Migration and Standing Stock of Fishes Associated with Artificial and Natural Reefs on Georgia's Outer Continental Shelf

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SEDAR32-RD14

11 February 2013

MIGRATION AND STANDING STOCK OF FISHES
ASSOCIATED WITH
ARTIFICIAL AND NATURAL REEFS ON GEORGIA'S OUTER CONTINENTAL SHELF

by

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February 1981

This study was funded through the Federal Aid in Fish Restoration Act under Dingell-Johnson Project F-31, Georgia.

FINAL REPORT

State: Georgia   Project Number: F-31-4

Project Type: Research and Survey

Study Title: Migration and Standing Stock of Fishes Associated with Artificial and Natural Reefs on Georgia's Outer Continental Shelf.

Study Objectives: To determine the migratory patterns and standing stocks of fish populations associated with selected artificial and natural reefs on the Georgia Outer Continental Shelf.

ABSTRACT

From 1974 to 1978, 5070 fishes, representing 22 species, were tagged and released at various artificial and natural reefs offshore of the Georgia coast. Fishermen and project personnel recaptured 1508 of the total tagged (29.7% recovery).

Black sea bass (*Centropristis striata*) represented 85.7% of all fish tagged and 95% of the fish recaptured. Over 98% of all recaptured fish were taken within one kilometer of their release site, although one black sea bass traveled 259 km in 31 days following its release. Overall tag and recapture results obtained during the study were significant only for black sea bass and indicate no migratory movement for this species.

Black sea bass standing stock estimates for fish over 200 mm total length from specific offshore reefs were computed using adjusted Schnabel and mean of Petersen analyses. Standing stock levels calculated utilizing the adjusted Schnabel equation generally were more reliable than estimates generated with the mean of Petersen method. The most reliable estimate revealed 203 to 343 black sea bass associated with an artificial reef composed of 300 eight-tire units.

INTRODUCTION

A broad and shallow area, the continental shelf off Georgia gently slopes eastward towards the Gulf Stream, which skirts the 100 fathom

(183 m) curve approximately 150 km offshore. Although primarily characterized by barren sand/clay expanses, some natural reef assemblages do exist on the shelf. These "live" bottoms, defined by Struhsaker (1969) as "outcrops of rock that are heavily encrusted with such sessile invertebrates as sponges and sea fans," occur sporadically as "islands" of broken relief that support a diversified ichthyofauna pervaded by snapper, grouper, and porgies (Struhsaker, 1969). Such habitat consists not only of elevated reefs, but also of flat hard bottom which supports live bottom communities (Miller and Richards, 1979).

Unfortunately, most of this live bottom is found over 70 km east of the Georgia coastline in depths usually exceeding 15 fathoms (27 m), and consequently is unaccessible to most small vessels. Recreational divers and Georgia anglers wishing to experience "blue-water" fishing prior to the 1970's were therefore essentially restricted to inshore wrecks and a few scattered live bottom areas such as Gray's Reef, located 25 km east of Sapelo Island (Figure 1).

As a response to the conditions present on the adjoining shelf, local sportfishing groups began the construction of artificial reefs[1] offshore during the mid-thirties by sinking an 18 m wooden vessel 5 km east of Jekyll Island. Additional reef construction did not occur again until the 1960's when the Golden Isles Skin Divers, seeking to emulate diving opportunities created by the wreckage of a torpedoed freighter off Cumberland Island, reinitiated offshore habitat enhancement efforts. Several artificial reefs composed of automobile and bus bodies, refrigerators, and other scrap materials were built by this group in the ocean waters off Glynn County, Georgia. Only short-term benefits were realized by offshore sportsmen, however, as the reef material quickly deteriorated and was lost. Further problems with funding and manpower shortages, as well as conflicts with an expanding shrimp fishery, ended these private attempts to increase recreational opportunities off the Georgia coast (Harris, 1978).

Local interest, however, continued in artificial reefs and eventually led to state involvement and the beginning of a governmental construction

[1]Parker et al. (1974) defines artificial reefs as "manmade or natural objects placed in selected areas of the marine environment to provide or improve rough bottom habitat and thereby increase the productivity and harvestibility of certain finfish and shellfish valuable to man."

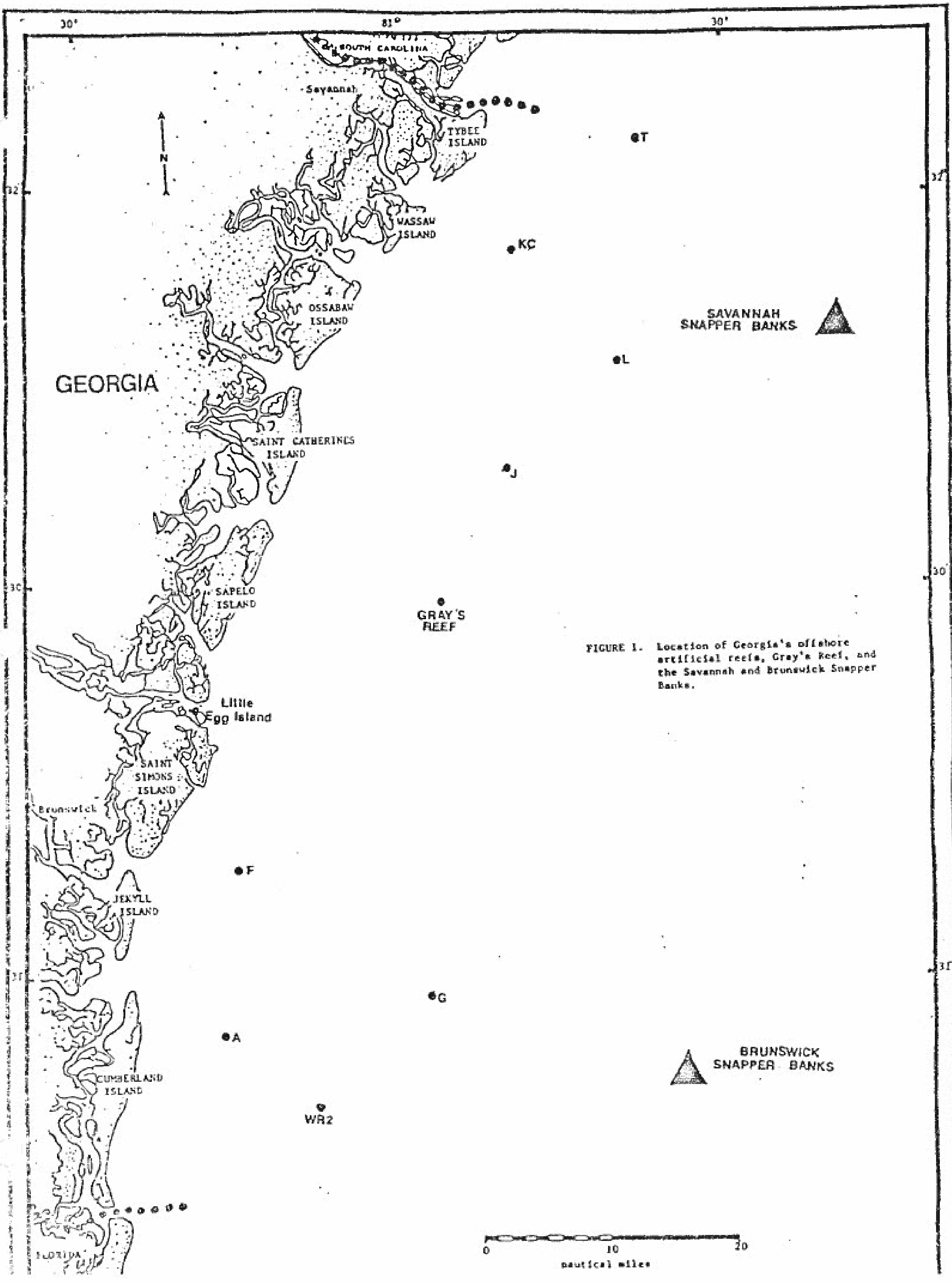


FIGURE 1. Location of Georgia's offshore artificial reefs, Gray's Reef, and the Savannah and Brunswick Snapper Banks.

program in 1970. Since then eight reefs, located from 13 to 43 km offshore (Figure 1) have been built utilizing vessels up to 135 m in length and scrap automobile tires bundled into units (Figure 2).

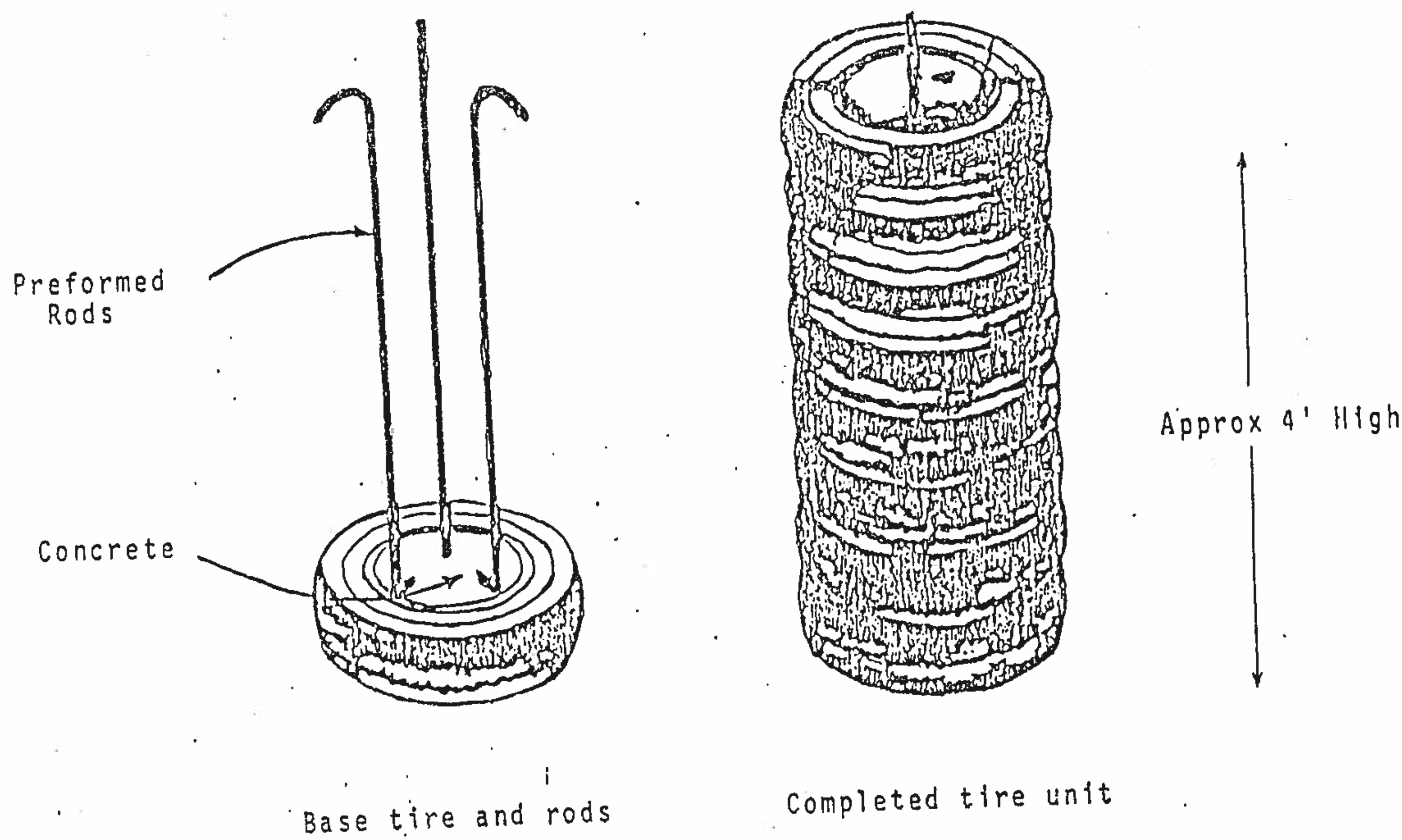
Artificial reefs have been used in the United States since the early 1800's to improve angler success (Stone and Parker, 1975). Quantitative comparisons of artificial and natural reef areas have shown that manmade reefs not only successfully emulate (Randall, 1963; Smith et al., 1979), but also complement adjacent natural reefs by increasing carrying capacity in the immediate area (Stone et al., 1979). These studies have suggested that artificial reefs can perform an integral function in a national fishery management plan (Stone, 1978), similar to levels already achieved in Japan (Sheehy, 1979).

The physical, structural, and logistical demands of an artificial reef program have been outlined by Stone (1972), Parker et al. (1974), and Mathews (1978). However, many questions remain regarding the biology and population dynamics of fish stocks utilizing reef areas. The acquisition of this knowledge, which by necessity must be localized in scope, is essential for effective reef construction and management.

Since the work of Longley and Hildebrand (1941) researchers have increasingly employed direct observational techniques, primarily SCUBA, to investigate the behavior of fishes associated with natural and artificial reefs (Springer and McErlean, 1962; Starck and Davis, 1966; Hobson, 1968; Turner et al., 1969; Dewees and Gotshall, 1974; Smith et al., 1975; Alevizon and Brooks, 1975; Ebeling and Bray, 1976; Smith, 1976; Harris, 1978; Parker et al., 1979; Stone et al., 1979). The use of SCUBA has provided investigators with new insight into the seasonality and diurnal/nocturnal movements of reef fishes, as well as into promising techniques that can be used to estimate standing stock and population densities (Brock, 1954; Bardach and Menzel, 1957; Bardach, 1959; Randall, 1963; Carlisle, 1964; Smith et al., 1979; Stone et al., 1979; Willan, 1979).

However, this technique is understandably limited in studies of long term movements and migrations of fish stocks over large distances. In this area, research has largely relied on mark/recapture (tagging) and other indirect observational techniques (Jones, 1979). Several tagging programs aimed at defining the movements of reef associated

Figure 2.--Eight-tire module used in construction on Georgia's artificial reefs.



The structural unit is a column of eight (8) automobile tires held together with three (3) 1/2-inch diameter preformed steel rods. The bottom tire is filled with concrete. The remaining rods are positioned with the rods passing through the center of the tires. The rods are preformed with a 90° bend 6-inches long on the bottom end, and a half-circle bend 8-inches in diameter on the top end. A completed unit weighs about 300 pounds and stands 4-feet high.

fishes have been conducted in California (Turner et al., 1969; Dewees and Gotshall, 1974); Bermuda (Bardach and Menzel, 1956); the Virgin Islands (Randall, 1961); Florida (Springer and McErlean, 1961; Ingle et al., 1962; Springer and McErlean, 1962; Beaumarriage, 1964; Beaumarriage and Wittich, 1966; Moe, 1966; Beaumarriage, 1969; Stone et al., 1979); and in other southeastern states (Cupka, 1973; Manooch, 1975; Parker, 1975; Parker et al., 1979; Hammond, 1980).

Mark/recapture studies conducted in the South Atlantic Bight have focused primarily on natural reef assemblages. Studies by Parker et al. (1979) and Hammond (1980) on South Carolina artificial reefs remain exceptions.

Mark/recapture techniques are also useful in obtaining data that can be effectively utilized in stock assessments and surveys, either alone or in conjunction with other methods (Alverson, 1971; Forbes and Nakken, 1972; Mackett, 1973; Gulland, 1975; Saville, 1977; Ulltang, 1977). Analysis of data gathered through these methods are outlined and discussed by Ricker (1975), Jones (1976), and Gulland (1977).

In 1974, mark/recapture studies aimed at providing insight into the biological activities of fish stocks utilizing the reefs offshore Georgia were implemented by the Georgia Department of Natural Resources. Funded through the Dingell-Johnson Federal Aid in Fish Restoration Act, this project was conducted to supplement earlier work by Harris (1978) on the seasonality of offshore reef-fish populations and to provide insight into the movements and standing stocks of ichthyofauna associated with Georgia's artificial and natural reefs. Such information, it was felt, would enable local resource managers to make qualified decisions regarding future reef construction, expansion, and use.

METHODS

Fish tagging was conducted from 1974-1978 on five Georgia artificial reefs and at Gray's Reef, a natural live bottom community situated east of Sapelo Island. Two additional live bottom areas, located 74-93 km offshore, were also sampled by project personnel in 1977 and 1978. These areas are shown in Figure 1 and are briefly discussed below.[2]

The first site of offshore reef construction by the Georgia Department of Natural Resources, artificial reef WR2 lies in 17 m (MLW) of water approximately 25 km east of Cumberland Island. Although many of the original tire modules became dismantled shortly following placement (L. Smith, pers. comm.), over 1500 eight-tire units have been offloaded on this area to complement the remains of the ESPARTA, a freighter torpedoed during World War II. Invertebrate growth consisting largely of barnacles (*Balanus* sp), hydroids, sea urchins, and hard and soft corals on the wreckage and tire units is typically extensive (Figure 3) and presents a stark contrast over the surrounding sand/shell substrate.

Artificial reef G, situated 43 km off Cumberland Island in 23 m (MLW) of water, marks the location of one of two 135 m liberty ships (Figure 4), obtained by Georgia for use in its artificial reef program. Other materials making up the reef include a 30 m steel tug, the 10 m utility vessel STRIKER, and 3000 tire units. Suspected patches of live bottom have been reported NNE and west of the area by local fishermen (C. Fendig, pers. comm.), although no naturally occurring live bottom apparently occurs on the site itself.

Over 6000 tire units scattered and clumped over a loose sand and broken shell bottom comprise the material utilized in the construction of artificial reef F. Averaging around 11 m (MLW), water depths are comparatively shallow over the area, which is located only 17 km east of Jekyll Island. One of Georgia's oldest artificial reefs, reef F is easily accessible to local angling interests based in Glynn County and the city of Brunswick.

Named and described by Hunt (1974), Gray's Reef, known locally as the Sapelo Live Bottom (SLB) and recently designated as a National Marine Sanctuary (U.S. Department of Commerce, 1980), is located 32 km offshore of Sapelo Island. According to Hunt (1974), the bottom consists of "an interfingering series of northeast-southwest trending ridges and troughs consisting of a limestone layer upon which abundant epifauna are

[2]For a more complete description of Georgia's artificial and natural reefs, the reader is advised to refer to "The Fisheries Resources on Selected Artificial and Live Bottom Reefs on Georgia's Continental Shelf" and "Location and Exploration of Natural Reefs on Georgia's Continental Shelf," both by Harris (1978).

Figure 3. Black sea bass, a predominant demersal fish species associated with Georgia's natural and artificial reefs, cluster about heavily encrusted tire units located at reef G, 43 km east of Cumberland Island, Georgia.

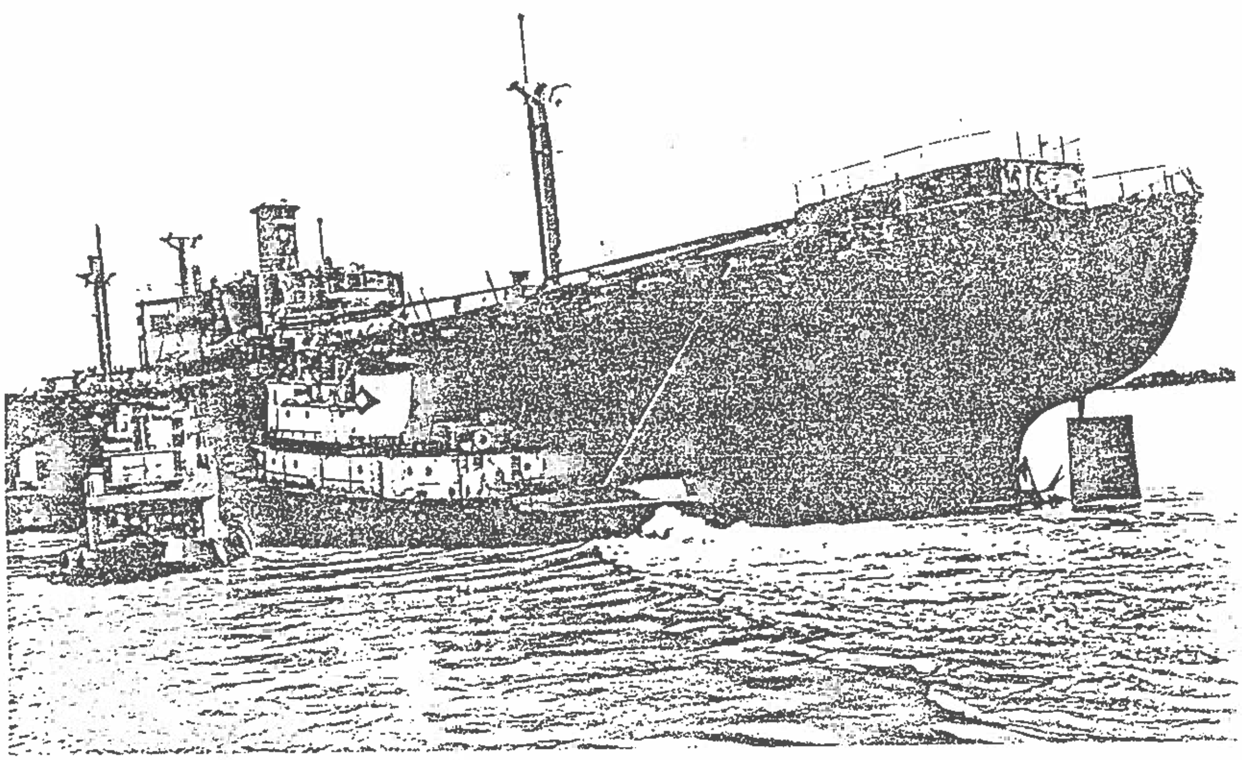


Figure 4. One of two 135 m liberty ships obtained by the state of Georgia, the ADDIE BAGLEY DANIELS now constitutes a major portion of artificial reef J, located east of St. Catherines Island.

attached" with "small vertical scarps from 0.15 m to 1.2 m in relief (Figures 5 and 6). Water depths range from 16.8 m to 23.5 m (MLW) over the reef area. Total areal extent is approximately 40.7 km^2.

Constructed 32 km east of St. Catherines Island, artificial habitat at reef J features the liberty ship ADDIE BAGLEY DANIELS (Figure 4), a 19.8 m wooden vessel, and 1000 eight-tire units. An undetermined amount of live bottom with ledges providing up to 1.5 m of vertifical relief also occurs south and east of J, although bottom substrate on the reef site itself consists largely of sand and shell. Water depth over the area averages around 21 m (MLW).

In many aspects similar to reef F, artificial reef KC is located at a relatively short distance from shore (17 km east of Wassaw Island) and is easily accessible to local sport fishing interests out of Savannah. Placed in a 12 m (MLW) of water, reef material likewise consists of scattered and clumped tire units over a sand/shell substrate. Over 4500 of these modules make up artificial reef KC.

The two remaining offshore areas sampled by project personnel were the Savannah and Brunswick "snapper banks", located 74-93 km east of Ossabaw and Cumberland Islands, respectively. Utilized commercially and recreationally, both areas feature extensive, although scattered, rock outcroppings that support large and diverse live bottom communities (Figure 7 and 8). Ledges associated with these reefs provide up to four meters of vertical relief over the adjacent sand-clay/broken shell substrate. Water depths over both locations range between 27 m and 39 m.

Tagging was also conducted at one inshore area off Little Egg Island through a cooperative program with a local sport fisherman. Project goals in this area were specifically aimed at the capture and marking of large red drum (*Sciaenops ocellata*) that congregate annually over the sand bars found throughout the Altamaha estuarine system. Resulting operations, however, were sporadic and extremely limited.

Various species of reef-associated fishes were landed, tagged and released at the seven offshore and one inshore study locations from 1974 to 1978. Although conventional hook and line techniques were employed throughout to obtain samples for mark/recapture studies, catches were substantially increased during the final years through the use of fish traps, or "sea bass pots", similar to those described by Rivers (1966). Constructed of 5 cm vinyl-coated mesh stretched over a 60 cm x

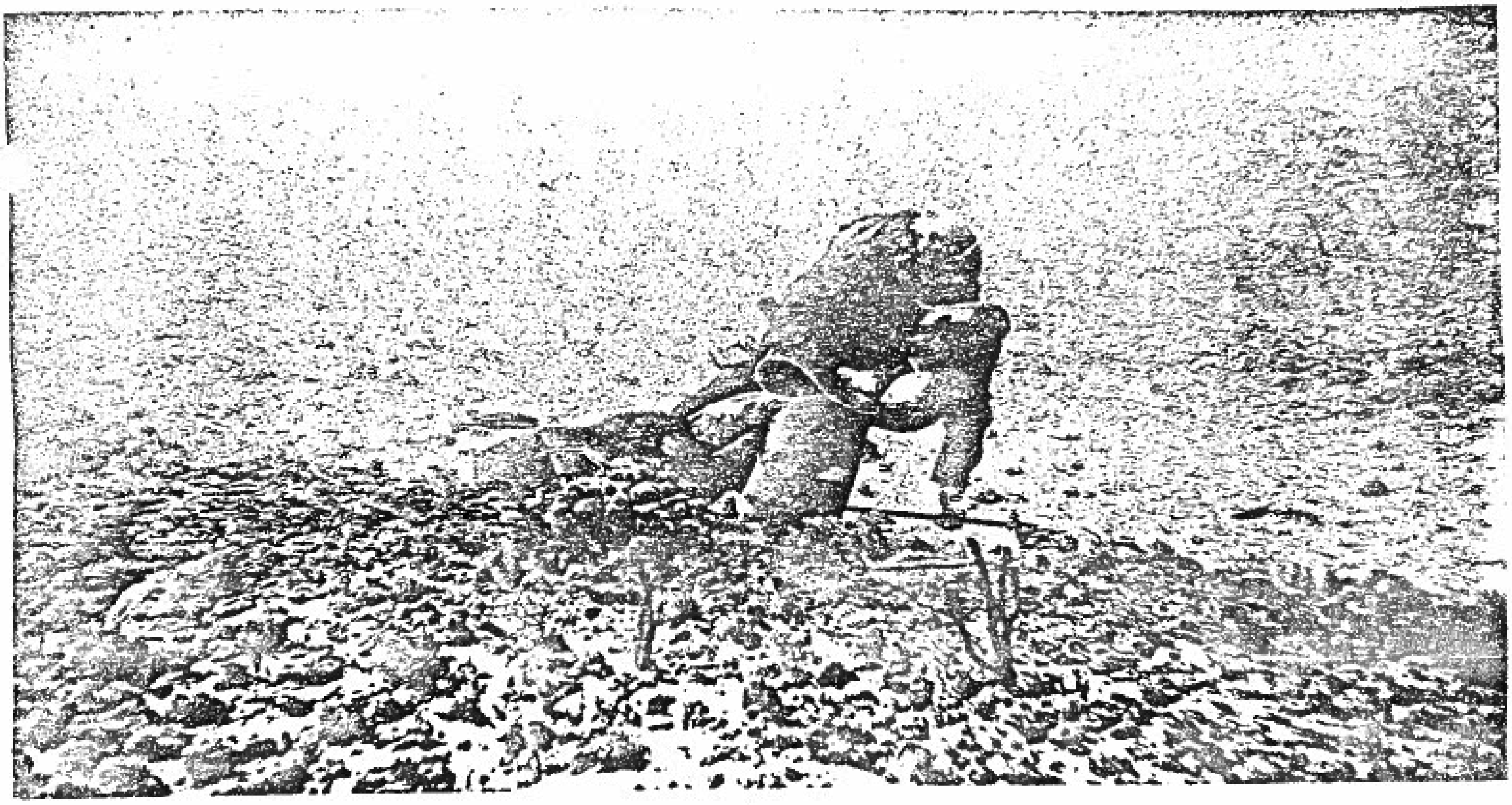


Figure 5. A DNR research diver investigates a low relief rock/sand interface at Gray's Reef east of Sapelo Island, Georgia.

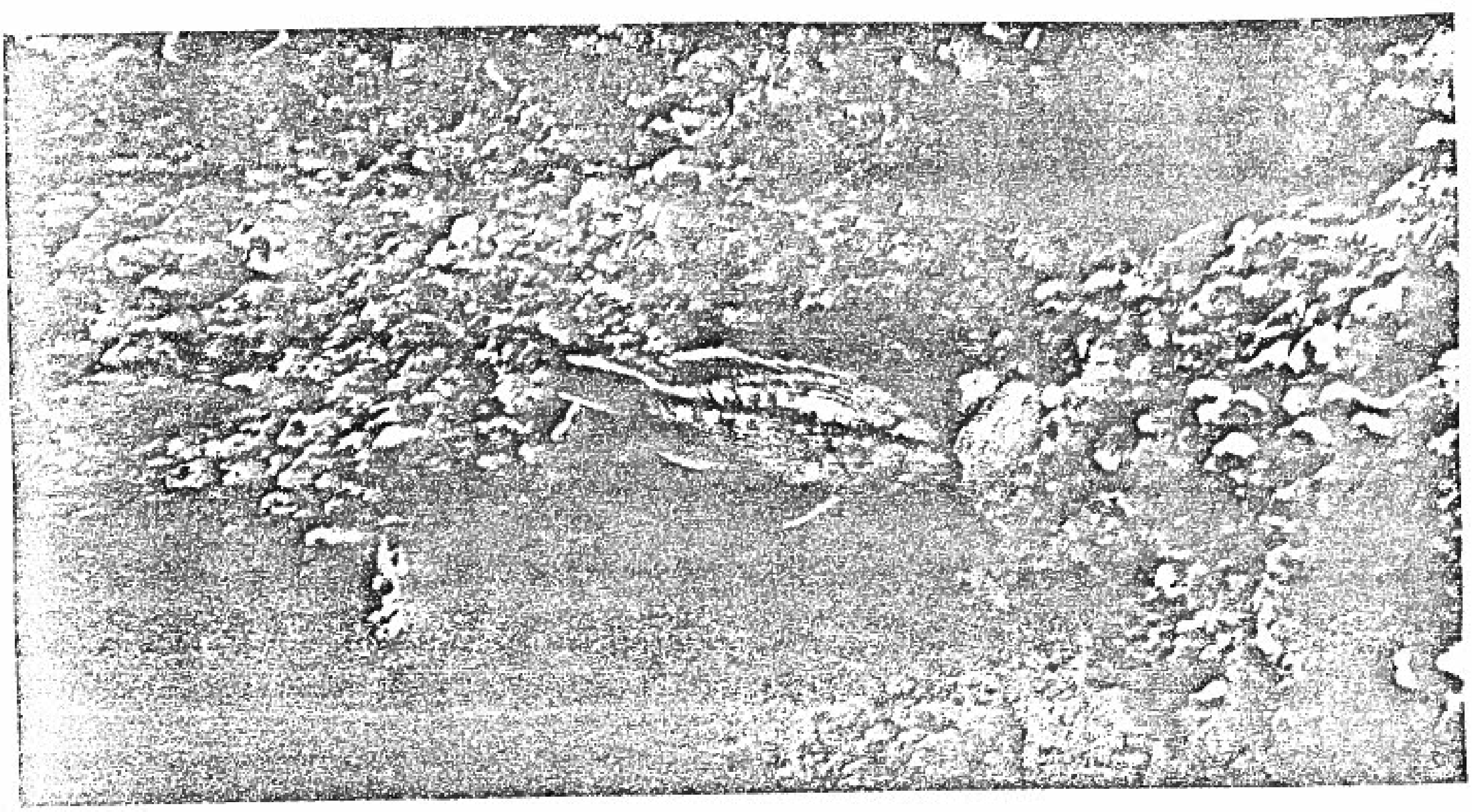


Figure 6. A black sea bass, *Centropristis striata*, swims along a deeply undercut rock ledge found at Gray's Reef, a natural live bottom area offshore Georgia.

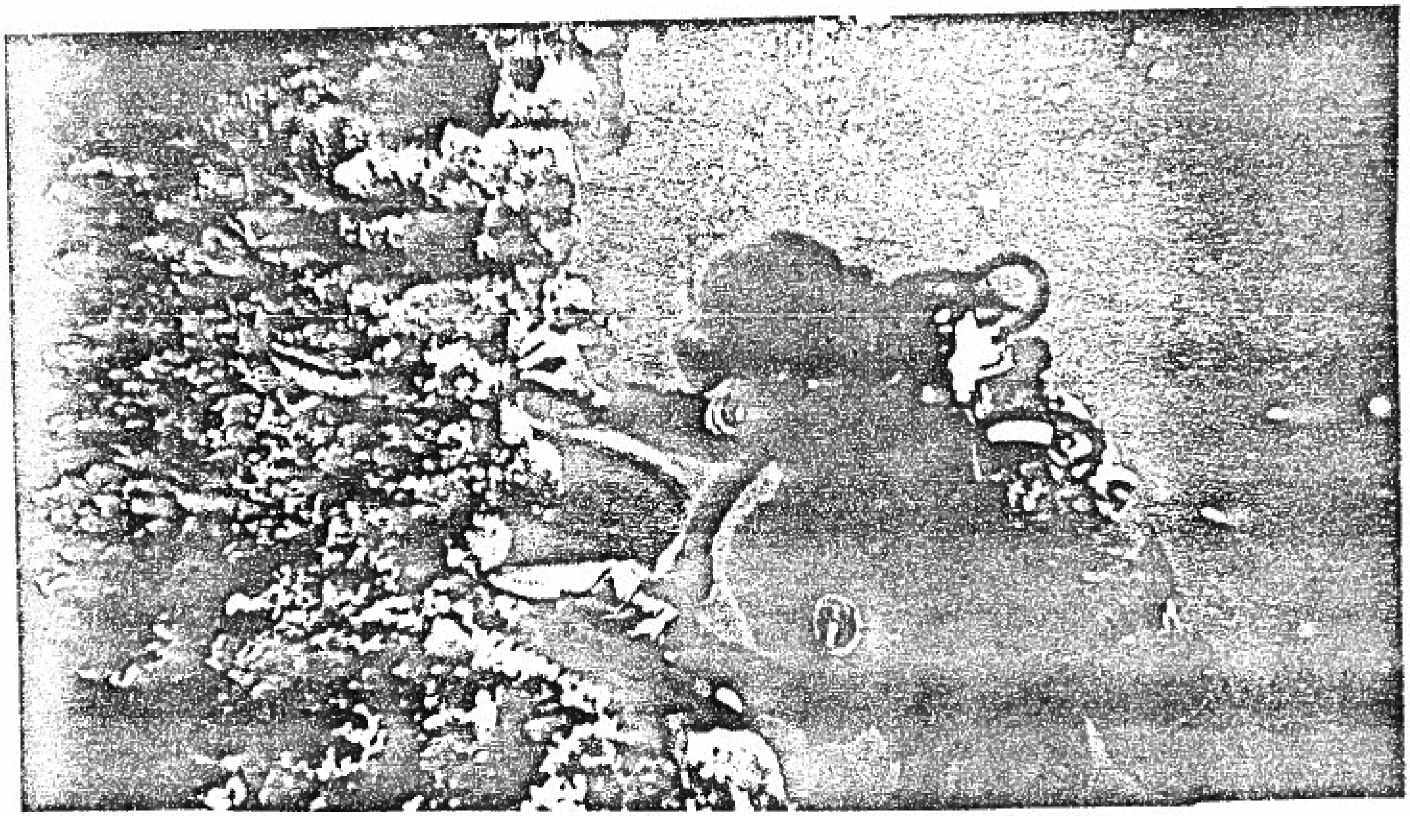


Figure 7. A Department of Natural Resources research diver collects benthos from the face of a sheer two meter rock ledge at the Brunswick Snapper Banks.

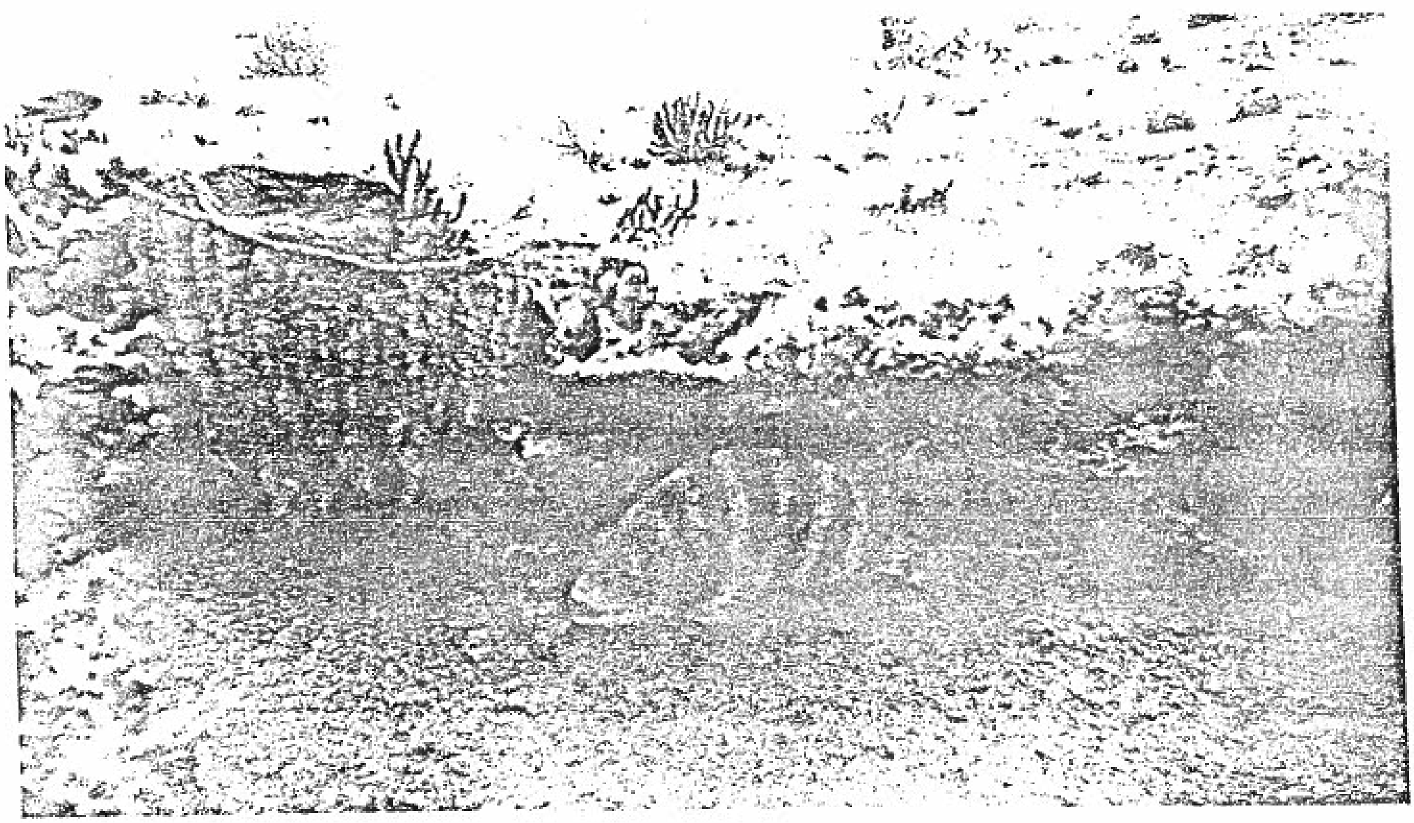


Figure 8. A sheepshead, *Archosargus probatocephalus*, rests beneath a low relief rock outcropping at the Savannah Snapper Banks.

60 cm x 42 cm metal frame and baited with fish, squid, or shrimp, these traps were particularly effective in capturing large amounts of demersal fishes.

Fish landed through either method during project operations were measured, tagged, and released as quickly as possible to minimize sample mortalities resulting from pressure and/or temperature differences and routine handling. Although problems were alleviated at most sites through the use of an on-board live well, the effects of pressure stresses on fish were, as expected, more acute in catches obtained from deepwater areas such as the Brunswick and Savannah Snapper Banks. Modifications employed to mitigate these effects included slower gear retrieval and selective lancing of distended fish, as suggested by Parker (pers. comm.).

Reef fish greater than 200 mm in total length (TL) were marked utilizing Floy® FD-68B internal anchor tags (Figure 9) inserted interneurally with a Dennison® FDM-78 tagging "gun" (Figure 10). Each tag, constructed of a colored vinyl streamer secured over a monofilament core terminated in a T-bar anchor, was labeled with the tag number, return address, and the word "REWARD". Fishermen recapturing marked fish were asked to return the tag with information on the date and location of capture for cash rewards that ranged from $1.00 to $10.00. All returns suggesting extensive movement were confirmed through followup correspondence with the fishermen.

Tagged fish recovered by project staff were typically remeasured and returned to the water. Similar information was also obtained for deeply-hooked and otherwise injured tagged fish although these individuals were not released again. Other data taken included water temperature, tagging location, and sea state.

It was anticipated that repeated tagging efforts would produce recaptures from previous release dates, and provide data that could be utilized to generate seasonal standing stock estimates for reef fishes. With this in mind, studies aimed at enumerating stock sizes were implemented on four offshore reefs - artificial reefs F, G, WR2, and Gray's Reef. Various target species were captured, tagged, and released on these areas in conjunction with field operations associated with the migration study. These efforts were continued, conditions permitting, over consecutive days in attempts to limit sampling biases caused by

Figure 9. Floy® FD-68B internal anchor tags used for tagging on the Georgia Reef Fish Migration Study, 1974-1979.

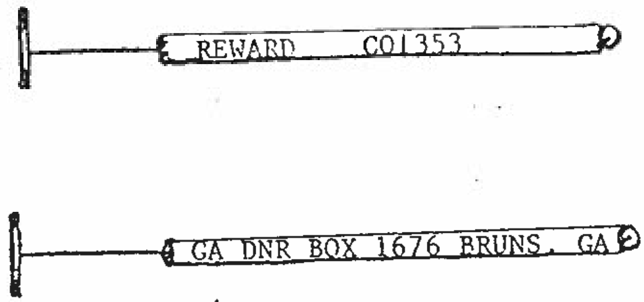
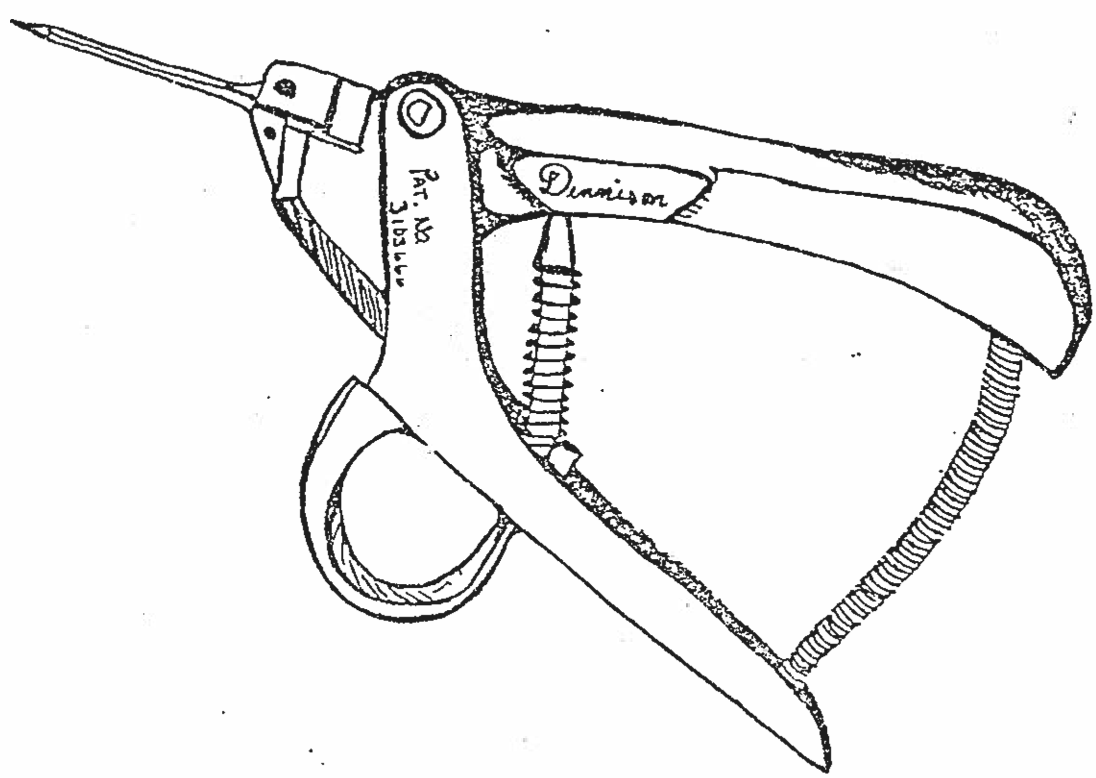


Figure 10. Dennison tagging® tagging "gun" utilized to insert FD-68B internal anchor tags.



the effects of stock immigration/emigration, natural mortality, and fishing mortality. Direct counting techniques employing SCUBA were performed, when possible, simultaneously with surface efforts to evaluate mark/recapture estimates and to develop feasible underwater techniques that could be useful in producing reliable quanitifications of reef-fish populations.

Standing stock estimates were computed from these data utilizing the adjusted Petersen equation (Ricker, 1975),

$$N = \frac{(M + 1)(C + 1)}{R + 1}$$

where N = size of population (estimate); M = number of fish marked; C = catch or sample taken for census; and R = number of recaptured marks in the sample;

the mean of these Petersen estimates (Ricker, 1975); and the adjusted Schnabel method (Ricker, 1975),

$$N = \frac{\Sigma\ CM}{\Sigma\ R + 1}$$

Confidence limits (95%) for the adjusted Petersen and Schnabel estimates were calculated by treating R as a Poisson variable or, when values of R were large, through use of Pearson's formula (Ricker, 1975),

$$x + 1.92 \pm 1.960 \sqrt{x + 1.0}$$

where x = R or the number of recaptured marks in the sample.

For estimates of N generated by taking the mean of Petersen estimates, lower (L_1) and upper (L_2) confidence limits were obtained by (Zar, 1974),

$$\bar{x} - t_{\alpha(2),\nu}\, s_{\bar{x}} \le \mu \le \bar{x} + t_{\alpha(2),\nu}\, s_{\bar{x}}$$

where $\bar{x}$ = sample mean, $t_{\alpha(2),\nu}$ = t value at the 95% confidence level, $s_{\bar{x}}$ = standard error of the mean, and μ = estimate of N.

Statistical analyses were computed using the SAS program (Helwig and Council, 1979) on an IBM 370 computer. Additional statistical calculations were conducted utilizing a Hewlitt-Packard mini-computer.

RESULTS

From 1974-1978, project personnel tagged and released a total of 5070 fish, representing over twenty-two offshore species (Table 1). Although most were tagged at the eight offshore study locations, seven large red drum (*Sciaenops ocellata*) were landed near Little Egg Island and released in the Altamaha estuarine system. None of these fish, however, were recaptured during the study period.

Black sea bass (*Centropristis striata*), a predominant component of the ichthyofaunal assemblages inhabiting Georgia's artificial and natural reefs (Harris, 1978), comprised 85.7% of the number tagged. Of the remaining demersal and pelagic species tagged, only gray triggerfish (*Balistes capriscus*), vermilion snapper (*Rhomboplites aurorubens*), red porgy (*Pagrus pagrus*), and red snapper (*Lutjanus campechanus*) accounted for more than one percent of the tagged total.

The overall recovery rate for all fish tagged during the study was 29.7%. Black sea bass again constituted the vast majority (95.6%) of the seven species recaptured (Table 2) and was the only fish species recovered and released by project personnel more than once. Included was an individual that was caught on six separate occasions before its seventh and final recovery by a fisherman 577 days after it was tagged. Most black sea bass, however, were typically recaptured shortly after their initial release. Almost 40% were recaptured within 20 days of tagging; 61% were landed within 60 days; and more than 87% of all tagged sea bass recaptured were landed within 140 days after their release (Figure 11). Mean days of freedom for all study species recaptured are presented in Table 3.

Project personnel accounted for 451 (including 163 multiple recoveries) of the 1508 fish recaptured in the study, while offshore fishermen landed the remaining 1057 fish (Table 4). Study returns by anglers were highest at reefs KC and F, the two tagging sites closest to shore, and at artificial reef G. Annual return percentages accrued for the offshore reefs ranged from 0% at Gray's Reef (1974-1976) and the Brunswick Snapper Banks (1976-1978) to a study high of 48.9% at reef KC (1977-1978).

Returns from the offshore areas by fishermen were generally higher in the spring and winter seasons, although these totals may reflect the

Table 1. Total number and percentage of each fish species tagged on the Georgia Reef Fish Migration Study, 1974-1978.

COMMON NAME	SPECIES	TOTAL # TAGGED	% TOTAL SAMPLE
Black sea bass	*Centropristis striata*	4343	85.7%
Gray triggerfish	*Balistes capriscus*	195	3.9%
Vermilion snapper	*Rhomboplites aurorubens*	156	3.1%
Red porgy	*Pagrus pagrus*	88	1.7%
Red snapper	*Lutjanus campechanus*	68	1.3%
Pinfish	*Lagodon rhomboides*	42	< 1.0%
Pigfish	*Orthopristis chrysoptera*	36	< 1.0%
Sea bass[1]	*Centropristis* sp.	30	< 1.0%
Tomtate	*Haemulon aurolineatum*	29	< 1.0%
Porgy[2]	Sparidae	27	< 1.0%
Weakfish	*Cynoscion regalis*	16	< 1.0%
Sheepshead	*Archosargus probatocephalus*	11	< 1.0%
Red drum	*Sciaenops ocellata*	9	< 1.0%
Greater amberjack	*Seriola dumerili*	4	< 1.0%
Atlantic spadefish	*Chaetodipterus faber*	3	< 1.0%
Toadfish	*Opsanus* sp.	3	< 1.0%
Bluefish	*Pomatomus saltatrix*	2	< 1.0%
Great barracuda	*Sphyraena barracuda*	2	< 1.0%
Grouper[3]	*Mycteroperca* sp.	2	< 1.0%
White grunt	*Haemulon plumieri*	2	< 1.0%
American eel	*Anguilla rostrata*	1	< 1.0%
Flounder	*Paralichthys* sp.	1	< 1.0%
	STUDY TOTALS	5070	100 %

[1]includes bank (*Centropristis ocyurus*) and rock (*C. philadelphica*) sea bass

[2]includes whitebone porgy (*Calamus leucosteus*), spottail pinfish (*Diplodus holbrooki*) and the genus *Stenotomus*

[3]includes the gag (*Mycteroperca microlepis*) and scamp (*M. phenax*)

Table 2. The number of each tagged fish species recaptured one or more times from 1974-1979 and the percentage each species comprised of the total study returns.

SPECIES	NO. TAGGED	TOTAL NO. RECAPTURED 1X	2X	3X	4X	5X	6X	7X	TOTAL RECAPTURES	% TOTAL RETURNS
Black sea bass	4343	1279	129	19	7	4	3	1	1442	95.6%
Gray triggerfish	195	45	-	-	-	-	-	-	45	3.0%
Red snapper	68	8	-	-	-	-	-	-	8	< 1.0%
Red porgy	88	5	-	-	-	-	-	-	5	< 1.0%
Vermilion snapper	156	4	-	-	-	-	-	-	4	< 1.0%
Sea bass[1]	30	2	-	-	-	-	-	-	2	< 1.0%
Pinfish	42	2	-	-	-	-	-	-	2	< 1.0%
Other species	148	-	-	-	-	-	-	-	-	---
STUDY TOTALS	5070	1345	129	19	7	4	3	1	1508	29.7%

[1] includes bank and rock sea bass

Table 3. Mean days of freedom, including the minimum and maximum number (range) of days at large, from the date of initial release to the final recorded date of recapture for all species recovered on the Georgia Reef Fish Migration Project, 1974-1979.

SPECIES	TOTAL # RECAPTURED	MEAN DAYS OF FREEDOM	RANGE OF DAYS AT LARGE
Black sea bass	1442	81	1 - 829
Gray triggerfish	45	70	5 - 353
Red snapper	8	143	10 - 501
Red porgy	5	67	67
Vermilion snapper	4	138	20 - 185
Sea bass[1]	2	38	7 - 68
Pinfish	2	122	10 - 234

[1] includes bank and rock sea bass

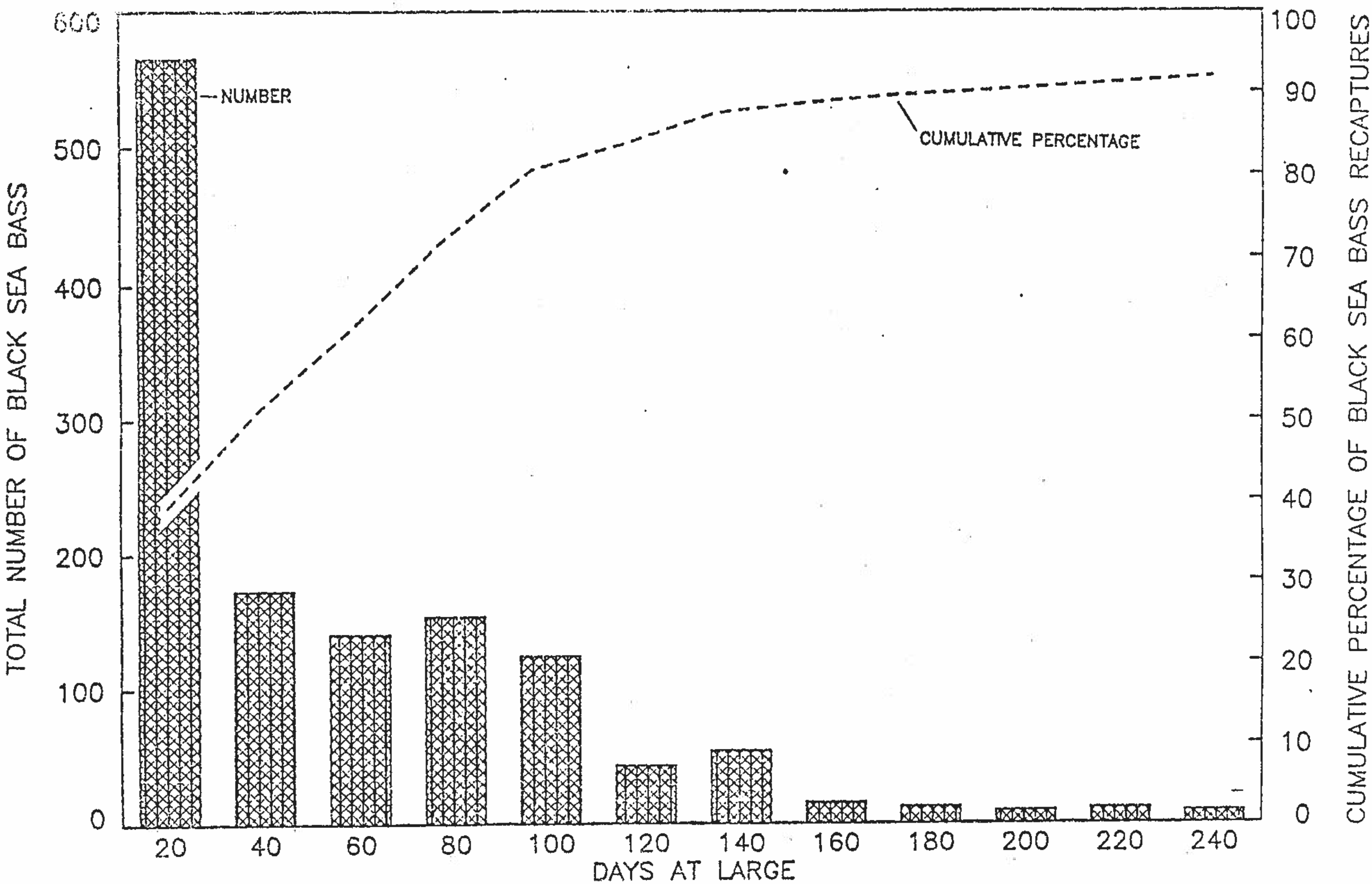


Figure 11. For all reefs combined, recaptures of black sea bass, *Centropristis striata*, by days at large from initial release to final recovery date. Cumulative percentages are also given.

Table 4. Number of fish tagged and recaptured (all species combined) by offshore fishermen for each study area and year, 1974-1979. Tagged totals represent the number of fish tagged during fall-summer, while recaptured totals represent fish recovered fall-summer plus one extra season added to insure maximum returns. Fish not recaptured within these set time frames are not reflected in the yearly totals.

AREA	1974 - 1975			1975 - 1976			1976 - 1977			1977 - 1978			STUDY TOTALS (1974-1979)			
	TAGGED TOTAL	RECAPTURED TOTAL	%	TAGGED TOTAL	RECAPTURED TOTAL	%	TAGGED TOTAL	RECAPTURED TOTAL	%	TAGGED TOTAL	RECAPTURED TOTAL	%	TAGGED TOTAL	RECAPTURED[2] TOTAL	%	RANGE
WR2	167	46	27.5%	177	7	4.0%	278	4	1.4%	225	34	15.1%	847	98	11.6%	9-772
F	247	82	33.2%	68	24	35.3%	178	34	19.1%	599	164	27.4%	1092	325	29.8%	1-829
G	256	48	18.8%	233	93	39.9%	329	82	24.9%	220	27	12.3%	1038	265	25.5%	1-730
Gray's Reef	73	0	0.0%	136	0	0.0%	228	17	7.5%	378	61	16.1%	815	83	10.2%	4-593
J	—	—	—	127	11	8.7%	132	25	18.9%	105	12	11.4%	364	68	18.7%	1-422
KC	9	1	11.1%	84	16	19.0%	100	13	13.0%	219	107	48.9%	412	147	35.8%	2-413
Brunswick Snapper Banks	—	—	—	—	—	—	63	0	0.0%	89	0	0.0%	152	0	0.0%	—
Savannah Snapper Banks	—	—	—	—	—	—	—	—	—	343	26	7.6%	343	33	9.6%	37-438
Little Egg Island	—	—	—	—	—	—	—	—	—	7	0	0.0%	7	0	0.0%	—
Other[1]	—	2	—	—	5	—	—	4	—	—	16	—	—	38	—	—
STUDY TOTALS	752	179	23.8%	825	156	18.9%	1308	179	13.7%	2185	447	20.1%	5070	1057	20.8%	1-829

[1]includes recaptured fish for which no return data was given

[2]includes fish returned during 1979

greater tagging successes usually achieved during the winter season (Figure 12). Overall percentages for the study show 45.7% of total fishermen returns occurred during the spring, 30.5% during the winter season, 12.3% during the fall, and 11.5% in the summer months.

More than 98% of the tagged fish recaptured were taken at the original release site, most often from that specific portion of the reef on which they were tagged. Only 24 black sea bass and one gray triggerfish, representing less than 0.5% of the total number marked and less than 2% of the total recaptured, were caught at areas more than one kilometer from the location of tagging. The most extensive movement recorded, 259 km, was made by a 320 mm black sea bass that was recaptured northeast of Cape Canaveral, 31 days after its release at artificial reef G. Other marked fish exhibiting significant movement during the study were recovered after 14-462 days of freedom at areas 19 to 192 km from the tagging location. Most movement was directed either offshore or south of the release sites, although some fish moved inshore and north (Figures 13-16). Ancillary data for this group are presented in Table 5.

Those individuals exhibiting movement were primarily tagged in the winter seasons and recaptured either the same or following season. However, tag release totals for the winter and spring seasons were also typically much higher than totals accrued for the rest of the year and largely were composed of black sea bass.

Standing stock levels were determined from single and multiple recoveries of tagged fish recaptured while sampling at artificial reefs WR2, F, and G, and Gray's Reef east of Sapelo Island. Conditions necessary for acquiring valid stock data, though, were rarely realized during the project, as field efforts were frequently curtailed by heavy seas, vessel breakdowns, shark activity, gear losses and damage, and/or lack of fishing success.

Similar factors also hampered associated underwater operations designed to enumerate tagged and untagged ratios within the study populations. Poor water visibilities at reef F prevented counts entirely. Stock estimates by divers at G and Gray's Reef were severely biased and essentially negated by the presence of fish tagged on prior sampling occasions.

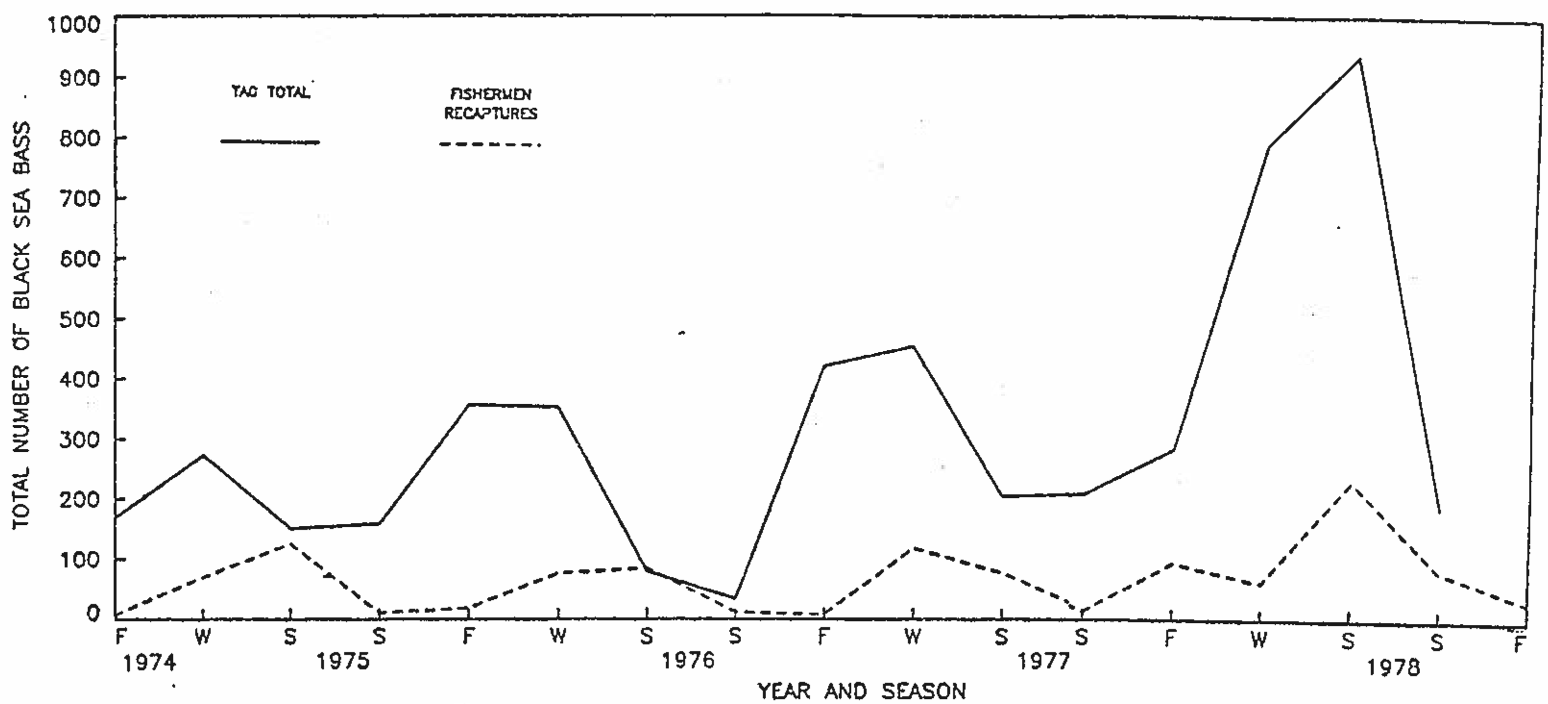


Figure 12. By season and year, the total number of tagged fish released and recaptured by fishermen during the Georgia Reef Fish Migration Study, 1974-1978.

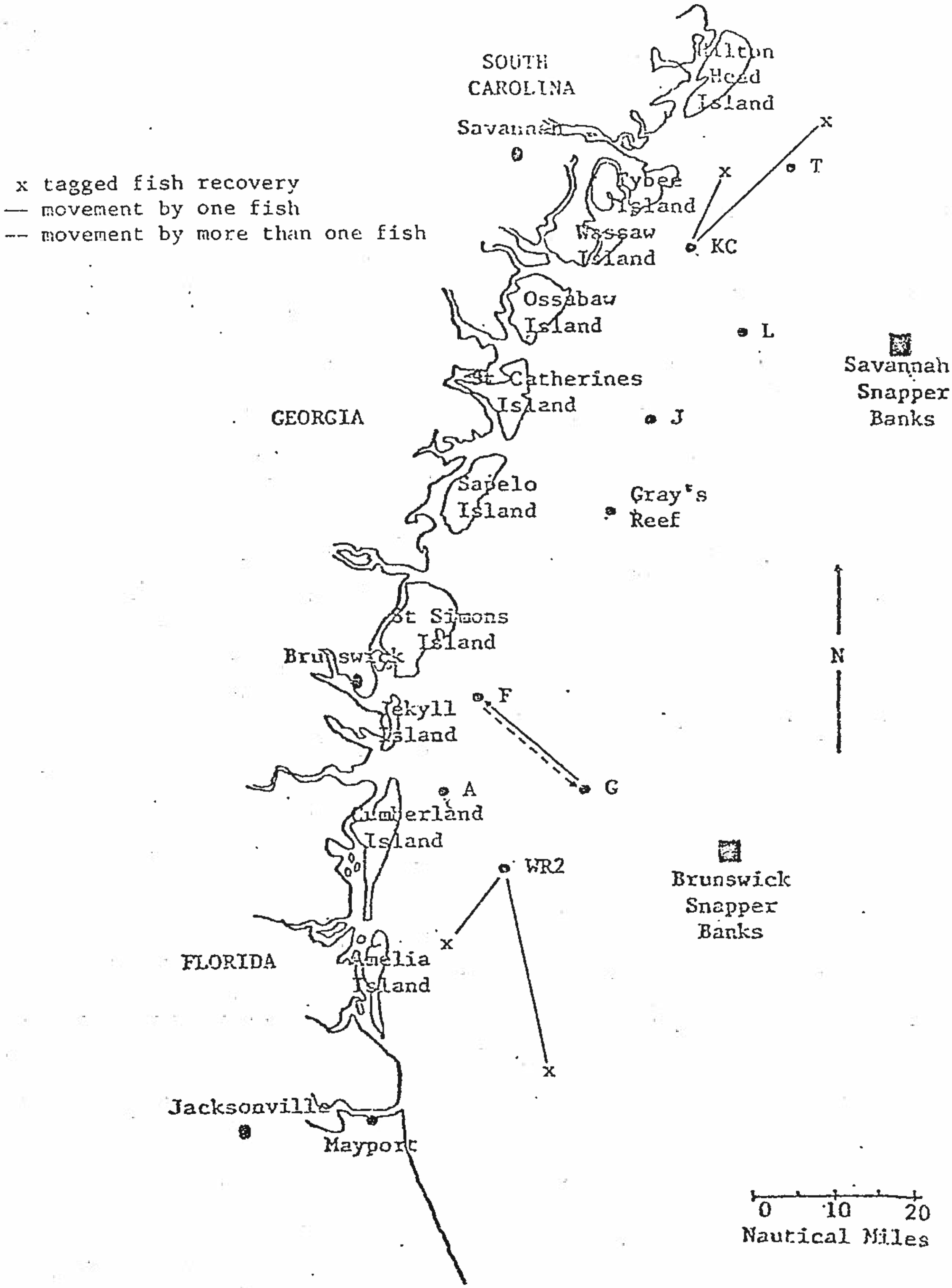


Figure 13. Directional movements of tagged fish recaptured 1975-76 more than on kilometer from the original release site.

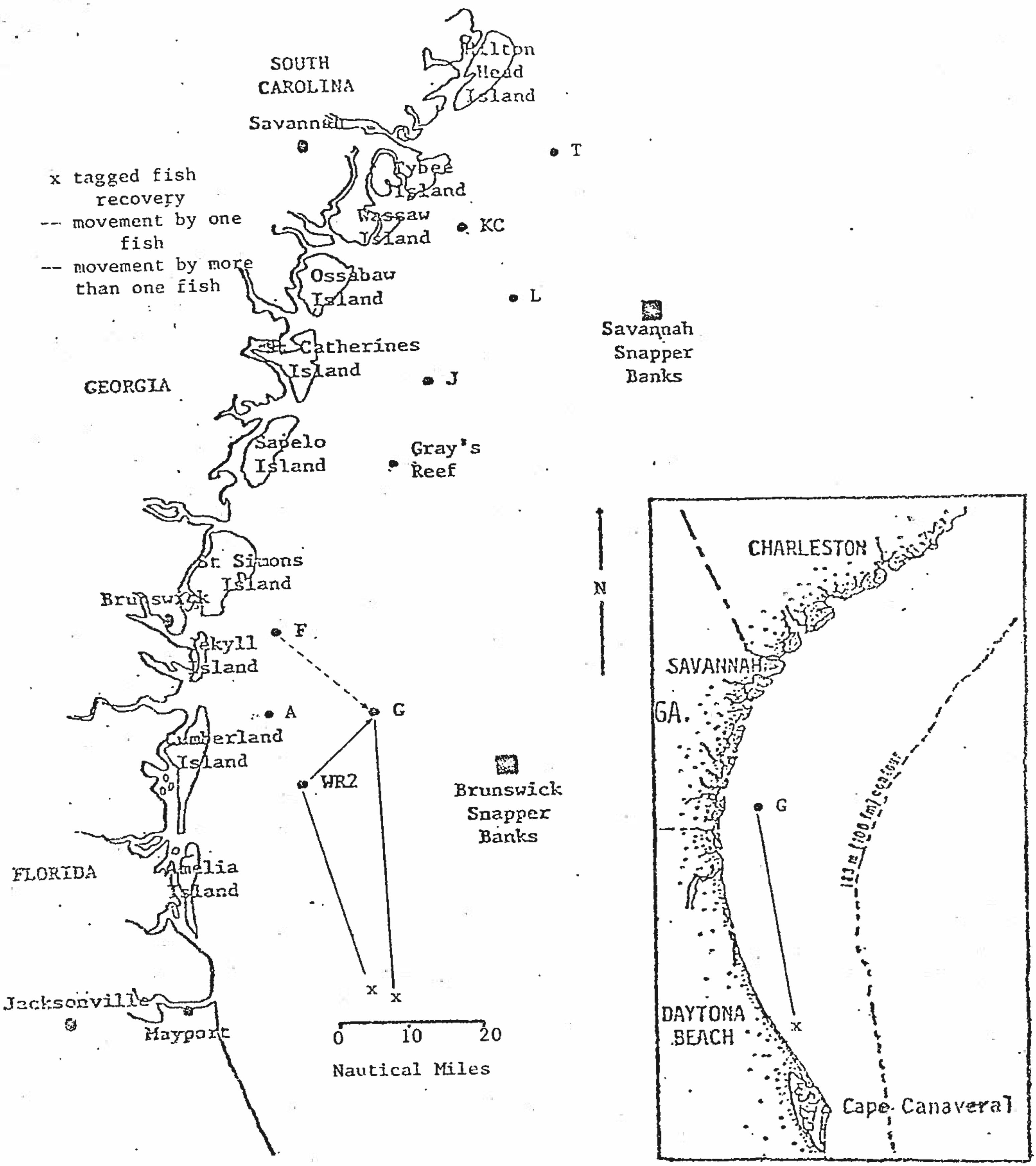


Figure 14. Directional movements of tagged fish recaptured in 1977 more than one kilometer from the original

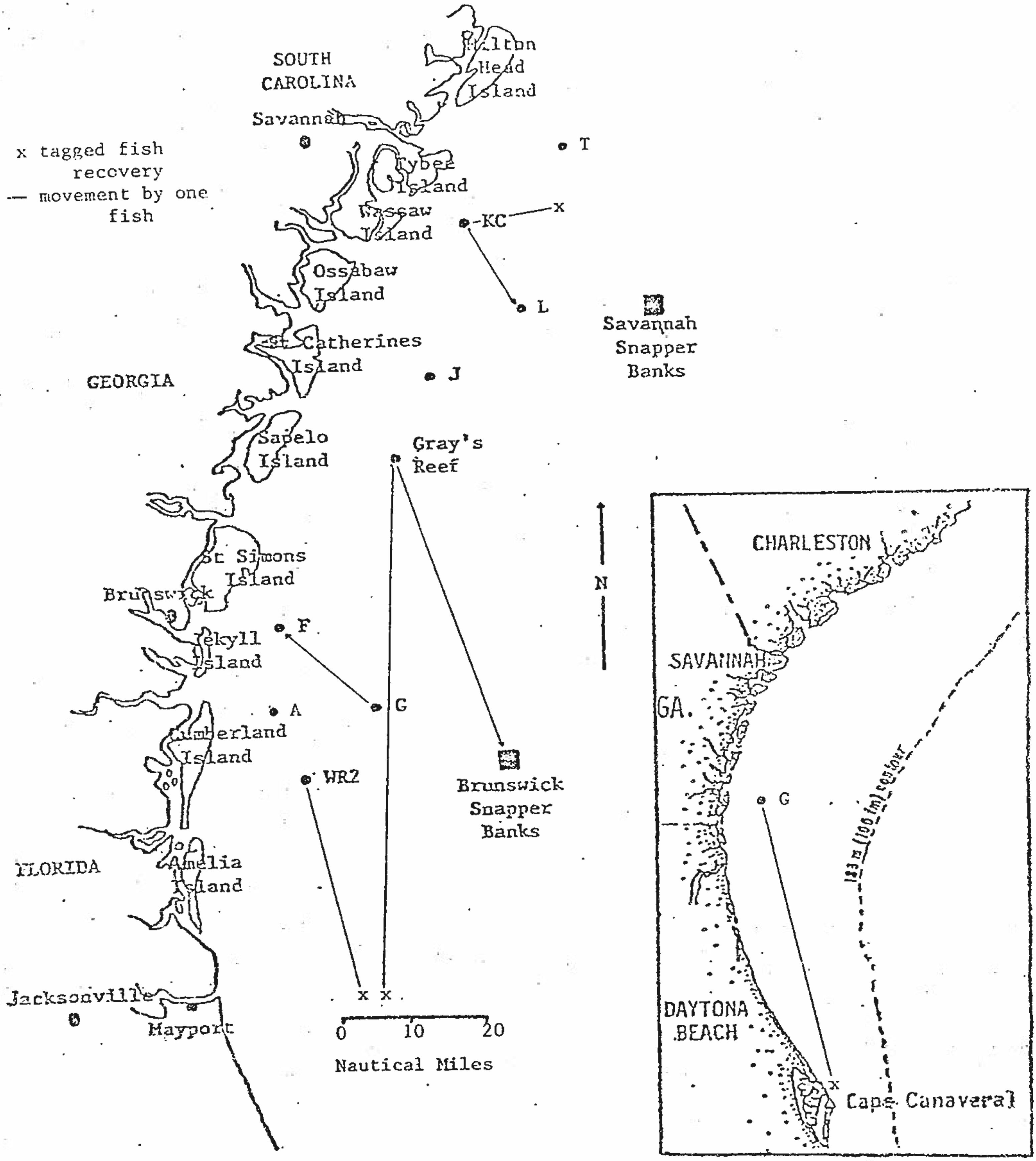


Figure 15. Directional movements of tagged fish recaptured in 1978 more than one kilometer from the original release site.

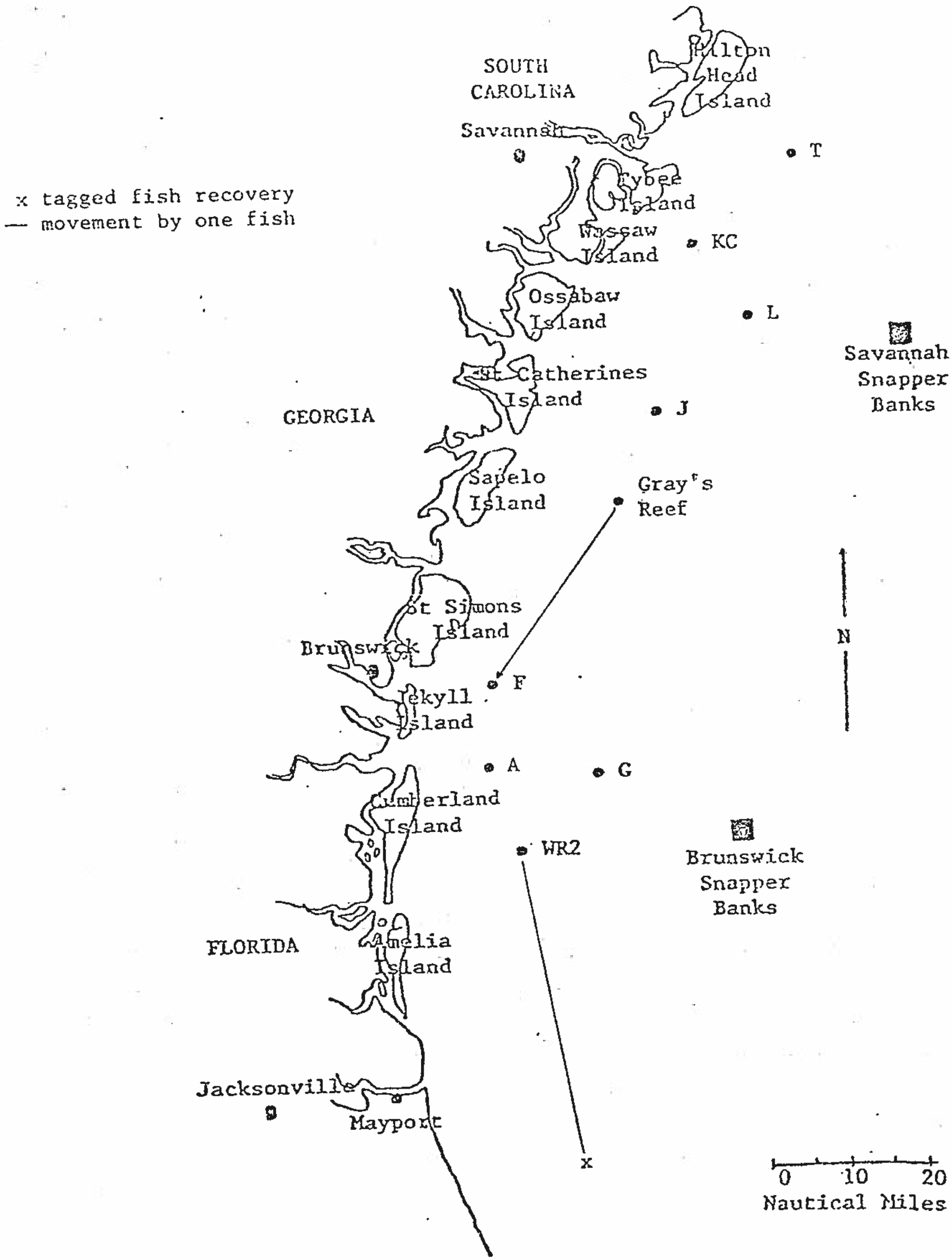


Figure 16. Directional movements of tagged fish recaptured in 1979 more than one kilometer from the original release site.

Table 5. Species, release and recovery dates and geographic locations, minimum distance traveled, and days at large for all fish recaptured that moved 1 km during the study, 1974-1979 (GTR= gray triggerfish; BSB= black sea bass).

SPECIES	MONTH AND YEAR OF RELEASE	RELEASE LOCATION	MONTH AND YEAR OF RECAPTURE	RECAPTURE LOCATION	MINIMUM DISTANCE TRAVELED (km)	DAYS AT LARGE
GTR	April, 1975	F	May, 1975	Reef G	28 km	23
BSB	October, 1975	F	January, 1976	Reef G	28 km	108
BSB	December, 1975	KC	April, 1976	Gaskin Banks	30 km	134
BSB	December, 1975	KC	April, 1976	Texas Tower	15 km	119
BSB	December, 1975	WR2	December, 1975	NE Florida	22 km	14
BSB	December, 1975	WR2	January, 1975	NE Florida	22 km	41
BSB	December, 1975	G	April, 1976	Reef F	28 km	115
BSB	January, 1976	F	February, 1976	Reef G	28 km	47
BSB	November, 1976	F	February, 1977	Reef G	28 km	103
BSB	December, 1976	F	February, 1977	Reef G	28 km	72
BSB	December, 1976	F	February, 1977	Reef G	28 km	72
BSB	December, 1976	F	February, 1977	Reef G	28 km	68
BSB	December, 1976	G	February, 1977	East of Daytona	192 km	57
BSB	January, 1977	G	April, 1977	NE Florida	63 km	105
BSB	January, 1977	WR2	February, 1977	NE Florida	20 km	26
BSB	August, 1975	WR2	April, 1977	Reef G	22 km	233
BSB	January, 1978	G	February, 1978	N of Cape Canaveral, Florida	259 km	31
BSB	January, 1978	Gray's Reef	May, 1978	NE Florida	124 km	131
BSB	January, 1978	WR2	March, 1978	NE Florida	59 km	71
BSB	February, 1978	Gray's Reef	June, 1978	Brunwick Snapper Banks	65 km	130
BSB	March, 1978	G	April, 1978	Reef F	28 km	54
BSB	April, 1978	KC	November, 1978	East of Wassaw Is,	19 km	211
BSB	April, 1978	KC	November, 1978	Georgia Reef L	19 km	214
BSB	June, 1978	Gray's Reef	February, 1979	Reef F	48 km	262
BSB	January, 1978	WR2	April, 1979	NE Florida	48 km	462

Raw data necessary for approximating standing stock levels, however, were obtained at most of the selected study sites, although much of the data is temporally and numerically limited. Utilizing methods appropriate to these data, estimates were generated for spatially isolated clumps of tire units at artificial reefs WR2 (approximately 300 tire units) and G (500-600 units); for reefs F and WR2 as a whole; and for a measured 46 m x 12 m section of a one meter ledge at Gray's Reef. Applicable only to black sea bass greater than 200 mm in total length (smaller fish were not tagged during the study). Resulting standing stock estimates and their accompanying confidence levels are given in Table 6.

DISCUSSION

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." Reciprocity of movement was also considered fundamental to his definition.

Black sea bass was the only species tagged and recaptured in sufficient numbers to allow conclusions regarding reef-fish movements. Because of this, the following discussion will be directed at this species, as well as at overall study results.

Significant seasonal movements have been reported for black sea bass populations north of Cape Hatteras (Pearson, 1932; Nesbit and Neville, 1935; Lavenda, 1949) and probably occur as a response to lowered water temperatures caused by the influx of the Labrador Current (Cupka, 1973).[3] 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 NE Florida exhibit minimal movement from the area on which they were tagged and are highly susceptible to recapture. Moe reported a 24.7%

[3]Kendall (1977) reports that black sea bass have a low temperature tolerance of 9°C. Harris (1978) reported black sea bass abundant, though, on Georgia reefs even as water temperatures approached 7°C.

Table 6. Adjusted Schnabel and Mean of Petersen Standing Stock Estimates and 95% confidence limits (L_1-L_2) for black see bass >200 mm total length inhabiting Georgia offshore reefs during the Georgia Reef Fish Migration Study, 1974-1979.

REEF	DATES	ADJUSTED SCHNABEL ESTIMATE	L_1-L_2	MEAN OF PETERSEN ESTIMATES	L_1-L_2
Artificial Reef WR2	1/16/75-4/07/75	280	183-484	312	0-831
	12/15/75-2/19/76	224	171-305	252	190-315
	1/12/77-4/13/77	357	280-470	335	163-507
Artificial Reef WR2*	1/16/75-4/07/75	209	137-387	230	0-565
	12/15/75-2/10/76	203	153-288	272	94-449
	1/12/77-4/13/77	343	270-453	315	142-488
Artificial Reef F	3/02/75-4/08/75	173	123-275	192	0-433
	11/11/76-12/16/76	521	318-1158	341	222-460
	11/23/77-1/24/76	1013	678-1800	---	---
Artificial Reef G	2/16/76-2/24/76	581	347-1360	---	---
Gray's Reef	6/06/78-6/08/78	206	133-363	179	0-1084

*a group of 300 eight-tire units

recovery rate for this species, with returns occurring during the warmer months, a result he attributed to reduction in fishing pressure during the fall and winter. Beaumarriage reported Schlitz tagging program returns from the area throughout the year for a higher recovery rate of 37.3%.

Mark/recapture studies conducted by Parker et al. (1979), Cupka (1973), and Hammond (1980 pers. comm.) on artificial and natural reefs off South Carolina also indicate little seasonal movement. In situ observations by Harris (1978) and Parker et al. (1979) confirm the presence of black sea bass on Georgia and South Carolina reefs year-round.

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 the larger, older, and predominantly male individuals may occur south of Cape Hatteras. Additional distributional analysis by Waltz et al. (1979) later confirmed the presence of similar stocks off South Carolina in water depths greater than 20 fathoms.

Project results correlate closely with those obtained by other investigators. High return rates of tagged fish from the original release site, including numerous multiple recoveries, and the correspondingly low return rate of individuals exhibiting movement indicate that the black sea bass populations associated with Georgia's reefs do not exhibit major movements, seasonal or otherwise, and are generally long-term residents of the reef areas. Movements that did occur were not significant (0.6% of all black sea bass tagged), and could not, by Moe's (1972) definition, be defined as migratory.

Extending this generalization to species other than *Centropristis striata* cannot be justified because of the few fish tagged and later recovered. Direct observations by Harris (1978) of many of these other species, including gray triggerfish and red and vermilion snapper, suggest that these groups do exhibit seasonal fluctuations on and off Georgia's reefs.

Fishing for offshore demersal species such as black sea bass is concentrated over wrecks, artificial and natural reefs, and other areas which provide shelter and food. Little fishing for these species is intentionally conducted over the sand and clay areas which primarily comprise Georgia's Outer Continental Shelf (Struhsaker, 1969). Examination of Table 4 indicates substantial fishing activity at most study sites, particularly at the offshore reefs nearest shore (KC, F) and more accessible to the population centers of Brunswick and Savannah (KC, F, G).

Despite this pressure, less than 13% of the total number of black sea bass recovered were recaptured more than 140 days after their release. Such data possibly indicates that additional losses, other than by recreational/commercial fishing pressure, could have occurred. This loss could be attributed to several reasons, including immigration/emigration and/or natural mortality. Based on available biological data (Kendall, 1977) and study results, however, it seems improbable that any of these factors could account for such a marked reduction of returns in such a short time.

Loss of tags could explain the lack of returns beyond 140 days of freedom. Other investigators have also suspected high sloughage rates for the tag type utilized in this study (Cupka, 1973; Parker, 1975; Hammond, pers. comm.). Tag retention studies by Sackett and Hein (1979) found that 58% of the tags were in place after 90 days, although 27% of these were broken or split.

No investigations were conducted during the study to determine either the cause or extent of tag losses from marked fish. Even if sloughage did occur, it seems doubtful that this fact would change study results to indicate that a major migratory movement of black sea bass does occur. The determination of long-term, gradual movements by black sea bass, as suggested by Cupka et al. (1973), however, would be seriously affected by such losses. Regardless, study returns of black sea bass exhibiting movement are too few statistically to refute or support Cupka's theory.

Standing stock estimates obtained for black sea bass inhabiting Georgia's offshore reefs vary considerably, depending on the method used to generate these figures. Overall, population levels calculated utilizing the adjusted Schnabel equation are more reliable than estimates generated using the adjusted Petersen and mean of Petersen methods.

Although black sea bass standing stocks were determined through application of the adjusted Schnabel method for all study sites, resulting estimates are perhaps most accurate for a limited group of eight-tire units located at reef WR2 east of Cumberland Island. Consisting of approximately 300 scattered and clumped units spatially isolated from the main portion of the reef, this area is extremely difficult to locate and consequently receives little fishing pressure. Winter standing stocks for black sea bass greater than 200 mm (TL) are not especially high for this area, ranging from 203-343 individuals, with confidence limits of 137-453 individuals. Such stocks could easily be depleted by offshore fishermen who take advantage of these seasonal peaks in reef-fish populations and harvest up to 150 kg. of black sea bass per outing (personal observation).

None of the remaining study areas for which standing stock estimates were generated support the assumptions necessary for obtaining unbiased stock estimates (as outlined by Ricker, 1975). In these cases study areas were not adequately delineated to allow quantification of resident fish stocks (reefs F and G) or were not isolated enough to show movement off the study site (Gray's Reef). Estimates calculated for these areas therefore can only be safely treated as rough approximations of associated black sea bass (total lengths greater than 200 mm) populations.

RECOMMENDATIONS

1. Black sea bass, *Centropristis striata*, constitute an important portion of recreational creels taken from Georgia's artificial and natural reefs. Further commercial exploitation of this species, particularly on areas well offshore, could conceivably occur in the future as commercial fishery efforts expand over the continental shelf. In order to provide data for effective management decisions concerning utilization of black sea bass stocks in Georgia's Fisheries Conservation Zone, several studies should be conducted:
   a) additional biological investigations, incorporating mark/recapture techniques, of the more offshore populations, since offshore investigators have thus far not been able to find conclusive evidence indicating the origin of these populations.
   b) determination of recruitment rates/movement of juvenile black sea bass populations.

c) determination of seasonal standing stocks associated with areas extensively utilized by recreational/commercial fishing interests through studies employing proven mark/recapture techniques and SCUBA estimates.

d) investigations of seasonal spawning influences, if they occur, and of associated reproductive behavior exhibited by black sea bass.

2. Present study results for other recreationally important species associated with Georgia's offshore reefs were inconclusive. Further investigations should be aimed specifically at the snapper/grouper complex, porgies, sheepshead, and gray triggerfish populations. These studies should be conducted in close coordination with other research agencies and restricted to selected target species over fewer and more accessible areas to insure sampling continuity and maximum effort.

3. Study findings indicate that Georgia's artificial and natural reefs are subject to significant recreational fishing pressure. These data, combined with the results of an offshore fishing survey (Harris and Ansley, 1981), reveal the extent of fishing pressure over the offshore areas and indicate reasons for low capture rates obtained by project personnel during the summer season. Such future creel surveys should be modified as needed and conducted at regular intervals to monitor shifts in fishing pressure and to assist resource agencies in management decisions.

4. Project results indicate that the existing artificial reef system, especially reefs KC and F, should be expanded. Expansion could not only extend present angling opportunities to more fishermen and increase success, but also could help alleviate the future effects of higher energy costs and possible fuel shortages since these reefs are close to coastal Georgia's major population centers. It is further recommended that enlargement of the reef system be obtained by expansion of existing reefs rather than through the creation of new reefs. This would help avoid additional cost and time loss necessitated with the maintenance and placement of new reef buoy systems.

5. Efforts should be made to locate all existing wrecks and live bottom areas, particularly those that would be more accessible to user groups currently utilizing Georgia's artificial reefs. Research and other available information on Georgia's offshore areas should be thoroughly reviewed for the location of potential fishing and diving sites. These areas should then be mapped employing surface remote-sensing survey equipment and evaluated through the use of SCUBA and/or underwater television. Locations of any areas found to support sufficient fish stocks or featuring habitat attractive to divers should be made publically available, including information regarding headings, LORAN coordinates, water depths, and bottom type. Placement of large buoy systems is not recommended, although small, inexpensive systems might be deployed seasonally.

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