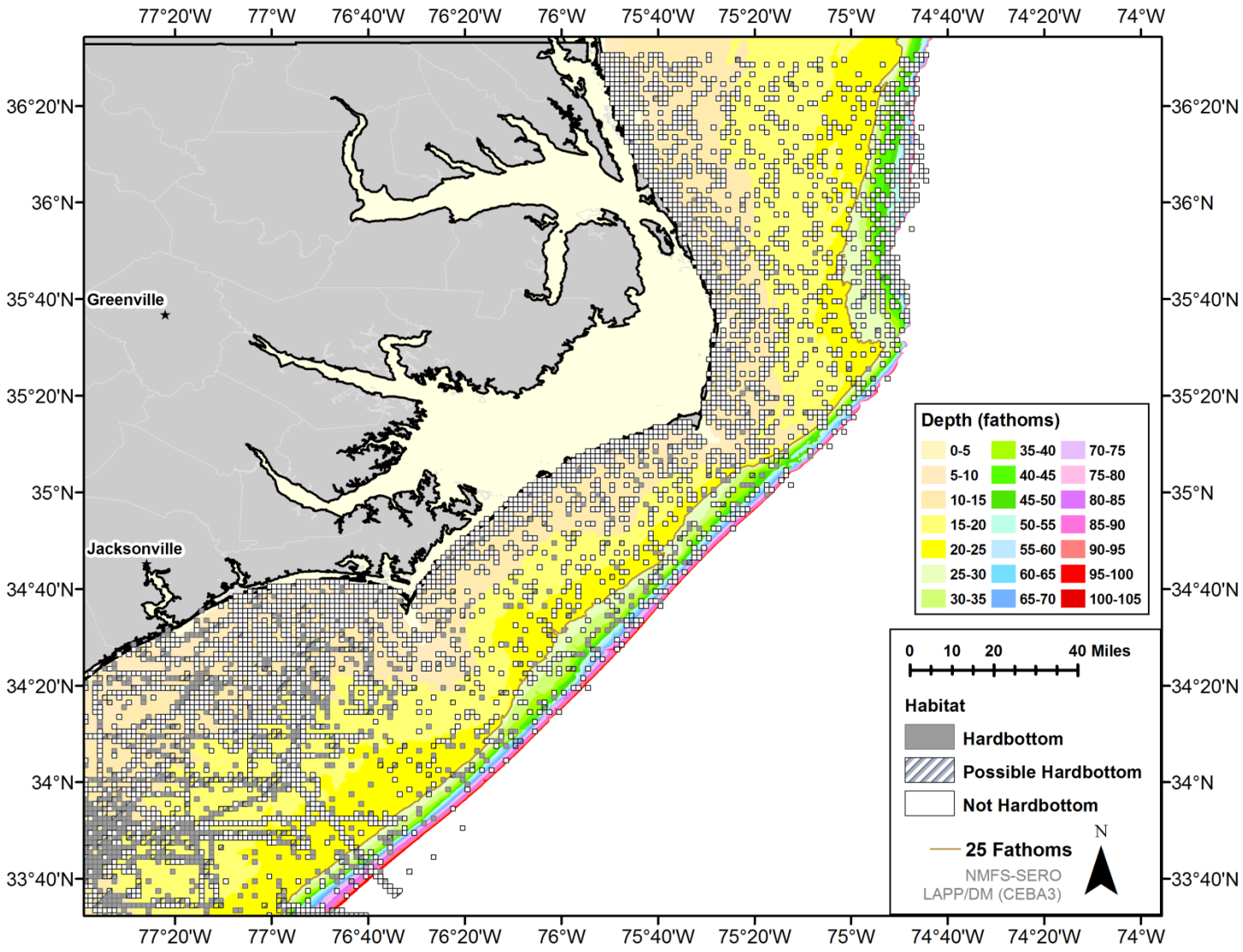

Figure 20. Habitat types off North Carolina relative to bathymetry.

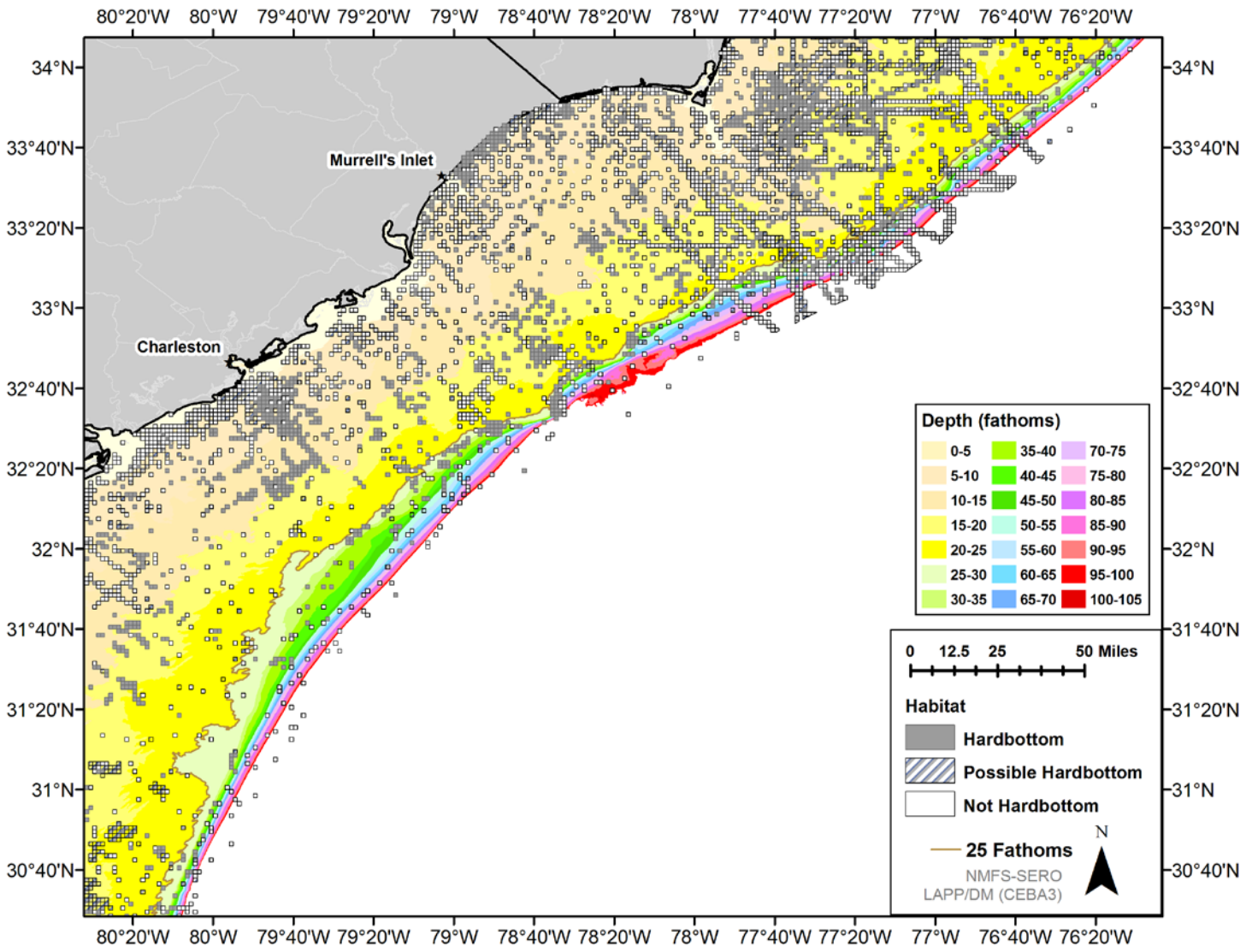

Figure 21. Habitat types off South Carolina relative to bathymetry.

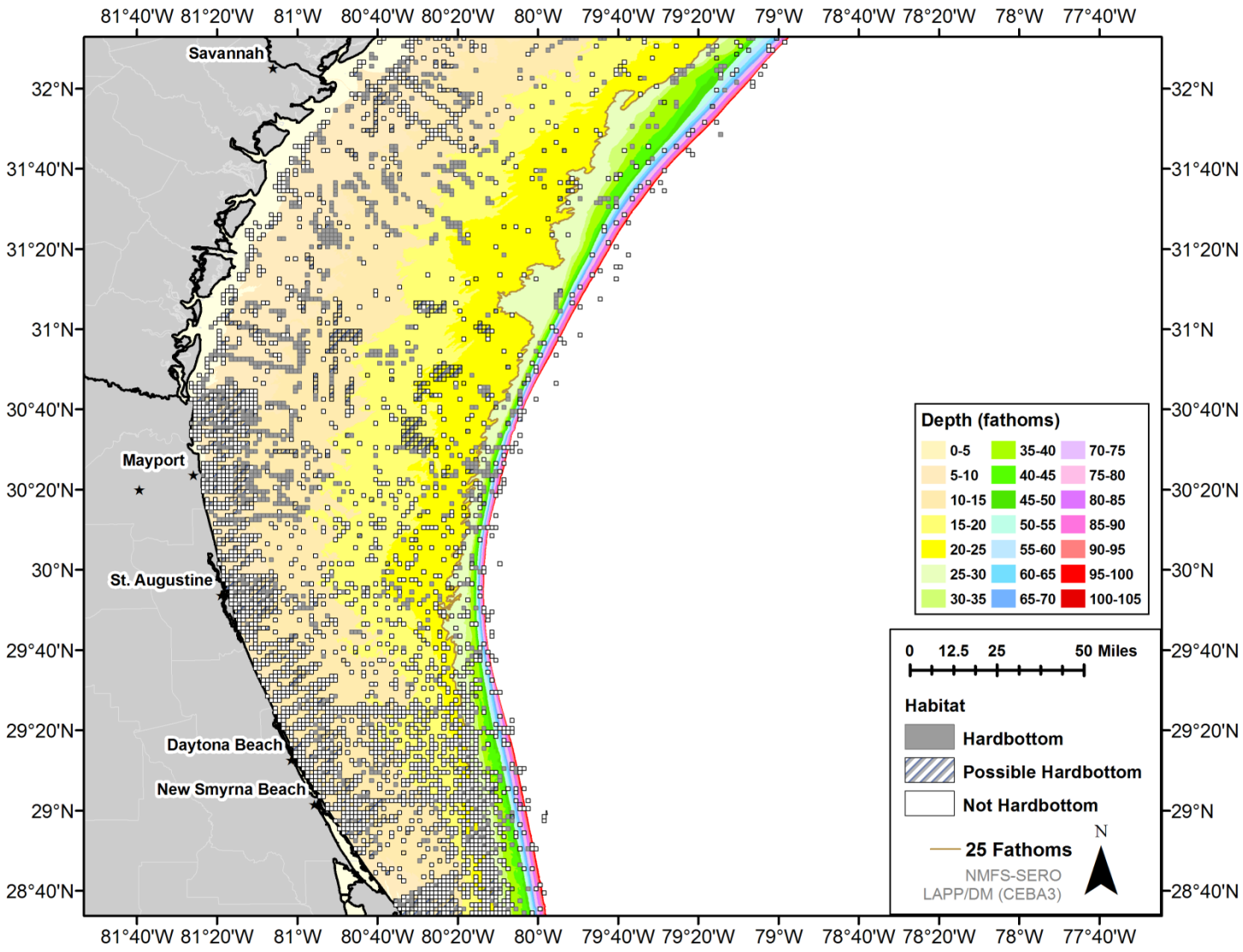

Figure 22. Habitat types off Georgia and northeast Florida relative to bathymetry.

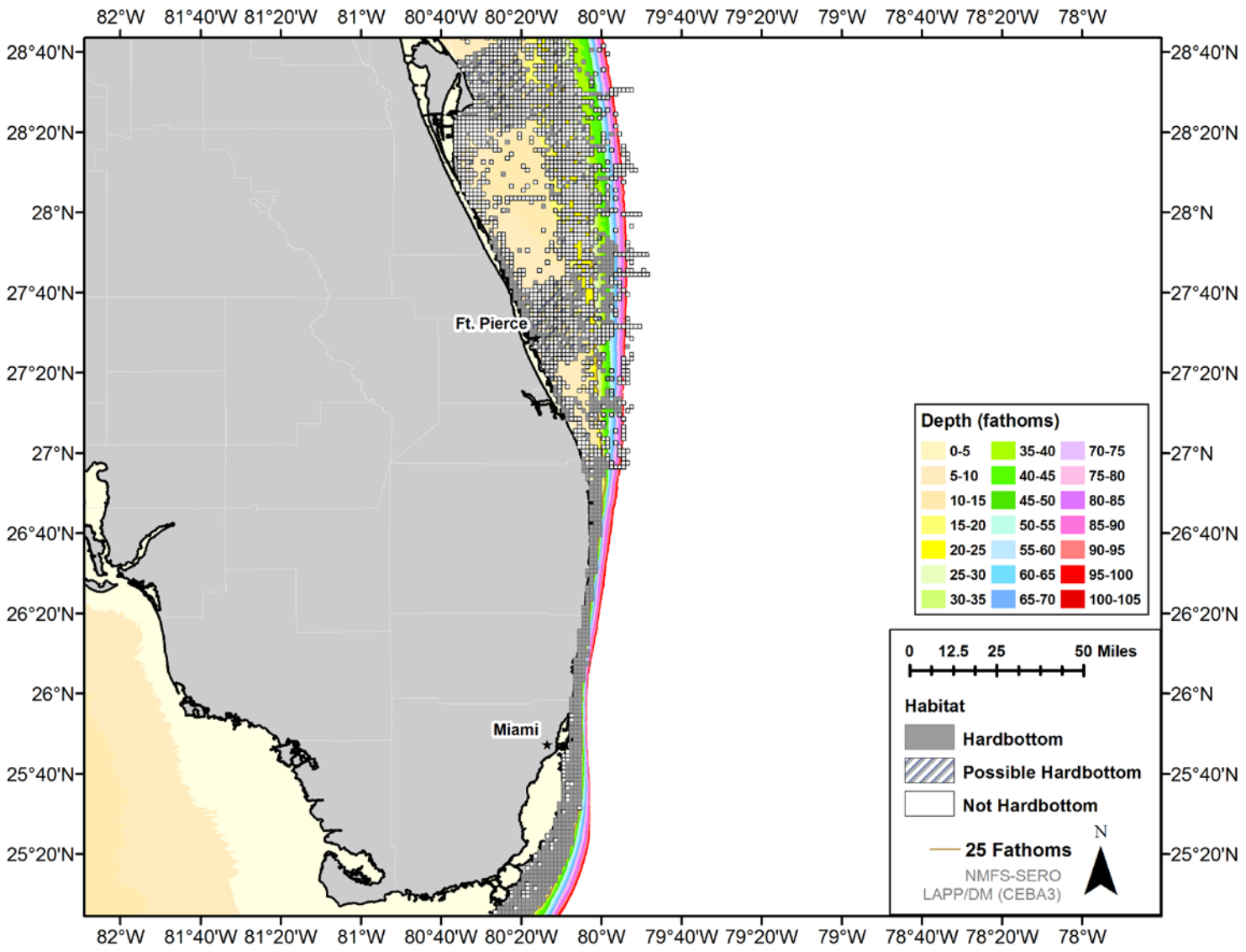

Figure 23. Habitat types off southeast Florida relative to bathymetry.

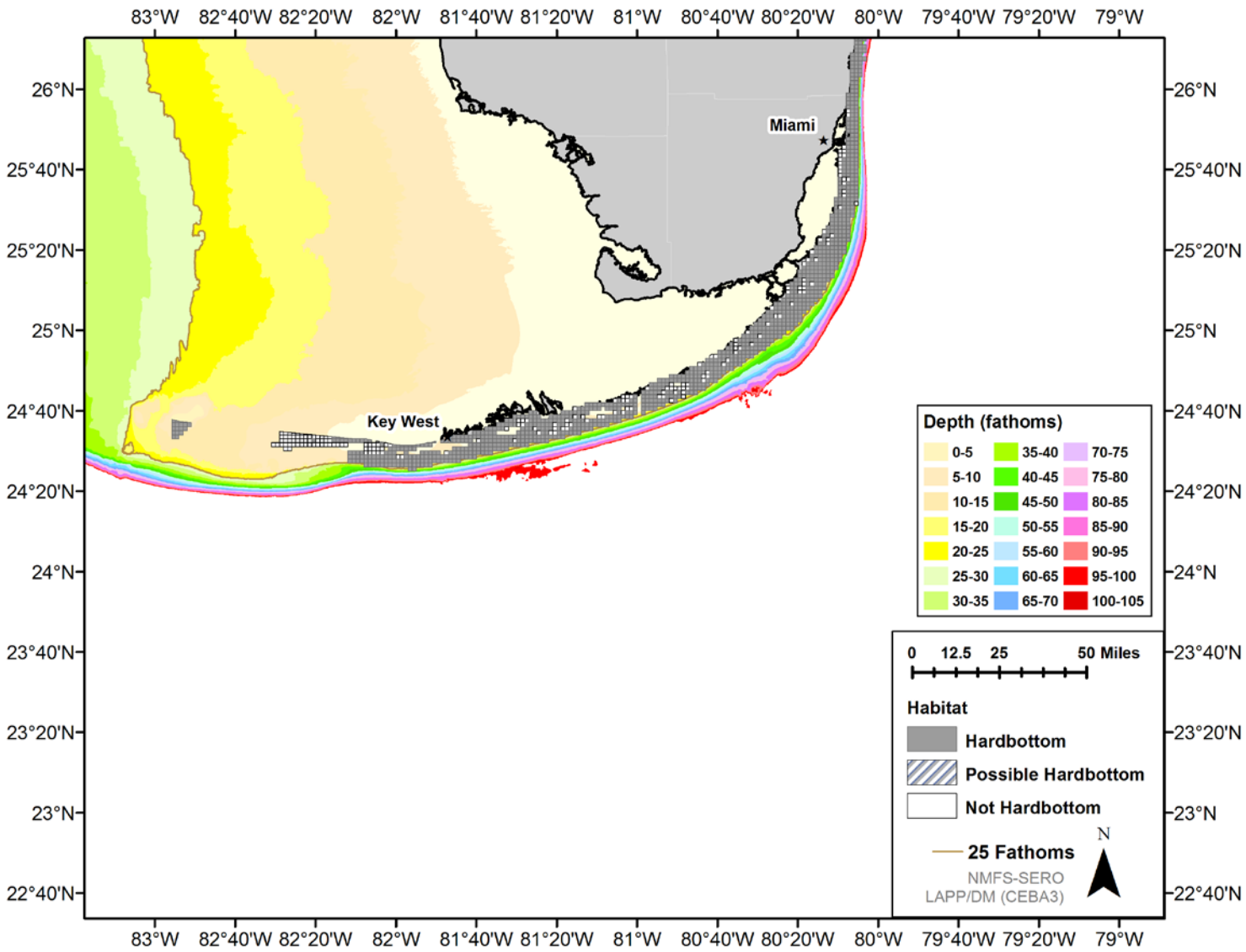

Figure 24. Habitat types off the Florida Keys relative to bathymetry.

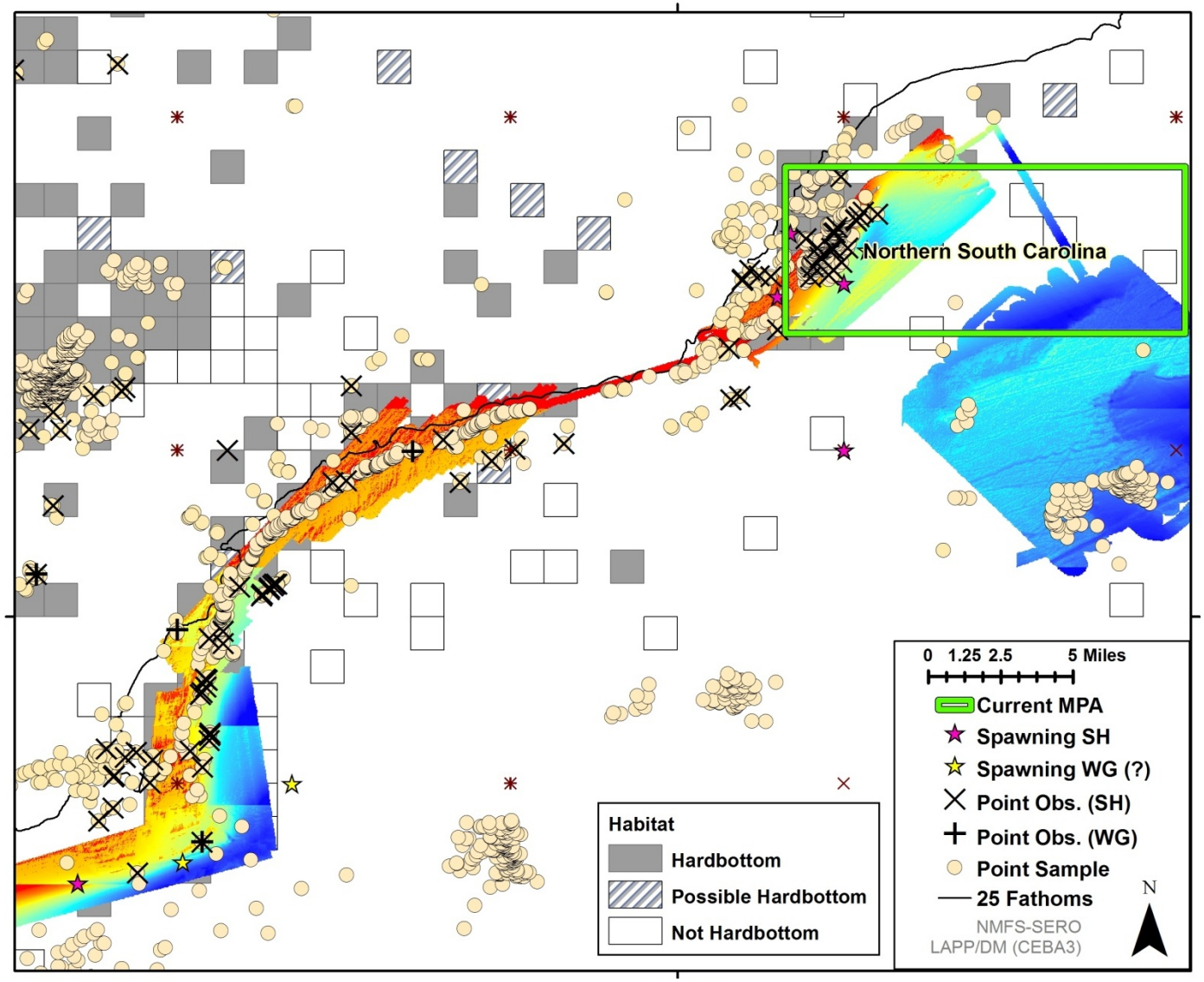

Figure 25. Point observations of speckled hind (X) and warsaw grouper (+) overlaid on high-resolution bathymetry and identified habitat types in and around Northern South Carolina MPA. Warmer tones denote shallower habitat, shadows denote relief.

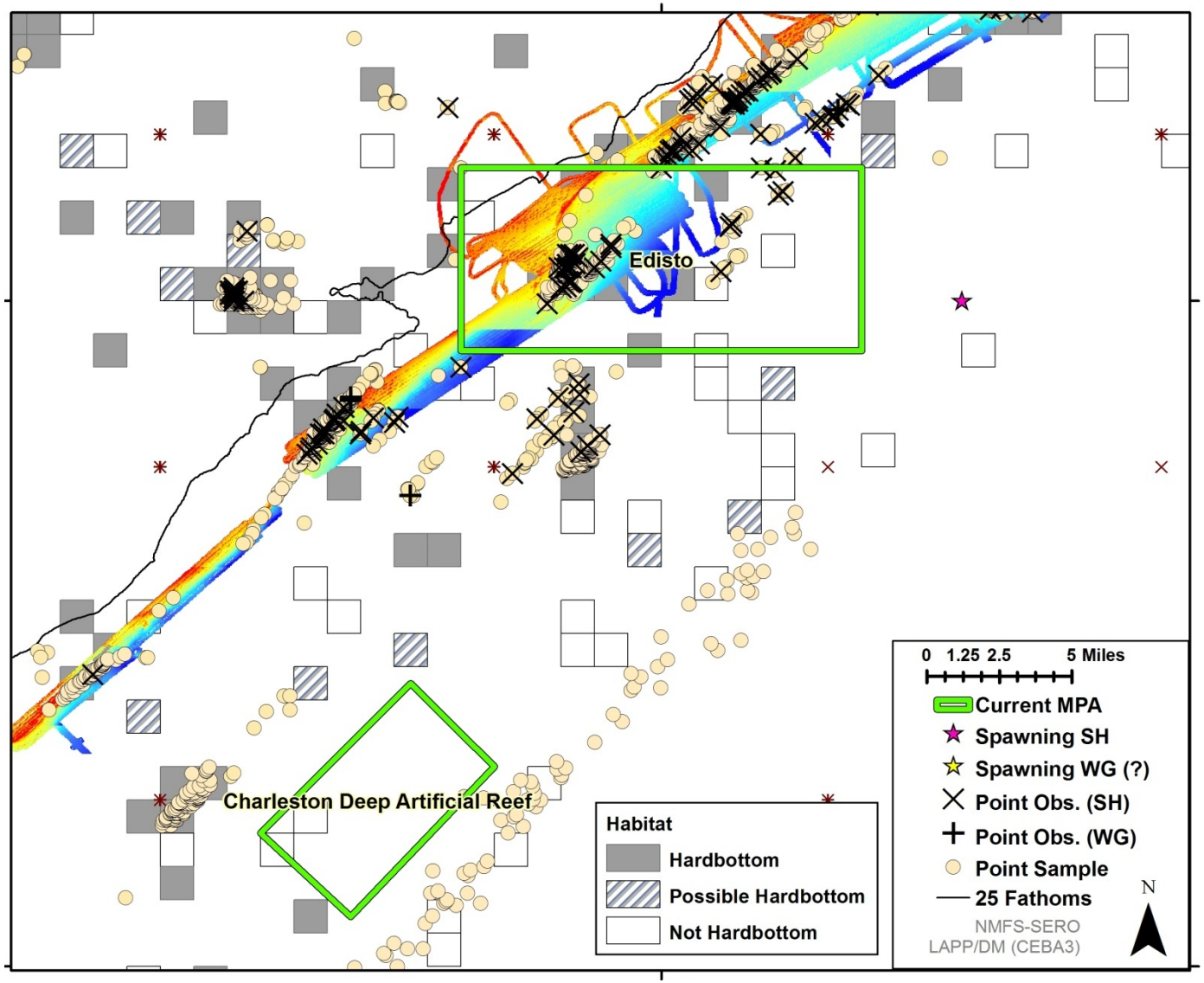

Figure 26. Point observations of speckled hind (X) and warsaw grouper (+) overlaid on high-resolution bathymetry and identified habitat types in and around Edisto MPA. Warmer tones denote shallower habitat, shadows denote relief.

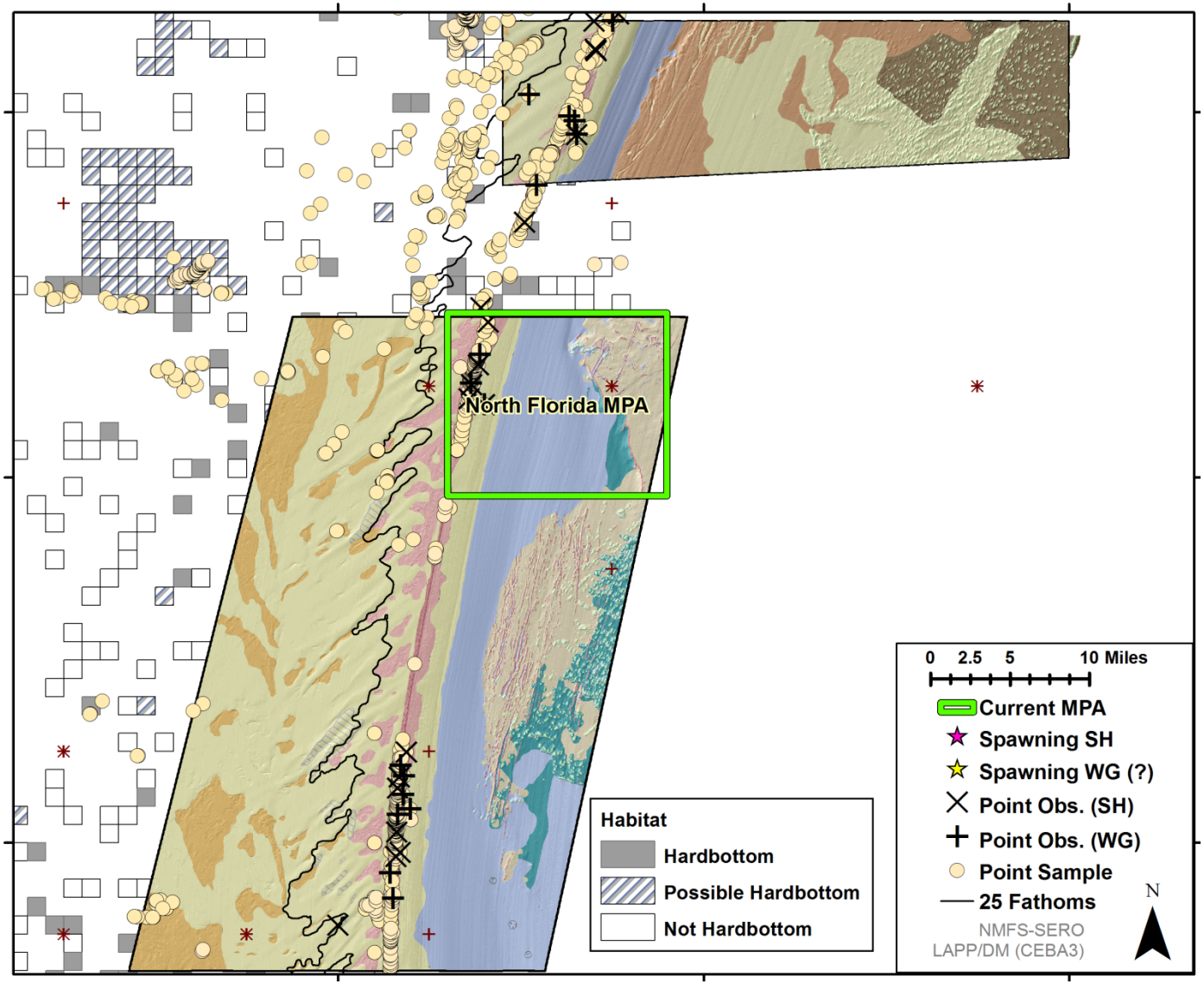

Figure 27. Point observations of speckled hind (X) and warsaw grouper (+) overlaid on high-resolution bathymetry and identified habitat types in and around North Florida MPA. Habitat types identified by NOAA as rock or reef are colored pink.

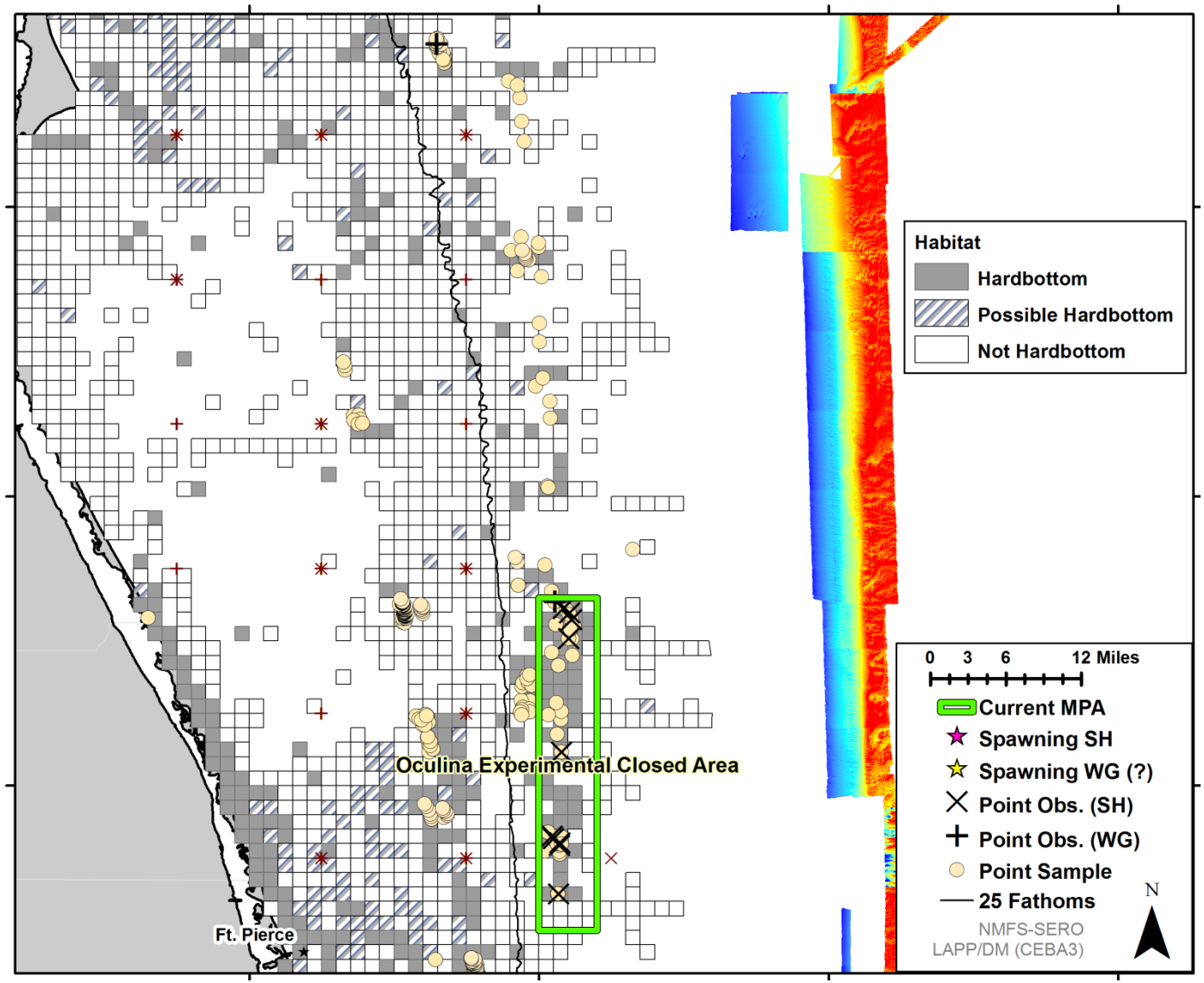

Figure 28. Point observations of speckled hind (X) and warsaw grouper (+) overlaid on high-resolution bathymetry and identified habitat types in and around Oculina MPA. Warmer tones denote shallower habitat, shadows denote relief.

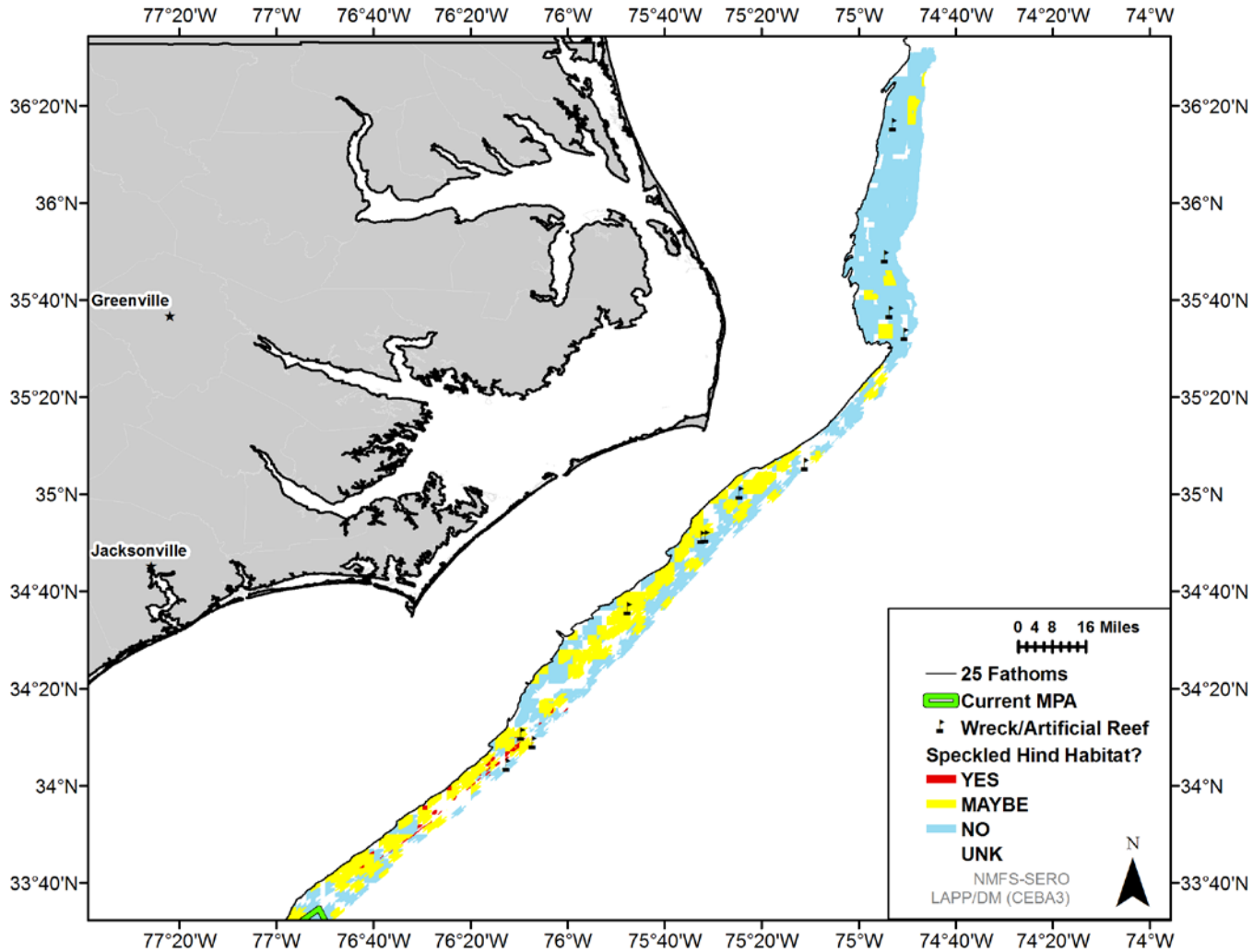

Figure 29. Habitat suitability analysis for speckled hind off North Carolina, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if speckled hind directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

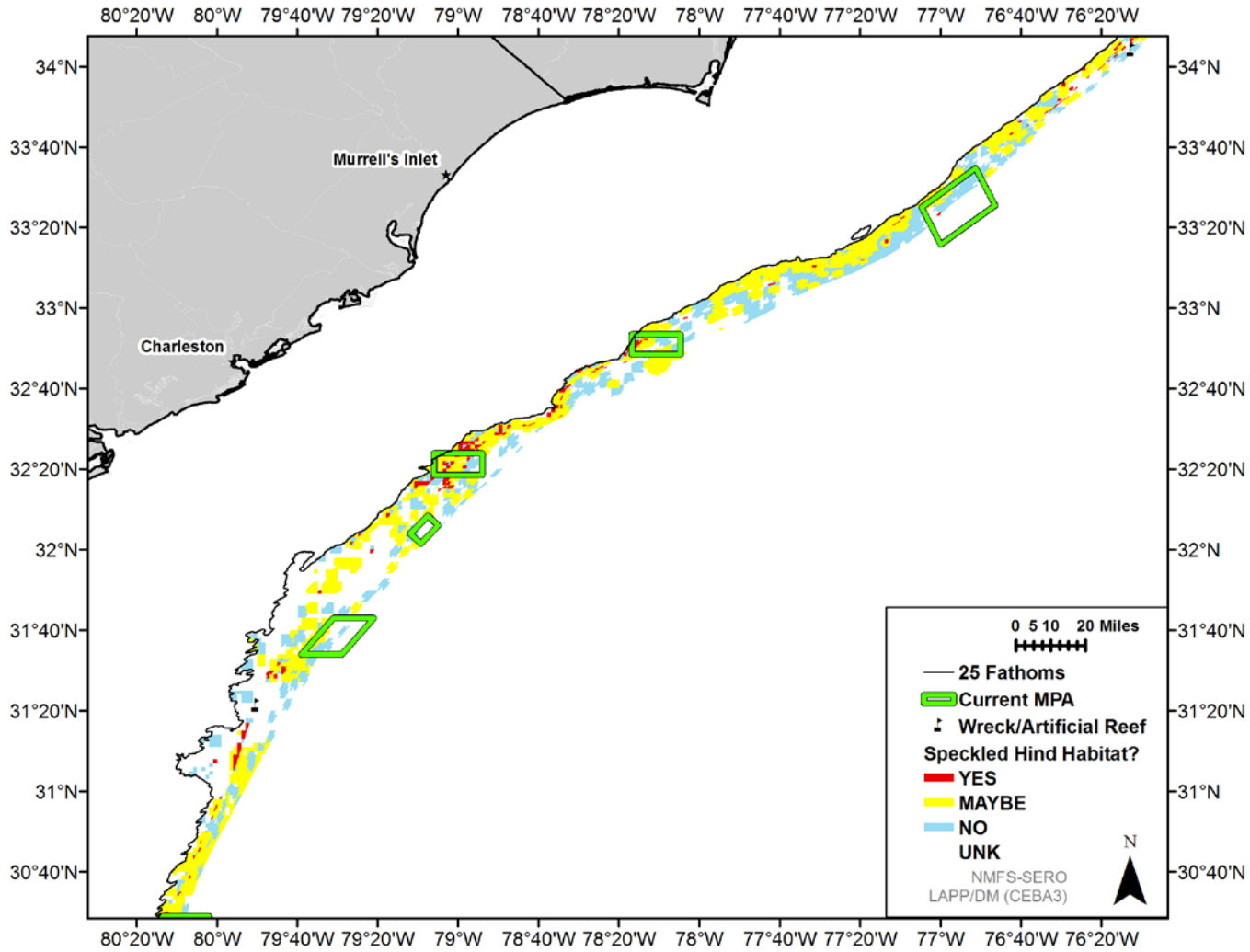

Figure 30. Habitat suitability analysis for speckled hind off South Carolina, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if speckled hind directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

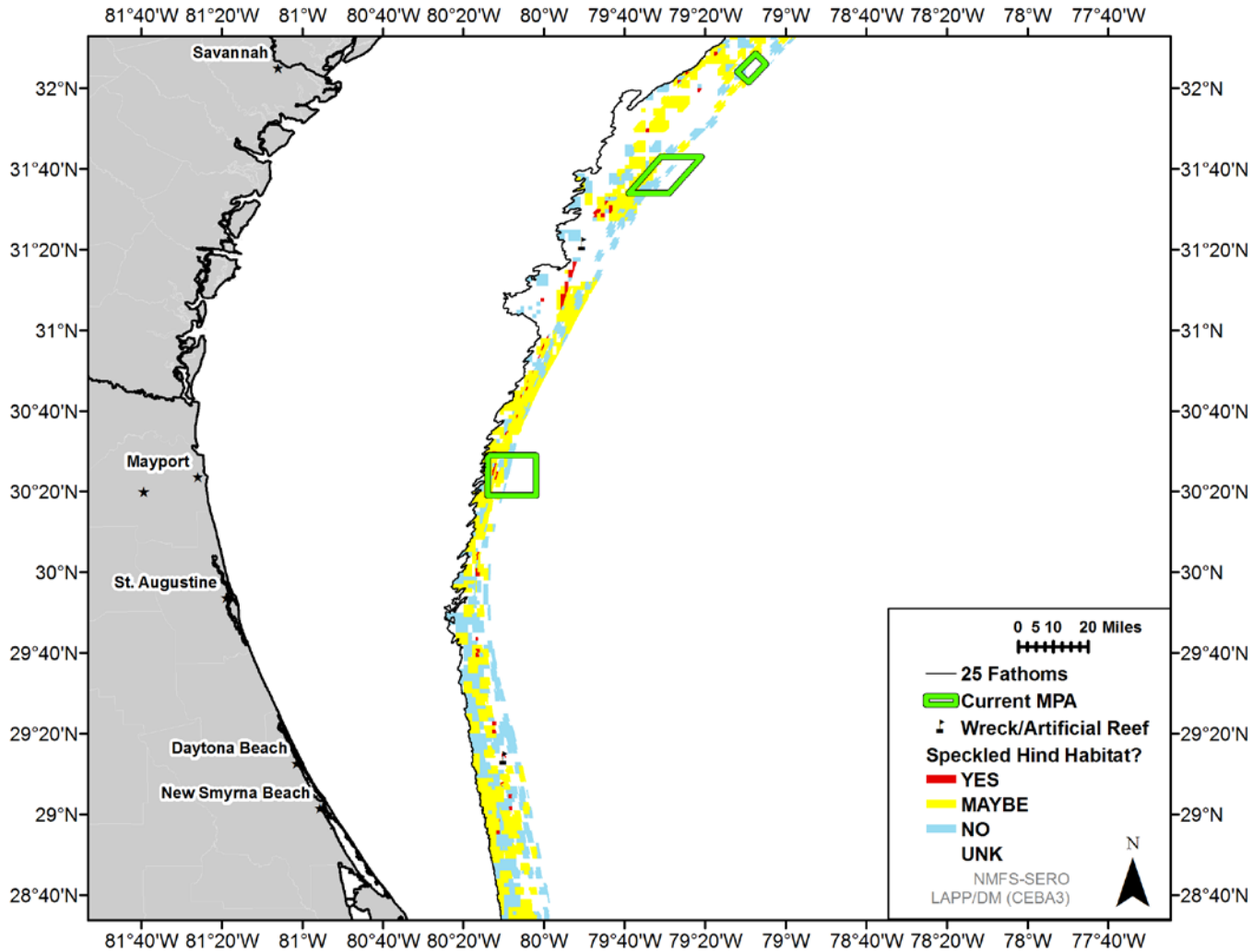

Figure 31. Habitat suitability analysis for speckled hind off Georgia/Northeast Florida, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if speckled hind directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

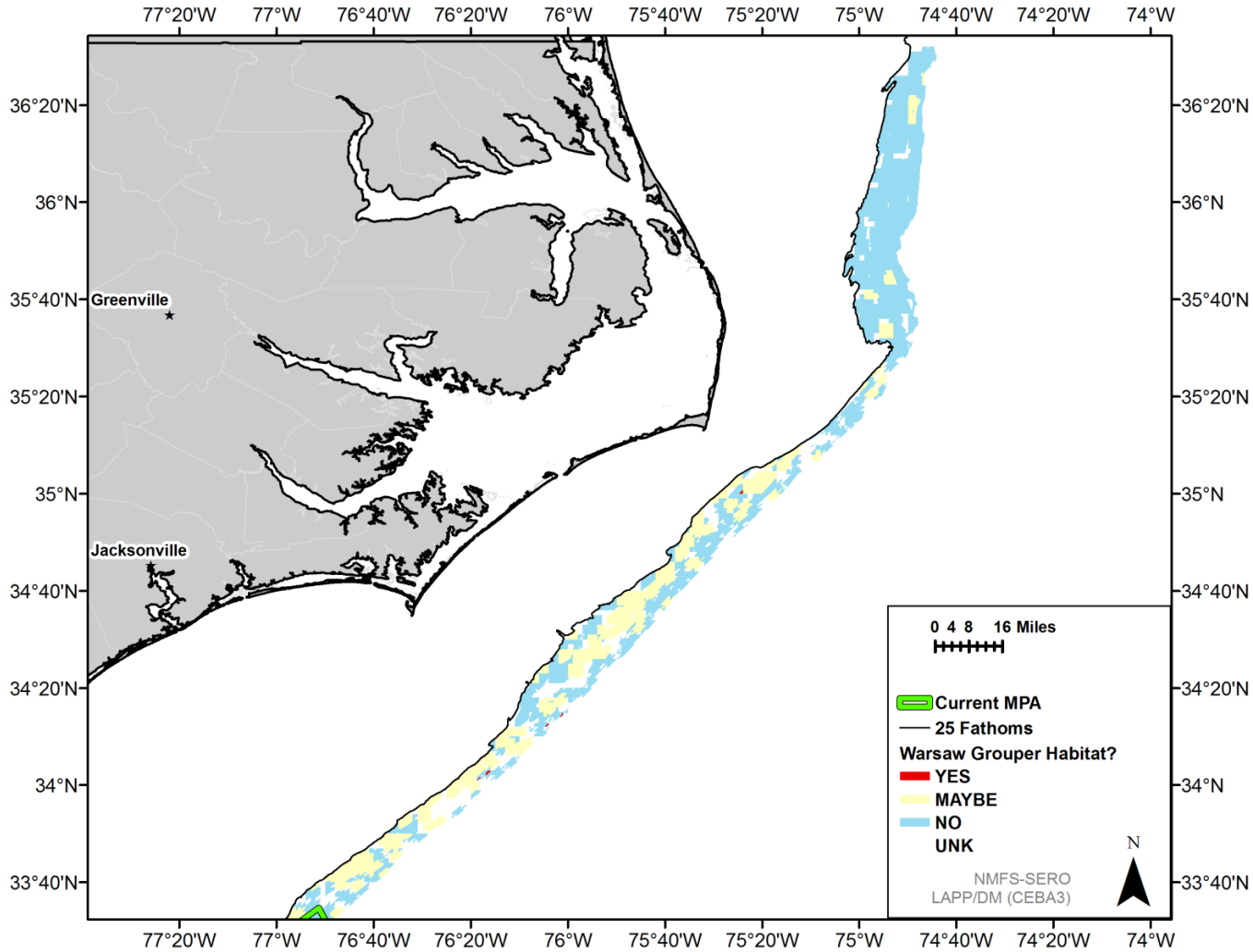

Figure 32. Habitat suitability analysis for warsaw grouper off North Carolina, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if warsaw grouper directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

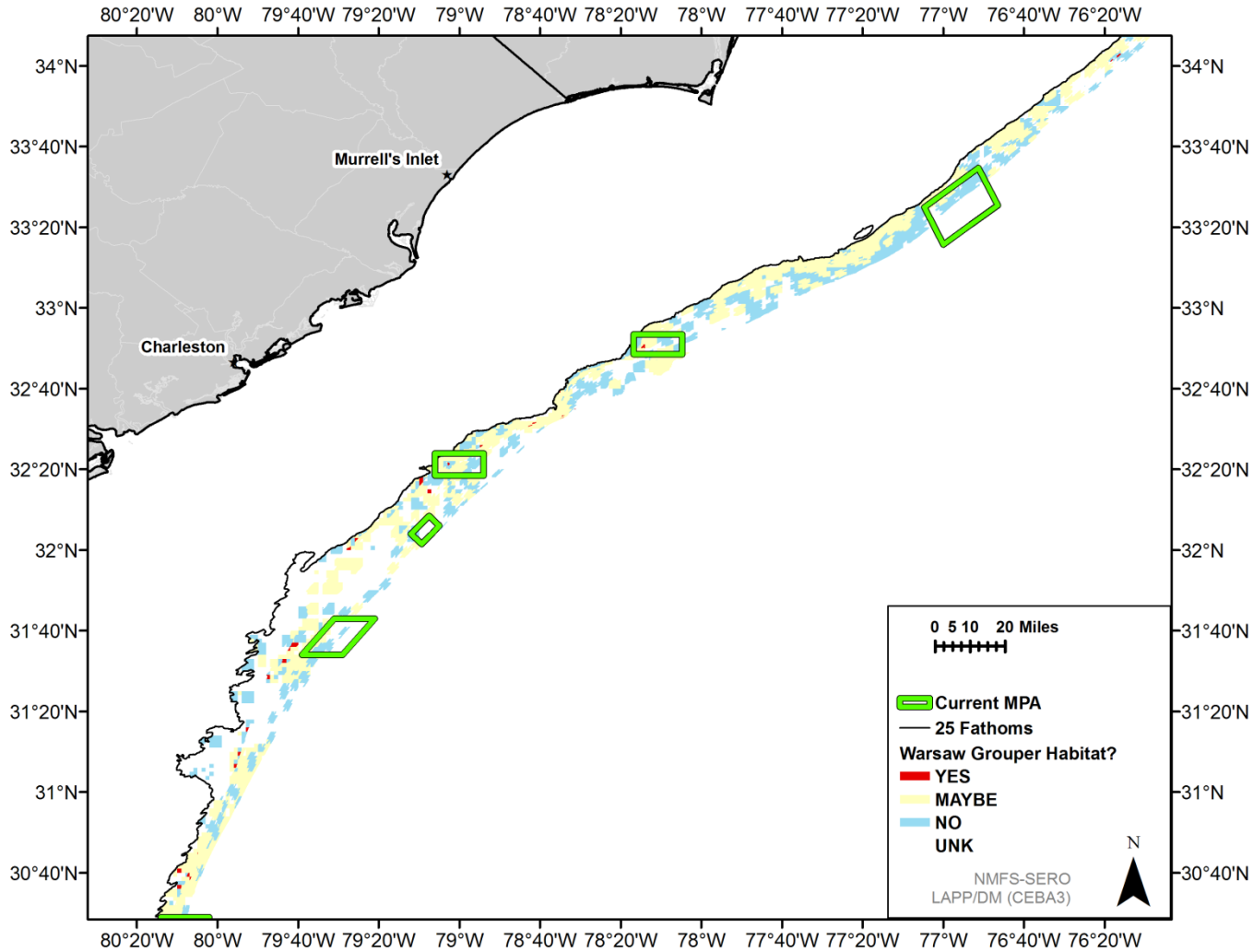

Figure 33. Habitat suitability analysis for warsaw grouper off South Carolina, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if warsaw grouper directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

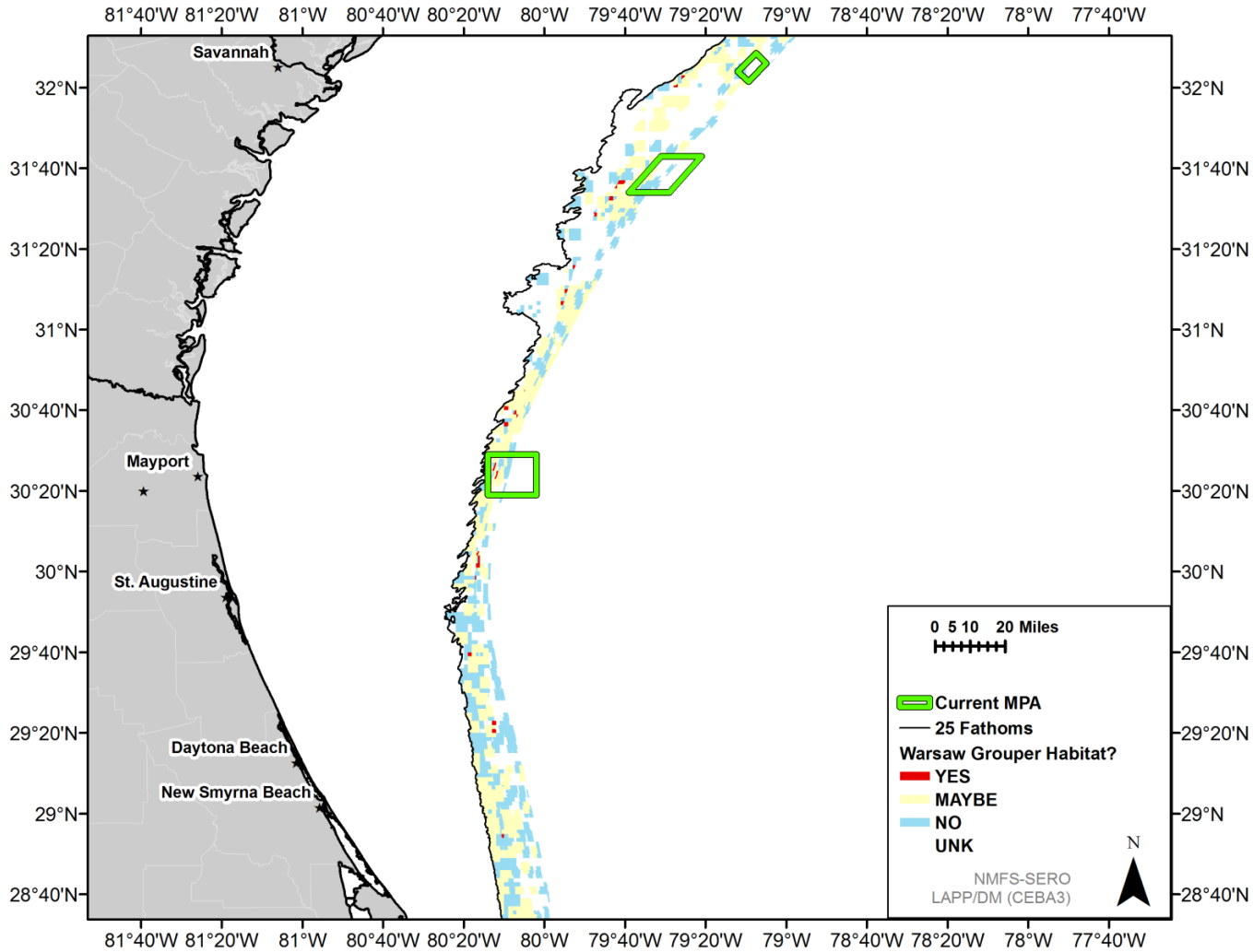

Figure 34. Habitat suitability analysis for warsaw grouper off Georgia/Northeast Florida, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if warsaw grouper directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

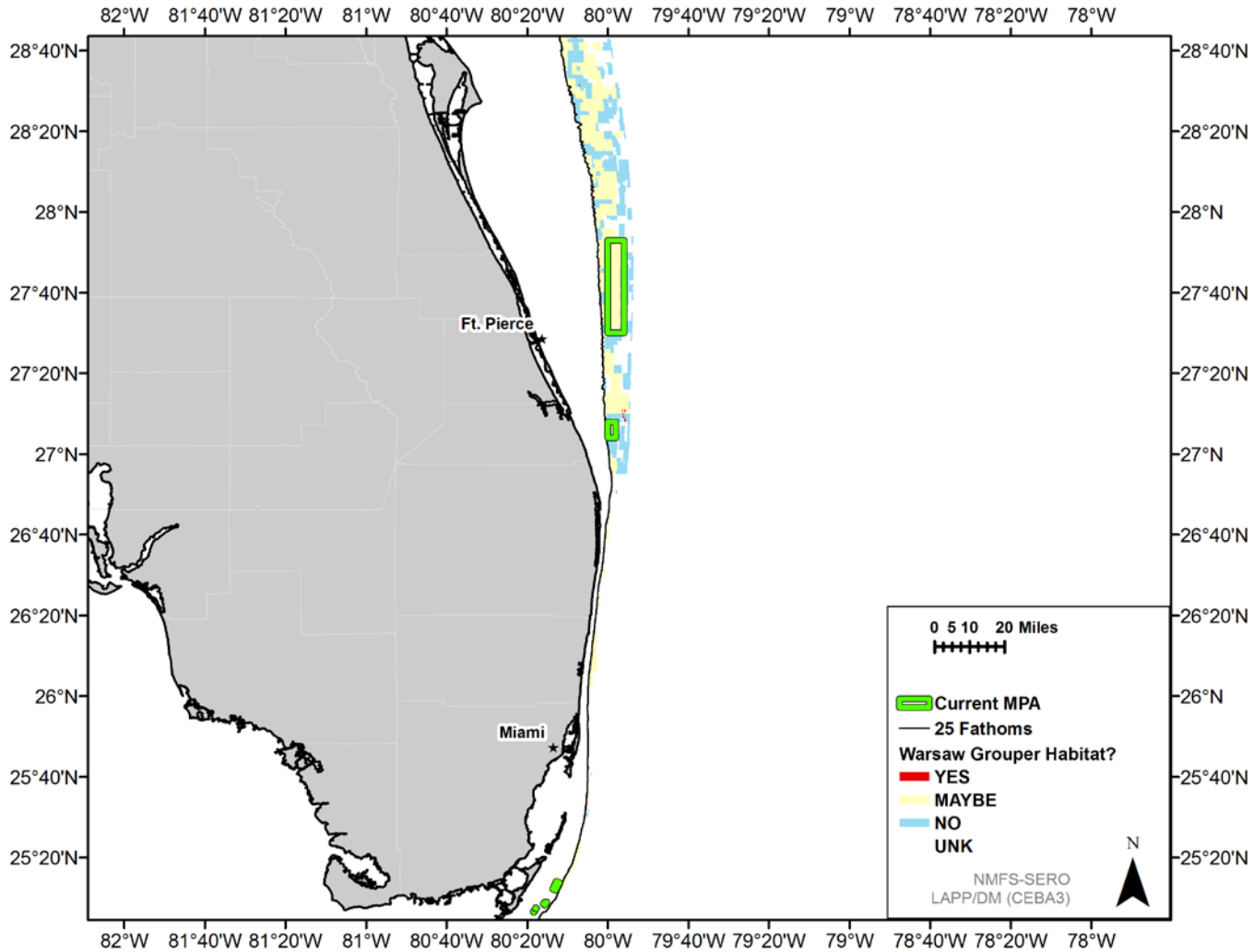

Figure 35. Habitat suitability analysis for warsaw grouper off southeast Florida, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if warsaw grouper directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

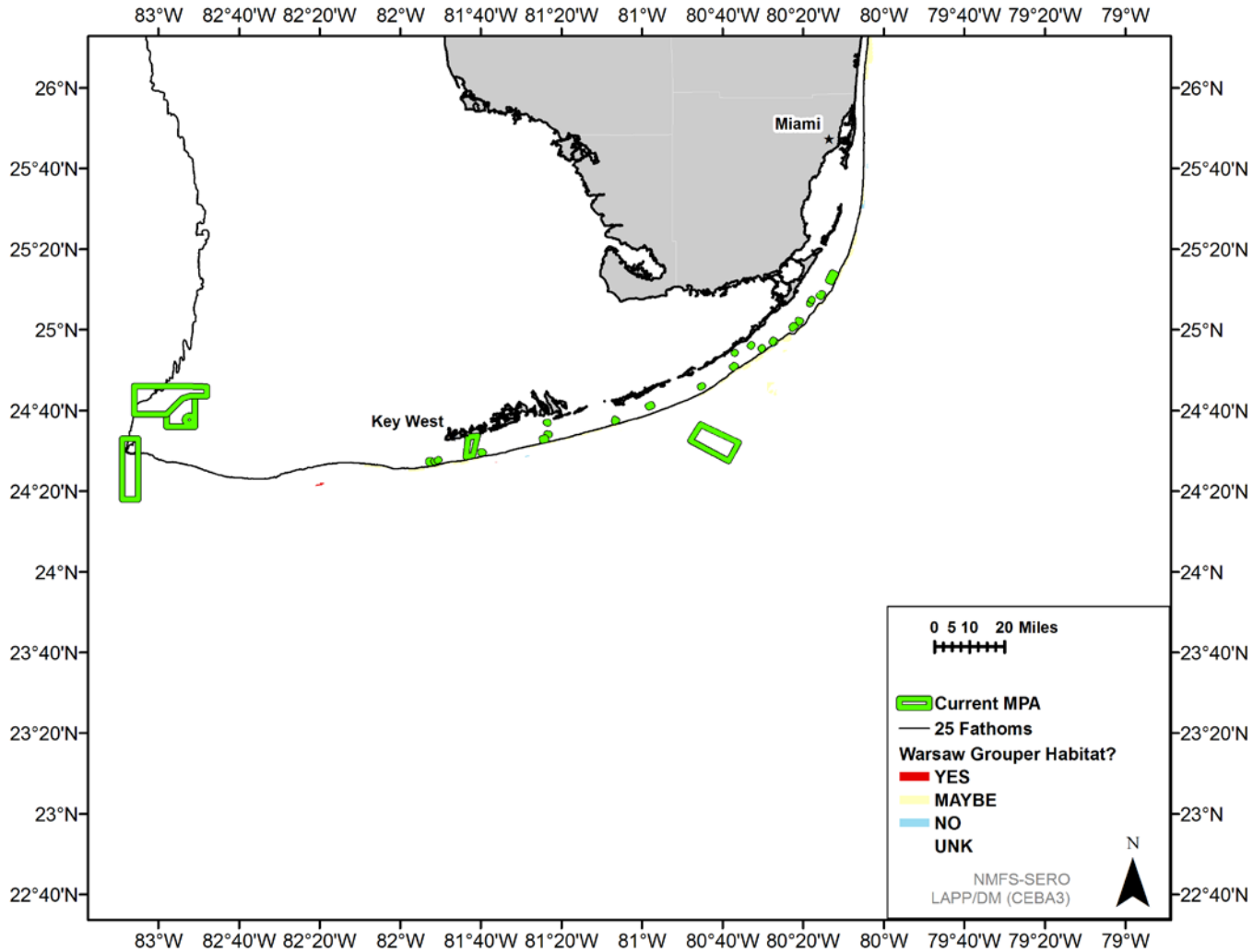

Figure 36. Habitat suitability analysis for warsaw grouper off the Florida Keys, with existing (green) marine protected areas (MPAs). Habitats are categorized as 'Yes' if warsaw grouper directly observed in area, as 'Maybe' if they contained hardbottom or possible hardbottom, and 'No' if they had been sampled more than five times with no observations.

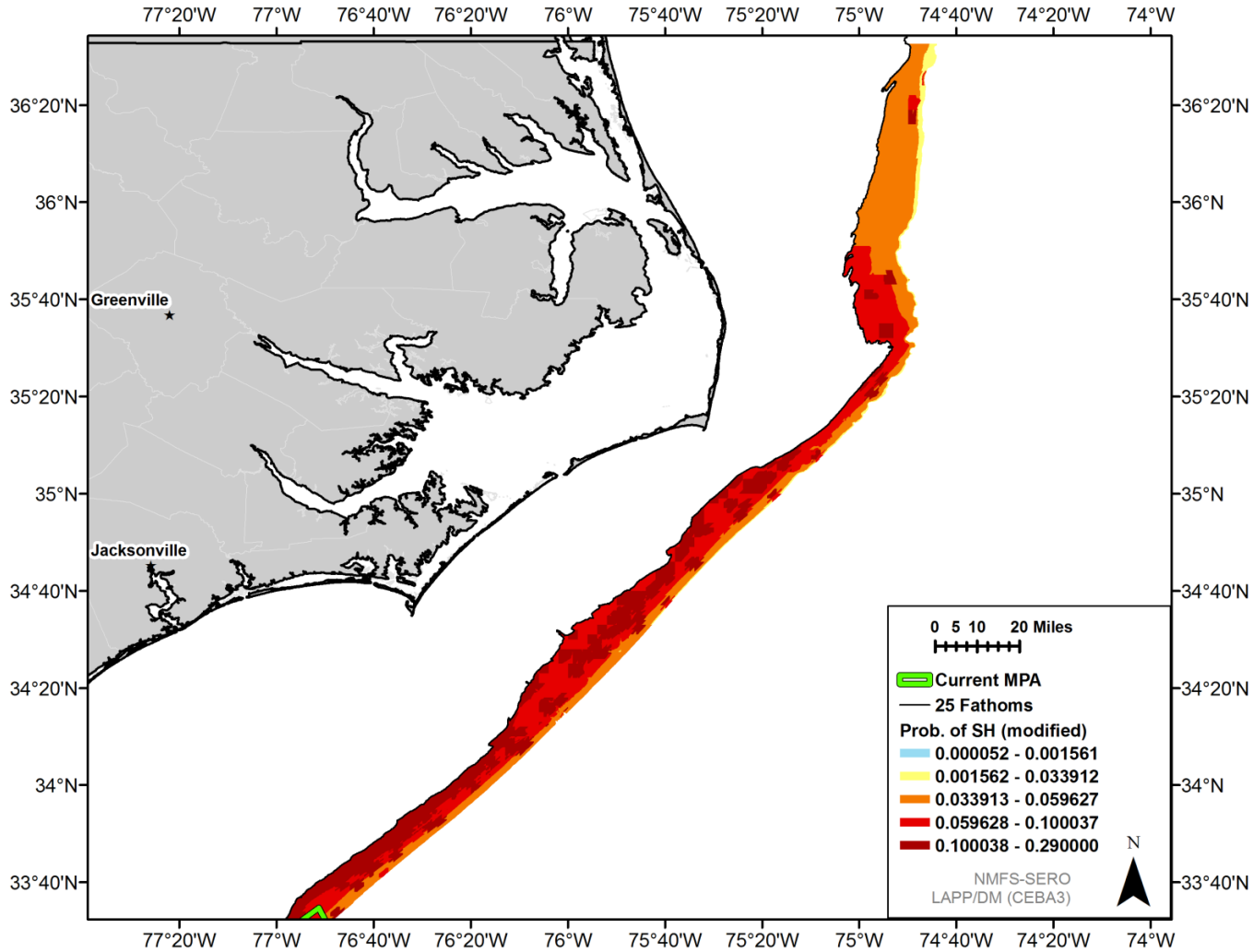

Figure 37. Quantitative habitat suitability analysis based on logistic regression output for speckled hind off North Carolina, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

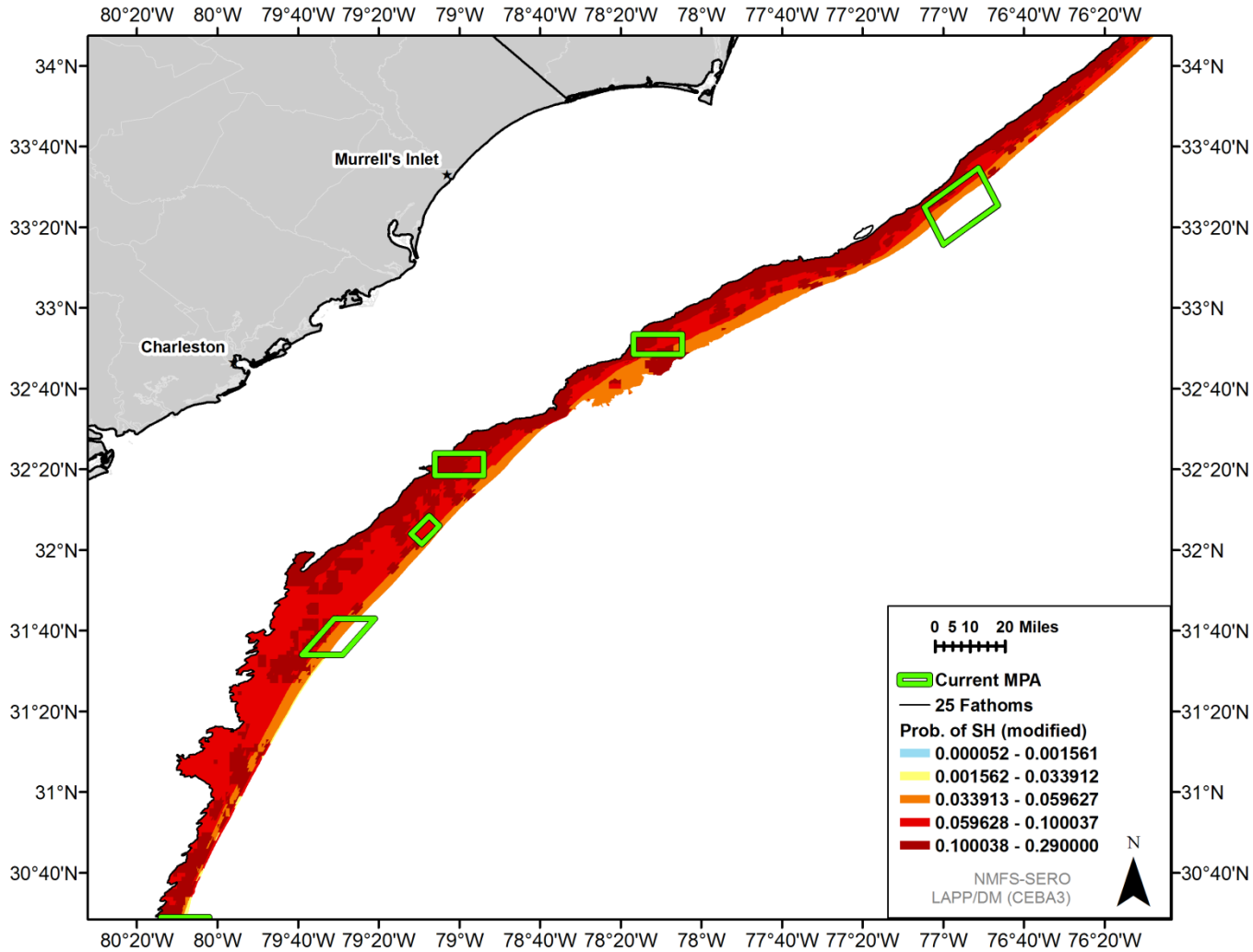

Figure 38. Quantitative habitat suitability analysis based on logistic regression output for speckled hind off South Carolina, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

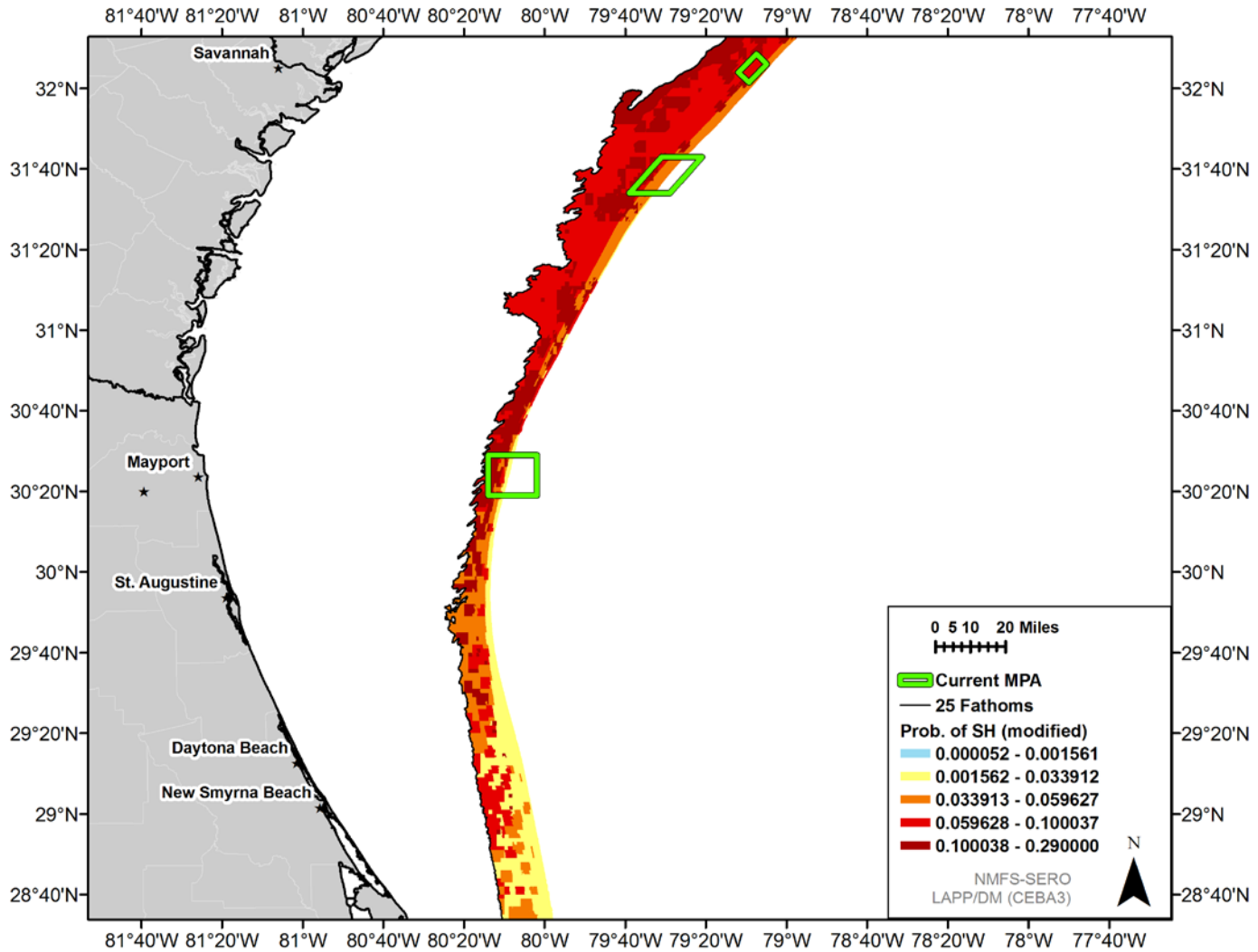

Figure 39. Quantitative habitat suitability analysis based on logistic regression output for speckled hind off Georgia/Northeast Florida, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

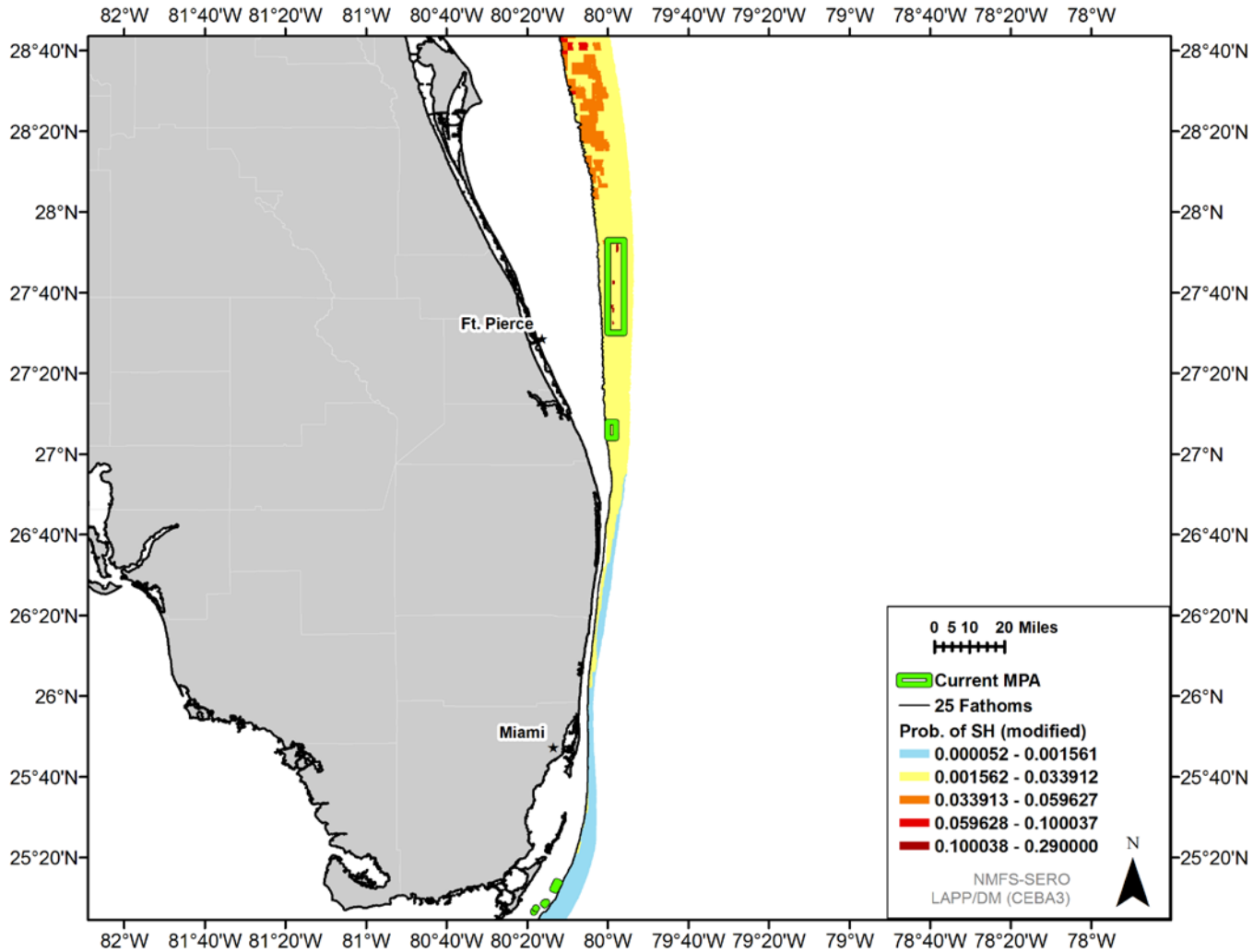

Figure 40. Quantitative habitat suitability analysis based on logistic regression output for speckled hind off southeast Florida, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

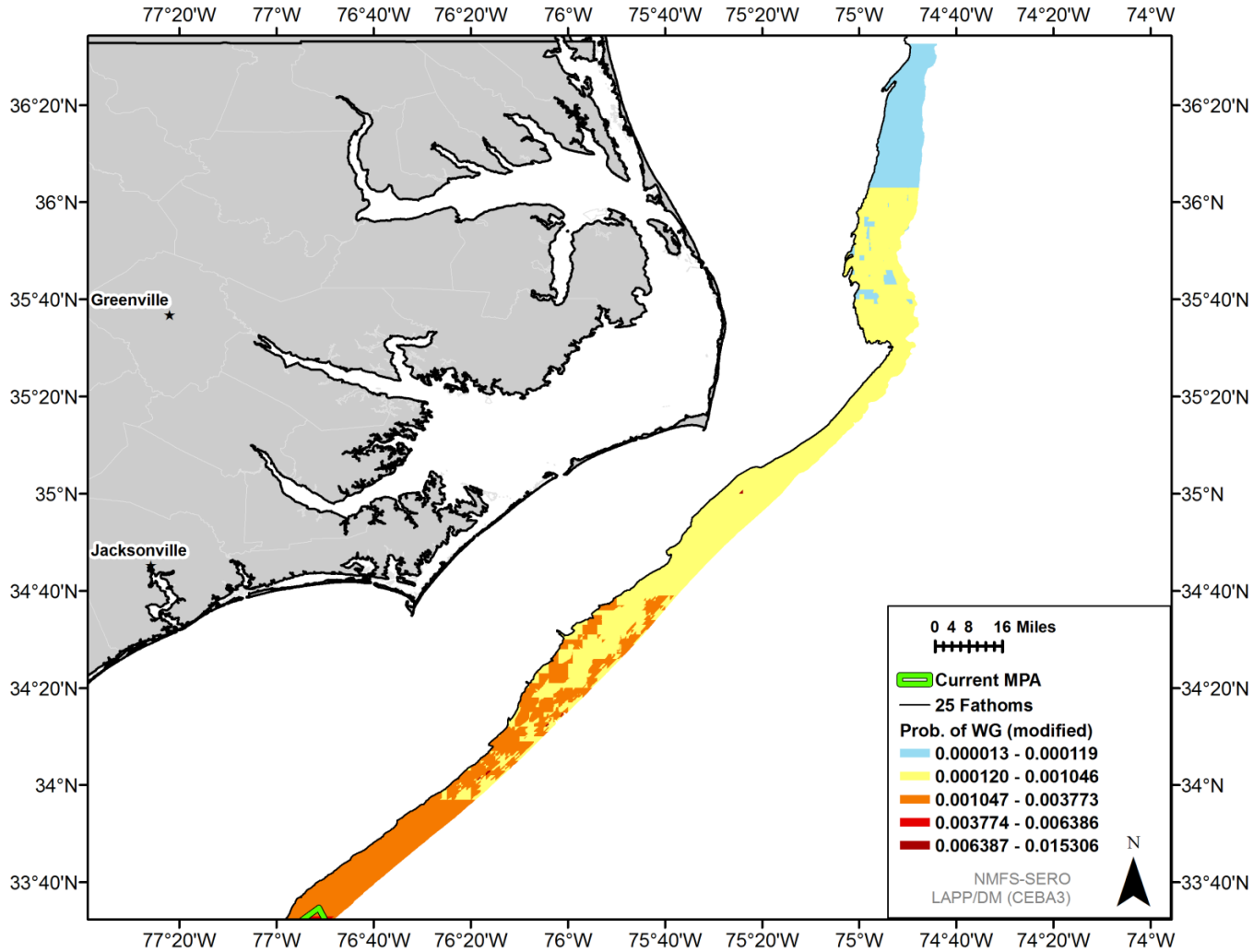

Figure 41. Quantitative habitat suitability analysis based on logistic regression output for warsaw grouper off North Carolina, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

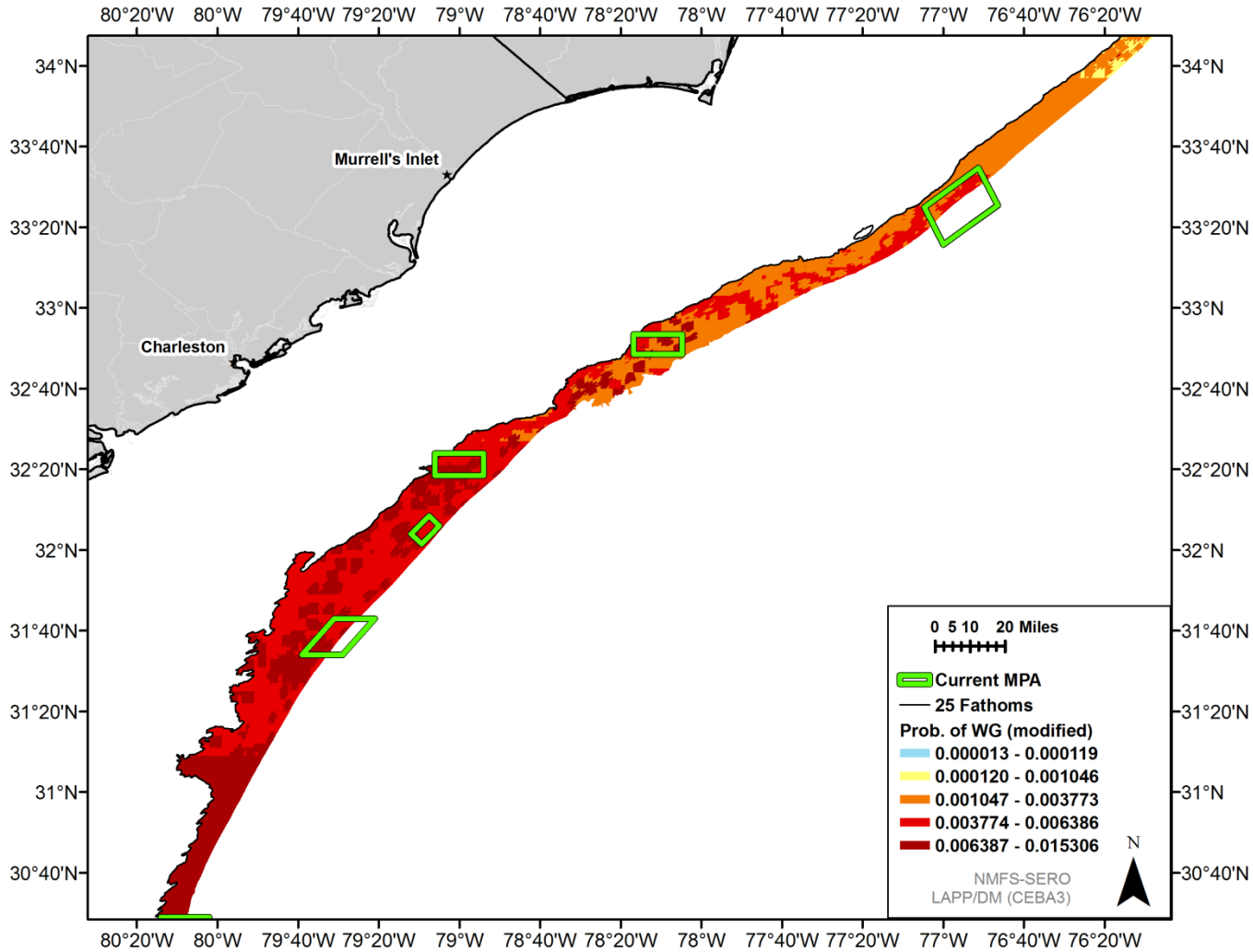

Figure 42. Quantitative habitat suitability analysis based on logistic regression output for warsaw grouper off South Carolina, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

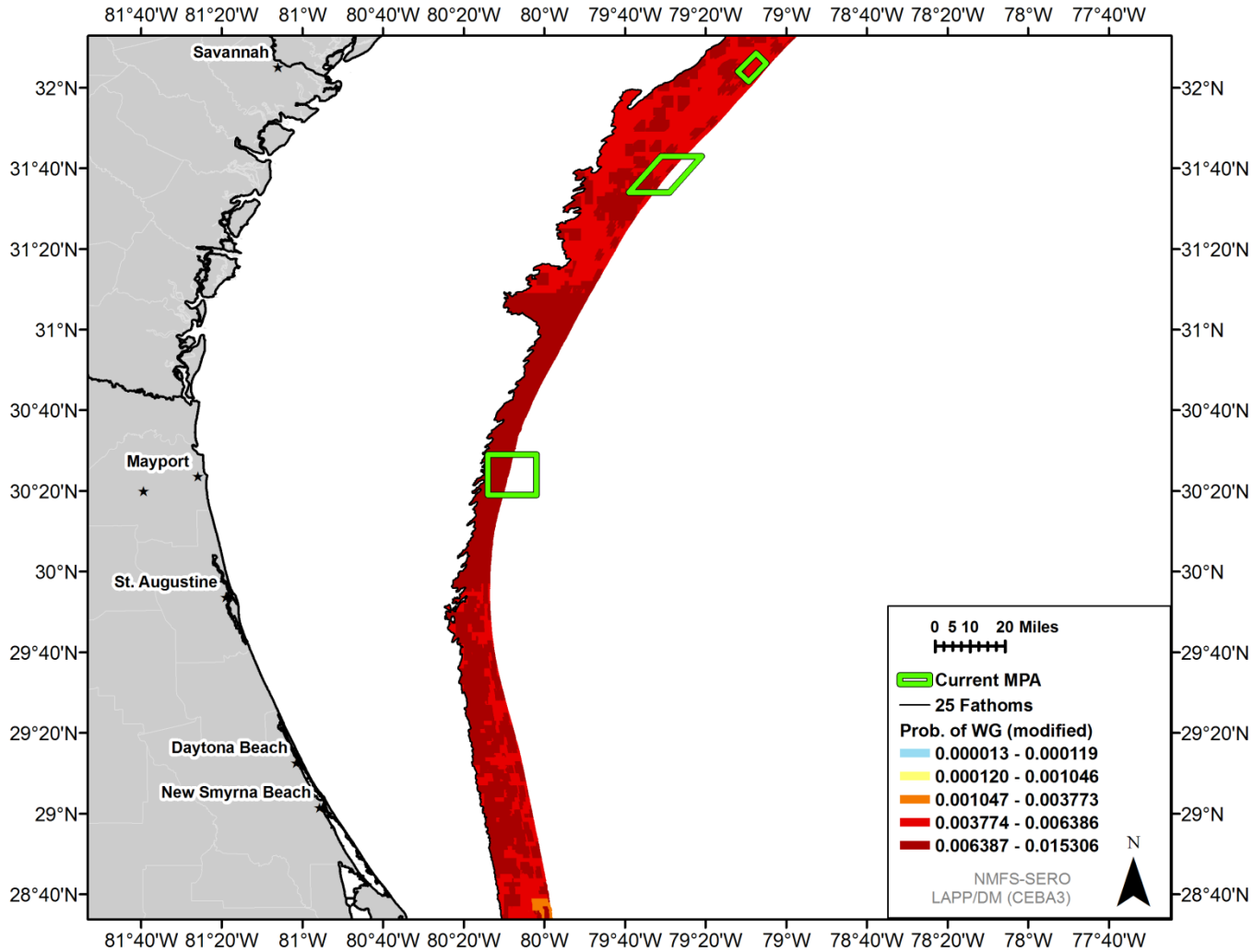

Figure 43. Quantitative habitat suitability analysis based on logistic regression output for warsaw grouper off Georgia/Northeast Florida, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

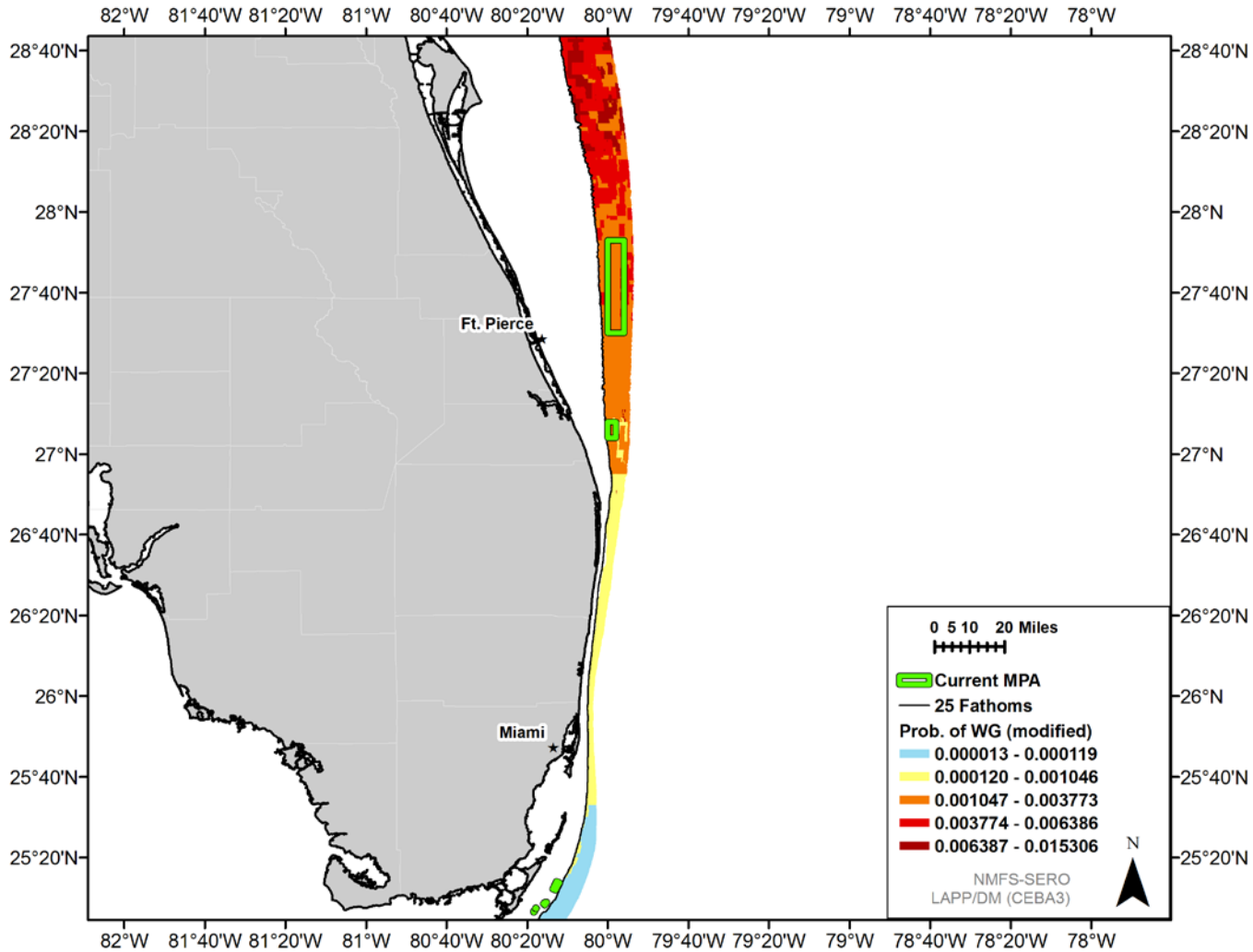

Figure 44. Quantitative habitat suitability analysis based on logistic regression output for warsaw grouper off southeast Florida, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

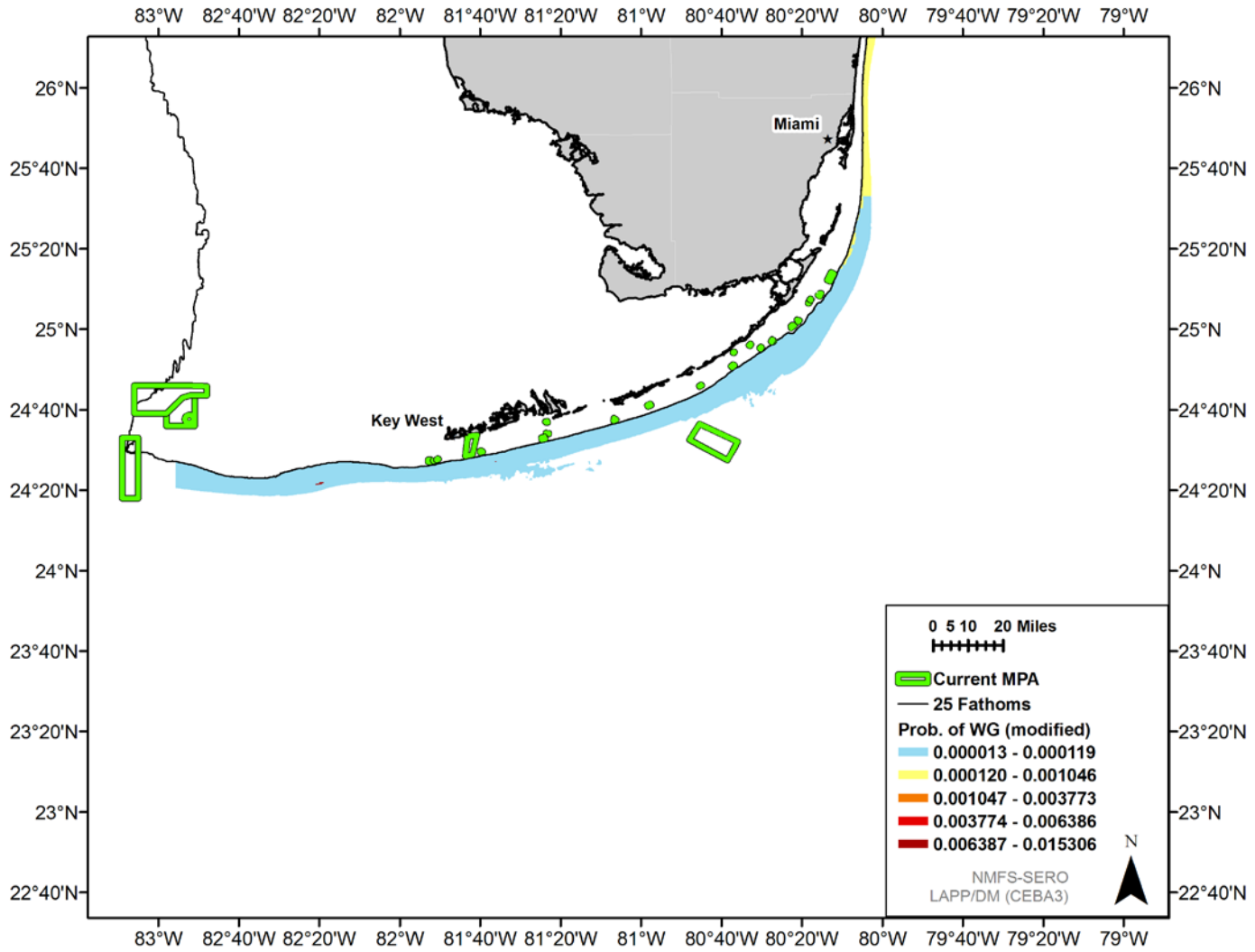

Figure 45. Quantitative habitat suitability analysis based on logistic regression output for warsaw grouper off the Florida Keys, with existing (green) marine protected areas (MPAs). Probability of an observation is expressed in decimal form and categorized by quantiles.

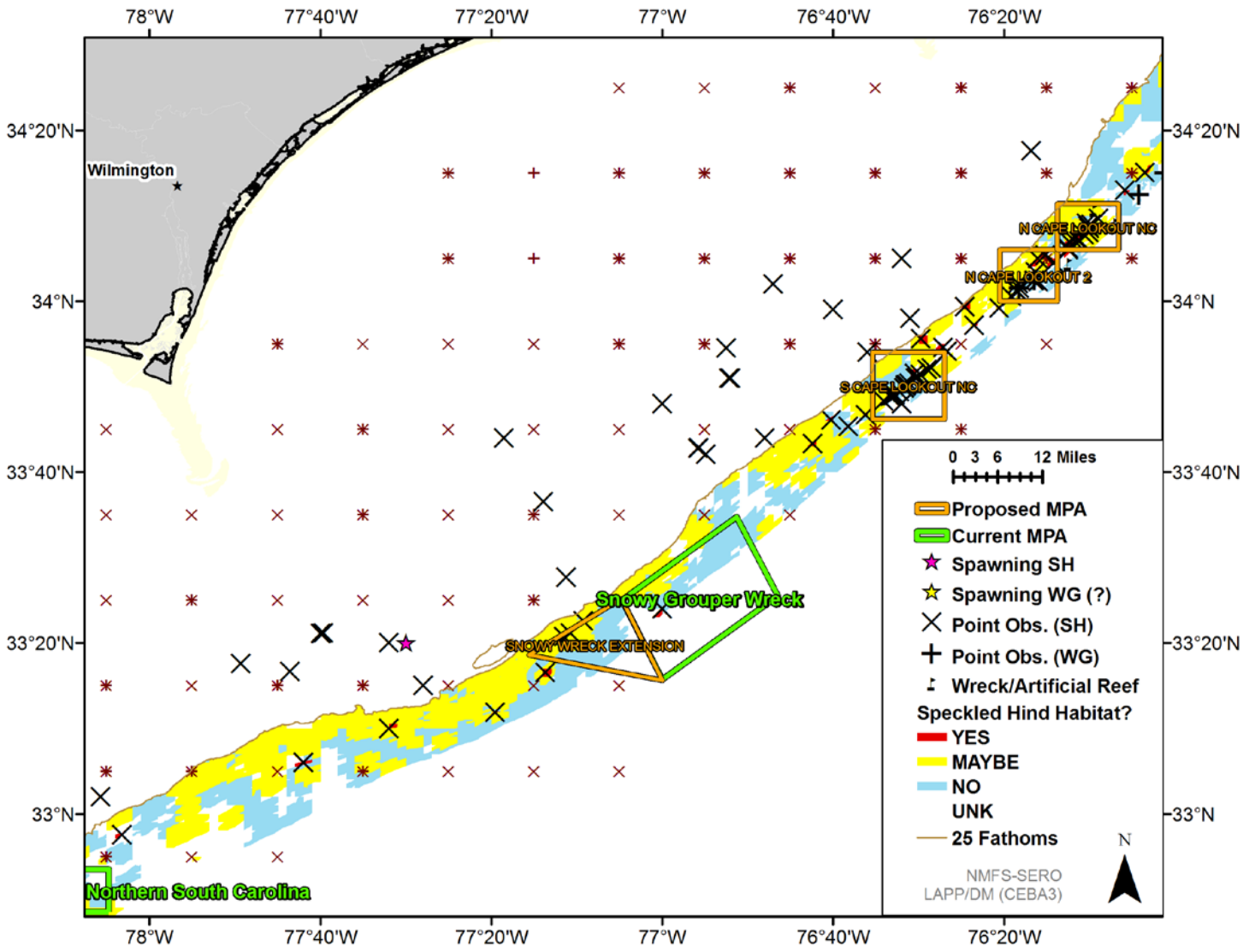

Figure 46. Proposed (orange) and existing spatial closures (green) off North Carolina relative to qualitative habitat suitability analysis for speckled hind and point observations of speckled hind and warsaw grouper.

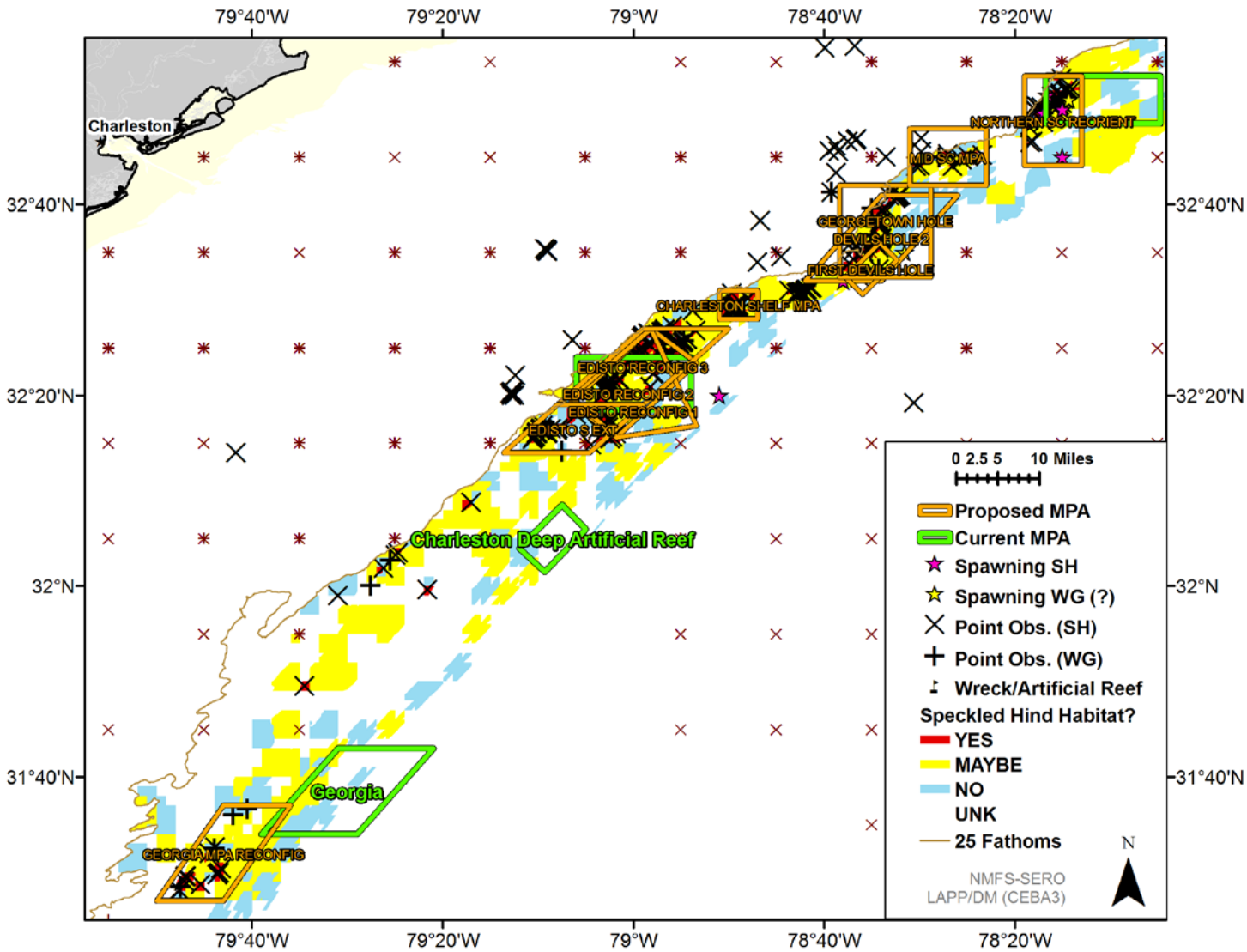

Figure 47. Proposed (orange) and existing spatial closures (green) off South Carolina relative to qualitative habitat suitability analysis for speckled hind and point observations of speckled hind and warsaw grouper.

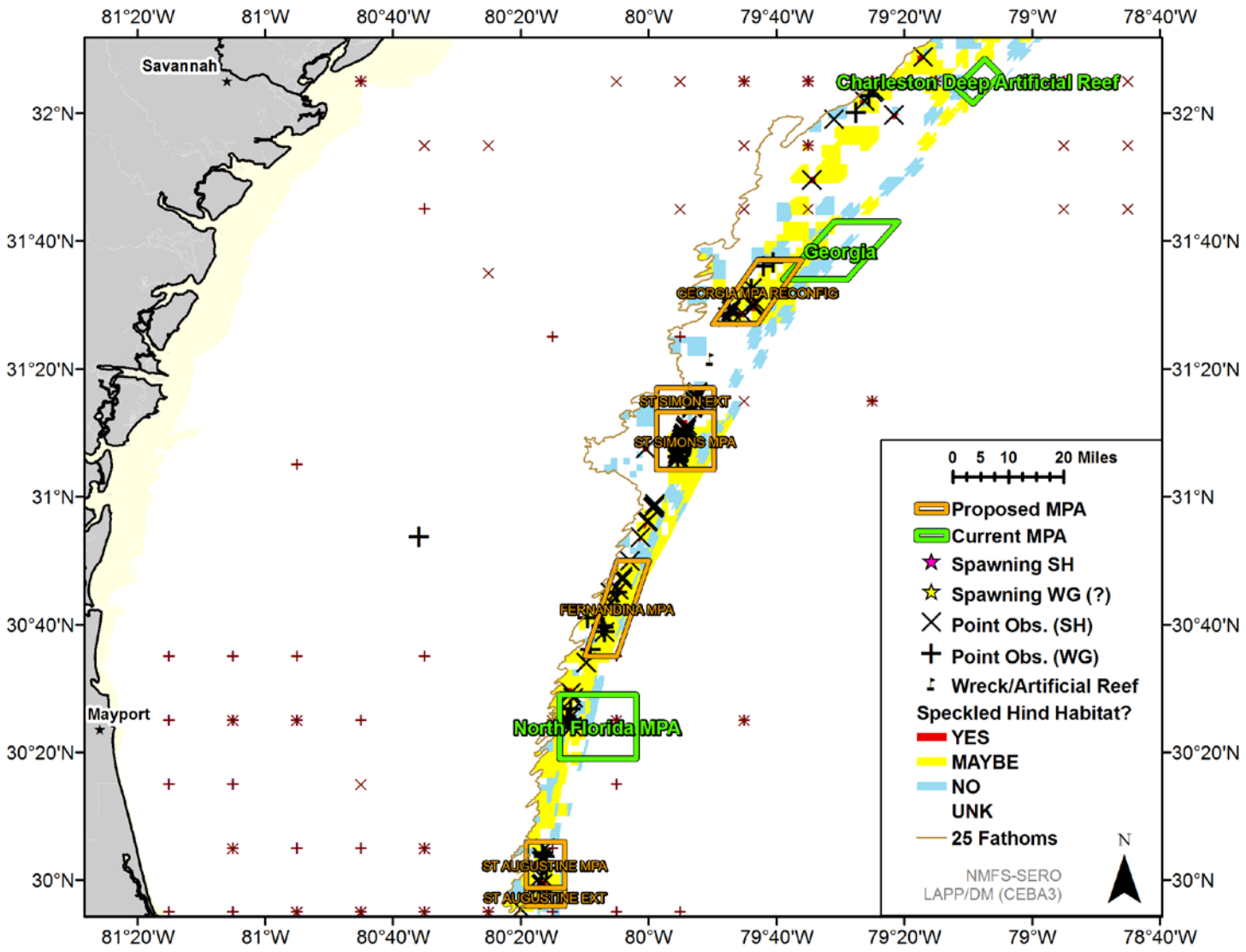

Figure 48. Proposed (orange) and existing spatial closures (green) off Georgia relative to qualitative habitat suitability analysis for speckled hind and point observations of speckled hind and warsaw grouper.

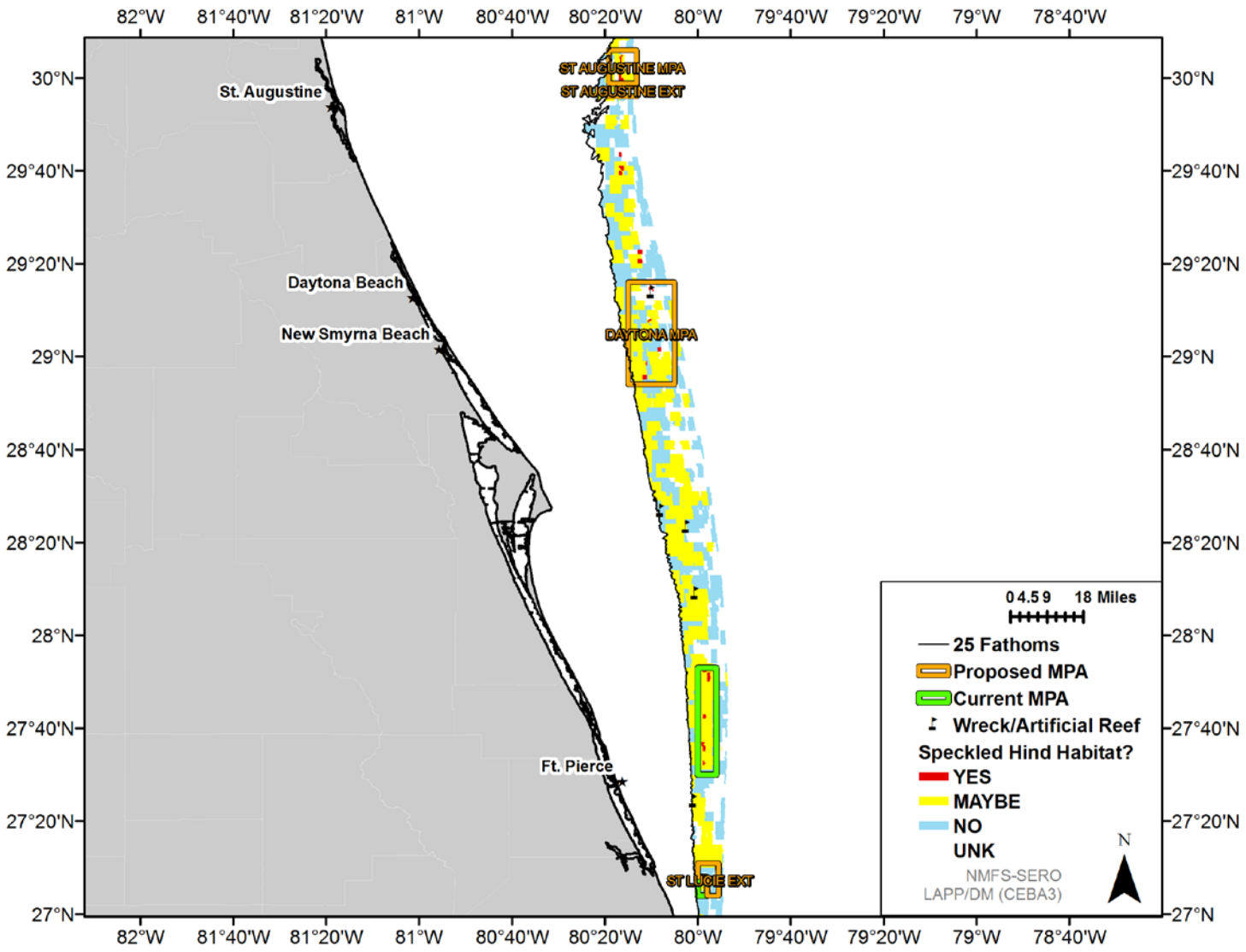

Figure 49. Proposed (orange) and existing spatial closures (green) off Southeast Florida relative to qualitative habitat suitability analysis for speckled hind and point observations of speckled hind and warsaw grouper.

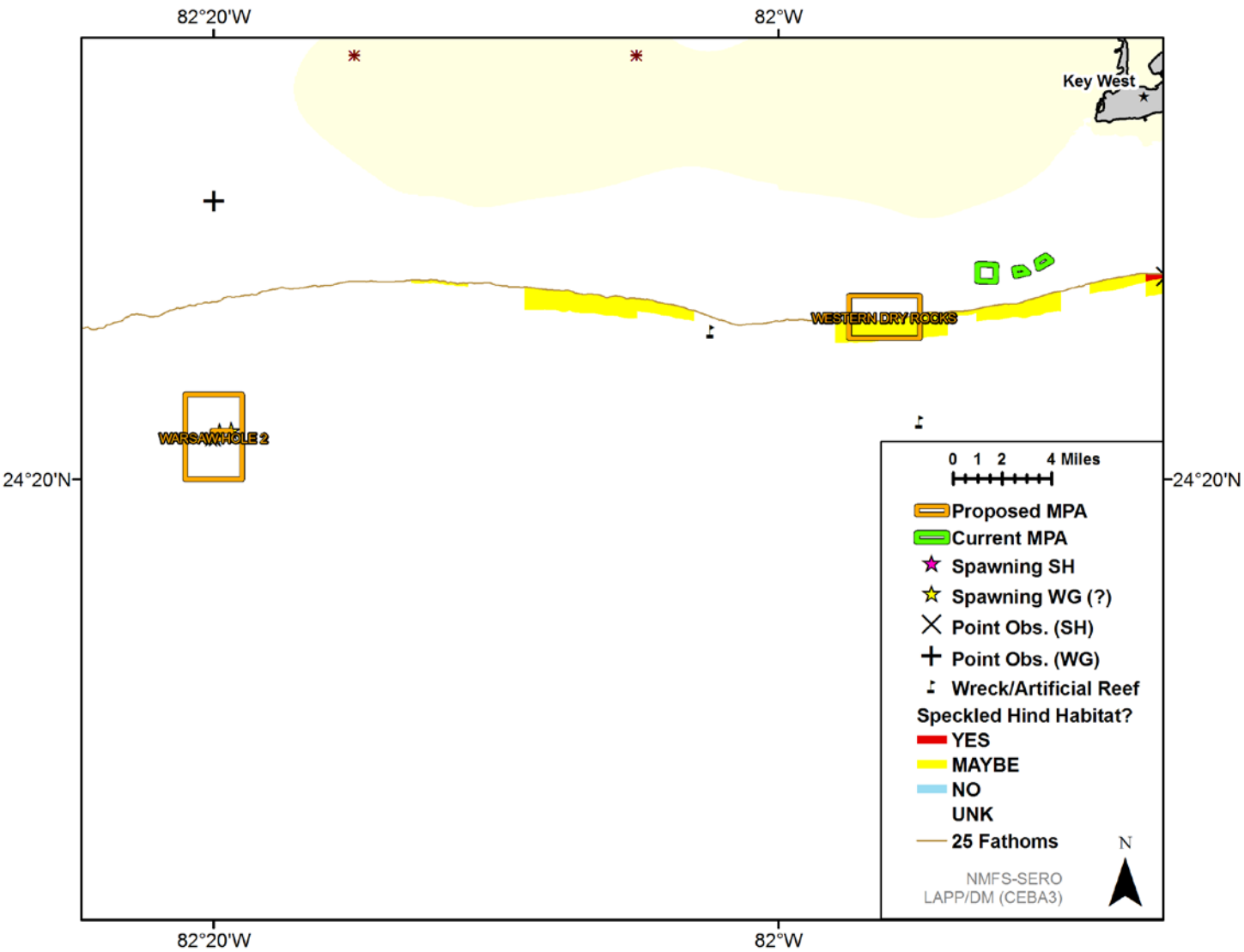

Figure 50. Proposed (orange) and existing spatial closures (green) off the Florida Keys relative to qualitative habitat suitability analysis for speckled hind and point observations of speckled hind and warsaw grouper.

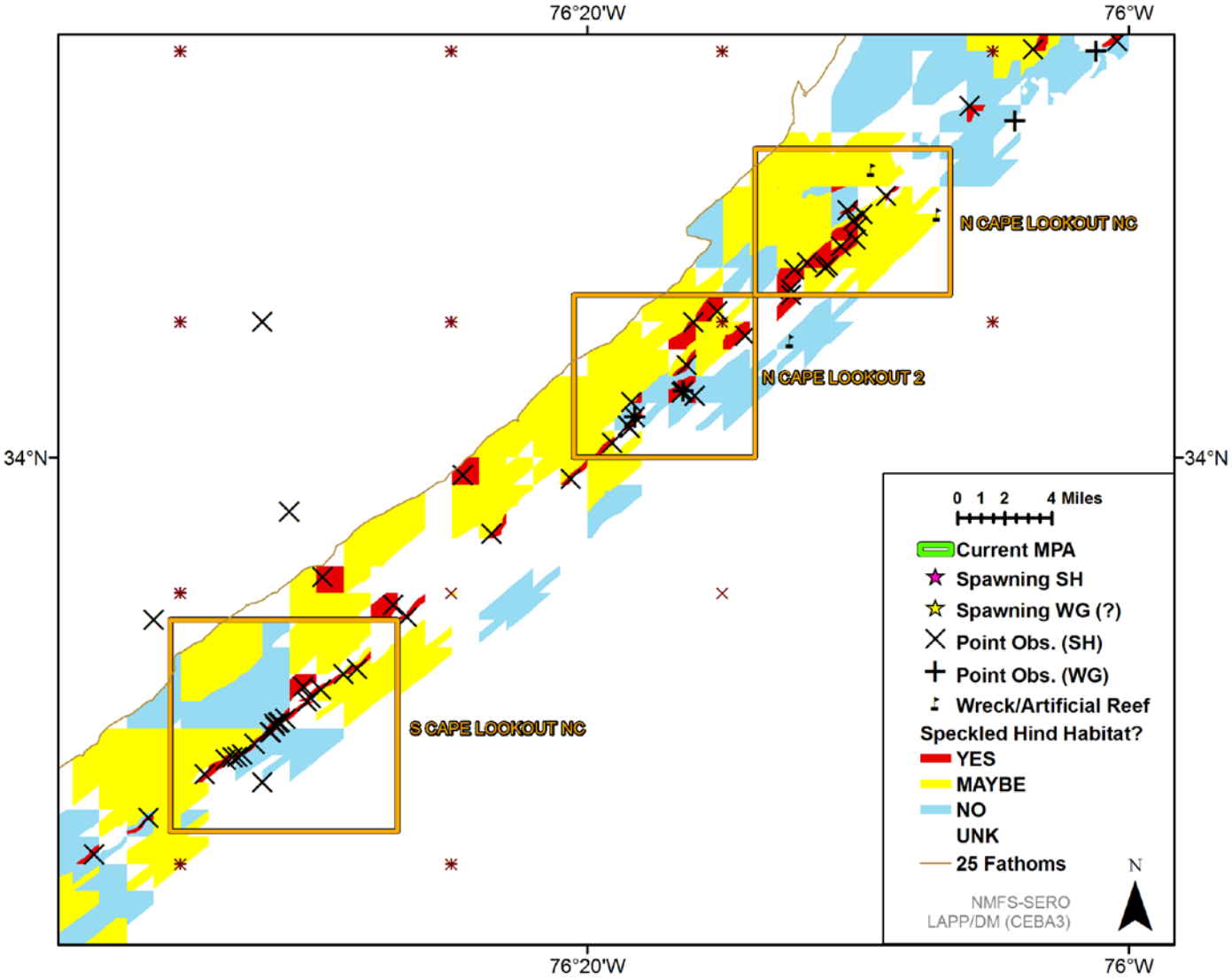

Figure 51. Close-up of proposed (orange) and current (green) marine reserves off North Carolina relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

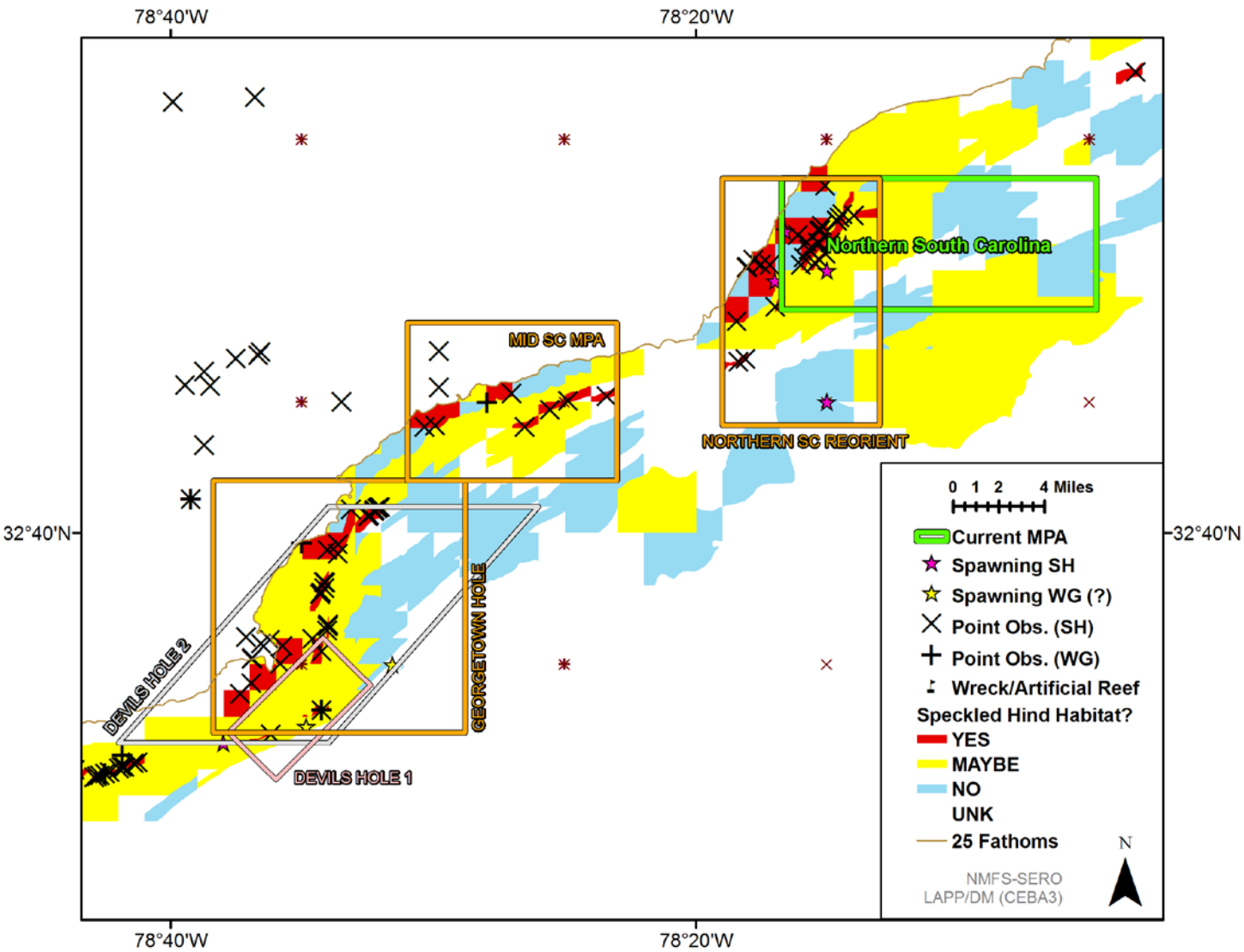

Figure 52. Close-up of proposed and current (green) marine reserves off northern South Carolina relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

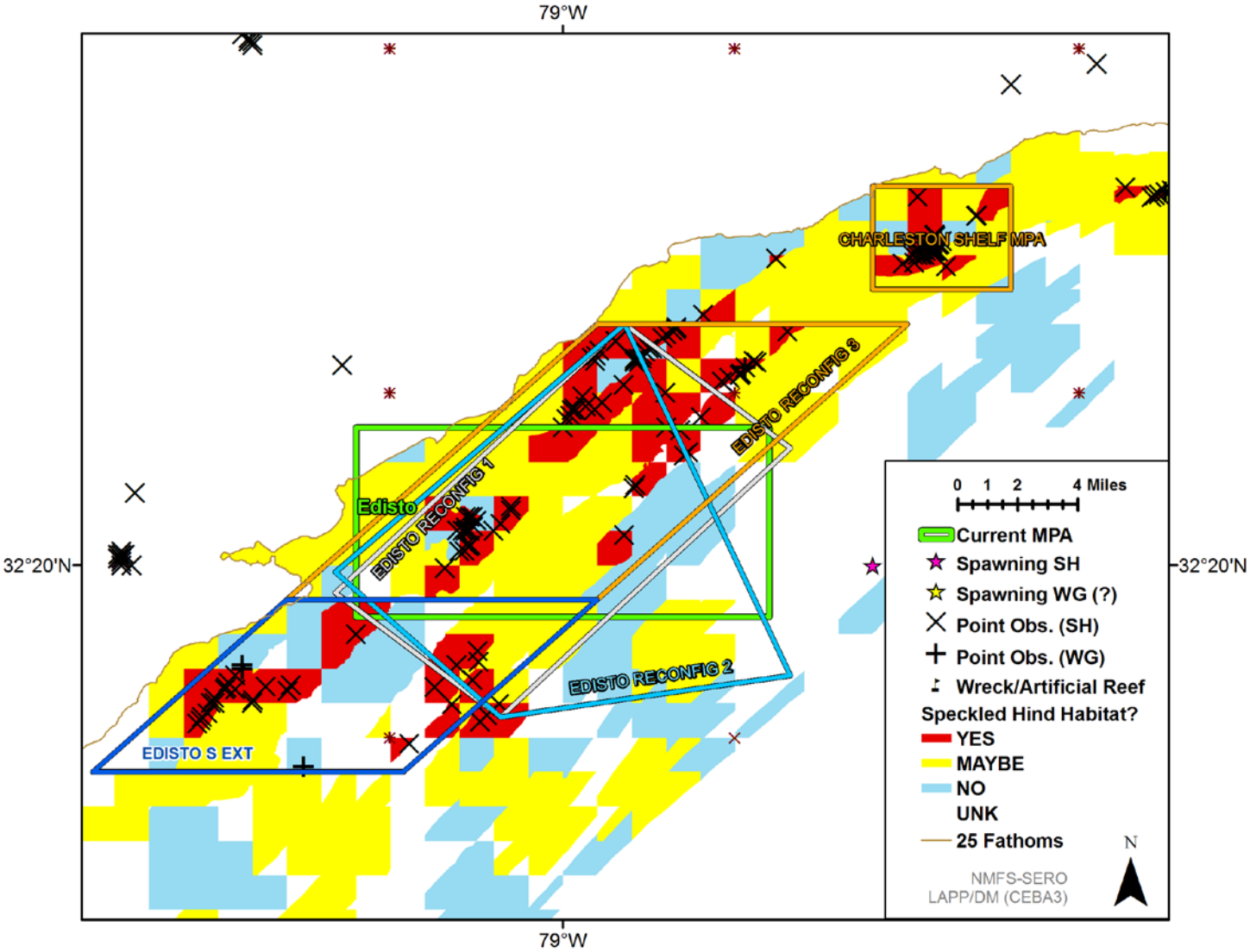

Figure 53. Close-up of proposed and current (green) marine reserves off southern South Carolina relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

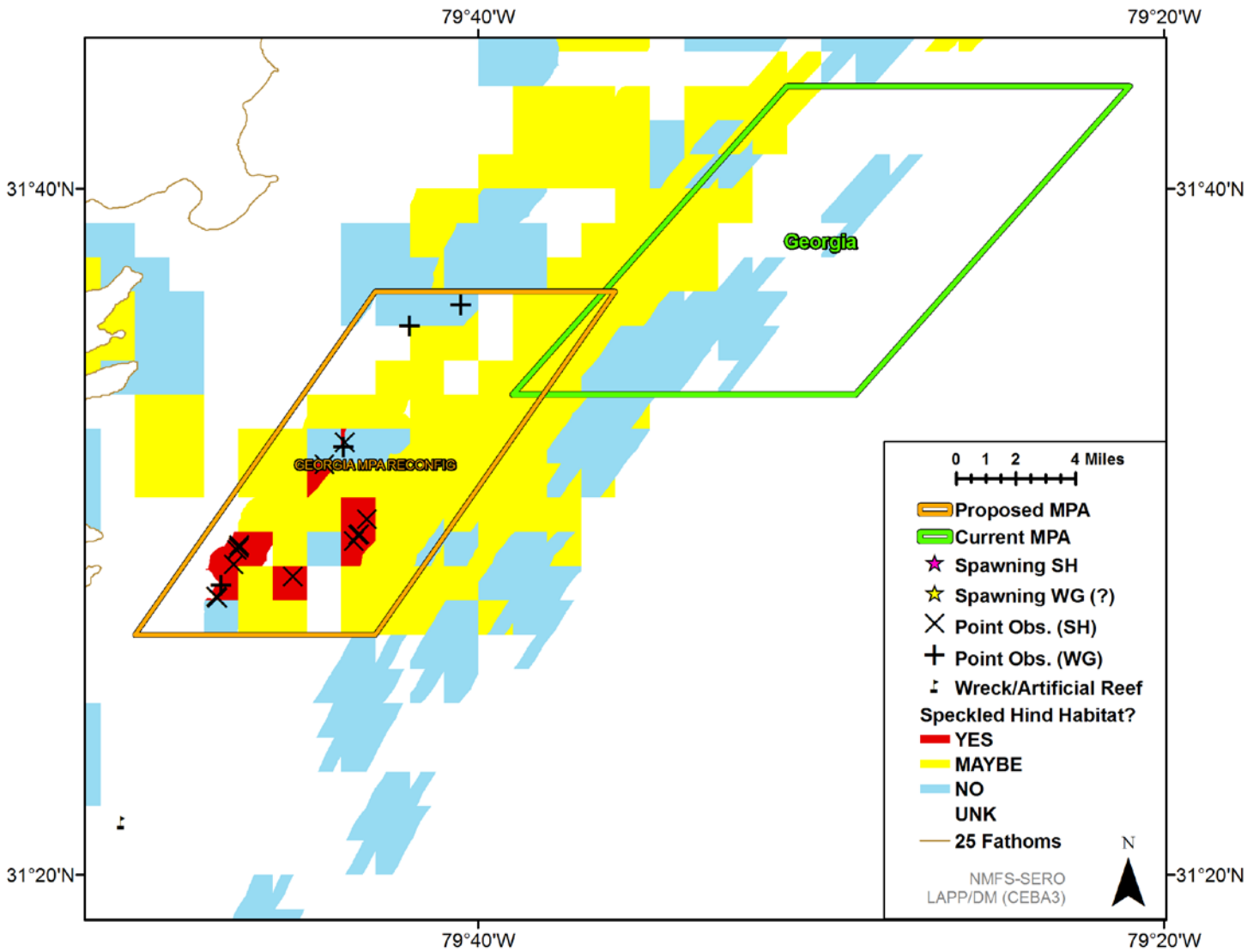

Figure 54. Close-up of proposed and current (green) marine reserves off northern Georgia relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

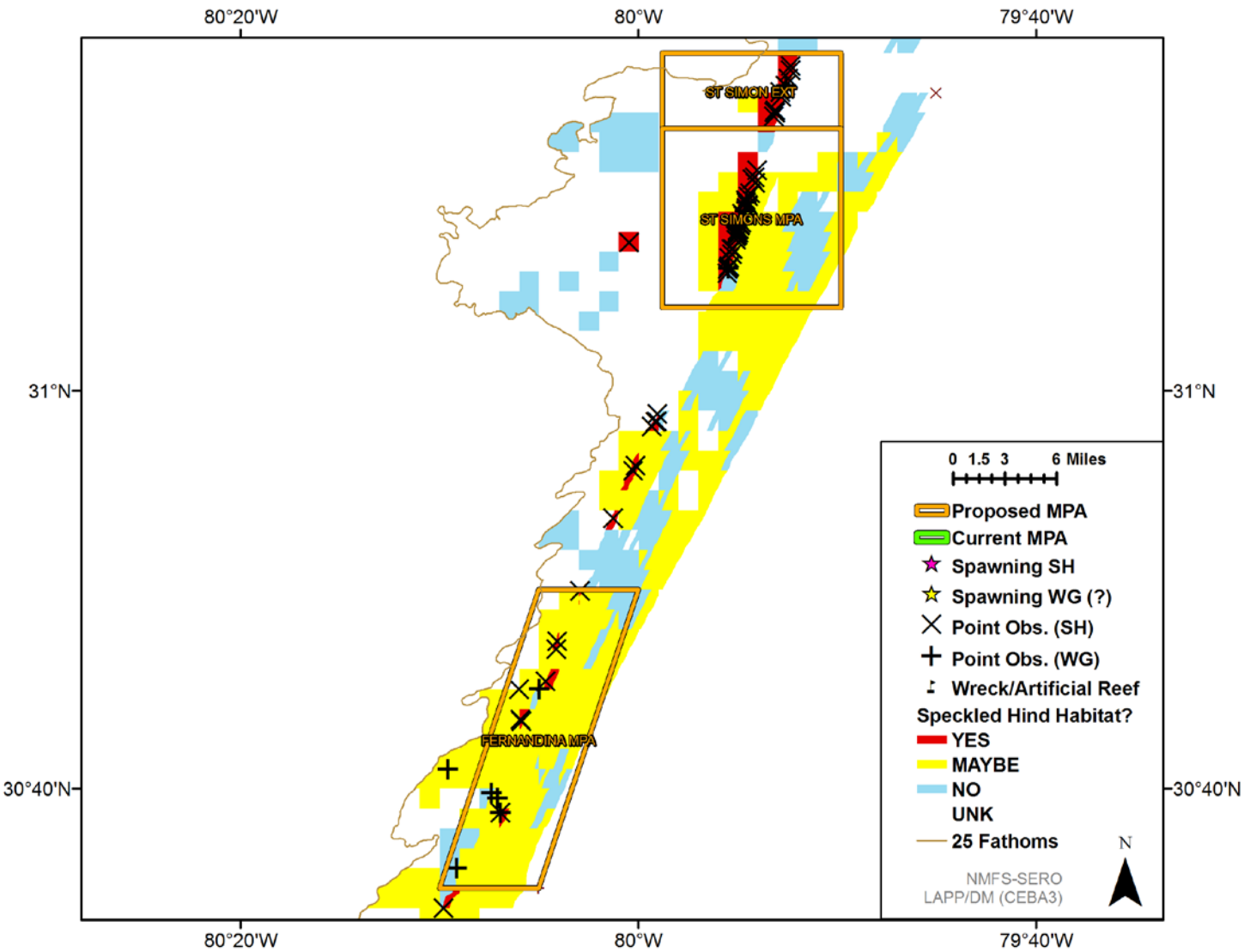

Figure 55. Close-up of proposed and current (green) marine reserves off southern Georgia and northern Florida relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

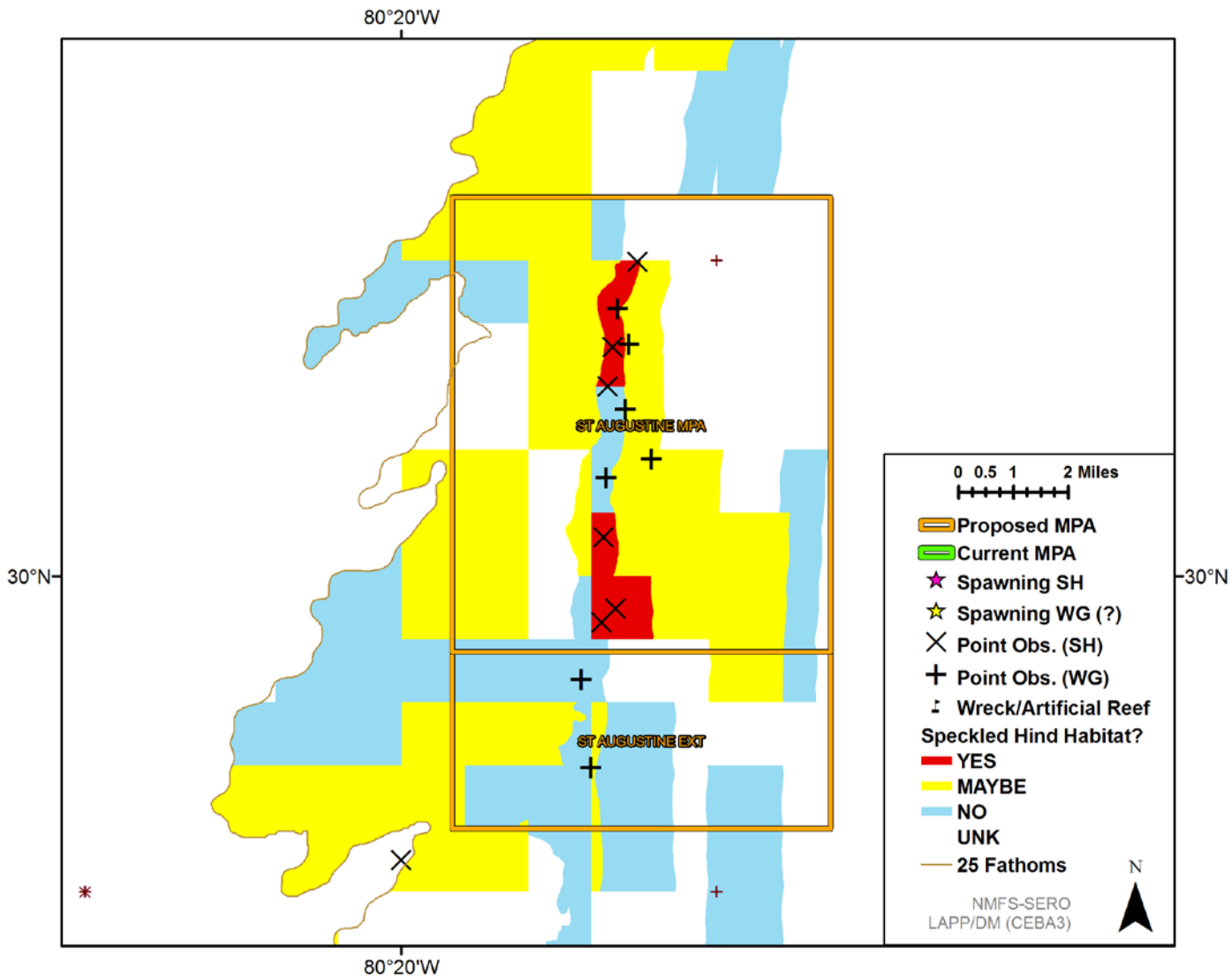

Figure 56. Close-up of proposed marine reserves off St. Augustine, Florida relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

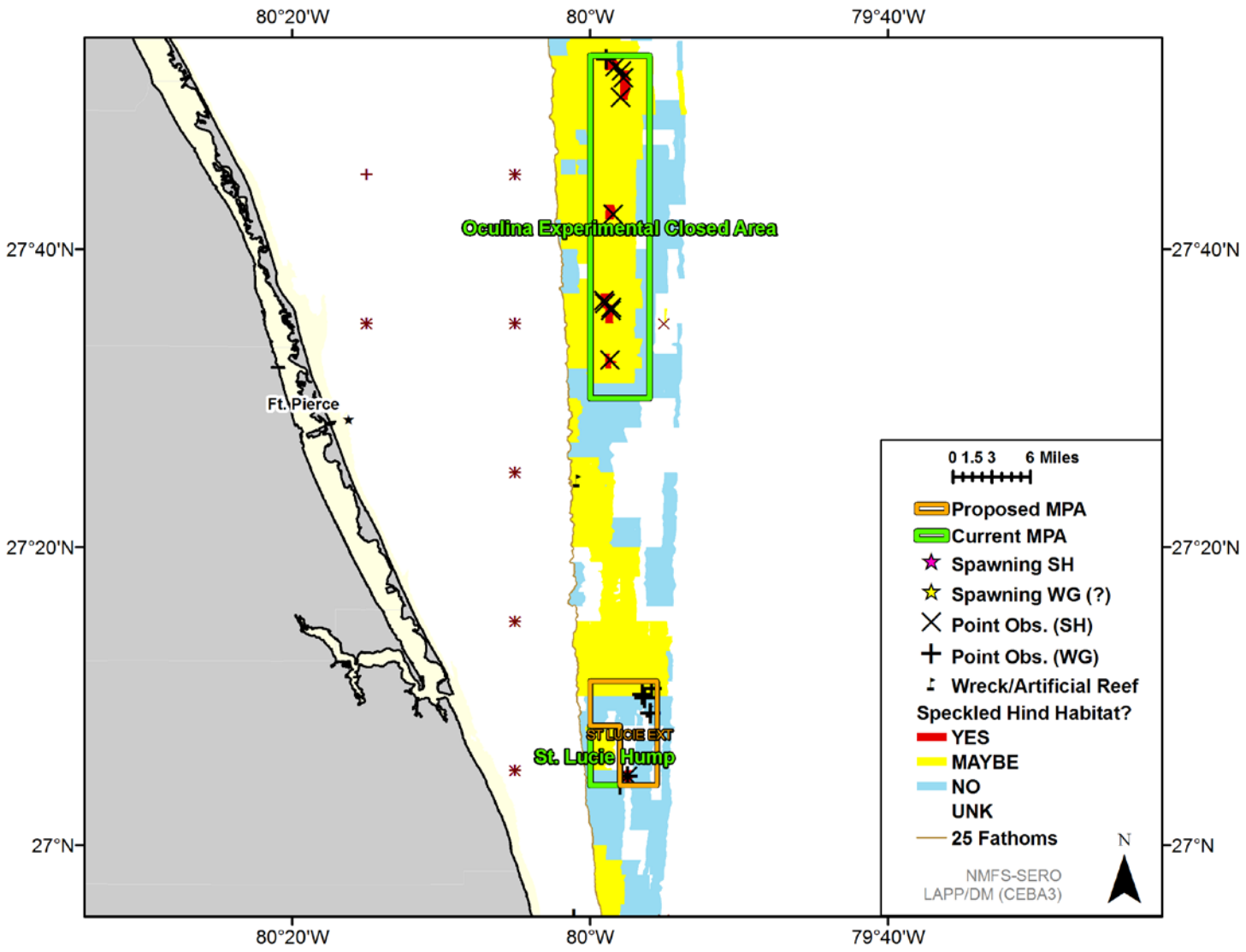

Figure 57. Close-up of proposed and current (green) marine reserves off southern Florida relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

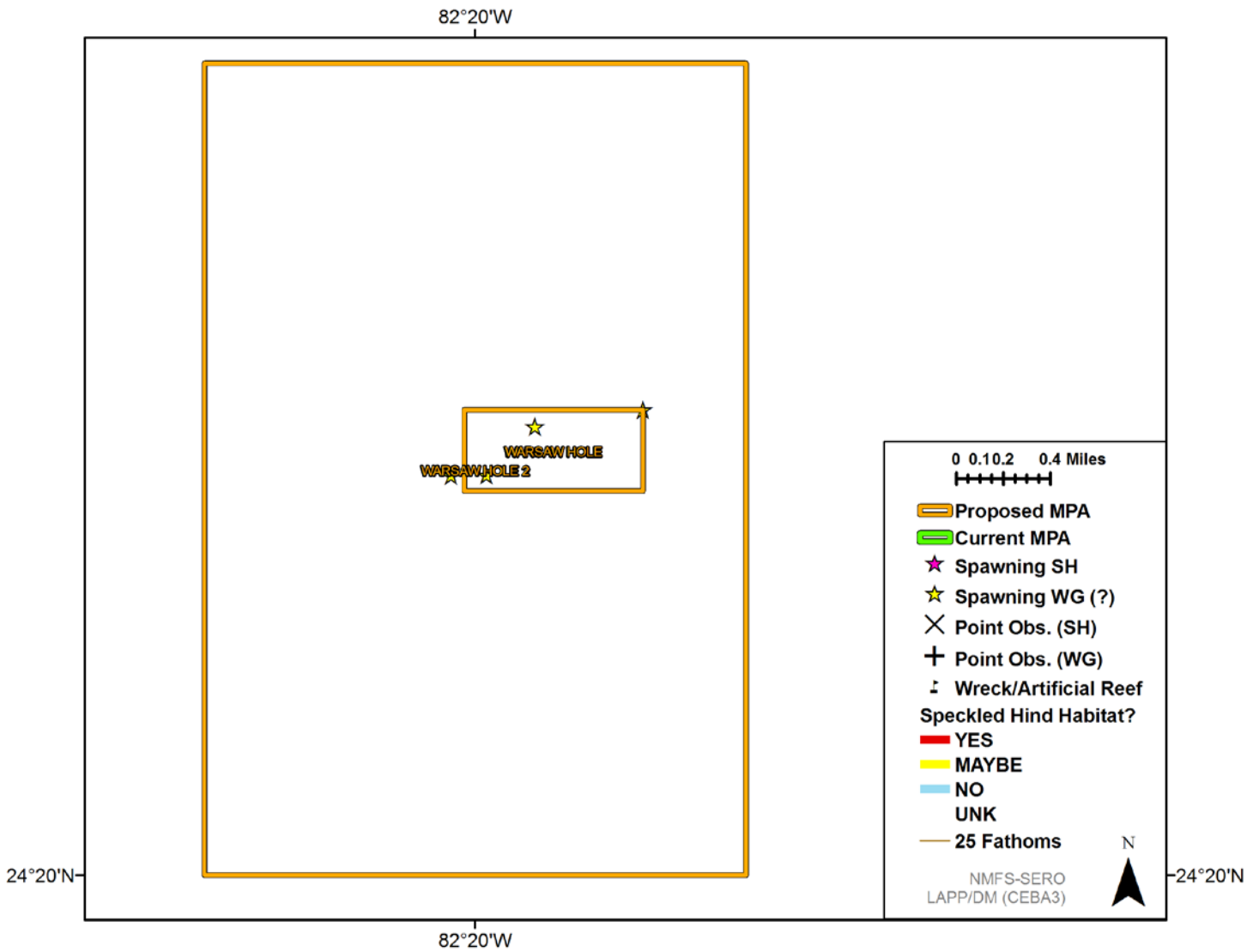

Figure 58. Close-up of proposed marine reserves off Key West, Florida relative to point observations of speckled hind (X) and warsaw grouper (+) and qualitative habitat suitability analysis for speckled hind.

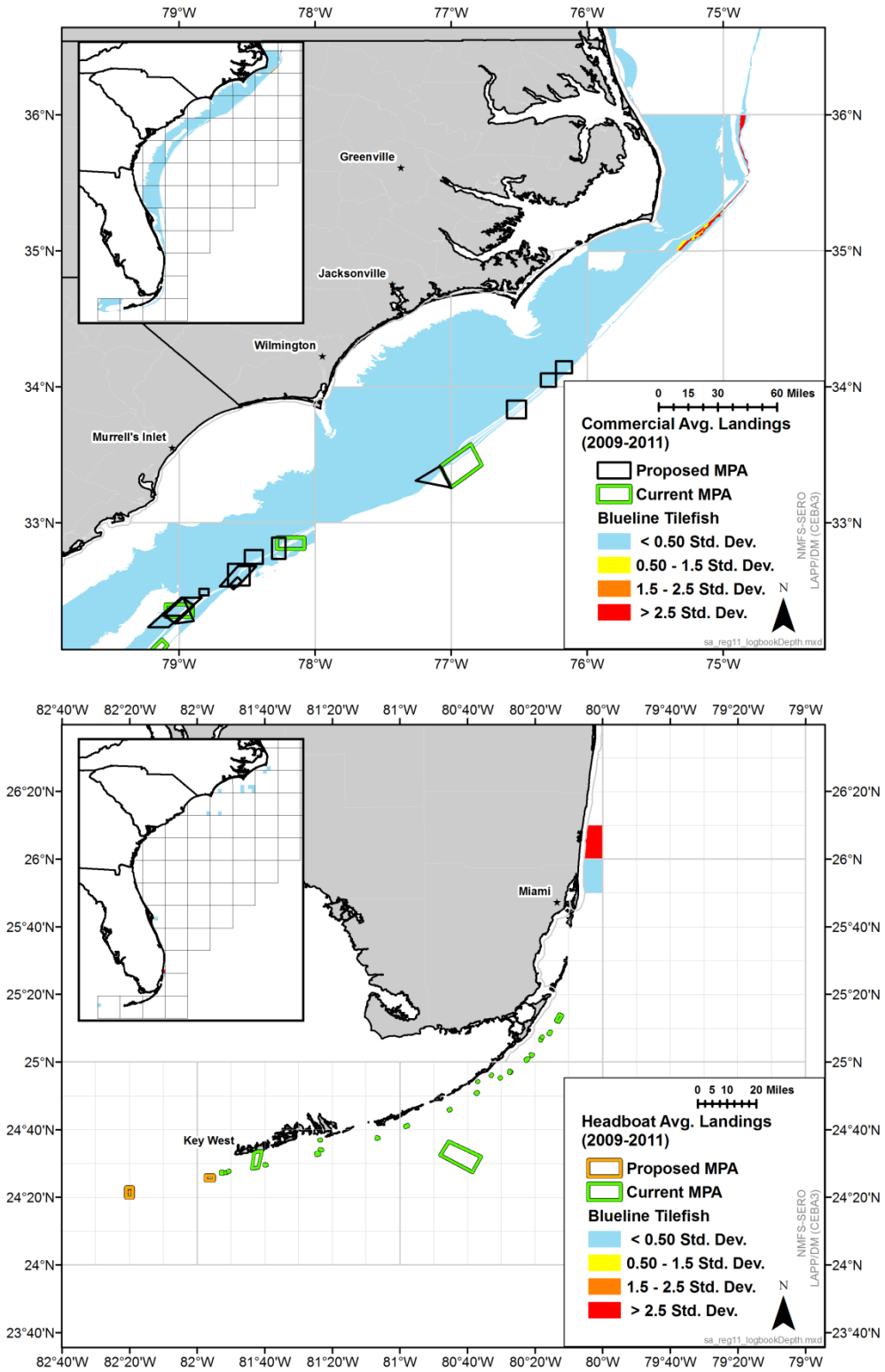

Figure 59. Average logbook-reported (2009-2011) blueline tilefish overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

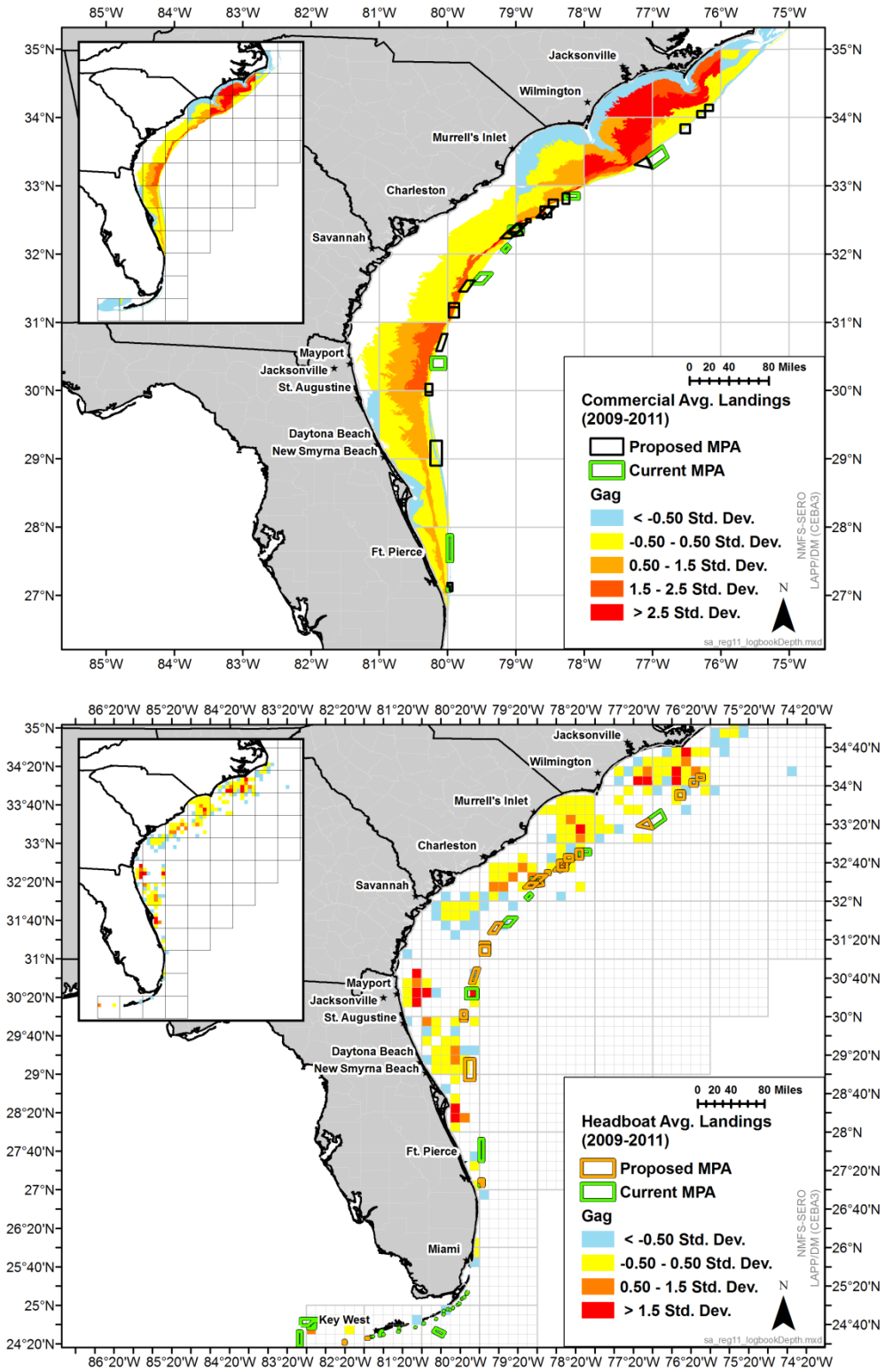

Figure 60. Average logbook-reported (2009-2011) gag overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

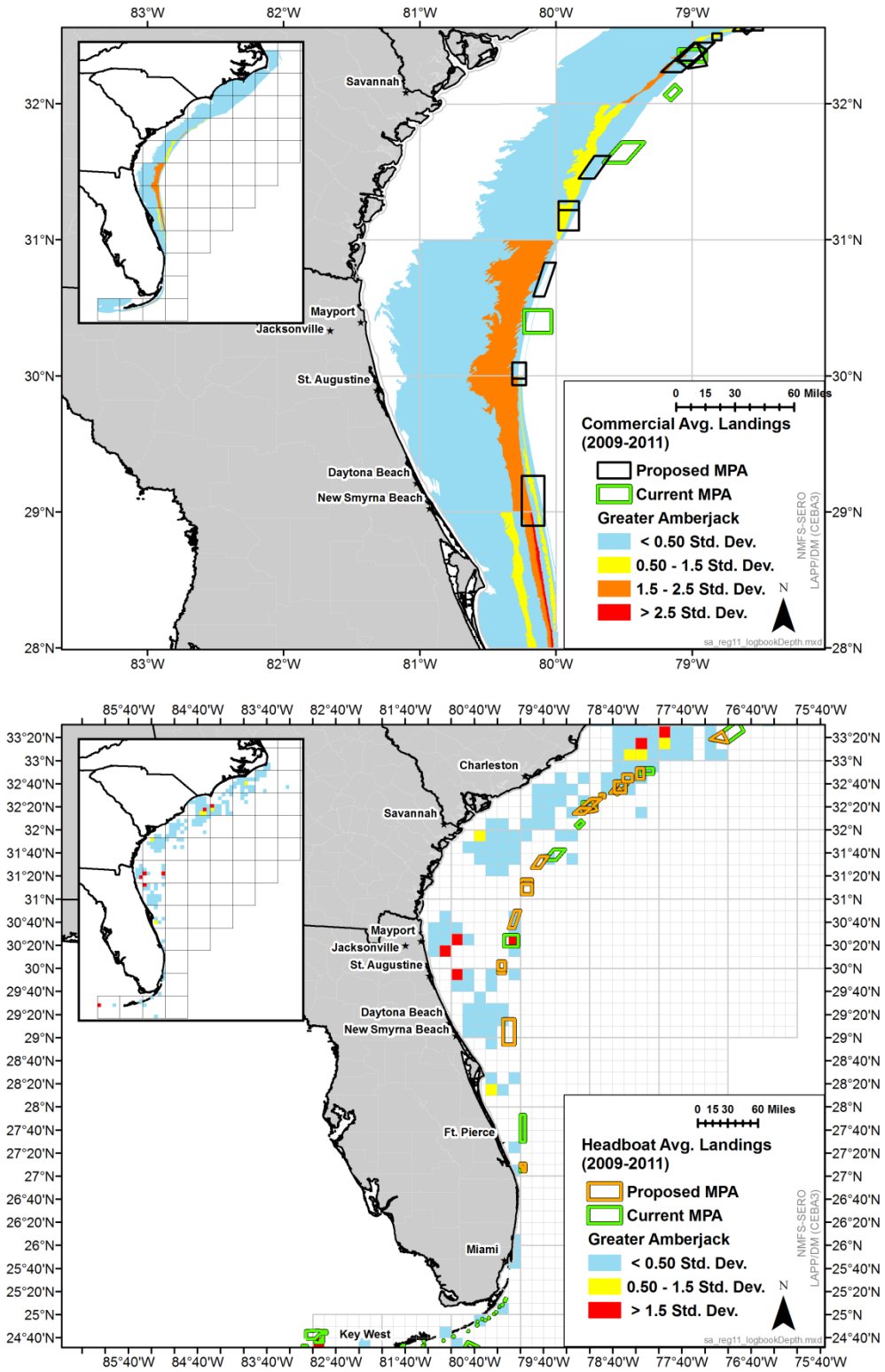

Figure 61. Average logbook-reported (2009-2011) greater amberjack overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

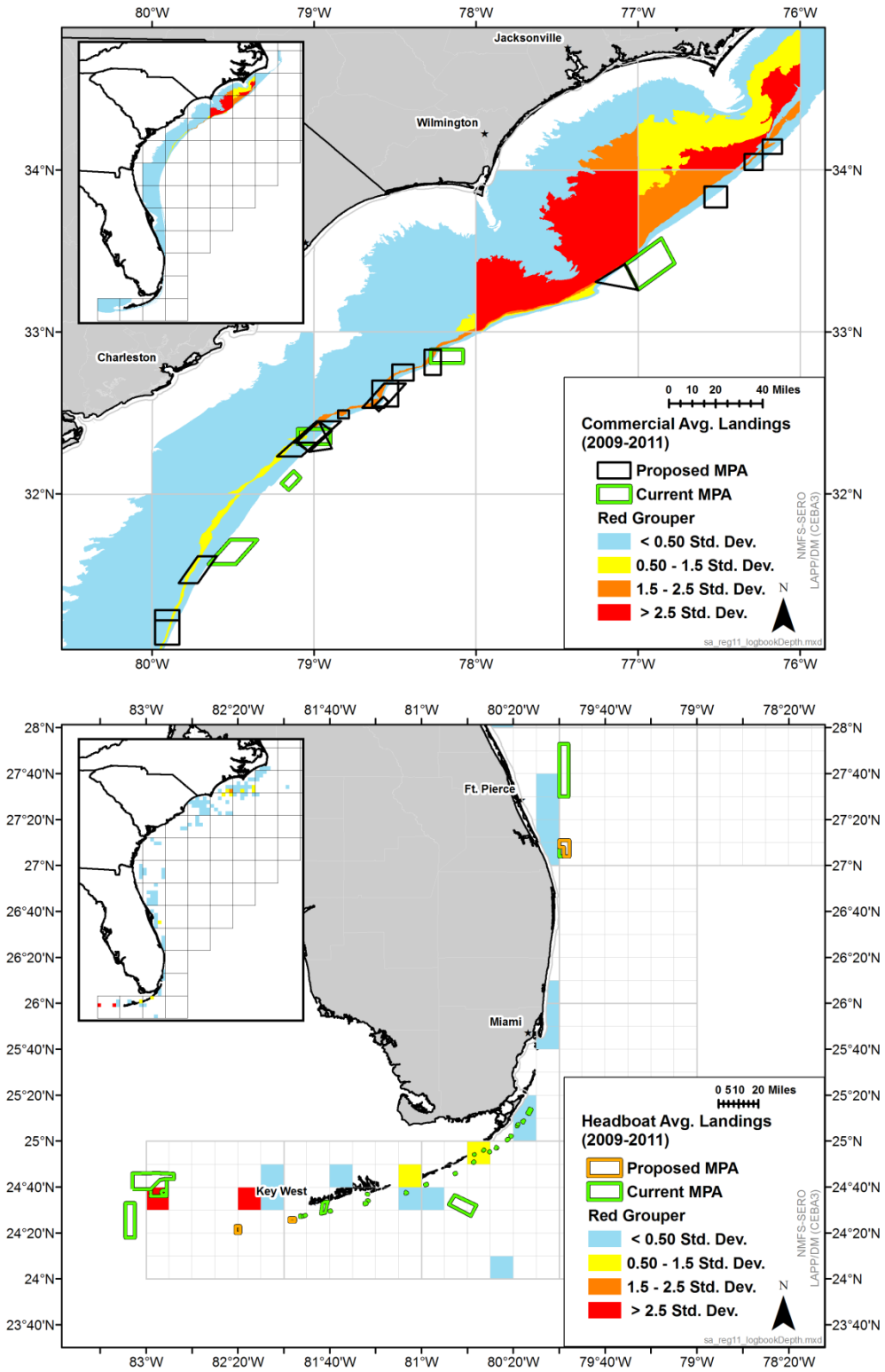

Figure 62. Average logbook-reported (2009-2011) red grouper overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

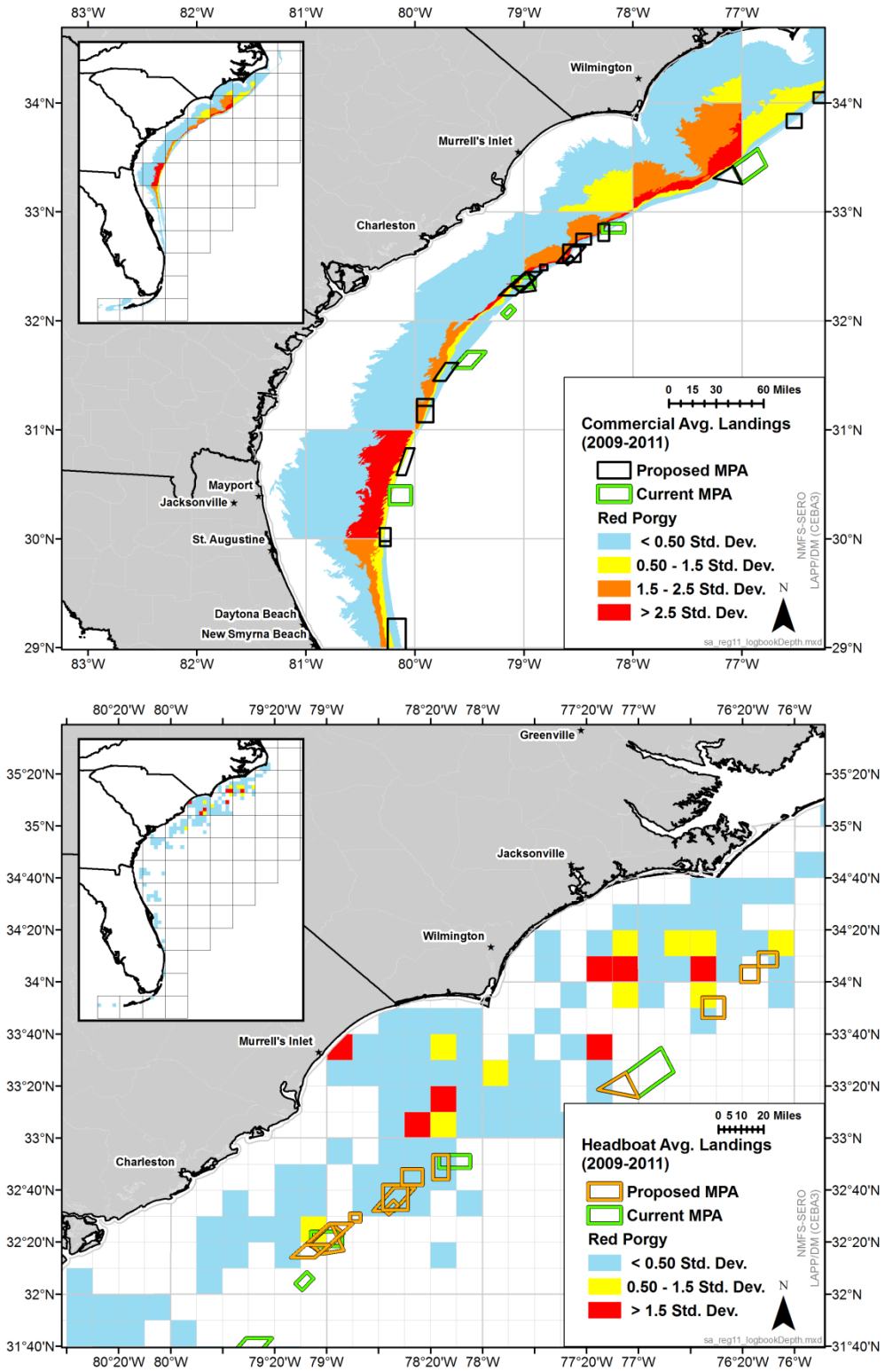

Figure 63. Average logbook-reported (2009-2011) red porgy overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

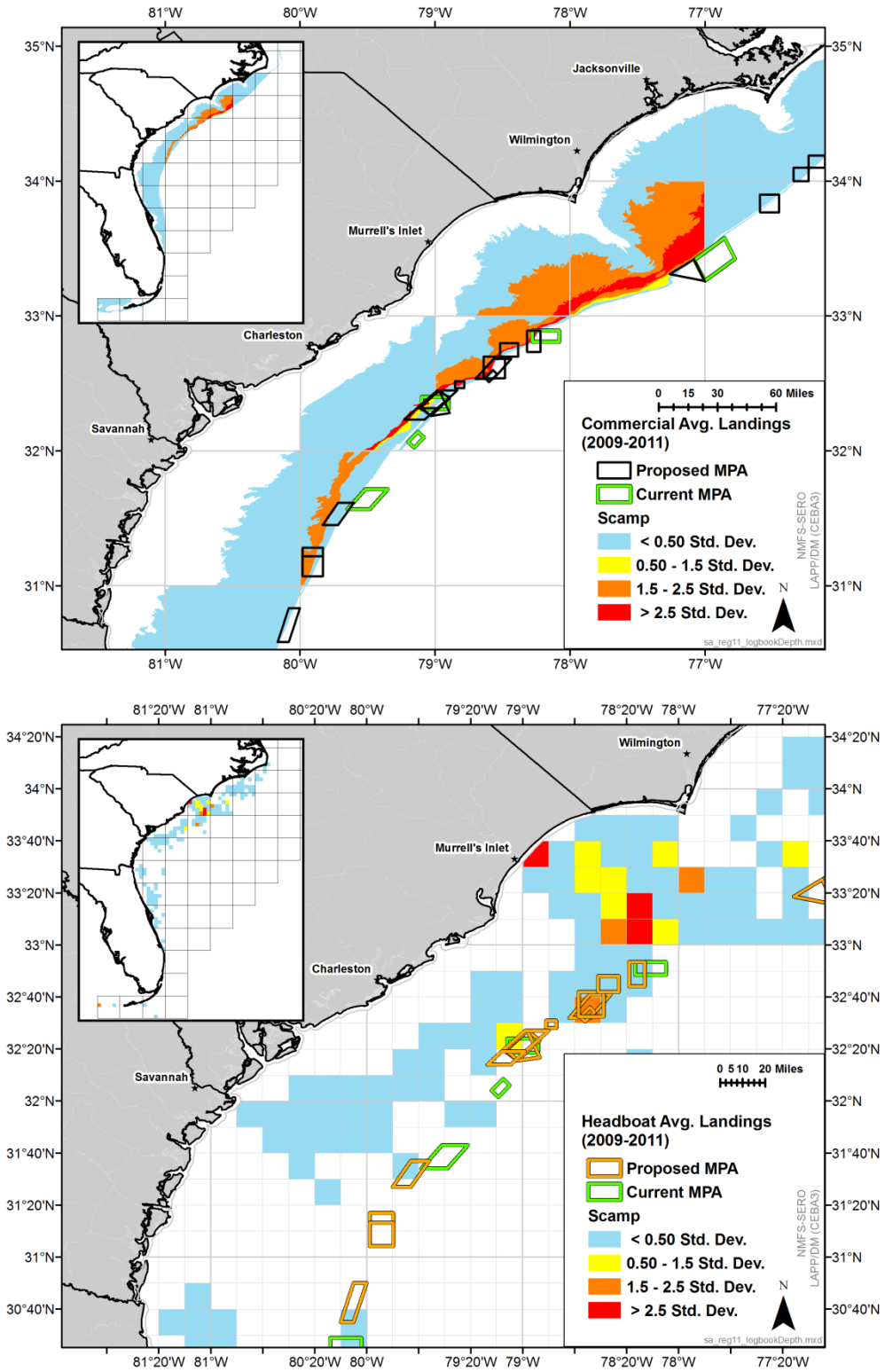

Figure 64. Average logbook-reported (2009-2011) scamp overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

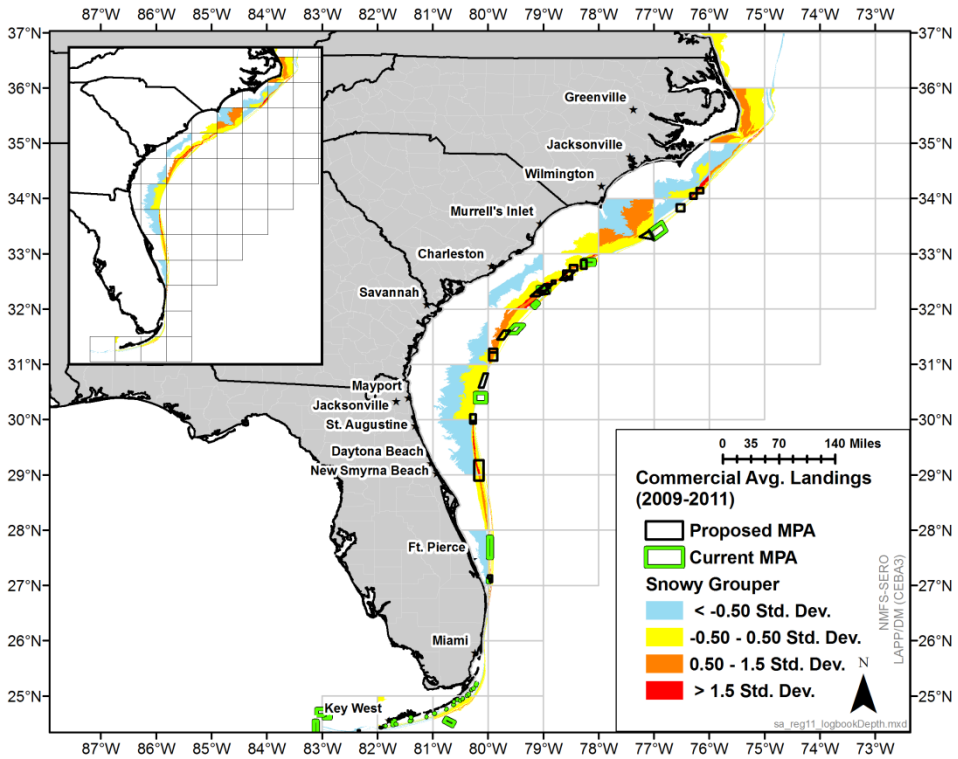

Figure 65. Average logbook-reported (2009-2011) snowy grouper overall (inset top) and core (top) commercial landings. Note there were no headboat landings of snowy grouper reported between 2009-2011.

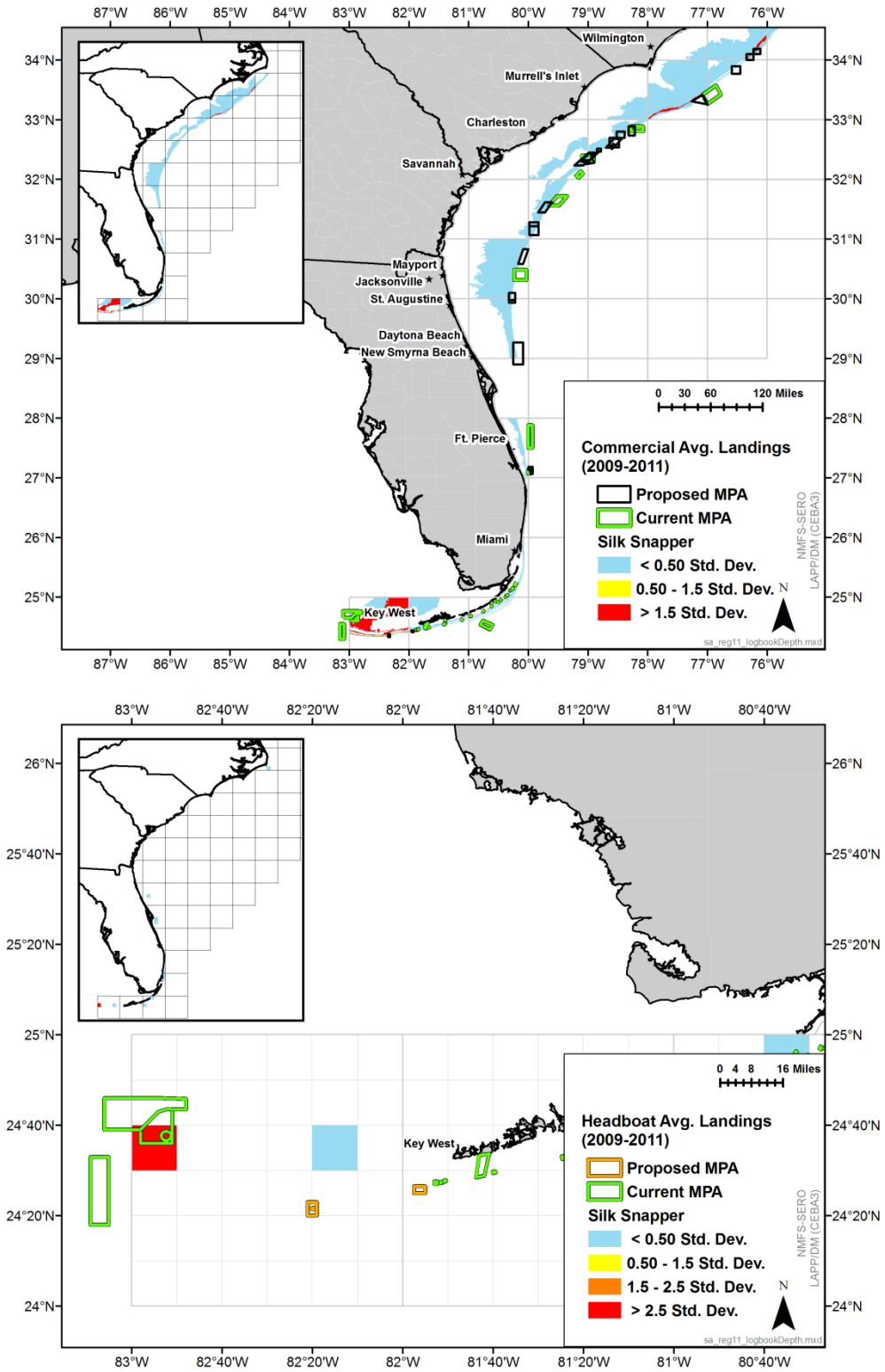

Figure 66. Average logbook-reported (2009-2011) silk snapper overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

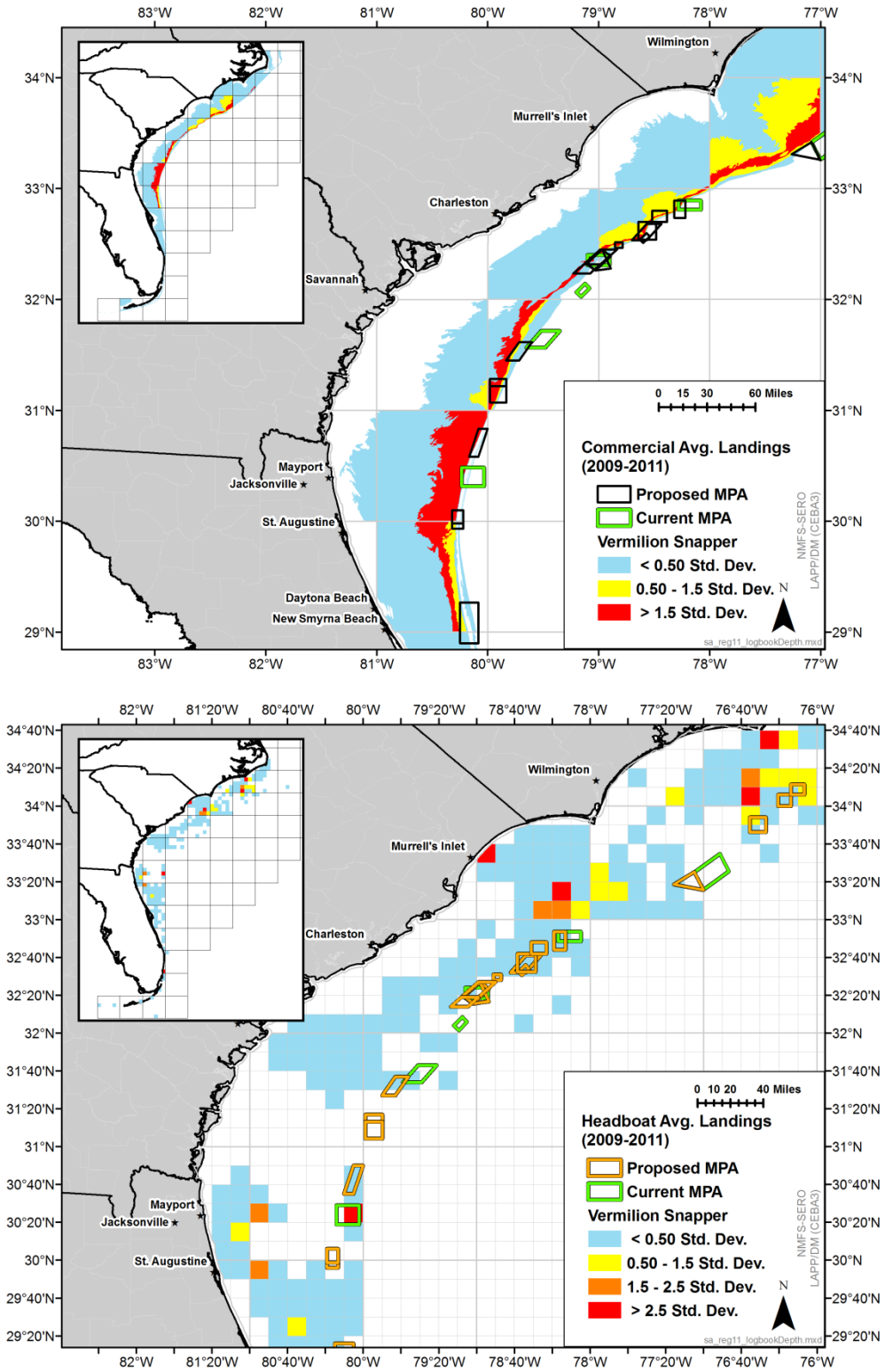

Figure 67. Average logbook-reported (2009-2011) vermilion snapper overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

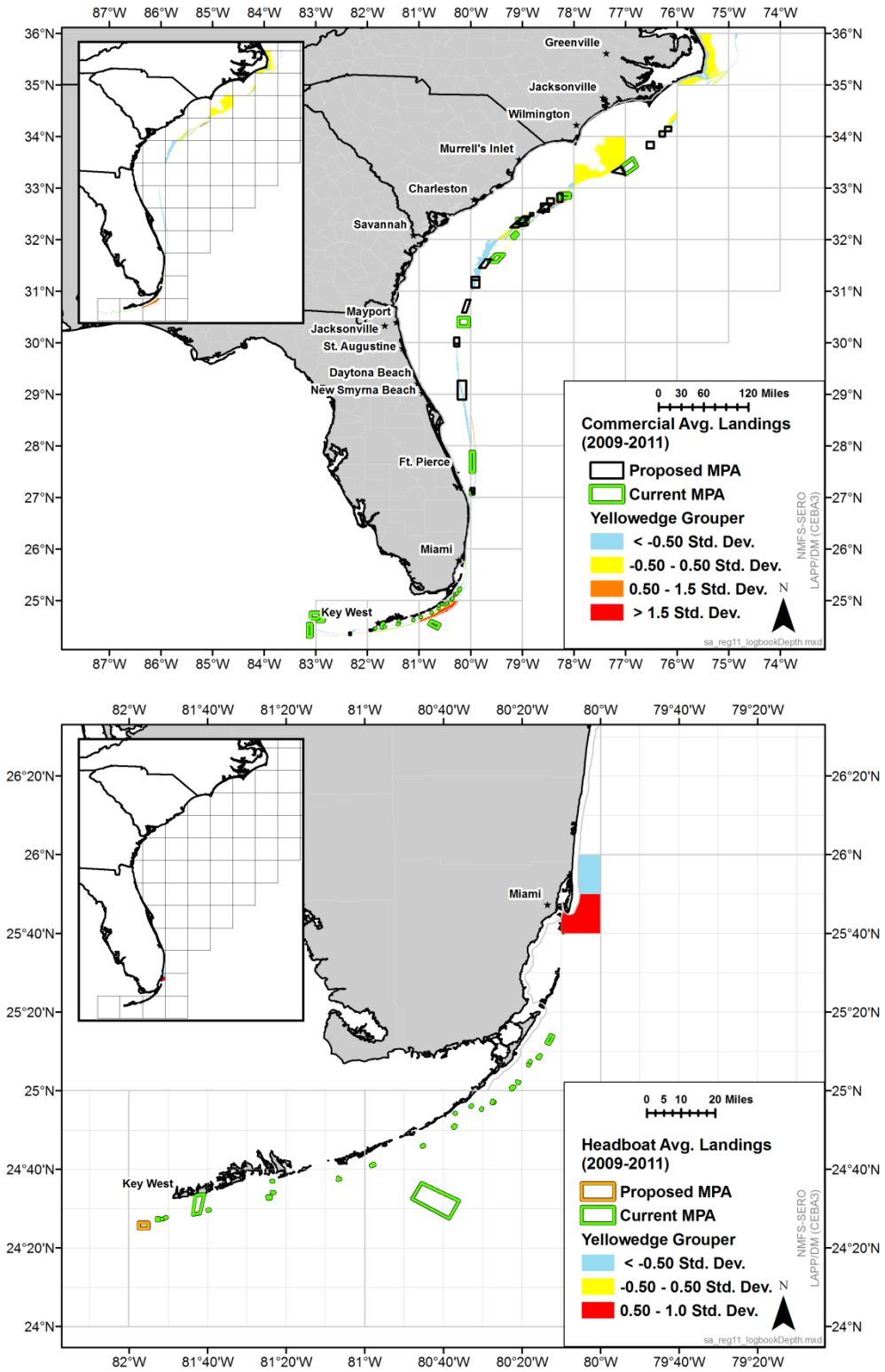

Figure 68. Average logbook-reported (2009-2011) yellowedge grouper overall (inset top) and core (top) commercial landings, and overall (inset bottom) and core (bottom) headboat landings.

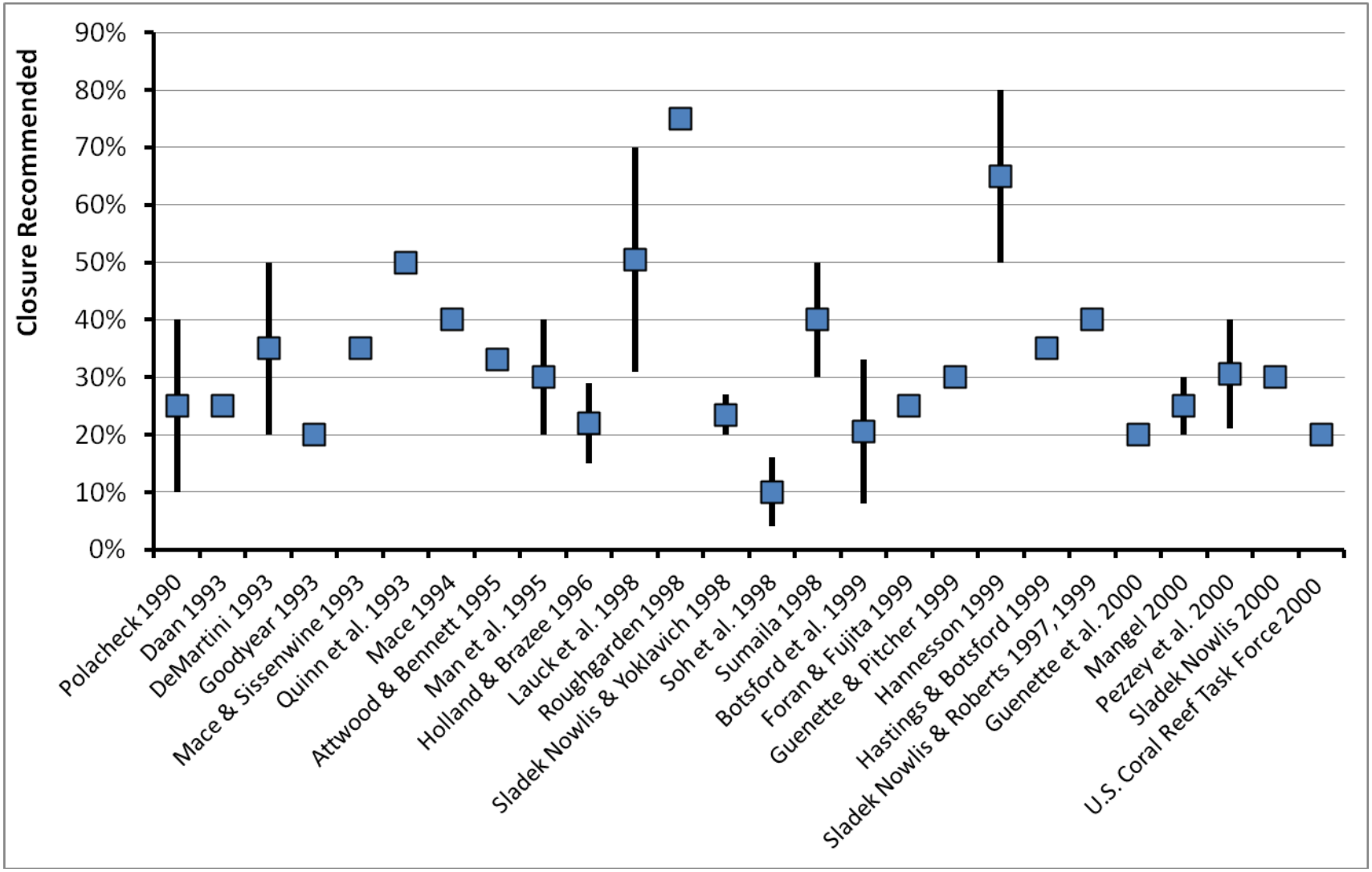

Figure 69. Meta-analysis of recommendations for percent closure recommendations from various peer-reviewed sources for yield maximization and reduction in risk of overfishing.

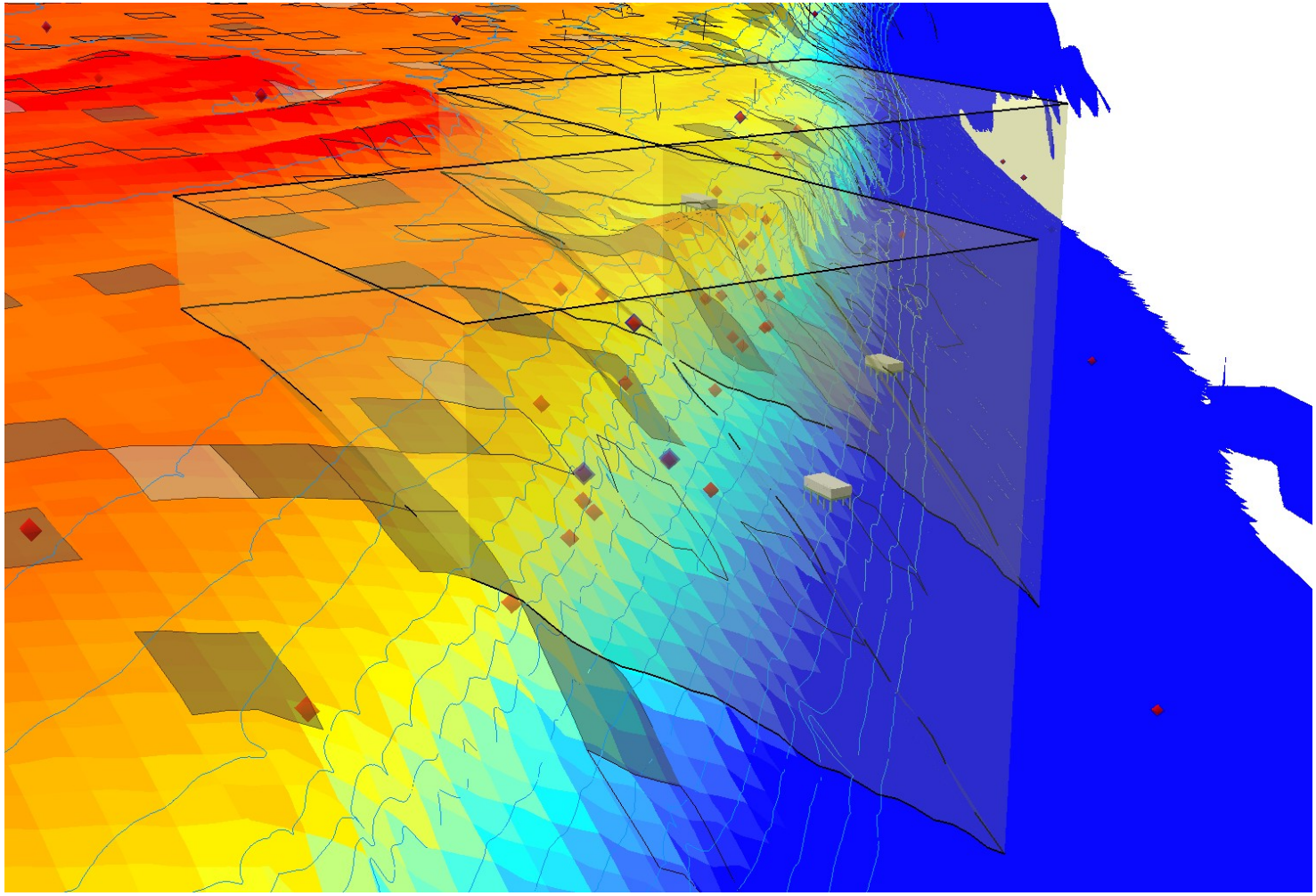

Figure 70. Three-dimensional image of shelf edge within north Cape Lookout NC marine protected areas (MPA) 1 and 2. Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

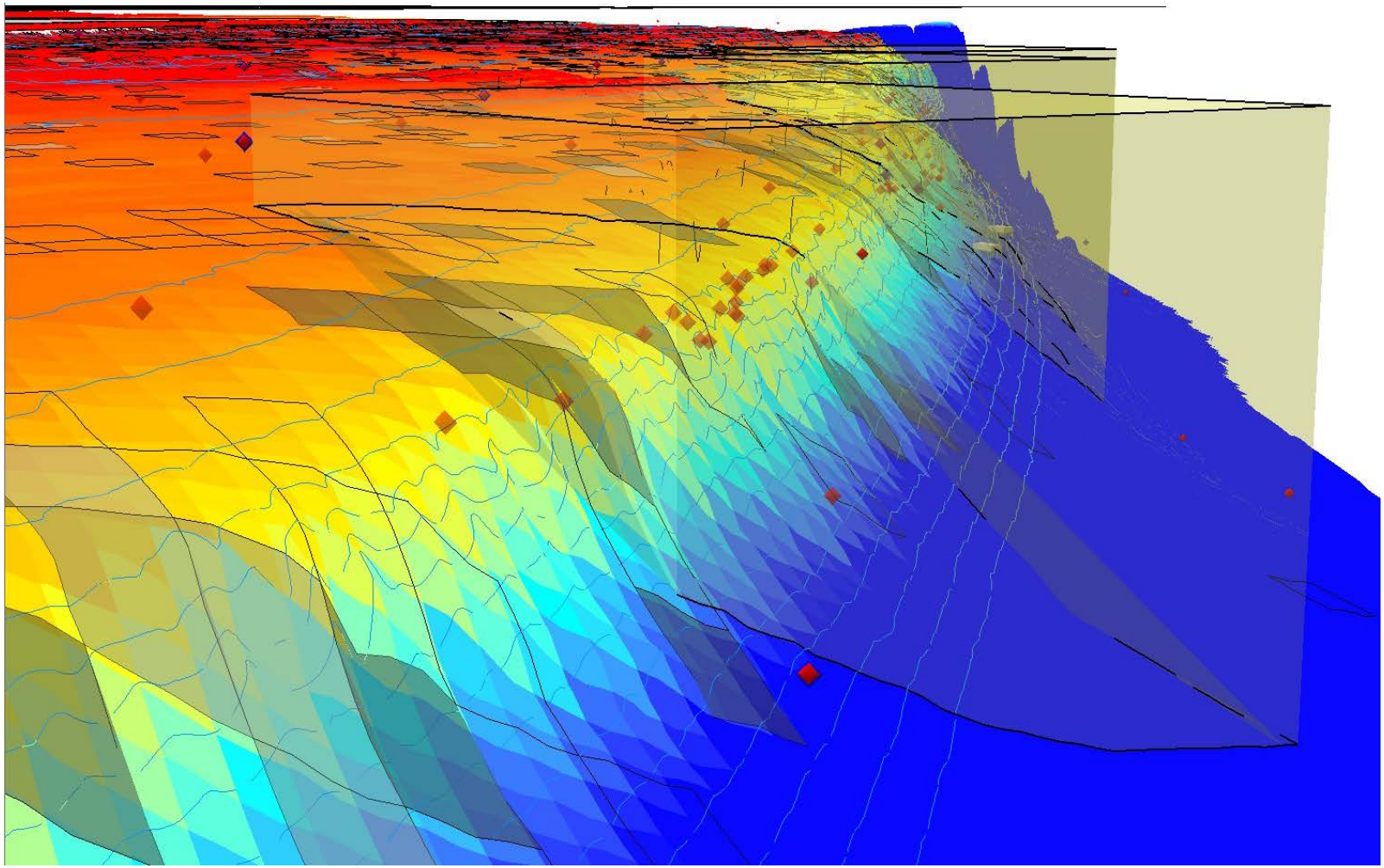

Figure 71. Three-dimensional image of shelf edge within south Cape Lookout NC marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

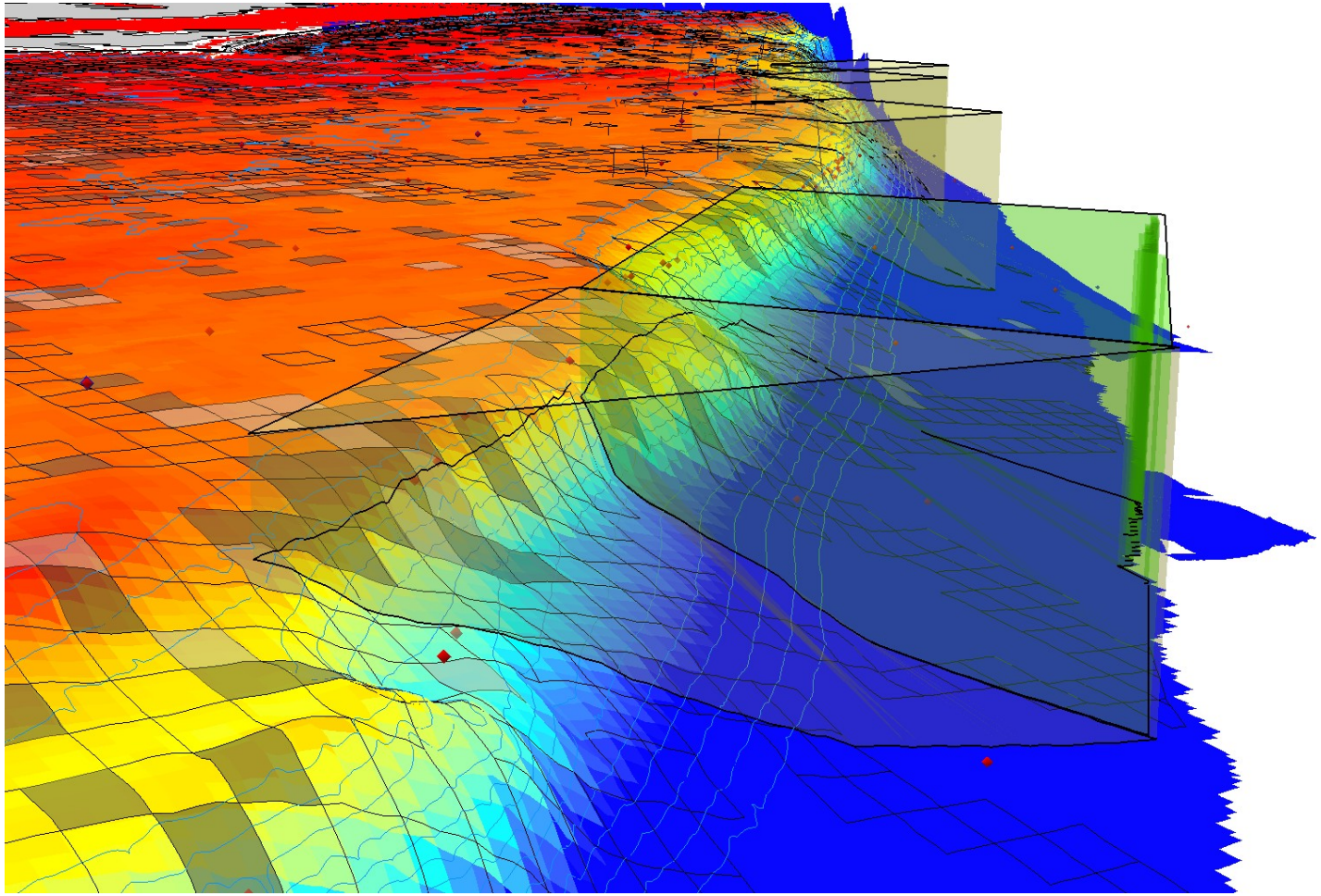

Figure 72. Three-dimensional image of shelf edge within Snowy Wreck marine protected area (MPA) and proposed extension. Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open). Note this figure contains point observation data from Rudershausen et al. (2010) which was received too late for analysis elsewhere in this report.

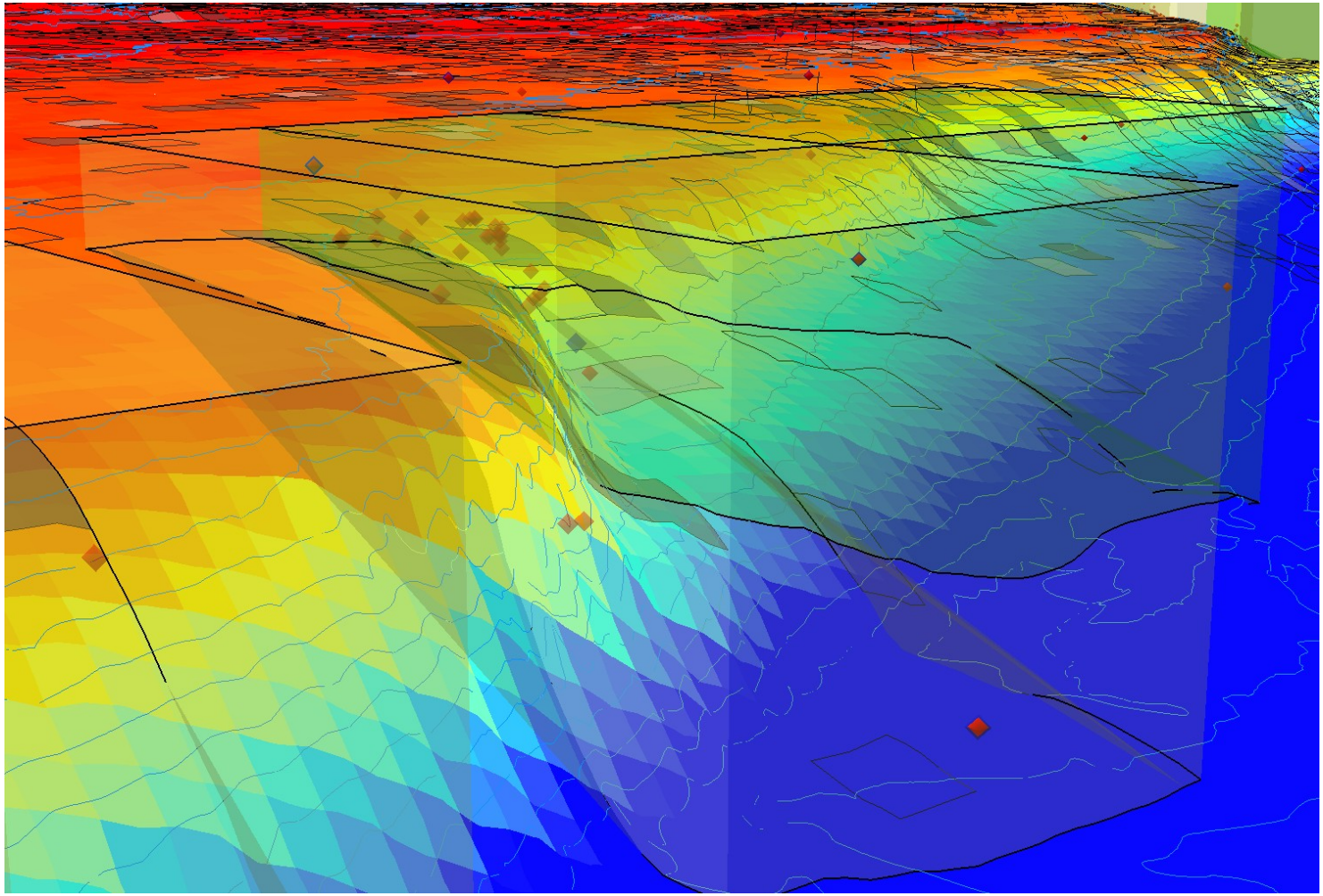

Figure 73. Three-dimensional image of shelf edge within Northern SC marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

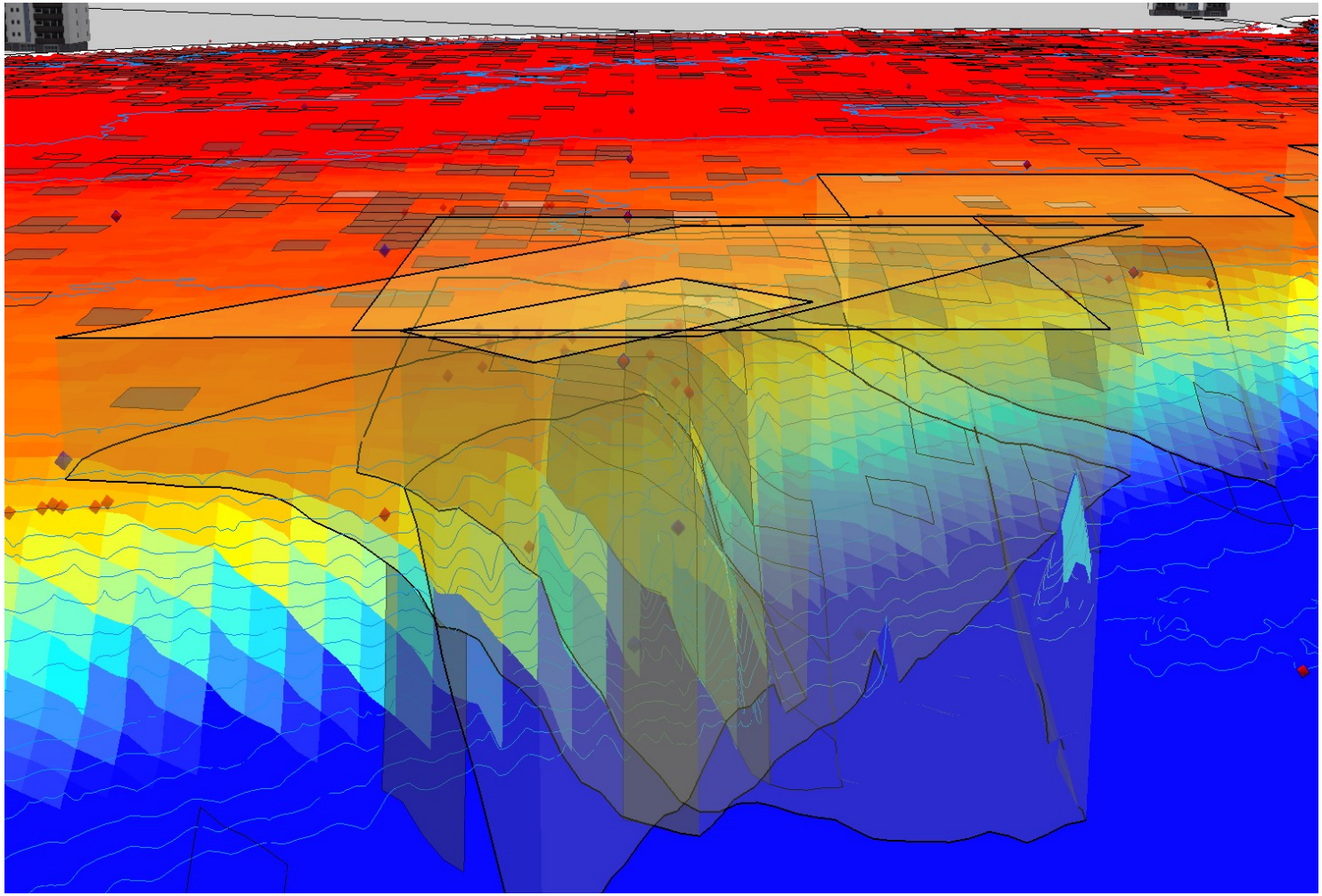

Figure 74. Three-dimensional image of shelf edge within proposed Charleston Shelf, Devil's Hole and Georgetown Hole SC marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

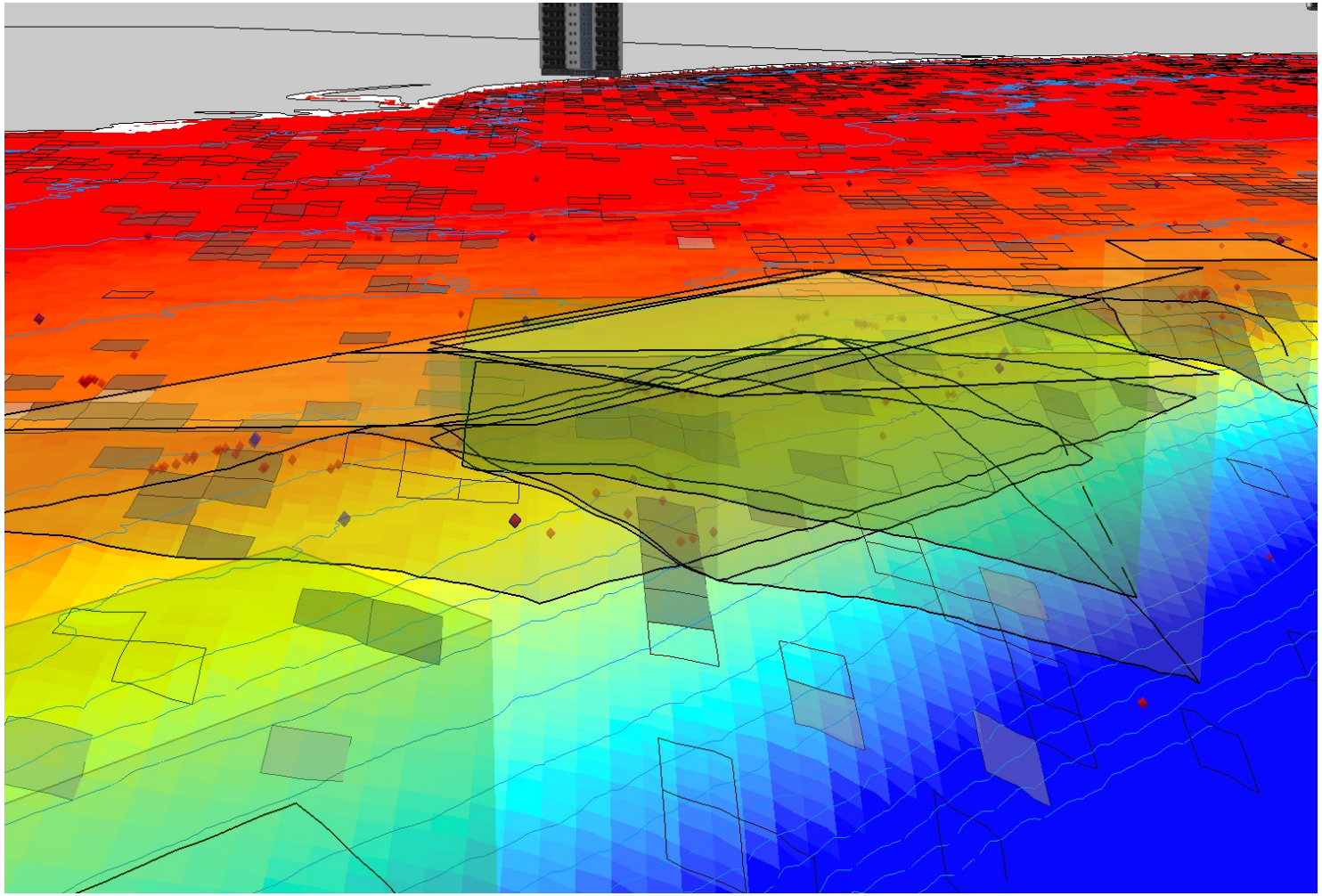

Figure 75. Three-dimensional image of shelf edge within existing and proposed reconfigurations of Edisto SC and Mid-SC marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

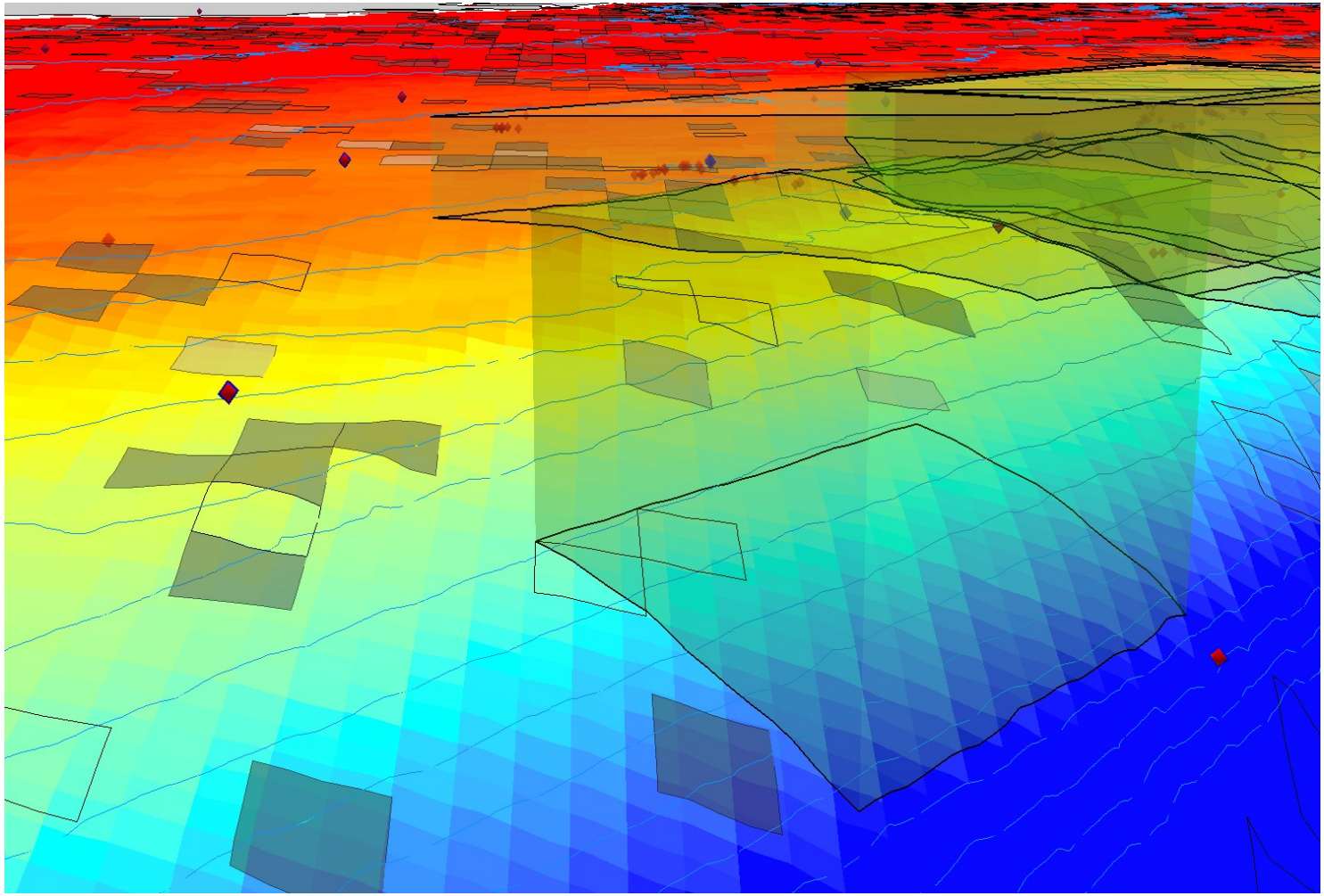

Figure 76. Three-dimensional image of shelf edge within Charleston Deep SC marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

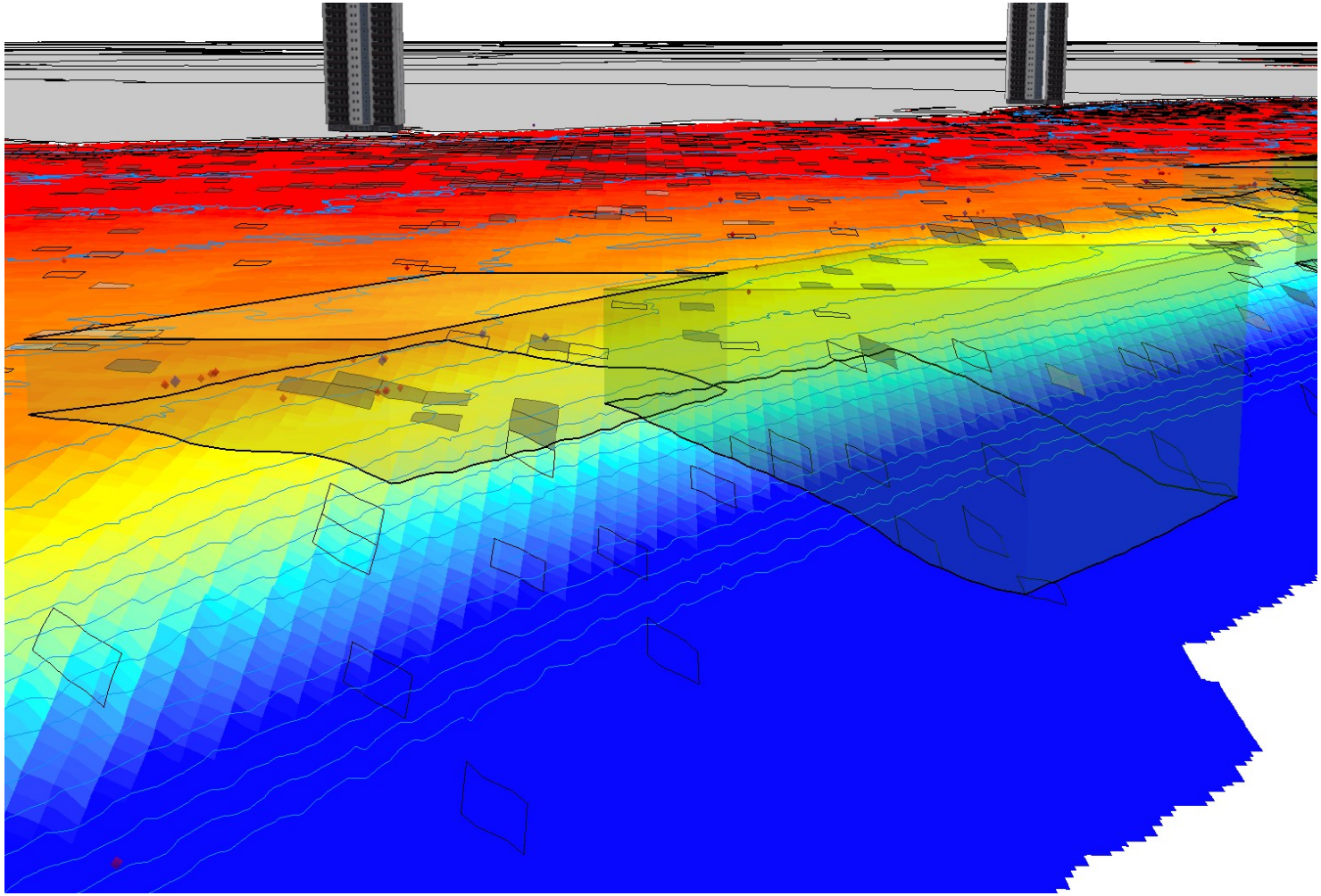

Figure 77. Three-dimensional image of shelf edge within existing and proposed reconfigurations of Georgia marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

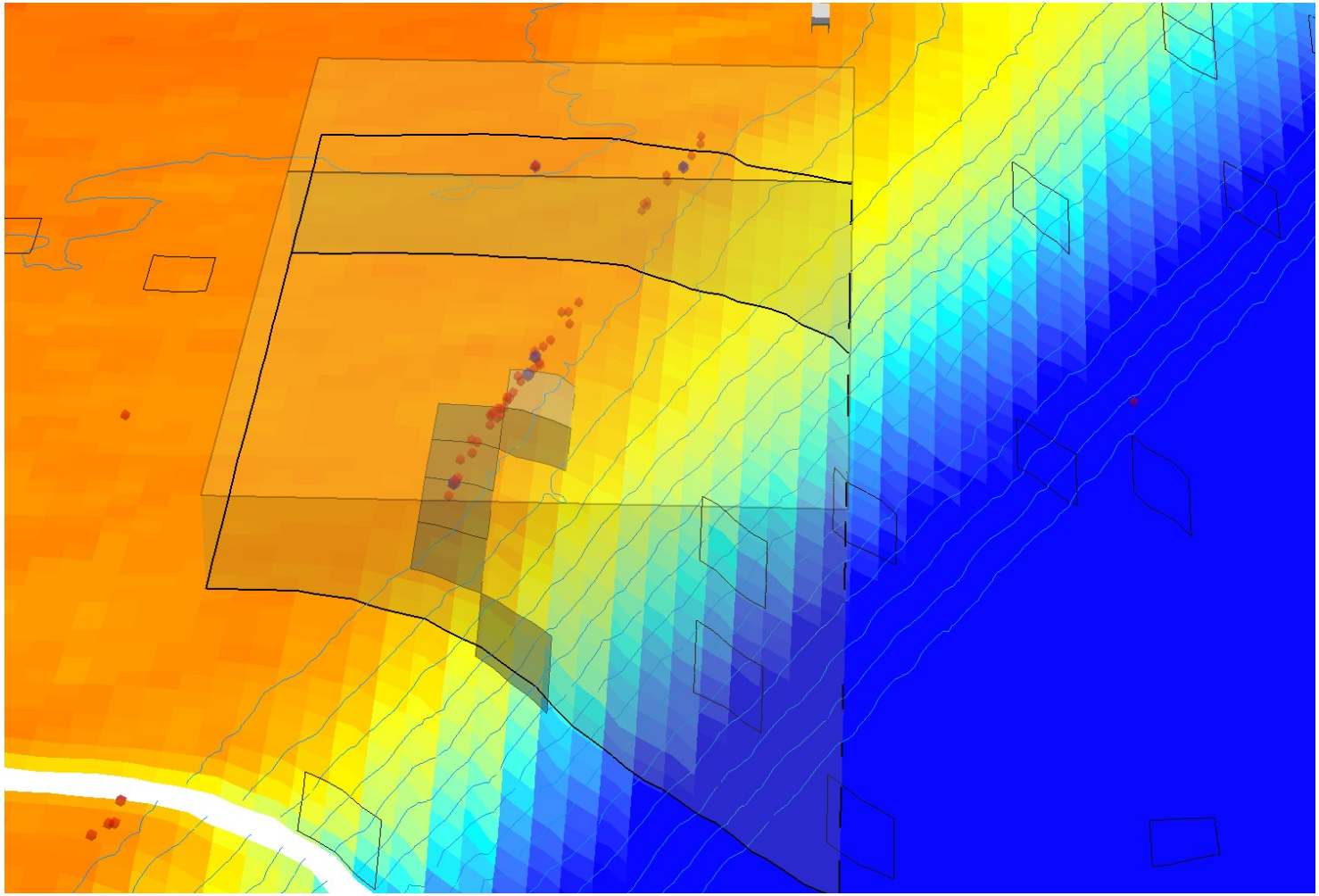

Figure 78. Three-dimensional image of shelf edge within proposed St. Simon's marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

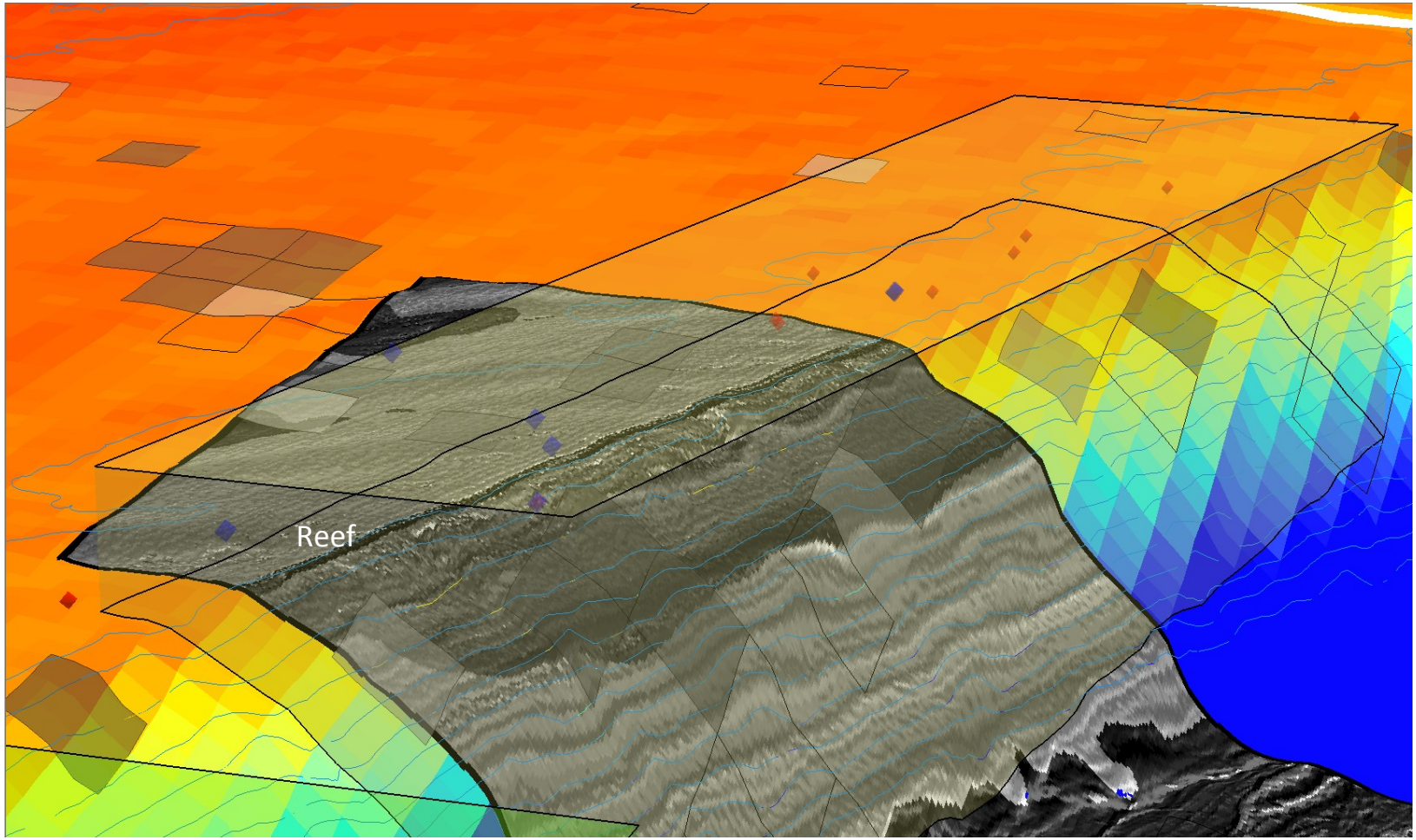

Figure 79. Three-dimensional image of shelf edge within proposed Fernandina FL marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open). High resolution bathymetric data from the US Navy indicates reef terrain along shelf break.

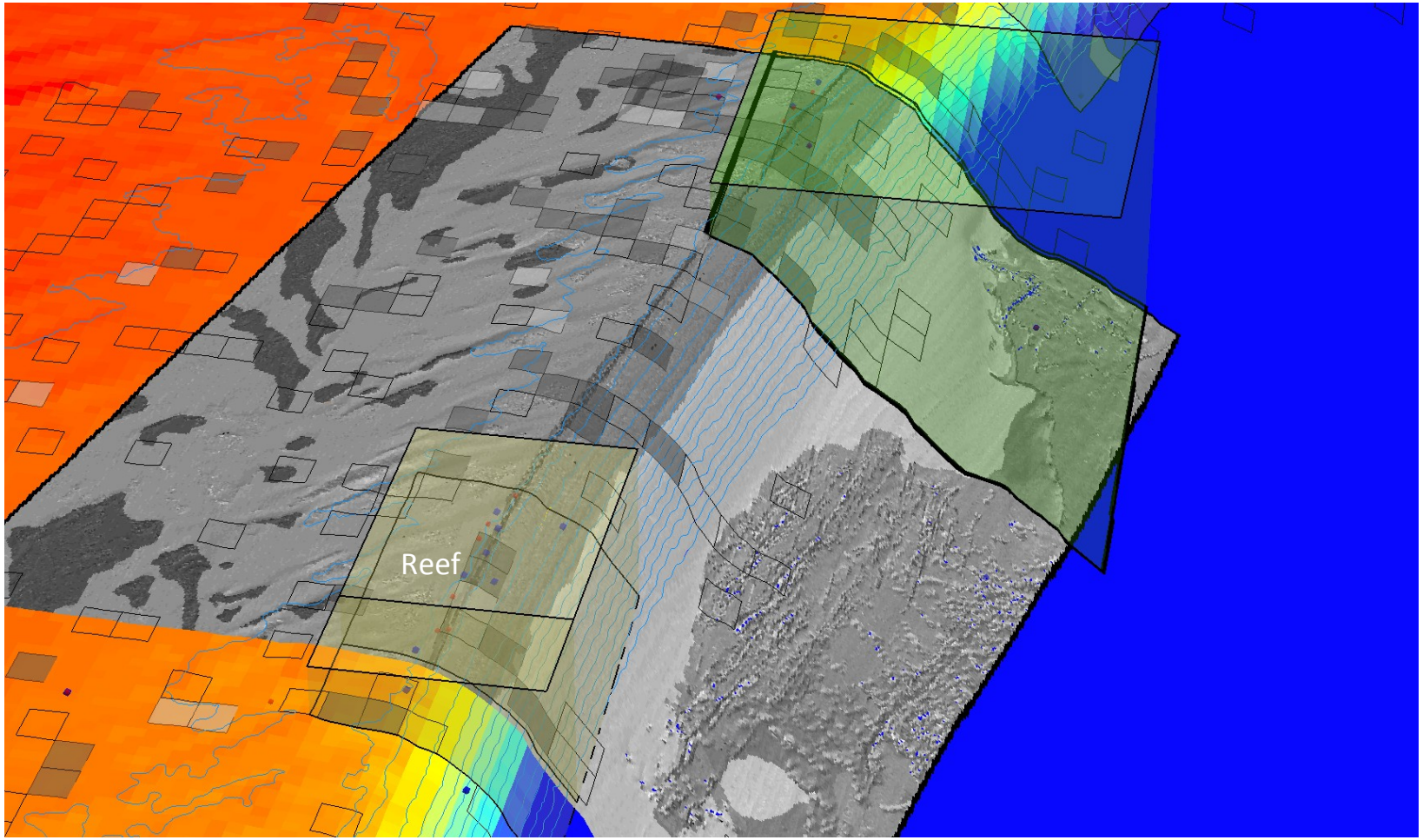

Figure 80. Three-dimensional image of shelf edge within North Florida, St. Augustine, and St. Augustine Extension marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open). High resolution bathymetric data from the US Navy indicates reef terrain along shelf break.

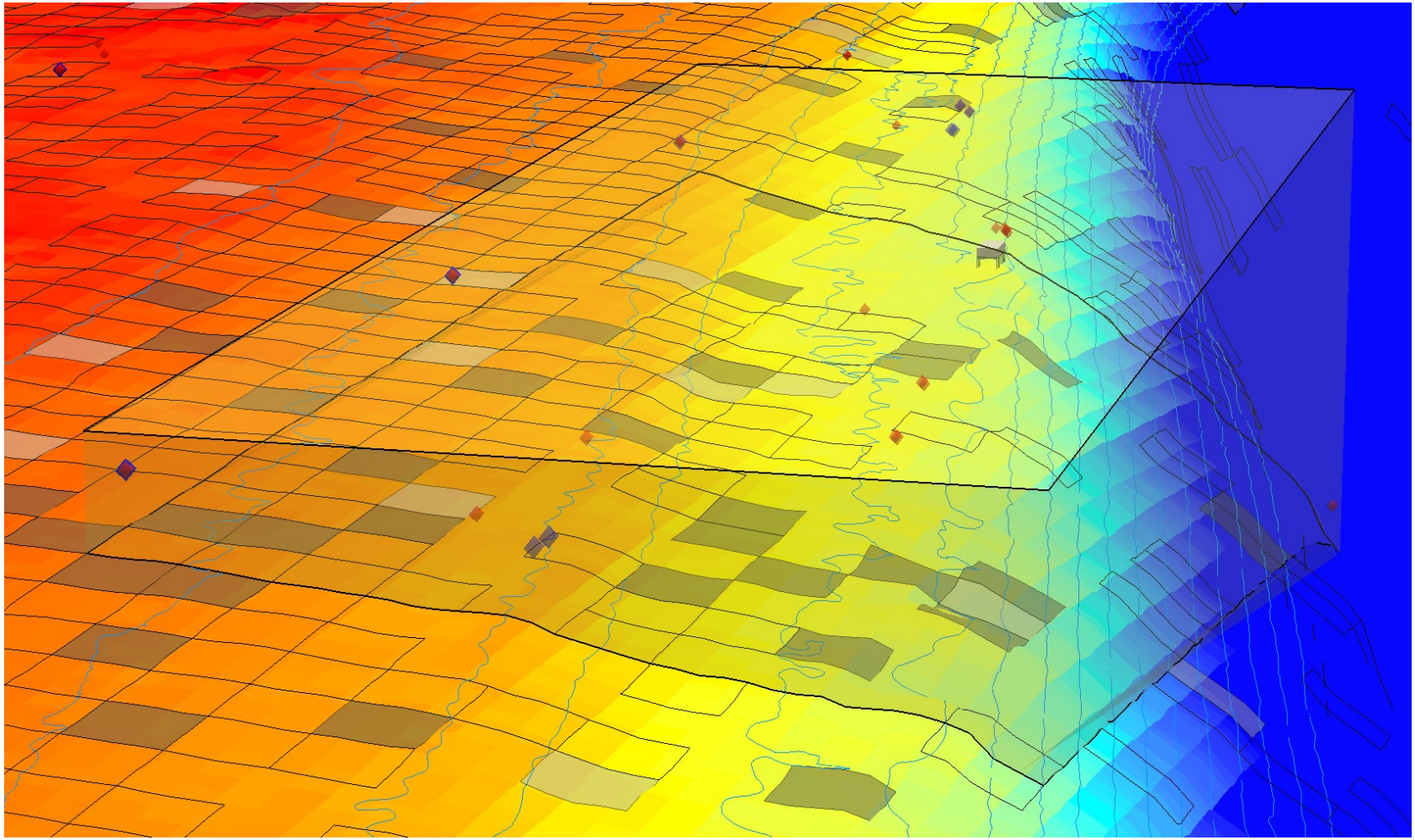

Figure 81. Three-dimensional image of shelf edge within Daytona proposed marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

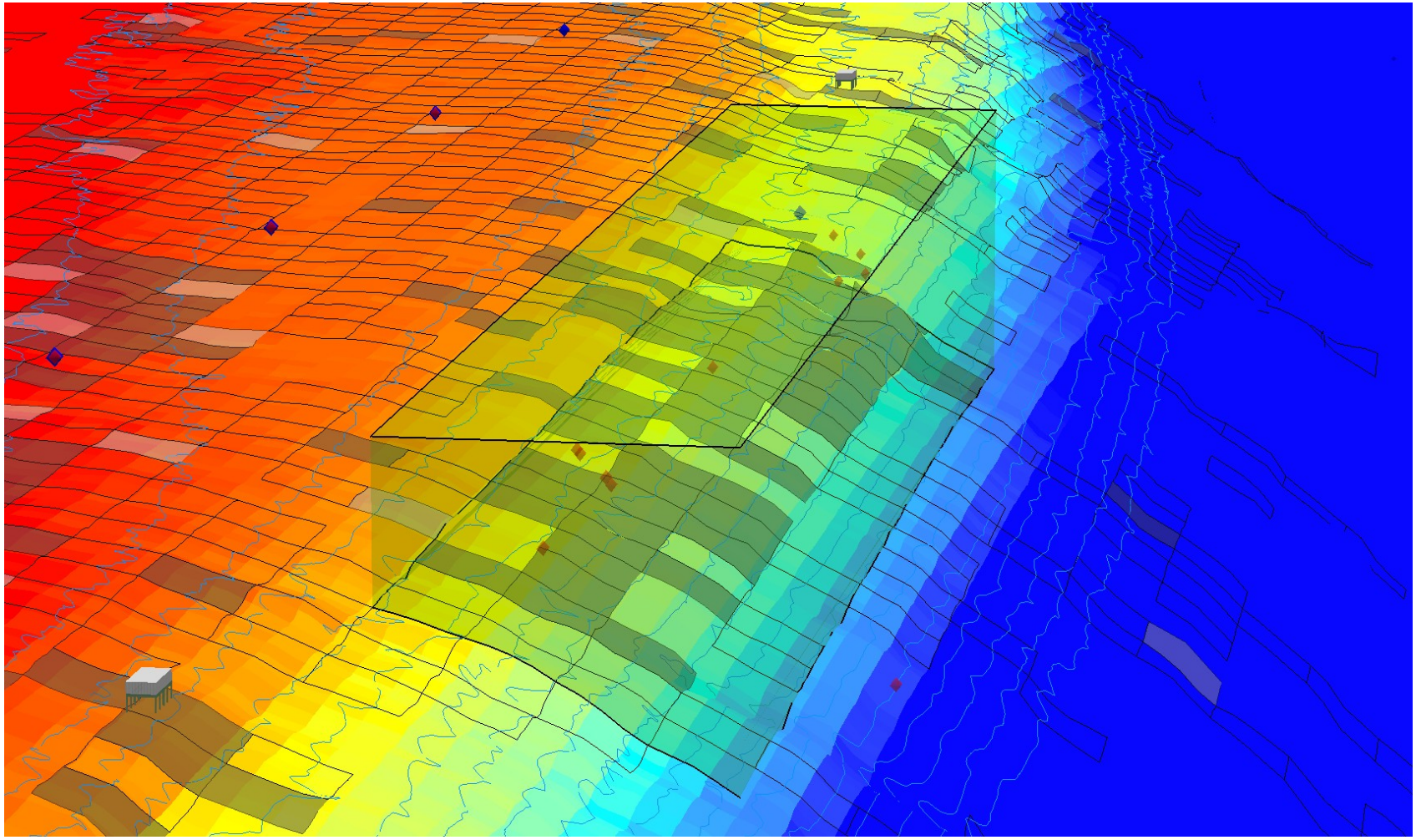

Figure 82. Three-dimensional image of shelf edge within Oculina Experimental Closed Area marine protected area (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

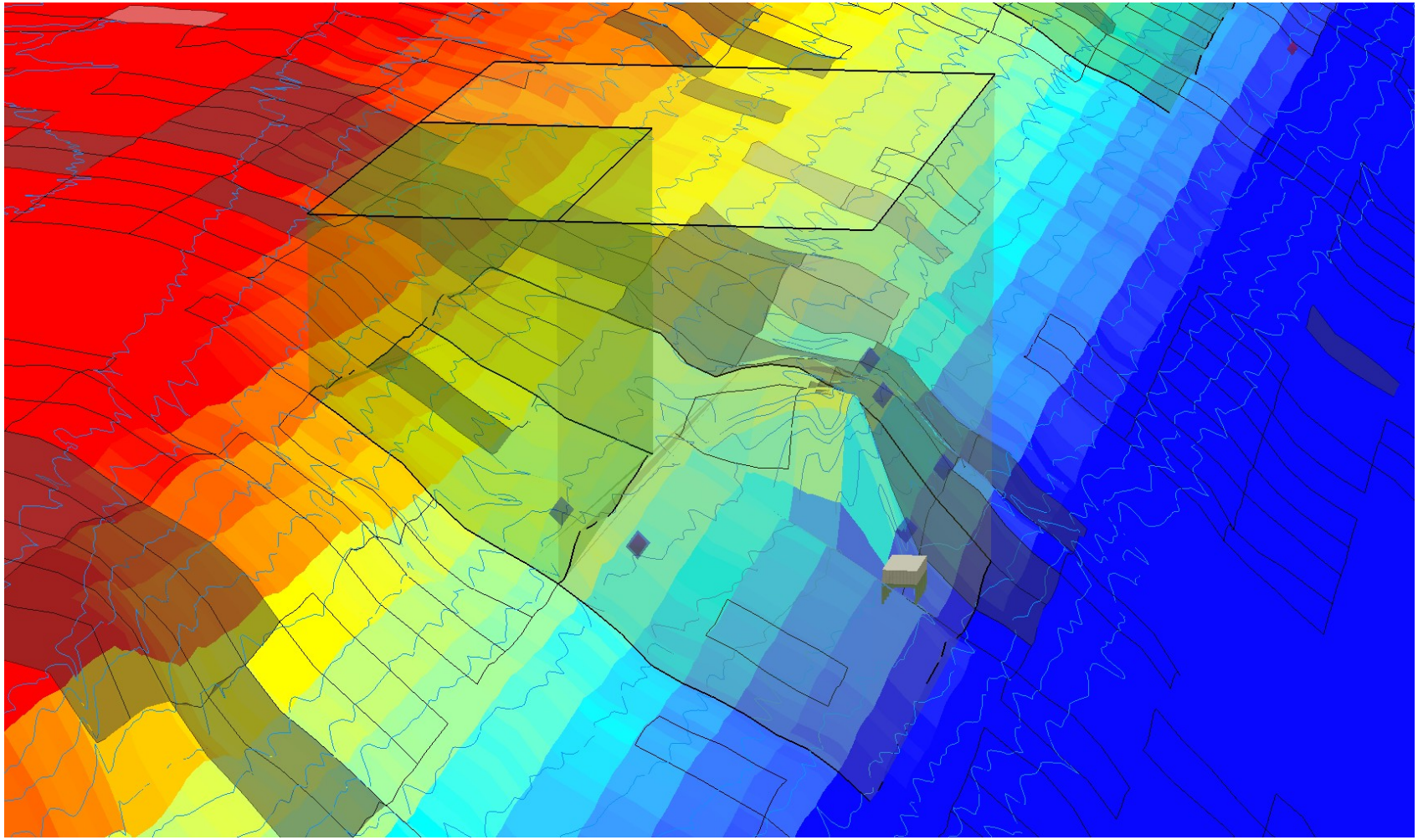

Figure 83. Three-dimensional image of shelf edge within existing St. Lucie Hump and proposed extension marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

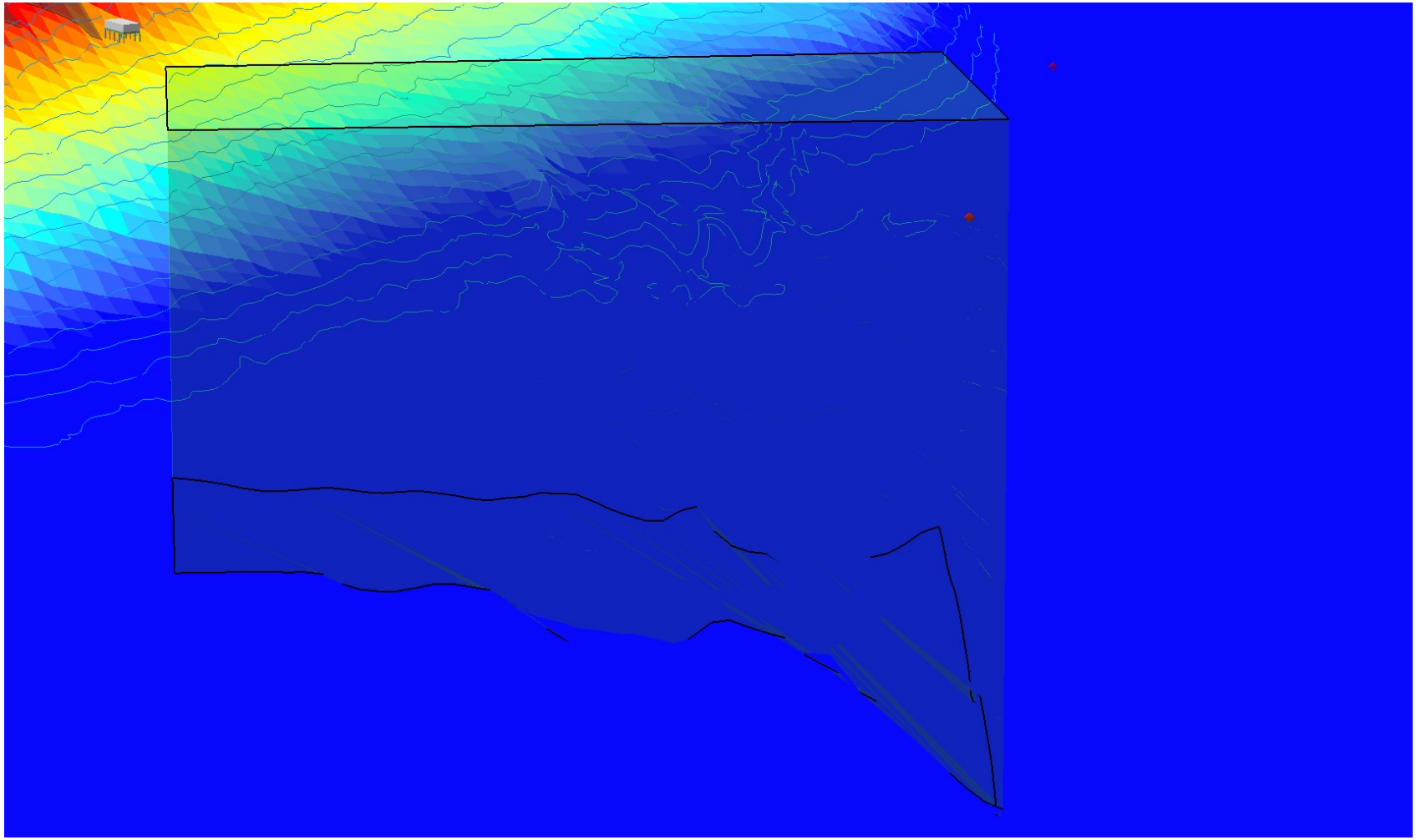

Figure 84. Three-dimensional image of shelf edge within Western Dry Rocks proposed marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).

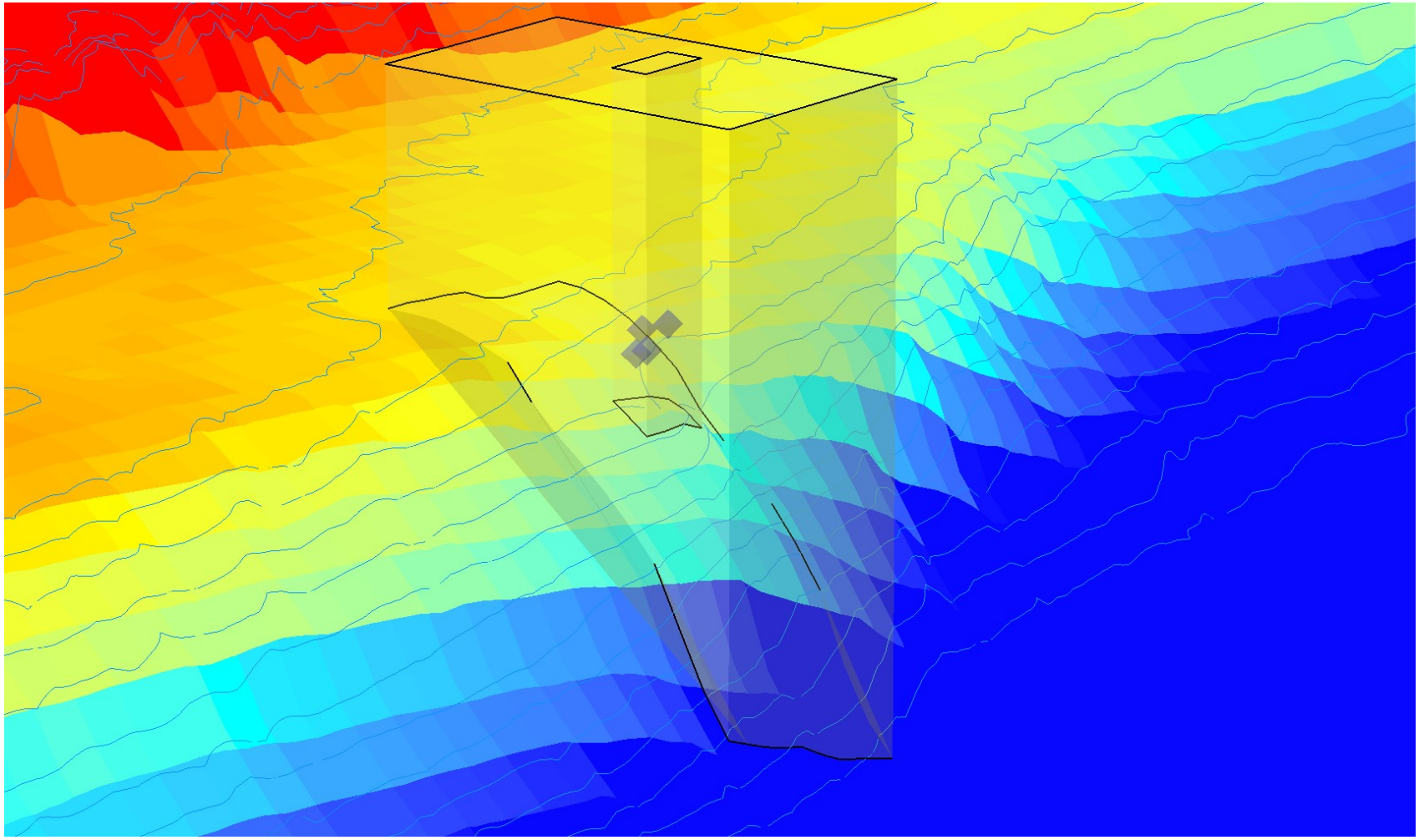

Figure 85. Three-dimensional image of shelf edge within Warsaw Hole (southeast of Key West, FL) proposed marine protected areas (MPA). Semi-transparent boxes indicate current (green) and proposed (yellow) MPA boundaries, diamonds indicate warsaw grouper (navy) and speckled hind (red) observations, blue lines denote 5 fathom generalized bathymetry from the Coastal Relief Model, and benthic structures denote artificial reefs or wrecks. Benthic squares denote SEAMAP-identified hardbottom (black), possible hardbottom (gray), and not hardbottom (open).