SEASONAL VARIATIONS IN THE POPULATION STRUCTURE OF BLACK SEA BASS, CENTROPRISTIS STRIATA, ON GRAY'S REEF NATIONAL MARINE SANCTUARY

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Seasonal Variations in the Population Structure of Black Sea Bass, *Centropristis striata*, on Gray's Reef National Marine Sanctuary
(Under the direction of ROBERT REINERT)

Variations in size and age structure, growth rates, and migration of black sea bass *Centropristis striata* on Gray's Reef National Marine Sanctuary were studied in 1988 and 1989. Fish were collected with 12.5 mm square mesh traps. Collections were typical of South Atlantic reef systems within the "20-m depth" zone and representative of an annual resident population dominated by non-harvestable sized fish less than 3 years old. Young-of-the-year sea bass were most abundant in summer. Sea bass older than two years ($\geq$ 205 mm total length) were most frequently captured in winter. Age and growth data documented six age classes. Harvestable size ($\geq$ 205 mm) was reached by the third age class. Daily growth rates for each age class differed from 0.099 mm/day at age 6 to 0.399 mm/day at age 1. Growth rates within each age class indicated no differences between seasons. Sea bass exhibited limited movement from original trapping locations. Recovery data from recreational fishermen suggested limited emigration southward to reef systems offshore of northeast Florida.

INDEX WORDS: *Centropristis striata*, size, age, growth rates, migration, recruitment, Gray's Reef National Marine Sanctuary

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by

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B.S., GEORGIA SOUTHERN COLLEGE, 1987

A Thesis Submitted to the Graduate Faculty
of The University of Georgia in Partial Fulfillment
of the
Requirements for the Degree

MASTERS OF SCIENCE

ATHENS, GEORGIA

1995

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July 26, 1995

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ACKNOWLEDGEMENTS

This thesis is dedicated to my parents, John and Nevelle Furse, my biggest supporters throughout my college years and without whom I could not have made it. I thank Dr. Robert Reinert and Dr. Mac Rawson for the opportunity to participate in this study and providing guidance and showing great patience throughout the completion of the work. I also express appreciation to Dr. Michael Conroy for his editing expertise and helpful comments, especially concerning the data analysis. The field work could not have been done without the help of David Dockery, Mike Yoder, Hamp Simkins, Drew Kendall, and John Furse. They put up with my constant demands in order to fish for black sea bass on Gray's Reef. I also thank the University of Georgia for the education with which I was provided and the enjoyment I gained over the years. Boat operation and handling were performed by Captain Daniel Colson and Thomas Shierling of the University of Georgia Marine Extension Service in Brunswick, Georgia. The sampling operation was conducted from the University of Georgia Marine Institute on Sapelo Island, Georgia. Permission to conduct research on Gray's Reef National Marine Sanctuary was granted by the National Oceanic and Atmospheric Administration.

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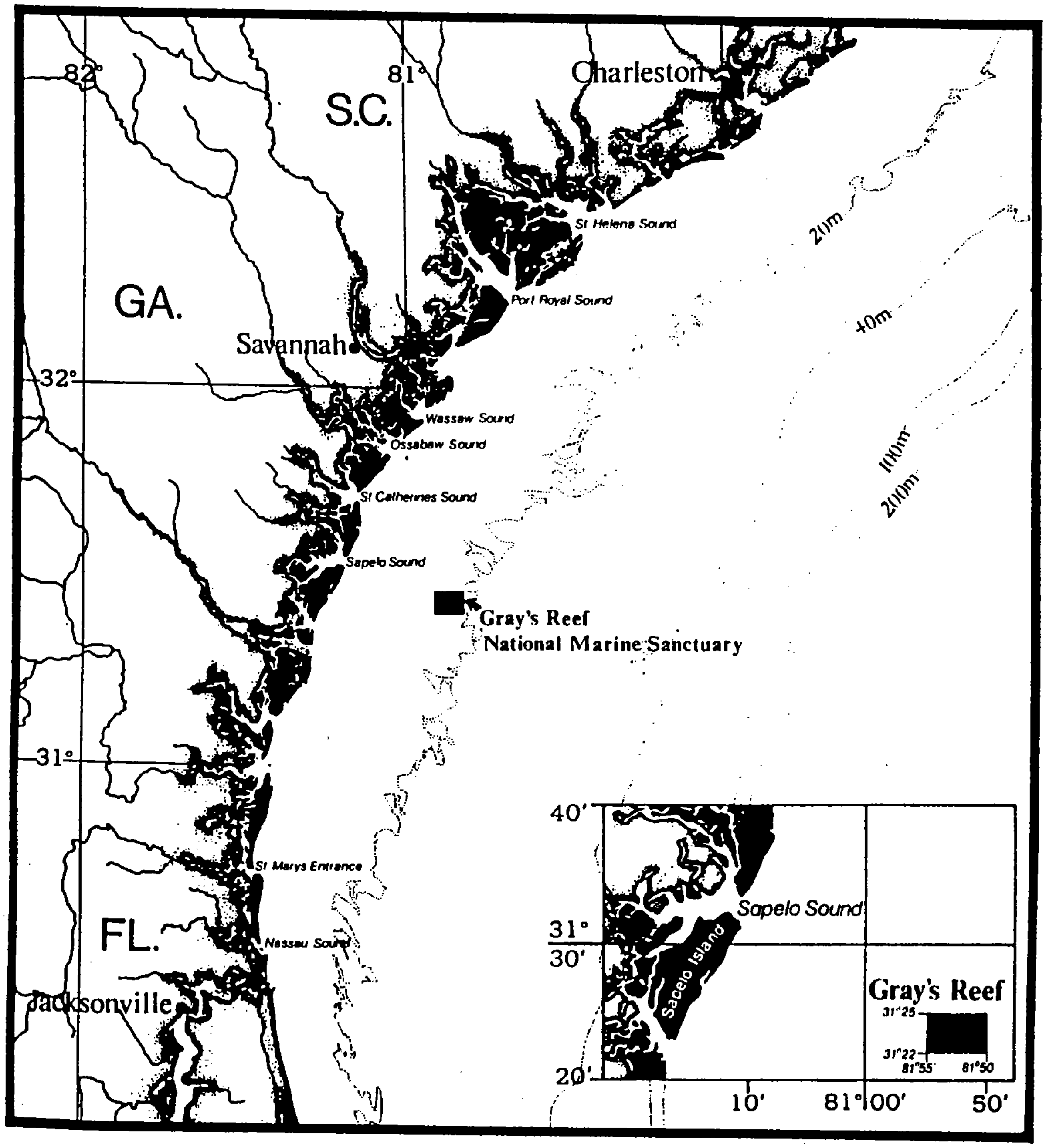
I. INTRODUCTION

Black sea bass (*Centropristis striata*) is the dominant species of commercial and recreational fisheries on near-shore and artificial reefs of Georgia and other South Atlantic and Middle Atlantic states (Cupka et al. 1973; Frame and Pearce 1973; McDonald 1974; Musick and Mercer 1977; Ulrich et al. 1977; Parker et al. 1979; Ansley and Harris 1981; Low 1981; Low 1982; Chester et al. 1984). One of the primary areas for black sea bass fishing off Georgia is Gray's Reef National Marine Sanctuary, located 65 km northeast of Brunswick, Georgia. As coastal Georgia becomes recognized for its fishing and diving opportunities, the pressures of commercial and recreational fisheries may create overharvesting of its fish stocks and conflicts between user groups. The Georgia Department of National Resources has identified the need for more information on offshore black sea bass stocks (Ansley and Harris 1981). Compilation of seasonal data concerning age, sex, and size distributions of black sea bass can provide the basis for better management strategies that will maintain stable black sea bass populations for use by all user groups. To that end, I examined variations in size structure and growth rates, age and sex structure, and migration of black sea bass on the Gray's Reef National Marine Sanctuary over two years.

Gray's Reef National Marine Sanctuary

The South Atlantic Bight of the western North Atlantic Ocean is comprised of the Continental Shelf and oceanic region from Cape Canaveral, Florida to Cape Hatteras, North Carolina. The Bight is primarily a broad, shallow, and barren sand/clay region of the Continental Shelf. Interspersed throughout the Bight, however, are natural, "live bottom" reefs (Ansley and Harris 1981). Struhsaker (1969) describes these areas as "outcrops of rock that are heavily encrusted with such sessile invertebrates as sponges and sea fans." Gray's Reef National Marine Sanctuary, the largest live bottom reef in Georgia, is located about 32.5 km due east of Sapelo Island, Georgia (Figure 1). The sanctuary is a 64 km^2 section of Gray's Reef. Its substrate is composed of limestone ridges, sand patches, and sedimentary soft bottoms which were deposited as calcareous mud between two and five million years ago during the Pliocene Epoch. Due to numerous fluctuations in sea levels during the Pleistocene Epoch, the substrate was subjected to processes of lithification, weathering and erosion (Gilligan 1989). As sediment was covered with water, an excellent habitat for marine invertebrate growth was created. The present-day reef is covered by a variety of organisms,

Figure 1. Location of Gray's Reef National Marine Sanctuary. Adapted from Gilligan (1989).


82°
81°
Charleston
S.C.
St Helena Sound
Port Royal Sound
20m
40m
GA.
Savannah
32°
Wassaw Sound
Ossabaw Sound
St Catherines Sound
100m
200m
Sapelo Sound
Gray's Reef
National Marine Sanctuary
31°
St Marys Entrance
FL.
Nassau Sound
Jacksonville
40'
Sapelo Sound
31°
30'
Sapelo Island
Gray's Reef
31°25
31°22
81°55'
81°50
20'
10'
81°00'
50'

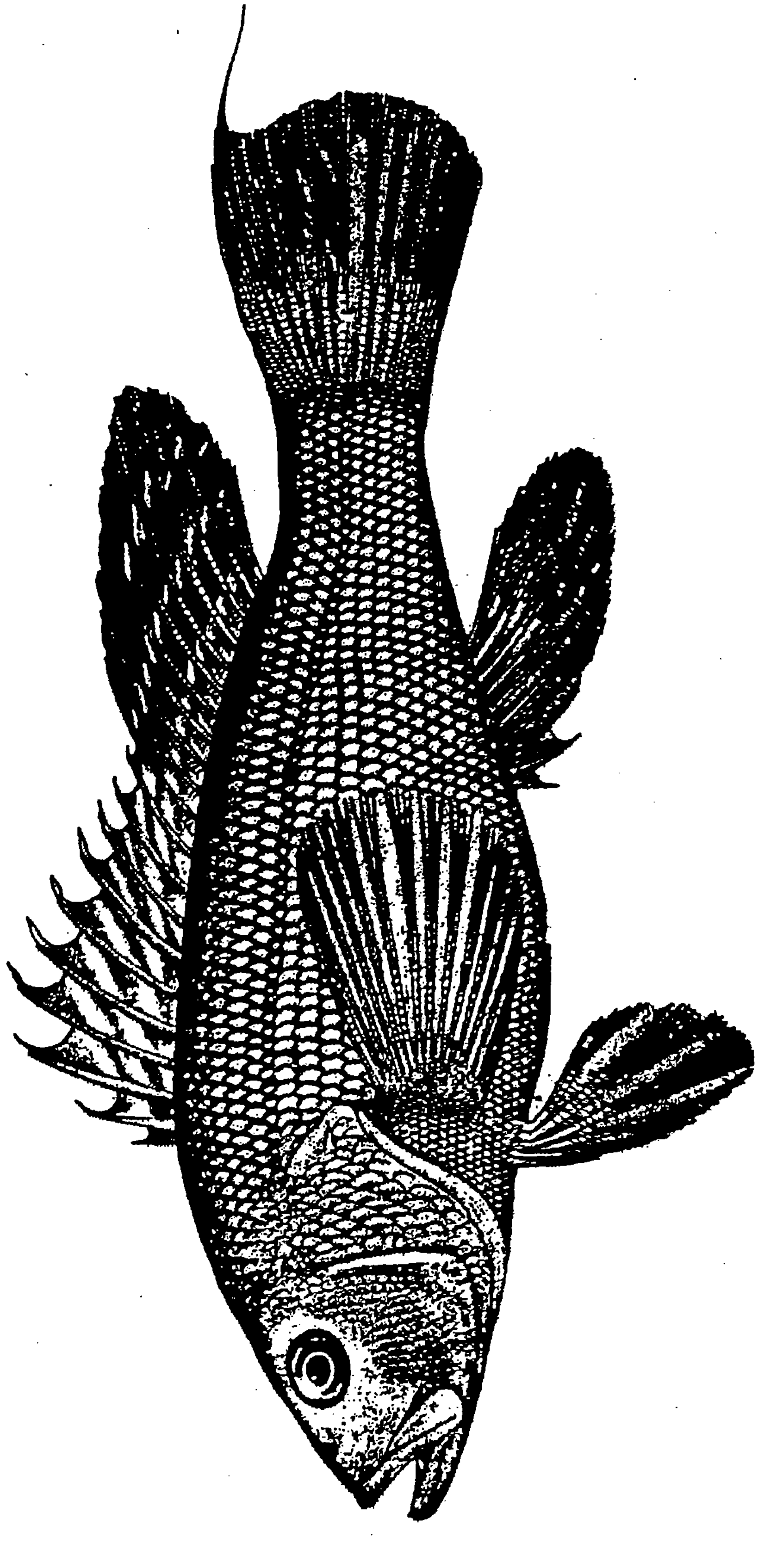
including sponges, hard and soft corals, and algae. The depth ranges from 15 to 21 m with sandy troughs and limestone ledges of up to two meters high running northeast to southwest (Hunt 1974 in Parker et al. 1994). Its rich faunal cover and rock outcrops provide excellent habitat for many species of fishes, including black sea bass, vermilion snapper (*Rhomboplites aurorubens*), and gray triggerfish (*Balistes capriscus*) (Johnson et al. 1985). The relatively accessible location and rich fish population provide excellent opportunities for recreational fishing and diving, especially for smaller boat owners who cannot fish reefs 60 to 80 km offshore. Commercial trap-fishing is not allowed on Gray's Reef (Johnson et al. 1985).

Taxonomy and Morphology

The black sea bass is a member of the class Osteichthyes, order Perciformes and family Serranidae (sea basses and groupers; Figure 2). The family is characterized by three opercular spines, one spine and five soft rays in the pelvic fin, three spines in the anal fin, and a continuous lateral line (Gilligan 1989). Other common names include blackfish, black bass, and black will (Gordon 1977).

Morphological features of black sea bass are as follows: continuous dorsal fin with 10 spines and 11 soft rays, anal fin with 3 spines and 7 soft rays, 17 to 18 pectoral rays, and gill rakers plus tubercules numbering

Figure 2. Black sea bass (*Centropristis striata*), 203 mm total length.



between 22 to 28 (20-29). The caudal fin is rounded in juveniles and most females and trilobed in older fish (mostly males). Scales are large with 47 (46-49) lateral line scales. The body is robust with a large head and the dorsal region is slightly elevated anteriorly. The snout is moderately pointed and the mouth is large and oblique. Spawning males develop adipose humps on their napes. Live black sea bass may appear smoky gray, dusky brown, or black-blue dorsally with a gradual ventral lightening. Scale centers appear light blue or white with longitudinal stripes along the backs and sides. Lateral sections may be mottled or have vertical crossbars (Johnson et al. 1985; Robins and Ray 1986). Breeding males display brilliant tints of fluorescent blue and green around the head and nape and are often referred to as "greenheads". Females are lighter in color, usually brown or gray. Juveniles have been described in four color phases: dark with white specks, light gray with dark specks, striped with one horizontal stripe and barred with six vertical bars (Miller 1959; Kendall 1977; Robins and Ray 1986; Gilligan 1989).

Biogeographic Region and Habitat

The black sea bass is primarily a nearshore reef fish. It is the dominant species associated with the nearshore live-bottom and artificial reef habitats found in the South Atlantic Bight. Black sea bass form a smaller segment of the population at deeper offshore reefs located more than sixty km off the Georgia coast. They have been observed along the entire Atlantic Bight from Maine to the Florida Keys (Cupka et al. 1973; Waltz et al. 1979). A subspecies, *Centropristis striata melana*, occurs along the northern and eastern coasts of the Gulf of Mexico. The greatest concentrations of black sea bass are found from Cape Cod, Massachusetts to Cape Canaveral, Florida (Miller 1959). Habitat depths range from 8 to 55 m (Musick and Mercer 1977; Parker et al. 1979).

Two separate populations of black sea bass are theorized to exist along the Atlantic coast with the distinction point being Cape Hatteras, North Carolina (South Atlantic Fishery Management Council 1978). The main area of difference between the populations is migration patterns. The northern population migrates southeast to deeper, offshore waters during the winter months and northwest into inshore water in the spring. This phenomenon is typically not observed in black sea bass from waters south of Cape Hatteras, where water temperatures rarely approach the sea bass' lower tolerance level of 10°C (Cupka et al. 1973). Although no seasonal migration is observed in waters below Cape Hatteras, past studies have noted an increase in the average size and age of black sea bass sampled in deeper, more distant offshore areas (Cupka et al. 1973; Musick and Mercer 1977; Waltz et al. 1979). It is suggested this phenomenon is caused by a gradual offshore movement of larger fish (Musick and Mercer 1977; Waltz et al. 1979; Wenner et al. 1986), but more likely reflects a reduction in fishing pressure with greater distances from shore.

Life History

Black sea bass are incompletely metagonous, protogynous hermaphrodites (Lavenda 1949). The majority of the young appear as females and undergo a gradual transition to males. This transition usually occurs when the fish are two to six years of age, primarily after the spawning period. Black sea bass mature between the ages of one and four. During this period, sea bass range in length from 100 to 250 mm. The highest percentage of females are three years old or less and measure 150 mm or less. The highest percentage of males are five years old or more and measure 230 mm or more (Mercer 1978; Wenner et al. 1986). Total lengths of black sea bass on Gray's Reef range from 75 mm to 475 mm. Average weight is about 0.9 kilograms with a maximum weight of 3.5 kilograms (Johnson et al. 1985).

Time and length of the spawning period are dependent on the area of the Atlantic Bight in which they are found. Black sea bass in the North Atlantic and Mid-Atlantic Bights spawn from June to October in waters from 18 to 45 m (Kendall 1972; Grosslin and Azarovitz 1982). In the South Atlantic Bight, spawning has been observed from January to

June, peaking in early March through May (Cupka et al 1973). A minor spawn occurs in September and October along the South Atlantic coast (Smith 1965).

Black sea bass are classified as quasi-catadromous, marine pelagic fish (Grosslin and Azarovitz 1982). Depending on their location along the Atlantic coast, sea bass may spawn in inshore estuaries or on offshore reefs. Although the eggs have been observed to be pelagic (Wilson 1891; Kendall 1972), little else is known about the early life history. Eggs are about 1 mm in diameter and hatch in 75 hours at 16°C. Larvae greater than 13 mm in length have not been collected, suggesting a short pelagic existence and a switch to a estuarine or demersal habitat (Kendall 1972). Although juveniles have been found in saline estuaries from Florida to Massachusetts and on offshore reefs, little is known about the routes or mechanisms of larval transport or what portion of the adult population remain at sea.

Juveniles have been observed in both inshore and offshore areas. Juvenile black sea bass have been collected in the estuaries of the Carolinas in water salinities ranging from 1 to 38 parts per thousand (ppt) and in water temperatures ranging from 6 to 30 °C (Kendall 1977). Juveniles congregate inshore around jetties, piers, and wrecks. In Georgia, young-of-the-year fish have been sampled throughout the year around oyster shell mounds found at the lowest reaches of estuaries (Music and Pafford 1984).

Commercial and Recreational Fisheries

Black sea bass are considered an important commercial and recreational fish in Mid-Atlantic and South Atlantic ports. Commercial landings rose rapidly after 1960 with the introduction of baited wire traps into the fishery (Frame and Pearce 1973; Low 1982). Commercial landings are much higher and of a greater economic importance along the Middle Atlantic Bight, due primarily to the propensity of nearshore natural reefs. Because the majority of reefs found in South Carolina, Georgia and North Florida are artificial and are therefore off limits to commercial fishing because of the danger of overfishing, commercial fishing is more limited in the South Atlantic Bight (Stone 1978; Parker et al. 1979; Stone et al. 1979; Stone 1982).

Commercial fisheries for black sea bass differ in the Mid-Atlantic and South Atlantic regions. The Mid-Atlantic fishery operates from May to December. Fishermen use 400 to 1,500 unbaited wooden slat lobster traps that are set for the entire season. The traps are set in transects of 15 to 20 traps with approximately 200 traps visited each day. The majority of the trawl fishery is located north of Cape Hatteras. Black sea bass are an incidental catch in the snapper-grouper handline fishery in the Mid-Atlantic Bight (Frame and Pearce 1973; Kendall 1977; Briggs 1978). In the South Atlantic Bight, a small trawl and handline fishery exists; however, the primary mode of harvest are baited wire crab traps. A year-round fishery exist along the 18 m contour. Highest landings are reported in winter and spring due to additional participation of offseason shrimp fishermen. Traps are deployed over live-bottom reefs and allowed to set for 20 to 45 minutes (Rivers 1966; McDonald 1974). Georgia contributes nominally, averaging 5.5 metric tons, to the South Atlantic commercial landings mean total of 467 metric tons from 1950 - 1984 (Fishery Statistics of the United States in Mercer 1989).

The development of more sophisticated boats and equipment and the popularity of the charterboat/partyboat fishery has caused an increase in the recreational catch of black sea bass. Based on charter boat and partyboat landings, black sea bass make up the majority of the North Carolina offshore reef fishery (75% by number and 64% by weight) and are second to red porgy in the inshore reef fishery (Struhsaker 1969; Chester et al. 1984). In Georgia, where artificial reefs and natural reefs less than 40 km from shore receive the bulk of the offshore fishery, black sea bass are considered the dominant recreational reef fish (Ansley and Harris 1981; Johnson et al. 1985)

Management of the Species

Management regulations for black sea bass caught in the Fishery Conservation Zone (the area in which the United States asserts exclusive fishery management authority and which extends 3 to 200 nautical miles [nmi] offshore) were established in the Fishery Management Plan for the snapper-grouper fishery of the South Atlantic Region (South Atlantic Fishery Management Council 1983). All species included in the management plan are used in commercial and recreational fisheries exclusively for human consumption. Based on a yield-per-recruit analysis which indicated a less than maximum harvest due to growth overharvesting, a minimum size limit of 203 mm (8 inches) was adopted for black sea bass. Restrictions on fish trap dimensions and trapping areas include a minimum mesh size of 25.4 mm by 50.8 mm (rectangular) or 38.1 mm (hexagonal) and closure of commercial fishing on marine sanctuaries, including Gray's Reef, and artificial reefs (South Atlantic Fishery Management Council 1988).

Objectives of a successful management strategy include the maintenance of healthy female-to-male sex ratios and age-to-size ratios in the population, a positively skewed age structure represented by several age classes, and sufficient recruitment and spawning (Low 1981). Although the minimum size limit of 203 mm allows black sea bass to reach sexual maturity and spawn at least one year as females, the reproductive history (female ---> male) of the fish also insures that a majority of black sea bass harvested will be males. Heavy fishing pressure may create a sex ratio which favors females, thus leaving an insufficient number of males for adequate reproduction (Musick and Mercer 1977). They theorized, within an exploited population, maintenance of a relatively constant sex ratio is initiated by social interactions within the population in which females undergo sexual metamorphosis to males at younger ages and smaller sizes. This phenomenon would be evidenced by higher incidence of small males within the population. Wenner et al. (1986), however, disagreed with this theory and described the primary source of males as being sex succession from mature females. They based their arguments on the presence of significantly skewed sex ratios towards females in early age groups, even though mortality rates were high (annual mortality > 0.5).

II. MATERIALS AND METHODS

Background/Selection of Sampling Sites

A mark and recapture study of black sea bass was conducted at twenty sites on Gray's Reef National Marine Sanctuary (See Appendix A for LORAN-C coordinates of stations). Sampling was done from the R/V Underdog, a 12 m "commercial lobster trapping"-type boat.

Preliminary samples were taken in April 1988 to determine the sample sites for the project. Fish captured during this period were used only in the age and growth portions of the study. Subsequent sampling periods were conducted at three-month intervals through May 1989. Sample sites were selected through the use of a Si-Tex chart recorder/depth recorder. A Si-Tex XJ-1 LORAN-C navigation unit (Texas Instruments Co.) was used to locate each sampling station. LORAN coordinates in time displacement (TD) units were used to delineate each station. Stations were selected on the basis of their topography and proximity to the boundaries of the reef proper. Locations near the reef boundary were preferred because their location enabled sampling of both sandy bottom and live bottom areas. This sampling strategy was needed to demonstrate not only suitable black sea bass habitat, but also to observe the range of migration off the reef and the "drawing" power of the baited sampling traps. The type of topography selected was medium substrate (ledge and live bottom; "washboard bottom") of more than 0.5 m relief with abundant faunal growth. This type of substrate is most often fished by commercial and recreational fishermen (Rivers 1966).

Small mesh (12.5 mm by 12.5 mm square mesh) traps measuring 610 mm by 610 mm by 460 mm were used to insure sampling over all size classes. Both small mesh and large mesh (63.5 mm by 38.1 mm hexagonal mesh) traps of the same dimensions were initially used in the study. The large mesh traps, however, yielded extremely low capture rates for black sea bass smaller than 205 mm (Table 1).

Trapping Method and Data Collection

Three sampling transects were utilized with six to eight traps per transect. Each trap was located at least 185 m (1.0 LORAN-C TD unit) from the other traps. Traps were set on the first morning and left undisturbed for 2 to 4 hours before the first sample was taken. They were retrieved again in the late afternoon after which they were allowed to set overnight. The traps were fished twice the second day, set to fish overnight and then retrieved at least once the third day.

Fish were captured and tagged on the first sampling day (usually a Friday) and recaptures were monitored over the next two days. A second recapture effort was conducted one

Table 1.-Mean catch rates ± SD (number of fish/trap set) by size-at-age classes of black sea bass captured with small mesh and large mesh traps, medium relief, Gray's Reef, Georgia, July 1988. Within each size-at-age class, means down a column without a letter (a, b) in common are significantly different (Tukey's, $P \leq 0.05$). If none of the values were different, letters are omitted.

Trap Mesh Type	Size-at-Age Class						Total
	1	2	3	4	5	6	
	< 131 mm	≥ 131 mm < 205 mm	≥ 205 mm < 280 mm	≥ 280 mm < 328 mm	≥ 328 mm < 359 mm	≥ 359 mm	
small mesh (n = 92)	6.26 a ±6.67	5.21 a ±5.17	3.78 a ±3.78	2.78 ±3.91	1.14 ±1.82	0.45 ±0.29	19.62 a ±12.28
large mesh (n = 35)	0.11 b ±0.32	0.11 b ±0.40	1.38 b ±1.72	2.20 ±3.10	1.09 ±1.48	0.51 ±0.18	5.40 b ± 5.98

week later for 3 or 4 days. Initial recaptures from previous tagging seasons were treated as unmarked fish for population estimation purposes. All unmarked black sea bass were tagged on the recapture dates. All fish caught at the sample site remained in on-board live wells until all fish were tagged and measured. Ocean water was pumped into the livewell to maintain constant water conditions. Tagged fish were kept in the livewell for the extent of the tagging process (2 to 20 minutes) to determine the extent of fish mortality caused by handling. All fish were then released at the capture site with the custom-designed release cage. Tagged fish were lowered to the reef bottom in the cage. A trip mechanism was released to open one side of the cage, which allowed the tagged fish to swim free. The cage was then retrieved to the boat.

Mortality of black sea bass attributable to tagging was tested for fish less than 203 mm (sublegal-size) and fish greater than or equal 203 mm (legal-size). During each season, at least 20 tagged sublegal-size fish and 10 tagged legal-size fish were held overnight (about 24 hours) in separate traps with closed entry holes. Upon retrieval of the trap, the number of dead fish were counted. Tagging mortality was calculated as percentage of dead sea bass to number held overnight.

Information recorded from each sample site included date, location of site (LORAN-C TD coordinates), water temperature, depth, sea state [eg., "choppiness" (wave action and size), such as smooth, light chop, or heavy chop], wind speed and direction, percent mortality in trap and in the live well, tag number of fish, length of fish, number of black sea bass, and number of recaptures. Fish were measured to the nearest millimeter from the tip of the mandible to the end of the longest median rays of the caudal fin [maximum total length; TL] (Anderson and Gutreuter 1983). Individually discrete tags (Floy FD-68B t-lock tags) were used to mark the fish and each tag number was recorded (Emery and Wydoski 1983). Floy streamer tags were originally used in the study. These tags had very low retention rates and caused handling stress for fish and biologist during the tagging process.

Determination of the age and sex distribution of the black sea bass population for each season was also conducted. Sixty black sea bass were kept on the final day of each sampling season. Twelve fish from five size classes were randomly selected. The size classes were in fifty millimeter increments beginning with fish less than 150 mm to fish greater than 300 mm. Although scales and otoliths were removed and examined, age determination was based solely on otolith readings. Gonads were extracted and used to determine sex and state of maturation.

<u>Length Distribution</u>

Length frequency distributions (number and percent frequency by 10-mm groups) were calculated for each season by sample period (day or night). The 10-mm groups were defined as follows: 0-mm group = 1 - 5 mm TL, 10-mm group = 6 - 14 mm TL, and so on. Log-likelihood ratios were used to determine if differences in black sea bass size composition existed between seasons (Zar 1984). Tukey's post hoc multiple-range test was employed to test between which seasons differences occurred (Zar 1984). Differences were considered significant at $P \leq 0.05$. Data were analyzed using the SYSTAT® statistical package (Wilkinson 1990).

<u>Age Structure and Growth Rates</u>

Validation of the use of otoliths as an satisfactory aging tool for black sea bass was performed by Cupka et.al (1973) and Mercer (1978) using the Van Oosten criteria (1929). Annulus formation occurs during the spawning period (Cupka et. al 1973; Mercer 1978). Data from past life history studies of black sea bass in the South Atlantic Bight have shown from seven (Cupka et. al 1973) to ten age classes (Waltz et. al 1979). These studies, however, may have been biased by sampling size and by the sampling locations (Cupka et. al 1973; Mercer 1978). A majority of the fish used in these studies were collected from reefs which received relatively light fishing pressure (e.g., areas may be inaccessible to small boat owners or difficult to locate). Although this type of sampling is suitable for basic life history studies, it does not provide information describing more heavily exploited areas in need of stringent management.

A total of 278 pairs of sagittal otoliths were examined for age determination, but only 246 otolith pairs were determined satisfactory for use. Otoliths were removed by cutting the gill isthmus and bending back the head, thereby cracking the auditory lobe to expose the otoliths. Once removed, otoliths were cleaned and stored dry in 120 mm by 60 mm coin envelopes. One week prior to examination, otoliths were placed in labeled 5 ml sampling vials and covered with glycerin to allow them to clear (Jearld 1983). When they had cleared, otoliths were removed from the vials, placed concave side up in a black dish, and covered with water. They were examined over a dark field under transmitted light with an American Optical dissecting scope at 12X magnification (Waltz et al 1979). Age was determined by counting the opaque zones (alternating with translucent bands) from the center kernel (age zero) to the dorsal margin (Cupka et. al 1973; Mercer 1978). From each fish, both sagittal otoliths were used to determine age. A standardized January birth date was used.

Two measures of growth were determined: annual growth using linear regression of otolith annulus radii (Ricker

1973) and direct calculation of daily growth from recapture data. Growth rates were determined from the 246 otolith pairs used for ageing and 756 black sea bass recaptured in sample traps during the study. Growth rates were for total maximum length.

Correlation between length and annulus radius was also determined. Annulus radii were measured using an ocular micrometer of an American Optical dissecting scope at 12X magnification. The radius of each ring was taken from the kernel to the outer edge of each annulus (Jearld 1983). A regression equation was then formulated to predict length-at-age from annulus radii and to correlate the relationship between body growth and otolith growth.

To compare growth results for this study in which total length was measured with studies in which standard length was measured, I used means of the results from Cupka et al.'s (1973) and Waltz et al.'s (1979) equations, which converted total length to standard length. The Cupka et al. (1973) equation is described as follows: $SL = 0.742\ (TL) + 9.4$ [$r = 0.997$], and Waltz et al.'s (1979) equation was: $SL = 0.7387\ (TL) + 8.179$ [$r = 0.97$], where SL represents standard length in millimeters and TL represents total length in millimeters.

Daily growth rates were determined by subtracting length at recapture from length at original capture and divided by the days at large. Age classes as determined by back-calculated length-at-age at time of original capture were separated and growth rates were calculated for each group. Growth rates, expressed in millimeters per day, were determined from season to season (spring 1988 to summer 1988, summer 1988 to fall 1988, fall 1988 to winter 1989, winter 1989 to spring 1989). One-way analysis of variance was used to determine if differences in daily growth rates existed between time periods or age groups (Zar 1984). Tukey's post hoc multiple-range test was employed to test between which groups differences occurred (Zar 1984). Significant differences were reported at $P \leq 0.05$.

Sex Structure and Spawning Patterns

Gonads were removed from sample fish within six hours of collection to diminish the effect of enzymatic degradation. Twelve fish from each 50-mm size class were examined each quarter, totaling 278 fish over the study period. Fish were examined for external sex characteristics [e.g., hump on the head, pronounced tri-lobed tail, very dark coloration (male), or presence of milt (male) or eggs (female) emitted from anal area] to check on-board sexing procedure and to obtain a general idea of the fish's sex. Fish were sliced open behind the pelvic and pectoral fins up to the crown of the head using a fillet knife or scalpel. Dissecting scissors were used to cut from the point of incision to the anal opening. The visceral contents were carefully removed, exposing the gonads along the top of the visceral cavity. This operation was probably aided by a compression and subsequent concentration of the visceral contents by the swim bladder which often expanded due to a lower atmospheric pressure at the surface when the fish were brought up from the reef. The gonads were grossly examined immediately for sex determination, wrapped in tagged gauze and placed in 10% buffered formalin. They were re-examined using an American Optical dissecting scope several days after removal. The fish were determined to be in one of five classes (key characters):

1) male/mature (testes: smooth, compressed; visual blood vessels),
2) male/ripe (presence of milt; milk-white, plump),
3) female/mature (development of ovaries; round, gray to light orange color),
4) female/gravid (presence of eggs, bright orange with rough or pebbly appearance),
5) immature (undifferentiated gonadal tissue).

Migration (on-reef and off-reef)

Movement of black sea bass on Gray's Reef was determined from recapture data derived from sample traps and recovery data from recreational anglers. On-reef migration was defined as any recapture which occurred more than 0.5 LORAN-C TD unit away from the original capture site.

Movement was determined for each season (within-season migration) and from season to season (between-season migration). Off-reef migration was estimated from recovery data obtained from recreational fishermen. Extent of migration was measured as the percentage of black sea bass that moved from the original capture site (on-reef migration) or away from Gray's Reef (off-reef migration). Chi-square analysis was performed to determine randomness of on-reef movement (Zar 1984). In theory, a black sea bass should have a 50% chance of being recaptured in the trap in which it was previously captured and a 50% chance of being captured in any of the other sample traps. Chi-square test values greater than the critical value at $P \leq 0.05$ were significant and movement was deemed non-random.

III. RESULTS AND DISCUSSION

A total of 8,915 black sea bass were captured in 451 trap-sets over five sampling quarters (spring 1988 to spring 1989). Of these fish, 7,465 fish were tagged and 1,440 individuals were recaptured (single and multiple). A total of 756 fish were recaptured from previous seasons. A total of 278 black sea bass from five size classes were kept as samples for use in ageing and sexing the population. A total of 52 species representing 28 families were captured in sample traps or with rod and reel from Gray's Reef (Appendix B).

Fish size and catch total in each trap varied among sets. The lengths of black sea bass ranged from 53 mm to 406 mm. A fish measuring 458 mm was sampled with rod and reel. Mean length of all fish was 194.4 mm (SD = 63.1). The catch total ranged from 0 fish in several sets to 83 fish. Mean catch rate for all traps was 19.7 (SD = 10.2).

In test sets made to compare catches between medium relief and low relief (sand; < 0.5 m relief) sets, medium relief sets provided much higher catches for all size classes of black sea bass. Medium relief sets averaged 19.50 (SD = 9.61) black sea bass per trap, and low relief sets averaged 0.26 (SD = 0.13) black sea bass (Table 2).

Table 2.-Mean catch rates ± SD (number of fish/trap set) by size-at-age classes of black sea bass captured over low-relief and medium-relief substrate with small mesh traps, Gray's Reef, Georgia, April and July 1988. Within each size class, means along a column without a letter (a, b) in common are significantly different (Tukey's, $P \leq 0.05$).

Reef Relief Type	Size-at-Age Class 1 < 131 mm	2 ≥ 131 mm < 205 mm	3 ≥ 205 mm < 280 mm	4 ≥ 280 mm < 328 mm	5 ≥ 328 mm < 359 mm	6 ≥ 359 mm	Total
low (n = 17)	0.22 a ±0.12	0.04 a ±0.02	0 a	0 a	0 a	0 a	0.26 a ± 0.13
medium (n = 85)	5.24 b ±2.34	5.66 b ±1.45	4.15 b ±1.54	3.09 b ±1.21	1.03 b ±0.43	0.33 b ±0.18	19.50 b ± 9.61

Differences in abundance and size composition were observed between day and night sets within each season. Day sets resulted in higher relative proportions of small black sea bass with mean lengths ranging from 144.8 mm (SD = 49.4) in summer to 169.5 mm (SD = 64.5) in winter (Table 3). Night sets resulted in higher proportions of larger fish with mean lengths ranging from 203.4 mm (SD = 53.7) in spring 1989 to 221.4 mm (SD = 68.7) in summer (Table 3). Possible reasons for these differences include smaller fish may escape from traps set over night, activity of smaller sea bass may be greater during the day, or larger fish may be more active at night. Wenner (1983) reported black sea bass were more common in otter trawl tows conducted at night versus daylight tows because of sea bass' increased vulnerability to night tows. Comparisons between seasons were done separately for day and night sets.

Length Distribution

Analysis of black sea bass length frequency for day sets revealed shifts in modal peaks from season to season. Two modal peaks were readily identifiable. Modal peaks were indicated at the 100-mm and 160-mm groups in summer, the 110-mm and 170-mm groups in fall, the 140-mm group in winter, and 160-mm group in spring (Figure 3). Differences in length frequency distributions were significant only in summer in which mean length (144.8 mm, SD = 49.4 mm) was

Table 3.-Length frequency of black sea bass by capture time period and sample quarter for black sea bass collected in small mesh traps, Gray's Reef, Georgia, July 1988 (summer) - May 1989 (spring). Differences in length frequency and mean total length between capture time periods were analyzed using log-likelihood ratios (G-statistic) and Tukey's test, respectively. Between capture time periods, means without a letter (a, b) in common are significantly different ($P \leq 0.05$).

Size Class (10 mm)	SUMMER			FALL		
	Day	Night	Total	Day	Night	Total
50	0	1	1	0	0	0
60	1	0	1	0	0	0
70	9	1	10	0	0	0
80	33	8	41	6	0	6
90	78	20	98	13	4	17
100	129	45	174	53	10	63
110	44	17	61	98	39	137
120	12	5	17	78	65	143
130	22	4	26	25	18	43
140	56	36	92	26	21	47
150	72	52	124	49	34	83
160	104	53	157	73	67	140
170	83	55	138	97	90	187
180	39	30	69	89	79	168
190	16	20	36	35	52	87
200	16	30	46	18	21	39
210	17	36	53	12	25	37
220	16	44	60	22	41	63
230	10	65	75	20	57	77
240	17	58	75	27	68	95
250	8	72	80	20	78	98
260	3	63	66	15	68	83
270	5	40	45	12	47	59
280	1	34	35	12	47	59
290	2	47	49	4	19	23
300	3	33	36	6	20	26
310	2	34	36	5	25	30
320	2	25	27	6	19	25
330	2	24	26	2	10	12
340	1	14	15	4	6	10
350	0	13	13	0	4	4
360	1	4	5	0	3	3
370	0	3	3	1	1	2
380	0	3	3	0	0	0
390	0	0	0	0	1	1
Total	804	989	1,793	828	1,039	1,867
Mean Length (±SD)	144.8 (±49.4) a	221.4 (±68.7) b		166.8 (±54.4) a	210.0 (±60.6) b	

G statistic = 639.1
$P < 0.001$ (df = 33)

G statistic = 280.7
$P < 0.001$ (df = 30)

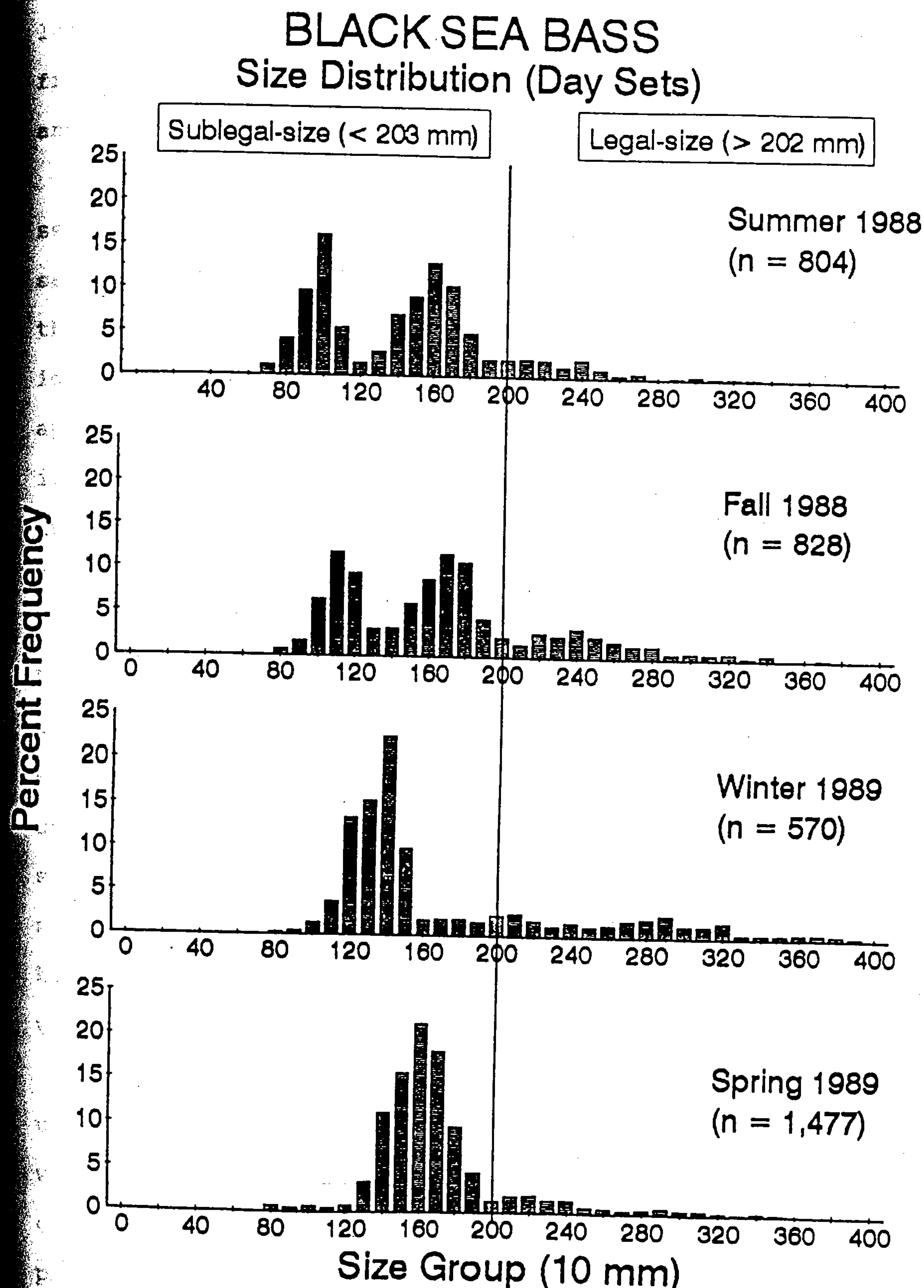
Table 3.-cont.

Size Class (10 mm)	WINTER Day	WINTER Night	WINTER Total	SPRING Day	SPRING Night	SPRING Total
50	0	0	0	0	0	0
60	0	0	0	0	0	0
70	0	0	0	0	0	0
80	1	0	1	10	1	11
90	2	0	2	8	2	10
100	8	1	9	10	3	13
110	22	5	27	6	1	7
120	77	15	92	12	2	14
130	88	52	140	52	16	68
140	128	129	257	167	55	222
150	57	57	114	234	76	310
160	10	36	46	316	107	423
170	11	39	50	270	86	356
180	11	43	54	144	58	202
190	9	77	86	68	29	97
200	13	99	112	19	23	42
210	14	108	122	28	48	76
220	10	111	121	30	41	71
230	6	72	78	20	60	80
240	9	71	80	21	38	59
250	7	73	80	10	28	38
260	8	65	73	9	29	38
270	11	86	97	5	23	28
280	12	83	95	6	28	34
290	15	61	76	10	30	40
300	8	55	63	8	17	25
310	8	43	51	6	15	21
320	10	24	34	3	6	9
330	2	25	27	1	4	5
340	2	11	13	3	3	6
350	2	8	10	1	6	7
360	3	6	9	0	0	0
370	3	11	14	0	1	1
380	2	3	5	0	1	1
390	1	1	2	0	0	0
Total	570	1,470	2,040	1,477	837	2,314
Mean Length (±SD)	169.5 (±64.5) a	224.2 (±59.1) b		167.9 (±34.8) a	203.4 (±53.7) b	

G statistic = 537.4
P < 0.001 (df = 31)

G statistic = 383.1
P < 0.001 (df = 29)

Figure 3. Percent frequency of black sea bass captured in small (12.5 mm) mesh traps, day sets, 10 mm groups, Gray's Reef, Georgia, July 1988 (summer) - May 1989 (spring).



BLACK SEA BASS
Size Distribution (Day Sets)
Sublegal-size (< 203 mm)
Legal-size (> 202 mm)
Summer 1988
(n = 804)
Fall 1988
(n = 828)
Winter 1989
(n = 570)
Spring 1989
(n = 1,477)
Percent Frequency
Size Group (10 mm)

lower compared to the other seasons (Table 4). Percent frequency of legal-size sea bass ranged from 10.7% in spring and 11.2% in summer to 20.3% in fall and 23.2% in winter.

Analysis of black sea bass length frequency for night sets revealed more demonstrative modal peaks from season to season than did day sets, although peaks were similar for the two sample set periods. Four modal peaks were identified; however, fish represented by the first two modes appear to be underrepresented. Modal group peaks were indicated at the 100-mm, 160-mm, 250-mm, and 290-mm groups in summer, the 120-mm, 170-mm, 250-mm, and 310-mm groups in fall, the 140-mm, 220-mm, and 270-mm groups in winter, and 160-mm, 230-mm, and 290-mm groups in spring (Figure 4). Differences in length frequency distributions as determined by log likelihood ratios and mean length values were significant between the summer (mean = 221.4 mm, SD = 68.7) and winter (mean = 224.2 mm, SD = 59.1 mm) periods and the spring (mean = 203.4 mm, SD = 53.7) and fall (mean = 210.0 mm, SD = 60.6) (Table 5). Percent frequency of legal-size black sea bass ranged from 45.2% in spring to 62.4% in winter.

Black sea bass were not fully recruited to the sample until they reached the 100-mm group; smaller fish, however, were frequently captured in day sets. These fish were most common in the summer, which suggests they were spawned the previous winter. Fish of this size were also collected in

Table 4.-Length frequency of black sea bass by sample quarter for black sea bass collected in small mesh traps, day sets, Gray's Reef, Georgia, July 1988 (summer) - May 1989 (spring). Differences in length frequency and mean total length between seasons were analyzed using log-likelihood ratios (G-statistic) and Tukey's test, respectively. Between seasons, means without a letter (a, b) in common are significantly different ($P \leq 0.05$).

	SEASON				
Size Class (10 mm)	SUMMER	FALL	WINTER	SPRING	TOTAL
60	1	0	0	0	1
70	9	0	0	0	9
80	33	6	1	10	50
90	78	13	2	8	101
100	129	53	8	10	200
110	44	98	22	6	170
120	12	78	77	12	179
130	22	25	88	52	187
140	56	26	128	167	377
150	72	49	57	234	412
160	104	73	10	316	503
170	83	97	11	270	461
180	39	89	11	144	283
190	16	35	9	68	128
200	16	18	13	19	66
210	17	12	14	28	71
220	16	22	10	30	78
230	10	20	6	20	56
240	17	27	9	21	74
250	8	20	7	10	45
260	3	15	8	9	35
270	5	12	11	5	33
280	1	12	12	6	31
290	2	4	15	10	31
300	3	6	8	8	25
310	2	5	8	6	21
320	2	6	10	3	21
330	2	2	2	1	7
340	1	4	2	3	10
350	0	0	2	1	3
360	1	0	3	0	4
370	0	1	3	0	4
380	0	0	2	0	2
390	0	0	1	0	1
Total	804	828	570	1,477	3,679
Mean Length (±SD)	144.8 (±49.4) a	166.8 (±54.4) b	169.5 (±64.5) b	167.9 (±34.8) b	

G statistic = 1,635.8 degrees of freedom = 99

$P < 0.001$ Index of dissimilarity = 25.6

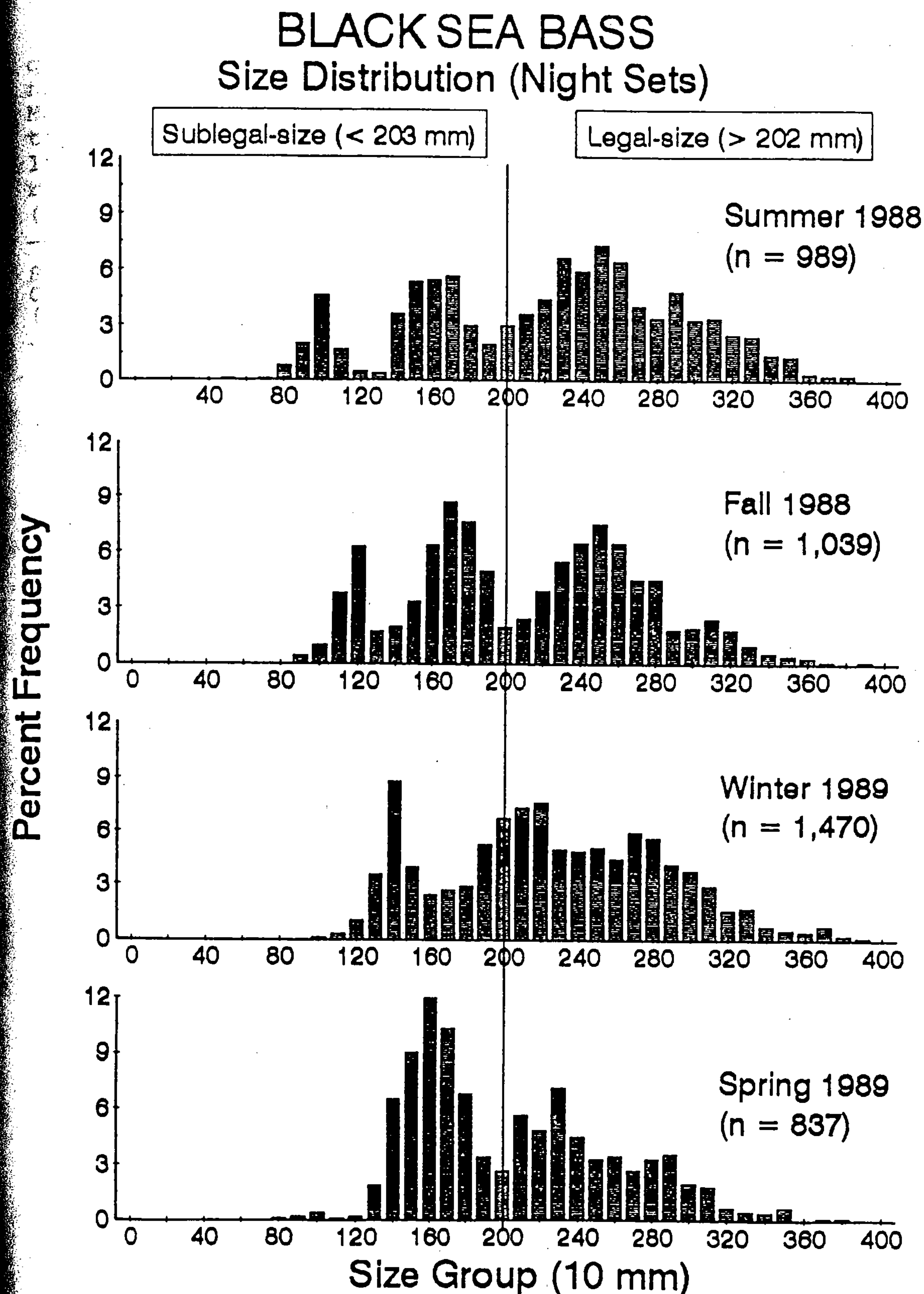

BLACK SEA BASS
Size Distribution (Night Sets)
Sublegal-size (< 203 mm)
Legal-size (> 202 mm)
Summer 1988
(n = 989)
Fall 1988
(n = 1,039)
Winter 1989
(n = 1,470)
Spring 1989
(n = 837)
Percent Frequency
Size Group (10 mm)
0
3
6
9
12
0
40
80
120
160
200
240
280
320
360
400

Table 5.-Length frequency of black sea bass by sample quarter for black sea bass collected in small mesh traps, night sets, from Gray's Reef, Georgia, July 1988 (summer) - May 1989 (spring). Differences in length frequency and mean total length between seasons were analyzed using log-likelihood ratios (G-statistic), and Tukey's test, respectively. Between seasons, means without a letter (a, b) in common are significantly different ($P \leq 0.05$).

Size Class (10 mm)	SEASON				
	SUMMER	FALL	WINTER	SPRING	TOTAL
50	1	0	0	0	1
60	0	0	0	0	0
70	1	0	0	0	1
80	8	0	0	1	9
90	20	4	0	2	26
100	45	10	1	3	59
110	17	39	5	1	62
120	5	65	15	2	87
130	4	18	52	16	90
140	36	21	129	55	241
150	52	34	57	76	219
160	53	67	36	107	263
170	55	90	39	86	270
180	30	79	43	58	210
190	20	52	77	29	178
200	30	21	99	23	173
210	36	25	108	48	217
220	44	41	111	41	237
230	65	57	72	60	254
240	58	68	71	38	235
250	72	78	73	28	251
260	63	68	65	29	225
270	40	47	86	23	196
280	34	47	83	28	192
290	47	19	61	30	157
300	33	20	55	17	125
310	34	25	43	15	117
320	25	19	24	6	74
330	24	10	25	4	63
340	14	6	11	3	34
350	13	4	8	6	31
360	4	2	6	0	13
370	3	1	11	1	16
380	3	0	3	1	7
390	0	0	1	0	2
Total	989	1,039	1,470	837	4,335
Mean Length (±SD)	221.4 (±68.7) a	210.0 (±60.6) b	224.2 (±59.1) a	203.4 (±53.7) b	

G statistic = 923.3 degrees of freedom = 99
P<0.001 Index of dissimilarity = 17.6

spring of the following year, which is indicative of a long spawning season. Highest numbers of young-of-the-year were observed during summer and fall. Catch totals of second-year fish were highest in spring and fall. In those size classes greater than 203 mm, spring yielded the lowest catch rates. Fall and winter periods had the highest catch rates of legal-size fish.

The smallest fish were collected during the summer and are representative of young-of-the-year black sea bass. The smallest fish of the year-2 fish were collected during the spring. This pattern and the shading of several size groups around modal peaks was the result of the extended spawning period (February to July) displayed by black sea bass in South Atlantic waters. In those size classes larger than the 200-mm group, no differences were observed between seasons. This homogeneity of sizes within the classes may be caused by an "equalization" pressure on larger black sea bass by a size limit of 203 mm on recreational harvesting. The smaller fish were not subject to fishing pressure. Seasonal size trends were also more noticeable in the smaller fish due to influx of young-of-the-year fish onto the reef over several months.

In areas of heavy fishing pressure (e.g., commercial fishing and inshore artificial reefs), differences in size composition have been observed between black sea bass caught in summer and black sea bass caught in winter (Low 1981).

Although age compositions were comparable, summer fish tended to be smaller than the winter fish, possibly due to the heavier fishing pressure and a subsequent increase in harvest of the larger, legal-size fish during the summer. In South Carolina, over 70% of sea bass harvest by recreational fishermen are taken from May through August and mean length of these fish barely exceeded 200 mm (Chester et al. 1984; Low and Waltz 1988; Low and Waltz 1991). In sparsely-fished areas, size and age composition were similar for summer- and winter-caught fish. The presence of commercial fisheries may also affect the size structure of black sea bass populations in other areas (Low 1981; Low 1982). However, restriction of commercial fishing in Gray's Reef National Marine Sanctuary discount its effect on sea bass harvest on the reef. In this study, mean lengths were not different between summer and winter for night-caught sea bass. Differences in mean length between summer and winter for day-caught fish were explained by the six months of additional growth for those fish captured in winter. The high numbers of YOY fish were not observed in winter as they were during the summer.

Age Structure and Growth Rates

Examination of otoliths confirmed studies by Cupka et al. (1973), Mercer (1978), and Waltz et al. (1979) in regard to annulus formation. Measurements of marginal increments demonstrated spring as the season having the highest incidence of annulus formation, although formation was also observed in otolith samples from winter. Gonadal examination revealed spring as the season having the highest percentage of gravid females and ripe males, thus further substantiating spring as the peak spawning and annulus formation period.

Six age classes were evident from examination of otoliths (Table 6). An age class as defined by Jearld (1983) was those "fish of the same calendar year, hatched in the same year". For example, fish in age class 1 represented fish of age 0+ (young-of-the-year) that have not formed their first annulus (up to their first birth date). No fish were observed with more than five annuli (i.e., no aged fish were six years or older.). Very few fish of sizes greater than those sampled for age determination were observed during the tagging and recapture phase of the study.

A predictive regression of length versus annulus radius (AR) for all sexes was formulated for all age classes ($TL = 103.6\ AR + 1.01$ [$r^2 = 0.98$]). Annual growth rates determined from back-calculated lengths (mm/year) were highest in the first year to 131 mm (Table 6). Black sea bass on Gray's Reef reached a harvestable size (205 mm) by their second birthday. Mean growth rates of age class 2 (75 mm) and age class 3 (73 mm) fish were similar. Fish in age

Table 6.-Mean total length (± SD) [TL (mm)] and mean annulus radius [AR (mm)] at age for black sea bass collected from Gray's Reef, Georgia, April 1988 - May 1989. Number and mean length at age of black sea bass by sex are included. Annulus radius is in parentheses. TL = 103.6 (AR) + 1.01; $r^2 = 0.98$.

Age Group	Sample Size	Mean Length at Capture	Mean Back-calculated Length-at-age 1	2	3	4	5	Sex: number captured by age (mean length at capture) Male	Female	Immature
1	25	114 (±26.6)						2 (115)	5 (117)	18 (113)
2	87	166 (±19.4)	132 (1.26)					9 (179)	52 (175)	26 (159)
3	79	241 (±29.7)	128 (1.23)	204 (1.96)				11 (257)	50 (248)	18 (225)
4	37	303 (±18.4)	130 (1.25)	202 (1.94)	275 (2.64)			15 (310)	18 (300)	4 (290)
5	13	344 (±24.3)	140 (1.34)	216 (2.08)	291 (2.80)	331 (3.19)		10 (348)	3 (331)	
6	5	367 (±10.2)	137 (1.31)	211 (2.03)	283 (2.72)	322 (3.10)	359 (3.46)	5 (367)		
Weighted Mean Length-at-Age			131 (1.26)	205 (1.97)	280 (2.69)	328 (3.16)	359 (3.46)			
Increments of Mean				74 (0.71)	75 (0.72)	48 (0.47)	31 (0.30)			
Weighted Mean Increment				75 (0.72)	73 (0.70)	40 (0.39)	37 (0.36)			
Growth by summation of mean increments			131 (1.26)	206 (1.98)	279 (2.68)	319 (3.07)	346 (3.43)			
Number of measurements			246	162	75	30	9			

classes 4 and 5 had lower growth rates of 48 and 31 mm, respectively.

Daily growth rates calculated from recapture lengths between season (mm/day) were also highest in year 1 fish (0.399 mm/day) (Table 7). Growth rates decreased with each increasing age class. Significant differences were detected between age class 1, age classes 2 and 3, age class 4, and age classes 5 and 6. No differences in daily growth rates within age classes were detected between seasons (Table 7); however, because sample size of age classes 1 and 2 from spring 1988 and summer 1988 tagging seasons were low due to poor tag retention in these fish, daily growth rates of those younger fish in spring and summer may not be adequately represented. Although extrapolated daily growth rates yielded annual growth rates slightly higher than those determined from back-calculated lengths, use of daily growth was helpful in determining if differences in growth existed between seasons.

Length-at-age data indicated day sets were dominated by age class 1 (TL $<$ 131 mm) and age class 2 (131 mm $\leq$ TL $<$ 205 mm) black sea bass (Table 8). Night sets were characterized by age class 2 and age class 3 (205 mm $\leq$ TL $<$ 280 mm) sea bass (Table 8). Age class 1 sea bass were not fully recruited to the traps for both day and night samples. Age class 2 fish (131 mm $\leq$ TL $<$ 205 mm) were not fully recruited

Table 7.-Mean growth rates ± SD (mm/day) for different age groups of black sea bass derived from recapture samples from Gray's Reef, Georgia, April 1988 - May 1989. Overall values include recaptures with days at large more than 200 (more than one quarter at large). Annual growth rates were extrapolated from daily growth rates by multiplying by 365.25. Within each age class, means along a row without a letter in common were significantly different; Within each time period, means down a column without a letter in common (a, b, c, and d) were significantly different (Tukey's, $P \leq 0.05$). If none of the values were different, letters were omitted.

SIZE-AT-AGE CLASS	SPRING 1988 – SUMMER 1988	SUMMER 1988 – FALL 1988	FALL 1988 – WINTER 1988	WINTER 1989 – SPRING 1989	OVERALL
1 TL < 131 mm	no recaptures	0.495 a (0.228) (n = 7) 181.8	0.467 a (0.241) (n = 23) 170.6	0.483 a (0.249) (n = 25) 176.4	0.399 a (0.390) (n = 92) 145.7
2 TL ≥ 131 mm TL < 205 mm	0.291 a (0) (n = 1) 106.3	0.295 b (0.098) (n = 22) 107.7	0.281 ab (0.111) (n = 69) 102.6	0.281 b (0.125) (n = 77) 102.6	0.272 ab (0.141) (n = 217) 99.3
3 TL ≥ 205 mm TL < 280 mm	0.220 a (0.097) (n = 9) 80.4	0.212 b (0.114) (n = 38) 77.4	0.213 b (0.127) (n = 86) 77.8	0.215 b (0.089) (n = 93) 78.5	0.207 b (0.100) (n = 340) 75.6
4 TL ≥ 280 mm TL < 328 mm	0.150 b (0.025) (n = 4) 54.8	0.130 bc (0.046) (n = 12) 47.5	0.137 bc (0.044) (n = 28) 50.0	0.140 c (0.053) (n = 23) 51.1	0.137 c (0.085) (n = 82) 50.0

Table 7.-cont.

SIZE-AT-AGE CLASS	SPRING 1988 / SUMMER 1988	SUMMER 1988 / FALL 1988	FALL 1988 / WINTER 1988	WINTER 1989 / SPRING 1989	OVERALL
5 TL ≥ 328 mm TL < 359 mm	0.097 b (0.014) (n = 2) 35.4	0.110 cd (0.030) (n = 3) 40.2	0.109 c (0.027) (n = 4) 39.8	0.111 c (0.023) (n = 4) 40.5	0.101 cd (0.075) (n = 19) 36.9
6 TL ≥ 359 mm	no recaptures	0.090 d (0) (n = 1) 32.9	0.101 c (0.042) (n = 2) 36.9	0.108 c (0.035) (n = 3) 39.4	0.099 d (0.031) (n = 6) 36.2

* = Annual growth rate (mm)

Table 8.-Length-at-age composition (number and percent frequency) of black sea bass by capture time period (day and night) and sample quarter collected in small mesh traps from Gray's Reef, Georgia, July 1988 (summer) - May 1989 (spring).

Season	Size-at-Age Class 1 < 131 mm	2 ≥ 131 mm < 205 mm	3 ≥ 205 mm < 280 mm	4 ≥ 280 mm < 328 mm	5 ≥ 328 mm < 359 mm	6 ≥ 359 mm	Total
DAY SETS							
Summer	316 (39.3%)	398 (49.5%)	77 (9.6%)	10 (1.2%)	3 (0.4%)	0 (0%)	804 (100%)
Fall	265 (32.0%)	395 (47.7%)	134 (16.2%)	28 (3.4%)	5 (0.6%)	1 (0.1%)	828 (100%)
Winter	162 (28.4%)	276 (48.4%)	73 (12.8%)	44 (7.7%)	9 (1.6%)	6 (1.1%)	570 (100%)
Spring	71 (4.8%)	1,248 (84.4%)	125 (8.4%)	29 (2.0%)	6 (0.4%)	0 (0%)	1,479 (100%)
Total	814	2,317	409	111	23	7	3,681
NIGHT SETS							
Summer	99 (9.8%)	290 (28.8%)	401 (39.8%)	164 (16.3%)	47 (4.7%)	6 (0.6%)	1,007 (100%)
Fall	131 (12.6%)	373 (35.9%)	417 (40.1%)	98 (9.4%)	16 (1.6%)	4 (0.4%)	1,039 (100%)
Winter	53 (3.6%)	515 (35.0%)	627 (42.7%)	220 (15.0%)	37 (2.5%)	18 (1.2%)	1,470 (100%)
Spring	17 (2.0%)	446 (53.3%)	282 (33.7%)	79 (9.5%)	11 (1.3%)	2 (0.2%)	837 (100%)
Total	300	1,624	1,727	561	111	30	4,353

to the traps set at night, with the exception of the spring sample. Black sea bass older than 4 years were rare; a total of 30 (of 3,681) fish were caught during the day, and 141 (of 4,353) sea bass were sampled at night.

Environmental factors (e.g., water temperature and salinity) on Gray's Reef are within the tropical range in summer and temperate range in winter (Gilligan 1989). The resulting abundance of prey species and favorable water quality should allow growth to remain fairly constant between seasons. In fact, fall and winter months, which are usually typified by slow growth, provide the best opportunity for growth due to reduction in recruitment of competitive species, such as vermilion snapper and other transient species onto the reef. These species use Gray's Reef as their spring and summer home before moving offshore or southward (Gilligan 1989).

Converted back-calculated length-at-age (standard length) for ages 1 through 5 were higher than those observed in other studies except Cupka et al. (1973) (Table 9). Mercer (1978) postulated that the larger size-at-age observed by Cupka et al. (1973) may have reflected conditions present before extensive commercial exploitation began in 1969. Size-at-age values from Gray's Reef, which were virtually identical to values reported by Cupka et al. (1973), would indicate a fairly unexploited population on Gray's Reef due largely to the absence of any commercial

Table 9.-Comparison between calculated mean back-calculated standard length, SL (mm) at age for black sea bass collected from Gray's Reef, Georgia, April 1988 - May 1989 and mean back-calculated length at age from studies conducted in the South and Middle Atlantic Bights.

Reference	Study Area	Sex	Age Group 1	2	3	4	5	6	7	8	9	10
Furse (1995)	SAB (GA)	Combined	109	166	223	259	283					
Cupka et al. (1973)	SAB (SC)	Combined	115	164	198	230	265	305	329			
Mercer (1978)	MAB (VA/MA)	Combined	87	141	177	205	231	244				
Waltz et al. (1979)	SAB (SC/GA)	Female	74	133	168	190	218	247	257	256	280	330
		Male	73	134	177	210	244	260	277	295	300	340
Wenner et al. (1986)	SAB (SC)	Combined	88	142	180	212	244	271	283			

SAB = South Atlantic Bight
MAB = Middle Atlantic Bight

GA = Georgia
SC = South Carolina
VA = Virginia to Massachusetts coastline

fishery or a fish community devoid of resource competition for sea bass. However, the low number of age classes observed (6) in this study compared to as many as 10 by Waltz et al. (1979) and Wenner et al. (1986) in similar study regions (South Carolina and Georgia) would indicate either a population which is heavily fished by recreational fishermen, extensive migration in older fish, or inefficient sampling for larger, older fish.

Sex Structure and Spawning Patterns

Forty-four of 112 (39.3%) black sea bass from age classes 1 and 2 were immature, 57 (50.9%) were mature females, and only 11 (9.8%) were mature males (Table 6). The majority of sea bass of age classes 3 and 4 were mature females (68 of 116; 58.6%); however, 18 fish from age class 3 and four in age class 4 were immature. Mature males were not abundant (15 of 37; 40.5%) until age class 4 at which time the mean length at capture for males and females was 303 mm (SD = 27.0 mm). Males dominated age classes 5 (10 of 13; 76.9%) and 6 (5 of 5; 100%).

Sex ratios of black sea bass were different from the theoretical 1:1 (male:female) relation. Overall, males were outnumbered by females by 1:1.96 ratio. Females outnumbered males up to age class 4, at which age sex ratios approximated 1:1. Sex ratios of older age classes favored males. These findings agree with those reported by Cupka et al. (1973), Mercer (1978), Waltz et al. (1979) and Wenner et al. (1986).

Peak spawning activity was observed in winter (February) and spring (April/May) collections and coincided with the period of annulus formation. Annulus formation had been initiated in 68.2% (71 of 104) of those sampled in winter and spring samples. Black sea bass in spawning condition (fish with ripening or gravid gonads) were observed most commonly during these same sample periods. In the winter sample, 66.7% (16 of 24) of mature females and 50% (4 of 8) of males were in spawning condition. In the spring samples, 37 of 53 mature females (68.9%) and 18 of 30 males (60.0%) had gonads in gravid or ripe condition. Only four gravid females (8.6%) and two ripe males (14.3%) were collected in summer (July). No fish from fall (October) samples were observed in spawning condition.

Study data suggest that black sea bass on Gray's Reef spawn from early February (mid winter) to early July (early summer). Other researchers have described either a migration of adult black sea inshore to spawn or a movement of sea bass larvae or eggs from offshore into estuarine areas (Kendall 1977; Musick and Mercer 1977; Mercer 1978). Evidence from this study suggest, however, that the entire life cycle of black sea bass in mild, temperate waters occurs on the reef. Presence of gravid females and ripe males on the reef, as well as, the presence of relatively high numbers of young-of-the-year black sea bass (fish less than 131 mm) in summer and fall support this theory. Black sea bass spawned in early winter are large enough to be sampled in the traps during the summer. Fish spawned in late spring show up in the traps in the fall. The smallest black sea bass were caught in the summer. These results may be due to a delayed emergence mechanism displayed by some fish species. The larval fish may remain hidden in rock crevices or algal growth found on the reef until they are large enough to begin active feeding. However, the more logical reasons are black sea bass in the first two or three months of life are too small to be sampled in the traps or, if spawning or larval maturation occurs off the reef, they have not moved from spawning areas, which may be inshore.

Migration (on-reef and off-reef)

Movement on Gray's Reef away from original capture sites was very low throughout the study (Table 10). Chi-square analysis indicated black sea bass movement was non-random and sea bass maintained limited home areas. Migration as determined by recapture rates more than 92.7 m from a fish's original capture site (off station) within ten days of the original capture date ranged from 11.1% in spring 1988 to 16.5% in summer 1988. Although movement away from the original capture site increased for recaptures

Table 10.-Migration of black sea bass on Gray's Reef as measured by percent of recaptured black sea bass which have moved at least 0.5 LORAN TD unit (0.05 nmi; 92.7 m) from the original tagging location on Gray's Reef, Georgia, April 1988 (spring) - May 1989 (spring). An asterisk (*) denotes non-random movement (Chi-square [X^2], 0.05). Test values are underlined; $X^2_{0.05, 1} = 3.841$

RECAPTURE SEASON	TAG SEASON				
	SPRING 1988	SUMMER 1988	FALL 1988	WINTER 1989	SPRING 1989
SPRING 1988	11.1 (2/18) <u>9.389</u>*	----	----	----	----
SUMMER 1988	26.3 (7/27) <u>5.333</u>*	16.5 (13/79) <u>34.228</u>*	----	----	----
FALL 1988	30.1 (4/13) <u>1.231</u>	31.8 (49/154) <u>19.643</u>*	11.3 (14/124) <u>72.782</u>*	----	----
WINTER 1989	40.0 (4/10) <u>0.100</u>	37.8 (14/37) <u>1.729</u>	29.6 (50/169) <u>27.361</u>*	11.2 (22/197) <u>117.279</u>*	----
SPRING 1989	100.0 (2/2) <u>0.500</u>	36.8 (7/19) <u>0.842</u>	34.9 (29/83) <u>6.940</u>*	29.8 (72/242) <u>38.880</u>*	14.0 (37/264) <u>135.307</u>*

between seasons, recapture rates of fish caught off station were similar regardless of time at large. Recapture ratesof fish caught off station at least 100 days (one season) from the original tagging date ranged from 26.3% (spring 1988 to summer) to 31.8 (summer to fall) over a three-month period, 30.1% (spring 1988 to fall) to 37.8% (summer to winter) over a six-month period, and 36.8% (summer to spring 1989) to 40.0% (spring 1988 to winter) over a nine-month period. Two fish were recaptured in sample traps on Gray's Reef 13 months after tagging, but were at locations on the reef different from their original tagging sites. Total lengths of sea bass recaptured on the reef averaged 209.5 mm (SD = 66.2) and ranged from 95 mm to 365 mm.

Migration off Gray's Reef was determined from 83 tag returns received from recreational fisherman. Only four black sea bass (4.8%) were caught off Gray's Reef (Table 11). The number of days at large ranged from 9 to 735, and the majority of fish were caught in winter (29; 34.9%) and summer (20; 24.1%). Length at tagging ranged from 120 mm to 376 mm. Mean total length was 237.0 mm (SD = 55.7). Several recovered fish were reported with lengths much less than their lengths at tagging. These discrepancies were probably due to underestimation of fish lengths by the anglers. Two fish that migrated off Gray's Reef were recovered approximately 125 km from Gray's Reef on livebottom reefs off Mayport, Florida. One fish (#R-00499),

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-00411	10/21/88	11/12/88	21	277	app. 250	45462 61529	Gray's Reef	no
R-00499	10/22/88	2/06/89	107	303	app. 300	45462 61535	32.5 km E Mayport, FL	yes
R-00532	10/23/88	12/30/88	68	260	app. 250	45462 61534	Gray's Reef	no
R-00819	10/28/88	12/25/88	58	237	app. 250	45462 61532	Gray's Reef	no
R-00929	10/28/88	2/01/89	96	220	app. 250	45462 61535	West ledge Gray's reef	no
R-01047	10/28/88	1/01/89	65	180	app. 200	45466 61532	Gray's Reef	no
R-01394	10/29/88	11/24/89	26	267	app. 300	45462 61529	Gray's Reef	no
R-01465	10/29/88	2/14/89	108	289	app. 300	45462 61534	Gray's Reef	no
R-01542	10/29/88	2/05/89	99	120	app. 200	45466 61534	Gray's Reef	no

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-01683	2/04/89	2/ ?/89	<24	278	unknown	45462 61531	Gray's Reef	no
R-01724	2/04/89	3/17/89	41	203	app. 200	45462 61534	Gray's Reef	no
R-01744	2/04/89	10/31/89	269	280	app. 300	45465 61535	Gray's Reef	no
R-01767	2/04/89	10/31/89	269	197	app. 250	45465 61534	Gray's Reef	no
R-01839	2/04/89	4/01/89	56	285	app. 300	45465 61532	Gray's Reef	no
R-02036	2/05/89	4/16/89	70	217	app. 200	45465 61530	Gray's Reef	no
R-02070	2/05/89	2/28/89	23	169	app. 200	45465 61530	Gray's Reef	no
R-02121	2/05/89	2/10/91	735	248	app. 356	45465 61531	45120, 61700 49 km SSW Fernidina Beach, FL	yes

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-02234	2/05/89	unknown	?	142	unknown	45465 61534	Gray's Reef	no
R-02318	2/05/89	2/ ?/89	<23	236	unknown	45462 61528	Gray's Reef	no
R-02349	2/05/89	6/10/89	125	215	app. 275	45462 61528	Gray's Reef	no
R-02401	2/05/89	9/05/89	212	233	app. 200	45462 61530	Gray's Reef	no
R-02456	2/05/89	3/14/89	37	127	app. 200	45462 61530	Gray's Reef	no
R-02487	2/05/89	2/ ?/89	<23	235	unknown	45462 61531	Gray's Reef	no
R-02538	2/05/89	3/14/89	37	368	app. 400	45462 61533	Gray's Reef	no
R-02540	2/05/89	2/ ?/89	<23	280	unknown	45462 61533	Gray's Reef	no
R-02542	2/05/89	9/05/89	212	220	app. 250	45462 61533	Gray's Reef	no

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-02553	2/05/89	2/ ?/89	<23	239	unknown	45462 61534	Gray's Reef	no
R-02565	2/05/89	2/ ?/89	<23	260	unknown	45462 61534	Gray's Reef	no
R-02637	2/05/89	5/28/89	112	211	app. 200	45465 61534	Gray's Reef	no
R-02688	2/05/89	10/31/89	268	287	app. 300	45465 61535	Gray's Reef	no
R-02830	2/06/89	2/ ?/89	<22	304	unknown	45462 61528	Gray's Reef	no
R-02833	2/06/89	2/ ?/89	<22	275	unknown	45462 61528	Gray's Reef	no
R-02852	2/06/89	2/ ?/89	<22	228	unknown	45462 61529	Gray's Reef	no
R-02882	2/06/89	2/ ?/89	<22	221	unknown	45462 61530	Gray's Reef	no
R-02896	2/06/89	3/14/89	36	138	app. 200	45462 61530	Gray's Reef	no

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-02914	2/06/89	2/ ?/89	<22	225	unknown	45462 61531	Gray's Reef	no
R-02939	2/06/89	5/29/89	112	326	unknown	45462 61533	Gray's Reef	no
R-03024	2/11/89	5/05/89	83	228	unknown	45462 61534	Gray's Reef	no
R-03029	2/11/89	5/05/89	83	172	unknown	45462 61535	Gray's Reef	no
R-03134	2/12/89	5/31/89	108	189	app. 200	45466 61532	Gray's Reef	no
R-03166	2/12/89	3/24/89	40	198	app. 200	45466 61531	Gray's Reef	no
R-03224	2/12/89	2/ ?/89	<16	238	unknown	45462 61528	Gray's Reef	no
R-03225	2/12/89	6/14/89	122	217	unknown	45462 61528	Gray's Reef	no
R-03234	2/12/89	6/14/89	122	200	unknown	45462 61528	Gray's Reef	no

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-03253	2/12/89	2/ ?/89	<16	205	unknown	45462 61530	Gray's Reef	no
R-03260	2/12/89	4/15/89	62	122	app. 200	45462 61530	Gray's Reef	no
R-03306	2/12/89	2/ ?/89	<16	279	unknown	45462 61535	Gray's Reef	no
R-03386	5/12/89	5/28/89	16	233	app. 200	45462 61532	Gray's Reef	no
R-03457	5/12/89	9/05/89	116	217	app. 200	45462 61529	Gray's Reef	no
R-03592	5/12/89	10/31/89	172	225	app. 300	45465 61535	Gray's Reef	no
R-03700	5/12/89	9/03/89	114	182	app. 200	45465 61532	2.5 km SE Gray's Reef buoy	no
R-03764	5/12/89	7/04/89	53	207	app. 200	45462 61531	45462, 61531 Gray's Reef	no
R-03774	5/12/89	6/10/89	29	230	app. 240	45462 61532	Gray's Reef	no

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-04169	5/13/89	6/18/90	401	177	305	45462 61532	28 km NNE Mayport, FL	yes
R-04188	5/14/89	8/05/89	83	212	unknown	45465 61530	Gray's Reef	no
R-04236	5/14/89	10/31/89	170	272	app. 300	45465 61534	Gray's Reef	no
R-04246	5/14/89	10/31/89	170	264	app. 300	45465 61535	Gray's Reef	no
R-04248	5/14/89	9/05/89	114	225	app. 250	45462 61535	Gray's Reef	no
R-04347	5/19/89	6/30/89	42	204	unknown	45466 61533	Gray's Reef	no
R-04523	5/19/89	7/04/89	46	185	app. 200	45462 61532	Gray's Reef	no
R-04768	5/20/89	6/30/88	41	206	unknown	45466 61530	Gray's Reef	no
R-04867	5/20/89	7/04/89	45	197	app. 200	45466 61532	Gray's Reef	no

Table 11.-cont.

Tag Number	Tagging Date	Recovery Date	Days at Large	Total Length at Tagging (mm)	Total Length at Recovery (mm)	Tagging Location (TD units)	Recovery Location	Migration off Reef (yes/no)
R-04902	5/20/89	7/14/89	55	197	app. 200	45462 61535	Gray's Reef	no
R-04913	5/21/89	12/31/89	224	174	app. 200	45462 61535	Gray's Reef	no
R-05033	5/21/89	12/31/89	224	177	app. 200	45462 61532	Gray's Reef	no
R-05172	5/21/89	12/31/89	224	167	app. 250	45466 61535	Gray's Reef	no

which measured 303 mm at tagging, was recovered 107 days later 32.5 km northeast of Mayport, Florida. The second fish (#R-04169) was recovered 28 km east of Mayport, Florida and measured 305 mm. It was at large for 401 days and was 177 mm when tagged. The third fish (#R-02121) traveled approximated 63 km from Gray's Reef to a reef system 49 km off Fernidina Beach, Florida. This fish was recovered 735 days after it was tagged and grew from 248 mm to about 356 mm. The fourth fish (#Y-09383) was recovered in Sapelo Sound approximately 28 km from Gray's Reef. No tagged fish were recovered at any of Georgia's artificial reefs or natural reefs located 60 to 80 km offshore.

Seasonal migrations have been reported for black sea bass populations north of Cape Hatteras (Pearson 1932; Nesbit and Neville 1935; Lavenda 1949; Musick and Mercer 1977) and probably occur as a response to lowered water temperatures caused by the influx of the Labrador Current (Cupka et al. 1973). However, little seasonal movement has been shown in populations south of Cape Hatteras, an area where generally warmer waters prevail. Moe (1966) and Beaumarriage (1969) found that black sea bass tagged off northeast Florida exhibit minimal movement from the area on which they were tagged and are highly susceptible to recapture. Mark and recapture studies conducted by Cupka et al. (1973), Parker et al. (1979), and Low and Waltz (1991) on artificial and natural reefs off South Carolina also indicate little seasonal movement. Based on their observation, Cupka et al. (1973) further suggested that, although seasonal movements due to temperature are probably limited to sea bass populations north of Cape Hatteras, gradual offshore movements of larger, older, and predominantly male individuals may occur south of Cape Hatteras. Ansley and Harris (1981) found, of 1,442 legal-size black sea bass recaptured during a study conducted on Georgia's natural and artificial reef system, only 24 (1.7%) moved more than 1 km from the tagging location.

The results of my study correlate closely with those obtained by other investigators. High numbers of young-of-the-year and adult black sea bass larger than 200 mm were captured and recaptured throughout the study. A minimum of 83.5% of those sea bass recaptured within season were captured within 92.7 m (0.5 LORAN-C TD unit) from the original capture site. Over 95% of the tag returns from recreational fishermen were either on Gray's Reef or specifically on the reef area southwest of the marker buoy (the tagging area). Moe (1972) defined migration as a "purposeful concurrent movement of a major portion of the population...(that) includes movement restricted temporally and spatially as well as extensive seasonal movement." Movements that did occur were not indicative, as defined by Moe (1972), of a migratory population.

These data are important for several reasons. Ease in capture and recapture of fish insures high recapture percentages which allows direct calculation of growth rates. Very low recapture rates more than 100 m from the original tagging sites demonstrate utilization of limited home areas and suggest limited immigration of other sea bass from other areas of the reef. Extremely limited movement within a section of the reef over several months indicates that emigration of black sea bass off Gray's Reef, even large sea bass, is minimal, thus insuring positive recruitment and stability of the population on the reef. My data suggest black sea bass populations associated with Gray's Reef and other South Atlantic Bight reef systems do not exhibit extensive migrations and are generally lifetime residents of reef areas.

IV. CONCLUSIONS

The black sea bass population from Gray's Reef National Marine Sanctuary was typical of reef systems, both natural and artificial, that are within the "20-m depth" zone of the South Atlantic Bight. Seasonal collections from day and night data were indicative of a resident population dominated by non-harvestable sized fish less than 3 years old. The population appeared to be either moderately to heavily exploited by recreational anglers, experienced high natural mortality, or was affected by both forces. Young-of-the-year (YOY) black sea bass were generally most abundant in summer. Those sea bass longer than 205 mm, though relatively low in abundance over all seasons, were most frequently captured in winter. Age and growth data documented six age classes and the greatest amount of growth occurred in the first year to 131 mm. Black sea bass on Gray's Reef reached a harvestable size (205 mm) at age 2. Comparison of daily growth rates within each age class indicated no differences between seasons, that is, growth was continuous throughout the year. Daily growth rates for each age class, however, differed from 0.399 mm/day at age class 1 to 0.099 mm/day at age class 6. Although growth rates appeared to decline as age increased, growth was not stunted in older fish. Spawning activity by black sea bass on Gray's Reef was indicated by observations of adults in spawning condition during early February, April, and late May with the highest incidence in April and May. These data demonstrate spawning by black sea on the reef and help to support the theory that black sea bass spend their entire life on the reef. Black sea bass of all sizes, however, exhibited little movement from the original trapping location within a season and between seasons. Recovery data from recreational fishermen suggested possible limited emigration southward to reef systems offshore of northeast Florida. Recapture and recovery data indicate that adult black sea bass do not move off the reef during spawning or upon reaching a certain size or age.

Data which were not necessarily applicable to the study concerning differences between seasons were valuable for their auxiliary use during this study and may be of interest to other researchers. Traps set on medium relief substrate yielded more black sea bass per set than traps set on low relief substrate. Small wire mesh traps provided a better sample of the black sea bass on Gray's Reef than did large wire traps. Small mesh traps captured fish of all size classes examined, and large mesh traps sampled only fish larger than 200 mm. Day sets differed from night sets in their proportions of black sea bass of each size class. Day sets demonstrated that, although YOY black sea bass were not fully recruited to the gear, older and larger fish were susceptible to capture. Because sea bass of age classes 1 and 2 were not fully recruited to the gear at night, catch rates suggested differences in diurnal behavior between smaller sea bass (< 205 mm) and larger sea bass (≥ 205 mm). Young fish may be less active at night when larger fish were more active.

The low catch rates of sea bass greater than 205 mm and older than 2 years appear to be due to a cropping of those legal-size fish by recreational fishermen. These conclusions are further supported by high growth rates over all seasons probably due to low competition for food resources, constant population abundance through the year, and presence of a non-migratory population. This situation may result in recruitment overfishing, which is caused by excessive harvest of spawning-size fish which reduces the number of fish recruited into the population.

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Appendix A: LORAN-C coordinates for sampling sites

Twenty primary stations were examined during all seasons of the study. Seven secondary stations were sampled during the first spring and summer periods. Primary stations were located on the reef proper. They contained suitable habitat (limestone ridges, invertebrate growth, 1 - 2 m relief) for black sea bass communities and were examined for each parameter discussed in the study. Secondary stations were located up to one LORAN-C TD unit off the reef. These locations were characterized by sandy, flat habitat considered non-preferred for black sea bass and were examined only for number of fishes captured and breakdown of size classes.

Primary stations consisted of three transects or LORAN lines: "45462", "45465" and "45466". The individual LORAN-C TD coordinates were as follows:

46462	45465	45466
61528	61530	61530
61529	61531	61531
61530	61532	61532
61531	61533	61533
61532	61534	61534
61533	61535	61535
61534		
61535.		

Secondary stations consisted of one transect, "45467". The individual LORAN-C TD coordinates were as follows: 45467, (61528; 61529; 61530; 61531; 61532; 61533; 61534).

Appendix B.-Common and scientific names of fish species collected on Gray's Reef National Marine Sanctuary from April 1988 through May 1989. An asterisk (*) indicates those species collected only with rod and reel. All other species were captured with sampling traps. Classification derived from Robins et al. (1991).

Common Name	Scientific Name
CARCHARHINIDAE--requiem sharks	
bull shark	*Carcharhinus leucas**
Atlantic sharpnose shark	*Rhizoprionodon terraenovae**
DASYATIDAE--stingrays	
southern stingray	*Dasyatis americana**
Atlantic stingray	*Dasyatis sabina**
MURAENIDAE--morays	
honeycomb moray	*Gymnothorax saxicola*
reticulate moray	*Muraena retifera*
OPHICHTHIDAE--snake eels	
palespotted eel	*Ophichthus puncticeps*
SYNODONTIDAE--lizardfishes	
inshore lizardfish	*Synodus foetens*
snakefish	*Trachinocephalus myops*
GADIDAE--cods	
Carolina hake	*Urophycis earlli*
southern hake	*Urophycis regia*
OPHIDIIDAE--cusk-eels	
bank cusk-eel	*Ophidion holbrooki*
BYTHITIDAE--viviparous brotulas	
brotula	*Ogilbia* sp.
BATRACHOIDIDAE--toadfishes	
leopard toadfish	*Opsanus pardus*
oyster toadfish	*Opsanus tau*
Atlantic midshipman	*Porichthys plectrodon*

Appendix B.-cont.

Common Name	Scientific Name
ANTENNARIIDAE--frogfishes	
ocellated frogfish	*Antennarius ocellatus*
HOLOCENTRIDAE--squirrelfishes	
squirrelfish	*Holocentrus adscensionis*
TRIGLIDAE--searobins	
searobin	*Prionotus* sp.
SERRANIDAE--sea basses	
bank sea bass	*Centropristis ocyurus*
rock sea bass	*Centropristis philadelphica*
black sea bass	*Centropristis striata*
sand perch	*Diplectrum formosum*
gag	*Mycteroperca microlepis**
whitespotted soapfish	*Rypticus maculatus*
belted sunfish	*Serranus subligarius*
ECHENEIDAE--remoras	
sharksucker	*Echeneis naucrates*
remora	*Remora remora*
CARANGIDAE--jacks	
greater amberjack	*Seriola dumerili**
LUTJANIDAE--snappers	
vermilion snapper	*Rhomboplites aurorubens*
HAEMULIDAE--grunts	
tomtate	*Haemulon aurolineatum*
pigfish	*Orthopristis chrysoptera*
SPARIDAE--porgies	
whitebone porgy	*Calamus leucosteus*
spottail pinfish	*Diplodus holbrooki*
pinfish	*Lagodon rhomboides*
red porgy	*Pagrus pagrus*
longspine porgy	*Stenotomus caprinus**

Appendix B.-cont.

Common Name	Scientific Name
SCIAENIDAE--drums	
cubbyu	*Pareques umbrosus*
EPHIPPIDAE--spadefishes	
Atlantic spadefish	*Chaetodipterus faber*
CHAETODONTIDAE--butterflyfishes	
spotfin butterflyfish	*Chaetodon ocellatus*
POMACENTRIDAE--damselfishes	
yellowtail reeffish	*Chromis enchrysurus*
bicolor damselfish	*Pomacentrus partitus*
LABRIDAE--wrasses	
slippery dick	*Halichoeres bivittatus*
pearly razorfish	*Hemipteronotus novacula*
ACANTHURIDAE--surgeonfishes	
doctorfish	*Acanthurus chirurgus*
SCOMBRIDAE--mackerels	
king mackerel	*Scomberomorus cavalla*
BALISTIDAE--leatherjackets	
orange filefish	*Aluterus schoepfi*
gray triggerfish	*Balistes capriscus*
planehead filefish	*Monacanthus hispidus*
OSTRACIIDAE--boxfishes	
scrawled cowfish	*Lactophrys quadricornis*
TETRAODONTIDAE--puffers	
striped burrfish	*Chilomycterus schoepfi*
southern puffer	*Sphoeroides nephelus*