Final Report
Gulf of Mexico Fishery Management Council
5-Year Review of the
Final Generic Amendment Number 3
Addressing Essential Fish Habitat Requirements, Habitat Areas of Particular Concern, and Adverse Effects of Fishing in the Fishery Management Plans of the Gulf of Mexico

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Gulf of Mexico Fishery Management Council
2203 North Lois Avenue, Suite 1100
Tampa, Florida 33607
813-348-1630
813-348-1711 (fax)
888-833-1844 Toll Free
http://www.gulfcouncil.org

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Abbreviations and Acronyms Used in this Document

AIC	Akaike's Information Criterion
CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESRI	Environmental Systems Research Institute
FGBNMS	Flower Garden Banks National Marine Sanctuary
FMP	Fishery Management Plan
FSSI	Fish Stock Sustainability Index
GAM	Generalized Additive Model
GIS	Geographical Information System
GMFMC	Gulf of Mexico Fishery Management Council
GOM	Gulf of Mexico
HAPC	Habitat Areas of Particular Concern
HEWG	Habitat Evaluation Working Group
IUCN	International Union for the Conservation of Nature
LNG	Liquefied Natural Gas
MARFIN	Marine Fisheries Initiative Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
ROV	Remotely Operated Underwater Vehicle
SAFMC	South Atlantic Fishery Management Council
SAV	Submerged Aquatic Vegetation
SEAMAP	Southeast Area Monitoring and Assessment Program

1.0 Introduction

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) set forth a new mandate to identify and protect important marine and anadromous fisheries habitat. The regional Fishery Management Councils, with assistance from NMFS, are required to delineate essential fish habitat (EFH) in fishery management plans (FMP) or FMP amendments for all Federally managed fisheries. Federal action agencies that fund, permit, or carry out activities that may adversely affect EFH are required to consult with NMFS regarding potential adverse impacts of their actions on EFH, and respond in writing to NMFS and Council recommendations.

Subpart J of 50 CFR Part 600 contains guidelines to assist Councils in developing EFH components for Fishery Management Council's FMPs. Under subpart J, Fishery Management Councils must identify EFH for each life stage of each managed species in the fishery management unit in each of their FMPs. Councils must identify as EFH those habitats that are necessary to the species for spawning, breeding, feeding, or growth to maturity. Councils must describe EFH in text and must provide maps of the geographic locations of EFH or the geographic boundaries within which EFH for each species and life stage is found. Habitat areas of particular concern (HAPC) are identified as EFH that is especially important ecologically or particularly vulnerable to degradation to help provide additional focus for conservation efforts. Councils must evaluate the potential adverse effects of fishing activities on EFH and must include management measures that minimize adverse effects of fishing on habitat to the extent practicable.

Subpart J of 50 CFR part 600 also states that each FMP should contain the following EFH components:

1. Descriptions and identification of EFH
2. Fishing activities that may adversely affect EFH
3. Non-Magnuson-Stevens Act fishing activities that may adversely affect EFH
4. Non-fishing activities that may adversely affect EFH
5. Cumulative impacts analysis
6. EFH conservation and enhancement recommendations
7. Prey species
8. Identification of habitat areas of particular concern (HAPC)
9. Research and information needs
10. Review and revision of EFH components of FMPs

Under component 10, Subpart J states that Councils and NMFS should periodically review the EFH provisions of FMPs and revise or amend EFH provisions as warranted based on available information. The review of information should include, but not be limited to, evaluating published scientific literature and unpublished scientific reports; soliciting information from interested parties; and searching for previously unavailable or inaccessible data. A complete review of all EFH information should be conducted as recommended by the Secretary, but at least once every 5 years.

This report documents the 5-year EFH review for the Gulf of Mexico Fishery Management Council (Council). Based on this report, the Council and NMFS will determine the need to revise the EFH designations and descriptions. If so, the Council will accordingly initiate FMP amendments, to revise EFH components or management measures within their seven FMPs or as another generic EFH amendment for all FMPs.

1.1 Previous EFH Designations

In 1998, the Council amended the seven FMPs of the Gulf of Mexico identifying and describing EFH based on where various life stages of 26 representative managed species and the coral complex commonly occur. The selected species accounted for about a third of the species under management and were selected because they were considered ecologically representative of the remaining species within the respective FMPs. In 2000, because of a lawsuit brought forth by a coalition of environmental groups, the agency's decisions on EFH amendments by several Councils (including the Gulf of Mexico Council) were found to be in accordance with the MSFCMA but in violation of the National Environmental Policy Act (NEPA). NMFS was ordered to complete new, more thorough NEPA analyses for each EFH amendment in question.

In 2004, the Council completed a Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment (2004 EFH EIS) addressing all required EFH components. As a result of the 2004 EFH EIS, the Council produced the 2005 Final Generic Amendment Number 3 for Addressing Essential Fish Habitat Requirements, Habitat Areas of Particular Concern, and Adverse Effects of Fishing in the Fishery Management Plans of the Gulf of Mexico (2005 EFH Amendment).

The 2005 EFH Amendment delineated EFH as areas of higher species density, based on the NOAA Atlas (NOAA 1985) and functional relationships analysis for the Red Drum, Reef Fish, Coastal Migratory Pelagics, Shrimp, Stone Crab, and Spiny Lobster FMPs; and on known distributions for the Coral FMP. Specifically, EFH consists of the following waters and substrate areas in the Gulf of Mexico:

> Red Drum FMP: all estuaries; Vermilion Bay, Louisiana, to the eastern edge of Mobile Bay, Alabama, out to depths of 25 fathoms; Crystal River, Florida, to Naples, Florida, between depths of 5 and 10 fathoms; and Cape Sable, Florida, to the boundary between the areas covered by the GMFMC and the South Atlantic Fishery Management Council (SAFMC) between depths of 5 and 10 fathoms.
>
> Reef Fish and Coastal Migratory Pelagics FMPs: all estuaries; the US/Mexico border to the boundary between the areas covered by the GMFMC and the SAFMC from estuarine waters out to depths of 100 fathoms.

Shrimp FMP: all estuaries; the US/Mexico border to Fort Walton Beach, Florida, from estuarine waters out to depths of 100 fathoms; Grand Isle, Louisiana, to Pensacola Bay, Florida, between depths of 100 and 325 fathoms; Pensacola Bay, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 35 fathoms, with the exception of waters extending from Crystal River, Florida, to Naples, Florida, between depths of 10 and 25 fathoms and in Florida Bay between depths of 5 and 10 fathoms.

Stone Crab FMP: all estuaries; the US/Mexico border to Sanibel, Florida, from estuarine waters out to depths of 10 fathoms; and from Sanibel, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC from estuarine waters out to depths of 15 fathoms.

Spiny Lobster FMP: from Tarpon Springs, Florida, to Naples, Florida, between depths of 5 and 10 fathoms; and Cape Sable, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 15 fathoms.

Coral FMP: the total distribution of coral species and life stages throughout the Gulf of Mexico including: coral reefs in the North and South Tortugas Ecological Reserves, East and West Flower Garden Banks, McGrail Bank, and the southern portion of Pulley Ridge; hard bottom areas scattered along the pinnacles and banks from Texas to Mississippi, at the shelf edge and at the Florida Middle Grounds, the southwest tip of the Florida reef tract, and predominant patchy hard bottom offshore of Florida from approximately Crystal River south to the Florida Keys.

1.2 Previous HAPC Designations

The EFH guidelines provide for the designation of subsets of EFH as habitat areas of particular concern (HAPC). The 2005 EFH Amendment identified several areas as HAPCs. Each proposed site is discrete, and meets one or more HAPC criteria:

1. Importance of ecological function provided by the habitat;
2. Extent to which the area or habitat is sensitive to human induced degradation;
3. Whether and to what extent development activities are stressing the habitat; and
4. Rarity of the habitat type.

HAPC were identified as the Florida Middle Grounds, Madison-Swanson Marine Reserve, Tortugas North and South Ecological Reserves, Pulley Ridge, and the individual reefs and banks of the Northwestern Gulf of Mexico: East and West Flower Garden Banks, Stetson Bank, Sonnier Bank, MacNeil, 29 Fathom Bank, Rankin Bright Bank, Geyer Bank, McGrail Bank, Bouma Bank, Rezak Sidner Bank, Alderice Bank, and Jakkula Bank.

1.3 Previous Measures to Minimize Fishing Impacts to EFH

The Gulf of Mexico Council has addressed threats to habitat from fishing activities and has included management measures to minimize these adverse threats since the first fishery management plans were published in the late 1970's. No new management measures or regulations were proposed in the 1998 EFH Amendment.

The Council's 2004 EFH EIS utilized a fishing gear sensitivity index and fishing effort to analyze the relative risk of impacts to EFH resulting from various fishing activities. The 2005 EFH Amendment proposed four additional measures to prevent, mitigate, or minimize the adverse effects of fishing on EFH in the Gulf of Mexico. These measures were to:

1. Prohibit bottom anchoring over coral reefs in HAPC (East and West Flower Garden Banks, McGrail Bank, Pulley Ridge, and North and South Tortugas Ecological Reserves) and on the significant coral communities on Stetson Bank.

2. Prohibit use of trawling gear, bottom longlines, buoy gear, and all traps/pots on coral reefs throughout the Gulf of Mexico EEZ (East and West Flower Garden Banks, McGrail Bank, Pulley Ridge, and North and South Tortugas Ecological Reserves) and on the significant coral resources on Stetson Bank.

3. Require a weak link in the tickler chain of bottom trawls on all habitats. A weak link is defined as a length or section of the tickler chain that has a breaking strength that is less than the chain itself and is easily seen as such when visually inspected.

4. Establish an education program on the protection of coral reefs when using various fishing gears in coral reef areas for recreational and commercial fishermen.

1.4 Five-Year Review Approach

This summary report documents the results of the 2010 5-year EFH review. This review includes:

1. reviewing existing EFH descriptions and designations by life stage for errors
2. evaluating new information available since the 2005 EFH Amendment for EFH descriptions and designations
3. determining possible new methods of designating EFH
4. evaluating how species specific EFH identifications and descriptions can be better presented in addition to the FMP description
5. making recommendations on whether EFH descriptions should be updated
6. reviewing any changes and new information on fishing impacts that may adversely affect EFH
7. reviewing any changes and new information on non-fishing impacts that may adversely affect EFH
8. reviewing habitat areas of particular concern (HAPC) designations

9. determining if current HAPC designations are adequate or if areas need to be removed or added.

In order to complete the above steps, two members of the Council staff along with a representative from the National Marine Fisheries Service reviewed the 2005 EFH Amendment for errors. Council staff performed an extensive literature search to determine if any new EFH information was available. They also communicated with researchers around the Gulf of Mexico to discover new information. Council staff explored new methods of designating EFH based mainly upon the findings of the Habitat Evaluation Working Group Report from the Northeast Fisheries Science Center (HEWG 2005). In evaluating how EFH should be described by species, the authors discussed the issue with NMFS Habitat Conservation Division staff who are responsible for reviewing Federal permit actions that affect EFH. A literature search was also performed to review any changes and new information on fishing impacts to EFH. Updated commercial fishing logbook data and recreational fishing effort data were obtained to examine if fishing effort or intensity has changed since the 2005 EFH Amendment. A literature review and discussions with experts were held to determine changes to non-fishing impacts that may adversely affect EFH. The HAPC designations and their adequacy were reviewed by talking to researchers and a literature review.

2.0 Reviewing Existing EFH Descriptions and Designations

One of the requirements for this document is to review the 2005 EFH Amendment for errors in existing EFH descriptions or identifications. During this review, several items from the 2005 EFH Amendment were found to be in error. During the development of the 2005 EFH Amendment, EFH was defined based upon EFH consisting of areas of higher species density, based on the NOAA Atlas (NOAA 1985) and a functional relationships analysis. The functional relationship analysis determined habitat suitability for each species life stage based on substrate type and depth and relative abundance within five Gulf of Mexico eco-regions established for the analysis. For each species and life stage, suitable habitat was mapped using a geographic information system (GIS) which was developed to help with this process. The EFH maps produced as a result of this process were deliberated by the Council to create the textual descriptions of EFH for each FMP. The Final Rule for implementing the EFH provisions of the Magnuson-Stevens Fishery Conservation and Management Act (EFH Final Rule) requires that EFH must be described in text, including reference to the geographic location or extent of EFH using boundaries such as longitude and latitude, isotherms, isobaths, political boundaries, and major landmarks. The EFH Final Rule states that if there are differences between the descriptions of EFH in text, maps, and tables, the textual description is ultimately determinative of the limits of EFH. Since the text in the 2005 EFH Amendment described the maps in text as required, the text differed slightly from the maps. For instance, red drum EFH was described in the text as “Vermilion Bay, Louisiana, to the eastern edge of Mobile Bay, Alabama, out to depths of 25 fathoms.” This was a textual description of a map that approximated what the map depicted. In some areas, on the map, red drum EFH was deeper than 25 fathoms and in some areas it was shallower than 25 fathoms. The text was a general description of the map and it therefore differed slightly.

In 2008, National Marine Fisheries Service took steps to correct these discrepancies. The GIS products from the 2005 EFH Amendment were modified to reflect accurately the EFH text descriptions. In addition, the National Coastal Data Development Center helped correct the topology and artifact problems that existed in the original GIS files. Metadata for the GIS files were created also.

The 2005 EFH Amendment listed Coral EFH as "the total distribution of coral species and life stages throughout the Gulf of Mexico." Figure 8 in the 2005 EFH Amendment delineates EFH for the Coral FMP. This coral distribution map was based upon a detailed bottom sediment map derived from Sheridan and Caldwell (2002). Sheridan and Caldwell (2002) derived their bottom sediment map from a map depicting the shelf sediment textures, hard banks, and gravel deposits on the continental shelf of the U. S. Gulf of Mexico (U. S. Department of the Interior 1983, Visual No. 3). In the process of digitizing the map, Sheridan and Caldwell (2002) made a mistake in classifying one area approximately 30 km east of San Antonio Bay, Texas. This area was classified as hardbottom in Sheridan and Caldwell (2002). The original source map U. S. Department of the Interior 1983, Visual No. 3 has this area classified as sandy silt. Therefore, it should not be EFH for coral.

Another possible problem with Coral EFH is that it is based upon the total distribution of coral species and life stages throughout the Gulf of Mexico. Therefore, it is limited to which map you use to depict its distribution. The distribution of coral areas depicted in the U. S. Department of the Interior 1983, Visual No. 3 differs somewhat from the NOAA Atlas (NOAA 1985). In 2005, the Gulf States Marine Fisheries Commission began a MARFIN funded project to develop a user friendly, interactive system that identifies, describes, and displays resources characterizing the seabed habitat of the Gulf of Mexico. The database was created from the recovery, interpretation, and integration of existing data for this region. The main focus of this project was to identify hardbottom and coral areas around the Gulf of Mexico. This database could be used to identify coral and hardbottom areas around the Gulf that were not previously classified as Coral EFH.

Errors in the digitization of the NOAA Atlas maps were discovered following publication of the 2005 EFH Amendment. Lake Rousseau was incorrectly mapped as EFH for the Coastal Migratory Pelagics, Red Drum, Reef Fish, Shrimp, and Spiny Lobster. Lake Rousseau is strictly a freshwater lake that has a lock and dam system in place on the Florida Barge Canal that effectively blocks marine fishery ingress and egress to Lake Rousseau. Historically accessible habitats may be identified and described as EFH (in accordance with 600.815(a)(1)(iv)(C)) however, Lake Rousseau and other reservoirs were inadvertently included on the EFH maps, but were not identified and described as EFH in the 2005 EFH Amendment.

The EFH maps also relied on data from U.S. Fish and Wildlife Service's National Wetland Inventory maps to represent an inland boundary of EFH which is not specified in the textual descriptions of EFH. NMFS Habitat Conservation staff have indicated that the lack of well defined inland boundaries creates a source of uncertainty and confusion among the public and federal regulatory agencies when conducting EFH Consultations pursuant to Section 305(b)(2) of the MSFCMA.

3.0 Results of Review

3.1 New Information about Species or Life Stage Distribution, Abundance, Density, Productivity, or Habitat Associations

In this section, new literature was evaluated to determine whether new information was available for species within the different FMPs. A literature survey of the published and unpublished scientific literature was performed. The literature survey resulted in 144 scientific articles concerning EFH and managed species distributions within the Gulf of Mexico. A summary of the literature is presented for each FMP below.

3.1.1 Coastal Migratory Pelagics

Coastal Migratory Pelagics EFH was identified in the 2005 EFH Amendment as "all estuaries; the US/Mexico border to the boundary between the areas covered by the GMFMC and the SAFMC from estuarine waters out to depths of 100 fathoms."

No new literature since the 2005 EFH Amendment describing EFH for species within the Coastal Migratory Pelagics FMP was found during the literature survey.

3.1.2 Coral

In the 2005 EFH Amendment, EFH for the Coral FMP was defined as "the total distribution of coral species and life stages throughout the Gulf of Mexico including: coral reefs in the North and South Tortugas Ecological Reserves, East and West Flower Garden Banks, McGrail Bank, and the southern portion of Pulley Ridge; hard bottom areas scattered along the pinnacles and banks from Texas to Mississippi, at the shelf edge and at the Florida Middle Grounds, the southwest tip of the Florida reef tract, and predominant patchy hard bottom offshore of Florida from approximately Crystal River south to the Florida Keys." Since the 2005 EFH Amendment, numerous studies have examined coral distribution and diversity within the Gulf of Mexico. The findings of this research are presented below.

Several research projects have studied deepwater coral reefs and their associated fauna within the Gulf of Mexico. These deepwater coral reefs are composed of *Lophelia pertusa* and *Madrepora oculata*. These two corals are found in several areas in the Gulf of Mexico (Figure 1) in waters deeper than 300 m and both have hard calcareous skeletons that can form reefs and extensive thickets. *M. oculata* is often found along with *L. pertusa*. These corals are usually found in association with hard substrates formed by authigenic carbonate precipitation resulting from the bacterial alteration of hydrocarbons and anaerobic methane oxidation in areas of active hydrocarbon seepage. *L. pertusa* and *M. oculata* are scleractinian coral, but unlike scleractinian coral in shallow water they do not depend on photosynthetic zooxanthellae. Deepwater corals rely on zooplankton or detritus to meet their nutritional requirements (CSA International, Inc. 2007). Schroeder et al. (2005) discussed the location of 17 sites in the northern Gulf of Mexico where *L. pertusa* and *M. oculata* had been recorded. The researchers briefly describe each site that are located in water depths of 300 to 900 m.

L. pertusa forms large thickets that provide habitat for many different organisms. *L. pertusa* appears to structure the surrounding slope community largely through the provision of habitat rather than food (CSA International, Inc. 2007). *L. pertusa* creates habitat for a number of associated species, many of which show significantly higher densities near coral. Cordes et al. (2008) describe the fauna associated with four different *L. pertusa* sites in Viosca Knoll Minerals Management Service Lease Area south of Mississippi and the Green Canyon Lease Area south of central Louisiana. The researchers found 68 taxa in their 15 collections at the sites. The most abundant organisms were sabellid polychaetes, an unidentified encrusting sponge, and hydroids. Sulak et al. (2007) examined the fish fauna of *L. pertusa* reefs and found them to be sparsely populated with demersal fish. They recorded 53 species, but only a few were considered common or abundant.

Barnette (2006) recorded extensive colonies of *Oculina varicosa* off the west Florida shelf (Figure 1) in an area known as the Twin Ridges. The Twin Ridges are south of Cape San Blas, Florida in approximately 75 m of water and consist of two rocky ledges running parallel to each other trending in a northwestward direction (Koenig et al. 2000). Barnette (2006) observed several species of fish in the area including greater amberjack (*Seriola dumerili*), scamp (*Mycteroperca phenax*), gag (*Mycteroperca microlepis*), and spotfin hogfish (*Bodianus pulchellus*) as well as numerous other coral and invertebrate species. *O. varicosa* is generally not known to occur in the Gulf of Mexico, but extensive colonies do exist off the east coast of Florida. Barnette (2006) cited a personal communication that suggested other colonies of *O. varicosa* exist in deepwater areas of the Gulf of Mexico at around these same depths. In addition, Church et al. (2007) examined World War II era shipwrecks in the Gulf of Mexico and noted that *O. varicosa* was located on a shipwreck in 87 m of water approximately 11.4 km south of the Southwest Pass of the Mississippi River.

Weaver et al. (2006a) used a submersible to identify reef fish communities, characterize benthic habitats, and identify deep coral reef ecosystems on Alderdice, McGrail, and Sonnier Banks off Louisiana. These banks were identified as HAPCs in the 2005 EFH Amendment. Sonnier Bank has previously been described by Rezak et al. (1985) as a salt dome structure rising from depths of 80 m or less and having a relief of about 4 to 50 m. Sonnier Bank is located approximately 135 km south of the Louisiana/Texas border. Sonnier Bank actually consists of eight separate banks or peaks on top of a single salt dome. The peaks are shaped like cones with a maximum relief of about 30 m. Weaver et al. (2006a) examined high-resolution multibeam bathymetry of Sonnier Bank and found up to at least a dozen additional lower relief peaks associated with the feature. Red snapper (*Lutjanus campechanus*), greater amberjack (*Seriola dumerili*), and gray triggerfish (*Balistes capriscus*) were found to inhabit these lower reef areas. Kraus et al. (2006) found large aggregations of vermillion snapper *(Rhomboplites aurorubens)* on Sonnier Bank along with red snapper, gray snapper *(Lutjanus griseus)*, yellowmouth grouper *(Mycteroperca interstitialis)*, and graysby *(Cephalopholis cruentata)* were also observed.

McGrail Bank is located approximately 180 km south of Louisiana. As described by Rezak et al. (1985), McGrail Bank is a pair of ridges separated by a valley. Along with East and West Flower Garden Banks, McGrail Bank is one of the few banks in the northwestern Gulf of Mexico that has extensive growth of reef-building corals (Weaver et al. 2006a). Weaver et al. (2006a) stated that McGrail Bank contained extensive growth hard corals dominated by the blushing star coral (*Stephanocoenia intersepta*), large brain corals (*Diploria strigosa* and *Montastrea cavernosa*), and a species of *Agaricia*. Weaver et al. (2006a) estimated coral coverage reached 30% in some areas, at a depth range of 45 to 60 m. Weaver et al. (2006a) also found a 2 m tall colony of *D. strigosa*.

Alderdice Bank is unique among the Louisiana and Texas offshore banks in that it has basalt outcrops associated with the salt dome. Alderdice Bank is located about 160 km south of the central Louisiana coast. While previous surveys of Alderdice Bank identified a single pinnacle, the multibeam data recorded by Weaver et al. (2006a) resolved two distinct pinnacles with lose rocks between them. Both pinnacles provide high profile structure and Weaver et al. (2006a) found large schools of creolefish, vermilion snapper, and several species of grouper, snapper, and jacks around them. Weaver et al. (2006a) also noted a rare marbled grouper (*Dermatolepis inermis*) on one of the submersible dives around Alderdice Bank.

Staghorn coral (*Acropora cervicornis*) and elkhorn coral (*Acropora palmata*), are important reef builders in the Caribbean, (Precht and Aronson 2004), but do not occur in the Gulf of Mexico due to their low tolerance for cold water. Zimmer et al. (2006) discovered a colony of elkhorn coral in 2003 at the top of West Florida Garden Bank in 21.6 m of water. In 2005, the researchers found another colony at the East Flower Garden Bank at a depth of 23.5 m. Not only are these the first discoveries of *Acropora* in the Gulf of Mexico, but they were found at greater depths than the species were known to occur in the Caribbean. Precht and Aronson (2004) theorize that staghorn and elkhorn coral are expanding their ranges into the northern Gulf of Mexico, coincident with increasing sea temperatures.

Harter et al. (2008) studied the extent of scleractinian corals and fish diversity around the Pulley Ridge HAPC. Pulley Ridge contains the deepest known hermatypic coral reef in U.S. waters. They discovered a distinct difference in habitat between northern and southern Pulley Ridge. Areas in the northern section of the Pulley Ridge HAPC were characterized as either sand, pavement, or low relief outcrops, with the pavement and low relief outcrops containing several species of sessile and encrusting invertebrates and algae. Harter et al. (2008) characterized the southern area of the Pulley Ridge HAPC as rock rubble with varying coverage of algae, coralline algae, hermatypic corals, solitary and encrusting sponges, octocorals, and antipatharians. They found fish diversity to be highest inside the southern portion of the HAPC on the rock rubble habitat, where they found sand tilefish (*Malacanthus plumieri*) mounds and red grouper (*Epinephelus morio*) pits. The stony coral, *Agaricia* spp., was only found in the southern portion of Pulley Ridge both inside and outside the HAPC in depths between 61.3 and 89.0 m. Rock rubble habitat in the southern HAPC had the highest fish diversity with 44 different species. Low relief outcrops had 29 species, followed by pavement with 17 species, and finally 12 different fish species in the sand habitat. Red grouper were the most abundant grouper species in the southern area. Scamp (*Mycteroperca phenax*) was the most frequently observed grouper in the northern HAPC. ROV dives and video camera recordings were also made in 104 to 117 m of water in areas west of the Pulley Ridge HAPC. Harter et al. (2008) describe the habitat as 100% rock with very little relief since they were on top of a ridge. The most abundant fish in these areas west of the Pulley Ridge HAPC were roughtongue bass (*Holanthias martinicensis*), creolefish (*Paranthias furcifer*), and red snapper (*Lutjanus campechanus*). Also of note, Harter et al. (2008) made several observations of fishing gear (monofilament line, longline, and fish traps) during the ROV dives along the entire ridge, both inside and outside the HAPC.

Harter et al. (2008) also made a submersible dive on a sinkhole west of the northern edge of the Pulley Ridge HAPC. Harter et al. (2008) describe the sinkhole as having steep rocky walls with numerous overhangs with the bottom of the sinkhole being composed of sand, shell-hash, and rubble. Most fish were found along the rim of the sinkhole. The most abundant species they observed were snowy grouper (*Epinephelus niveatus*), queen snapper (*Etelis oculatus*), roughtongue bass (*Pronotogrammus martinicensis*), bigeye soldierfish (*Ostichthys trachypoma*), and slimeheads (Trachichthyidae). Reed et al. (2005) also explored this area and found 14 taxa of sponges covering the walls of the sinkhole along with hydrocorals. Reed et al. (2005) found fourteen species of fish, with large schools (10 to 100 individuals) of greater amberjack (*Seriola dumerili*). Reed et al. (2005) also documented red porgy (*Pagrus pagrus*), blueline tilefish (*Caulolatilus microps*), snowy grouper (*Epinephelus niveatus*), speckled hind (*Epinephelus drummondhayi*), Warsaw grouper (*Epinephelus nigritus*), and yellowedge grouper (*Epinephelus flavolimbatus*) around the top edge of the sinkhole. Aggregations of 10 to 20 large groupers were seen in this area.

3.1.3 Red Drum

Red drum EFH was identified in the 2005 EFH Amendment as "all estuaries; Vermilion Bay, Louisiana, to the eastern edge of Mobile Bay, Alabama, out to depths of 25 fathoms; Crystal River, Florida, to Naples, Florida, between depths of 5 and 10 fathoms; and Cape Sable, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC between depths of 5 and 10 fathoms."

Gain (2009) looked at habitat selection of juvenile red drum (*Sciaenops ocellatus*) ranging in size from 15 mm to 30 mm SL. Gain (2009) found that in the absence of a predator, that structured habitat did not influence juvenile red drum habitat selection. Juvenile red drum used both complex and simple habitats. However, when exposed to predators red drum selected for more structured, complex habitat. Gain (2009) determined that the results suggest that oyster reef may function similarly to seagrass or marsh edge habitat types and may provide a refuge from predation for some fish and crustaceans.

Holt (2008) conducted hydrophone surveys around Aransas Pass, Texas to investigate spawning activity of adult red drum. Holt (2008) reported that red drum spawning aggregations usually consisted of pairs or small groups scattered over a wide but distinct area and typically engaged in pair or group spawning. Holt (2008) determined that after examining the distribution of sound production, red drum apparently spawn all along the nearshore region of the central Texas coast. Holt (2008) stated that the survey was not spatially broad enough to fully delineate the spawning area, but it made clear that red drum spawning activity is widespread and not concentrated at inlets or passes.

Rooker et al. (2010) examined the stable carbon (δ13C) and oxygen (δ18O) isotope ratios in otoliths to assess the level of connectivity between early life and adult habitats of red drum in the northern Gulf of Mexico. Rooker et al. (2010) state that the results clearly demonstrate that otolith δ13C and δ18O are viable markers of nursery origin and can be used to assess contribution rates of different nurseries to adult populations of red drum. They report that mixing occurs between regional estuaries in the Gulf of Mexico, but the majority of adult red drum appear to either remain close to their nursery estuary or even return to their nursery area after a dispersive phase. Rooker et al. (2010) state that red drum fishery yields are directly linked to local production with some contributions from adjacent estuaries. Therefore, local impacts such as pollution, fishing pressure and freshwater inflow will influence population dynamics of red drum within a specific region. The researchers suggest that spatially explicit management may be needed at the bay or estuary level to aid in achieving desired levels of production throughout the geographic range of the species.

Stunz et al. (2002a) examined the growth rate of juvenile red drum in salt marsh, seagrass, oyster reef, and on nonvegetated bottom areas in the Galveston Bay, Texas. The researchers found that growth rates of juvenile red drum captured at marsh, nonvegetated, and seagrass sites were not significantly different. The researchers did not capture any juvenile red drum on oyster reefs. Stunz et al. (2002a) reported an overall growth rate of 0.45 mm per day. The researchers also performed enclosure experiments over the four habitat types to examine any differences in growth rates between the different habitats. Stunz et al. (2002a) calculated growth rates of 0.12 mm per day in oyster reef, 0.21 mm per day on nonvegetated bottom, 0.40 mm per day in salt marsh, and 0.42 mm per day in seagrass. The researchers stated the growth potential for red drum was significantly higher in marsh and seagrass enclosures, but growth results in enclosures should be evaluated carefully, because fish movement between the different habitats may be important in these shallow estuarine systems.

Stunz et al. (2002b) examined patterns of habitat use for newly settled red drum at six sampling areas in Galveston Bay, Texas. Two areas contained seagrass beds while the other four areas did not contain seagrass. The researchers found that the peak recruitment of juvenile red drum occurred during September through December. The highest densities of red drum were found in seagrass meadows with the predominant seagrass being *Halodule wrightii*. The *Spartina alterniflora* marsh edge interface contained the second highest densities with low densities of red drum found on nonvegetated bottoms. The researchers did not find red drum within the marsh vegetation away from the marsh edge. The researchers also did not find any red drum associated with oyster reefs. Stunz et al. (2002b) state that even though red drum densities were lower at the marsh edge interface, marsh areas are much more extensive in Galveston Bay than seagrass. Therefore, the marsh edge interface may function as a significant nursery for red drum in Galveston Bay. Stunz et al. (2002b) also state that in order to understand the contribution that a habitat type makes to red drum production, you need to consider not only density patterns, but also the areal extent of the habitat, the differential survival and growth within the habitat, and the movement of fish among the different habitat types.

3.1.4 Reef Fish

Reef fish EFH was identified in the 2005 EFH Amendment as "all estuaries; the US/Mexico border to the boundary between the areas covered by the GMFMC and the SAFMC from estuarine waters out to depths of 100 fathoms."

Acosta et al. (2007) conducted a trawl survey in the seagrass beds of the Florida Keys to examine the ichthyofauna of these areas. Acosta et al. (2007) determined that the seagrass beds served as important habitat for small and juvenile fishes especially lane snapper (*Lutjanus synagris*) and hogfish (*Lachnolaimus maximus*). Mangrove snapper (*Lutjanus griseus*) were also collected in high numbers, but Acosta et al. (2007) stated that the majority of these fish were late juveniles.

Albanez-Lucero and Arreguin-Sanchez (2009) modeled the spatial distribution of red grouper (*Epinephelus morio*) on the Campeche Bank area. Albanez-Lucero and Arreguin-Sanchez (2009) noted seasonal changes in red grouper distribution. Juveniles show two main regions of high abundance near the coast in sandy areas. Pre-adults were high in abundance during winter near coral reefs. Adults were located in deeper, offshore waters also on sandy substrates.

Coleman et al. (2010) sought to describe the physical and faunal differences between red grouper holes and surrounding areas and to determine whether red grouper associated with these holes were actively excavating and maintaining the areas surrounding these holes. Coleman et al. (2010) found that red grouper were acting as habitat engineers in that red grouper actively excavate sediment from holes in hardbottom areas in the northeastern Gulf of Mexico. Coleman et al. (2010) stated that this red grouper excavating behavior is maintained throughout their ontogeny. Coleman et al. (2010) conclude that active sediment removal by red grouper increases biological diversity by exposing rocky substrate that provides settlement sites for sessile organisms and increases architectural complexity, which attracts many reef associated species and provides shelter for juvenile stages of some economically important species.

Cook (2007) used fishery independent longline and trawl data to determine that yellowedge grouper (*Epinephelus flavolimbatus*) were primarily found in depths of 50 to 300 m throughout the Gulf of Mexico. Cook (2007) stated that in the western and central Gulf of Mexico, yellowedge grouper appeared to prefer mostly soft substrate, but were found associated with smaller reef and rock patches, outcroppings, sinkholes, pockmarks and ledges in the eastern Gulf of Mexico. Cook (2007) reported that the bottom temperature from capture locations ranged from 10.7° to 27.0° C. Cook (2007) noted that yellowedge grouper in the western Gulf of Mexico were larger, older, and more abundant while fish in the eastern Gulf of Mexico were smaller and younger. Yellowedge grouper in the eastern Gulf of Mexico tended to cluster in denser aggregations than those in the western Gulf. Cook (2007) stated that this might be due to habitat differences between the two regions. The primarily carbonate substrate in the eastern Gulf makes burrow construction difficult due to a lack of cohesive sediment. The data showed that the highest densities of yellowedge grouper from the eastern Gulf were from Tampa to south of Charlotte Harbor, Florida along the 100 fathom contour. This area contains patchy smaller reef and rock patches, outcroppings, sinkholes, pockmarks and ledges. Cook (2007) theorized that these patchy habitat areas possibly caused yellowedge grouper to live in denser groups to take advantage of the available habitat.

Faunce and Serafy (2007) examined the utilization of seagrass beds and mangrove shorelines by mangrove snapper. They stated that peak recruitment of mangrove snapper into seagrass beds was observed from September to October. After residing in seagrass beds for approximately eight months, mangrove snapper moved into mangrove habitats. Faunce and Serafy (2007) found that the maximum size of mangrove snapper within seagrass beds matched the smallest average size of individuals within mangrove habitat, suggesting that mangroves are utilized as a secondary or sequential habitat by these species. Faunce and Serafy (2007) conclude that mangrove snapper shift from utilizing seagrass to mangroves after approximately eight to ten months and at a size of 10.5 to 12 cm total length. Faunce and Serafy (2007) state that the move to mangroves was likely due to the inability of seagrass to shelter comparatively large mangrove snapper from predation.

Fodrie et al. (2010) sampled seagrass areas in Mississippi, Alabama, and northern Florida previously sampled in the 1970s to compare the ichthyofauna between the two periods. The comparison showed several new species including lane snapper, red grouper, and yellowtail snapper (*Ocyurus chrysurus*). Several other species showed large increases in abundance between 1979 and 2006, including gag grouper and mangrove snapper. The researchers also observed increased air and sea surface temperatures, which they theorize have led to northern shifts in the distribution of these warm water fish. Fodrie et al. (2010) found that nearly 20% of the fish species collected in northern Gulf of Mexico seagrass meadows during 2006–2007 were tropical or subtropical, and were either absent, or much less abundant than they were in the

1970s. Fodrie et al. (2010) conclude that the presence of these fish may be an early indicator for the extension of tropical conditions in the northern Gulf of Mexico.

Frias-Torres (2006) evaluated the importance of underwater mangrove habitat structure to the distribution of juvenile goliath grouper (*Epinephelus itajara*) in the Florida Keys. Frias-Torres (2006) used underwater visual surveys to record juvenile presence, abundance, and size. Habitat characteristics such as depth, canopy, overhang, prop root width, bottom type, sun exposure, shoreline shape, and shoreline type were also recorded. Frias-Torres (2006) found that juvenile goliath grouper aggregated in areas at least 80 cm deep during high and flood tides, with undercuts and/or well-developed canopy and overhangs, which provide both shade and structural complexity underwater. Frias-Torres (2006) concluded that these types of mangrove areas were the most valuable habitat type for juvenile goliath grouper.

Koenig and Coleman (2006) examined areas to characterize red grouper habitat off the west coast of Florida. Koenig and Coleman (2006) examined near shore areas for juvenile red grouper and found that red grouper were always found in association with exposed solution holes in hardbottom areas that were in water depths of 2 to 4 m. Juvenile red grouper were found in sites that ranged from 1 to 3 m^2 and extended about a meter below the surface. Koenig and Coleman (2006) stated that the dominant organisms around these areas were basket sponges and coralline algae. They examined offshore areas in 80 m of water for adult red grouper habitat. Koenig and Coleman (2006) state that red grouper were always found in association with large sandy cone-shaped pits that were roughly 6.8 m in diameter and 2 m deep. These pits were clustered and differed somewhat in their geomorphology. Koenig and Coleman (2006) found that the slopes of the pit contained scattered boulders with exposed rocky outcrops in the center of each depression that covered approximately 36% of the pit area.

Koenig et al. (2007) examined mangrove use by goliath grouper in the Ten Thousand Islands area and Everglades National Park for nursery habitat by looking at abundance, density, survival, age structure, home range, mangrove habitat association, habitat quality, and recruitment to the adult population. Koenig et al. (2007) reported that goliath grouper remained in mangroves for 5 to 6 years until they were approximately one meter in length before they left for offshore habitats. Koenig et al. (2007) found that juveniles had smaller home ranges around islands (170 m) than they did in rivers (586 m) and had slower growth rates in rivers. They also found that juvenile densities were higher around mangrove islands than densities in rivers. Koenig et al. (2007) postulated that rivers were more likely than mangrove islands to experience frequent hypoxic or low salinity conditions due to upland freshwater management projects.

Lara et al. (2009) collected juvenile goliath grouper in tributary mouths in the Ten Thousand Islands area of Florida. The juveniles measured between 15 and 87 mm standard length and were found over a limited area in shallow water near mangroves. Lara et al. (2009) calculated that these newly settled juveniles were 30 to 80 days old and were probably spawned offshore during the full moon during the months of July to October.

Lindberg et al. (2006) examined the colonization of the Suwannee Regional Reef System that was built of standard artificial reefs in 1991 to 1993. Lindberg et al. (2006) stated that colonization of the artificial reef zone by gag over the first six years showed significant interactions with artificial reef size, spacing, and reef age. Lindberg et al. (2006) reported that larger reefs contained more gag than smaller reefs. Lindberg et al. (2006) found that average relative weight and incremental growth were greater on smaller reefs than on larger reefs. Lindberg et al. (2006) determined that shelter limits local densities of gag, which, in turn, regulates their growth and condition. They found that gag selected shelter at the expense of maximizing their growth. Lindberg et al. (2006) conclude that if the objective of building artificial reefs is to enhance gag stocks then they should be small, widely scattered patch reefs with appropriately sized cavities as these reefs can enhance the biological production of gag.

Luo et al. (2009) evaluated habitat utilization of mangrove snapper across mangrove, seagrass, and coral reef habitats in the Florida Keys. Luo et al. (2009) found that mangrove snapper exhibit a pattern where shallow seagrass beds are frequented nocturnally and mangroves and other habitats with complex structure are occupied diurnally. Luo et al. (2009) also found that during the spawning season mangrove snapper move from these inshore habitats to offshore reefs for spawning.

Lyczkowski-Shultz and Hanisko (2007) used plankton data from the SEAMAP fishery independent plankton surveys to describe the distribution of red snapper larvae in the Gulf of Mexico. Lyczkowski-Shultz and Hanisko (2007) stated that red snapper larvae first appeared in May and were present as late as November. Red snapper larvae were most abundant during July and September. Lyczkowski-Shultz and Hanisko (2007) reported that while larvae were captured throughout the survey area, they were captured in greatest abundance on the middle of the continental shelf west of the Mississippi River. Abundances were especially high off western Louisiana and central Texas.

Mann et al. (2009) studied goliath grouper at two spawning aggregation sites near the Dry Tortugas during summer and fall. Mann et al. (2009) implanted an acoustic telemetry transmitter on one goliath grouper that indicated the depth of the fish. During the two month recording period, this fish only left the aggregation site for one day and was located near the bottom for the majority of the time. The depth recordings showed that the fish made several forays to shallower depths with these occurring between midnight and 3:00 a.m. Mann et al. (2009) believe that these forays to shallower water could possibly indicate spawning ascents. Mann et al. (2009) conclude that efforts to document spawning should be concentrated around midnight.

Mikulas and Rooker (2008) studied nursery habitat of lane snapper at Heald and Sabine Banks and Freeport Rocks in the northwestern Gulf of Mexico. Trawl surveys were conducted on inshore mud, shell ridge, and offshore mud to quantify lane snapper distribution and abundance. Post-settlement lane snapper were observed on the banks from June through September, with peak densities occurring in July and August. Mikulas and Rooker (2008) found that the density of lane snapper varied among banks and years sampled. Mikulas and Rooker (2008) found habitat specific differences in density, but the patterns were not consistent among the banks. The mean sizes of lane snapper within banks were greater on the ridge habitat in three of four surveys suggesting that larger individuals select for, or move to structured habitat as they grow. The researchers found that lane snapper do not appear to favor shell ridge habitats over mud bottoms during the early post-settlement period. Mikulas and Rooker (2008) conclude that Heald Bank, Sabine Bank, and Freeport Rocks all serve as settlement habitat for lane snapper, and that lane snapper appear to be capable of successful settlement across a variety of habitats.

Patterson et al. (2005) used SEAMAP data to examine areas of high, median, and low abundances of juvenile red snapper off the Mississippi and Alabama coasts. Offshore areas were mapped using side scan sonar and differences in acoustic reflectance of the seabed were ground truthed with sediment analyses of boxcore samples. Patterson et al. (2005) found that juvenile red snapper density was significantly higher in areas with shell rubble or sponge habitat, thus indicating juvenile red snapper prefer habitat with small-scale complexity. The researchers also used trawls to sample for juvenile red snapper. They found that age-0 red snapper catch per unit effort was highest from an area containing a mixture of fine sand and shell rubble sediments. The SEAMAP data showed the highest densities of juvenile red snapper were in an area that contained the highest percentage of shell rubble habitat. Patterson et al. (2005) also found that sponge density was positively correlated with estimated juvenile red snapper density, and they postulate that sponges also supply habitat complexity at a scale required by juvenile red snapper. Patterson et al. (2005) stated that the scale of habitat complexity required by red snapper increases with fish size and age.

Rooker et al. (2004) conducted trawl surveys to examine patterns of distribution and abundance of post settlement red snapper on Freeport Rocks Bathymetric High, a shell bank in the northwestern Gulf of Mexico. The highest densities of post settlement juvenile red snapper were observed in July and August, and mean density among shell bank, inshore mud, and offshore mud was similar during the first year of the study, but a habitat effect was detected during the second year of the study with the highest density on the shell bank. Rooker et al. (2004) found that post settlement red snapper were first detected at approximately 16 mm standard length, and individuals less than 20 mm were present in all habitats. Rooker et al. (2004) estimated the red snapper to be from 26 to 121 days old. Rooker et al. (2004) predicted that spawning occurred from early April to mid August with a single peak occurring from late May to early June. While the mean densities of juvenile red snapper did not differ significantly between habitat types, Rooker et al. (2004) found that red snapper residing in the inshore mud habitat had significantly higher growth rates and significantly lower mortality rates. Therefore, Rooker et al. (2004) concluded that the recruitment potential of red snapper residing in the inshore mud habitat was greater than for individuals using shell bank or offshore mud habitat.

Rooker et al. (2005) used side scan sonar and multibeam bathymetry to characterize Freeport Rocks, Sabine Bank, Heald Bank, and Rio Grande Bank. The resultant data were used to produce habitat maps of the areas to direct targeted trawling for juvenile red snapper to delineate potential juvenile red snapper nursery areas. Rooker et al. (2005) found that peak recruitment occurred from July to August on Sabine Bank, Heald Bank, and Freeport Rocks. The highest densities of red snapper were found on Freeport Rocks. Settlement patterns of lane snapper were also assessed and the highest densities of lane snapper were found on Sabine Bank. Rooker et al. (2005) stated that red snapper densities were higher on the offshore mud habitat at both Sabine Bank and Heald Bank than shell ridge or inshore mud habitats. Rooker et al. (2005) reported that temporal variability in the settlement season of red snapper in the northwest Gulf of Mexico was relatively low, while regional variability in recruitment to these natural banks was high. Rooker et al. (2005) stated that newly settled red snapper and lane snapper settled successfully to a variety of substrates, including both shell hash and mud bottom habitats. Rooker et al. (2005) determined that only Freeport Rocks appeared to be an important nursery area for red snapper.

Weaver et al. (2006b) used a research submersible to characterize the deepwater reef fish at Riley's Hump and Miller's Ledge inside the Tortugas South Ecological Reserve. They found that the high profile rock face of Miller's Ledge provides feeding grounds for large groupers and snappers and their prey. Weaver et al. (2006b) observed numerous scamp along the ledge along with Warsaw grouper. The Warsaw grouper was believed to be a dominant male that was potentially spawning in the area. A total of 108 fish were recorded during SCUBA, ROV, and submersible observations. Weaver et al. (2006b) also noted other species of groupers including scamp, red grouper, snowy grouper, and speckled hind. Weaver et al. (2006b) postulate that Miller's Ledge may be a potential spawning location for both commercially important and rare deep reef species, and as a potential source of larval recruits for the Florida Keys and other deep reef ecosystems of Florida.

Wells and Cowan (2007) used video to enumerate red snapper and other fish over sand, shell, and natural hardbottom off Alabama. They found small, intermediate, and large sized red snapper over sand, shell, and reef habitats, respectively. Wells and Cowan (2007) stated that juvenile red snapper were predominately collected over low relief sand habitats, while sub-adult and adult red snapper were found over higher relief habitats such as the shell-rubble and natural hardbottom reef habitats.

Wells and Rooker (2004a) examined the distribution and abundance of fish associated with *Sargassum* mats in the northwestern Gulf of Mexico. They identified a total of 36 species in their samples. Planehead filefish (*Monacanthus hispidus*), blue runner (*Caranx crysos*), gray triggerfish (*Balistes capriscus*), chain pipefish (*Syngnathus louisianae*), sergeant major (*Abudefduf saxatilis*), sargassum fish (*Histrio histrio*), and greater amberjack (*Seriola dumerili*) composed over 97% of the catch. Wells and Rooker (2004a) found that over 95% of the fishes were in their early life stage with 72% of the fish being less than 50 mm (SL). The researchers sampled areas off Galveston and Port Aransas, Texas. The researchers stated that S*argassum* was more abundant off Port Aransas than off Galveston. Wells and Rooker (2004a) concluded that because of the abundance of juvenile fish collected in association with *Sargassum* that these mats serve as important nursery habitat for pelagic fish.

Wells and Rooker (2004b) examined the size range of greater amberjack in association with *Sargassum*. They report that greater amberjack are associated with *Sargassum* over a limited size range and exhibit rapid growth during the first six months. Sizes ranged from approximately 30 to 210 mm (SL) with the researchers positing that the limited size range associated with pelagic *Sargassum* indicates that a shift in habitat use by greater amberjack occurs at approximately 5 to 6 months of age. Wells and Rooker (2004b) state that greater amberjack larger than 210 mm (SL) have not been found in association with pelagic *Sargassum*. The researchers stated that greater amberjack transition from a pelagic to a demersal existence at this late juvenile stage. Wells and Rooker (2004b) determined the average growth of greater amberjack to be 1.45 mm per day. Wells and Rooker (2004b) reported that greater amberjack seem to have a protracted spawning period across the northwest Gulf of Mexico. This was based on samples showing the relative abundance of small greater amberjack was highest in May, and then declined in June, but increased again in July. Finally, Wells and Rooker (2004b) state that *Sargassum* appears to provide important nursery habitat for young of the year greater amberjack.

3.1.5 Shrimp

Shrimp EFH was identified in the 2005 EFH Amendment as "all estuaries; the US/Mexico border to Fort Walton Beach, Florida, from estuarine waters out to depths of 100 fathoms; Grand Isle, Louisiana, to Pensacola Bay, Florida, between depths of 100 and 325 fathoms; Pensacola Bay, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 35 fathoms, with the exception of waters extending from Crystal River, Florida, to Naples, Florida, between depths of 10 and 25 fathoms and in Florida Bay between depths of 5 and 10 fathoms."

Clark et al. (2004) developed a density prediction model for juvenile brown shrimp (*Farfantepenaeus aztecus*) using three bottom types, five salinity zones, and four seasons to quantify patterns of habitat use by juvenile brown shrimp in Galveston Bay, Texas. The three bottom types were vegetated marsh edge, submerged aquatic vegetation, and shallow non-vegetated bottom. Clark et al. (2004) used a multiple regression to develop density estimates, and that was then coupled with a geographical information system (GIS) to provide a spatial map of predicted habitat use. Their results indicated that juvenile brown shrimp less than 100 mm selected vegetated habitats in salinities of 15−25 ppt and that seagrass was preferred over the marsh edge when these two habitats were found in close proximity. Marsh edge was the preferred habitat in areas where seagrass was absent. The researchers estimated that the overall population of juvenile brown shrimp less than 100 mm in shallow water habitats within Galveston Bay was approximately 1.3 billion during the spring. Clark et al. (2004) estimated that the brown shrimp population was highest in the lower bay with approximately 225,000 shrimp per hectare. Seagrass beds accounted for more than 60% of the estimate with 145,142 per hectare and marsh edge and nonvegetated bottom types combined were estimated at approximately 79,000 per hectare.

Caudill (2005) compared nekton habitat utilization between marsh (*Spartina alterniflora*), black mangrove (*Avicennia germinans*), and a transition zone between the two in Louisiana's Barataria Basin estuary. Caudill (2005) found habitat specific trends in nekton use. Fish showed affinities for the marsh site, while crustaceans showed an affinity for the mangrove. White shrimp (*Litopenaeus setiferus*) biomass was significantly greater in mangrove habitat than in the marsh and transition zone. Caudill (2005) stated that higher crustacean biomass within the mangrove habitat was due to the greater structural complexity of the mangroves over the marsh habitat. Caudill (2005) reported that most of the crustaceans found in the mangrove habitat were juvenile white shrimp, brown shrimp, blue crabs (*Callinectes sapidus*), and gulf stone crab (*Menippe adina*).

Fry (2008) stated that even though most researchers in the past have shown that brown shrimp production is closely related to acreage of *Spartina alterniflora* marsh, open bays are also an important habitat for juvenile brown shrimp. In the study, Fry (2008) examined juvenile brown shrimp densities in marsh ponds defined as ponds less than 20 m in diameter and adjacent open bays defined as areas less than 1 m in depth and at least 2 km in diameter. Using sulfur stable isotopes to determine the origin (open bay or marsh area) of the shrimp, Fry (2008) found that marsh areas supported about 33% of total shrimp production while open bays supported 67% of Louisiana's brown shrimp production. In Louisiana, these open bay areas were found to be three to four times more extensive than marsh areas.

Fry et al. (2003) used stable carbon and nitrogen isotopes to determine residency time and movement of postlarval and juvenile brown shrimp migrating into a Louisiana estuary. The researchers found that small 10–20 mm postlarval and juvenile brown shrimp arriving in estuaries in April and May from offshore waters continue movement through sub-optimal habitats such as deep channels and open bays, but exhibit much less movement once an optimal habitat such as a marsh pond or shallow channel margin is reached. Fry et al. (2003) found that by combining estimates of shrimp densities, residency, growth rate, and mortality allows evaluation of the importance of different habitat types for shrimp production. Fry et al. (2003) state that shallow ponds, that are similar to fertile aquaculture ponds, appear to be hot spots for brown shrimp production.

King and Sheridan (2006) looked at habitat characteristics and nekton densities in monospecific beds of stargrass (*Halophila engelmanni*) and shoalgrass (*Halodule wrightii*) in addition to adjacent nonvegetated substrates. The study took place in Galveston Bay, Texas where subsidence and erosion of intertidal salt marsh has created new areas of subtidal habitat that have been colonized by seagrass in recent years. King and Sheridan (2006) found that nekton densities (both fish and crustaceans) were higher in seagrass habitat than in nonvegetated habitat. Brown shrimp densities were found to be higher in shoalgrass areas, but pink shrimp (*Farfantepenaeus duorarum*) were equally abundant in either seagrass. The researchers state that nekton densities in these new seagrass habitats equaled or exceeded densities associated with historical and current *Spartina alterniflora* marsh. King and Sheridan (2006) conclude that the new seagrass beds seem to be functioning as well as the marsh habitat when it comes to secondary production, and the researchers did not see a net change in secondary production.

Minello et al. (2008) examined the distribution patterns of nekton over the marsh surface to estimate population abundances of juvenile brown shrimp, white shrimp, and blue crab in Galveston Bay, Texas. The researchers estimated the biomass and production of these species from salt marshes and open water areas. In their 17,673 hectare study area composed of marsh vegetation with a 150 m water buffer, they estimated 19,382 brown shrimp, 17,406 white shrimp, and 16,726 blue crabs per hectare. These estimates were 3.0, 2.2, and 4.2 times the number of organisms per hectare for shallow, open bay water. Minello et al. (2008) estimated that the annual production from the marsh area was substantially higher than for open water and was estimated at 128 kg/ha for brown shrimp, 109 kg/ha for white shrimp, and 170 kg/ha for blue crabs. For shallow, open water areas outside of the marsh complex, Minello et al. (2008) estimated standing crops of about 6,400 brown shrimp per hectare, 8,000 white shrimp per hectare, and 4,000 blue crabs per hectare. The researchers also estimated the annual production for the marsh area in lower Galveston Bay to be 2.2×10^6 kg for brown shrimp, 1.9×10^6 kg for white shrimp, and 3.0×10^6 kg for blue crabs.

Reese et al. (2008) examined how the opening of the Packery Channel affected recruitment into a nearby seagrass habitat in Corpus Christi, Texas. Packery Channel opened in 2005 and now connects the Gulf of Mexico with the Upper Laguna Madre. Reese et al. (2008) found significantly higher mean densities of newly settled estuarine dependent species such as red drum and penaeid shrimp after the opening. Before Packery Channel was opened nekton had very limited access to the seagrass habitat in the upper Laguna Madre due to the great distance (35 km) from the nearest tidal inlet. The researchers found that penaeid shrimp were able to disperse into the upper Laguna Madre via other tidal inlets before the opening of Packery Channel, but they found a significant increase in juvenile penaeid shrimp in adjacent habitats after the opening. Reese et al. (2008) reported that nekton were using Packery Channel as a means of ingress into areas of the upper Laguna Madre's seagrass meadows that were previously inaccessible.

Roth et al. (2008) designed a spatially explicit model to investigate the influence of inundation and habitat fragmentation on brown shrimp production in a site in Louisiana and a site in Texas. The results of the study show that inundation is more important than habitat fragmentation for determining production. However, marsh configuration has a strong influence on shrimp production within a single inundation regime. The researchers found that shrimp production had a dome shaped relationship with various measures of marsh condition, but these simple measures of marsh condition and production may not indicate how further marsh fragmentation will impact production. Sea level rise and natural subsidence will increase inundation, but will also lead to increased marsh fragmentation through elevated erosion from wave action and the drowning of sediment stabilizing plants. Roth et al. (2008) state that eventually the marsh fragments to the point where it disappears or is completely submerged. Roth et al. (2008) conclude that sea level rise and marsh erosion affect the competing positive effects of shrimp access to vegetation versus the negative effects of marsh loss. Roth et al. (2008) suggested further study of this in the future to allow better shrimp management in a changing environment.

Rozas and Minello (2006) compared nekton use of subtidal nonvegetated bottom, marsh shoreline vegetation, and *Vallisneria* beds, a submerged aquatic vegetation. The researchers found that *Vallisneria* may provide an important nursery habitat for young blue crab and white shrimp that use oligohaline estuarine areas. *Vallisneria* provides an alternative, structured habitat to emergent vegetation during periods of low water. Rozas and Minello (2006) found that blue crabs were 8 and 10 times more abundant at *Vallisneria* than subtidal nonvegetated bottom sites and densities of white shrimp were 30 times higher at *Vallisneria* than subtidal nonvegetated bottom sites in the fall.

Rozas et al. (2007) examined the rate of wetland loss in Galveston Bay, Texas and determined that 61% of the wetlands in the study area were converted to open water between 1982 and 1995. The researchers determined that marsh edge, the marsh area within 1 m of the shoreline, was reduced by 70% during this time. Rozas et al. (2007) developed a fishery model that showed subsequent declines in brown shrimp, white shrimp, and blue crab due to this loss of marsh edge. A marsh-terracing project in 1999 restored approximately 65% of the wetlands that were lost. The restoration project tripled the amount of marsh edge within the area. Six years after the restoration project, Rozas et al. (2007) found that population estimates of brown shrimp, white shrimp, and blue crab increased by 55, 83, and 30%, respectively. The researchers stated this was in direct response to the increase in marsh area and marsh edge that resulted from the restoration effort.

Shervette and Gelwick (2008) evaluated the potential of vegetated marsh edge, nonvegetated soft bottom, and oyster reefs to serve as nurseries for juvenile white shrimp in the Grand Bay National Estuarine Research Reserve in Mississippi. Shervette and Gelwick (2008) found that juvenile white shrimp had higher growth rates in oyster reefs as compared to vegetated marsh edge and nonvegetated soft bottom in the absence of predators. In additional experiments where blue crabs were used as predators, juvenile white shrimp experienced significantly higher survival rates in vegetated marsh edge and nonvegetated soft bottom when compared with oyster reefs. Shervette and Gelwick (2008) state that juvenile white shrimp may select for oyster reefs over nonvegetated bottom because of higher quality food or higher abundances of target food resources and not for refuge needs. Their results also suggest that juvenile white shrimp habitat needs shift with individual growth, indicating that the relative nursery value of a habitat is not inclusive for all juvenile sizes. Shervette and Gelwick (2008) reported that the majority of smaller shrimp were collected from the vegetated marsh edge habitat while the majority of large shrimp were collected from nonvegetated soft bottom areas in deeper water.

3.1.6 Spiny Lobster

Spiny lobster EFH was identified in the 2005 EFH Amendment as "from Tarpon Springs, Florida, to Naples, Florida, between depths of 5 and 10 fathoms; and Cape Sable, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 15 fathoms."

Behringer et al. (2009) found that hardbottom areas containing macroalgae were superior to seagrass as a nursery habitat for spiny lobster in Florida. A caging study showed that spiny lobster survival was greater in hardbottom than in seagrass. Behringer et al. (2009) also found that spiny lobsters were larger and more abundant in hardbottom areas than those found in seagrass areas. The researchers state that settlement of spiny lobster in seagrass may be especially important in areas where hardbottom is unavailable or of poor quality for lobster settlement. Behringer et al. (2009) state that juvenile spiny lobster have been found in seagrass meadows and mangrove prop roots, but these habitats are not their preferred settlement habitat.

Bertelsen et al. (2009) characterized the shallow benthic hardbottom communities in the Florida Keys, and examined how these hardbottom areas influenced the abundance of juvenile spiny lobster. The researchers assessed more than 100 hardbottom sites in the Florida Keys to estimate the abundance of juvenile lobsters by looking at the bottom coverage of seagrass and macroalgae and the abundance of sponges, octocorals, hard corals, and other crevice-bearing structures. Bertelsen et al. (2009) found that branching-candle sponges and octocorals were used less frequently as shelter by juvenile lobsters than expected based on their availability. Loggerhead sponges, coral heads, and solution holes were used more frequently as shelter by juvenile lobsters than expected based on their availability. The researchers noted an ontogenetic shift in the shelter preference of juvenile lobsters with the smallest juvenile lobsters (15–35 mm carapace length) preferentially using a variety of sponges while avoiding hard, rocky substrates such as solutions holes and hard corals. Intermediate size juvenile lobsters (35–45 mm carapace length) preferentially utilized vase sponges while large juvenile lobsters preferred vase sponges, solution holes, and hard coral heads. Bertelsen et al. (2009) also noted that the specific types of shelters used by lobsters in any particular region varied depending on the availability of suitable shelters. When natural shelters were limited, suboptimal shelters were readily occupied.

Coleman et al. (2010) examined holes excavated by red grouper (*Epinephelus morio*) in the Florida Keys and found that these grouper holes provided important diurnal refugia for spiny lobster. The researchers state that the occurrence of grouper holes could influence lobster survivorship in this region.

3.1.7 Stone Crab

Stone crab EFH was identified in the 2005 EFH Amendment as "all estuaries; the US/Mexico border to Sanibel, Florida, from estuarine waters out to depths of 10 fathoms; and from Sanibel, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC from estuarine waters out to depths of 15 fathoms."

Caudill (2005) compared the nekton use and habitat value of *Spartina alterniflora* and black mangroves (*Avicennia germinans*) in Louisiana's coastal environment. Historically, small populations of black mangroves have been present in Louisiana in the extreme southern portion of the state. Black mangrove distribution was limited by cold winter temperatures. Black mangrove populations are now expanding in southern Louisiana's *Spartina* dominated marshes (Perry and Mendelssohn 2009). Caudill (2005) noted that gulf stone crab (*Menippe adina*) abundances were significantly higher in mangroves than in *Spartina* marsh.

Krimsky and Epifanio (2008) looked at how substrate affected the metamorphosis of Florida stone crab, *Menippe mercenaria*, from the megalopa stage to the first juvenile stage. The researchers measured the mean time to metamorphosis to determine which habitats the planktonic megalopa found suitable for settlement. Krimsky and Epifanio (2008) found that megalopa that were exposed to the brown alga *Sargassum fluitans*, rock/rubble substratum from natural stone crab habitat, and oyster shell metamorphosed sooner than megalopa exposed to the seagrass *Thalassia testudinum* and sand from the surrounding open bottom areas. The researchers stated that while *S. fluitans* is a floating alga it is very closely related to the common benthic algae *S. filipendula* that is common off Florida. Krimsky and Epifanio (2008) stated that algae, rock/rubble substrate and oyster shell seem to be the preferred settlement habitat for stone crab megalopa.

3.2 Changes to the Status of Managed Species

The official status of stocks managed in federal fishery management plans is maintained by the NOAA Fisheries Office of Sustainable Fisheries and is updated on a quarterly basis. The status of 50 stocks in Gulf of Mexico FMPs that are subject to action in this amendment, as of the third quarter 2009, is shown in Table 1 (annual stocks such as shrimp other than royal red, and stocks managed under a joint FMP are not included). Four stocks are currently listed as overfished and undergoing overfishing (gag, gray triggerfish, greater amberjack, red snapper), although the overfishing status of red snapper is expected to change as a result of the 2009 update assessment. Nine stocks are classified as not undergoing overfishing but overfished status is unknown or undefined (red drum, goliath grouper, Nassau grouper, stone crabs, and five classifications of corals). Five stocks are also classified as neither undergoing overfishing nor overfished (mutton snapper, red grouper, vermilion snapper, yellowtail snapper, and royal red shrimp). For the remaining 32 stocks, classifications have not been determined, either because there is no stock assessment, or because the assessment was inconclusive. The most recent status of stocks listing is available at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm.

The Fish Stock Sustainability Index (FSSI) is a performance measure for the sustainability of selected U.S. fish stocks that are important to commercial and recreational fisheries. Stocks with an FSSI index are assigned a point value of 0 to 4 (higher is better) based on availability of information to determine overfishing/overfished status and the status of the stock. A detailed description of the FSSI is available at http://www.nmfs.noaa.gov/sfa/statusoffisheries/2009/thirdquarter/fssi_summary_changes_q3_2009.pdf.

3.3 Species Added or Eliminated from Fishery Management Unit

Since the 2005 EFH Amendment, no species have been added or removed from the fishery management unit. However, changes to several taxa are being considered as part of the GMFMC Generic ACL/AM Amendment that is in development (as of June 2010). Taxa being considered for changes include: 1) Octocorals (Family Gorgoniidae, Class Anthozoa, Subclass Octocorallia), 2) Stone Crab Fishery Management Plan (*Menippe mercenaria and M. adina*), 3) Nassau Grouper, *Epinephelus striatus*, 4) Yellowtail Snapper, *Ocyurus chrysurus*, 5) Mutton Snapper, *Lutjanus analis* Sand Perch, 6) *Diplectrum formosum* and Dwarf Sand Perch, *Diplectrum bivittatum*. A full description of proposed changes is available in the GMFMC Generic ACL/AM Amendment currently being developed.

3.4 Mapping Larval Distributions Using SEAMAP Data

The EFH provisions state that EFH should be defined for all life stages. The 2005 EFH Amendment had significant gaps in the known information on the early life history stages of fish and invertebrates for many of the species under management. Over the past twenty-eight years plankton samples and associated environmental data have been (and continue to be) collected in the Gulf of Mexico under the Southeast Area Monitoring and Assessment Program (SEAMAP). This long-term set of observations on the early life history stages of fish and selected invertebrates can be used to define more precisely the EFH for many of these managed species.

3.4.1 SEAMAP Plankton Surveys and Collections

The goal of plankton surveys under SEAMAP has been to assemble a time series of data on the occurrence, abundance, and geographical distribution of fish eggs and larvae, as well as, to collect data on selected physical properties of their pelagic habitat. SEAMAP ichthyoplankton sample data has been collected primarily during four survey periods: spring (April to early June, annually, 1982 to present), summer (June and July, annually, 1982 to present), late summer/early fall (typically in September, annually, 1986 to present) and fall (October and November, annually, 1982 to present). The spring survey covers only open Gulf waters within the U.S. EEZ, while the summer and fall (trawl) surveys encompass only continental shelf waters from south Texas to Mobile Bay. The late summer/early fall surveys encompasses the continental shelf waters from south Texas to south Florida. During the SEAMAP time series there have been four winter plankton surveys/sampling (1983, 1984, 1993 and 1996) in open GOM waters and, more recently, winter surveys in 2007, 2008 and 2009. Additional samples have also been conducted outside of the long-term established SEAMAP surveys (e.g. during Louisiana seasonal trawl surveys, SEAMAP Squid/Butterfish surveys, and other serendipitous or special projects).

Plankton sampling on SEAMAP surveys is conducted around the clock at predetermined stations arranged in a fixed, systematic grid across the EEZ. Most systematic grid locations or SEAMAP stations are located at approximately 56 km or 0.5-degree intervals along this grid. Over the time series, sampling has occurred at locations other than the standard stations. Although other plankton sampling gear types and mesh sizes have been used over the SEAMAP time series, the gear and methodology considered as standard for SEAMAP surveys are those described in Kramer et al. (1972), Smith and Richardson (1977) and Posgay and Marak (1980). A 61 cm (outside diameter) bongo frame fitted with 0.333 (0.335) mm mesh netting is fished in a double-oblique tow path from a maximum depth of 200 m or 2–5 m off the bottom at depths less than 200 m. A single or double 2x1 m pipe frame neuston net fitted with 0.947 (0.950) mm mesh netting is towed at the surface with the frame half-submerged for 10 minutes.

3.4.2 Sample Processing and Identification of Larvae

Ichthyoplankton sorting and identification protocols focus effort on identifying specimens in the families Clupeidae, Sciaenidae, Serranidae, Scombridae, Stromateidae, Mugilidae, Lutjanidae and Carangidae to the lowest possible taxon (i.e. genus and species). Larvae of other families are identified to the genus or species level only when such identifications can be made easily with little additional time. Invertebrate protocols focus on commercially important decapod crustacean larvae, with most only identified to family or genus level. Identification of larval stages (particularly the smallest/earliest) of many species remains problematic, even though great strides have been made in our knowledge of larval fish and invertebrate development. The simple fact is that larvae of many key groups of fish and invertebrates cannot yet be identified to species in SEAMAP collections.

3.4.3 SEAMAP Plankton and EFH for Current Management Plans

Select taxa from the SEAMAP ichthyoplankton and invertebrate collections can be used to update the EFH descriptions for species in the current Gulf of Mexico FMPs.

Under the Coastal Migratory Pelagics FMP the distribution and abundance of king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*Scomberomorus maculatus*), cobia (*Rachycentron canadum*), little tunny (*Euthynnus alletteratus*), and dolphin (*Coryphaena* spp.) can all be mapped. Red drum (*Sciaenops ocellatus*) can be mapped from the Red Drum FMP. In the Reef Fish FMP, red snapper (*Lutjanus campechanus*), mangrove snapper (*L. griseus*), wenchman (*Pristipomoides aquilonaris*), vermilion snapper (*Rhomboplites aurorubens*), and gray triggerfish (*Balistes capriscus*) can all be mapped at the species level.

Larval grouper are difficult to identify to the species level. Current larval identifications for the Serranidae family are problematic below the family level because smaller sized larvae have not developed certain key characteristics that would permit identification to the serranid subfamily Epinephelinae (Lyczkowski-Shultz et al. 2004). Serranid larvae are distinctive and can be identified to this subfamily once diagnostic characters such as head, dorsal, and pelvic spines are developed. However, identification beyond the subfamily and tribe is still problematic. Limited distribution and abundance data are available for identifications to the tribe level of Epinephelini that includes all grouper and to the genus *Mycteroperca* for black grouper (*Mycteroperca bonaci*), yellowmouth grouper (*M. interstitialis*), gag (*M. microlepis*), scamp (*M. phenax*), and yellowfin grouper (*M. venenosa*). Tilefish can only be identified and mapped at the family level as Malacanthidae. Greater amberjack (*Seriola dumerili*), lesser amberjack (*S. fasciata*), almaco jack (*S. rivoliana*), and banded rudderfish (*S. zonata*) can only be identified and mapped to the Genus *Seriola* level.

The shrimp within the Shrimp FMP can only be identified and mapped to the family Penaeidae level with a limited number of years and seasons at this time. Larvae within the Spiny Lobster FMP can only be identified as lobster larvae with a limited number of years and seasons available. Stone crab larvae can only be identified to the genus *Menippe* level, but larval distribution maps can be produced.

3.4.4 Mapping the Early Life History Stages for Selected Taxa

Larvae of snappers, mackerels and decapod shrimp in the family Penaeidae are used to highlight the mapping of EFH for the early life history stages of fish and invertebrates from SEAMAP plankton collections (Figures 6 to 25). Red and vermilion snapper and king and Spanish mackerels are mapped for the Spring Plankton (1982-2002), Summer Groundfish (1982-2002), Fall Plankton (1986-2006), and Fall Groundfish (1986-2002) surveys. Although data are available through 2008 for each time series, we have limited our observations to years for which the identifications of selected taxa have been re-examined and verified. Penaeid shrimp larvae and postlarvae are mapped only for the 2007 Winter Plankton, 2005 Spring Plankton and 2003 Fall Plankton surveys for which data is currently available. Larval occurrence and abundance from 61 cm, 0.333 mm mesh bongo collections for each time series (all years combined) or survey are summarized by 0.5-degree blocks of longitude by latitude for each taxa. Information for each block includes the mean number of larvae/postlarvae under 10 m^2 of sea surface, the number of times the taxa occurs and the total number of samples for a 0.5 degree longitude by latitude degree grid. ArcGIS9 (Geographic Information Systems from ESRI) and its extensions are then use to generate distribution, abundance and occurrence maps from the summarized data. The resulting maps show temporal and spatial patterns that could be used to define EFH for these early life history stages of fish and invertebrates.

<u>4.0 Alternative Methodologies for use in Essential Fish Habitat Designation in the Gulf of Mexico</u>

The purpose of this section is to review current Essential Fish Habitat (EFH) designation methodologies and provide an overview of potential alternative methods for identifying EFH and characterizing the influence of environmental characteristics on EFH status. This section provides an overview of existing methods with emphasis on recently developed methods with discussion of data requirements, technical expertise, time, and software considerations necessary.

Data used for EFH designation should use the best available data including peer-reviewed literature, unpublished scientific reports, government agency reports, and other sources of information. Habitat data should be organized to the four levels described in the EFH Rule (600.815(a)((1)(iii)(A)) and the highest levels of information available should be used.

Essential Fish Habitat designation in the Gulf of Mexico is based on areas of higher species density, based on the NOAA Atlas (NOAA 1985), functional relationships analysis for the Red Drum, Reef Fish, Coastal Migratory Pelagics, Shrimp, Stone Crab, and Spiny Lobster FMP's, and on known distributions for the coral FMP (2005 EFH Amendment p. 16). However, in effort to improve EFH designation and to potentially incorporate higher levels of data based upon the EFH Rule, regional fishery management councils may explore novel methodologies to identify EFH including science-based tools for use with EFH designation. In recent years the use of correlation-based statistical or machine-learning models that link habitat attributes with abundance or distribution patterns have increased rapidly in both scope and complexity and could aid in the identification of EFH. In the Gulf of Mexico, application of these new techniques could improve delineation of EFH and the environmental attributes that influence habitat quality for a variety of marine taxa (Knudby et al. 2010). Moreover, these techniques are based on environmental relationships thus may provide useful tools for evaluating future effects of management decisions or habitat alteration and could provide habitat-based, spatially explicit information for use in stock assessments of managed species.

Techniques employed for this purpose use a variety of statistical tools including conventional techniques (e.g., linear models, generalized linear models, generalized additive models), geostatistical (e.g., kriging, inverse distance weighted, natural neighbors, splines), and machine-learning techniques (e.g., support vector machine, ensemble regression tree methods). The Pacific Council in conjunction with the Pacific Groundfish Risk Assessment developed a Bayesian model that relates the likelihood of occurrence of a species or life stage to habitat characteristics (HEWG 2005). The types, performance, data requirements, and technical requirements necessary for these models vary widely, therefore identifying the most appropriate methodology a priori can be difficult or in some cases, impossible.

To facilitate the development and implementation of improved tools to identify EFH, a Habitat Evaluation Working Group report developed by Northeast Fisheries Science Center summarized and compared several methods to assist with identification and description of EFH (HEWG 2005). This report compared 14 potential EFH designation methods (Table 2) and developed recommendations based on model performance, data requirements, software and technical expertise requirements. This report indicated the need for critical input data validation in conjunction with thorough reviews of modeling techniques to ensure that EFH designation has good scientific basis. Northeast Fisheries Science Center completed an extensive review of current EFH designation methodologies (Table 2) and investigated alternative methods for the identification of important habitats (HEWG 2005). This review recommended the use of generalized additive models (GAMs) as these models could provide quantitative and testable species-levels foundations for ecosystem analyses. This review also supported continued development and evaluation of geo-spatial techniques, as they are often necessary for developing modeling inputs to be used in statistical models (i.e., GAM).

The Habitat Evaluation Working Group (Northeast Fisheries Science Center) also considered alternative EFH designation methods such as canonical correspondence analysis, environmental envelopes, and regression trees. While these methods are theoretically applicable, they were not evaluated in part due to a lack of example applications in marine fisheries. However, subsequent to this 2005 report, these, and other methodologies have continued to evolve. For example, regression tree analysis has been applied to marine fisheries (Pittman et al. 2007). This method has also been extended to include regression tree based boosting techniques (Elith et al. 2008) that may provide improved predictive capabilities and has recently been applied to fishes in the Gulf of Mexico (Froeschke et al. 2010). Knudby et al. (2010) reviewed several modern approaches to modeling fish-habitat relationships compared to these methods with a variety of other methods including GAM (the preferred methodology of the HEWG (2005)). Knudby et al. (2010) suggest that novel methods (e.g., boosted trees) may substantially improve predictions of fish distribution and abundance and that the tree-based ensemble techniques often exhibited lowest prediction error rates and identified fewer predictor variables than linear models or generalized additive models (GAM). Moreover, Knudby et al. (2010) suggest the potential to contribute to improved management and conservation using these techniques. The purpose of this section was to explore the efficacy of employing the preferred techniques of the HEWG Report (Generalized Additive Models) and the Knudby et al. (2010) (tree-based ensemble techniques) for science-based essential fish habitat designation in the Gulf of Mexico.

4.1 A Discussion and Case Study of Brown Shrimp (*Farfantepenaeus aztecus*)

Brown shrimp (*Farfantepenaeus aztecus*) was used as a model species to explore the efficacy of correlation based habitat models for EFH delineation. This species was chosen based on data availability, applicability of methods Gulf-wide for an economically important federally managed species. Also, environmental based distribution patterns of the species have been reported (Craig et al. 2005). Example applications demonstrate potential utility of statistical-based approaches for examination of EFH and highlight the need for high quality, fisheries independent data necessary for model development and evaluation. This example application is not intended to serve as an official delineation of EFH for this species, rather serve as a demonstration of an alternative methodology that is routinely applied for this purpose in other fisheries worldwide. Moreover, this model produces predicted catch rates that may contribute, but do in and of themselves designate EFH; this remains a fisheries management decision.

Habitat based distribution models are become increasingly popular tools both to understand environmental influences on biological patterns and to predict responses to environmental disturbance or management. Increasingly, these approaches are being employed to improve conservation and management and have been applied widely across terrestrial, aquatic, and marine landscapes. The importance of habitat for sustaining marine populations is well recognized (Beck et al. 2001). In 1998 fishery management councils were charged to identify EFH for all managed species (Levin and Stunz 2005).

In effort to improve EFH delineation for federally managed species, the original EFH Amendment was updated in 2005 as part of the 2005 EFH Amendment. Overall, from this assessment, the areal extent of EFH in the Gulf of Mexico was reduced in 2005 relative to 1998 primarily because habitat greater than 100 fathoms depth was thought to be of limited value for most managed species. The result of this process increased focus on areas and habitats most important for population persistence and is an important aspect of fisheries management as resources are inadequate to characterize or manage all marine habitat and mechanisms (Levin and Stunz 2005). This process provides increased focus on critical habitats provide opportunities for improved management and conservation efforts with existing resources. To this end, the process of identifying and delineating EFH has continued to evolve as new information and analytical techniques become available for this purpose (HEWG 2005). Through this process, the effects of habitat quality on fish populations can be recognized and incorporated into fishery management plans (FMPs) as necessary to manage species for maximum benefit to stakeholders and the nation. In an effort to improve EFH designation methodology, the efficacy of using correlation based statistical models for EFH delineation has been explored by other Councils for the purpose of EFH designation and this was explored for the federally managed brown shrimp (*Farfantepenaeus aztecus*) in the Gulf of Mexico.

Shrimp have been intensively harvested for decades in the Gulf of Mexico and under federal management in the Gulf of Mexico since 1981 (GMFMC 1981). Brown shrimp is an important commercial fishery species and supports one of the most valuable fisheries in the United States. In the Gulf region, shrimp support a large and economically valuable fishery. In the Gulf of Mexico, brown shrimp comprise a majority (77%) of the catch (Li and Clarke 2005), contribute 58% of total fisheries revenue, and there is growing interest in improving our understanding of environmental and spatial aspects of distribution patterns for exploited species (Craig et al. 2005). This interest in linking distribution and abundance patterns to environmental drivers has occurred in part, due to concerns about changing environmental conditions and potential impacts on ecosystems or population dynamics of exploited species or the desire to incorporate spatial planning into management. Moreover, changes in spatial distributions of species may precede stock declines thus providing an indicator of stock size for resource managers. Changes in distribution as a function of population density have been attributed to density-dependent processes where organisms move into marginal habitats as population size increases and completion becomes more intense (MacCall 1990, Swain and Wade 1993).

In the Gulf of Mexico, brown shrimp distribution expands offshore during years of high abundance (Craig et al. 2005) highlighting the importance of both understanding interactions between density and distribution patterns for this species. However, there are substantial inter-annual variations in population size of brown shrimp in the Gulf of Mexico, and fluctuations in environmental features may contribute to this variation. Thus, improving our understanding between the environment and realized distribution patterns may improve our ability to delineate essential habitat and provide improved predictions about stock sizes and appropriate harvest rates of annual species such as brown shrimp. To this end, catch data of brown shrimp were investigated using long-term fisheries independent catch data to develop spatially based distribution models using readily available data inputs (i.e., depth, location, season) that could be used to identify areas with high catch rates.

4.1.1 Methods

Catch data from the Southeast Area Monitoring and Assessment Program's (SEAMAP) Shrimp/Groundfish Survey (n=3,701) were used to determine distribution patterns of brown shrimp (*Farfantepenaeus aztecus*) in the Gulf of Mexico (Figure 2). The Shrimp/Groundfish Survey has taken place annually since 1982. A 13.1 m trawl net was used to sample shrimp and demersal finfish. Approximately 300 to 400 trawl samples were conducted annually in waters from 5 to 50 fathoms from west Florida, to Brownsville, Texas. Surveys were conducted between June and November each year each using standardized survey design, techniques, gear, and vessels. A total of 3,701 trawls samples from 1982 through 2009 were sorted from the SEAMAP database (Figure 2). As trawl samples were designed to cover a depth stratum, trawl towing times were different among stations. Therefore, all catches were standardized on a 60-minute tow time to allow equal comparisons of catches. Catches or catch per unit effort (CPUE) were recorded as the number of individuals of each species caught per hour.

Depth, latitude, and longitude and season (summer or fall) were used as predictors to model shrimp distribution in the Gulf of Mexico. Location of and depth were determined at the starting location of each sample.

Catch per unit effort of brown shrimp were related to depth, longitude, latitude, and season (summer or fall) using generalize additive models (GAMs). This model was fit forward, stagewise and cubic smoothers were fit through 10-fold crossvalidation using a Poisson error distribution. Prior to analyses, CPUE were transformed using the natural logarithm $\ln(x+1)$ to reduce overdispersion in the model residuals. Akaike's information criterion (AIC) was used for variable selection and to determine if predictors should be used as a linear or smoothed term. Analyses were carried out in R (version 2.10, R Development Core Team, 2009) using the "mgcv" library. Predicted catch rates from the fitted model were compared to catch data using simple linear regression.

Spatially explicit predictions of the GAM models were produced by creating rasterized grids of the predictor variables and making predictions to the gridded surface. Gridded bathymetry data were obtained from Gulf of Mexico Coastal Ocean Observing System (http://gcoos.tamu.edu/products/topography/MB-Grid.html). Spatial predictions were constrained to the study area (i.e., predictions not made beyond areas sampled) and developed for both summer and fall seasons to characterize seasonal effects on distribution patterns.

4.1.2 Results

Brown shrimp were captured in 73.8% of samples and abundance ranged from 0 to 4,300 per sample. Due to relatively high number of samples with zero individuals as well as a few samples with very high abundances, capture data were highly overdispersed, thus transformed using the natural logarithm to reduce over-dispersion in the statistical model. Transformed data approximated a Poisson distribution (i.e., variance ~ mean). The best-fit model included all four predictor variables as well as non-linear smoothers for each term and explained 30.0% of the deviance (Tables 3 and 4). Model predictions from the fitted GAM displayed a significant, positive relationship to observed catch rates (linear regression $F = {}_{1,3695}$, $p < 0.001$, $R^2 = 0.72$) (Figure 3).

To develop spatially explicit, distribution models, GAM model output were used to predict seasonal catch rates throughout the study area (Figure 4). Overall, catch rates were highest in inshore waters of the western Gulf. Catch rates were extremely low off the coasts of Alabama and Florida. Spatial patterns also varied seasonally as catch rates were higher in the inshore areas during summer (Figure 4a) while catch rates increased in deeper waters during the fall sampling period (Figure 4b). Seasonal differences in catch rates between seasons were most obvious in the western Gulf of Mexico and indicate the offshore movement of the stock (Figure 4c).

4.1.3 Discussion

Physical and spatial data were used to examine distribution patterns of brown shrimp in the Gulf of Mexico. Brown shrimp are an annual species, year-class strength is strongly correlated to environmental conditions, and improving our understanding of species-habitat relationships could inform management and provide spatially based information for inclusion in stock assessments. The goal of this application was to develop a relatively simple (few covariates), correlation based statistical model based on physical and spatial data that are widely available in the Gulf of Mexico and compare this approach to the status quo methodology of identifying EFH. The current approach was based on the working recommendations of the HEWG (2005) report and if effective could be rapidly applied to a variety of taxa due to its simple data input requirements (location and depth). Despite the modest complexity of this model, results are informative and could be used to inform EFH decisions. While inclusion of additional covariates may lead to improved model performance, it could limit applicability for some species or regions due to lack of data availability for some covariates throughout the management region.

Currently, shrimp EFH includes all estuaries from the US/Mexico border to Fort Walton Beach, Florida as well as waters out to depths of 100 fathoms from Grand Isle, Louisiana, to Pensacola Bay, Florida. From Pensacola Bay, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 35 fathoms between depths of 100 and 325 fathoms with the exception of waters extending from Crystal River, Florida, to Naples, Florida, between depths of 10 and 25 fathoms and in Florida Bay between depths of 5 and 10 fathoms. However, based on SEAMAP trawl data the vast majority of catches occur in the central and western Gulf. In addition, there is a seasonal interactive effect suggesting that shrimp migrate offshore to deeper waters in the fall as compared to summer. This result suggests that not all area currently considered EFH may be equivalent in terms of density based on trawl samples. There may be important temporal components to habitat value that could be incorporated into spatial based planning if conflict or overlap of other uses was to be minimized. For example, shrimp harvesting also removes large numbers of juvenile red snapper from the Gulf each year. While the effect of shrimp harvesting on red snapper populations is equivocal, species specific distribution patterns could be identified using the approach described here to potentially identify and direct shrimp effort toward areas with high shrimp and lower juvenile red snapper abundance.

This example is not intended to define or modify the existing shrimp EFH description from 2005 EFH Amendment. This exercise simply serves to inform and evaluate methodology that could be used to inform EFH decisions. For example, thresholds, based on catch rates could be selected by managers to delineate EFH in an effort to continue refining EFH to the most critical areas for promoting sustainable, harvestable populations. These efforts could provide increased focus on areas to prioritize conservation and management measure and provide better estimates of potential impacts of natural (e.g., hurricanes) or anthropogenic (e.g., oil spills) disturbances in the Gulf of Mexico. Methodology could also be expanded to include other types of data (e.g., socio-economic, climate-change) and/or updated as new information becomes available.

4.1.4 Summary and Conclusions

Description and mapping of essential fish habitat is necessary to improve our understanding of the role of habitat in marine population dynamics and to promote the use of marine resources for maximum benefit to the nation. In the Gulf of Mexico, EFH was first described in 1998 for various life stages of 26 managed species based on areas where they commonly occur (GSMFC 1998). In order to increase focus on the most important habitats, the 2005 EFH Amendment removed EFH designation from Gulf waters between the 100-fathom and the seaward limit of the EEZ. The current exercise explores options for continued refinement of EFH that could be developed or implemented for selected species or life-stages to provide increased focus on the most important habitats.

Data to evaluate new methodology should come from the best available sources and used in a manner consistent with National Standard 2. Habitat information should be organized according to the four levels described in the EFH Rule (600.815(a)((1)(iii)(A)) and the highest levels of information should be used. A general approach for data acquisition, model development evaluation to provide guidance to the Council that could be used to refine EFH is described in Figure 5.

4.1.5 Levels of Data

Perhaps the biggest challenge to implementing model based approaches to EFH description lie in obtaining appropriate data and determining what level and spatial scales are appropriate. In general, the goal is to use the highest level of data available, usually limited to presence-absence (type I) or density (type II) data. The present examples used type II data for shrimp and this was based on the data availability and statistical properties of the data set. Despite the trend for using the highest level of data available, there can be compelling reasons to use presence-absence over abundance data. Presence-absence models can be very informative and often yield similar results to abundance level data. Moreover, fisheries data are often characterized by many samples with "zeros" as well as some samples with very large numbers of catches (over-dispersion). Statistical models have some (and increasing) capacity to deal with these properties but there are limits to what types of abundance data can be practically modeled. This approach has been widely employed in fisheries applications (Stoner et al. 2001) and could be applied in the Gulf of Mexico to describe EFH. The biggest advantage of modeling approaches to describing EFH is that it provides a rigorous basis for describing EFH that provides insight into mechanisms of species-habitat interactions that could be used to predict or interpret consequences of environmental change.

A second consideration for model-based approaches to EFH description is the availability and quality of relevant environmental predictors of distribution or abundance of managed species. Developing spatially-explicit maps requires the developing surfaces of relevant predictor variables such as temperature, salinity, or depth. Surfaces are often created by interpolating point-data of relevant variable in a geographic information system (GIS). Surface interpolation requires careful consideration of relevant data sources and routines.

5.0 Review Any Changes and New Information on Fishing Impacts That May Adversely Affect EFH

The purpose of this section is to review research that has occurred since the previous fishing impacts to EFH analysis in 2005 to see if our knowledge on the way that fishing may impact EFH has changed. In addition, if new knowledge is available, we need to determine if this knowledge might substantially change our perception on the effects of fishing on EFH in the Gulf of Mexico. A literature search of peer-reviewed literature, unpublished scientific reports, data files of government resource agencies, fisheries landing reports, and other sources of information was conducted to look for new published and unpublished scientific literature since the publication of the 2005 EFH Amendment. Since 2003, sixty-two articles and reports were found detailing potential fishing impacts to habitat. Of these articles and reports, seven of the studies were conducted in the Gulf of Mexico or were germane to fisheries in the Gulf of Mexico. A brief synopsis of these studies is presented below.

Chiappone et al. (2005) examined the impacts of lost fishing gear on benthic organisms and habitat structure. The research took place on the coral reefs within the Florida Keys National Marine Sanctuary that are not located in the Gulf of Mexico, but lost fishing gear should impact coral in the Gulf of Mexico in similar ways. The researchers found that hook and line fishing gear accounted for 87% of the fishing related debris. Lost hook and line gear was responsible for 84% of the impacts to sponges and benthic cnidarians. Of note, fishing related marine debris was recorded at 92% of sampling sites, including all no fishing zones sampled. The researchers found that the damage to the coral reefs caused by lost hook and line fishing gear appears to be minor.

Dellapenna et al. (2006) studied the impact of shrimp trawling in Galveston Bay, Texas. The study found that the shrimp net, trawl doors, and tickler chain excavated the seabed to a maximum depth of 1.5 cm. The researchers stated that the turbidity plume after passage of a shrimp trawl was comparable to the turbidity produced by a 9 to 10 m/s wind event at the study site. The trawl doors were found to the impact the bottom the most. The researchers state that at least 100% of Trinity Bay bottom was trawled each year and that 30% of the area is impacted by the trawl doors.

Lewis et al. (2009) examined how lobster traps in the Florida Keys can be moved during storms or winter cold fronts and impact coral reefs. The researchers found that lobster traps when sustained winds were greater than 27.8 km/hr persisted for more than 2 days. Lobster traps moved approximately 3.63 m in water depths of 4 m and moved approximately 0.73 m in water depths of 12 m. Lobster trap movement caused significant damage to stony coral, octocoral, and sponges. The researchers state that due to the large numbers of lobster traps deployed that the damage to sessile fauna and loss of benthic faunal cover caused by traps needs to be considered to effectively protect coral reefs and manage essential fish habitat in the future.

Sheridan et al. (2005) looked at the use of fish and lobster traps in the U.S. Virgin Islands, Puerto Rico, and the Florida Keys. The researchers found that less than 20% of the deployed traps actually impacted corals, gorgonians, or sponges. The damage mainly affected hard corals and was considered patchy and less than the total trap footprint.

Sheridan and Doerr (2005) examined the effects of shrimp trawling on Texas benthic habitats by comparing an area closed to shrimp trawling for seven months with an area open to trawling. The researchers looked at the benthic community structure and sediment cores to determine whether shrimp trawling caused an impact. The researchers concluded that shrimp trawling effort during winter and spring off the middle Texas coast had little impact on benthic organisms. They did state that an annual seven-month closure might not be long enough to determine the true impacts of trawling.

Uhrin and Fonseca (2005) looked at how spiny lobster traps potentially affect seagrass beds in the Florida Keys. The study was designed to examine the degree of injury to seagrass because of trap deployment duration, the species of seagrass affected, and the recovery of seagrass following trap removal. The authors found that lobster traps impacted seagrass if they were left in the same area for more than six weeks. Manatee grass was more impacted by lobster traps than turtle grass. The researchers stated that standard fishing practices with soak times of less than five weeks should not result in a significant injury to seagrass beds in the Florida Keys.

Wells et al. (2008) examined the effects of trawling on demersal fish and invertebrate communities in the northern Gulf of Mexico. Sand, shell rubble, and natural hardbottom habitats were compared in trawled and non-trawled areas. Non-trawled shell rubble had the highest diversity index. Higher diversity indices were found over trawled sand bottom than over non-trawled sand bottom. The researchers state that habitats that are more complex may be more sensitive to the effects of trawling activities and trawling may cause reductions in habitat complexity, which can lead to increased predation on species relying on the structure.

The Council's 2005 EFH Amendment proposed four measures to prevent, mitigate, or minimize the adverse effects of fishing on EFH in the Gulf of Mexico. These measures were to:

1. Prohibit bottom anchoring over coral reefs in HAPC (East and West Flower Garden Banks, McGrail Bank, Pulley Ridge, and North and South Tortugas Ecological Reserves) and on the significant coral resources on Stetson Bank.

2. Prohibit use of trawling gear, bottom longlines, buoy gear, and all traps/pots on coral reefs throughout the Gulf of Mexico EEZ (East and West Flower Garden Banks, McGrail Bank, Pulley Ridge, and North and South Tortugas Ecological Reserves) and on the significant coral communities on Stetson Bank.

3. Require a weak link in the tickler chain of bottom trawls on all habitats throughout the Gulf of Mexico EEZ. A weak link is defined as a length or section of the tickler chain that has a breaking strength less than the chain itself and is easily seen as such when visually inspected.

4. Establish an education program on the protection of coral reefs when using various fishing gears in coral reef areas for recreational and commercial fishermen.

These measures were analyzed along with other alternatives in the Council's 2004 EFH EIS. These process used to develop these measures involved several steps. These steps were to

1. prepare habitat maps and identify EFH;
2. develop an index of the sensitivity of fish habitats to fishing impacts, by gear;
3. determine the extent of the fishing activity, by geographic location and gear (fishing effort);
4. combine the sensitivity index and the fishing effort into a spatially structured index of fishing impacts, by gear and habitat; and
5. develop alternatives that potentially reduce the fishing impacts index and thereby prevent, mitigate, or minimize adverse effects of fishing on EFH.

The only step that has changed since the 2004 EFH EIS is step 3, the amount of fishing effort. Fishing effort data in the 2004 EFH EIS were from 2000 and 2001. Data from 2000 to 2008 or

2009 were obtained from the NMFS Southeast Fisheries Science Center (commercial data), Texas Parks and Wildlife Department (Texas recreational data), the Atlantic Coastal Cooperative Statistics Program (commercial spiny lobster and stone crab data), and NMFS Office of Science and Technology (recreational data) to determine trends in fishing effort since the 2005 EFH Amendment. Figures 26 through 35 display the trend associated with fishing effort for both recreational and commercial fishing in the Gulf of Mexico. Since 2000, fishing effort has declined for all fisheries and gears that were examined. Therefore, the alternatives that were developed in the 2005 EFH Amendment should still be adequate to protect EFH from fishing impacts.

6.0 Review Any Changes and New Information on Non-fishing Impacts That May Adversely Affect EFH

The review of non-fishing activities focused on Section 3.5.3 of the 2004 EFH EIS. That section of the EIS identifies non-fishing activities that have the potential to adversely impact EFH in order to support recommendations provided in accordance with the consultations requirements of the Magnuson-Stevens Fishery Conservation and Management Act (Section 305(b)).

In February 2008, NOAA published Technical Memorandum NMFS-NE-209 entitled "Impacts to Marine Fisheries Habitat from Non-fishing Activities in the Northeastern United States". The report was the outcome of a technical workshop intended to assist the Northeast and Mid-Atlantic Fishery Management Councils in updating non-fishing impact analysis within their Fishery Management Plans. During the course of the workshop, it was recognized that the information being generated was applicable to a larger audience and the scope of the report was expanded. Although produced for the northeast United States, the comprehensive nature of the report provided a means to evaluate the 2004 EFH EIS analysis.

The following activities were analyzed in the Council's 2004 EFH EIS and conservation measures identified in the Council's original EFH Amendment (GMFMC 1998) to satisfy Section 600.815(a)(4) of the EFH guidelines:

- Navigation channels and boat access canals
- Docks and piers
- Boat ramps
- Marinas
- Cables, pipelines, and transmission lines
- Drainage canals and ditches
- Housing developments
- Bulkheads and seawalls
- Transportation
- Impoundments and other water level controls in wetlands
- Oil and gas exploration and production in coastal marsh, open bay, and OCS
- Other mineral mining/extraction
- Sewage treatment and disposal

- Steam-electric plants and other facilities requiring cooling or heating water
- Disposal of dredged material
- Water intakes and discharges
- Aquaculture/Mariculture

A review of the NOAA Technical Memorandum (NOAA 2008) identified information that could augment the analysis of several sections of the 2004 EFH EIS including:

1. Navigation channels: temporal impacts to water quality (e.g., turbidity) and benthic species composition; losses of submerged aquatic vegetation, intertidal habitats and wetlands; impacts associated with different dredging methods
2. Docks and piers: impacts associated with vessels including mooring, grounding, prop-dredging, and wave-induced erosion; shading affects of floating structures, and water quality considerations of anti-fouling agents
3. Housing developments: alteration of local hydrodynamics including natural filtration of runoff, groundwater recharge, and floodwater retention
4. Bulkheads and seawalls: nearshore groins, jetties, and breakwaters
5. Offshore mineral mining for beach nourishment and other purposes
6. Municipal and industrial discharges
7. Non-point source discharges
8. Water intakes: impingement and entrainment of larval and juvenile life stages
9. Marine debris: abandoned and derelict vessels and intentional vessel disposal

NOAA (2008) also provides analysis of activities that have emerged and begun to emerge since the 2004 EFH EIS including liquid natural gas (LNG) facilities, offshore wind energy facilities, wave and current energy facilities, and climate change. While NOAA (2008) provides an analysis of mariculture and aquaculture activities, through their preparation of a Fishery Management Plan for offshore aquaculture the Gulf Council has completed a comprehensive analysis specific to the Gulf of Mexico.

While invasive plants and aquatic fish and invertebrates have presented problems in Gulf of Mexico estuaries, truly marine invasive fish have not been recorded. Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) are the first non-native marine fishes to establish themselves in the Western North Atlantic. Lionfish are long-finned reef-associated species that are widely distributed throughout the western Pacific. Lionfish were first confirmed in the United States in 1985 (Dania, FL) and since that period have rapidly spread in distribution and increased in abundance. Lionfish are now considered established off the Atlantic coast of the United States, Bermuda Island, the Bahamas, Turks and Caicos Islands, Cuba, Jamaica, Dominican Republic, Puerto Rico, Mexico, Honduras, and Costa Rica. Lionfish are present but not considered established in the US Virgin Islands, Gulf of Mexico, Belize, Panama, and Colombia and their range continues to expand. Reports have come from the Gulf of Mexico (Florida), Belize, Panamá and Colombia; although lionfish are not considered established in these localities as of August 2009 (Schofield 2009). However, specimens were collected during the 2010 SEAMAP

Summer Shrimp/Groundfish Survey in the Gulf of Mexico and invasions appear imminent in this region (Schofield 2009). Several lionfish were also sighted on artificial reefs off Alabama and Pensacola, Florida and on oil platforms off Louisiana in September 2010. A summary of lionfish occurrences and ranges expansion is described in Figure 36.

Lionfish inhabit reefs from 10 to about 175 m depth. Individuals are relatively inactive during the day, typically sheltering in reef crevices. The lionfish is a nocturnal species and moves to deeper waters at night to forage. The prey of the lionfish includes small fishes and crustaceans (Fishelson 1975; Harmelin-Vivien and Bouchon 1976), which are swept up and trapped with the extended pectoral fins. The species is relatively quick to adapt to novel prey types, and quickly learns to avoid noxious prey (Fishelson 1997). An increase in piscivory occurs with age (Harmelin-Vivien and Bouchon 1976). The dorsal- and anal-fin spines of the lionfish contain potent venom and there are few known predators of these fishes in the Atlantic population.

In the U.S., the lionfish has rapidly increased in abundance and are now as abundant as many native grouper species in the Atlantic Ocean (Whitfield et al. 2007). It was thought the species' northward expansion along the Atlantic coast of the U.S. would be limited by cool water temperatures however, lionfish have been observed in water as cold as 56° F off the southern coast of Long Island.

7.0 Review Habitat Areas of Particular Concern (HAPC) Designations

The 2005 EFH Amendment identified several areas as HAPCs. Each proposed site is discrete, and meets one or more HAPC criteria:

1. Importance of ecological function provided by the habitat;
2. Extent to which the area or habitat is sensitive to human induced degradation;
3. Whether and to what extent development activities are stressing the habitat; and
4. Rarity of the habitat type.

HAPC were identified as the Florida Middle Grounds, Madison-Swanson Marine Reserve, Tortugas North and South Ecological Reserves, Pulley Ridge, and the individual reefs and banks of the Northwestern Gulf of Mexico: East and West Flower Garden Banks, Stetson Bank, Sonnier Bank, MacNeil, 29 Fathom Bank, Rankin Bright Bank, Geyer Bank, McGrail Bank, Bouma Bank, Rezak Sidner Bank, Alderdice Bank, and Jakkula Bank.

Since the 2005 EFH Amendment, there have not been any directed studies to look at the effectiveness of the Council’s HAPCs. The purpose of designating HAPCs was to help provide additional focus for conservation efforts for these areas. Some of these areas are already afforded protection through other means. The Madison-Swanson Marine Reserve is a marine protected area designated by the Council in 2000. Its designation as a marine protected area is designed to protect spawning aggregations of gag grouper and is closed to all fishing except for trolling for highly migratory species. The Tortugas North and South Ecological Reserve was designated in 2001 and is closed to all fishing. East and West Flower Garden Banks and Stetson Bank are part of the Flower Garden Banks National Marine Sanctuary (FGBNMS).

While there have not been any directed studies to look at the effectiveness of protecting habitat in the areas designated as HAPCs, conversely there have not been any reports of habitat damage either. The HAPC designation has focused the Council's efforts in review of projects that may adversely affect these areas.

7.1 Addition or Removal of HAPCs in the Gulf of Mexico

In discussions with staff of the FGBNMS to determine the effectiveness of the Council's HAPC designations, they suggested that the individual HAPC designations for East and West Flower Garden Banks be combined to include an area known as Horseshoe Reef. Horseshoe Reef is located 9 km east-southeast of West Flower Garden Bank and 10 km southwest of East Flower Garden Bank. Horseshoe Reef was unknown until high-resolution multibeam surveys of the area were conducted in 2004. The bathymetry shows extensive deepwater habitat in the form of hundreds of patchy outcroppings. Subsequent ROV surveys have confirmed the presence of extensive deep coral assemblages on these outcroppings. The discontinuous outcroppings cover an area approximately 3 km wide and have 5 to 15 m of relief above the seafloor. The surrounding seafloor ranges from about 115 m in depth in the north to about 150 m depth in the south. Several conical-shaped mud volcanoes are in the area, one of which rises 100 m above the seafloor. HAPC designation would allow increased protection for this deepwater area.

The FGBNMS staff suggested that Elvers, Ewing, Parker, Sackett, and Sweet Banks also be considered for HAPC designation (Figure 37). Elvers Bank is located approximately 200 km off southwestern Louisiana. Elvers Bank covers approximately 55 km^2. Rezak et al. (1981) describe Elvers Bank as having vertical relief of approximately 200 m off the surrounding bottom up to a crest at approximately 70 m. Calcium carbonate secreting coralline algae are the overwhelmingly dominant organisms on the uppermost part of Elvers Bank (Rezak et al. 1981). The following text comes from the description provided by Rezak et al. (1981). "Above 76 m, 75 to 100% of the bottom is covered with large coralline algal nodules, accompanied by carbonate gravel, and underlain by coarse carbonate sand. Below 84 m, the large nodules are replaced by carbonate sand with substantial amounts of carbonate gravel and shell material bearing live crusts of coralline algae. Between 90 and 97 m, an abundant population of very thin, pancake-sized discs of coralline algae occurs, covering over 20% of the sand and rubble bottom in places. This zone of algal discs terminates rather abruptly at 97 to 98 m depths. Living coralline algae encrust gravel, flakes, and chips lying on the sand to depths of at least 108 m, but populations of coralline algae are substantially reduced on the unconsolidated sediment below 100 m. Carbonate sand with gravel persists as the predominant sediment down to approximately 110 m. Below this, with increasing depth, greater and greater amounts of silt size and clay size particles are present." Rezak et al. (1981) also noted the presence of large depressions constructed by snowy grouper, *Epinephelus niveatus*, in depths of 167 to 177 m.

Ewing Bank is located approximately 105 km off the central Louisiana coast. The bank rises approximately 61 m off the surrounding seafloor. The dominant organisms above 70 m depth are coralline algae, nodules of which cover most of the upper part of the bank. Small, growing, coralline algal reef patches of low relief occur here and there on the bank's upper platforms and at ledges (Parker and LeBlanc 1978). In 2010, researchers tagging whale sharks, *Rhincodon typus*, found approximately 100 of the sharks concentrated over Ewing Bank (Hoffmayer, personal communication). The researchers have studied these whale shark congregations for several years, and it is thought that the whale sharks are feeding on little tunny (*Euthynnus alletteratus*) eggs (Hoffmayer et al. 2007). Parker and LeBlanc (1978) stated, "From the standpoint of environmental protection, Ewing Bank should be considered one of the highest priority Outer Continental Shelf biotopes."

Parker Bank is located approximately 180 km off the central Louisiana coast. Parker Bank is nearly circular and has a maximum relief of 73 m. Its highest peak is located 57 m below the water's surface. Parker and LeBlanc (1978) reported that the top of the bank is occupied by coralline algal nodules and leafy algae with large populations of crinoids, sponges, *Cirripathes* corals, and other invertebrates. Parker and LeBlanc (1978) also found sand tilefish (*Malacanthus plumieri*) burrows on the upper part of the bank. Parker and LeBlanc (1978) also observed coralline algal reefs near the top of the bank, while carbonate ledges were observed at water depths of 73 m. Parker and LeBlanc (1978) stated that Parker Bank should be classified as a first priority bank from the standpoint of environmental protection.

Sackett Bank or the Midnight Lump is located approximately 35 km from the mouth of Southwest Pass of the Mississippi River. The bank rises to within 64 m of the water's surface. The topmost part is flat and composed of sand with carbonate rubble and a few scattered coralline algal nodules and drowned coralline algal reef patches (Parker and LeBlanc 1978). Parker and LeBlanc (1978) observed limited amounts of live coralline algae on the reef patches and tops of the rubble and nodules. They state that currently the carbonate production by coralline algal populations on Sackett Bank does not appear to be substantial. Sackett Bank is a fishing destination for anglers looking to catch yellowfin tuna (*Thunnus albacores*), blackfin tuna (*Thunnus atlanticus*), greater amberjack (*Seriola dumerili*), king mackerel (*Scomberomorus cavalla*), dolphin (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and cobia (*Rachycentron canadum*).

Sweet Bank is located approximately 180 km off the central Louisiana coast. The crest of Sweet Bank is approximately 75 m below the water's surface. Continental Shelf Associates, Inc. (1980) reported that the crest of Sweet Bank (75 to 80 meters) was generally covered by a layer of algal nodules that was underlain by a sand or hardbottom. They reported that rock outcrops with relief of less than 1 m to more than 3 m were observed between water depths of 79 to 105 m.

Section 3.2.2.2.2 of the Council's 2004 Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment to the Fishery Management Plans of the Gulf of Mexico

(2004 EFH EIS) contains a detailed description of the Pinnacle Trend area off the Mississippi and Alabama coasts at depths between 60 and 110 m. Most of these pinnacle features in this region appear to be non-diapiric, drowned, or fossil reefs initially formed during low sea level stands during the Pleistocene, and colonized by invertebrate communities (Gardner et al. 2001). Weaver et al. (2001) recorded 159 fish species at the Pinnacle Trend area including yellowedge grouper (*Epinephelus flavolimbatus*), snowy grouper (*E. niveatus*), warsaw grouper (*E. nigritus*), gag grouper (*Mycteroperca microlepis*), greater amberjack (*Seriola dumerili*), lesser amberjack (*S. fasciata*), gray triggerfish (*Balistes capriscus*), red snapper (*Lutjanus campechanus*), vermilion snapper (*Rhomboplites aurorubens*), king mackerel (*Scomberomorus cavalla*), dolphin (*Coryphaena hippurus*), and wahoo (*Acanthocybium solandri*). This area was considered as a HAPC in the 2004 EFH EIS and had the same characteristics of other areas that were chosen as HAPCs, but the Pinnacle Trend area was not selected as a HAPC.

Since that time, several non-fishing activities have potentially affected the area. Oil and gas exploration and production continues in this area. TORP's Bienville Offshore Energy Terminal for offloading and vaporizing liquefied natural gas (LNG) has been proposed to be located approximately 16 km south of the Pinnacle Trend area. While the LNG offloading facility will not directly impact habitat in the Pinnacle Trend area, the proposed pipeline transporting the natural gas could affect some areas. According to the Final Supplemental Environmental Impact Statement for the Bienville Offshore Energy Terminal, numerous pinnacles are located along the Dauphin Interconnect Pipeline route. The closest seafloor pinnacles to the pipeline route are located approximately 61 m away from the pipeline route. The Bureau of Offshore Energy and Management, Regulation, and Enforcement's Bottom (Pinnacle Trend) Stipulation does provide protection of pinnacle trends and live bottom from oil and gas related development. The Live Bottom (Pinnacle Trend) Stipulation is designed to prevent drilling activities and anchoring activities from damaging pinnacles and, as such, no bottom disturbing activities may occur within 30 m of any hard bottoms/pinnacles that have a vertical relief of 2.4 m or more. The BP Deepwater Horizon oil platform was located approximately 50 km south of the Pinnacle Trend area. The impacts of the oil and dispersant on the Pinnacle Trend area are unknown at this time.

7.2 HAPC Recommendations

Marbled grouper, *Dermatolepis inermis*, are considered rare throughout their range. Marbled grouper have recently been listed as near threatened by the International Union for Conservation of Nature (IUCN). Not much is known about marbled grouper, but SEAMAP reef fish surveys have only shown the species to occur on a handful of banks in the northwestern Gulf of Mexico. Geyer Bank may be the only known area for spawning aggregations (Rocha et al. 2008). Geyer Bank is located approximately 200 km off the coast of Louisiana. In order to protect spawning aggregations of marbled grouper, a seasonal fishery closure around Geyer Bank may be warranted.

8.0 Recommendations on Updating EFH Information

The 2004 EFH EIS resulted from a court order to NMFS to complete a new and more thorough NEPA analysis of actions to minimize adverse effects of fishing on EFH. NMFS and the Councils decided the scope of the EIS should address all required EFH components of Section 303(a)(7) of the MSFCMA. This effort represents the first "periodic" review of EFH information solely for the purposes of satisfying Section 600.815(a)(10) of the EFH Final Rule. The required EFH information of Subpart J of 50 CFR Part 600.815(a) is discussed below:

8.1 Description and Identification of EFH

While the literature review provided new information on some managed species' habitat utilization, the new literature did not provide any information that would dramatically alter current EFH designations and descriptions.

Section 3.4 details the mapping of EFH for larval fish and shrimp using SEAMAP plankton data. While habitat association tables in previous EFH Amendments have described the preferred habitat for larval fish and shrimp, species and species life stage maps were never produced. The larval fish and shrimp mapping represents a significant gain in knowledge for describing and designating EFH for the early life history of managed species.

Section 4.0 details new methodologies for designating EFH. While many new models and methods exist, they require the appropriate data inputs to produce accurate results. Brown shrimp were used to demonstrate a correlation based habitat model with SEAMAP trawl data. SEAMAP trawl data could also possibly be used to produce EFH maps for white shrimp, juvenile red snapper, and possibly other managed species. Unfortunately, data are lacking for most managed species across their entire ranges and life cycles. However, other data sources (e.g., NMFS longline monitoring) may be suitable fisheries independent data for refined EFH maps for additional managed species (e.g., red snapper) or age classes.

8.2 Identification of Habitat Areas of Particular Concern (HAPC)

Habitat Areas of Particular Concern seem to be working effectively in the Gulf of Mexico, but directed studies to measure their effectiveness have been lacking. The FGBNMS staff suggested that the HAPC for East and West Flower Garden Banks be combined to include an area known as Horseshoe Reef. This area was only recently discovered during high-resolution multibeam surveys of the area. The FGBNMS staff also suggested five additional banks be considered for HAPC designation. Ewing and Parker Banks were recommended for high levels of protection when they were first surveyed back in the 1970s. In addition, the Pinnacle Trend Area off Mississippi and Alabama has been nominated as a HAPC. This unique area provides habitat for several managed species. This area was considered as a HAPC in the 2004 EFH EIS. Since that time, several non-fishing activities have potentially affected the area.

8.3 Fishing Activities That May Adversely Affect EFH and Non-Magnuson-Stevens Act Fishing Activities That May Adversely Affect EFH

The fishing impacts on habitat literature review did not produce any new evidence or understanding on how current fisheries in the Gulf of Mexico are impacting habitat. Since the 2005 EFH Amendment, one potentially destructive gear, fish traps, has been banned in the Gulf of Mexico. As seen in Figures 26 through 35, recreational and commercial fishing effort has declined since 2000.

8.4 Non-fishing Activities That May Adversely Affect EFH and EFH Conservation and Enhancement Recommendations

A review of recent literature (NOAA 2008) identified some information gaps regarding threats to EFH that could be incorporated into the 2004 EFH EIS discussion of non-fishing impacts. Additionally, several new sources of threats to EFH have emerged since the 2004 EFH EIS including new and emerging industries as well as invasive exotic species. Incorporation of these new threats into the Council's FMPs would be necessary to satisfy Section 600.815(a)(4) of the EFH Final Rule.

8.5 Research and Information Needs

In May 2010, NMFS published a Habitat Assessment Improvement Plan (NMFS, 2010) which provides a general description of national and regional habitat related research programs and an assessment of regional staffing needs to meet identified tiers of habitat assessment excellence in the plan. Also in May 2010, the 1st National Habitat Assessment Workshop was held jointly with the National Stock Assessment Workshop. The goals of the meeting were to: 1) Improve communication and coordination within the community of NOAA Fisheries habitat ecologists, stock assessment scientists, and resource managers; 2) Produce the first steps towards building a coordinated, national habitat research program and community; 3) Address issues of national concern; 4) Begin implementing the key recommendations of the Habitat Assessment Improvement Plan (HAIP); and, 5) Integrate habitat science with other areas of research and promote interdisciplinary research. The three-day meeting was well attended with over 200 registrants participating. Workshop attendees came from every NOAA Fisheries Science Center, Regional Office, and several Headquarters Offices, as well as participants from universities and several Fishery Management Councils. A proceedings document was under development at the time of this review precluding any incorporation of the outcomes of that workshop into this review.

8.6 Prey Species

Prey species were identified, as required, for each fishery management unit (FMU) in the 2004 EFH EIS. During the course of conducting literature searches and communicating with researchers around the Gulf of Mexico during the preparation of this document no new information regarding prey of the FMUs became known.

8.7 Review and Revision of EFH Components of FMPs

As noted above this effort represents the first periodic review of EFH information solely for the purposes of satisfying Section 600.815(a)(10) of the EFH Final Rule. Although a pre-defined process was not in place the authors utilized guidance provided by NMFS through the Southeast Region. After examining the contents of the report, a comprehensive or generic EFH amendment does not appear warranted at this time. It is the recommendation of the preparers that the Council's EFH information be updated as fishery management actions are developed for FMPs in the Gulf of Mexico. Specific actions to consider are: 1) SEAMAP plankton data can be used to designate and describe EFH for the early life history of managed species; 2) Additional HAPC designations can be considered; 3) EFH maps can be refined to species and life-stages and provide higher resolution of spatial EFH representation. Other methods for designating EFH can be explored over time with a possible refinement of EFH designations for applicable species and life stages.

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10.0 Tables

Table 1. Status of stocks in Gulf of Mexico FMPs subject to annual catch limits as of first quarter 2010.

FMP	Stock	Overfishing?	Overfished?	Approaching Overfished Condition?	FSSI Score
Red Drum	Red drum	No	Undefined	Unknown	1.5
Reef Fish	Almaco jack	Unknown	Undefined	Unknown	non-FSSI
	Anchor tilefish	Unknown	Undefined	Unknown	non-FSSI
	Banded rudderfish	Unknown	Undefined	Unknown	non-FSSI
	Black grouper	Unknown	Undefined	Unknown	0
	Blackfin snapper	Unknown	Undefined	Unknown	non-FSSI
	Blackline tilefish	Unknown	Undefined	Unknown	non-FSSI
	Blueline tilefish	Unknown	Undefined	Unknown	non-FSSI
	Cubera snapper	Unknown	Undefined	Unknown	non-FSSI
	Dog snapper	Unknown	Undefined	Unknown	non-FSSI
	Dwarf sand perch	Unknown	Undefined	Unknown	non-FSSI
	Gag	Yes	Yes	N/A	1
	Goldface tilefish	Unknown	Undefined	Unknown	non-FSSI
	Goliath grouper	No	Unknown	Unknown	1.5
	Gray snapper	Unknown	Undefined	Unknown	non-FSSI
	Gray Triggerfish	Yes	Yes	N/A	1
	Greater amberjack	Yes	Yes	N/A	1
	Hogfish	Unknown	Undefined	Unknown	0
	Lane snapper	Unknown	Undefined	Unknown	non-FSSI
	Lesser amberjack	Unknown	Undefined	Unknown	non-FSSI
	Mahogany snapper	Unknown	Undefined	Unknown	non-FSSI
	Misty grouper	Unknown	Undefined	Unknown	non-FSSI
	Mutton snapper	No	No	No	non-FSSI
	Nassau grouper	No	Undefined	Unknown	1.5
	Queen snapper	Unknown	Undefined	Unknown	non-FSSI
	Red hind	Unknown	Undefined	Unknown	non-FSSI
	Red grouper	No	No	No	4

Table 1 Continued.

	Red snapper	Yes	Yes	N/A	1
	Rock hind	Unknown	Undefined	Unknown	non-FSSI
	Sand perch	Unknown	Undefined	Unknown	non-FSSI
	Scamp	Unknown	Undefined	Unknown	non-FSSI
	Schoolmaster	Unknown	Undefined	Unknown	non-FSSI
	Silk snapper	Unknown	Undefined	Unknown	non-FSSI
	Snowy grouper	Unknown	Undefined	Unknown	0
	Speckled hind	Unknown	Undefined	Unknown	non-FSSI
	Tilefish	Unknown	Undefined	Unknown	non-FSSI
	Vermilion snapper	No	No	No	4
	Warsaw grouper	Unknown	Undefined	Unknown	non-FSSI
	Wenchman	Unknown	Undefined	Unknown	non-FSSI
	Yellowedge grouper	Unknown	Undefined	Unknown	0
	Yellowfin grouper	Unknown	Undefined	Unknown	non-FSSI
	Yellowmouth grouper	Unknown	Undefined	Unknown	non-FSSI
	Yellowtail snapper	No	No	No	4
Shrimp	Royal red shrimp	No	No	No	3
	Brown shrimp	No	No	No	4
	Pink shrimp	No	No	No	3
	White shrimp	No	No	No	4
Stone Crab	Stone crabs	No	Undefined	Unknown	1.5
Spiny Lobster in the Gulf of Mexico and South Atlantic	Caribbean spiny lobster - Southern Atlantic Coast / Gulf of Mexico	No	Unknown	Unknown	1.5
Coral and Coral Reefs	Black corals (Antipatharia)	No	Undefined	Unknown	non-FSSI
	Fire corals (Milleporidae)	No	Undefined	Unknown	non-FSSI
	Hydrocorals (Stylasteridae)	No	Undefined	Unknown	non-FSSI
	Soft corals (Octocorallia)	No	Undefined	Unknown	non-FSSI
	Stony corals (Scleractinia)	No	Undefined	Unknown	non-FSSI

Table 1 Continued.

Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic	Cobia - Gulf of Mexico	No	No	No	4
	King Mackerel- Gulf of Mexico	No	No	No	4
	King Mackerel- Southern Atlantic Coast	No	No	No	4
	Little tunny- Gulf of Mexico	No	Undefined	Unknown	1.5
	Spanish mackerel- Gulf of Mexico	No	No	No	4
	Spanish mackerel- Southern Atlantic Coast	No	No	No	4
	Dolphinfish- Southern Atlantic Coast / Gulf of Mexico	No	No	No	4

Table 2. List of EFH designation methods reviewed in the Habitat Evaluation Working Group report developed by the Northeast Fisheries Science Center (2005).

a.	EFH considerations and topics relating commercial fisheries to benthic habitat
b.	Habitat Suitability Index model (HSI)
c.	Linear, Generalized Linear, and Generalized Additive models
d.	Novel EFH algorithm or EFH strawman
e.	Assessing habitat vulnerability, availability and risk
f.	Simulated annealing – MARXAN
g.	West coast EFH model
h.	Geo-spatial analysis (GIS)
i.	Habitat use by life history stage
j.	A strictly habitat approach
k.	Habitat that impacts vital rates of sensitive life history stages
l.	Bioenergetic model
m.	Connectivity approach
n.	Status quo methodology

Table 3. Environmental variables used to predict catch rates of brown shrimp in the northern Gulf of Mexico.

Variable	Description	Mean (range)
Depth	Starting depth of each trawl (fathoms)	30.6 (1.9-81.0)
Latitude	Latitude at start of trawl sample (decimal degrees)	28.5 (26.0-30.4)
Longitude	Longitude at start of trawl sample (decimal degrees)	28.5 (-97.4.0- -82.0)
Season	Season sample occurred (summer or fall)	NA

Table 4. Model summary of generalized additive models fit to brown shrimp. Model was fit using cubic-spline smoothers and 10-fold cross-validation. Model parameters explained 30.0% of total deviance.

parametric terms	z	p
Summer	26.18	< 0.001
Fall	1.54	0.122
non-parametric term	edf	p
s(Latitude)	8.202	< 0.001
s(Longitude)	7.596	< 0.002
s(Depth)	7.893	< 0.003
Season	2.68	< 0.004

11.0 Figures

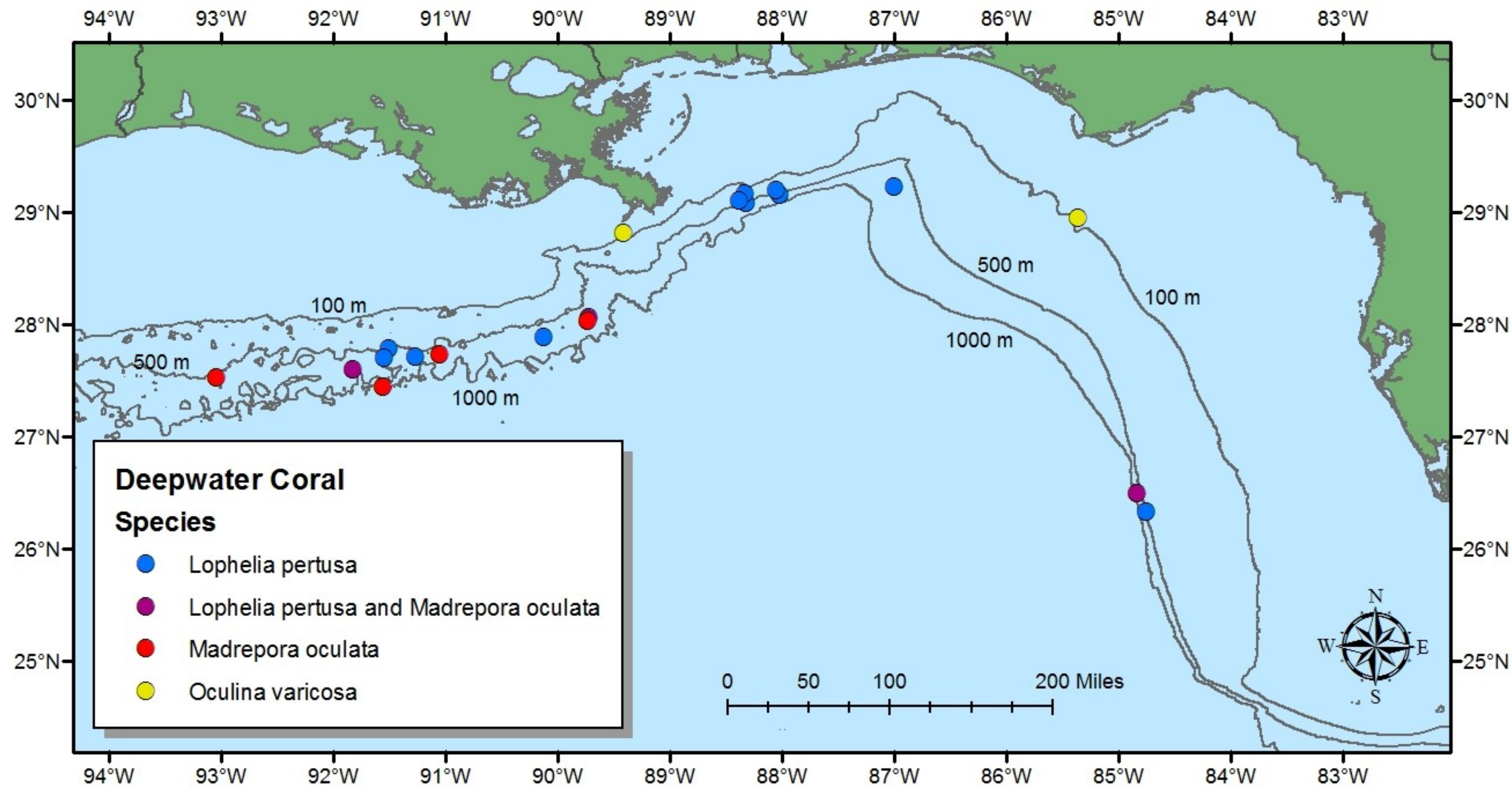


Figure 1. Locations of recent reports of deepwater corals in the Gulf of Mexico.

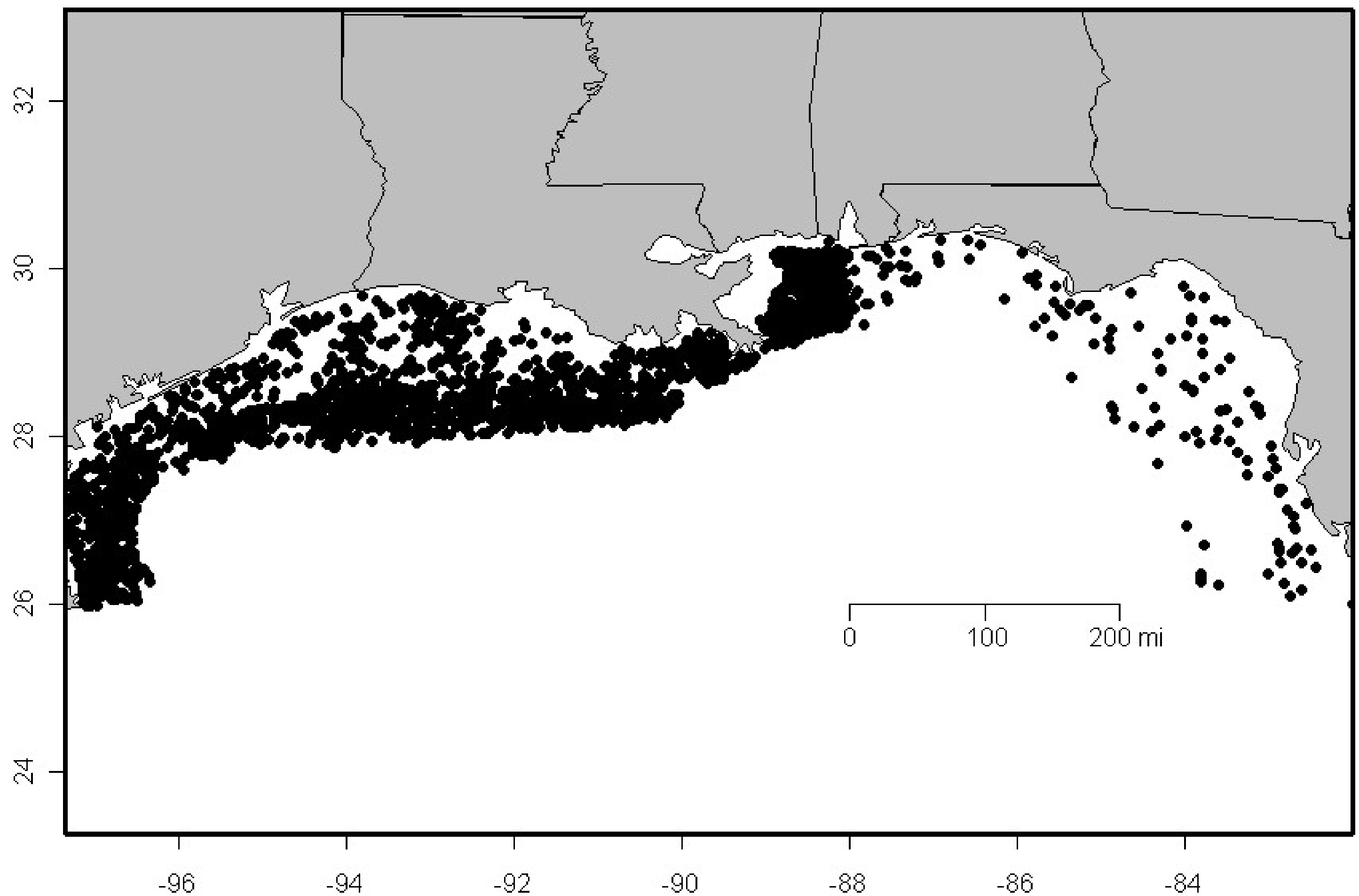


Figure 2. Map of sample locations (n = 3701) from 1982 to 2009. Samples occurred from June to November each year.

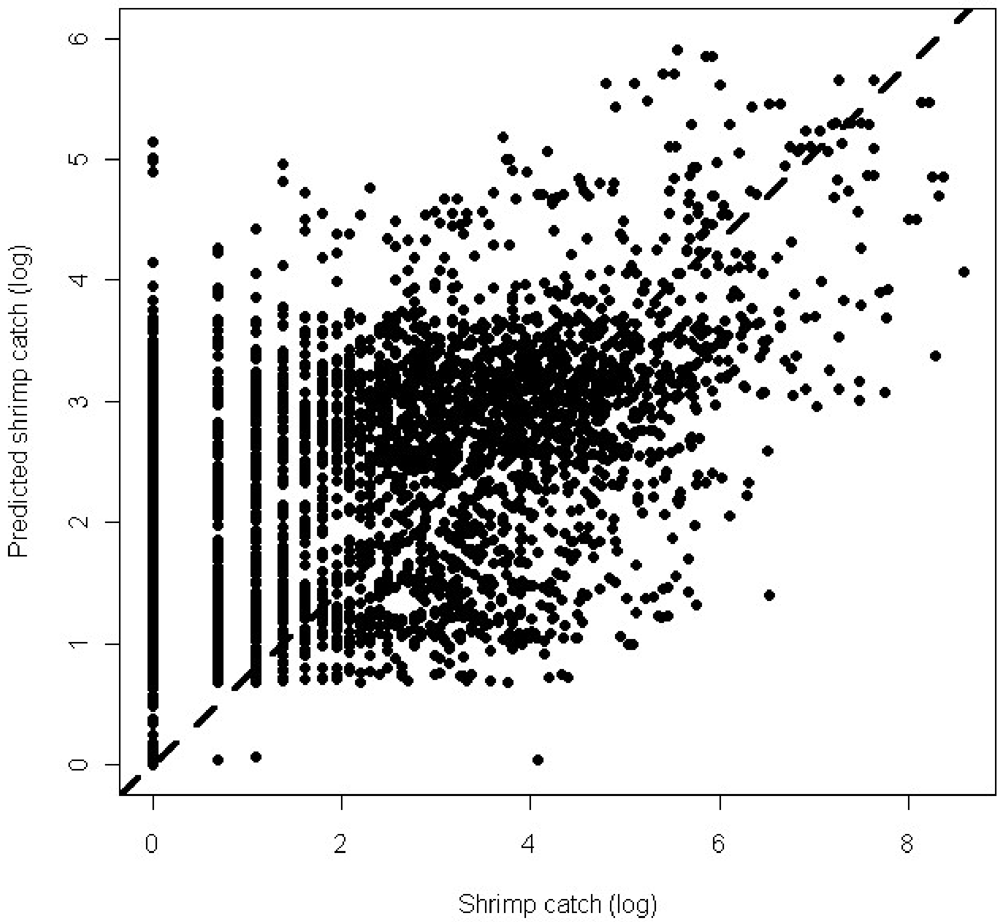


Figure 3. Predicted and observed catch per unit effort (CPUE) for brown shrimp in the Gulf of Mexico. There was a significant, positive relationship between shrimp catch and predicted values from the fitted GAM (linear regression $F = _{1,3695}$, $p < 0.001$, $R^2 = 0.72$).

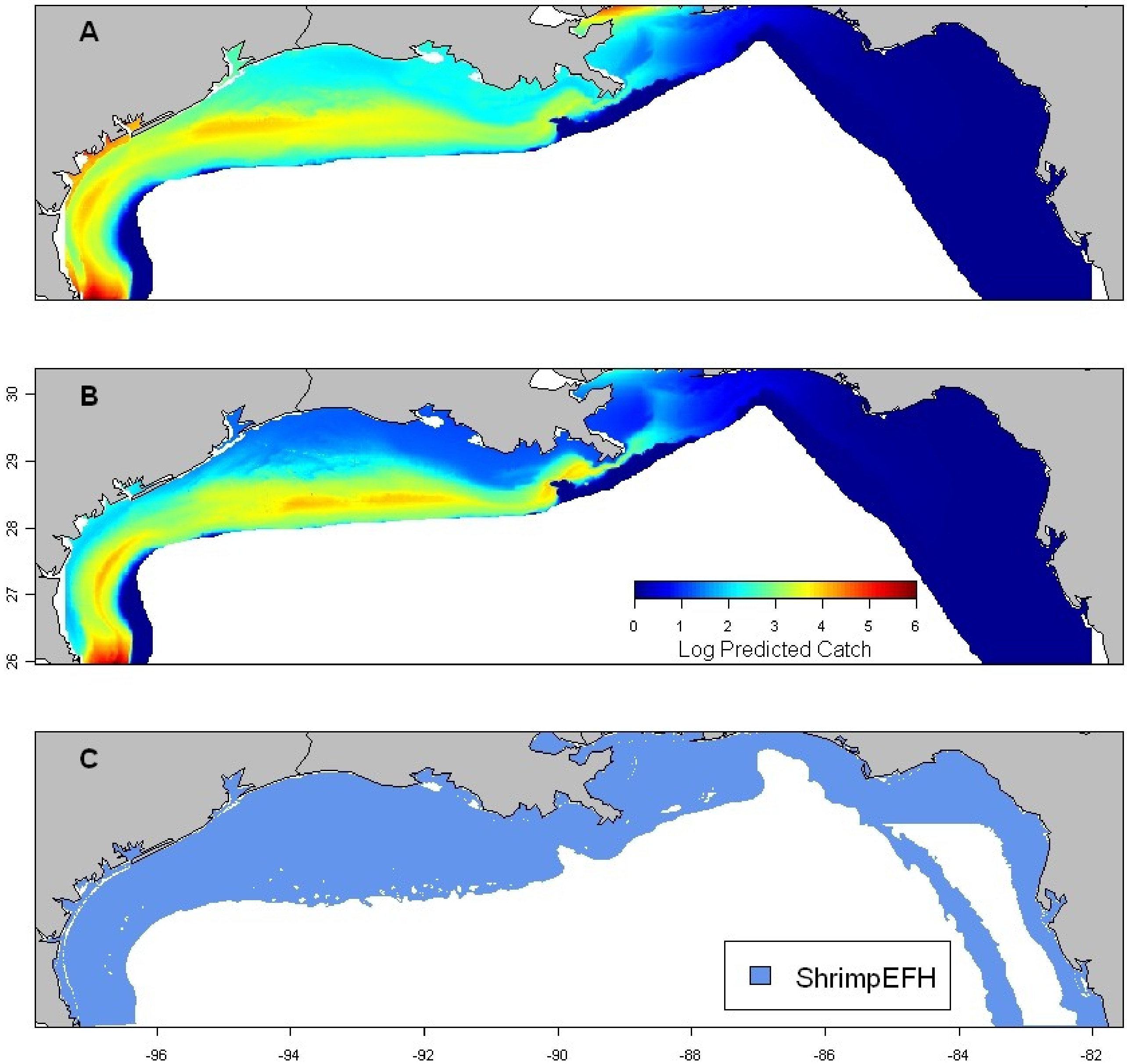


Figure 4. Predicted catch rates of brown shrimp from SEAMAP trawl surveys from (A) summer and (B) fall sampling periods in comparison to (C) current shrimp EFH in the Gulf of Mexico (GMFMC 2005).

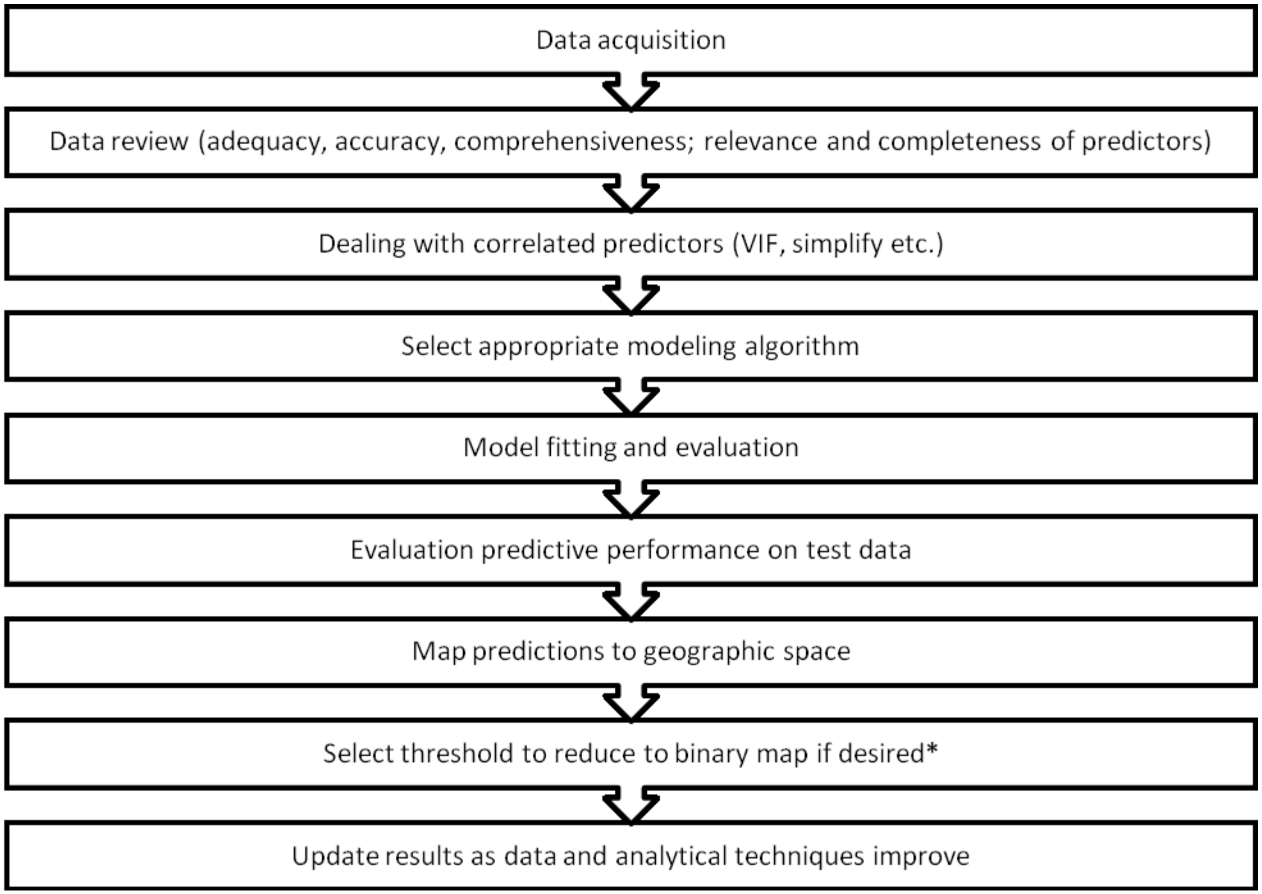
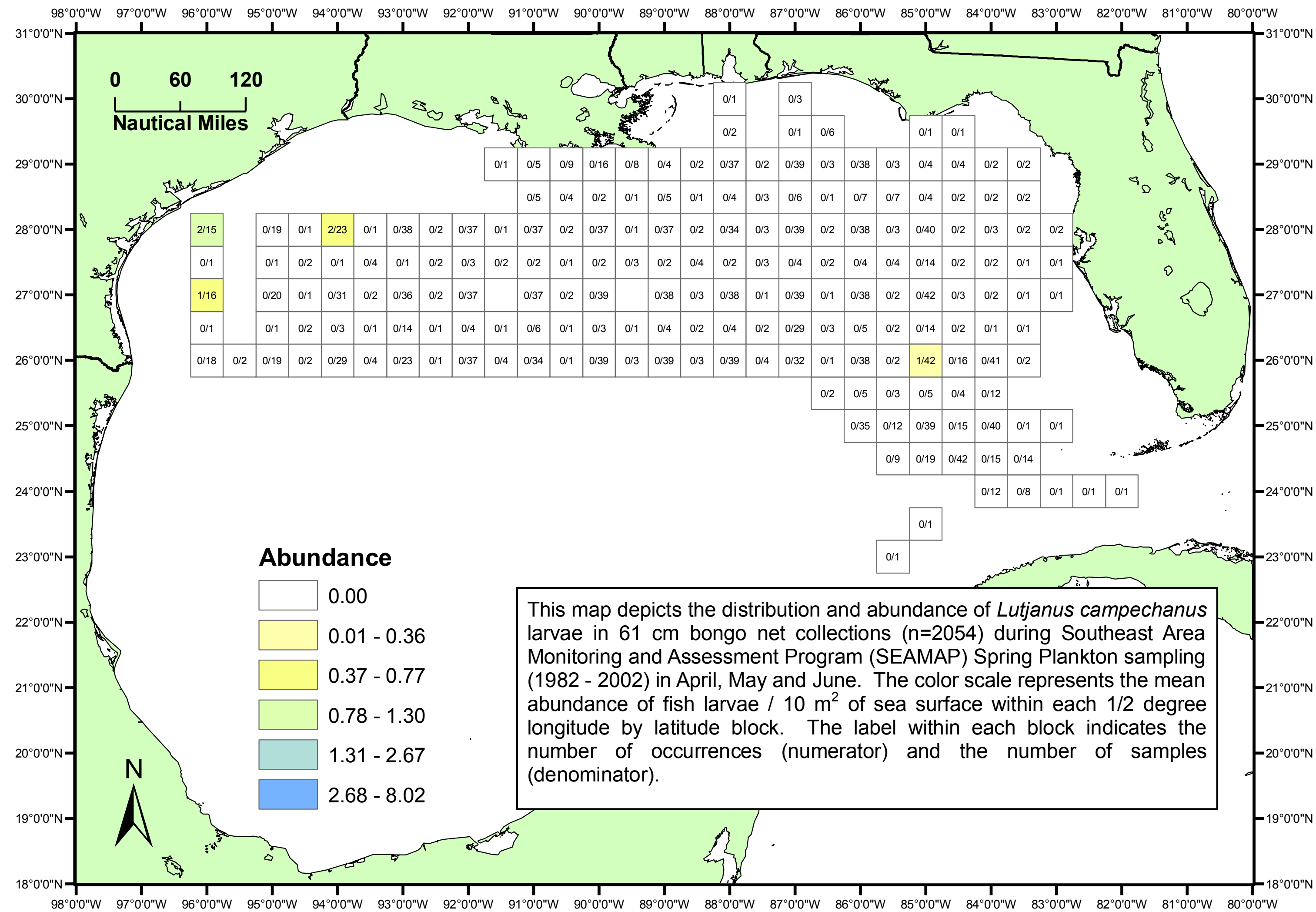


Figure 5. A general process of species habitat modeling for the identification of essential fish habitat. Asterisks (*) indicates this process remains a management process that is dependent on management or conservation goals for a particular area or species. This threshold may also change in response to conservation or management needs.



This map depicts the distribution and abundance of *Lutjanus campechanus* larvae in 61 cm bongo net collections (n=2054) during Southeast Area Monitoring and Assessment Program (SEAMAP) Spring Plankton sampling (1982 - 2002) in April, May and June. The color scale represents the mean abundance of fish larvae / 10 m^2 of sea surface within each 1/2 degree longitude by latitude block. The label within each block indicates the number of occurrences (numerator) and the number of samples (denominator).

NOAA Fisheries Service
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Figure 6. Distribution and abundance of red snapper larvae in bongo net collections during SEAMAP Spring Plankton sampling (1982-2002) in April, May, and June.

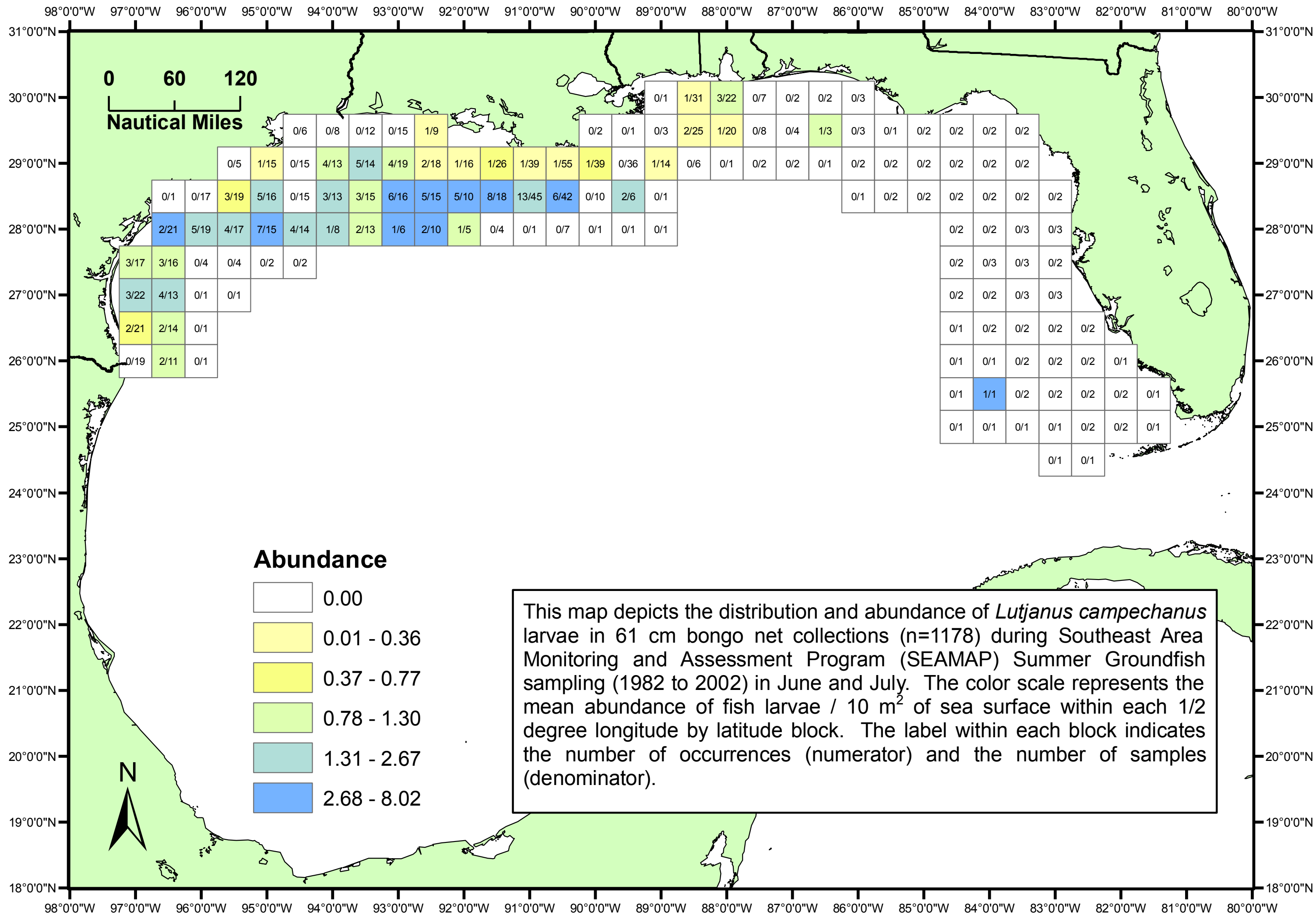

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Figure 7. Distribution and abundance of red snapper larvae in bongo net collections during SEAMAP Summer Groundfish sampling (1982-2002) in June and July.

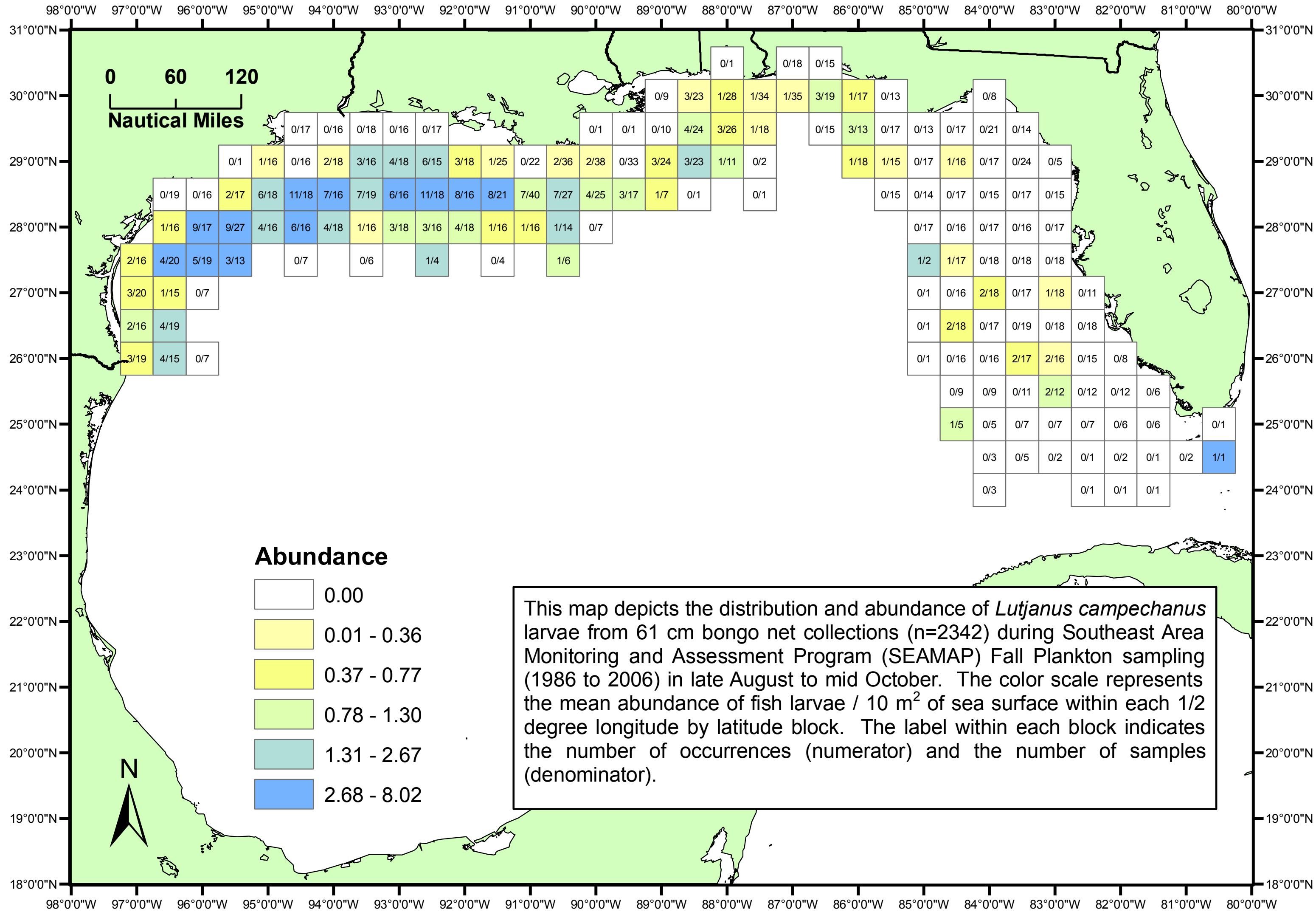

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Figure 8. Distribution and abundance of red snapper larvae in bongo net collections during SEAMAP Fall Plankton sampling (1986-2006) in late August to mid October.

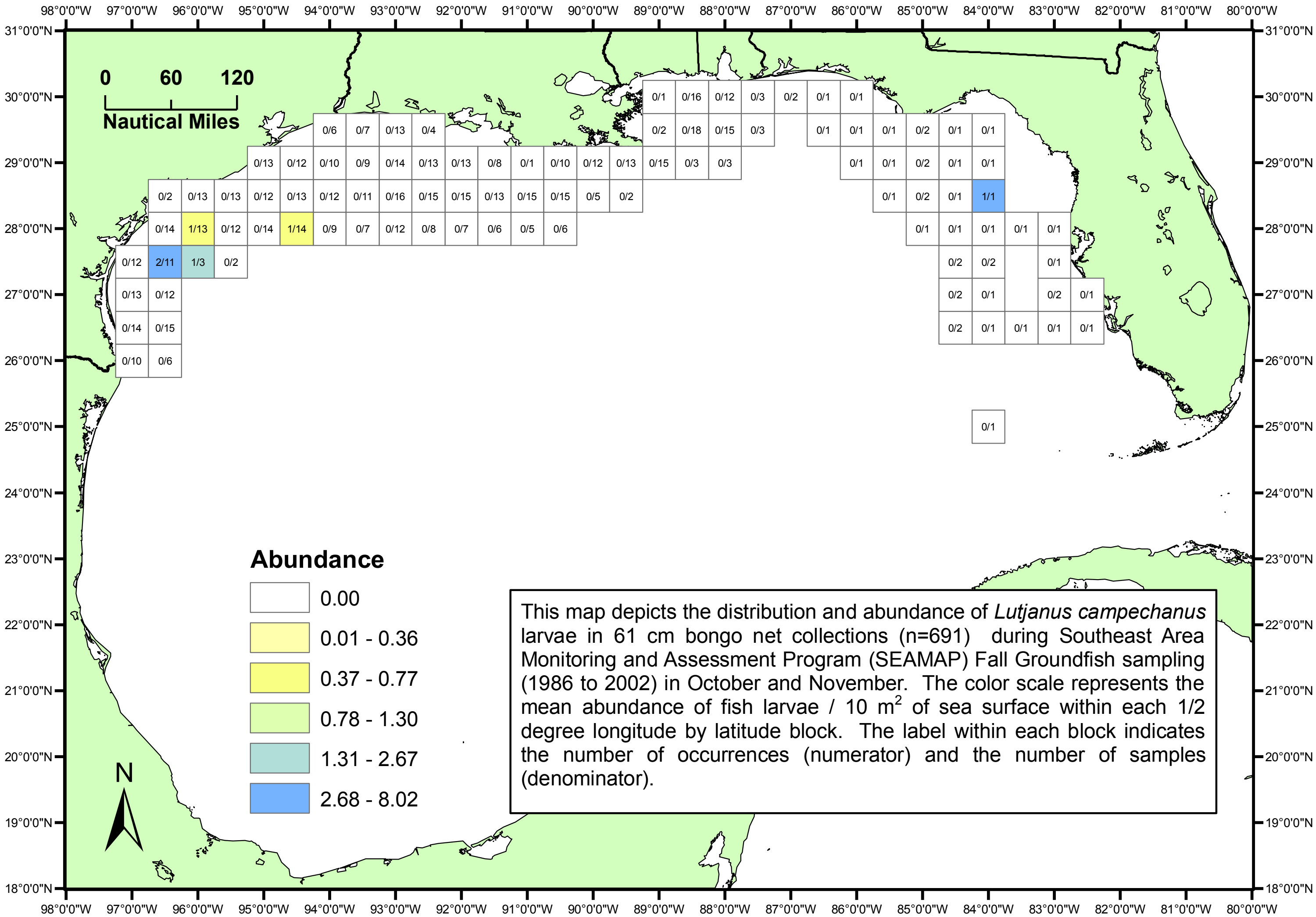

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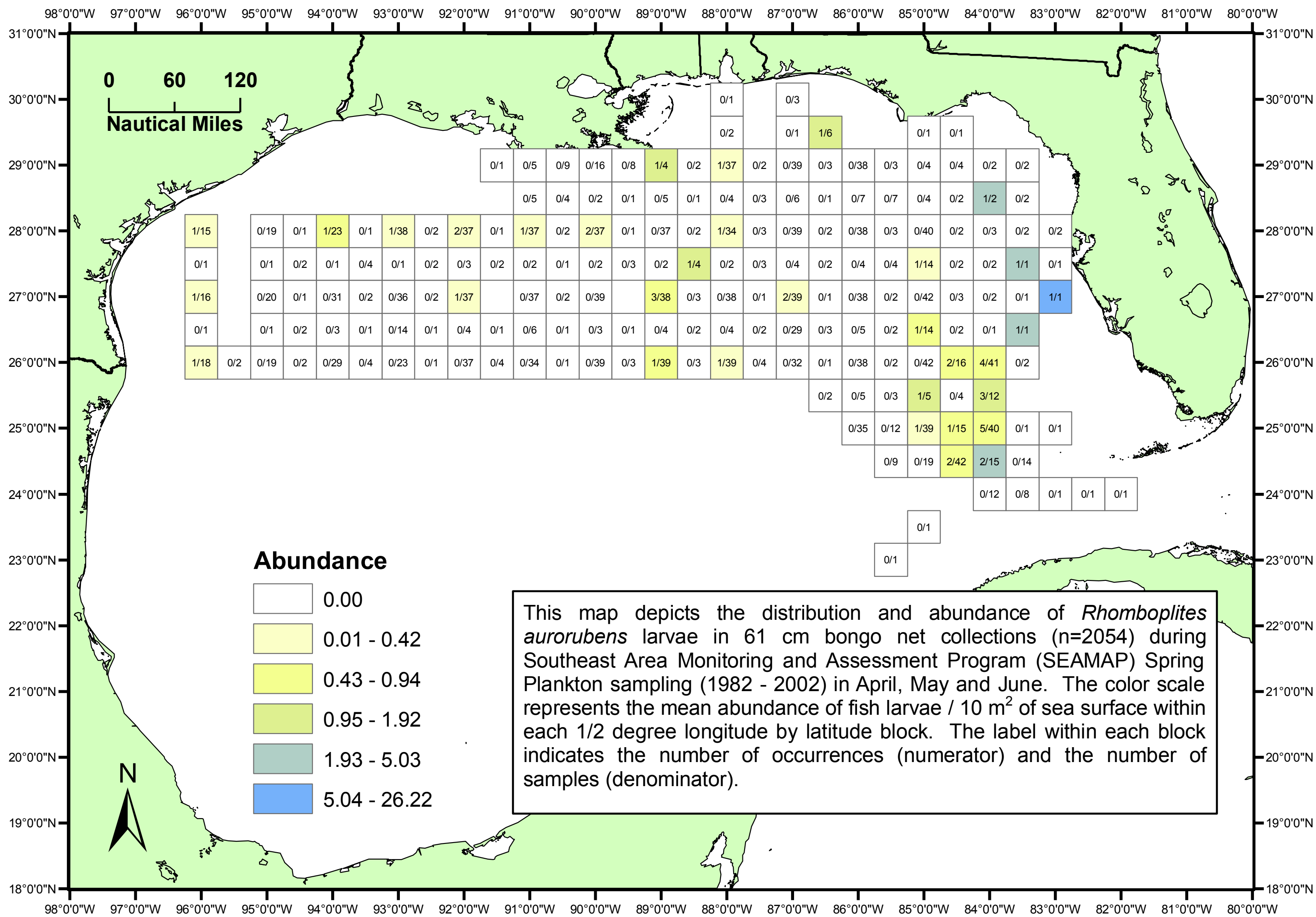
Figure 9. Distribution and abundance of red snapper larvae in bongo net collections during SEAMAP Fall Groundfish sampling (1986-2002) in October and November.



This map depicts the distribution and abundance of *Rhomboplites aurorubens* larvae in 61 cm bongo net collections (n=2054) during Southeast Area Monitoring and Assessment Program (SEAMAP) Spring Plankton sampling (1982 - 2002) in April, May and June. The color scale represents the mean abundance of fish larvae / 10 m^2 of sea surface within each 1/2 degree longitude by latitude block. The label within each block indicates the number of occurrences (numerator) and the number of samples (denominator).

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Figure 10. Distribution and abundance of vermilion snapper larvae in bongo net collections during SEAMAP Spring Plankton sampling (1982-2002) in April, May, and June.

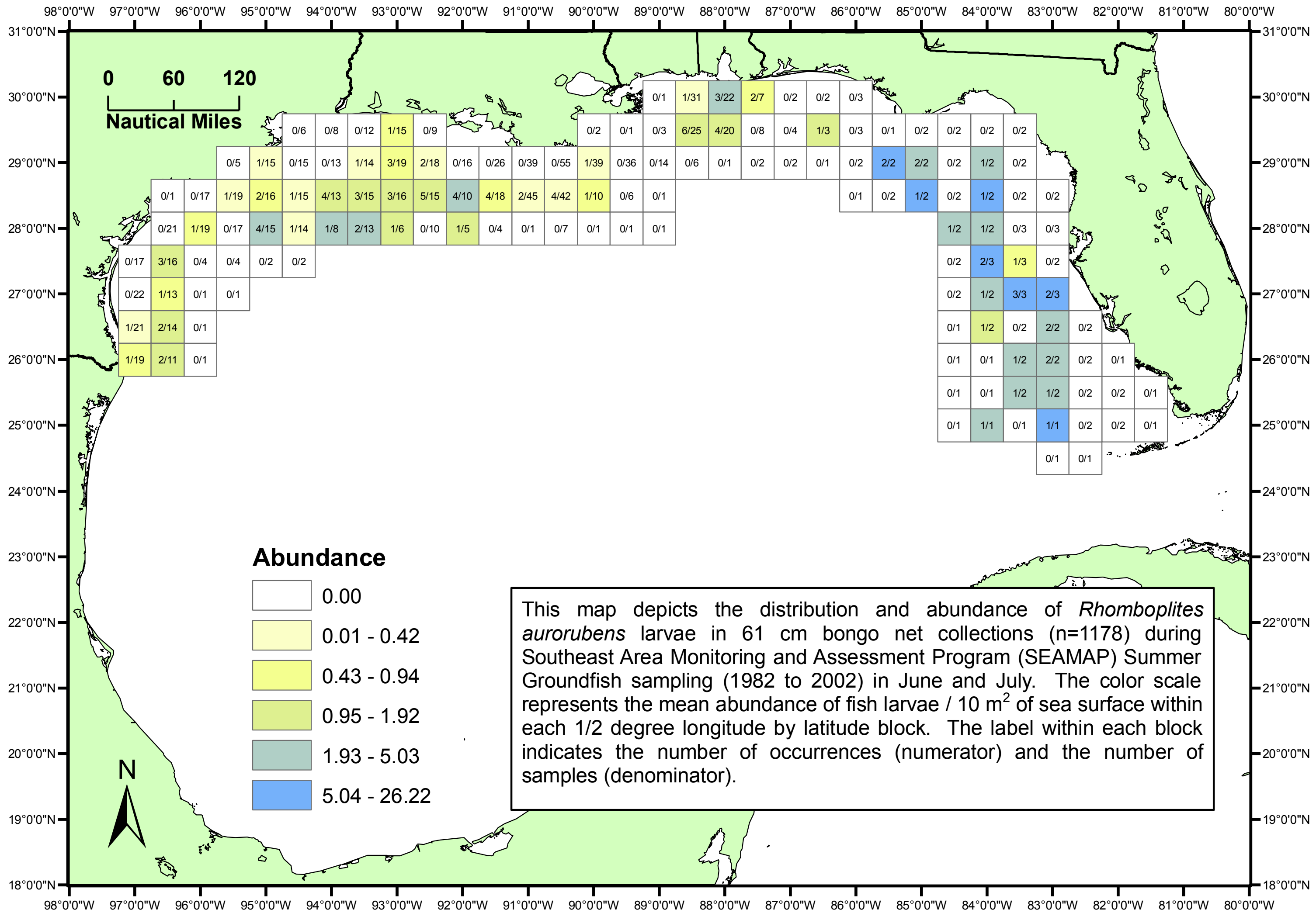

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Figure 11. Distribution and abundance of vermilion snapper larvae in bongo net collections during SEAMAP Summer Groundfish sampling (1982-2002) in June and July.

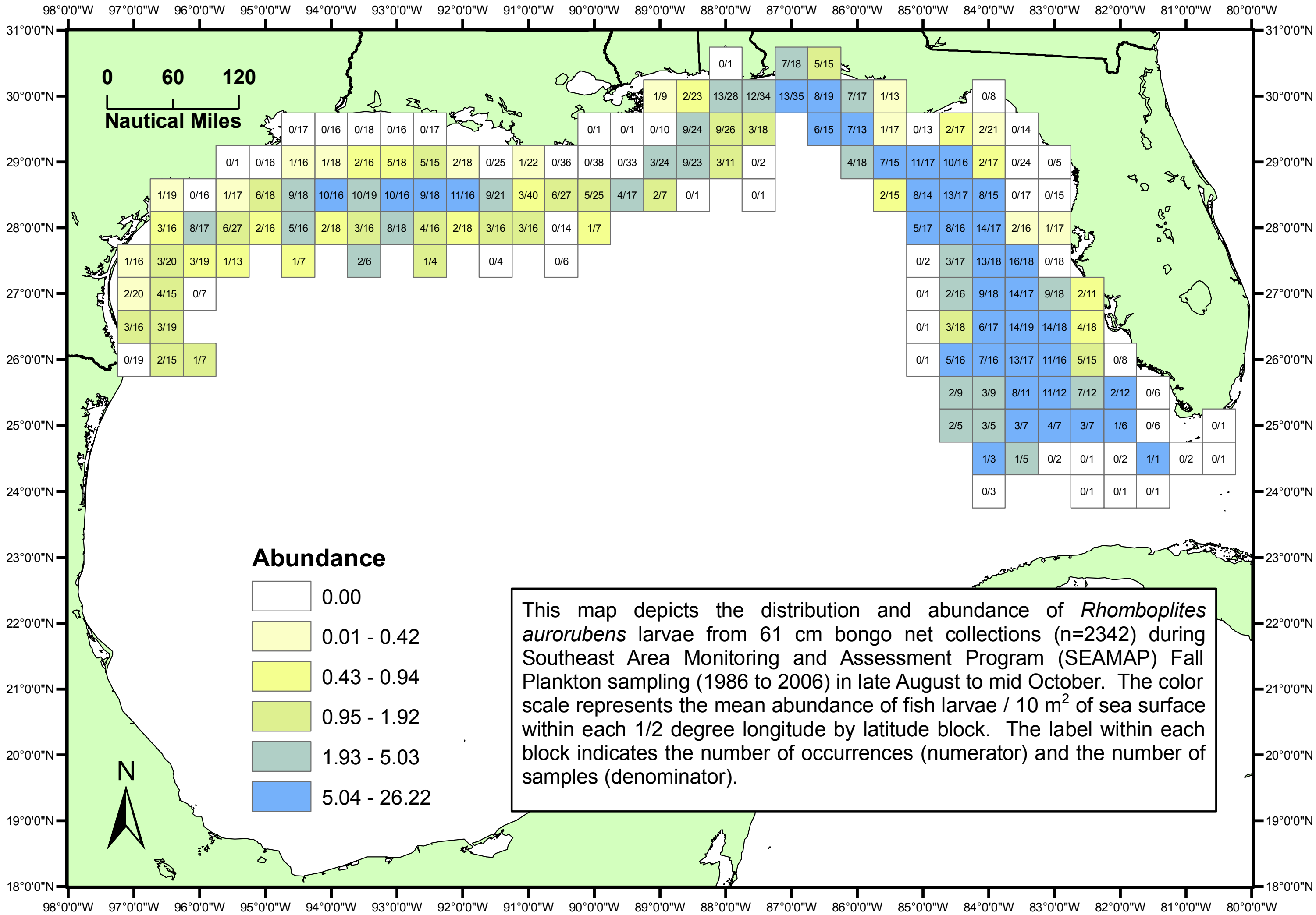

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Figure 12. Distribution and abundance of vermilion snapper larvae in bongo net collections during SEAMAP Fall Plankton sampling (1986-2006) in late August to mid October.

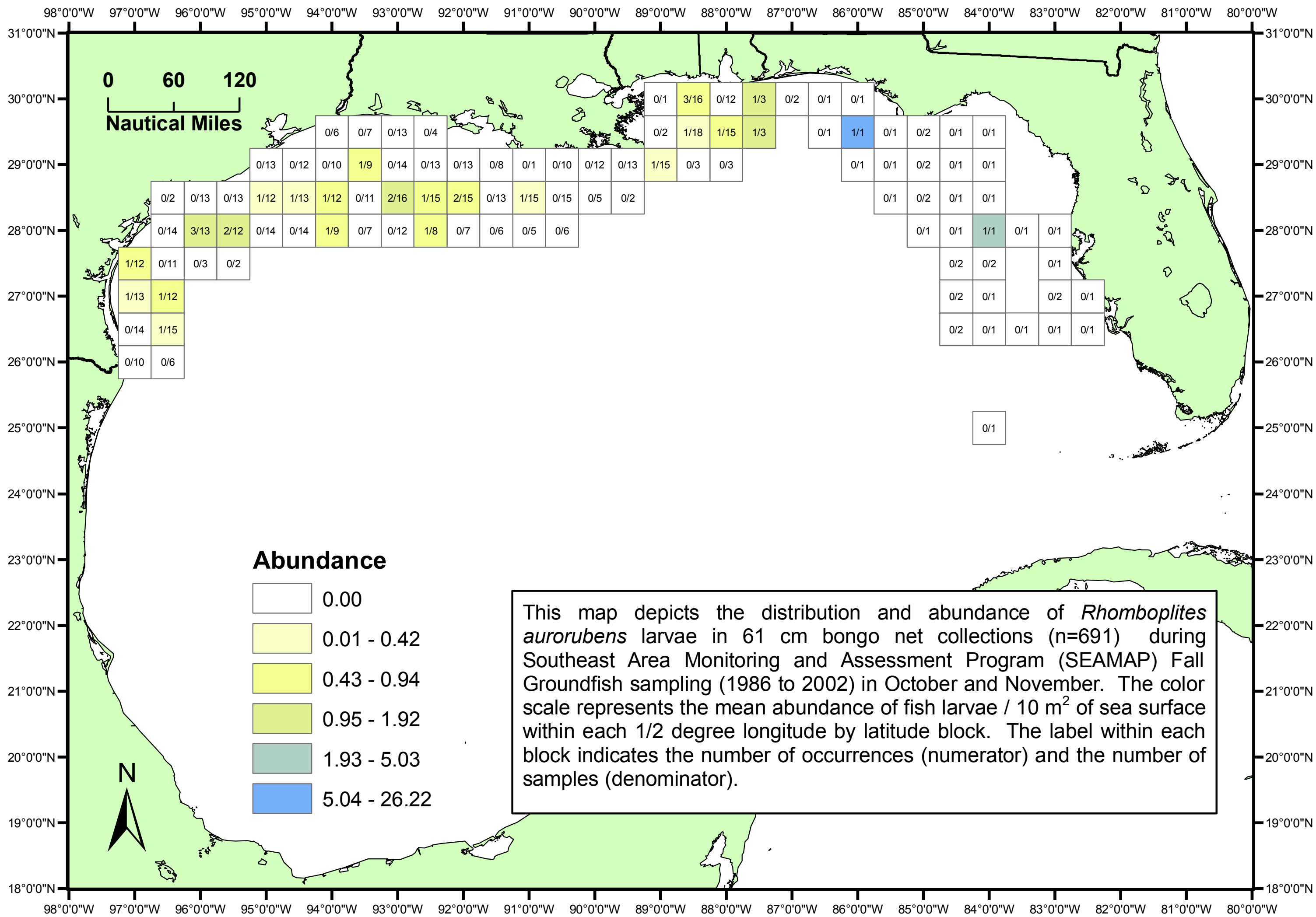

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Figure 13. Distribution and abundance of vermilion snapper larvae in bongo net collections during SEAMAP Fall Groundfish sampling (1986-2002) in October and November.

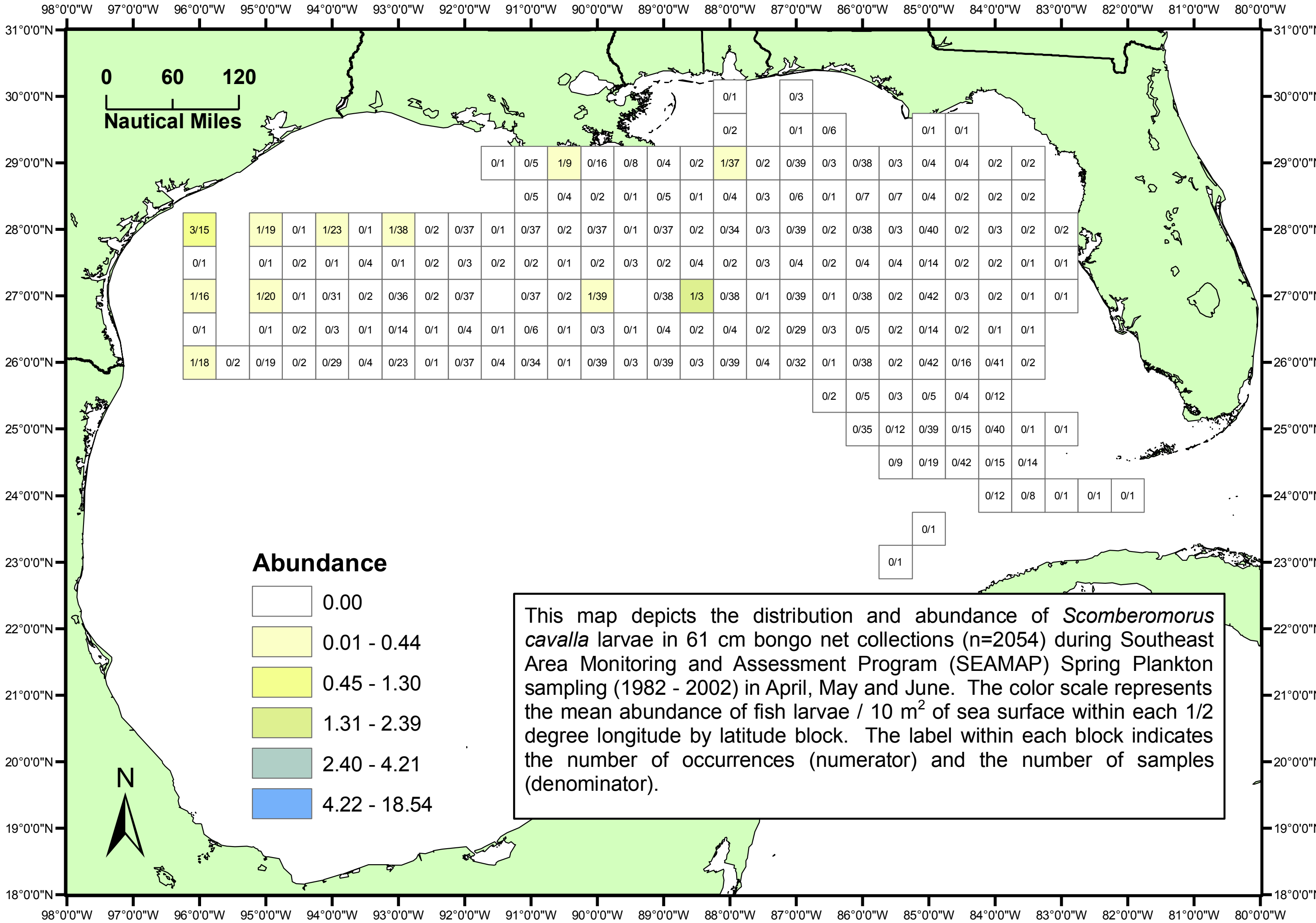

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Figure 14. Distribution and abundance of king mackerel larvae in bongo net collections during SEAMAP Spring Plankton sampling (1982-2002) in April, May, and June.

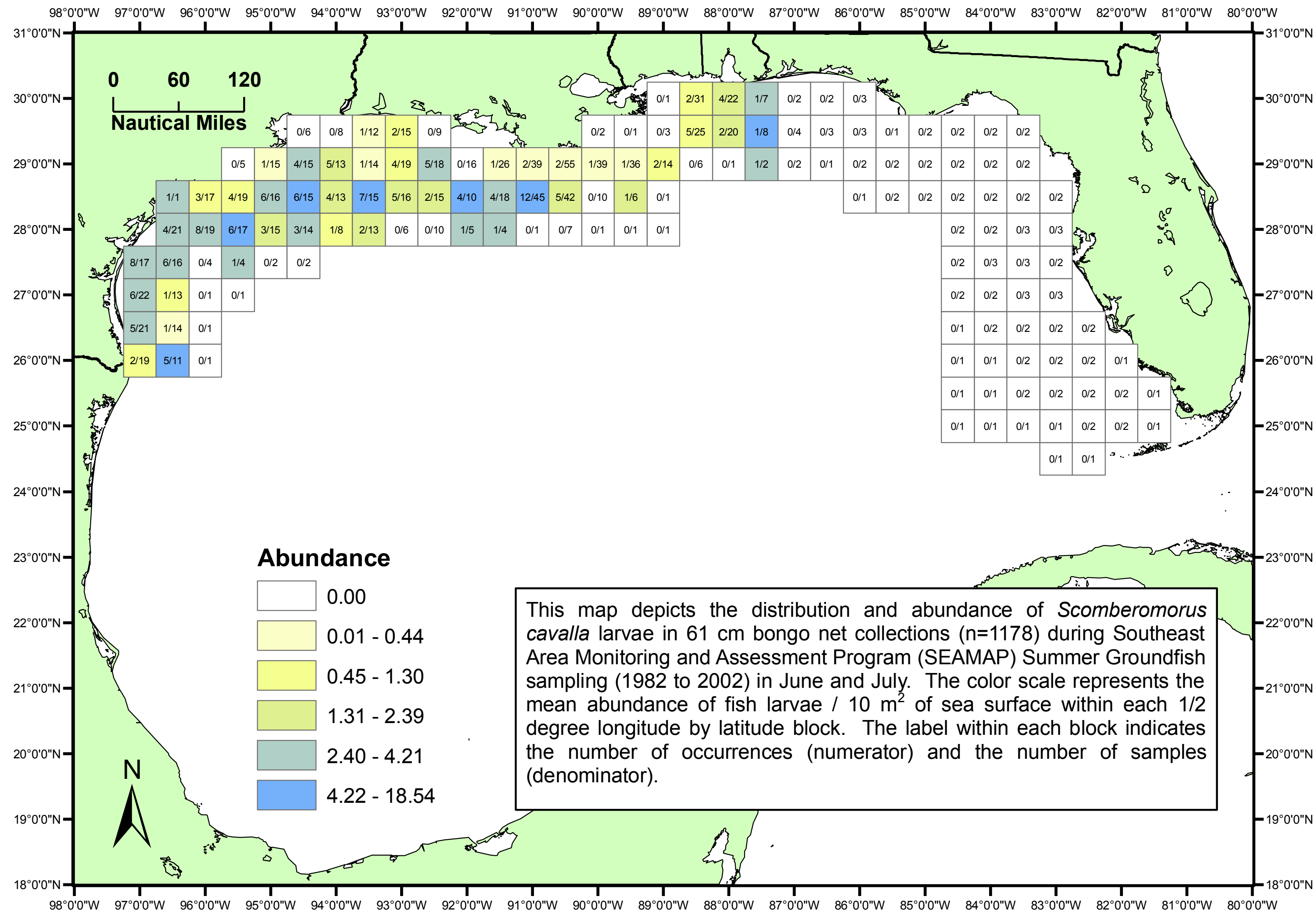

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Figure 15. Distribution and abundance of king mackerel larvae in bongo net collections during SEAMAP Summer Groundfish sampling (1982-2002) in June and July.

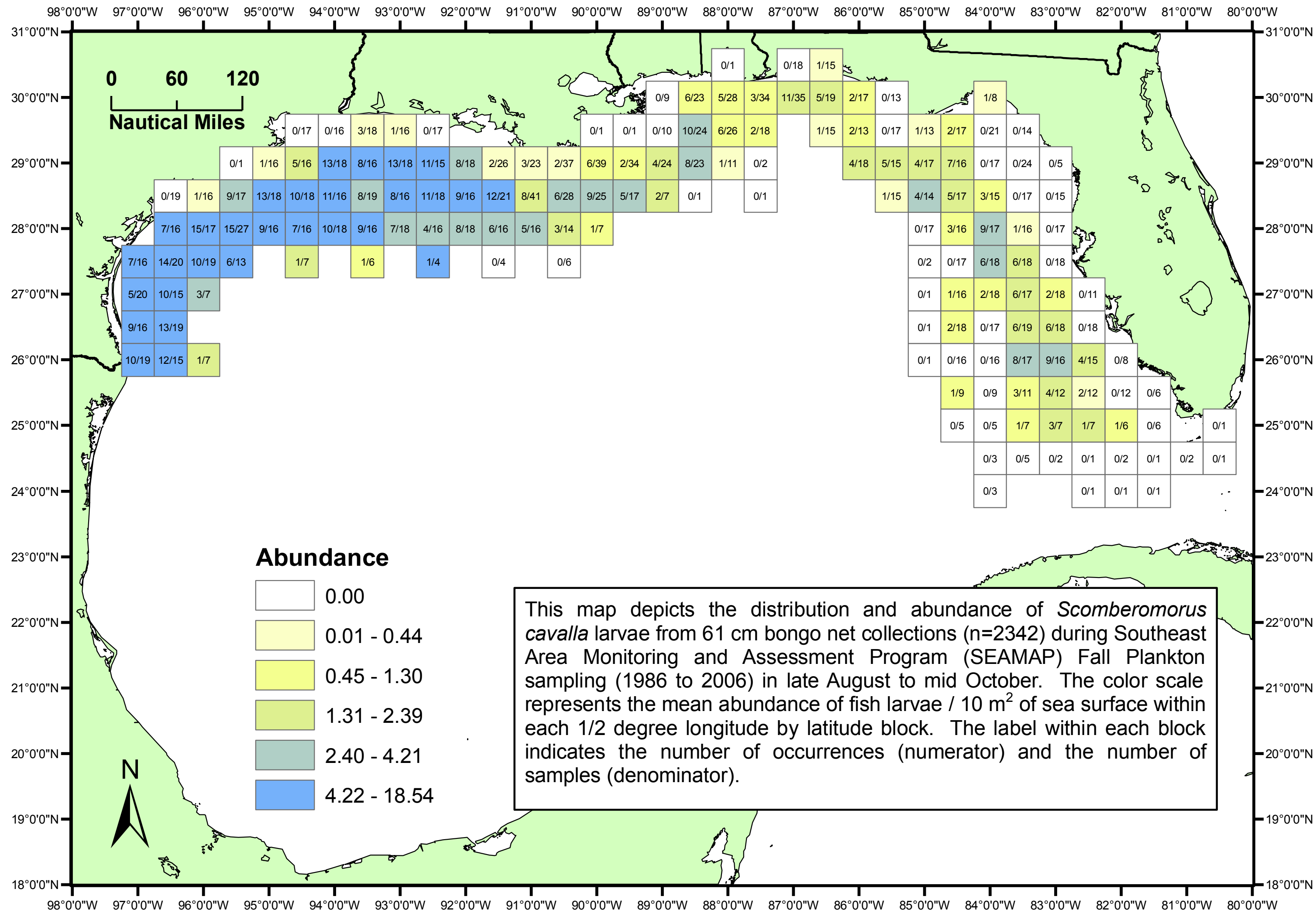

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Figure 16. Distribution and abundance of king mackerel larvae in bongo net collections during SEAMAP Fall Plankton sampling (1986-2006) in late August to mid October.

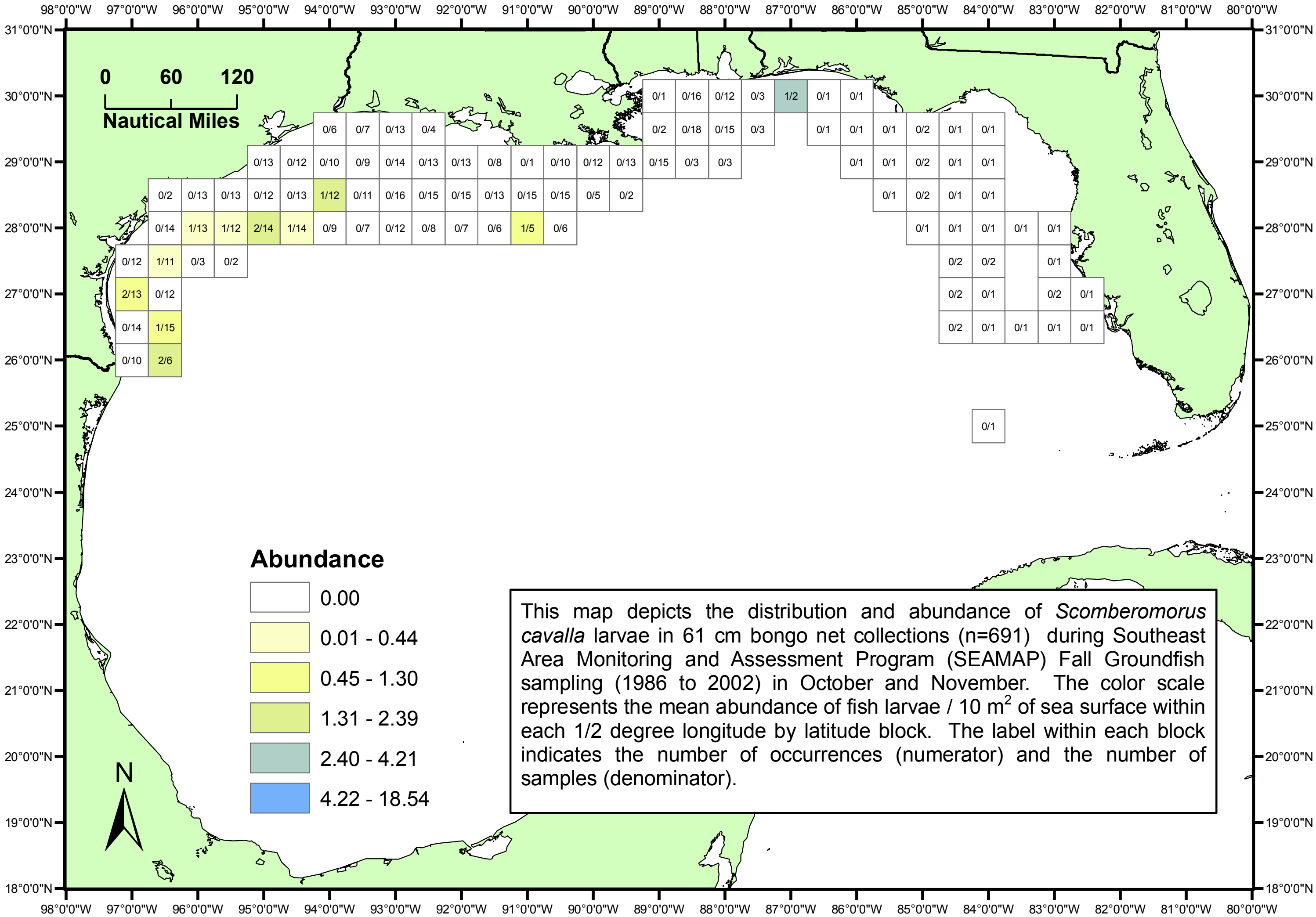

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Figure 17. Distribution and abundance of king mackerel larvae in bongo net collections during SEAMAP Fall Groundfish sampling (1986-2002) in October and November.

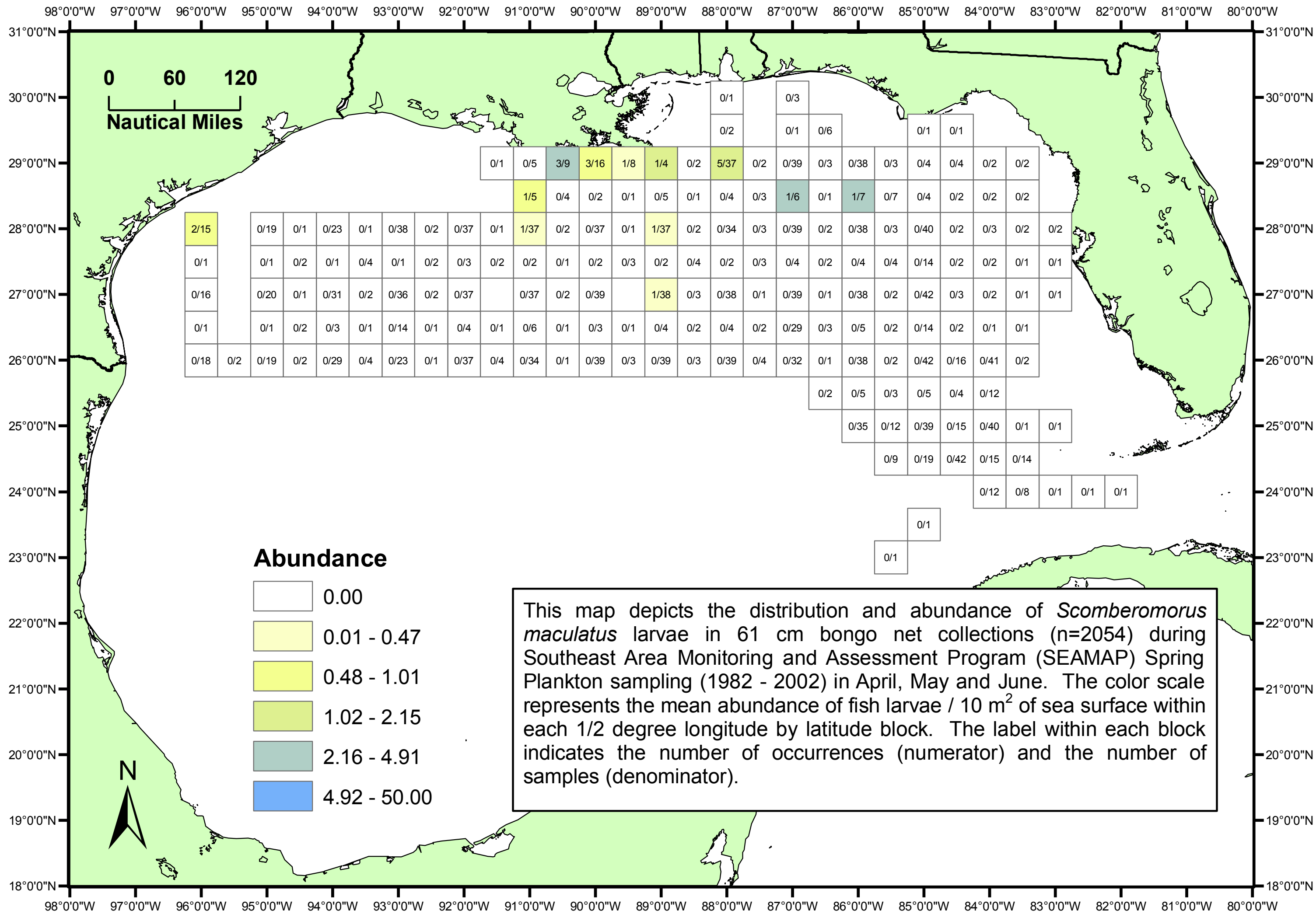

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Figure 18. Distribution and abundance of Spanish mackerel larvae in bongo net collections during SEAMAP Spring Plankton sampling (1982-2002) in April, May, and June.

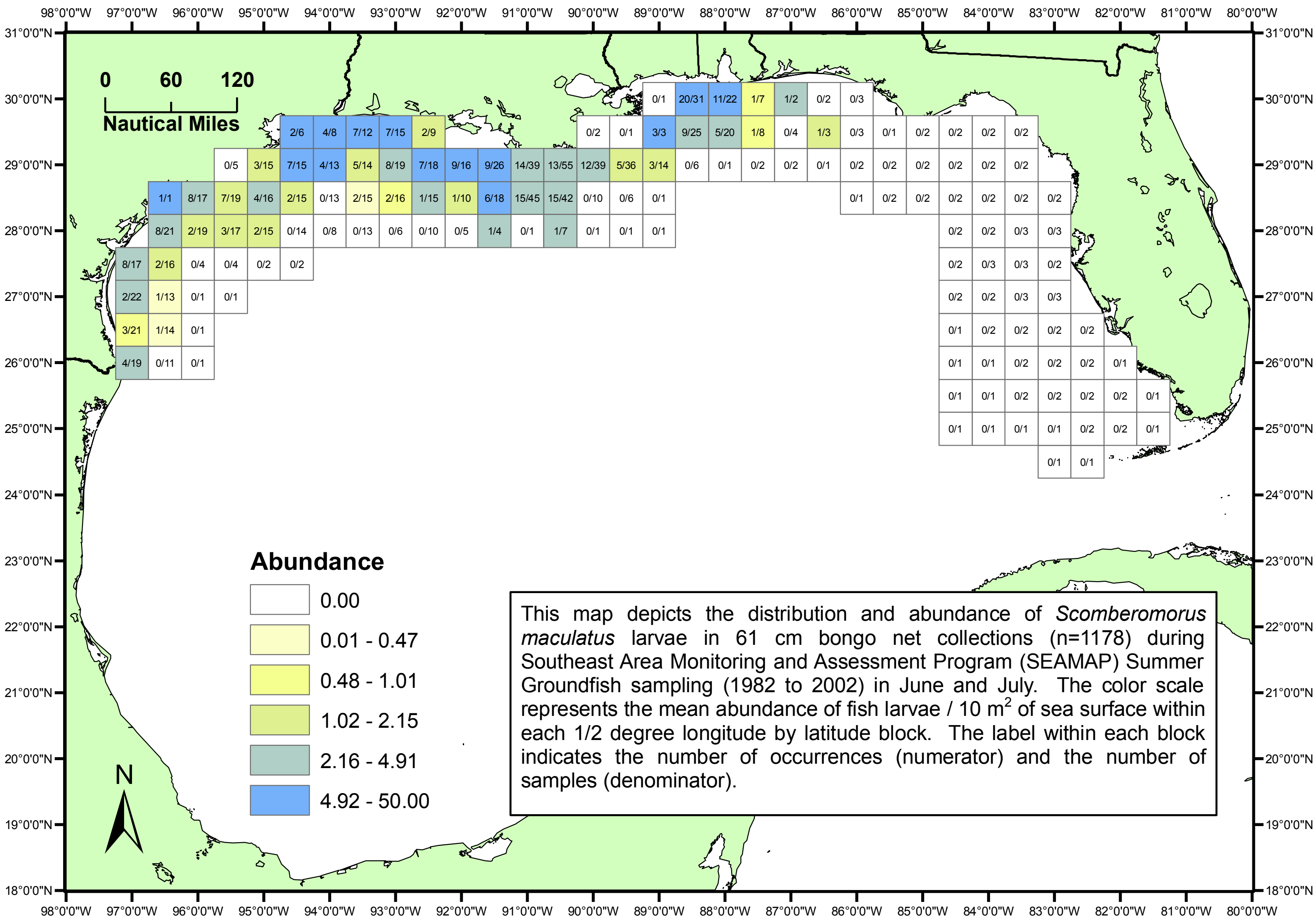

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Figure 19. Distribution and abundance of Spanish mackerel larvae in bongo net collections during SEAMAP Summer Groundfish sampling (1982-2002) in June and July.

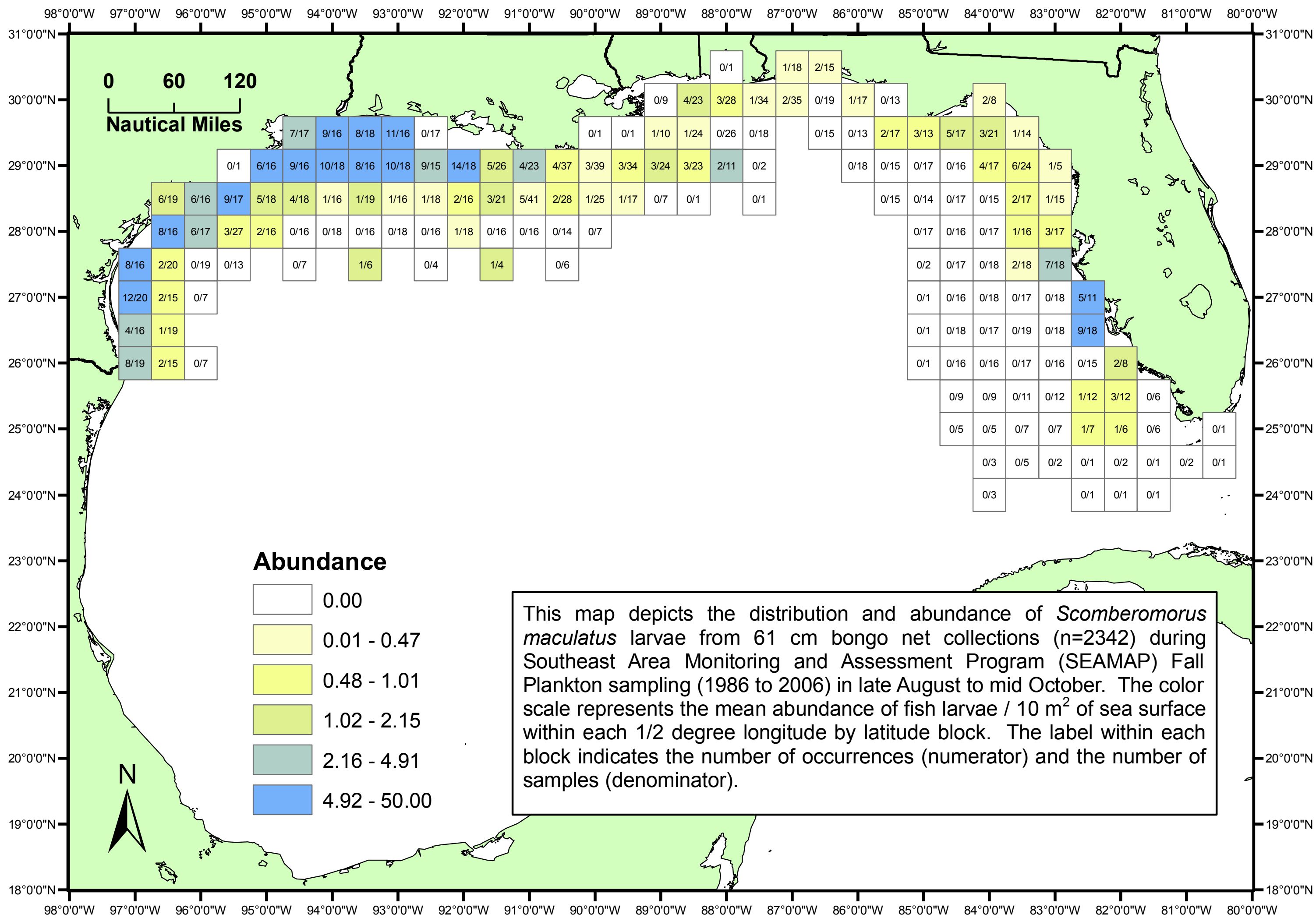

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Figure 20. Distribution and abundance of Spanish mackerel larvae in bongo net collections during SEAMAP Fall Plankton sampling (1986-2006) in late August to mid October.

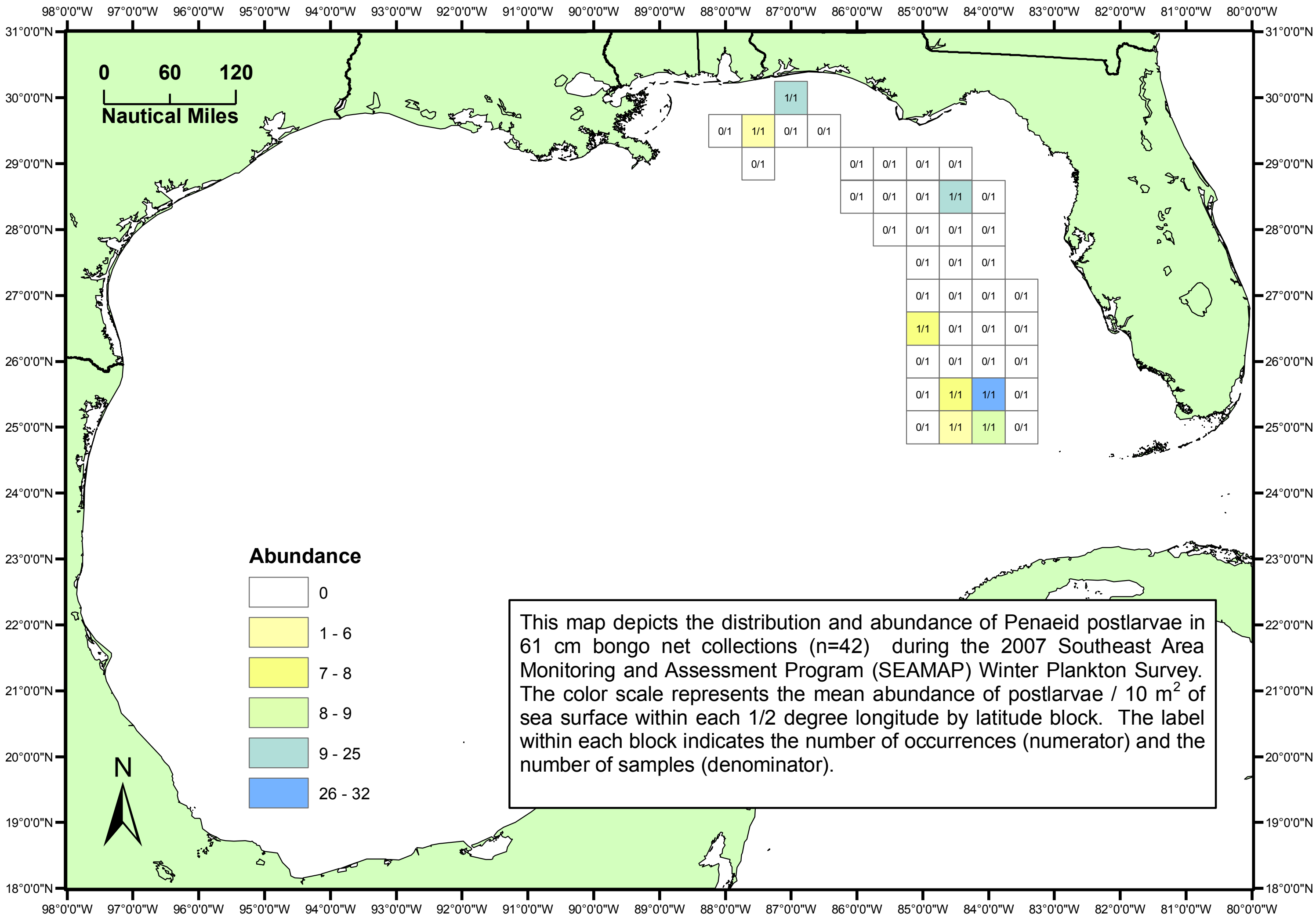

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Figure 21. Distribution and abundance of Penaeid shrimp postlarvae in bongo net collections during the 2007 SEAMAP Winter Plankton Survey.

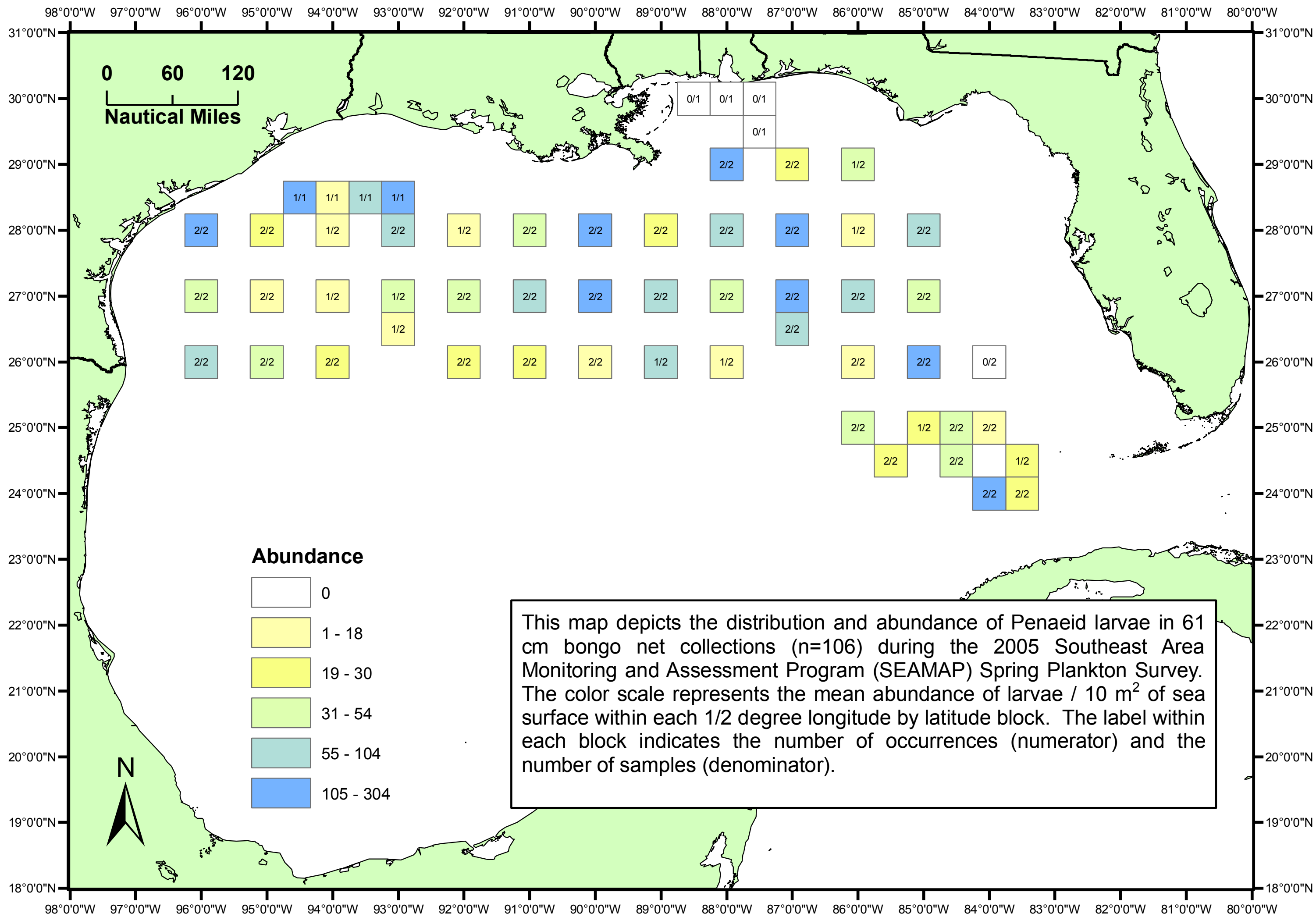

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Figure 22. Distribution and abundance of Penaeid shrimp larvae in bongo net collections during the 2005 SEAMAP Spring Plankton Survey.

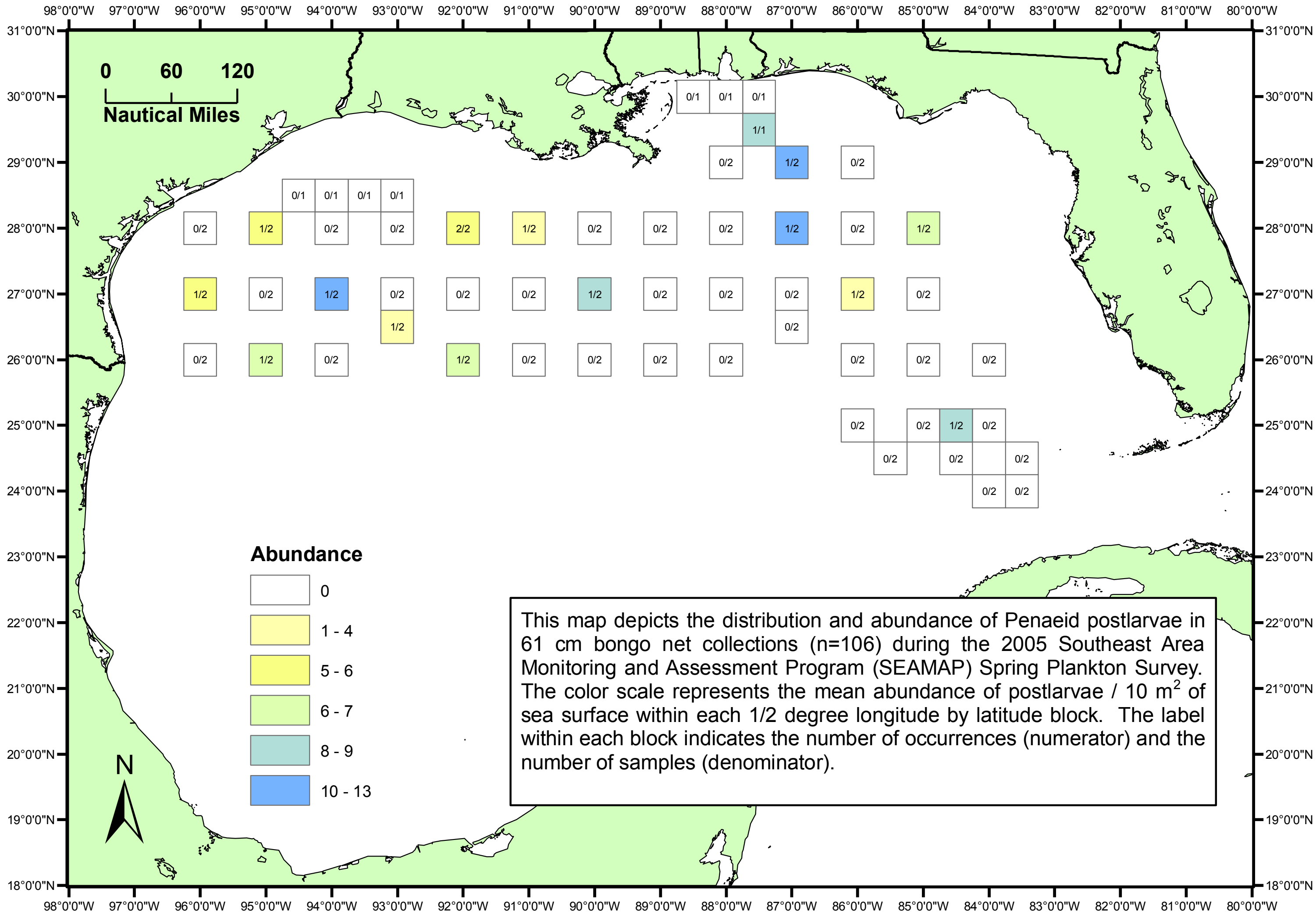

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Figure 23. Distribution and abundance of Penaeid shrimp postlarvae in bongo net collections during the 2005 SEAMAP Spring Plankton Survey.

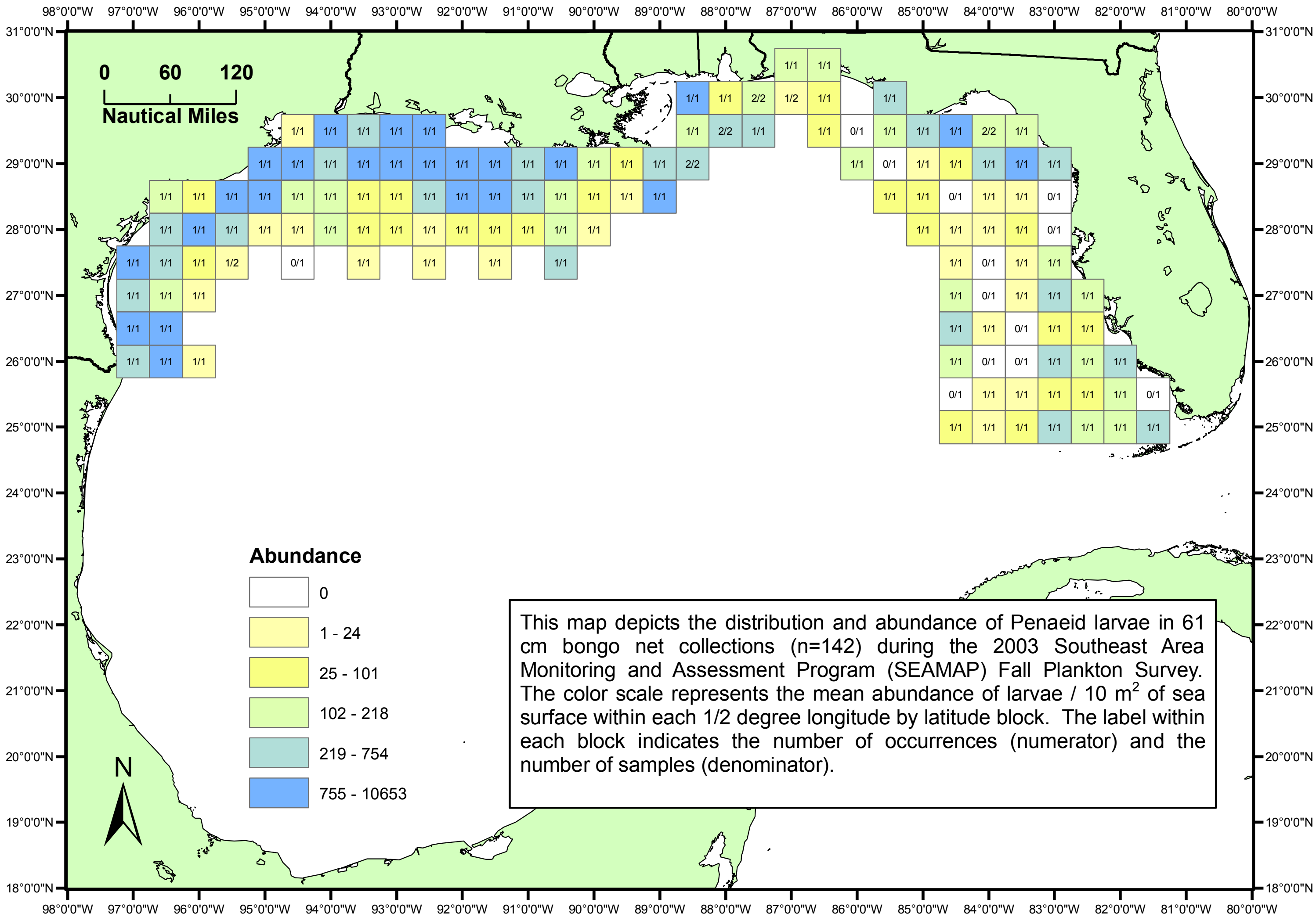

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Figure 24. Distribution and abundance of Penaeid shrimp larvae in bongo net collections during the 2003 SEAMAP Fall Plankton Survey.

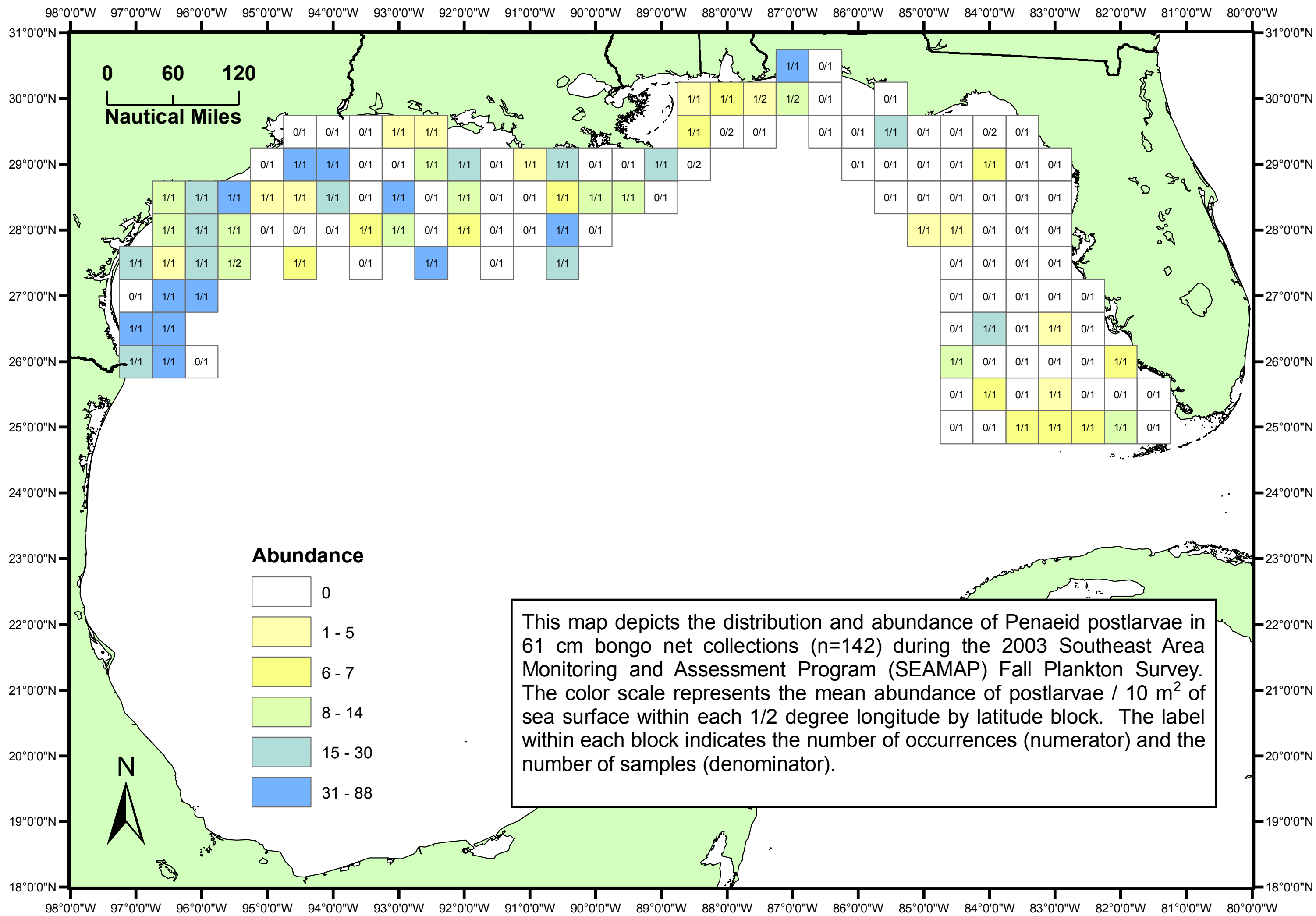

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Figure 25. Distribution and abundance of Penaeid shrimp postlarvae in bongo net collections during the 2003 SEAMAP Fall Plankton Survey.

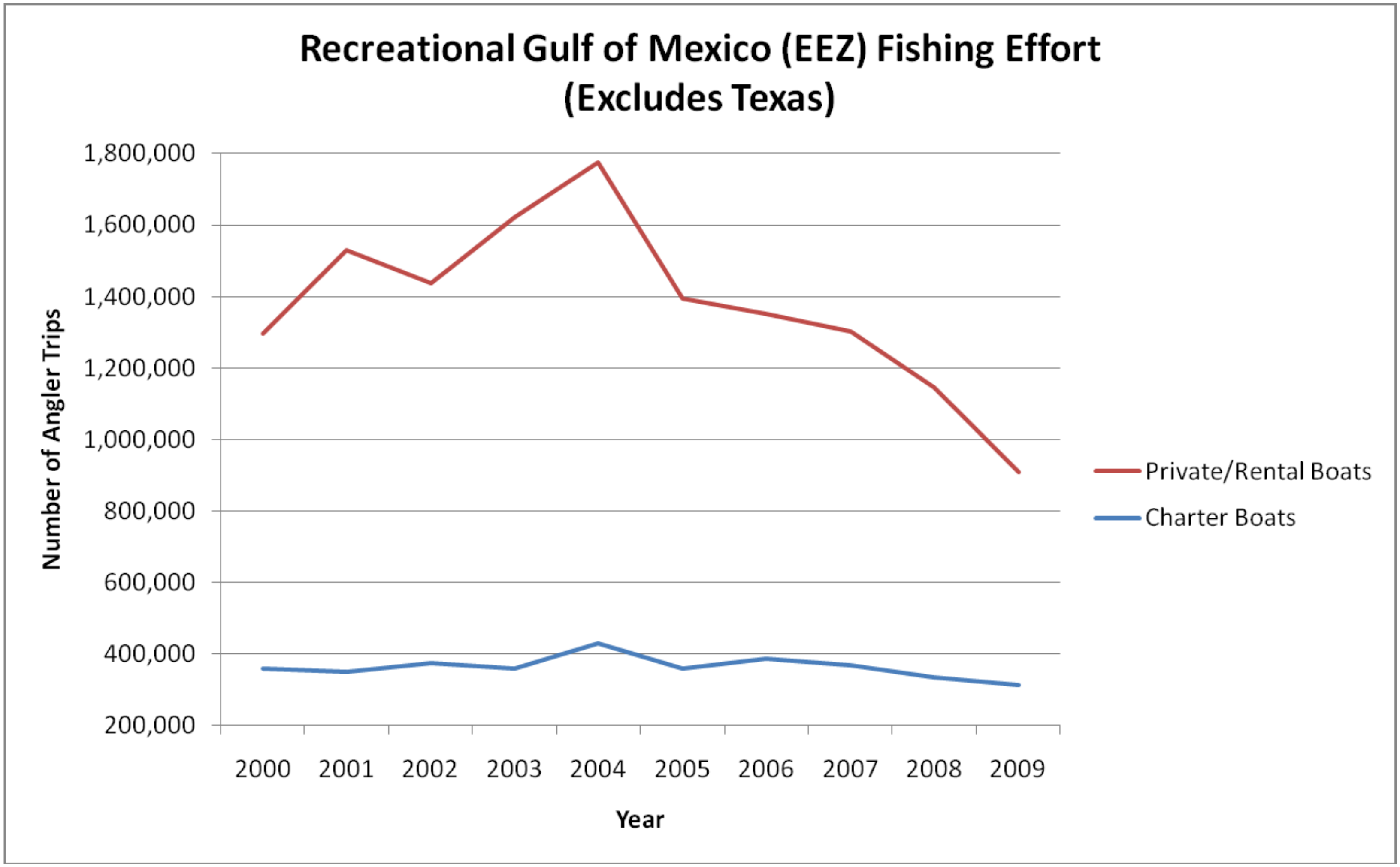

Figure 26. Recreational fishing effort for trips to the EEZ originating in Louisiana, Mississippi, Alabama, and Florida. Data were obtained from the NMFS Office of Science and Technology on their web page at http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html. Effort is measured in the number of angler trips for both private/rental and charter boats.

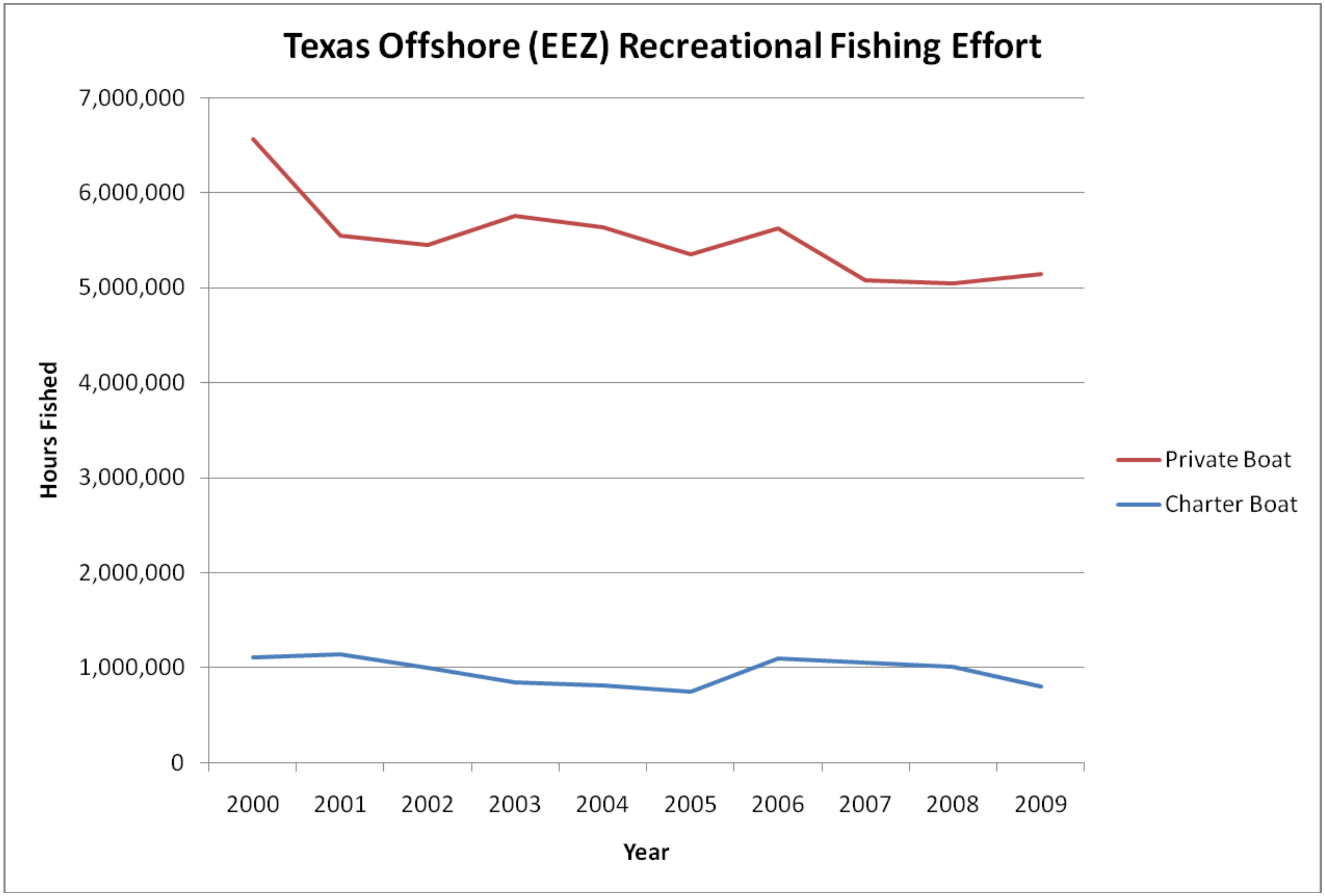

Figure 27. Texas recreational fishing effort for EEZ trips in the Gulf of Mexico. Data were obtained from the Texas Parks and Wildlife Department. Effort is measured in the number of hours fished for charter boats and private boats.

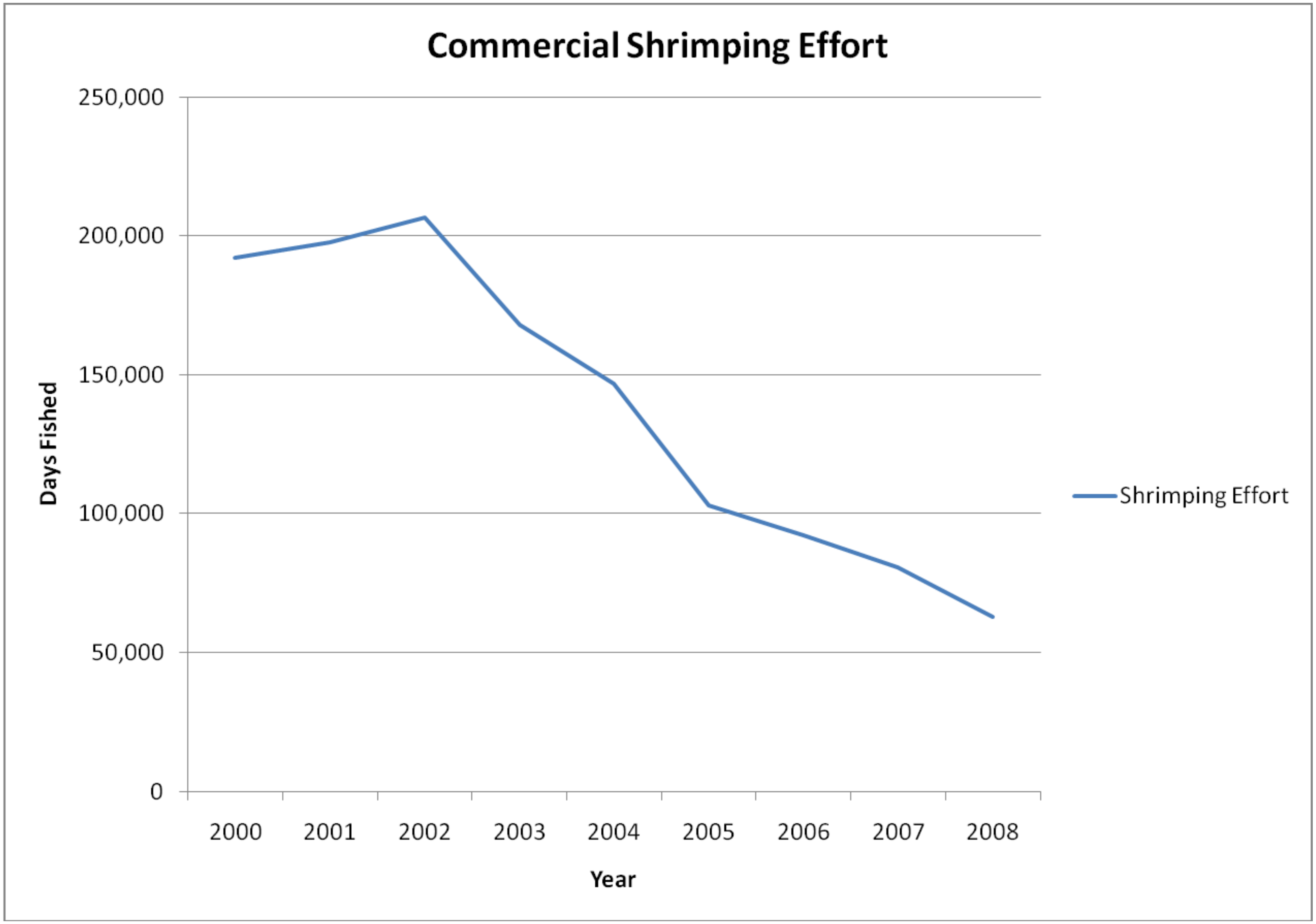

Figure 28. The commercial shrimping effort for the Gulf of Mexico measured in the number of days fished. Data were obtained from the NMFS Southeast Fisheries Science Center Galveston Laboratory.

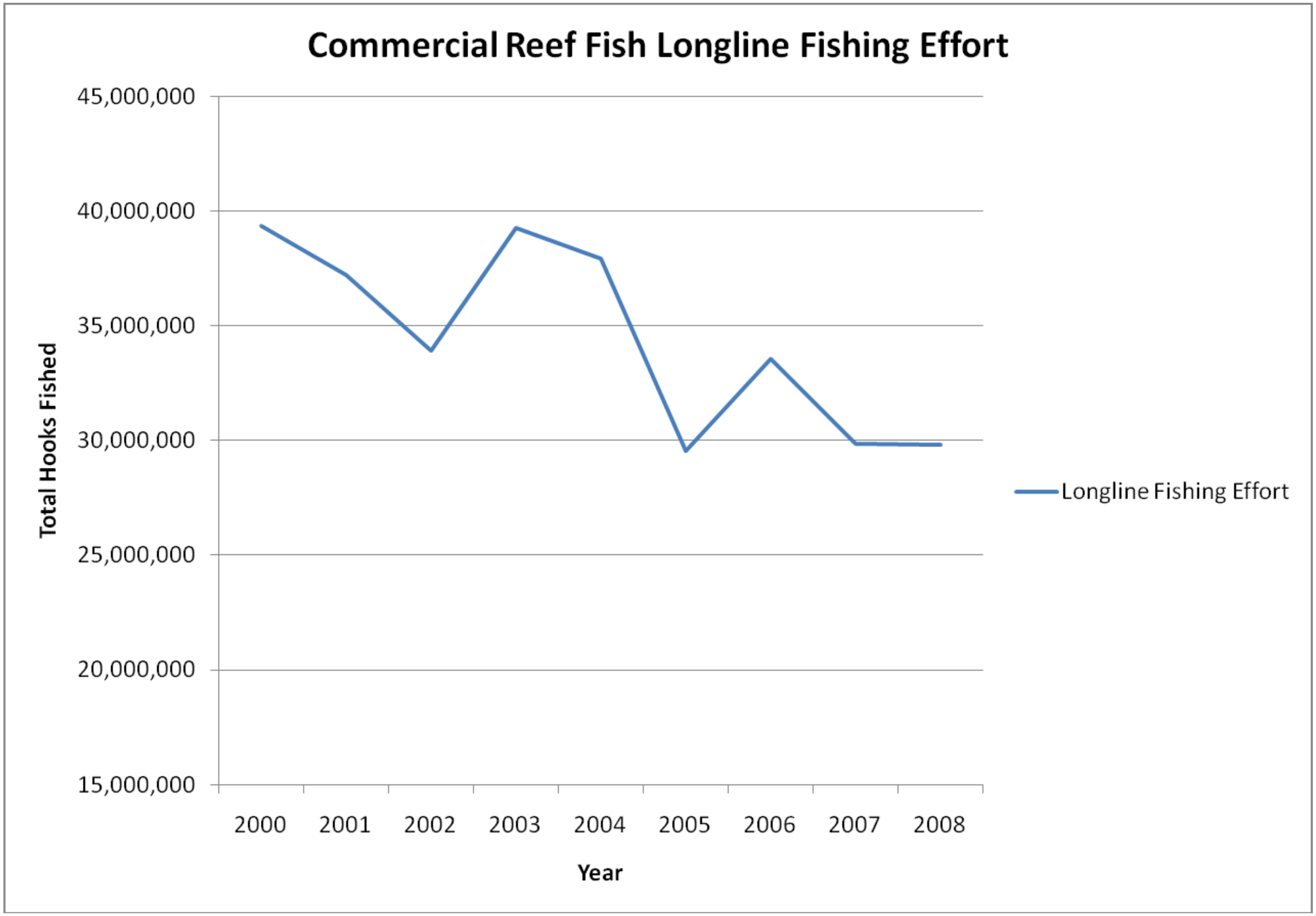

Figure 29. The commercial reef fish longline fishing effort for the Gulf of Mexico measured in the total number of hooks fished. Data were obtained from the NMFS Southeast Fisheries Science Center Miami Laboratory.

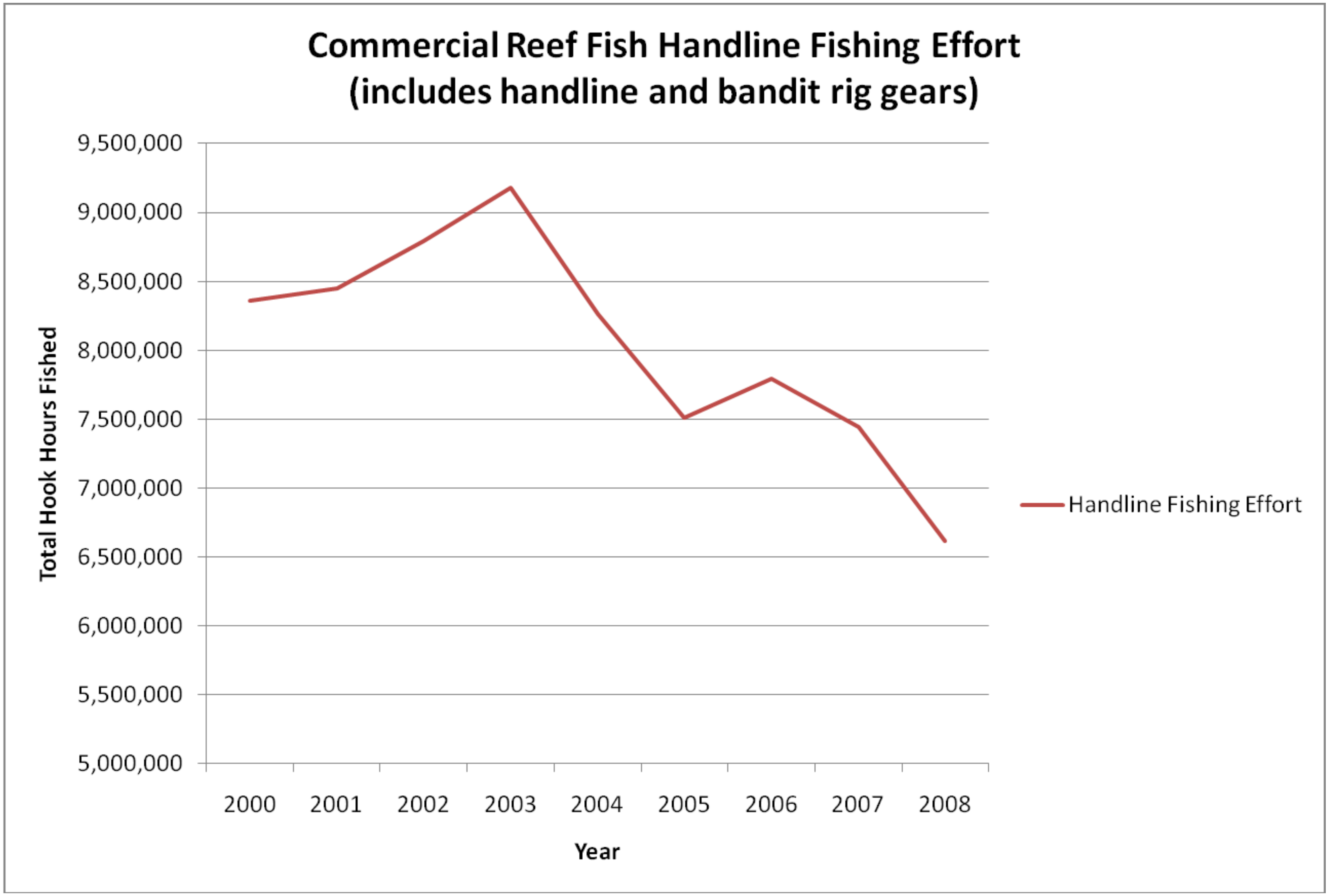

Figure 30. The commercial reef fish handline fishing effort for the Gulf of Mexico measured in the total number of hook hours fished. Data were obtained from the NMFS Southeast Fisheries Science Center Miami Laboratory.

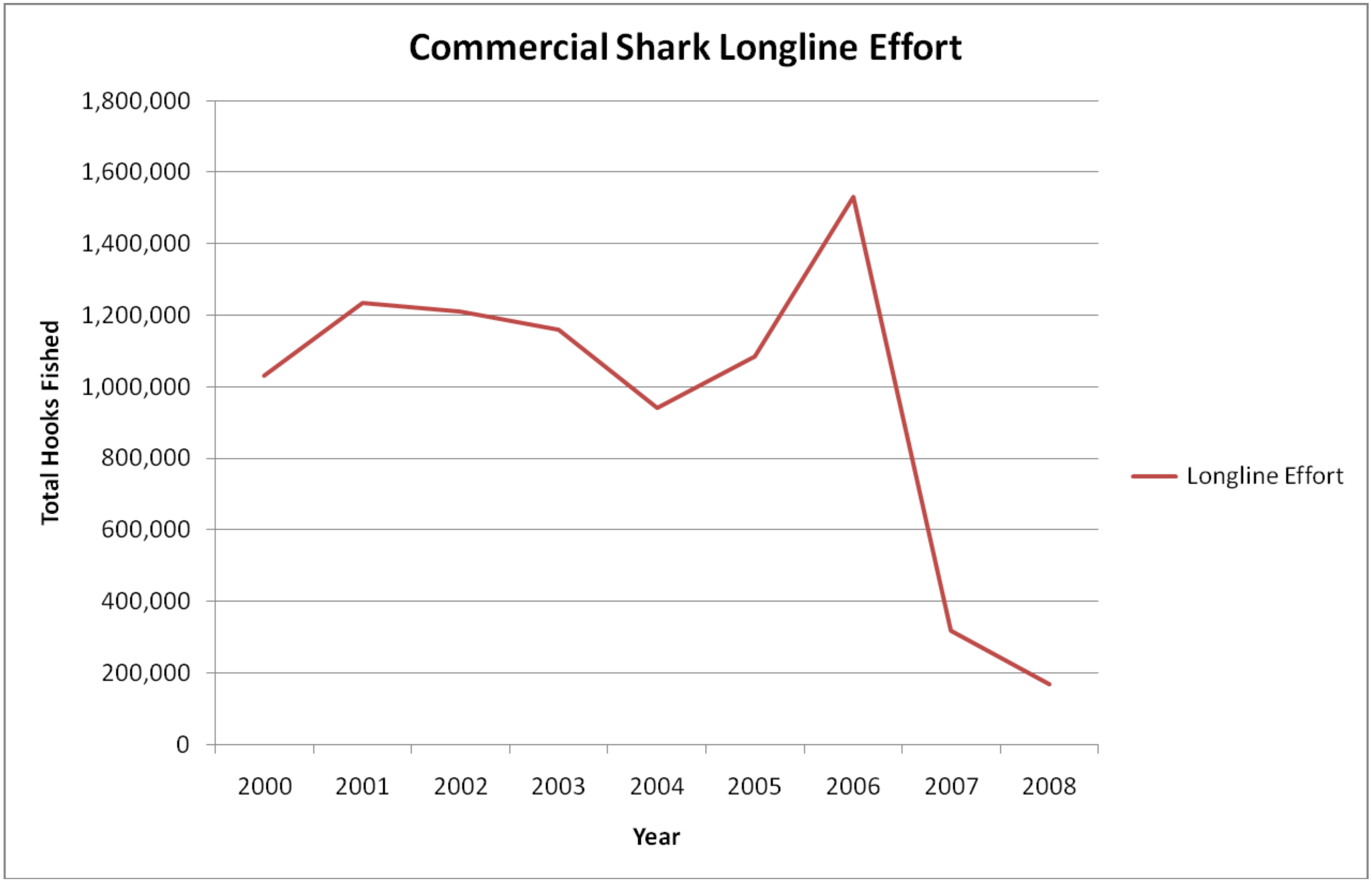

Figure 31. The commercial shark longline effort for the Gulf of Mexico measured in the total number of hooks fished. Data were obtained from the NMFS Southeast Fisheries Science Center Miami Laboratory.

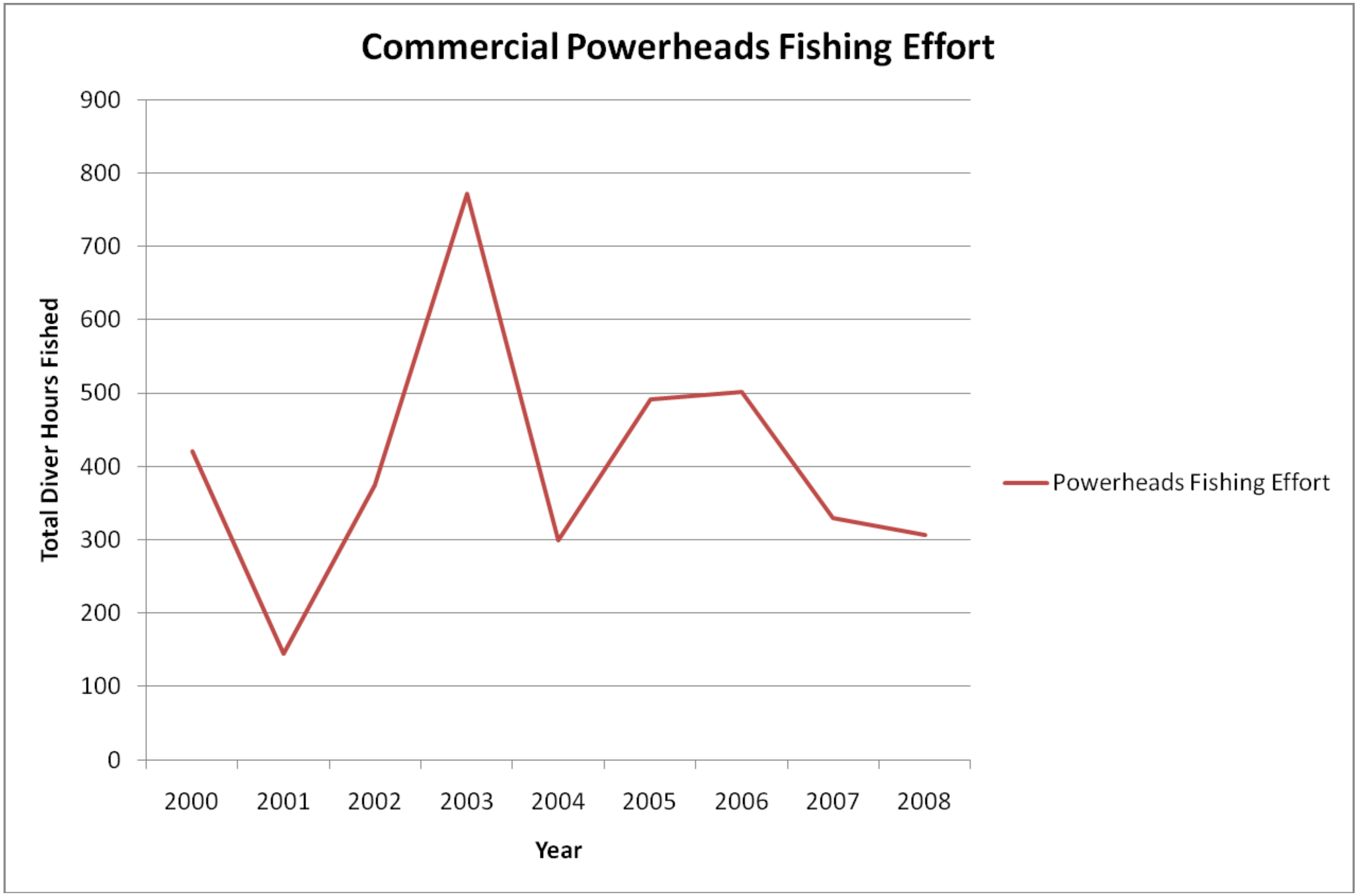

Figure 32. The commercial powerhead fishing effort for the Gulf of Mexico measured in the total number of diver hours fished. Data were obtained from the NMFS Southeast Fisheries Science Center Miami Laboratory.

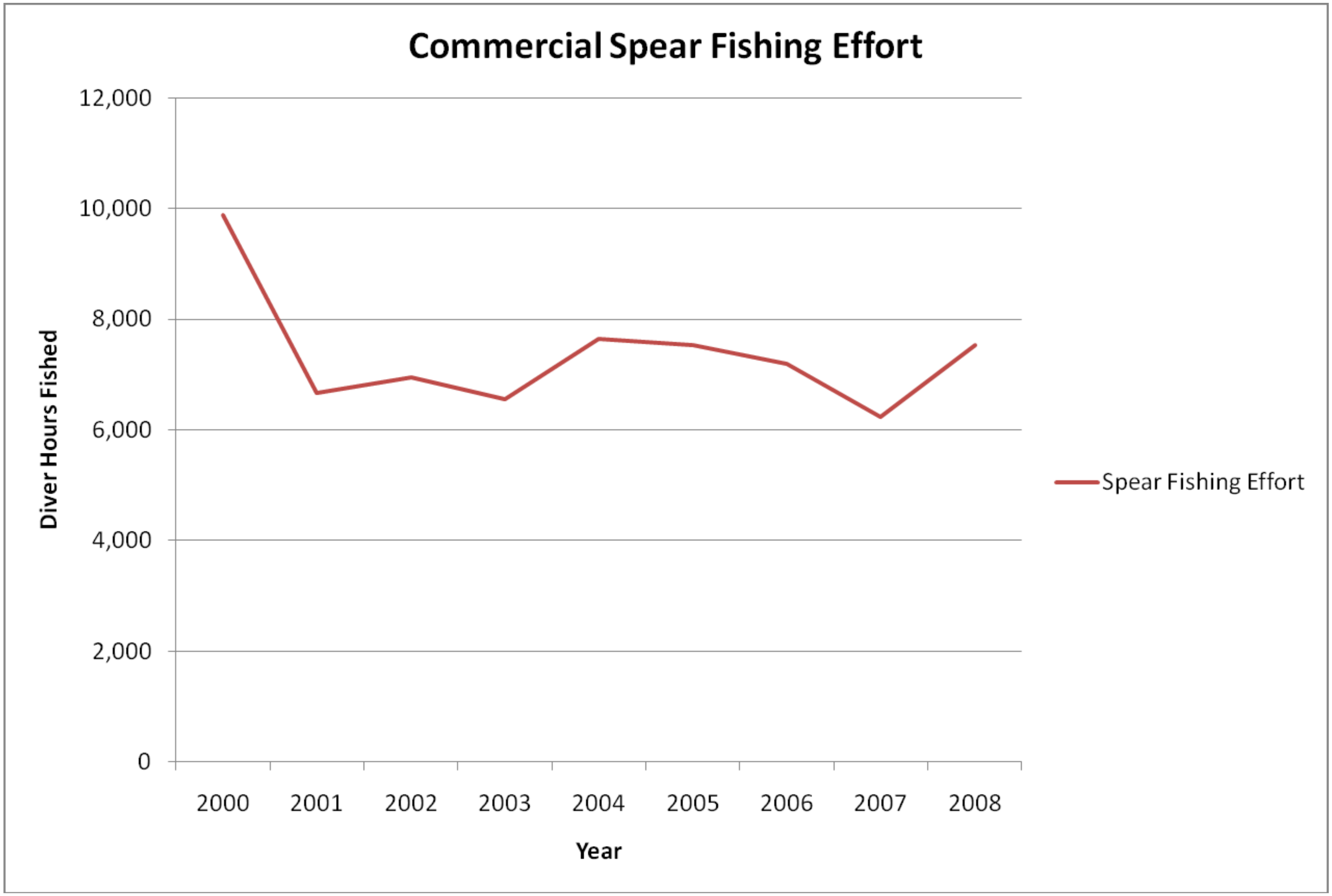

Figure 33. The commercial spear fishing effort for the Gulf of Mexico measured in the number of diver hours fished. Data were obtained from the NMFS Southeast Fisheries Science Center Miami Laboratory.

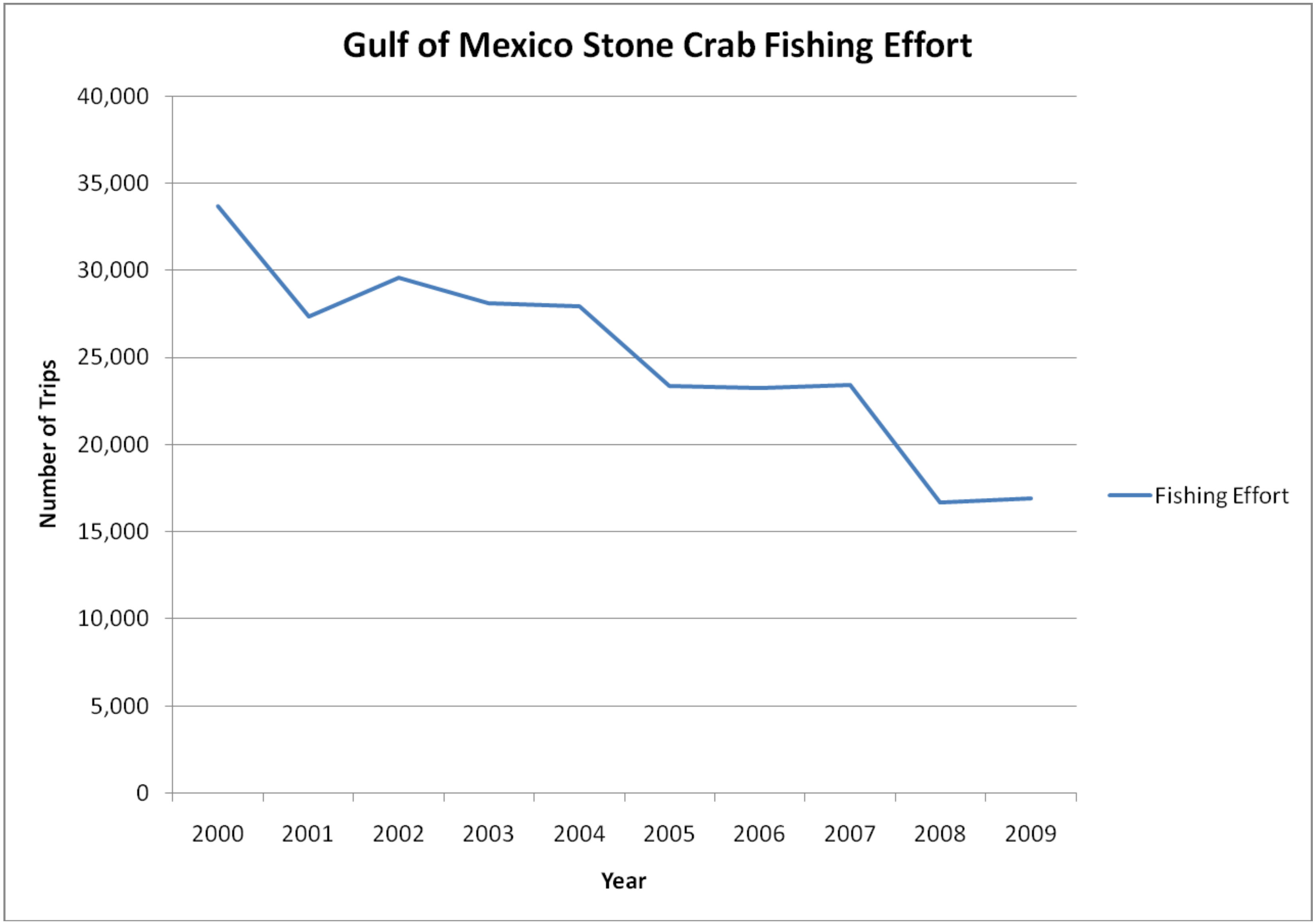

Figure 34. The commercial stone crab fishing effort for the Gulf of Mexico measured in the number of trips per year. Data were obtained from the Atlantic Coastal Cooperative Statistics Program.

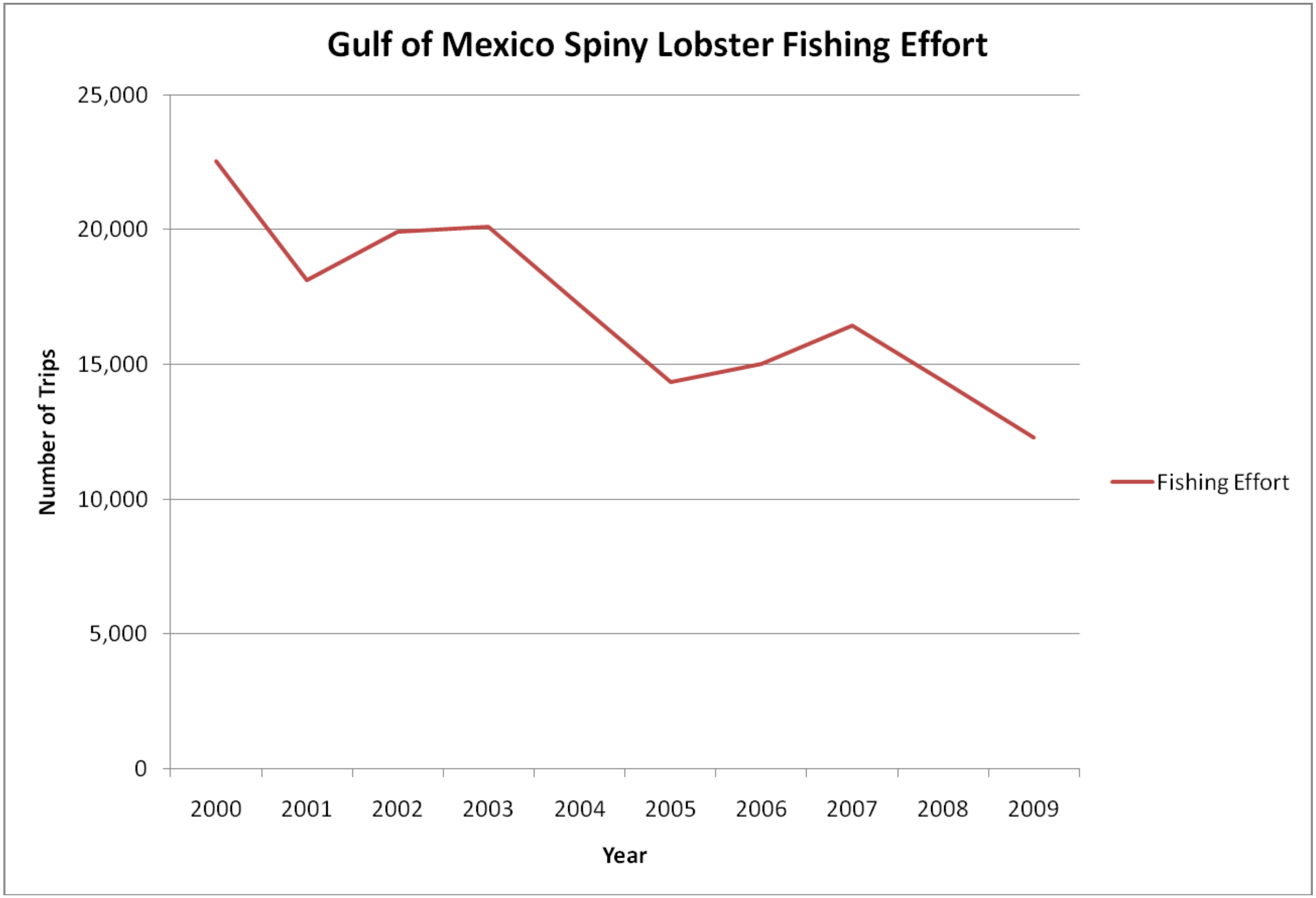

Figure 35. The commercial spiny lobster fishing effort for the Gulf of Mexico measured in the number of trips per year. Data were obtained from the Atlantic Coastal Cooperative Statistics Program.

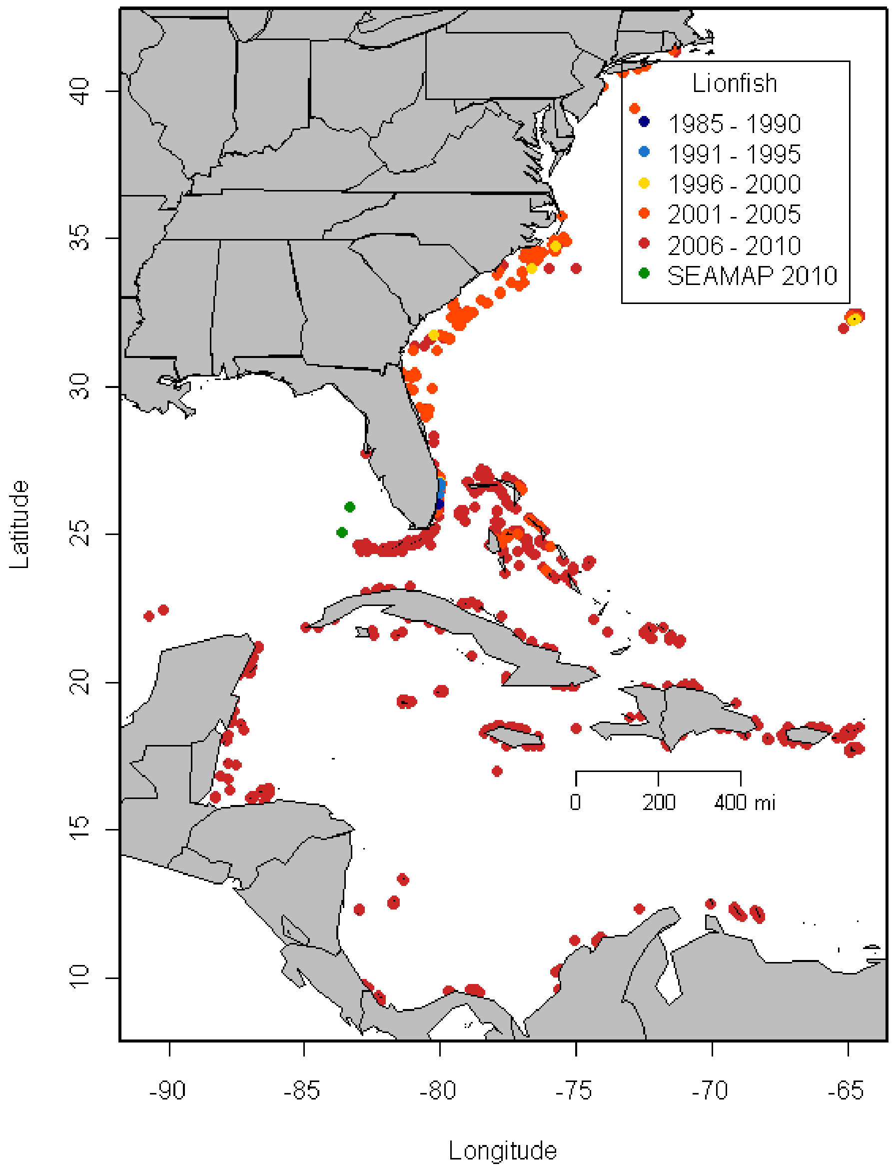

Figure 36. Distribution and time sequence of lionfish sightings throughout the western Atlantic.

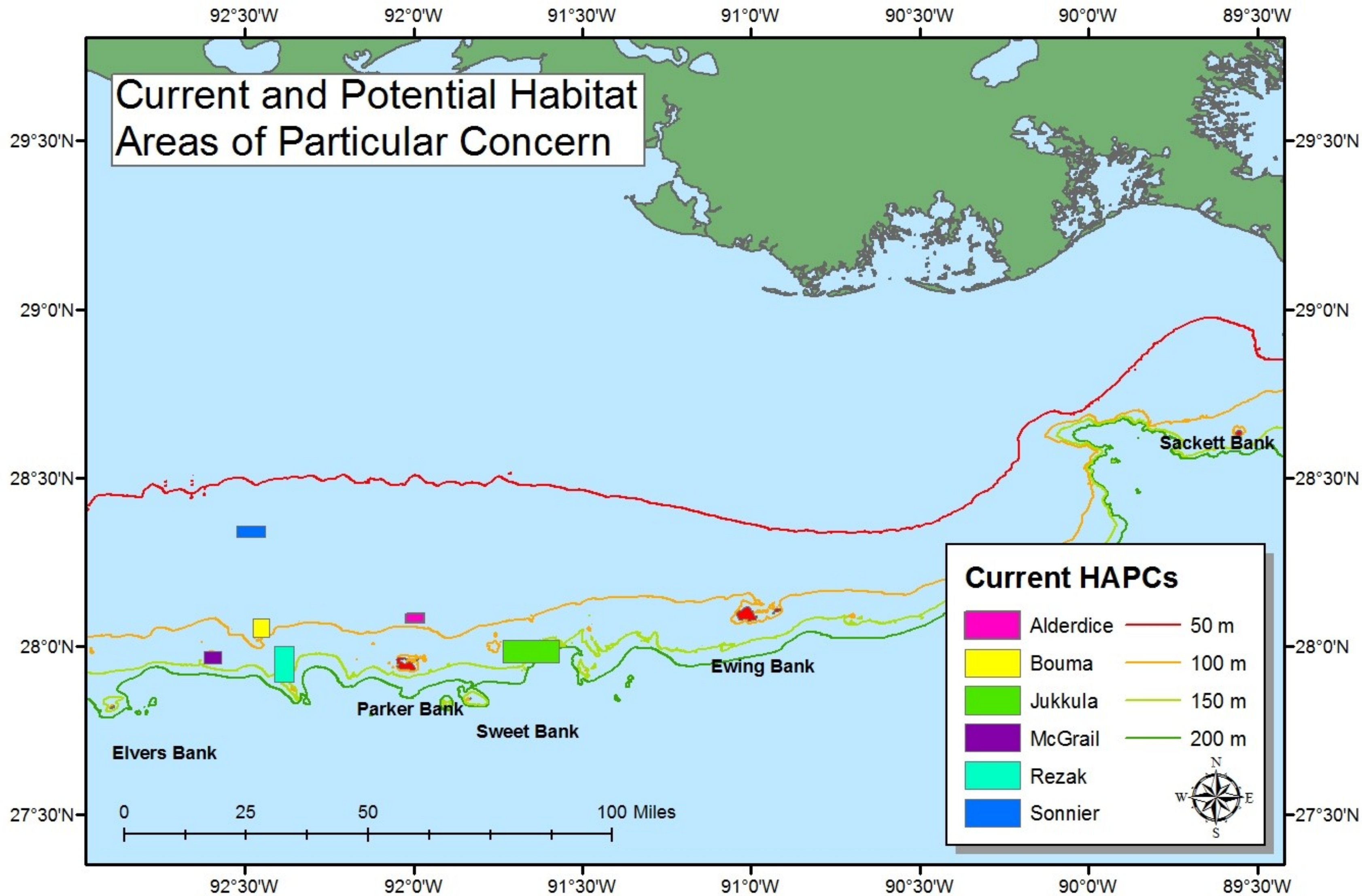

Figure 37. Current and potential HAPCs in the northwest Gulf of Mexico.