Fish fauna of Gray’s Reef National Marine Sanctuary and the implications for place-based management.

Jonathan A. Hare*
Harvey J. Walsh
Katrin E. Marancik
NOAA NOS NCCOS
Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road
Beaufort, North Carolina 28516

* Current address
NOAA NMFS NEFSC
Narragansett Laboratory
28 Tarzwell Drive
Narragansett, RI 02882

E-mail address: jon.hare@noaa.gov

David Score**
NOAA NOS ONMS Gray’s Reef National Marine Sanctuary
10 Ocean Science Circle
Savannah, Georgia 31411

**Current address
NOAA Ship NANCY FOSTER
Marine Operations Center, Atlantic
439 West York Street
Norfolk, Virginia 23510-1145

George R. Sedberry
SCDNR Marine Resources Research Institute
P. O. Box 12559 (217 Ft. Johnson Rd.)
Charleston, South Carolina 29422-2559

Richard O. Parker Jr.
NOAA NMFS SEFSC
Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road
Beaufort, North Carolina 28516

Roger W. Mays
NOAA NOS NCCOS
Center for Coastal Fisheries and Habitat Research
101 Pivers Island Road
Beaufort, North Carolina 28516

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Abstract - Marine Protected Areas (MPAs) are becoming an important tool both for
single-species and ecosystem-based management, and an important initial step in MPA
design is identification of the species that reside in specific areas or that use
representative habitats within specific ecosystems. The southeastern U.S. continental
shelf ecosystem encompasses a variety of habitats, yet most discussions of MPAs in the
region have revolved around the need to protect rocky-reef habitat, which supports
important commercial and recreational fisheries. Gray’s Reef National Marine Sanctuary
could serve a role in a larger network of marine reserves, or could serve as a
representative site for documenting the ecology of species associated with inner-shelf
rocky reefs; this latter information then could be used in design criteria for selecting other
rocky-reef sites to serve as marine reserves. The purpose of this study was to develop a
more complete view of the fish species that inhabit Gray’s Reef NMS. Data on larval,
juvenile, and adult life stages was combined from previous studies to provide as complete
a view as possible of the ichthyofauna of Gray’s Reef NMS. One-hundred eighty one
species of fish were found in the vicinity of the Sanctuary; 27 species were classified as
common, and 46 species are currently managed for fishery purposes. Classification of
species as either resident or transient revealed that resident species accounted for 37% of
the total. The fish species collected in the Sanctuary used a diverse array of habitats over
a wide range of bathymetric zones. As adults, fishes were reported from unconsolidated
sediments, reefs, submerged vegetation, pelagic, and pelagic vegetation habitats from
estuaries to the outer shelf. From the perspective of the ichthyofauna, species that inhabit
the Sanctuary use a wide-range of habitats, spread over a large portion of the shelf, and
include areas to the north and south of the Sanctuary. Research to quantitatively
understand the inter-dependencies among species and habitats is clearly needed, yet from the qualitative data presented here, Gray’s Reef NMS cannot be managed successfully in isolation, underscoring the broader importance of managing fish and habitat on the southeast U.S. continental shelf using ecosystem-wide approaches to achieve multiple management goals.
Introduction

Marine Protected Areas (MPAs)\(^1\) are becoming an important tool both for single-species and ecosystem-based management (Lubchenco et al., 2003). One subset of MPAs are marine reserves, defined as areas in which some or all of the biological resources are protected from removal or disturbance (NRC, 2001; Lubchenco et al., 2003). Marine reserves are typically implemented to protect or rebuild specific marine resources (e.g., species, representative habitats, representative parts of ecosystems). A number of design criteria have been proposed for marine reserves and other types of MPAs, and an important element of these criteria is knowledge of the distribution, abundance, and dynamics of species within the ecosystem (Hockey and Branch, 1997; Leslie et al., 2003; Roberts et al., 2003a, b). Further, implementation and management of MPAs requires ecological information about constituent species, in particular the dependence of resources within an MPA to outside areas and outside resources, and the movement of resources from inside to outside of the MPA (Polacheck, 1990; NRC, 2001). Thus, an important initial step in MPA and marine reserve design and implementation is identification of the species that reside in specific areas or that use representative habitats within specific ecosystems (see Roberts et al., 2003a, b).

The southeastern U.S. continental shelf ecosystem is comprised of a variety of habitats, yet most discussions of MPAs have revolved around the need to protect rocky-reef habitat, which supports important commercial and recreational fisheries. Rocky reefs are interspersed among unconsolidated sediments along the southeast U.S. continental shelf and upper slope from the east coast of Florida to Cape Hatteras, North Carolina.

\(^1\) Marine Protected Areas are defined as “… any area of the marine environment that has been reserved by Federal, State, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein”. (FR, 2000).
Approximately 30% of the bottom is estimated to be rocky-reef habitat with the remaining bottom covered by unconsolidated sediments (Parker et al., 1983; SEAMAP-SA, 2001). In addition to exposed rock, there are areas where large sessile invertebrates such as sponges and corals attach to the rock, and there are many areas where these sessile invertebrates protrude through a thin veneer of unconsolidated sediment, which covers underlying rock (Wenner et al., 1983). Rocky reefs and sandy areas with associated attached invertebrates will be termed rocky-reef habitat. Rocky-reef habitat supports a distinct assemblage of fishes, which include a number of commercially and recreationally important species (Wenner et al., 1983; Sedberry and Van Dolah, 1984; Parker and Ross, 1986; Parker et al., 1994). For example, many of the 73 species in the South Atlantic Fishery Management Council’s (SAFMC) snapper-grouper management unit are associated with rocky-reef habitat (SAFMC, 1998). Some of these fishery species are overfished (17.8%; NMFS, 2003), whereas others are not (13.7%, NMFS, 2003), but the status of the majority of species within the management unit is unknown (68.5%, NMFS, 2003). The SAFMC is considering MPAs, specifically marine reserves that would prohibit bottom fishing, as fisheries management tools to assist in the rebuilding of overfished stocks and to contribute to a strategy of ecosystem management (SAFMC, 1990; 2001).

Along the southeast U.S. coast there are several large coastal MPAs, including National Estuarine Research Reserves and National Marine Sanctuaries (Fig. 1). Gray’s Reef National Marine Sanctuary (Gray’s Reef NMS) is one of the few MPAs that encompasses continental shelf areas along the southeast coast of the United States. The Sanctuary is 58 km² and is located approximately 30 km east of Sapelo Island, Georgia
Designated in 1981 (FR, 1981), the Sanctuary is representative of inner-shelf rocky reefs of the southeast U.S. shelf (Sedberry and Van Dolah, 1984; Parker et al., 1994), although it has more vertical relief than most other inshore rocky-reefs (> 1 m, Parker et al., 1994). The objectives of the Sanctuary are to provide protection and comprehensive management for the rocky-reef habitat and associated biological communities (FR, 1981). Gray’s Reef NMS was not established as a fisheries management tool (i.e., a marine reserve), and regulations generally conform to fishing restrictions imposed by the SAFMC, which has jurisdiction in federal waters of the region. In addition to following SAFMC regulations, Gray’s Reef NMS prohibits wire fish traps, bottom trawling, longlines and spears equipped with explosive projectiles (powerheads). Commercial fishing gear such as vertical hook and line (the dominant gear in the reef fish fishery in the region) is allowed, as is all recreational fishing gear. It is unlikely that Gray’s Reef NMS will become a marine reserve (i.e., a no-take zone). However, Gray’s Reef NMS could serve a role in a larger network of marine reserves, or could serve as a representative site for documenting the ecology of species associated with inner-shelf rocky reefs. This latter information then could be used in design criteria for selecting other rocky-reef sites on the southeast U.S. shelf to serve as marine reserves. An important step in understanding the role of Gray’s Reef NMS in the larger context of marine reserves on the southeast U.S. shelf is determining the species that occur in the Sanctuary. Adult and large juvenile fishes have been enumerated with trawl collections, trap collections, and diver-conducted video surveys (Sedberry and Van Dolah, 1984; Parker et al., 1994; Sedberry et al., 1998), but these studies emphasized the rocky-reef habitat in the Sanctuary. Although adult fishes have been described in
unconsolidated sediments (Parker et al., 1994), there is little information regarding the entire assemblage of species that occur on unconsolidated habitats within the Sanctuary, even though these areas make up approximately 70% of bottom habitat (Matt Kendall, NOAA NOS NCCOS Center for Coastal Monitoring and Assessment, pers. comm.). Further, previous studies have examined adult and large juvenile fishes in the Sanctuary, but there is only limited information regarding the occurrence of larval and juvenile stages.

The purpose of this study was to develop a more complete view of the fish species that inhabit Gray’s Reef NMS. We combined additional adult census data with previously published data. We also included larval and juvenile fish data collected around the perimeter of the Sanctuary. The various datasets describe a much more diverse fish fauna, and the view emerges that Gray’s Reef NMS is much more than an area protecting rocky-reef habitat and reef fishes. Further, there is evidence for substantial interaction between species that use rocky-reef habitat in the Sanctuary and species that use a number of other habitats in the coastal ocean indicating that management efforts should focus on the entire ecosystem rather than specific habitats.

**Materials and methods**

Data for fishes in Gray’s Reef NMS were derived for three life stages from six sources. Large juvenile/adult data were derived from trawl collections, fish trap collections, diver video transects, and stationary diver point counts. Juvenile data were derived from beam trawl collections. Larval data were derived from ichthyoplankton collections. The specific methods associated with each data source are provided below; the sampling time,
effort, and gears used are detailed in Table 1. Only bony fishes (Osteichthyes) will be considered here, because most of the gears reviewed did not collect sharks and rays (Chondrichthyes).

**Adult and large juvenile censuses**

**Bottom Trawls.** Trawling was conducted in the area of Gray’s Reef NMS before designation as a NMS. Briefly, a 40/54 high rise trawl was used, which is effective in sampling fishes on rough bottom (Sedberry and Van Dolah, 1984). Trawl samples were standardized by towing the net for an approximate distance of 1 km. Adult and large juvenile fish were collected, sorted to species and counted. Data were collected in 1980 and 1981 and stratified by season: winter (January-March, 1980; March 1981), spring (April, 1981), summer (August-September, 1980; July 1981), and fall (October, 1981). Seasonal abundance was calculated as total number of individuals collected in a season divided by number of trawls made in a season (see Sedberry and Van Dolah, 1984).

**Traps.** Chevron-shaped wire fish traps were baited with cut clupeids and deployed at randomly selected reef stations within Gray’s Reef NMS for approximately 90 min. Trap deployments were made during summer (July) from 1993-2002. Upon retrieval of the trap, adult and large juvenile fish were sorted to species and counted. Abundance was calculated as total number of individuals caught divided by the number of trap sets (see Sedberry et al., 1998).
Video Transects. Divers swam 15-min transects at randomly selected sites in five habitats within Gray's Reef NMS. One diver swam with a video camera in a rigid forward position approximately 1 m above the bottom. Transect distance was measured using a towed surface buoy. Videotaped transects were viewed to estimate the abundance of each fish species on a given transect. Video surveys were conducted in the spring (May), summer (August), and fall (November), but data were pooled across season and stratified by habitat. Abundance was calculated as total number of fish counted divided by total transect distance in a given habitat (see Parker et al., 1994).

Point Counts. In 1995, a permanent study site was established on a randomly chosen rocky-reef ledge within the Sanctuary, and 22 stations at this site were randomly selected. At each station, a stainless steel rod (1 cm x 100 cm) was cemented into holes drilled into the reef substrate. Following the random selection of fixed stations, a modified version of the stationary sampling method was used to enumerate fishes (Bohnsack and Bannerot, 1986) with a cylinder width of 4 m radius. Point counts were made over eight years in three seasons: spring (April), summer (June, July, and August), and fall (October and November). Data were stratified by season; abundance was calculated as number of fish counted divided by number of point counts made in a given season.

Juvenile and larval census

Juvenile and larval fish sampling was conducted approximately every other month from April 2000 through February 2002. Ten stations were located approximately 18.5 km apart along a 93-km cross-shelf transect spanning the Georgia shelf. The sampling
transect bisected Gray’s Reef NMS and four stations were sampled just outside the
perimeter of the Sanctuary. All four seasons were sampled: winter (January, February,
and March), spring (April and May), summer (June and August), and fall (October). Only
the species abundance data by seasons from the stations around Gray’s Reef NMS were
considered here. The full cross-shelf juvenile fish dataset was analyzed by Walsh et al.
(in review) and the full cross-shelf larval fish data set was analyzed by Marancik et al.
(2005).

Beam Trawl. At each station, juvenile fish collections were made with a 2-m beam trawl
with 6-mm mesh body and a 3-mm mesh tail bag. Three replicate, 5-min tows were made
at each station. Juvenile fish abundance was calculated as fish per 5 min tow and the
three replicates were averaged to represent abundance at each station. Adults were
removed from the analyses of beam trawl collections using the estimated size of first
maturity as a minimum size threshold for inclusion in data analysis (see Walsh et al., in
review).

Bongo. Larval fish collections were made with a 61-cm paired bongo frame with either
333 or 505 µm mesh nets. The net was fished double obliquely and deployed to within 1
m of the bottom. On one sampling cruise, a 1-m ichthyoplankton sled with 333-µm mesh
was used. Larval fish collected with the 1-m sled and 61-cm bongo were similar and data
from both gears were used (Marancik, 2003). Larval concentration was calculated as fish
100 m⁻³.
Data compilation and analysis

Percent abundance was calculated for each taxon from the sum of all abundances-per-unit-effort within a season, or in the case of the video transect data, within a habitat. Species were ranked by relative abundance and cumulative percent abundance was calculated. Common species observed during each census were defined as species making up greater than 5% of the total abundance. Typically, fewer than five species per census and season were classified as common.

Data from the different census techniques were combined to derive an overall species list for Gray’s Reef NMS. The species list was then used to derive a list of managed species that occur within the vicinity of the Sanctuary. Data from the larval and juvenile censuses were also used to determine which species are spawning (the occurrence of small larvae) and which species are settling (the occurrence of settlement size juveniles) in the vicinity of the Sanctuary. Sedberry et al. (in press) presented spawning times and locations for a number of fishes on the southeast U.S. shelf based on reproductive data obtained from trawl, trap, and hook-and-lines samples. All records of spawning females within 30 km of Gray’s Reef NMS were obtained and used to augment spawning information derived from larval surveys.

Patterns in the seasonal and habitat-specific occurrence of species were then examined qualitatively from comparison of the species number, abundance of fish, and diversity. Species number is simply the number of taxa occurring in a census. Abundance was calculated as the number of fish per unit of sampling (per see above). Species diversity (H’) was calculated following Pielou (1969):

\[ H’ = - \sum_{i=1}^{S} p_i (\log_2 p_i) \]
where $S$ is the total number of species and $p_i$ is the proportion of the total sample belonging to species $i$.

Finally, distribution and habitat information was obtained for each species from the literature. Dominant sources of information included data from studies that were included here (Sedberry and Van Dolah, 1984; Marancik et al., 2005; Walsh et al., in review). However, a number of additional sources were used to compile complete distribution and habitat-specific occurrences of each species (see Appendix 2). Distribution was categorized into six cross-shelf zones: palustrine, estuarine, inner-shelf, mid-shelf, outer-shelf, and upper slope. Six habitat categories were defined: rocky reef, sediment, submerged vegetation, pelagic vegetation, and pelagic. Fish distribution and habitat use was defined for larval, juvenile, and adult life stages. In addition, the mode of spawning was categorized as either pelagic or benthic. Finally, a determination was made whether a species is resident or transient in Gray’ Reef NMS. These life history, distribution, and habitat attributes were then summarized to examine general patterns in the ecology of fishes that inhabit Gray’s Reef NMS.

**Results**

**Common species**

A total of 27 taxa were found to be common (> 5% of total) in one or more fish censuses in the vicinity of Gray’s Reef NMS (Table 2). Some of these taxa included multi-species groups (e.g., *Anchoa* spp., *Etropus* spp.), and thus the number of common species in Gray’s Reef NMS likely exceeds 30. The adult and large juvenile censuses all provided a similar view of the ichthyofauna of Gray’s Reef NMS with common species including
*Haemulon aurolineatum*, *Stenotomus* spp., *Decapterus macarellus--D. punctatus* (the en-dash means that fish were identified as *D. macarellus* or *D. punctatus*), *Halichoeres bivittatus*, *Serranus subligarius*, *Diplodus holbrooki*, and *Centropristis striata*. A different view of common fishes was obtained from juvenile fish collections: *Etropus* spp., *Prionotus* spp., *Ophidion selenops*, *Diplectrum formosum*, *Microgobius carri*, *Stephanolepis hispidus*, *Dactyloscopus moorei*, and *Leiostomus xanthurus*. Larval fish collections provided yet another view of the ichthyofauna of Gray’s Reef NMS, with common species including *Caranx* sp.--*Chloroscombrus chysurus*, *Symphurus* spp., *Ophidion marginatum*, *Diplogrammus pauciradiatus*, *Larimus fasciatus*, *Brevoortia tyrannus*, *Micropogonias undulatus*, *Anchoa* spp., *Etropus* spp. *Prionotus* spp., *Microgobius carri* [as included in Gobiidae], *Leiostomus xanthurus*, and *Citharichthys spilopterus*. In addition, sparid larvae were common but could not be identified below family level. Although common species differed between census types, species common in one census were often present in another census in lower numbers and thus, all three approaches (adult, juvenile and larval censuses) provide different, yet complementary views of the ichthyofauna of Gray’s Reef NMS.

**Managed Species**

A total of 46 species managed by various state and federal agencies were found in Gray’s Reef NMS (Table 3). Half of these species are part of the SAFMC Snapper-Grouper complex (NMFS, 2003), and a number of managed mackerel and tuna species also occurred in the Sanctuary. Species managed by the Mid-Atlantic Fisheries Management Council (MAFMC), New England Fisheries Management Council (NEFMC) and
Atlantic States Marine Fisheries Commission (ASMFC) were present in Gray’s Reef NMS, as well as, a number of species that are regulated by Florida, Georgia, South Carolina, and North Carolina. Managed species that are common (Table 4) include members of the Snapper-Grouper complex managed by the SAFMC and three species managed by the ASMFC (Micropogonias undulatus, Brevoortia tyrannus, and Leiostomus xanthurus), which spawn on the shelf during fall, winter, and spring, and whose juveniles use estuarine habitats.

Spawning

The occurrence of small larvae and spawning females indicated that 53 taxa of fish spawn in the vicinity of Gray’s Reef NMS (Table 4). A number of managed species spawn in the vicinity of the Sanctuary, including coastal migratory pelagic species managed by the SAFMC (e.g., Scomberomorus cavalla and S. maculatus) and species managed by the ASFMC and the southeastern states (e.g., Brevoortia tyrannus, Leiostomus xanthurus, and Sciaenops ocellatus). Although the management focus of Gray’s Reef NMS is rocky-reef habitat, the general absence of lutjanid and epinepheline larvae indicates that snapper and grouper are not spawning in the vicinity of Gray’s Reef NMS. However, spawning females of Rhomboplites aurorubens and Diplectrum formosum were collected within 30 km of Gray’s Reef NMS (Sedberry et al., in press).

Settlement

Settlement stage juveniles of 20 taxa were found in the vicinity of Gray’s Reef NMS (Table 5). In addition, four pelagic species were collected that were undergoing the
larval-juvenile transition. A wide range of species were collected that settle to a broad
range of habitats. Importantly, very few settlement-stage reef fish were collected, but this
likely results from gear biases (i.e., the lack of direct sampling on rocky reefs) rather than
the absence of reef fish settlement at Gray’s Reef NMS.

Seasonal Patterns in Species Number, Abundance and Diversity

There was a strong seasonal pattern in the number of species collected across gear types
(Fig. 2A). Species number was highest during the summer for all collection methods and
was second highest in the fall for all censuses except the juvenile census. Winter and
spring had a relatively similar number of species with a few more species collected
during spring in the adult censuses and more species collected during winter in larval and
juvenile censuses. The higher number of species during winter in larval and juvenile fish
collections was due in part to the presence of estuarine-dependent species in the vicinity
of Gray’s Reef NMS during winter (B. tyrannus, L. xanthurus, M. undulatus).

Seasonal patterns also were observed in absolute abundance, but were not
consistent across censuses (Fig. 2B). Absolute abundance was highest during summer or
fall, depending on the census. The high summer and fall abundances in the bottom trawl
collections were driven by Stenotomus spp. and Haemulon aurolineatum in the summer
(42.6% and 42.2% of total catch) and Sardinella aurita in the fall (43.9% of total catch)
(see Table 1). The high summer and fall abundances in adult point counts were driven
largely by Decapterus punctatus--D. macarellus (77.6% in summer and 54.6% in fall of
total catch). Abundances in the juvenile censuses were relatively even over the seasons,
but the dominant taxon in the fall was Prionotus spp. (52.0% of total catch). Summer
abundances of larvae were more even across species with *Anchoa* spp., *Caranx* sp--
*Chloroscombrus chrysurus*, *Symphurus* spp., *Diplogrammus pauciradiatus*, and Gobiidae
accounting for 80.1% of total abundance.

There was little congruence in the seasonal pattern of species diversity (H’)
between sampling methods (Fig. 2C), which was expected owing to the patterns observed
in the number of species and their numerical abundance. For bottom trawl collections of
large juveniles and adults, H’ was highest in winter owing to the relatively even
distribution of abundance among species. In point counts, H’ was highest in spring, again
owing to the relatively even distribution of abundance among species. Highest H’ in
juvenile and larval censuses occurred in the summer and fall respectively because of the
high number of species collected. Relatively high H’ in winter larval collections was
again caused by relatively few species with an even abundance distribution.

Compilation of species and ecological information

A total of 181 species was reported from Gray’s Reef NMS from the six censuses
combined (Appendix 1). Classification of species as either resident or transient revealed
that resident species accounted for 37% of the total (Table 4). A majority of the transient
species were likely seasonal migrants (52% of total), and a relatively small number of
expatriated species occurred in the Sanctuary (9% of total). Three eel species that move
through the Sanctuary during their life cycle also occurred (2% of total; *Anguilla
rostrata*, *Conger oceanicus*, and *Myrophus punctatus*). In considering only common
species (> 5% of total in any one census method), 49% of common species were resident
and 51% were transient, and all the transient species were likely seasonal migrants (Table
A higher percentage of managed species were transients (74%) compared to residents (26%), and most of these transients were seasonal migrants with a few expatriates.

Although the management focus of Gray’s Reef NMS is rocky-reef habitat and associated biological communities, the fishes collected in the Sanctuary used a diverse array of habitats. As adults, fishes were reported from unconsolidated sediments, reefs, submerged vegetation, pelagic, and pelagic vegetation habitats (in rank order, Fig. 3). Juveniles were reported from a similar array of habitats as adults, but more species occurred in pelagic vegetation as juveniles than as adults. Fewer species were reported from reef habitats as juveniles, but part of this difference resulted from a lack of knowledge of juvenile habitat for many reef fish species. These patterns in habitat use were consistent when considering all species, abundant species, and managed species, with the exception that a greater proportion of managed species were found in reef habitat.

The species that occurred at Gray’s Reef NMS were reported to use habitats from the estuary to the slope (Fig. 4). The greatest number of species reportedly use the inner and mid-shelves as adults (~54%). A fewer number of species are reported to use areas inshore of the inner-shelf and offshore of the mid-shelf (23%). A greater percentage of juveniles were found in habitats inshore of the inner-shelf (29%) compared to the inner- and mid-shelves (48%); the percentage of juveniles found in habitats offshore of the mid-shelf was similar to the percentage of adults (23%). A greater percentage of common species were reported from coastal and estuarine areas (27% and 29%) compared to all species combined. The importance of habitats inshore of the inner-shelf was even more
evident for the adult and juvenile stages of managed species (30% and 45% of managed species) compared to all species combined.

Discussion

One-hundred eighty one species of fish were found in the vicinity of Gray’s Reef NMS. A total of 27 species were common (Table 2), and 46 species are currently managed for fishery purposes (Table 3). A clear pattern in species occurrence from all the censuses was an increase in the number of species in the summer, which has been documented in earlier studies (Sedberry and Van Dolah, 1984; Wenner and Sedberry, 1989; Marancik et al., 2005). Much of the summertime increase in species number was due to the seasonal migration of warmer-water species. There was some additional evidence that species number increases in the summer owing to the settlement from the plankton of warm-water species. In the winter, species diversity (H’) was relatively high, because a number of estuarine and pelagic species were abundant again owing to seasonal migrations.

The fraction of marine migratory species using estuaries decreases with latitude (see review by Nordlie 2003). The gradient is illustrated by reviews of fishes in Mid-Atlantic estuaries and Florida Bay. Able and Fahay (1998) determined that in Mid-Atlantic estuaries, 28% of 70 fish species were resident, and 66% were transient. In a similar study of Florida Bay, Powell et al. (in review) reported that 47% of the 60 fish species were resident and 53% were transients. At Gray’s Reef NMS, a location in between Mid-Atlantic estuaries and Florida Bay, an intermediate percentage of species were categorized as resident (37%) and transient (63%). These data suggest that the latitudinal trend in marine migratory species in estuarine habitats may extend onto the
shelf and future work examining large-scale spatial patterns in the composition of ichthyofauna would contribute to regional management strategies.

Taxonomy remains a limiting factor in the study and management of fishes along the southeast U.S. coast. This study illuminates three general taxonomic issues. First, our ability to identify the early life stages of a number of species is still limited. The larval census (Marancik et al., 2005) identified some common fishes and managed fishes to genus or family only (e.g., Symphurus spp., Urophyscis spp., Serraninae, Caranx sp--Chloroscombrus chrysurus). Similarly in the juvenile census, the identification of several abundant species was to genus only (e.g., Prionotus spp., Etropus spp.). New methods of early life stage identification (e.g., Hare et al., 1998; Sevigny et al., 2000) coupled with traditional techniques (see Fahay, 1984; Richards et al., in press) will improve early life stage taxonomy, but the application of these new techniques is still not widespread. A second taxonomic issue is the identification of species by divers. Without collecting voucher specimens and verifying the identifications of each diver, there may be inconsistencies among divers. An example is the identification of Decapterus macarellus--D. punctatus. Divers identified large schools of these fish as either one species or the other. Both species are outwardly similar in appearance (Robins and Ray, 1986) and impossible to identify to species in mixed-species schools. Taxonomic experience of divers can be balanced by sample size if the availability of inexperienced divers leads to greater number of observations (Pattengill-Semmens and Semmens, 1998). Yet, it seems prudent for monitoring programs to determine likely taxonomic problems and either disregard data collected for problematic species or use higher taxonomic groups (as done here). A third issue is outstanding taxonomic uncertainties
along the southeast U.S. shelf. For example, *Stenotomus* spp. have been identified as *Stenotomus aculeatus* (Wenner and Sedberry, 1989; Sedberry et al., 1998), but Eschmeyer (2004) considered the taxa as a synonym of *S. chrysops*. Both *S. chrysops* and *S. caprinus* are reported from the area (Carpenter, 2003) and as a result of this taxonomic uncertainty, ecology of *Stenotomus* along the southeast U.S. coast remain unresolved.

In addition to taxonomic limitations, our understanding of Gray’s Reef NMS ichthyofauna is limited by several data gaps including: the ecology of juvenile reef fish, understanding of the pelagic fish fauna, trophic linkages between reef and non-reef habitats, and the importance of unconsolidated sediments on the shelf to fish productions. Further, our review considered only bony fishes; information regarding elasmobranches is not included. These data gaps hamper the development of ecosystem approaches to fisheries and place-based management. Very little is known regarding the ecology of juvenile reef fish on rocky reefs along the southeast U.S., yet the ecology of juvenile coral reef fish has been the focus of intense study and has yielded great insights both scientifically and for management (e.g., Lindeman et al., 2000; Levin and Grimes, 2002). Juvenile fish ecology in temperate rocky reefs has also been studied in regions other than the southeast U.S. shelf and again lead to improved management of fisheries and habitat resources (Vigliola et al., 1998; Planes et al, 2000).

Another important data gap includes pelagic fishes. Juvenile and adult pelagic fishes associated with *Sargassum* are relatively well studied (e.g., Dooley, 1978; Coston-Clements et al., 1991; Settle, 1993). Similarly, pelagic fish of commercial importance (e.g., king mackerel, Spanish mackerel) also are well studied (e.g., Collins and Stender, 1987; Collins et al., 1998; Harris and Dean, 1998). In contrast, relatively little is known
regarding the juvenile and adult stages of most pelagic fishes. The abundance of these species (e.g., *Decapterus punctatus*, *D. macarellus*, and *Chloroscombrus chrysurus*) suggests an important ecological role in the ecosystem that has yet to be investigated (but see Hales, 1987; McBride et al., 2002).

Concepts of fish habitat utilization are developing on the southeast U.S. shelf (SAFMC, 1998). In a few habitats, particularly submerged vegetation in estuaries, the effect of habitat on vital rates has been examined (Hoss and Thayer, 1993; Irlandi and Crawford, 1997; Taylor and Miller, 2001; Levin and Hay, 2003). However, such detailed information on the interaction between habitat and fish population vital rates has not been conducted for the majority of habitats in the southeast U.S. ecosystem.

The focus of Gray’s Reef NMS is protection of rocky-reef habitat. Additionally, the Sanctuary is mandated to provide protection and comprehensive management for biological communities associated with rocky-reef habitat. From the perspective of the ichthyofauna, associated biological communities include a wide-range of habitats, spread over a large portion of the shelf, and include areas to the north and south of the Sanctuary. Most species reported from the Sanctuary have pelagic larvae (Appendix 1) and thus, the ichthyofauna is connected to other areas through pelagic larval transport (sensu Roberts et al., 1997; Cowen, 2002); the areal extent of these connections has not yet been quantified. Additionally, a number of the adult stages, which inhabit rocky reefs in the Sanctuary, use other habitats as both juveniles and adults. *Mycteroperca microlepis* and *Centropristis striata* use habitats within estuaries as juveniles (Able et al., 1995; Ross and Moser, 1995); *M. microlepis* spawns on the edge of the continental shelf, and *C. striata* spawns across the shelf (Sedberry et al., in press). Several species of *Caranx* use...
pelagic sargassum as juvenile habitat (Coston-Clements et al., 1991; Settle, 1993).

Centropristis ocyurus and Stenotomus sp. use unconsolidated sediments during both
juvenile and adult stages (Wenner et al., 1983; Sedberry and Van Dolah, 1984; Walsh et
al., in review).

In addition to using multiple habitats, there are a large number of transient species
that spend a portion of their life cycle in Gray’s Reef NMS. The seasonal pattern in
species number in part reflects the increase in transient species using the system in the
summer. However, a number of transient species also use the Sanctuary in the fall and
winter. The abundance of these transient species is affected in part by ecological
processes and human actions outside of the Sanctuary’s boundaries.

Many resident species are distributed over a wide cross-shelf region, yet the
movement of individuals has only been examined for a few of the 67 resident species.
Tagging indicated that approximately 6% of C. striata in Gray’s Reef NMS move out of
the Sanctuary within one month (Sedberry et al., 1998). Seasonal data is documented for
other species, but more shorter-time scale information on movement is not available for
the remaining 66 species resident in Gray’s Reef NMS.

Diet studies and stable isotope analyses indicate trophic links between pelagic,
unconsolidated sediments, and rocky-reef habitats (e.g., Sedberry 1989; Thomas and
Cahoon, 1993). Although these links have been identified, they have yet to be combined
into a trophic model of the ecosystem (e.g., Polovina, 1984).

From the perspective of the ichthyofauna, the connections among life history stages,
habitats, and different portions of the shelf (both along and across), indicate that
associated biological communities include much of the southeast U.S. ecosystem. Thus, it
is not possible for Gray’s Reef NMS to protect and provide comprehensive management for the ichthyofauna associated with ‘live-bottom’ and rocky-reef habitats, since authority does not extend to the biological boundaries of the ichthyofauna. In addition, the Sanctuary imposes few restrictions on harvest beyond those employed by the regional fisheries management council (SAFMC). In fact, Gray’s Reef NMS is an area of intense recreational fishing and fishing mortality there may exceed other areas of the shelf. Management objectives need to be achieved by working with other management groups that have authority in the areas outside the Sanctuary boundaries (e.g., SAFMC, State of Georgia), and by extending the Sanctuary boundaries to encompass a greater range of the southeast U.S. continental shelf ecosystem. Such large sanctuaries do exist in the Florida Keys and along the west coast of the United States.

From the perspective of MPAs and marine reserves on the southeast U.S. shelf, the present study indicates that separating individual components of the ecosystem for protection will be difficult. For example, many of the species that use rocky-reef habitat also use a range of other habitats; protecting only rocky-reef habitat will provide only partial protection for these species. Similar difficulty was encountered identifying Essential Fish Habitat (EFH) for the 72 species of the snapper-grouper management unit; almost every structural habitat type was identified as EFH (SAFMC, 1998; Lindeman et al., 2000). If management goals include the protection of one to several species, specific habitats and cross-shelf regions could be defined, but as the number of species expands and protection goals move from species to habitats, the scale required for protection quickly becomes most, if not all of the elements of the southeast U.S. shelf ecosystem. In 1990, cross-shelf MPA corridors were discussed (SAFMC, 1990), but then were dropped
from consideration. Modeling studies with sessile invertebrates indicate that to protect biodiversity, the scale of MPAs needs to be approximately equal to the scale of larval dispersal (Botsford et al., 2003; Shanks et al., 2003). In the case of marine fishes, the protection of biodiversity becomes much more complicated with ontogenetic movements and seasonal migrations. The fishes of Gray’s Reef NMS depend on a broad array of habitats and areas throughout much of the southeast U.S. continental shelf ecosystem. Research to quantitatively understand these inter-dependencies is needed. Yet, from the qualitative data presented here, Gray’s Reef NMS cannot be managed successfully in isolation, underscoring the broader importance of managing the southeast U.S. continental shelf ecosystem to achieve multiple management goals (NMFS, 1999).

Acknowledgements

We thank all the people involved in the collection of the data presented here. We also thank Allyn Powell, Don Hoss, and Greg McFall for reviewing earlier drafts of this manuscript, Mike Fahay for taxonomic expertise. Gray’s Reef National Marine Sanctuary and the Office of National Marine Sanctuaries supported this compilation and supported many of the censuses used in the compilation. The MARMAP Program supported the trap census and the Minerals Management Service supported the trawl census.

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Table 1. Sampling details for various fish censuses of Gray’s Reef National Marine Sanctuary considered in this study stratified by season.

Habits sampled are abbreviated as: reef (R), live-bottom (LB), unconsolidated sediments (US), and pelagic (P)

<table>
<thead>
<tr>
<th>Census Type</th>
<th>Sampling method</th>
<th>Effort</th>
<th>Habitat</th>
<th>Season and Year</th>
<th>Reference</th>
</tr>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1981 data - previously unpublished</td>
</tr>
<tr>
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<td></td>
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<td>1981 data - previously unpublished</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Previously unpublished, 1996-2002</td>
</tr>
<tr>
<td>Adult video census</td>
<td>Diver-conducted video</td>
<td>22</td>
<td>R</td>
<td></td>
<td>Parker et al. (1994)</td>
</tr>
<tr>
<td></td>
<td>transects</td>
<td></td>
<td>Dense LB</td>
<td></td>
<td>Parker et al. (1994)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>Moderate LB</td>
<td></td>
<td>Parker et al. (1994)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>Sparse LB</td>
<td></td>
<td>Parker et al. (1994)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21</td>
<td>US</td>
<td></td>
<td>Parker et al. (1994)</td>
</tr>
<tr>
<td>Adult point counts</td>
<td>Diver-conducted</td>
<td>83</td>
<td>R</td>
<td>Fall, 1995-2002</td>
<td>previously unpublished</td>
</tr>
<tr>
<td></td>
<td>stationary 4 m²</td>
<td></td>
<td></td>
<td></td>
<td>previously unpublished</td>
</tr>
<tr>
<td></td>
<td>cylinder point counts</td>
<td>105</td>
<td>R</td>
<td>Spring, 1995-2002</td>
<td>previously unpublished</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>previously unpublished</td>
</tr>
<tr>
<td></td>
<td></td>
<td>124</td>
<td>R</td>
<td>Summer, 1995-2002</td>
<td>previously unpublished</td>
</tr>
<tr>
<td>Juvenile trawl census</td>
<td>2-m Beam Trawl</td>
<td>36</td>
<td>US</td>
<td>Winter 2000-2002</td>
<td>Walsh et al. (in review)</td>
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<tr>
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<td></td>
<td>23</td>
<td>US</td>
<td>Spring 2000-2002</td>
<td>Walsh et al. (in review)</td>
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<td>46</td>
<td>US</td>
<td>Summer 2000-2002</td>
<td>Walsh et al. (in review)</td>
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<td>24</td>
<td>US</td>
<td>Fall 2000-2002</td>
<td>Walsh et al. (in review)</td>
</tr>
<tr>
<td>Larval census</td>
<td>60 cm bongo with 505</td>
<td>26</td>
<td>P</td>
<td>Winter 2000-2002</td>
<td>Marancik et al. (2005)</td>
</tr>
<tr>
<td></td>
<td>um mesh</td>
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<td></td>
<td></td>
<td>Marancik et al. (2005)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>P</td>
<td>Fall 2000-2002</td>
<td>Marancik et al. (2005)</td>
</tr>
</tbody>
</table>
Table 2. Common fish species occurring in the vicinity of Gray’s Reef National Marine Sanctuary. Percent total abundance calculated as abundance of taxa divided by sum abundance of all taxa. Only those species that comprised >5% of total abundance in at least one census were considered common. Bold numbers indicate abundance >5%. No entry indicates that taxa was not collected in that particular season or gear. The stratification of collection data is described in the Methods and the following abbreviations are used: Sp – spring, Su – summer, F – fall, W – winter, L – ledge, DLB – dense live-bottom, MLB – moderate live-bottom, SLB – sparse live-bottom, and S - sand. Parker et al. (1996) provides more detail regarding the habitat definitions.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Adult and Large Juvenile</th>
<th>Juvenile and Small Adult</th>
<th>Larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottom Trawl</td>
<td>Traps</td>
<td>Video Transect</td>
</tr>
<tr>
<td></td>
<td>Sp</td>
<td>Su</td>
<td>F</td>
</tr>
<tr>
<td>Sthenotomus sp.</td>
<td>93.4</td>
<td>42.6</td>
<td>10.2</td>
</tr>
<tr>
<td>Haemulon aurorhineum</td>
<td>42.2</td>
<td>20.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Urophycis regia</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centropristis striata</td>
<td>1.6</td>
<td>3.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Lagodon rhomboides</td>
<td>0.0</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Sparidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decapterus macarellus-D. punctatus</td>
<td>0.3</td>
<td>1.8</td>
<td>1.3</td>
</tr>
<tr>
<td>Halichoeres bivittatus</td>
<td>0.3</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Diplodus holbrooki</td>
<td>0.1</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Serranus subligarius</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sardinella aurita</td>
<td>0.0</td>
<td>0.3</td>
<td>43.9</td>
</tr>
<tr>
<td>Anchoa spp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Etropus spp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prionotus spp.</td>
<td>0.7</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Ophidion selevos</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diplectrum formosum</td>
<td>0.1</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Microgobius carri-- Gobiidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stephanolepis hispida</td>
<td>0.8</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Dactylacopus moorei</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leioptomus xanthus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caranx sp.--Chloroscombrus chrysuras</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Symphurus spp.</td>
<td></td>
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<td></td>
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<tr>
<td>Ophidion marginatina</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diplogrammus pauciradiatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larimus fasciatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brevoortia tyrannus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microgobios undulatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citharichthys siluopterus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes
1 - Larvae identified as Urophycis spp. (the most-defined taxonomic level for this genus in larval identifications) were included here.
2 - Adults and juveniles identified as Prionotus spp., Prionotus carolinus, Prionotus ophryas, and Prionotus scitula were grouped and considered as Prionotus spp. owing to inability to identify larvae, some juveniles and some adults to species.
3 - Larvae identified as Gobiidae (the most-defined taxonomic level for this family in larval identifications) were included here.
4 - Adults and juveniles identified as Chloroscombrus chrysuras, Caranx bartholomaei, Caranx crysos, Caranx ruber, and Caranx dentex were grouped and considered as Caranx spp.--Chloroscombrus chrysuras owing to inability to identify larvae to species.
5 - Juveniles identified as Symphurus uropsilus, Symphurus minor, Symphurus diomedianus and Symphurus plagiusa were grouped and considered here as Symphurus spp. owing to the inability to identify larvae to species.
Table 3. List of managed fish species reported from the vicinity of Gray’s Reef National Marine Sanctuary. Common species (Table 2) are indicated by a C. Management authorities included are Atlantic States Fisheries Management Commission (ASFMC), Northeast Fisheries Management Council (NEFMC), Mid-Atlantic Fisheries Management Council (MAFMC), South Atlantic Fisheries Management Council (SAFMC), National Marine Fisheries Service (NMFS), State of Florida (FL), State of Georgia (GA), State of South Carolina (SC), and State of North Carolina (NC).

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Management Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anguilla rostrata</em></td>
<td>American eel</td>
<td>ASFMC, NC</td>
</tr>
<tr>
<td><em>Brevoortia tyrannus</em></td>
<td>Atlantic menhaden</td>
<td>C ASFMC</td>
</tr>
<tr>
<td><em>Centropristis ocyurus</em></td>
<td>bank sea bass</td>
<td>SAFMC, SC</td>
</tr>
<tr>
<td><em>Centropristis striata</em></td>
<td>black sea bass</td>
<td>C MAFMC, SAFMC, ASFMC, FL, GA, SC, NC</td>
</tr>
<tr>
<td><em>Centropristis philadelphica</em></td>
<td>rock sea bass</td>
<td>SAFMC, SC</td>
</tr>
<tr>
<td><em>Mycteroperca microlepis</em></td>
<td>gag</td>
<td>SAFMC, FL, GA, SC, NC</td>
</tr>
<tr>
<td><em>Mycteroperca phenax</em></td>
<td>scamp</td>
<td>MAFMC, ASFMC, FL, GA, SC, NC</td>
</tr>
<tr>
<td><em>Pomatomus saltatrix</em></td>
<td>bluefish</td>
<td>SAFMC, FL, GA, SC, NC</td>
</tr>
<tr>
<td><em>Rachycentron canadum</em></td>
<td>cobia</td>
<td>SAFMC, SC, NC</td>
</tr>
<tr>
<td><em>Caranx bartholomaei</em></td>
<td>yellow jack</td>
<td>C SAFMC, SC, NC</td>
</tr>
<tr>
<td><em>Caranx cryos</em></td>
<td>blue runner</td>
<td>SAFMC, SC, NC</td>
</tr>
<tr>
<td><em>Caranx ruber</em></td>
<td>bar jack</td>
<td>SAFMC, SC, NC</td>
</tr>
<tr>
<td><em>Seriola dumerili</em></td>
<td>greater amberjack</td>
<td>SAFMC, SC, NC, NC</td>
</tr>
<tr>
<td><em>Seriola rivoliana</em></td>
<td>almaco jack</td>
<td>SAFMC, SC, NC</td>
</tr>
<tr>
<td><em>Coryphaena hippurus</em></td>
<td>dolphin</td>
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<td><em>Lutjanus campechanus</em></td>
<td>red snapper</td>
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<td><em>Lutjanus griseus</em></td>
<td>gray snapper</td>
<td>SAFMC, FL, SC, NC</td>
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<tr>
<td><em>Lutjanus analis</em></td>
<td>mutton snapper</td>
<td>SAFMC, FL, SC, NC</td>
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<td><em>Ocyurus chrysurus</em></td>
<td>yellowtail snapper</td>
<td>SAFMC, FL, SC, NC</td>
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<td><em>Rhomboplites aurorubens</em></td>
<td>vermilion snapper</td>
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<td><em>Haemulon aurolineatum</em></td>
<td>tomtate</td>
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<td><em>Haemulon plumieri</em></td>
<td>white grunt</td>
<td>SAFMC, SC, NC</td>
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<td><em>Archosargus probatocephalus</em></td>
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<td>red porgy</td>
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<td><em>Stenotomus sp.</em></td>
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</tr>
<tr>
<td><em>Pogonias cromis</em></td>
<td>black drum</td>
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</tr>
<tr>
<td><em>Cynoscion regalis</em></td>
<td>weakfish</td>
<td>GA</td>
</tr>
<tr>
<td><em>Menticirrhus americanus</em></td>
<td>southern kingfish</td>
<td>GA</td>
</tr>
<tr>
<td><em>Menticirrhus littoralis</em></td>
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</tr>
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<td>Species</td>
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<td>Management Agency</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><em>Micropogonias undulatus</em></td>
<td>Atlantic croaker</td>
<td>C</td>
</tr>
<tr>
<td><em>Sciaenops ocellatus</em></td>
<td>Red drum</td>
<td>C</td>
</tr>
<tr>
<td><em>Leiostomus xanthurus</em></td>
<td>Spot</td>
<td>C</td>
</tr>
<tr>
<td><em>Chaetodipterus faber</em></td>
<td>Atlantic spadefish</td>
<td>C</td>
</tr>
<tr>
<td><em>Mugil curema</em></td>
<td>White mullet</td>
<td>C</td>
</tr>
<tr>
<td><em>Mugil cephalus</em></td>
<td>Striped mullet</td>
<td>C</td>
</tr>
<tr>
<td><em>Tautoga onitis</em></td>
<td>Tautog</td>
<td>C</td>
</tr>
<tr>
<td><em>Scomberomorus cavalla</em></td>
<td>King mackerel</td>
<td>C</td>
</tr>
<tr>
<td><em>Scomberomorus maculates</em></td>
<td>Spanish mackerel</td>
<td>C</td>
</tr>
<tr>
<td><em>Euthynnus alletteratus</em></td>
<td>Little tunny</td>
<td>C</td>
</tr>
<tr>
<td><em>Peprilus triacanthus</em></td>
<td>Butterfish</td>
<td>C</td>
</tr>
<tr>
<td><em>Paralichthys lethostigma</em></td>
<td>Southern flounder</td>
<td>C</td>
</tr>
<tr>
<td><em>Paralichthys albigutta</em></td>
<td>Gulf flounder</td>
<td>C</td>
</tr>
<tr>
<td><em>Scophthalmus aquosus</em></td>
<td>Windowpane</td>
<td>C</td>
</tr>
<tr>
<td><em>Balistes capriscus</em></td>
<td>Gray triggerfish</td>
<td>C</td>
</tr>
</tbody>
</table>
Table 4. List of species that likely spawn in the vicinity of Gray’s Reef National Marine Sanctuary. Determination of spawning was made from the occurrence of small larvae in ichthyoplankton collections made in the vicinity of the Sanctuary (source = Larvae) and the occurrence of spawning females within 30 km of the Sanctuary (source = Adults). Common species are indicated by a C (see Table 2).

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoa spp.</td>
<td>anchovies</td>
<td>Larvae</td>
</tr>
<tr>
<td>Beloniform</td>
<td>flying fishes</td>
<td>Larvae</td>
</tr>
<tr>
<td>Blenniidae</td>
<td>blennies</td>
<td>Larvae</td>
</tr>
<tr>
<td>Brevortia tyrannus</td>
<td>Atlantic menhaden</td>
<td>Larvae</td>
</tr>
<tr>
<td>Caranx sp.—Chloroscombrus chrysurus</td>
<td>jacks</td>
<td>Larvae</td>
</tr>
<tr>
<td>Citharichthys spilopterus</td>
<td>bay whiff</td>
<td>Larvae</td>
</tr>
<tr>
<td>Coryphaena hippurus</td>
<td>dolphin</td>
<td>Larvae</td>
</tr>
<tr>
<td>Cynoscion nothus</td>
<td>silver seatrout</td>
<td>Larvae</td>
</tr>
<tr>
<td>Cynoscion regalis</td>
<td>weakfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Diplectrum formosum</td>
<td>sand stargazer</td>
<td>Larvae</td>
</tr>
<tr>
<td>Decapterus macarellus—D. punctatus</td>
<td>mackerel / round scad</td>
<td>Larvae</td>
</tr>
<tr>
<td>Diplogrammus pauciradiatus</td>
<td>spotted dragonet</td>
<td>Larvae</td>
</tr>
<tr>
<td>Eutropus crossothus</td>
<td>fringed flounder</td>
<td>Larvae</td>
</tr>
<tr>
<td>Eutropus spp.</td>
<td>smallmouthed flounders</td>
<td>Larvae</td>
</tr>
<tr>
<td>Euthynnus alletteratus</td>
<td>little tunny</td>
<td>Larvae</td>
</tr>
<tr>
<td>Gobiidae</td>
<td>gobies</td>
<td>Larvae</td>
</tr>
<tr>
<td>Halichoeres bivittatus</td>
<td>slippery dick</td>
<td>Larvae</td>
</tr>
<tr>
<td>Hippoglossina oblonga</td>
<td>four spot flounder</td>
<td>Larvae</td>
</tr>
<tr>
<td>Lactophrys quadricornis</td>
<td>scrawled cowfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Lagodon rhomboides</td>
<td>pinfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Larimus fasciatus</td>
<td>banded drum</td>
<td>Larvae</td>
</tr>
<tr>
<td>Lutjanus spp.—Ophistognathidae</td>
<td>snapper/jawfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Menticirrhus americanus</td>
<td>southern kingfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Menticirrhus littoralis</td>
<td>gulf kingfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Micropogonias undulatus</td>
<td>Atlantic croaker</td>
<td>Larvae</td>
</tr>
<tr>
<td>Myrophus punctatus</td>
<td>speckeled worm eel</td>
<td>Larvae</td>
</tr>
<tr>
<td>Ophichthus cruentifer</td>
<td>margined snake eel</td>
<td>Larvae</td>
</tr>
<tr>
<td>Ophidion holbrooki—O. antipholis</td>
<td>cusk eel</td>
<td>Larvae</td>
</tr>
<tr>
<td>Ophidion marginatum</td>
<td>striped cusk eel</td>
<td>Larvae</td>
</tr>
<tr>
<td>Ophidion selenops</td>
<td>moon eyed cusk eel</td>
<td>Larvae</td>
</tr>
</tbody>
</table>

40
<table>
<thead>
<tr>
<th>Fish Name</th>
<th>Common Name</th>
<th>Life Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opisthonema oglinum</td>
<td>Atlantic thread herring</td>
<td>Larvae</td>
</tr>
<tr>
<td>Peprilus burti</td>
<td>gulf butterfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Peprilus paru</td>
<td>butterfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Peprilus triacanthus</td>
<td>butterfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Pogonias cromis</td>
<td>black drum</td>
<td>Larvae</td>
</tr>
<tr>
<td>Prionotus spp.</td>
<td>searobins</td>
<td>Larvae</td>
</tr>
<tr>
<td>Rhomboplites aurorubens</td>
<td>Vermillion snapper</td>
<td>Adult</td>
</tr>
<tr>
<td>Sciaenidae</td>
<td>drums</td>
<td>Larvae</td>
</tr>
<tr>
<td>Sciaenops ocellatus</td>
<td>red drum</td>
<td>Larvae</td>
</tr>
<tr>
<td>Scomberomorus cavalla</td>
<td>king mackerel</td>
<td>Larvae</td>
</tr>
<tr>
<td>Scomberomorus maculatus</td>
<td>Spanish mackerel</td>
<td>Larvae</td>
</tr>
<tr>
<td>Scorpaenidae</td>
<td>scorpionfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Serranichthys pumilio</td>
<td>pygmy seabass</td>
<td>Larvae</td>
</tr>
<tr>
<td>Serranichthys subligarius</td>
<td>belted sandfish</td>
<td>Larvae</td>
</tr>
<tr>
<td>Sparidae</td>
<td>porgies</td>
<td>Larvae</td>
</tr>
<tr>
<td>Sphoeroides spp.</td>
<td>pufferfishes</td>
<td>Larvae</td>
</tr>
<tr>
<td>Syacium papillosum</td>
<td>gulf stream flounder</td>
<td>Larvae</td>
</tr>
<tr>
<td>Synodontidae</td>
<td>lizardfishes</td>
<td>Larvae</td>
</tr>
<tr>
<td>Trinectes maculates</td>
<td>hogchocker</td>
<td>Larvae</td>
</tr>
<tr>
<td>Uranoscopidae</td>
<td>stargazers</td>
<td>Larvae</td>
</tr>
<tr>
<td>Urophycis spp.</td>
<td>hakes</td>
<td>Larvae</td>
</tr>
<tr>
<td>Xyrichtys novacula</td>
<td>pearly razorfish</td>
<td>Larvae</td>
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</tbody>
</table>
Table 5. List of species that undergo the larval/juvenile transition in the vicinity of Gray’s Reef National Marine Sanctuary. Determination of ‘settlement-stage’ was made based on fish size and comparison of size-at-settlement data in the literature (see Walsh et al., in review). Common species are indicated by a C (see Table 2).

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Common name</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoa spp.</td>
<td>anchovies</td>
<td>C</td>
</tr>
<tr>
<td>Ancylopsetta quadrocellata</td>
<td>Ocellated flounder</td>
<td></td>
</tr>
<tr>
<td>Ariosoma balcaricum</td>
<td>bandtooth conger</td>
<td></td>
</tr>
<tr>
<td>Bothus ocellatus—B. robinsi</td>
<td>eyed/spottail flounder</td>
<td></td>
</tr>
<tr>
<td>Brevoortia tyrannus</td>
<td>Atlantic menhaden</td>
<td>C</td>
</tr>
<tr>
<td>Citharichthys spp.</td>
<td>Whiffs</td>
<td></td>
</tr>
<tr>
<td>Cynoscion nothus</td>
<td>silver seatrout</td>
<td></td>
</tr>
<tr>
<td>Cynoscion regalis</td>
<td>weakfish</td>
<td></td>
</tr>
<tr>
<td>Dactyloscopus moorei</td>
<td>sand stargazer</td>
<td></td>
</tr>
<tr>
<td>Decapterus macarellus—D. punctatus</td>
<td>mackerel / round scad</td>
<td>C</td>
</tr>
<tr>
<td>Diplectrum formosum</td>
<td>sand perch</td>
<td>C</td>
</tr>
<tr>
<td>Etropus spp.</td>
<td>smallmouthed flounders</td>
<td>C</td>
</tr>
<tr>
<td>Leiostomus xanthurus</td>
<td>spot</td>
<td>C</td>
</tr>
<tr>
<td>Microgobius carri</td>
<td>seminole goby</td>
<td>C</td>
</tr>
<tr>
<td>Stephanolepis hispidus</td>
<td>planeheaded filefish</td>
<td>C</td>
</tr>
<tr>
<td>Ophidion selenops</td>
<td>moon-eye cusk eel</td>
<td>C</td>
</tr>
<tr>
<td>Peprilus triacanthus</td>
<td>butterfish</td>
<td></td>
</tr>
<tr>
<td>Prionotus spp.</td>
<td>searobins</td>
<td>C</td>
</tr>
<tr>
<td>Scophthalmus aquosus</td>
<td>windowpane flounder</td>
<td></td>
</tr>
<tr>
<td>Serraniculus pumilio</td>
<td>pygmy sea bass</td>
<td>C</td>
</tr>
<tr>
<td>Stenotomus sp.</td>
<td>scup</td>
<td></td>
</tr>
<tr>
<td>Syacium papillosum</td>
<td>gulf stream flounder</td>
<td></td>
</tr>
<tr>
<td>Synodus foetens</td>
<td>inshore lizardfish</td>
<td></td>
</tr>
<tr>
<td>Urophycis regia</td>
<td>spotted hake</td>
<td>C</td>
</tr>
</tbody>
</table>
Table 6. Designation of fishes from Gray’s Reef National Marine Sanctuary as resident or transient, and further designation of transient species as seasonal migrants, expatriates, and other. Other includes three eel species that move through the Sanctuary during their life cycle.

<table>
<thead>
<tr>
<th></th>
<th>Resident</th>
<th>Transient</th>
<th>Seasonal Migrants</th>
<th>Expatriates</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Species</td>
<td>67</td>
<td>114</td>
<td>94</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Abundant Species</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Managed Species</td>
<td>12</td>
<td>34</td>
<td>29</td>
<td>4</td>
<td>1</td>
</tr>
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</table>
Figure 1. Map of the southeast U.S. continental shelf showing the location of Gray’s Reef National Marine Sanctuary.

Figure 2. The number of fish species, abundance, and species diversity for each of four seasons from four fish censuses conducted at Gray’s Reef National Marine Sanctuary.

Figure 3. The percentage of species reported from Gray’s Reef National Marine Sanctuary that occur in different habitats of the southeast U.S. continental shelf ecosystem. Data are presented for both adult and juvenile life stages. Data are provided in Appendix 1, and sources are provided in Appendix 2.

Figure 4. The percentage of species reported from Gray’s Reef National Marine Sanctuary that occur in different cross-shelf zones of the southeast U.S. continental shelf ecosystem. Data are presented for both adult and juvenile life stages. Data are provided in Appendix 1, and sources are provided in Appendix 2.
Figure 3

- **All Species**
  - Adults
  - Juveniles

- **Abundant Species**

- **Managed Species**
  - Reef
  - Sediment
  - Pelagic Vegetation
  - Submerged Vegetation
  - Pelagic
Figure 4

[Graph showing the percentage of species by age (Adults vs. Juveniles) for different habitats (All Species, Abundant Species, Managed Species) across various ecological zones (Palustrine, Estuarine, Coastal, Inner-Shelf, Mid-Shelf, Outer-Shelf, Slope).]
### Appendix 1: Compilation of life history information for fishes reported from Gray’s Reef National Marine Sanctuary.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Taxonomic Name</th>
<th>Genus</th>
<th>Species</th>
<th>Habitat</th>
<th>Egg</th>
<th>Larvae</th>
<th>Juveniles</th>
<th>Adults</th>
</tr>
</thead>
</table>

#### References (see Appendix 2)

- **Coral, Rocky, Oyster Reef**
- **Pelagic**
- **Submerged Sediment**
- **Submerged Vegetation**
- **Abysmal**
- **Slope**
- **Outer-shelf**
- **Mid-shelf**
- **Inner-shelf**
- **Reef**
- **Coastal**
- **Pelagic Vegetation**
- **Submerged Sediment**
- **Bethic Vegetation**
- **Abysmal**
- **Mid-shelf**
- **Inner-shelf**
- **Coastal**
- **Palustrine**
- **Submerged Vegetation**
- **Emergent Vegetation**
- **Abysmal**
- **Mid-shelf**
- **Inner-shelf**
- **Coastal**
- **Estuarine**
- **Pelagic / Non-pelagic**
- **Expatriates / Life History**
- **Resident / Transient**
- **Abundance**
- **Spawning**

- **American eel**
- **Anguilla rostrata**
- **Speckled worm eel**
- **Ariosoma balearicum**
- **Bandtooth conger**
- **Gymnothorax moringa**
- **Opisthonema oglinum**
- **Atlantic thread herring**
- **Brevoortia tyrannus**
- **Sardinella aurita**
- **Spanish sardine**
- **Anchoa hepsetus**
- **Striped anchovy**
- **Anchoa mitchilli**
- **Engraulis eurystole**
- **Round herring**
- **Etrumeus teres**
- **Inshore lizardfish**
- **Synodus foetens**
- **Sand diver**
- **Synodus intermedius**
- **Snakefish**
- **Trachinocephalus myops**
- **Urophycis earlli**
- **Urophycis floridana**
- **Southern hake**
- **Urophycis regia**
- **Bank cusk-eel**
- **Ophidion holbrooki--O. antipholis**
- **Striped cusk-eel**
- **Ophidion marginatum**
- **Mooneye cusk-eel**
- **Polka-dot cusk-eel**
- **Opsanus pardus--O. tau**
- **Porichthys plectrodon**
- **Atlantic midshipman**
- **Roughback batfish**
- **Ogcocephalus parvus**
- **Skilletfish**
- **Hemiramphus brasiliensis**
- **Chain pipefish**
- **Syngnathus louisianae**
- **Bull pipefish**
- **Hippocampus erectus**
- **Barbfish**
- **Smoothhead scorpionfish**
- **Scorpaena calcarata**
- **Hunchback scorpionfish**
- **Scorpaena plumieri**
- **Scorpaena brasiliensis**
- **Smoothhead cusk-eel**
- **Prionotus scitulus**
- **Leopard searobin**
- **Datylopterus volitans**
- **Bank sea bass**
- **Centropristis ocyurus**
- **Centropristis philadelphica**
- **Centropristis striata**
- **Black sea bass**
- **Diplectrum formosum**
- **Pygmy sea bass**
- **Gag**
- **Scamp**
- **Rypticus saponaceus**
- **Priacanthus arenatus**

---

**Note:** The table above provides a compilation of life history information for fishes reported from Gray’s Reef National Marine Sanctuary, including their occurrence in various habitats and ecological zones. The references are indicated in Appendix 2 for further details.
<table>
<thead>
<tr>
<th>Location</th>
<th>Life History</th>
<th>Species</th>
<th>Abundance</th>
<th>Location</th>
<th>Life History</th>
<th>Species</th>
<th>Abundance</th>
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</thead>
<tbody>
<tr>
<td>Coral, Rocky, Oyster Reef</td>
<td>Residency</td>
<td>Grunts</td>
<td>28</td>
<td>Pelagic, Non-pelagic</td>
<td>Expatriate</td>
<td>Grunts</td>
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<td>Submerged Sediment</td>
<td>Residency</td>
<td>Grunts</td>
<td>28</td>
<td>Pelagic, Non-pelagic</td>
<td>Expatriate</td>
<td>Grunts</td>
<td>28</td>
</tr>
<tr>
<td>Submerged Vegetation</td>
<td>Residency</td>
<td>Grunts</td>
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<td>Expatriate</td>
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<tr>
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</tr>
<tr>
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<td>Grunts</td>
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<td>Pelagic, Non-pelagic</td>
<td>Expatriate</td>
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<td>Expatriate</td>
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</tr>
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<td>Grunts</td>
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<td>Pelagic, Non-pelagic</td>
<td>Expatriate</td>
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<td>Grunts</td>
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<td>Expatriate</td>
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<td>Residency</td>
<td>Grunts</td>
<td>28</td>
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<td>Expatriate</td>
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<td>Expatriate</td>
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<td>Coastal</td>
<td>Residency</td>
<td>Grunts</td>
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<td>Pelagic, Non-pelagic</td>
<td>Expatriate</td>
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<td>Submerged Sediment</td>
<td>Residency</td>
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</tr>
</tbody>
</table>
Egg Larvae Juveniles Adults

References (see Appendix 2)
Appendix 2. References used in the determination of habitat utilization and cross-shelf zone utilization of larval, juvenile, and adult stages of fishes from the vicinity of Gray’s Reef National Marine Sanctuary (see Appendix 1).


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