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MORTALITY, MOVEMENT, AND GROWTH OF RED DRUM IN GEORGIA

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ABSTRACT

From January 1984 to June 1989, 4,616 red drum were tagged and released in four Georgia estuaries. Return rates varied greatly among the estuarine systems examined with the Altamaha system exhibiting the lowest (6%) and St. Simons the highest (23%). The overall return rate with all systems combined was 19%. Exploitation of age 0 red drum was high, but decreased following implementation of a 14 inch minimum size limit. Exploitation of sub-adult red drum was less than that of juveniles, but increased substantially during the latter part of the study. The disappearence rates of immature red drum in coastal Georgia appears to be very high and is apparently a result of emigration and fishing mortality. Estimates of total instantaneous mortality (Z) in the St. Simons system varied from 1.26-3.23 during the study period. Over 75% of the recaptured red drum were recovered within 10 km of the release site and six months of release. Inter-estuarine and inter-state movement of immature red drum was minimal. Age composition of Georgia's red drum stock was estimated from length-frequency data and back-calculations of scales and otoliths. Low abundance of sub-adults and young adults suggests that the high inshore harvest of juveniles is reducing survival to the spawning stock. Variability in cohort survival was indicated by differences in relative abundance of adult red drum which may be related to winter-kill mortalities.

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INTRODUCTION

The red drum, Sciaenops ocellatus, found from New York to Texas (Fischer 1978), is a valuable recreational and commercial species throughout its range. The popularity of this species with coastal anglers in the southeastern United States has increased during the past decade (Schmeid and Burgess 1987). Expanding demand for red drum in both the commercial and recreational sectors stimulated much applied research in propagation and culture. However, little is known about the reproductive biology, stock identity, movement, and mortality rates of exploited red drum populations throughout the South Atlantic region.

In Georgia, red drum have been protected from harvest by gill net in estuarine waters since the 1950s and a large scale commercial fishery has never developed. Inaccessibility of the barrier island beaches prevented the development of a haul seine fishery. Therefore, Georgia has avoided much of the controversy seen in the Gulf of Mexico and other South Atlantic states concerning allocation of red drum among commercial and recreational interests. Today, while there is no directed commercial fishery for red drum, there are a small number of anglers who utilize hook and line gear to harvest red drum which they sell to local restaurants and seafood markets. These individuals must possess a personal commercial fishing license and are not exempt from recreational limits.

Red drum catch by shrimp trawls has been the subject of much controversy during recent years as Georgia may periodically open its estuarine waters for harvest of food shrimp when conditions warrant. Shrimp trawling in the sounds is perceived by some anglers as a significant threat to Georgia's marine sportfish populations (Woodward 1990); however, bycatch studies in Georgia

(Anderson 1968, Knowlton 1972, Mahood et al. 1974) and commercial landings statistics do not substantiate the angling public's fears. Georgia's estuarine waters have been open to food shrimp trawling for a total of 26 days during the past decade. Even when the estuarine waters are open to power-drawn nets, the temporal and spatial aspects of trawling combined with habitat preferences of red drum prevent all but incidental catch. Reported commercial landings of red drum accounted for less than 2% of Georgia's total red drum harvest during 1985-1987 (Pafford and Nicholson 1989).

While commercial harvest was perceived as a threat as early as the 1950s, recreational harvest was considered to have no deleterious effects on red drum abundance and remained unregulated until the past decade. During 1979, the National Marine Fisheries Service (NMFS) began monitoring the recreational harvest of marine finfish throughout the United States and its territories utilizing the Marine Recreational Fisheries Statistics Survey (MRFSS). In 1985, the Georgia Department of Natural Resources (GADNR) entered a cooperative agreement with NMFS to expand the level of effort within the MRFSS. This allowed for an increased number of access-site intercepts, additional telephone interviews, and provided more detailed data on effort and catch within the state's growing marine recreational fishery.

Results from this survey provided the first quantitative evidence of the increasing pressure on Georgia's marine sportfish. The number of resident saltwater fishing trips increased approximately 60% from 1979 to 1987. In addition, the MRFSS documented that red drum was the second most often targetted sportfish by Georgia's marine anglers. The total estimated catch of red drum by recreational anglers increased from 62,000 fish in

1979 to over 300,000 in 1987. During 1987, red drum comprised over 9% of the total recreational finfish catch in Georgia.

Red drum typically recruit to the recreational fishery during June-July of the first year following spawn. At this time age 0 red drum are approximately 250 mm in length and 0.23 kg in weight. From 1979 to 1985 over 70% of all red drum harvested in Georgia were less than 14 inches in length (Pafford and Nicholson 1989). Tagging studies conducted by Music and Pafford (1984) indicated that exploitation of young juvenile red drum (<350 mm) was high (>28%) with most fish being recaptured within 6 months of release. Growth data from previous studies in Georgia (Music and Pafford 1984) indicated that a two-three month delay in harvest would allow red drum to attain a length of approximately 350 mm with a concurrent threefold increase in weight (0.70 kg).

A 350 mm red drum is approximately 12 months old and will not be sexually mature for another 2-3 years. Therefore, high exploitation of juvenile red drum could negatively impact the stability of the adult stock. The aforementioned information combined with low abundance of sub-adults and adults (>600 mm) in fishery-independent sampling during the late 1970s and early 1980s suggested that red drum could potentially be recruitment overfished in Georgia. Consequently, GADNR recommended a 356 mm (14 in) minimum size limit for red drum and a two fish bag limit for red drum over 32 inches. These recommendations were promulgated as laws by the Georgia General Assembly during 1986. Implementation of these regulations was designed to improve the yield from the red drum fishery, enhance survival to adulthood, and protect the existing adult stock.

While these regulations were supported by a large segment of the sportfishing public, a vocal group of anglers resisted these management efforts. One of the most prominent concerns voiced by these groups was that delay of harvest would allow red drum to migrate from state waters and reduce fishing opportunities for Georgia's coastal anglers. The concerns of these anglers were unfounded as early tagging studies by Music and Pafford (1984) documented that most red drum were recaptured in the estuary where they were released. During 1979 to 1982 red drum traveled an average of 10 km before being recaptured. Other studies (Beaumariage and Wittich 1966; Osburn et al. 1982; Overstreet 1983; Ross and Stevens 1989) also have documented that movement of immature red drum is limited and appears to be random within estuaries and bays.

Several investigators have studied age and growth of red drum throughout the Gulf of Mexico and South Atlantic (Pearson 1929; Gunter 1945; Simmons and Breuer 1962; Theiling and Loyacano 1976; Rohr 1980; Wilson et al. 1988; Beckman et al. 1989). Music and Pafford (1984) investigated age and growth of red drum in Georgia and found that length-frequency distributions could be used to determine the age of red drum for the first three years of life. Both scales and otoliths were useful for determining the age of juvenile and sub-adult red drum; however, scales were unreliable after the first three years and could not be used for aging adults. Red drum grow rapidly during the first two years of life reaching a total length of over 600 mm at age 2. Growth slows as red drum approach maturity and there is minimal annual growth after sexual maturity. There is virtually no information available on the age and growth of adult red drum in Georgia and throughout the South Atlantic.

During the late 1980s, the continued increase in angling effort prompted GADNR to recommend length and bag limits for seventeen marine finfish species. Included in these recommendations was a 10 fish daily limit for red drum between 14-32 inches. Since implementation of the 14-in minimum size limit the average size of red drum caught by recreational anglers increased from approximately 0.5 kg in 1985 to almost 1.8 kg in 1987 (Pafford and Nicholson 1989). However, continued high exploitation of juveniles appeared to be limiting survival to adulthood. Information from the 1987 MRFSS indicated that only 1% of the saltwater fishing trips harvested over 50% of the red drum that year. A 10 fish bag limit would have minimal impact on most anglers; however, it would substantially reduce the number of large catches and thereby reduce fishing mortality.

In 1988, the South Atlantic Fishery Management Council (SAFMC) requested that the NMFS Southeast Fishery Center conduct an annual stock assessment of South Atlantic red drum. Information from the 1989 stock assessment (Vaughan and Helsner 1989) indicated that South Atlantic red drum were overfished and that reductions in fishing mortality were necessary to allow the stock to recover. Estimates of total instantaneous mortality (Z), fishing mortality (F), and natural mortality (M) for red drum in the South Atlantic vary tremendously (Murphy and Taylor 1986; Tilmant et al. 1989; Vaughan and Helsner 1989). The variation in these parameters due to differences in exploitation, emigration from estuarine waters, and gear selectivity indicate that additional field study is needed. Previous tagging studies (Music and Pafford 1984) have documented the high exploitation of juveniles in Georgia; however, little is known about the mortality and survival of juveniles, sub-adult and adult red drum.

As coastal populations expand and development continues to escalate, pressure on Georgia's red drum will likely increase.

Effective management to prevent overfishing necessitates a knowledge of this species' growth, mortality, and movement. The objectives of this study were 1) determine exploitation, mortality, and survival of juvenile and sub-adult red drum; 2) determine the magnitude and extent of red drum movement including the effects of season and size at release; and 3) evaluate age and growth of red drum.

METHODS

Description of Study Area

The coastal area of Georgia lies within the western-most portion of the Blake Plateau of the North Atlantic Ocean and is approximately 160 km in length. The coastal area is composed of a series of bar-built estuaries with a total of 14 major barrier islands (Figure 1). Distance between major tidal inlets ranges from 4 to 28 km and barrier islands are separated from the mainland by a 5-10 km band of marshland. Georgia's estuarine systems contain approximately 200,000 ha of freshwater, brackish, and saline marshes of which over 50% are dominated by smooth cordgrass, *Spartina alterniflora.* These marshes are subject to diurnal tides of 1.8 to 2.4 meters and, during the spring and fall, astronomical tides augmented by easterly winds can exceed 3 meters. Estuarine surface water temperatures vary from 7 to 33^{o}C annually. Extremely cold winters can result in estuarine water temperatures below 5^{o}C and mortalities of estuarine species such as penaeid shrimp and Sciaenids.

The study area consisted of five estuarine systems within the coastal area of Georgia: Wassaw, Altamaha, St. Simons, St. Andrew, and Cumberland (Figure 1). The Wassaw estuarine system is adjacent to the metropolitan area of Savannah and Chatham county; the most populous area on the Georgia coast. This area contains

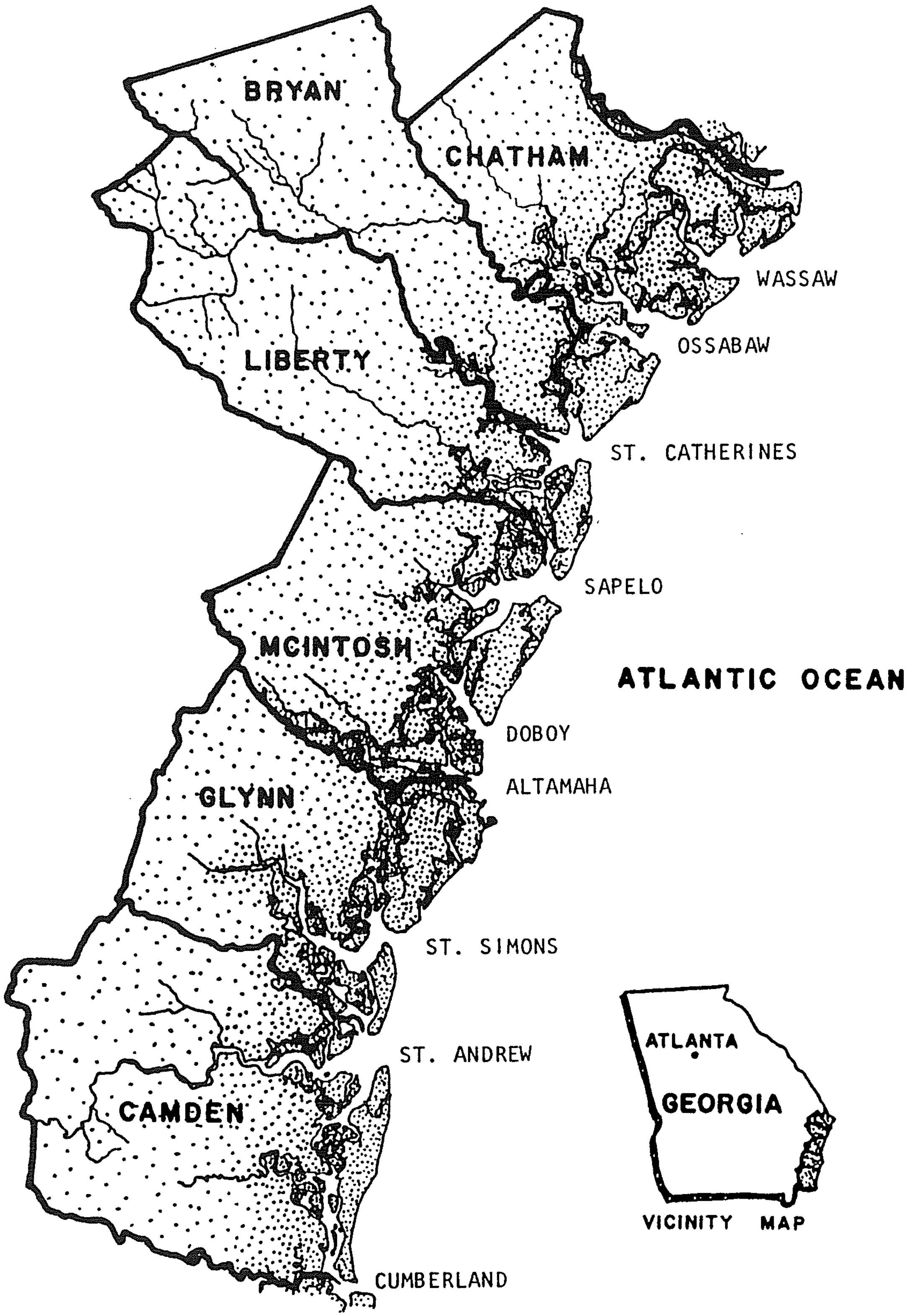

Figure 1. Study area within coastal waters of Georgia.

approximately 24% of the saline marshes and 60% of the population of Georgia's six coastal counties.

The Altamaha system is located in McIntosh and Glynn counties near the city of Darien. The Altamaha River originates in the piedmont of Georgia and forms a broad delta at the interface with the Atlantic Ocean. This delta is dissected by numerous tidal rivers and creeks which are subject to considerable changes in salinity and temperature due to the influence of the Altamaha River which has an average annual discharge of 14,000 cfs.

The St. Simons and St. Andrew systems are located in Glynn county adjacent to the city of Brunswick and the populated barrier islands of St. Simons, Sea, and Jekyll. Due to proximity and morphological similarities these two systems were combined during analyses. The Satilla River, a coastal plain stream, enters the St. Andrew system, while the St. Simons system is influenced by the Altamaha River.

The Cumberland estuarine system is located in the extreme south portion of the coast near the city of St. Marys. Freshwater inflow in this system comes from the St. Marys River, a coastal plain stream. Population expansion within the Camden county area surrounding the Cumberland system has been rapid following the construction of a U.S. Navy Trident submarine base during the 1980s.

Collection Methods

Red drum were collected for age and growth analyses and tagging during fishery-independent sampling efforts using a monofilament trammel net: 137 X 1.8 m with an inner panel of 7.0-cm stretched mesh and outer panels of 15.2-, 22.9-, and 35.6-cm stretched mesh; and a monofilament gillnet: 30 X 1 m with stretched mesh of 5.7-cm. Juvenile red drum collected during a hooking mortality study and adults collected in nearshore waters by cooperative recreational anglers were included in some of these analyses.

Trammel nets and gillnets were deployed in perimeter areas of the marsh surface during the 1/2 ebb to slack low tide period. A typical net set consisted of placing the end of the trammel net on the shoreline, moving perpendicular for approximately 30 m, then moving upcurrent parallel to the shoreline with the remainder of the net. The area inside of the net was struck with noise to drive fish into the net. Net set duration was approximately 20 minutes. Additional information on the temporal and spatial aspects of sampling can be found in Nicholson et al. (1990).

Red drum were held in a holding ring in ambient estuarine water until tagging. Those sacrificed for age and growth analyses were held on ice and returned to Coastal Resources Division (CRD) headquarters for processing. All sampling was conducted during daylight hours. Environmental data recorded for each collection included: salinity (ppt); surface water temperature (C); moon phase; and wind direction and velocity (mph).

Tagging

Red drum were individually inspected for injuries, measured (mm FL), and only active, apparently unharmed fish were tagged. Internal anchor tags (FD-68BC) manufactured by Floy Tag and Manufacturing, Inc. of Seattle, Washington were used for tagging red drum throughout the study period. The internal anchor tags were laminated oval plastic disks measuring 6 X 25 X 0.8mm with a 2 mm hole in the center. The streamer portion of the internal tag was constructed of 2 mm diameter flourescent orange vinyl tubing 75 mm in length. Both the disk and streamer portion included a unique five digit number. The disk portion also included the following legend: "REWARD, SEND TAG, DATE, EXACT LOCATION, LENGTH, PHONE, HOW CAUGHT & BAIT USED TO: COASTAL RES. DIV. 1200 GLYNN AVE. BRUNSWICK, GA 31523". Insertion of the internal anchor tag was accomplished following the procedure outlined by Moffett (1961) and Music and Pafford (1984).

During the latter portion of the study period, plastic tipped dart tags (PDT and PDB-T) manufactured by Hallprint LTD. of Australia were used to tag red drum. A white PDT dart tag (100 mm) was used for marking red drum less than 600 mm, while a yellow PDB-T dart tag (125 mm) was used for marking fish >600 mm. Both tags were constructed from a solid plastic core molded to a plastic barbed head. The streamer or marker portion containing the legend was covered by a fused layer of clear polyethylene. Both dart tags included a unique five digit number and the following legend: "$REWARD$-RETURN TO: DEPT. NAT. RES. CRD 1200 GLYNN AVE., BRUNSWICK, GA 31523". Insertion of dart tags followed the method of Qualia (1987).

Anglers were requested to provided the following information when returning a tag: species, tag number, location and date of capture, and total length. Rewards of $2.50, $5, or $10 and a letter containing release information pertaining to the tagged fish were provided to anglers as an incentive for participation in the tagging study.

The tagging study was publicized by placing posters at sporting goods stores, marinas, docks and launching sites throughout coastal Georgia. Additional publicity was obtained through local newspapers, radio and television, and speaking engagements at civic organizations and sportfishing clubs.

Age and Growth

Scale and otolith samples were taken from red drum collected during fishery-independent sampling efforts in the St. Simons and Altamaha systems. Marginal increment analysis and comparisons of scale samples taken from recaptured tagged red drum were used to validate the number of marks formed annually.

Red drum $\geq$ 800 mm collected in nearshore ocean waters using hook and line gear and trammel nets were sacrificed to determine the age composition of Georgia's adult red drum stock. Sex of these individuals was determined by macroscopic examination of the gonads.

A minimum of three scales was removed from the area behind the left pectoral fin (Miller 1966; Barger and Johnson 1980; Music and Pafford 1984). Scale impressions were made using cellulose plastic sheets and a Carver laboratory press. These impressions were viewed on a DataMate 414 microfiche projector at 24X magnification.

Sagittal otoliths were removed and laterally sectioned through the nucleus into 0.45 mm sections using an Isomet low speed saw with a diamond-edge wafering blade. Otolith sections were submerged in a small black disk containing water and examined under reflected light at 20X magnification (Lux 1971; William and Bedford 1974).

Previous investigations in Georgia (Music and Pafford 1984) determined a linear relationship for fish length and scale radius. Therefore, length at time of annulus formation were determined using back-calculations utilizing the direct proportion formula $L'=S'/S \times L$ (Klima and Tabb 1959).

Year-of-birth was calculated for red drum following the method described by Beckman et al. (1989). Abundance was plotted against year-of-birth to detect possible fluctuations in cohort survival during past years.

Meristic Relationships

Length-weight relationships were determined by fitting the general parabola $A=aL^b$. Coefficients "a" and "b" were determined by regressing log A on log L utilizing a standard linear model. The headgirth-age relationship was examined using simple linear regression (Sokal and Rohlf 1981) to evaluate its efficacy as an alternative method for estimating the age of large red drum ($\geq$ 800 mm). Headgirth (mm) was measured at the junction of the opercle and the body proper utilizing a flexible fiberglass metric tape.

Data Analysis

Mean lengths of red drum tagged in each estuary were compared using a one-way analysis of variance (Sokal and Rohlf 1981) to determine if size varied among systems. Length-frequency distributions of all released and recaptured tagged fish were plotted as total number vs. FL in 25-mm increments to evaluate the effects of size on return rate. Growth of recaptured red drum was determined by comparing length at release and length at recapture.

Movement of red drum was determined by plotting the release and recapture locations on a NOAA nautical chart and measuring the shortest nautical distance (km) between the two sites. Days-at-large was the time in days between the release date and the recapture date, inclusive of both dates. The relationship between distance traveled and days-at-large for fish was examined using linear regression (Sokal and Rohlf 1981). Relationships between distance moved vs. season, estuarine areas, and size at release were also examined to reveal temporal and spatial aspects of red drum movement.

Red drum recaptured during fishery-independent sampling efforts were included in the estimates of growth and mortality. Red drum with incomplete recapture information were excluded from the appropriate analyses.

Exploitation rates were determined for red drum released in each estuarine system and for red drum in the St. Simons system based on age at release. An age-length key developed during this study was utilized to assign ages to returned red drum based on length at release. Recent efforts to determine fish tag nonreporting rates in Georgia (Woodward 1989) indicated that reporting was considerably less than 100%; however, small sample sizes prevented determination of valid rates. Therefore, the minimum exploitation rate was determined by adjusting the number of reported tags by 50%.

Annual survival and mortality was estimated for several groups of red drum released during the spring and fall seasons throughout the study period in St. Simons estuary following Ricker (1975). In each increment of tag data examined, the number of red drum released was reduced by 5% to account for possible short-term tag loss. The following formulae were used in computation of mortality and survival:

$$S = R_2/R_1 \qquad A = 1-S$$

$$Z = -(\log R_2 - \log R_1)$$

$$F = uZ/A$$

$$M = Z-F$$

where: R_1 = recaptures in year of marking
R_2 = recaptures in year following marking
S = rate of survival between years
A = annual mortality rate
Z = instantaneous rate of total mortality
F = instantaneous rate of fishing mortality
M = instantaneous rate of natural mortality
u = rate of exploitation

The following assumptions were made for the movement and survival data analyses: 1) Return information from all anglers was valid, 2) there were no behavioral differences between tagged and untagged red drum, 3) fishing pressure was similar in all areas where tagged fish may have moved, 4) anglers returned only 50% of the recovered tags, and 5) tag loss and tagging mortality were minimal.

RESULTS

Exploitation, Mortality, and Survival

From January 1984 to June 1989, 4,616 red drum were tagged and released in four of Georgia's estuaries (Table 1). The mean length of red drum tagged in the Altamaha system (658 mm) was significantly greater ($P < 0.05$) than the mean lengths of tagged red drum in the three other estuarine systems examined, which were not significantly different. A total of 176 red drum ≥ 800 mm was tagged in the Altamaha system by cooperative anglers. Excluding these larger fish, the mean length of juvenile and sub-adult red drum tagged in Altamaha was similar to that in the other estuarine systems.

Table 1. Number, mean length, and return rates of red drum tagged and released in Georgia estuaries 1984-1989

Estuary	Number Tagged	Mean Length	Range	Number Returned	%
Wassaw	589	357	193-772	91	16
Altamaha	668	658	192-1149	41	6
St. Simons	3132	396	196-824	729	23
Cumberland	227	424	210-804	27	12
Combined	4616	436	192-1149	888	19

Return rates varied greatly among the estuarine systems examined (Table 1) with the Altamaha system having the lowest (6%) and St. Simons having the highest (23%). The overall return rate with all systems combined was 19%. The return rate of adult-size red drum was extremely low (0.5%). Excluding the larger red drum released in the Altamaha system, the release length distributions of tagged and recaptured red drum were similar in all estuarine systems examined (Figure 2).

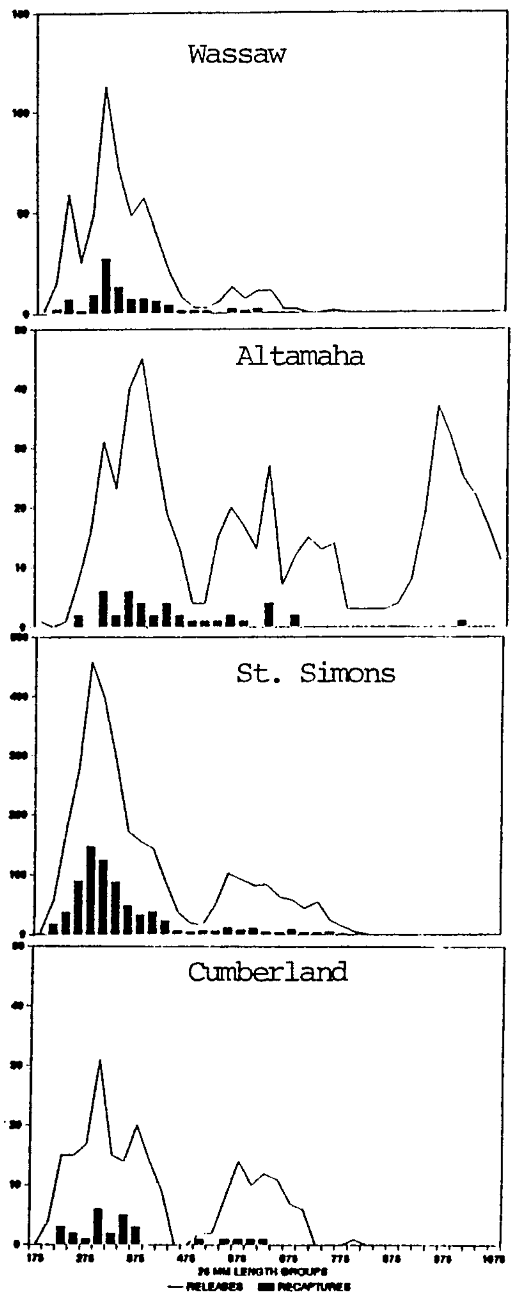

Figure 2. Length distribution of red drum tagged in Georgia estuaries 1984-1989.

Age-specific exploitation rates of red drum in St. Simons estuarine system adjusted for 50% nonreporting are presented in Table 2. Exploitation of age 0 and age 1 red

Table 2. Age-specific exploitation (%) of red drum in St. Simons estuary adjusted for 50% nonreporting (n = number released)

	Year of Release									
Age	n	1984	n	1985	n	1986	n	1987	n	1988
0	339	80	482	63	186	82	568	55	540	39
1	58	41	29	26	51	27	110	24	135	34
2	42	5	37	32	75	19	76	11	48	38
3	26	23	5	0	28	7	22	0	46	26

drum was high throughout the study period. Exploitation rates of age 0 red drum decreased in the latter years of the study, while the exploitation of age 1 red drum was highest in 1984, remained stable in years 1985-87, and increased again in 1988. Exploitation rates of age 2 red drum were highest in 1985 and 1988. The greatest variation occured in the age 3 red drum which had a 23% rate in 1984, virtually no exploitation during 1985-87, and increased to 26% in 1988.

Estimates of survival (S), instantaneous total mortality (Z), fishing (F), and natural mortality (M) are found in Table 3. These estimates were determined for several groups of red drum tagged throughout the study period in the St. Simons system. Total mortality fluctuated depending on the increment of tagging data used in the analysis; however, total mortality generally decreased during toward the latter period of the study. Exploitation and fishing mortality were very high during the early period of the study and, in some analyses, fishing mortality comprised over 80% of the total mortality. Estimates of total mortality were lowest in the fall/winter and highest during the July to September period. In all data analyzed the estimates of natural mortality were high and some cases exceeded fishing mortality.

Table 3. Estimates of exploitation (u) adjusted for 50% nonreporting, survival (S), instantaneous rates of total (Z), fishing (F), and natural (M) mortality for red drum in coastal Georgia 1984-89

Period of Release	Number Tagged	R_1	R_2	u	S	Z	F	M
7-9/84	301	117	6	0.82	0.05	2.97	2.56	0.41
7-9/85	319	79	5	0.54	0.06	2.76	1.61	1.15
10/85-2/86	144	16	5	0.31	0.31	1.16	0.52	0.64
7-8/86	156	62	4	0.85	0.06	2.75	2.49	0.26
10/86-2/87	150	10	2	0.17	0.20	1.61	0.34	1.27
7-9/87	370	102	4	0.60	0.04	3.23	2.02	1.21
10/87-2/88	150	26	3	0.39	0.11	2.16	1.00	1.16
7-9/88	370	64	10	0.42	0.16	1.86	0.93	0.93
10/88-2/89	451	55	8	0.29	0.15	1.93	0.66	1.27

Movement

With the Wassaw, Altamaha, St. Simons, and Cumberland systems combined, 77% of the recaptured red drum moved less than 10 km from the release site (Table 4). Only 12% of the recaptured red drum moved greater than 30 km from the release location. Fish released in the Wassaw system evidenced the greatest net movement with approximately 29% moving greater than 30 km while red drum in St. Simons moved the least with only 9% of the recoveries moving further than 30 km (Table 4). Red drum tagged and released in spring exhibited greater movement than those released in the fall; however, season explained little of the variation in distance traveled (Figure 3). Distance traveled by red drum based on age-group is presented in Table 5. The majority of red drum tagged were age 0

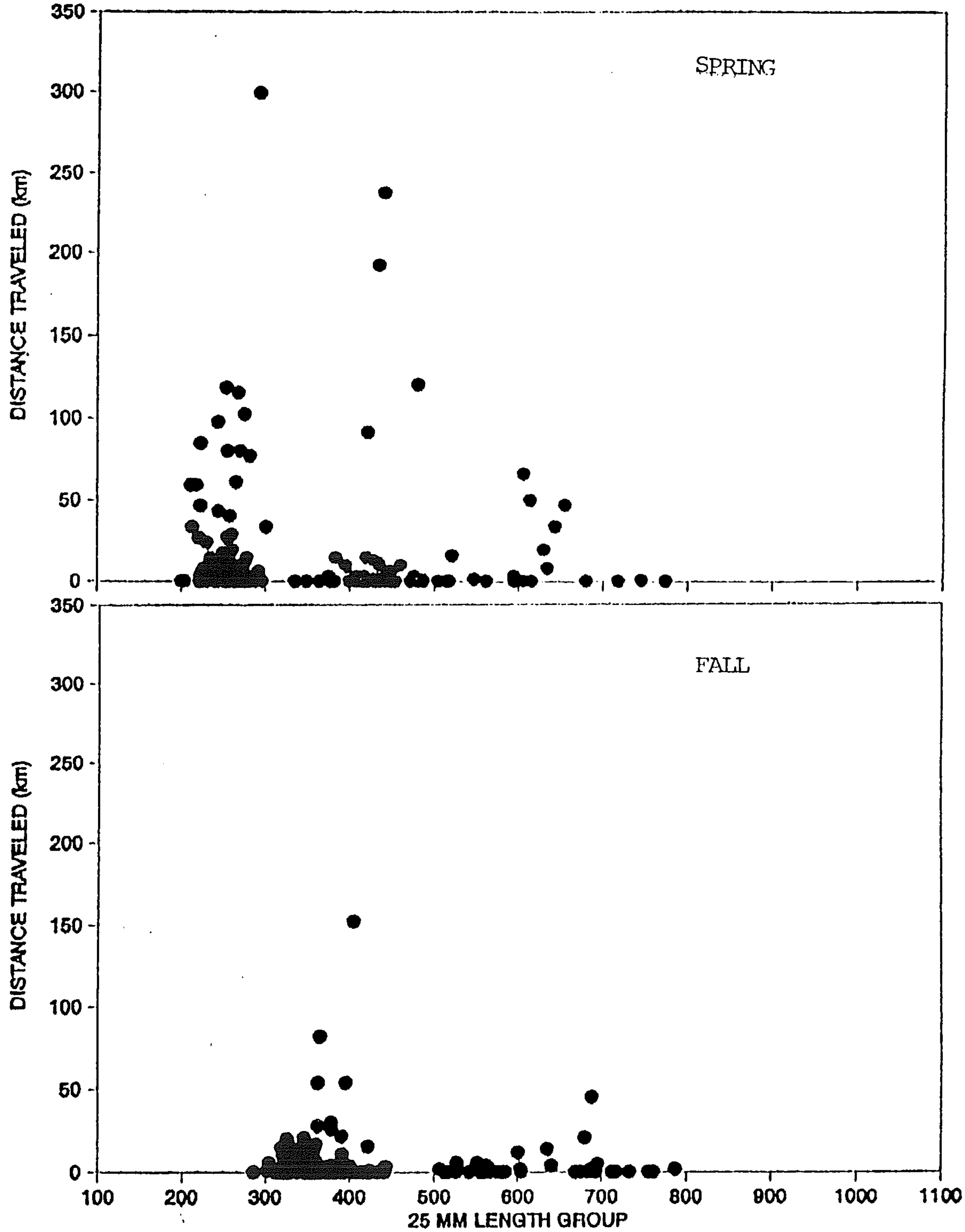

Figure 3. Minimum distance traveled (km), season of release, and length at release for red drum tagged in Georgia estuaries 1984-1989.

Table 4. Percent of returned red drum in relation to distance traveled (km) from release location during 1984-89

	Distance Traveled						
Estuary	0-5	6-10	11-15	16-20	21-25	26-30	>30
Wassaw	49	6	6	2	7	1	29
Altamaha	63	10	7	7	3		10
St. Simons	71	10	4	3	2	1	9
Cumberland	56	4	7		11		22
Combined	68	9	4	3	3	1	12

fish and most (76%) were recaptured within 10 km of the release site. Age 2 red drum had the greatest net movement; with age 3 exhibiting the least. Neither red drum length at tagging and days-at-large were significantly related to distance traveled (Figures 4-5).

Table 5. Percent of returned red drum in relation to age and distance traveled (km) from release during 1984-89

		Distance Traveled						
Age	N	0-5	6-10	11-15	16-20	21-25	26-30	>30
0	724	66	10	4	3	3	2	12
1	89	83	8	4	2			3
2	36	50	8		8	3		31
3	10	90						10
>3	1	100						

Information on inter-estuary and inter-state movement is presented in Table 6. Most red drum were recaptured in the estuarine system where they were released; however, there was some movement among estuarine systems. Over 80% of the red drum released in St. Simons, which were recaptured, were recovered within that system. Tagged red drum released in St. Simons were also recaptured in every estuarine system in coastal Georgia during the study period. Additionally, red drum tagged and released in St. Simons estuary were

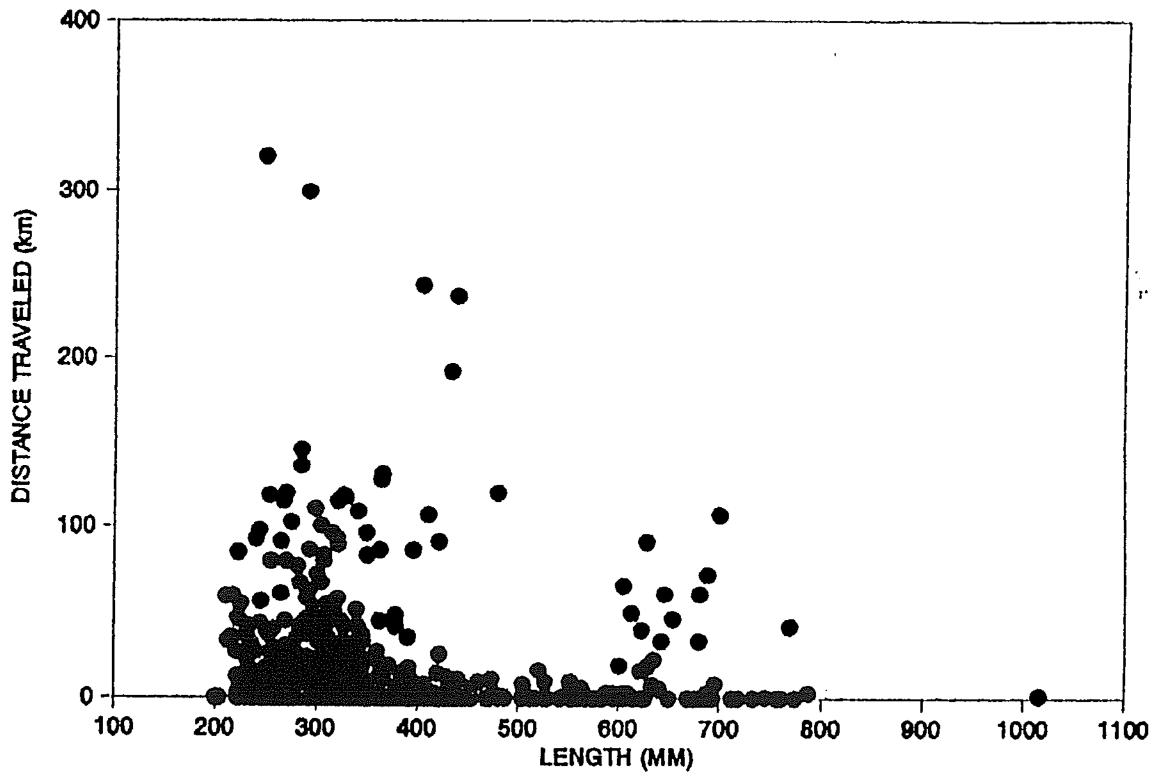

Figure 4. Minimum distance traveled (km) and release length for red drum tagged in Georgia estuaries 1984-1989.

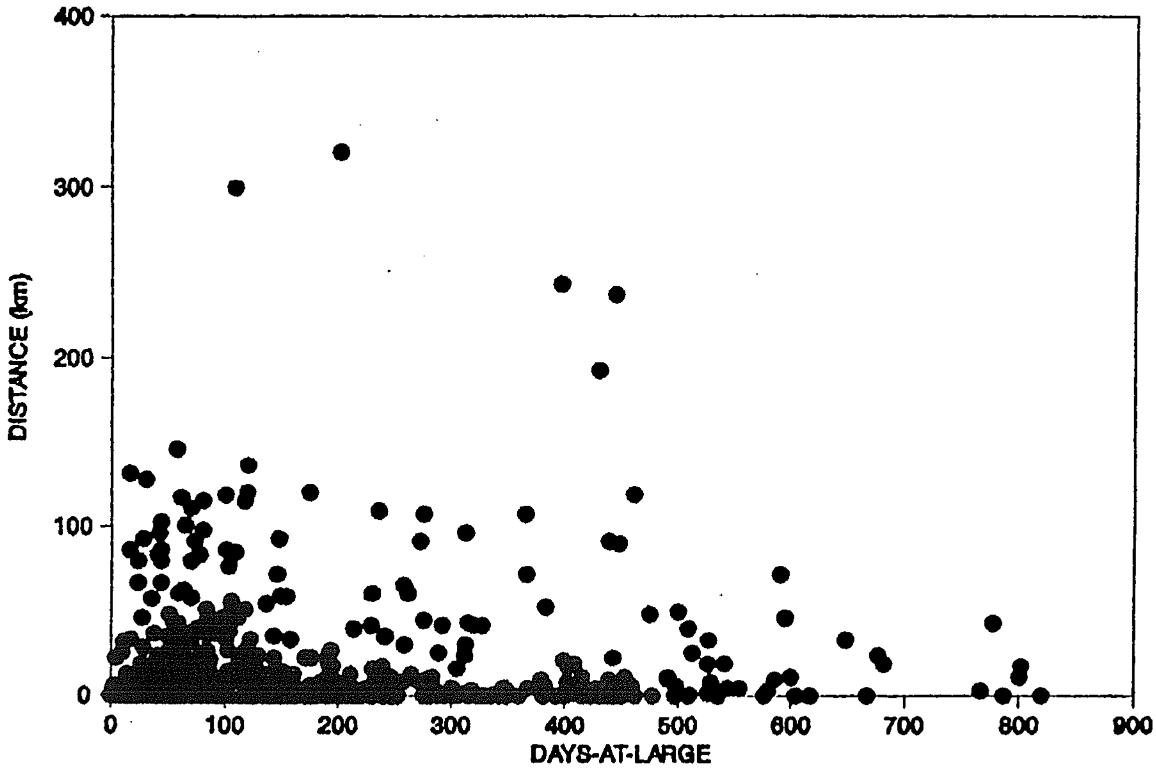

Figure 5. Minimum distance traveled (km) and days-at-large for red drum tagged in Georgia estuaries 1984-1989.

recaptured in South Carolina (4 fish) and Florida (12 fish). Red drum recoveries from outside the coastal waters of Georgia comprised less than 3% of the total recaptures from the St. Simons system during the study period.

Table 6. Inter-estuary and inter-state movement of tagged red drum released in Georgia estuaries 1984-1989

Recapture	Percent by Estuary of Release			
Location	Wassaw	Altamaha	St. Simons	Cumberland
Wassaw	70	0	2	4
Ossabaw	2	0	<1	0
St. Catherines	6	0	1	0
Sapelo	2	10	2	0
Doboy	0	3	<1	0
Altamaha	2	74	7	4
St. Simons	8	8	83	21
Cumberland	0	0	2	67
South Carolina	10	0	<1	4
Florida	0	5	2	0
# of Recaptures With Information	89	39	690	27

The extent of inter-estuarine movement of tagged red drum in the three other estuarine systems examined was less than that of red drum in St. Simons. Seventy percent of the red drum recaptures from Wassaw were recovered in that system. Red drum released in Wassaw were recovered in all but two (Doboy and Cumberland) of Georgia's estuarine systems and in South Carolina (9 fish).

Red drum released in the Altamaha estuary were recovered in the Sapelo, Doboy, and St. Simons systems with 74% of the recaptures from the Altamaha system. Two tagged red drum from the Altamaha system were recovered in Florida.

A large percentage (33%) of the red drum released in the Cumberland system were recaptured outside of that system; however, inter-estuarine movement was restricted to the

Wassaw, Altamaha, and St. Simons systems. One red drum from the Cumberland system was recaptured in South Carolina and traveled a minimum distance of 146 km in 57 days. Red drum recaptures from outside Georgia's coastal waters comprised less than 4% of the total recaptures during this study.

Information on time between release and recapture for tagged red drum expressed as days-at-large is found in Table 7. With all systems combined over 75% of the tagged red drum

Table 7. Percent of returned red drum in relation to days-at-large during 1984-89

Estuary	Days-at-Large 0-90	91-180	181-270	271-365	366-730	>730
Wassaw	49	24	7	8	12	
Altamaha	52	9	15	9	15	
St. Simons	53	24	8	5	8	2
Cumberland	74	15	7			4
Combined	53	23	8	6	9	1

recovered were captured within 6 months of release. Only 10% of the recaptured red drum were at large for over 1 year. Linear regression analysis indicated that fish length at release explained little of the variation in time free prior to recapture (Figure 6).

Direction moved for red drum at large ≤90 days was examined to determine seasonal trends in movement (Table 8). Movement from the area of release was greatest during the summer and fall months, with most red drum exhibiting a northward movement. June was the only month when less than 50% of the recaptures were recovered from the release site.

Estuarine area of recapture was examined to determine seasonal distribution of red drum in coastal Georgia (Table 9). There were no apparent seasonal trends in red drum dis-

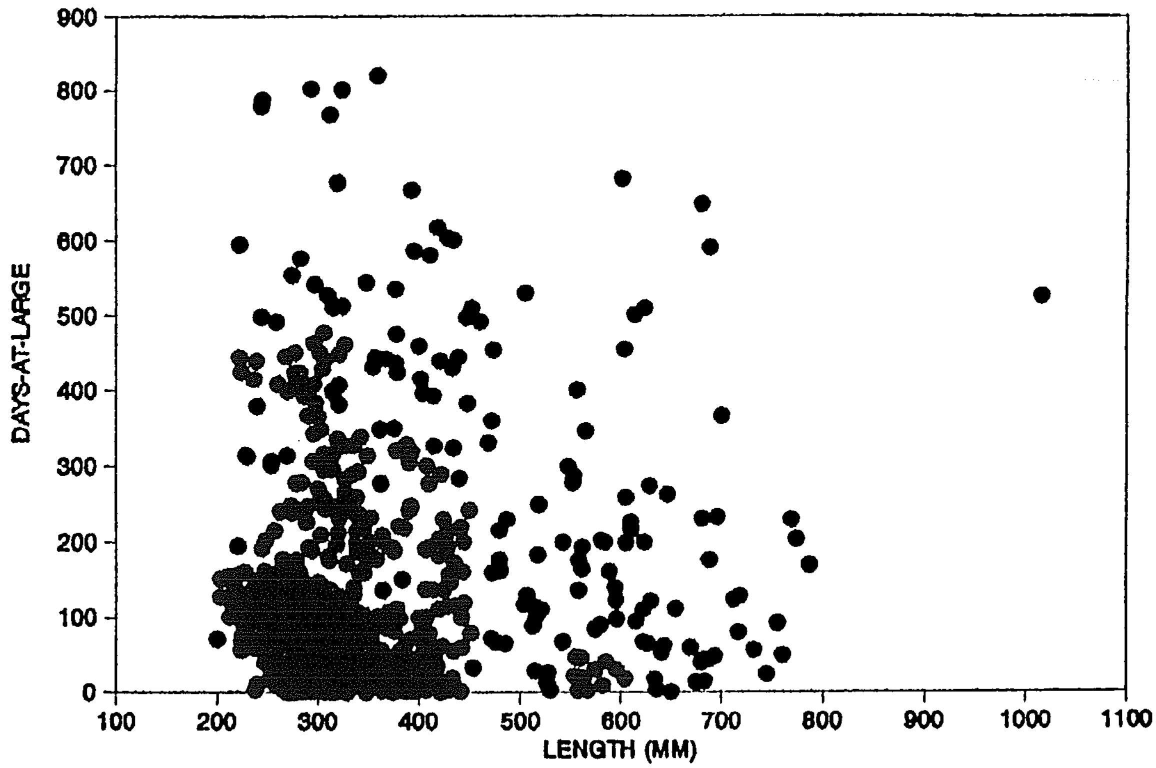

Figure 6. Days-at-large and release length for red drum tagged in Georgia estuaries 1984-1989.

tribution based on recapture information within the estuaries examined. Approximately 44% of the red drum were recaptured along the beaches and lower sounds. Data from fishery-independent sampling in Georgia (Nicholson et al. 1990) confirms that immature red drum are most abundant in the lower estuary.

Table 8. Percent of returned red drum at-large ≤ 90 days in relation to direction moved and month of release during 1984-89

Month of	Direction Moved				
Release	No Movement	East	West	North	South
January	100				
February	87	13			
March	67	11		11	11
April	100				
May	50			50	
June	46	15	10	18	11
July	65	4	4	18	9
August	69	4	3	11	13
September	53	7	8	17	15
October	53	3	8	23	13
November	60	13	7	13	7
December	89			8	3

Table 9. Percent of returned red drum in relation to estuarine area and month of recapture 1984-89

Month of Recapture	Beaches and Lower Sounds	Upper Sound/ Major Rivers	Creeks and Tidal Basins
January	27	40	33
February	42	42	16
March	21	31	48
April	46	23	31
May	43	24	33
June	43	35	22
July	49	32	19
August	45	28	27
September	54	14	32
October	39	18	43
November	48	25	27
December	52	25	23
Combined	44	25	31

Recapture information obtained during fishery-independent sampling indicated that red drum will remain together in schools for extended periods of time. Seven red drum (621-688 mm) were released during March 4-7,1988 in St. Simons estuary and recovered together in the same location where they were tagged on December 7, 1988. These fish were at large for 275 days before recapture. There were several instances where two or more tagged red drum released on the same date would be recaptured together in a different location after several months. For example, two tagged red drum (285 and 340 mm) were released in July 1985 and recaptured together during January 1987 after 537 days at large. This schooling behavior appears to be greatest in sub-adult red drum larger than 600 mm.

Age and Growth

A total of 5,130 red drum (192-1149 mm) was collected from February 1984 through March 1990. Length-frequency distributions of red drum collected by gear type are shown in Table 10. The trammel net was used most often and accounted for 77% (3,934) of the drum collected. A monofilament gillnet was used to sample smaller juvenile red drum (<300 mm) and hook and line gear was primarily used to collect both sub-legal juvenile (<356 mm) and adult red drum (>800 mm).

Monthly length-frequency data were used to determine age composition and periodicity of occurrence for red drum from approximately 10 months of age to approximately three years (age 2 individuals). Overlapping of lengths in larger red drum limited the usefulness of length-frequency distributions for estimating age.

Table 10. Number of red drum collected by 20 mm length group and gear type in Georgia from February 1984 through March 1990.

Length Group	Number of Red Drum: Gill Net (5.7 cm)	Trammel Net	Hook & Line	Combined	Length Group	Number of Red Drum: Gill Net (5.7 cm)	Trammel Net	Hook & Line	Combined
181-200	4	2	1	7					
201-220	37		1	38	701-720		60	3	63
221-240	159	22	16	197	721-740		82	1	83
241-260	154	37	30	221	741-760		43	1	44
261-280	80	197	48	325	761-780		37	3	40
281-300	42	386	55	483	781-800		18	3	21
301-320	7	467	45	519	801-820		6	6	12
321-340	2	341	30	373	821-840		5	9	14
341-360	6	257	27	290	841-860		3	5	8
361-380		221	5	226	861-880		3	8	11
381-400		247		247	881-900		4	24	28
401-420		186		186	901-920		1	21	22
421-440		176		176	921-940		5	45	50
441-460	1	86	2	89	941-960		2	18	20
461-480		45	1	46	961-980		4	63	67
481-500		24		24	981-1000		9	54	63
501-520		16	3	19	1001-1020		2	45	47
521-540		47	7	54	1021-1040		3	10	13
541-560		143	10	153	1041-1060		1	32	33
561-580		120	4	124	1061-1080		2	28	30
581-600		110	4	114	1081-1100		1	11	12
601-620		113	1	114	1101-1120		2	6	8
621-640		137	3	140	1121-1140			1	1
641-660		108	3	111	1141-1160			3	3
661-680		82	3	85					
681-700		70	5	76	Sample Size	492	3,934	704	5,130

Length-frequency data indicate that age 0 red drum measuring 225 - 275 mm recruit to the trammel net sampling gear in coastal Georgia during June. Red drum spawned in the late summer of 1984 averaged 309 mm in August-September of 1985 (Table 11). By February-March 1986, the 1984 cohort was approximately 18 months old and averaged 435 mm. This cohort averaged 609 mm a year later in 1987 and 704 mm in February-March of 1988. Music and Pafford (1984) reported that annual marks are detectable on Georgia red drum scales and otoliths from mid-February through March with all annual marks detectable by mid-April. Therefore, February and March was selected for year-class growth comparisons based on empirical lengths.

Scale samples from 1,620 red drum (256-1065 mm) were examined with 1,339 (83%) samples considered legible for age determinations and increment measurements. Of these, 538 (41%) were determined to be age 1 or older (Table 12). Most of the illegible scale samples were from red drum greater than 800 mm, presumably fish older than four years. In addition, otolith sections from 282 red drum from 401 to 1105 mm were examined. Of these, 279 (99%) were considered legible for age determinations with 270 (97%) being age 1 or older (Table 13). Both scales and otoliths proved useful for ageing red drum measuring less than 750 mm. However, circuli disconformities and closely spaced annuli of larger drum made scales unreliable for determining the age of red drum older than three years. Utilizing scale samples, the oldest red drum that could be aged reliably was four years old.

Linear regression analyses on the relationship between fish lengths and scale radii produced a significant relationship ($r^2=0.93$; $P < 0.0001$) and indicated that back-calculations based on fish length/scale radius would be reliable for estimating fish

Table 11. Number of red drum collected in two-month periods in Georgia from February 1984 through March 1990.

LENGTH (mm)	1984 FEB MAR	1984 APR MAY	1984 JUN JUL	1984 AUG SEP	1984 OCT NOV	1984 DEC JAN	1985 FEB MAR	1985 APR MAY	1985 JUN JUL	1985 AUG SEP	1985 OCT NOV	1985 DEC JAN	1986 FEB MAR	1986 APR MAY	1986 JUN JUL	1986 AUG SEP	1986 OCT NOV	1986 DEC JAN
176-200														1				
201-225									3						7			
226-250									52						20			
251-275			25	17					102	7					31			
276-300			64	68					110	53					27	9		
301-325			10	60	11				22	65					13	37		
326-350				31	22				4	22	2				1	35		
351-375				13	25	2	3		1	10	6					26	9	1
376-400	2	1			6	1	4	3		2	27	1	2			7	16	7
401-425	2	6			5	6	8	6	1		11	3	5				7	17
426-450	2	4	5			11	3	9			5	1	10	2		1	2	21
451-475	1	2	4					4	1	1			5	6	1			7
476-500		2	4	2				1					1	2		2		3
501-525			4	1	1										1		1	
526-550				2	5											6	6	2
551-575	1	2	1	2	6	2		1					1			9	13	7
576-600	5	1	1		3	1	3		1		1	6	5	1			10	16
601-625	1	3	1	2	3	1	1	3			2	13	6	1			8	16
626-650	2	3	2	3	4		6	5	1		2	10	7	1			9	15
651-675	1	3	4	1	2		3			6	1	10	2	1				3
676-700	2		3		4		1			6	2	14	2	1		1	3	4
701-725	2	2			4				1	1		10					2	3
726-750	4	2	3	1	4			1		5		5	3	1		1	2	3
751-775		3								1		6					4	1
776-800		1										2						
801-825																		
826-850										1							1	
851-875					1													
876-900					1						1					1		
901-1000					11					5	10					5	2	
1001-1100					5					6	1					6	1	
1101-1200																	1	
COMBINED	25	35	131	203	123	24	32	33	299	191	71	81	49	17	101	146	97	26

Table 11. (Continued)

LENGTH (mm)	1987 FEB MAR	1987 APR MAY	1987 JUN JUL	1987 AUG SEP	1987 OCT NOV	1987 DEC JAN	1988 FEB MAR	1988 APR MAY	1988 JUN JUL	1988 AUG SEP	1988 OCT NOV	1988 DEC JAN	1989 FEB MAR	1989 APR MAY	1989 JUN JUL	1989 AUG SEP	1989 OCT NOV	1989 DEC JAN	1990 FEB MAR	COMBINED
176-200			3						1	1					1					7
201-225			50	2					6						5					73
226-250			137	8					28	7										252
251-275			65	13					47	27					2	6				342
276-300			22	50	5				36	124	2				6	21				597
301-325			7	194	32	2			19	124	7	1			3	17				624
326-350	1		1	119	65	9	4			72	17	2	1			3	3	1	1	416
351-375	2		1	38	45	12	16	2		21	39	23	6			3	3	2	4	313
376-400	8	1	1	4	15	32	35	3		1	32	54	15	3		1	3	9	6	302
401-425	22	5			7	14	28	4	1		3	56	8	5			2	11	5	248
426-450	18	3	1			6	10	3	2	1	1	18	4	10				14		167
451-475	14	2	1	2			6	2	2	1	3	2	1	3	1			3		75
475-500	3		1	1								4			1	2		1	1	31
501-525		2	3	2		1			1	2	5	4						1		29
526-550	3	3	1	1	4		5			2	8	35		4	1	5	3	3	1	100
551-575	3	4	1	2	7	5	6	2		1	9	80	2	4	1	1	2	2		177
576-600	14	8	1	1	13	3	13	2	1	1	7	29	1	1	1		2	6		158
601-625	17	6	1		7	8	8	3	4		2	11	1	1		1	3	8	4	146
626-650	10	8	5	4	5	4	22	4	1		1	9	2	6	1	1	7	8	5	173
651-675	7	10	2	1	2	1	5	4	1		5	18		2				5	7	107
676-700	1	1	1		3	3	11		2		6	21		5		1		1	1	100
701-725	2	5			2	1	6	2		1	6	18		1		1		2	3	75
726-750	6	2			2		7				5	29		5		2		1	1	95
751-775	5		1				8				6	21		1	1		1		1	60
776-800					1		1				1	11	1	2			1			21
801-825						1	1	2			3	7				2	3			19
826-850							1				2	1				3	5			14
851-875											3	2	1			4	1			12
876-900					1						12	3				1	8			28
901-1000			1	3	26					1	93	1	1	8		14	41			222
1001-1100			3	3	38					1	28	3	8	13		1	18			135
1101-1200					3						7			1						12
COMBINED	136	60	310	448	283	102	193	33	152	388	313	463	52	75	24	90	106	78	40	5,130

Table 12. Back-calculated lengths from scales for red drum collected in Georgia from February 1984 through March 1990.

		Length At Capture		Mean Back-calculated Lengths of Successive Scale Annuli			
Age	Number	Range	Mean	1	2	3	4
0	801	256-494	387				
1	304	348-715	537	411			
2	191	521-788	661	421	607		
3	41	600-790	731	417	614	702	
4	2	726-776	751	421	656	719	751
		Weighted Means		415	609	703	751
		Growth Increments		415	194	94	48

length at time of annulus formation. Due to unreliability of scales, length-at-age determinations for red drum greater than 800 mm were based on otoliths. However, due to overlapping among age classes, back-calculations provided little valid information for length-at-age determinations for adult red drum (Figure 7). Approximately 60% of the red drum older than age 7 exhibited lengths smaller than the largest seven year old drum. Otoliths from the oldest red drum collected in Georgia exhibited 40 detectable rings and that individual measured 1,057 mm (Table 13). Although larger red drum (1,140 mm) were collected during tagging activities, the largest fish aged measured 1,105 mm and exhibited 36 winter or hyaline rings. For scale and otolith back-calculated age comparisons and to limit the effect of Lee's phenomenon (Bagenal 1978) when ageing long lived fish, only the first four ages are shown in Table 14. Agreement in the length-at-age determinations using the two structures was similar with only slight variation (5%) in estimated lengths.

Two methods were utilized to validate the number of marks formed annually on scales: marginal increment analysis and comparisons of scale samples taken from subsequent recaptures of tagged fish. Insufficient numbers of otoliths were available for marginal increment analysis. However, annulus formation on scales

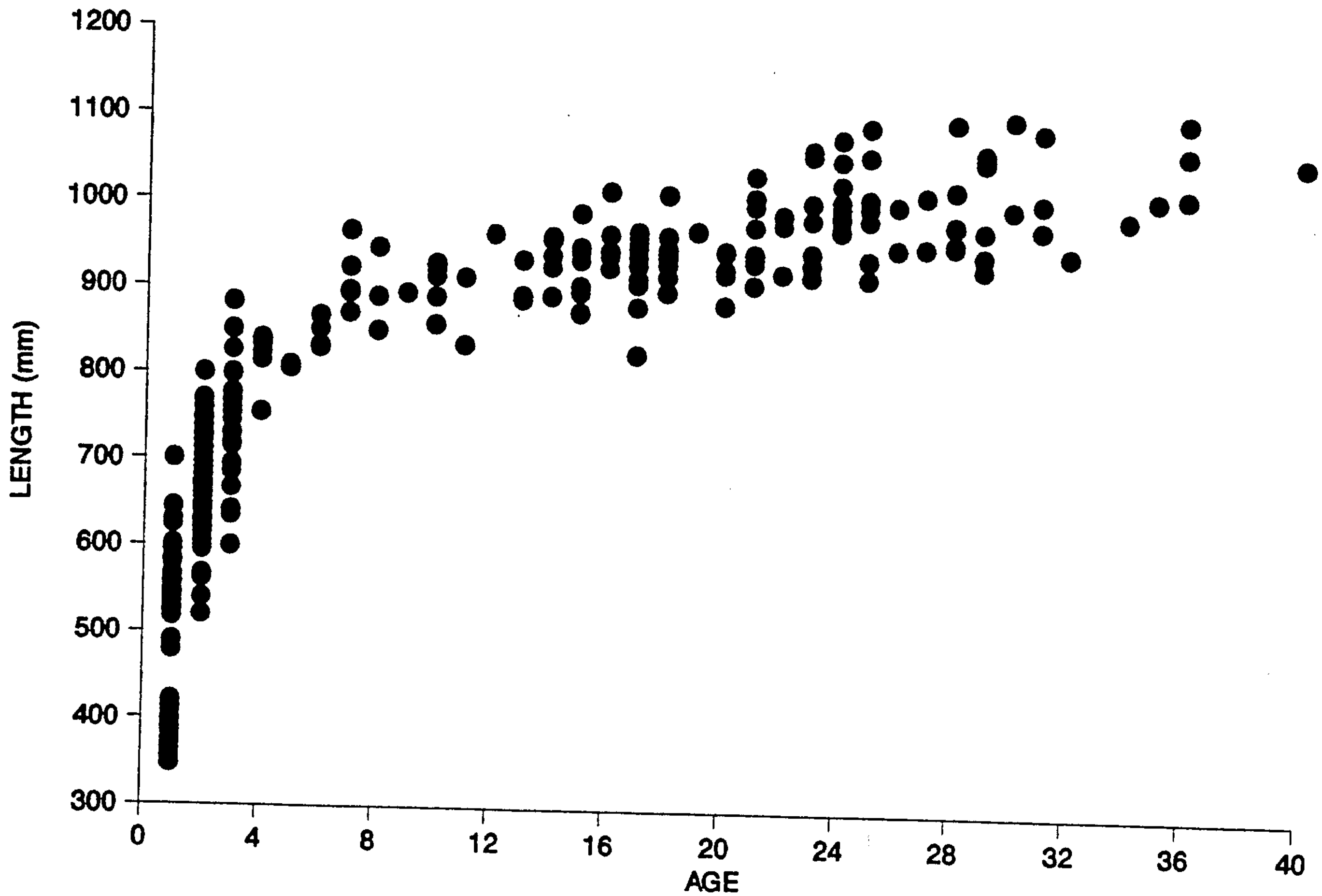

Figure 7. Empirical length and otolith age relationship for red drum collected in Georgia.

Table 13. Back-calculated lengths utilizing otoliths from red drum collected in Georgia from February 1984 through March 1990.

AGE	NUMBER	CAPTURE LENGTH (mm) RANGE	CAPTURE LENGTH (mm) MEAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	49	348 - 700	505	416																			
2	55	521 - 800	672	455	615																		
3	25	600 - 882	741	430	581	705																	
4	6	755 - 840	818	441	592	695	776																
5	2	806 - 810	808	404	557	650	715	771															
6	3	833 - 867	851	417	541	640	721	778	826														
7	5	870 - 965	910	434	561	666	738	793	844	886													
8	4	850 - 945	884	394	538	640	697	746	790	829	865												
9	1	894 - 894	894	342	495	609	672	723	767	812	850	888											
10	7	858 - 928	904	384	504	589	647	698	741	783	821	855	886										
11	2	835 - 912	874	362	468	543	596	643	683	720	757	792	820	848									
12	1	963 - 963	963	373	506	602	686	722	758	794	831	867	891	915	939								
13	4	888 - 934	902	319	421	528	590	634	672	710	743	772	806	834	861	830							
14	5	893 - 961	936	332	438	539	605	654	693	727	757	787	818	846	874	897	918						
15	8	874 - 989	921	306	418	492	552	604	645	687	720	750	779	807	834	861	886	910					
16	6	927 -1015	957	337	430	512	575	620	660	695	728	760	792	819	844	870	896	919	941				
17	10	827 - 962	921	318	422	500	550	593	630	665	694	723	750	775	800	823	846	869	890	911			
18	8	900 -1012	945	316	428	504	558	601	637	670	702	731	759	782	806	828	849	869	890	898	930		
19	1	970 - 970	970	313	396	475	522	574	615	647	678	709	751	772	798	819	845	866	887	913	939	960	
20	5	886 - 948	926	280	397	458	511	555	595	626	657	686	711	736	761	782	803	823	840	860	878	898	915
21	9	910 -1035	966	287	387	469	523	567	602	636	665	693	721	746	771	794	815	835	856	876	889	909	935
22	4	923 - 991	971	276	381	459	515	561	595	629	660	686	710	739	765	788	809	826	849	869	888	905	925
23	7	920 -1066	988	296	395	471	518	559	591	624	653	681	709	732	743	780	804	824	844	863	881	899	920
24	10	973 -1080	1009	287	384	461	516	556	593	626	657	687	714	739	764	788	811	833	854	874	893	912	930
25	7	919 -1094	1001	257	354	427	476	518	553	587	618	648	675	703	727	749	773	796	818	839	856	876	897
26	2	953 -1003	978	301	404	462	504	539	560	592	619	637	662	686	707	728	749	777	796	812	831	850	868
27	2	955 -1015	985	325	411	475	520	549	580	609	635	661	685	706	725	747	766	761	780	821	837	857	871
28	6	957 -1100	1000	270	361	440	482	520	552	579	609	635	661	686	708	729	750	768	787	805	827	845	863
29	6	931 -1065	1005	279	371	441	480	514	547	577	587	626	649	672	693	714	734	753	770	789	809	827	845
30	2	1000 -1105	1053	274	375	450	503	541	573	603	631	655	678	703	725	748	773	790	807	827	844	862	884
31	3	977 -1090	1025	272	357	409	458	496	527	556	583	606	641	648	669	690	738	759	777	795	814	832	852
32	1	948 - 948	948	297	383	440	479	517	546	565	589	603	627	646	670	689	704	718	737	756	776	785	804
33																							
34	1	991 - 991	991	273	355	418	464	496	527	555	577	600	618	641	659	682	700	714	732	746	764	782	796
35	1	1014 -1014	1014	263	349	415	460	497	534	562	583	608	628	649	669	686	702	718	735	747	764	780	796
36	3	1017 -1105	1063	282	377	443	491	525	556	583	608	632	655	676	697	713	734	749	763	781	798	813	827
37																							
38																							
39																							
40	1	1057 -1057	1057	249	346	417	453	480	506	533	560	586	604	622	640	657	675	693	711	724	737	751	764
		WEIGHTED MEANS		374	490	537	563	597	632	662	683	706	732	748	769	789	811	826	838	851	862	873	891

MEAN BACK-CALCULATED LENGTHS OF SUCCESSIVE OTOLITH RINGS (continued)

AGE	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
21	953																			
22	943	959																		
23	938	956	974																	
24	947	966	982	997																
25	913	933	952	970	990															
26	880	896	913	927	943	959														
27	885	899	916	930	945	969	976													
28	881	897	911	925	942	960	975	971												
29	862	879	896	910	927	945	961	979	993											
30	897	916	929	946	963	978	995	1011	1028	1045										
31	868	883	897	914	926	941	955	979	985	1000	1015									
32	819	833	843	852	862	871	881	891	900	914	919	929								
34	809	827	841	855	868	882	896	909	923	936	946	959	973	982						
35	809	821	833	850	862	879	891	903	920	932	944	961	977	989	1002					
36	845	859	875	888	905	919	931	946	959	973	986	1001	1013	1028	1042	1054				
40	777	791	804	817	826	844	862	875	888	902	915	933	946	959	973	986	999	1013	1030	1048
WEIGHTED MEANS	894	916	929	937	936	939	952	960	971	974	973	969	989	1002	1020	1037	999	1013	1030	1048

NOTE: Based on the effect that Lee's phenomenon has on back-calculating age of long-lived fish, annual growth increments determined from weighted back-calculated mean lengths were not appropriate for inclusion in this table.

and otoliths from red drum collected in Georgia were found to be relatively simultaneous.

Table 14. Back-calculated lengths for age one through four red drum collected in Georgia from October 1988 through March 1990.

Age	Number	Length at Capture Range	Length at Capture Mean	Mean Back-calculated Lengths Of Successive Otolith Rings 1	2	3	4
0	62	302-467	391				
1	49	348-700	505	416			
2	55	521-800	672	455	615		
3	25	600-840	741	430	581	705	
4	6	755-840	818	441	592	695	776
		Weighted Means		436	604	701	776
		Growth Increments		436	168	97	75

NOTE: To limit Lee's phenomenon, only red drum exhibiting less than five annuli were included in this analysis.

Marginal increment analysis was conducted for red drum up to 3 years (Figure 8). Sample sizes of older red drum (>3 years) were inadequate for marginal increment analysis. Scale annuli were detectable as early as February and annulus formation was complete by the first week of April. Due to the young age of red drum (<7 months), limited scale growth, and difficulty of detecting the first annulus, most investigators do not consider the first winter mark formed on scales as the age 1 annulus for back-calculating age of red drum. To document the occurrence of this early (<7 month) winter mark, scale impressions and otolith sections from 30 juvenile red drum collected in March and ranging in lengths from 382 to 439 mm were examined. During March of the second year of life, these 30 drum would be approximately 18 months old and be forming what was typically considered their first annuli on scales and otoliths. Examination of the first winter mark near the focus of the scales produced a mean back-calculated length of 55 mm (32 -92 mm). However, otoliths from these fish did not exhibit a detectable ring for the first winter. Based on the limited

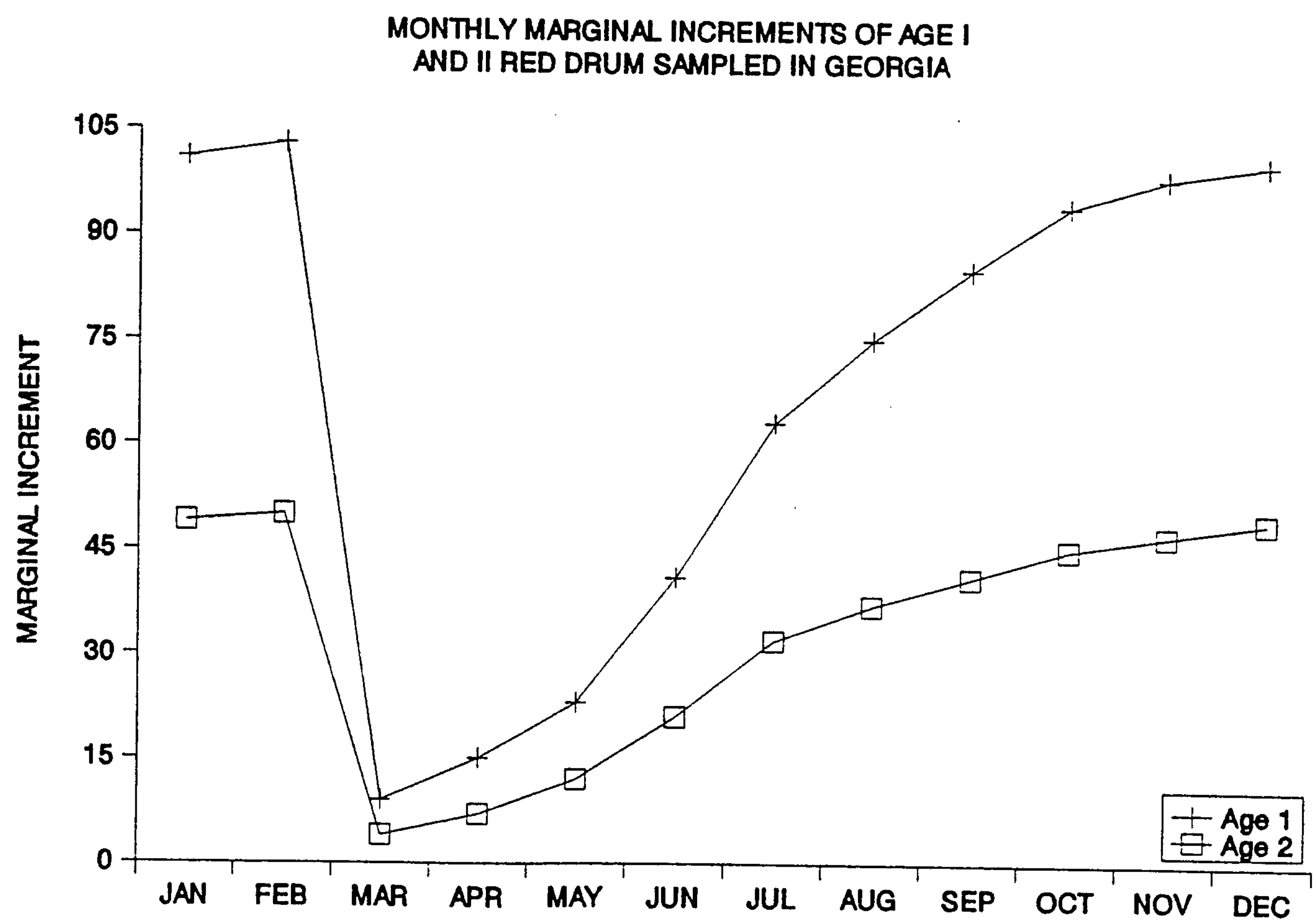

Figure 8. Mean monthly marginal increments on scales for 1 and 2 year old red drum collected in Georgia.

incremental growth exhibited on scales for the first winter, if a first winter ring was formed in otoliths it was apparently obscured inside the opaqueness of the core. Bagenal (1978) stated that in temperate latitudes, annuli may fail to appear in age 0 fish that overwinter at small sizes. Therefore, for ease of scale and otolith age comparisons, marks formed during their second winter of life when approximately 18 months of age were considered to be age 1 fish.

Red drum collected in January exhibited the largest mean monthly marginal increment with fish in March showing the smallest monthly mean (Figure 8). All scales and otoliths exhibited recent annuli by the first week of April. Analyses of marginal increments indicated a single mark was formed annually for the first three years and was detectable during late February through March.

In addition to marginal increment analysis, scale samples collected from 52 recaptured tagged red drum were used to validate the number of annual marks formed. Release and recapture scale samples were available for red drum at large as long as 1,024 days with 15 fish at large greater than one year and 6 red drum at large more than two years. Scales of red drum at large during the April-January period did not exhibit additional annuli. Red drum recaptured after one or more winters at large exhibited an additional annulus for each winter at large. These results indicate that young red drum form one annulus per year for the first three years of life. Scale samples from these recaptured fish indicated that tagging did not initiate formation of false annuli.

To gain additional information on the age composition of Georgia's adult red drum, otoliths were removed from large red drum ($\geq$800 mm). Although only 148 red drum of the red drum (>800 mm) were aged in 1988 and 1989, findings indicate a paucity of young adults in the spawning population. In 1988, approximately 65% (28) of the drum collected (43) were older than 15 years (Figure 9). In 1989, the sample size was increased (105) and several young adults (4-6 years) were collected (Figure 10). However, the percentage (64%) of red drum older than 15 years changed little.

Of the 148 red drum ($\geq$800 mm) collected for age structure analyses, sex was determined for only 131 fish. The sex ratio for these 131 red drum ($\geq$800 mm) was 2.6:1 females to males (Table 15). Most (119) of the 131 red drum were collected with hook and line with the remainder caught by trammel net. The sex ratio for hook and line drum was 2.5:1 females to males and 5.0:1 for trammel net. Fourteen red drum ranging in length from 810-1,094 mm were collected with hook and line approximately 13 km offshore, and the sex ratio of these individuals was 4.7:1 females to males. The overall sex ratio changed little (2.5:1) when red drum greater than 700 mm were included.

Table 15. Number, mean age, and sex ratio of red drum $\geq$700 mm collected for age structure analyses during 1988 and 1989.

Length Group	Female N	Female Mean Age	Male N	Male Mean Age	Combined N	Combined Mean Age	Combined F:M Ratio
700-799	19	2.4	10	2.3	29	2.4	1.9:1
800-899	22	6.8	11	11.5	33	8.4	2.0:1
900-999	46	19.2	21	21.2	67	19.1	2.2:1
1000-1105	27	25.6	4	34.8	31	26.8	6.8:1
Combined	114		46		160		2.5:1

NOTE: F:M denotes female to male in relation to sex ratio.

Empirical lengths of red drum obtained during fishery-independent sampling in February and March were compared to back-calculated lengths. The empirical and back-calculated lengths for red drum collected during February and March of the

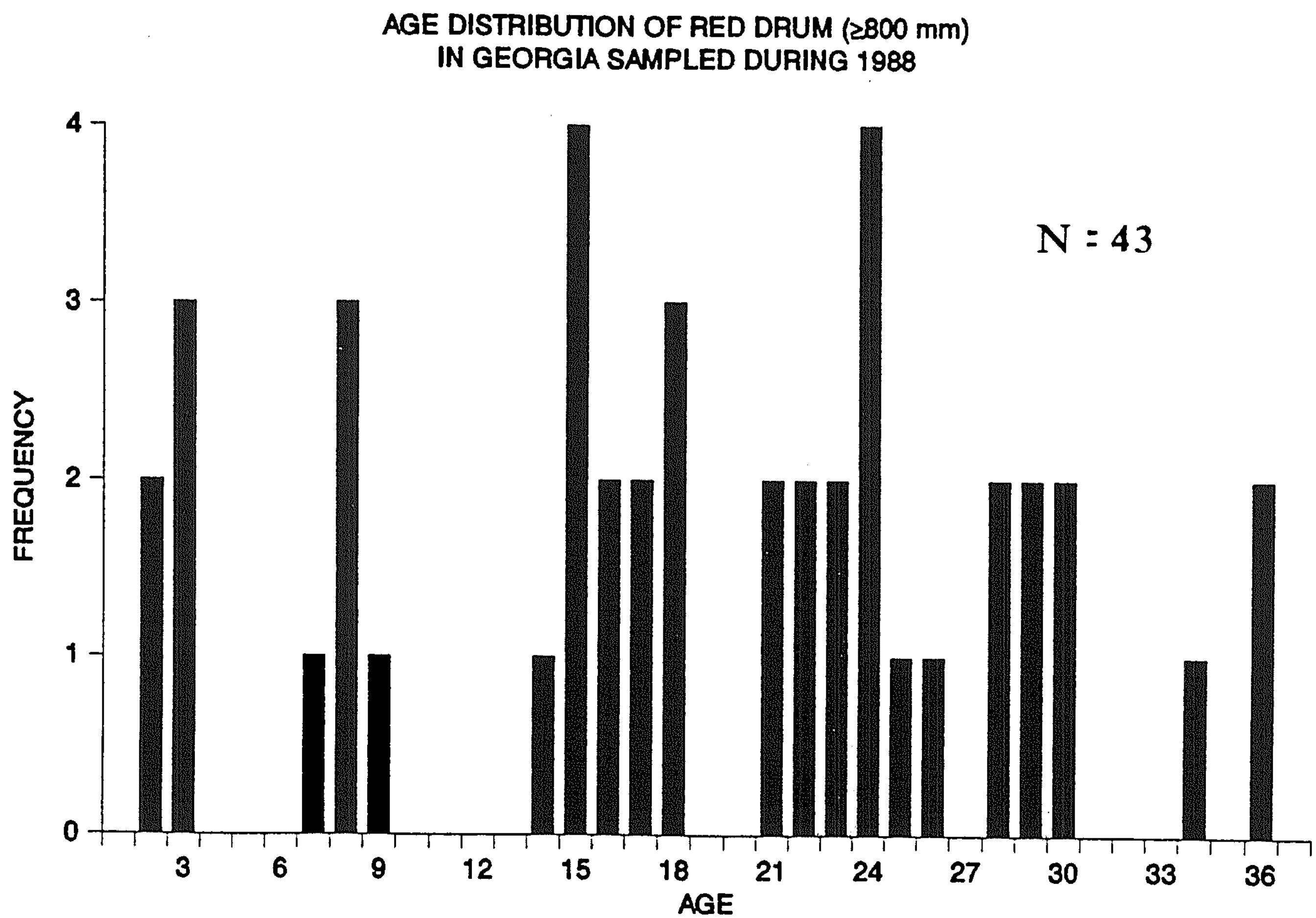

Figure 9. Age distribution of red drum collected in Georgia during 1988.

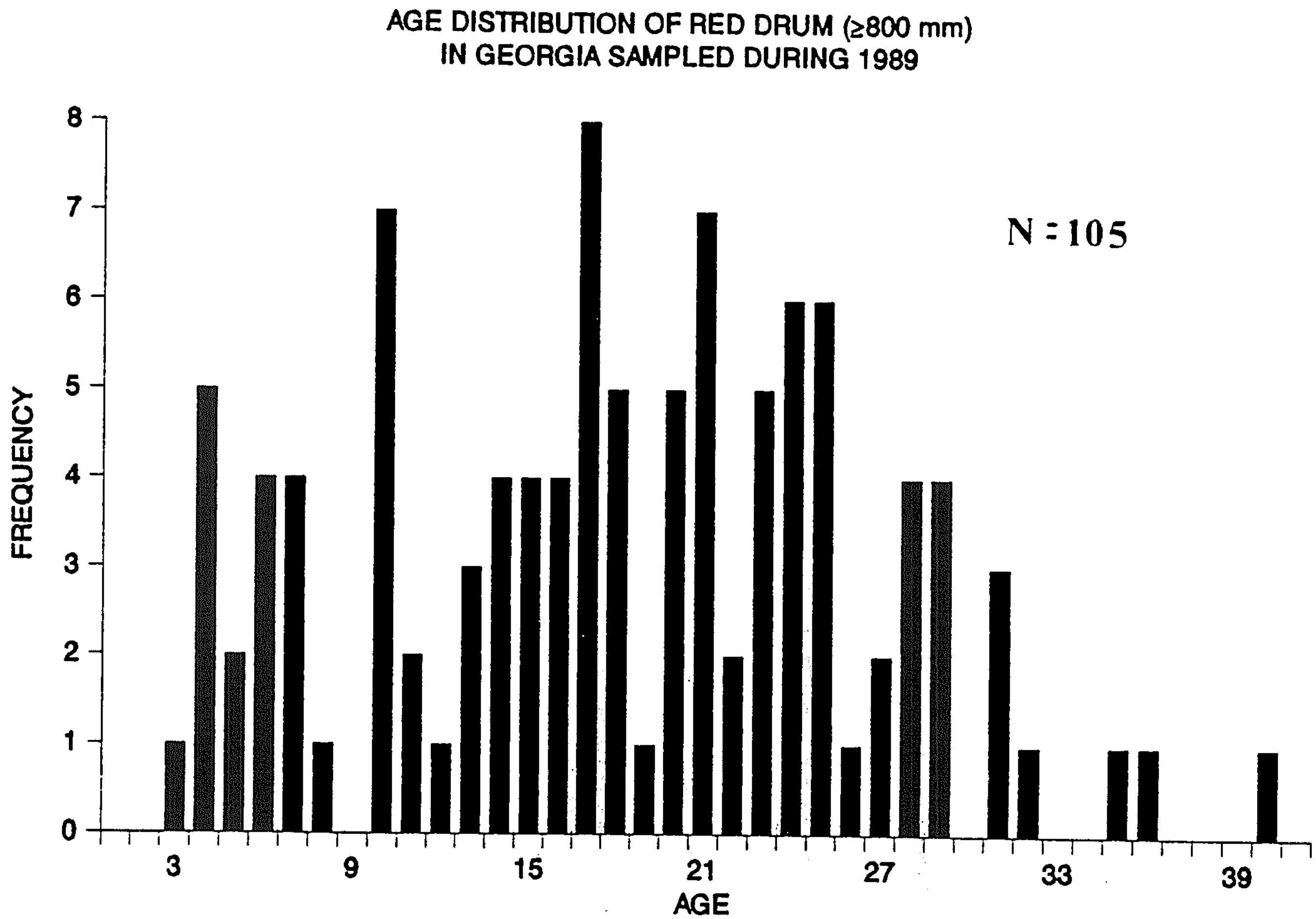

Figure 10. Age distribution of red drum collected in Georgia during 1989.

1984 through 1989 are shown in Table 16. Empirical and back-calculated lengths for age 1 red drum varied only 14 mm with age 2 length comparisons differing by 20 mm and age 3 varying only 11 mm.

Growth rates based on back-calculations and monthly length-frequency data indicate red drum grow approximately 24 mm a month for the first 18 months of life (Table 17). Age 1 and 2 red drum exhibited slower monthly growth rates of 15 and 8 mm, respectively.

Empirical lengths and reported recapture lengths of tagged red drum were compared (Table 18). These data indicate reasonable agreement between lengths reported by fishermen and expected length based on monthly length-frequency distributions. However, since Georgia enacted a minimum size limit of 14 inches in 1986, there is a tendency for fishermen to report a slightly larger size at recapture than would be expected for age 0 red drum.

Year-of-birth was calculated for fish ≥800 mm to document and compare relative abundance of various year classes in Georgia's adult red drum population. Based on findings from macro-and microscopic gonadal examination in North Carolina (Ross and Stevens 1989) and histological analysis of gonadal tissue in South Carolina (Wenner et al. 1990), most red drum are sexually mature by age 4 at approximately 800 mm FL. Therefore, only red drum ≥800 mm were included in this analysis (Figure 11).

Of the 5,130 red drum collected from February 1984 through March 1990, 442 (8.6%) exhibited lengths greater than 800 mm with only 12 (0.2%) greater than 1,100 mm (Table 11). Red drum collected from Georgia's inshore waters ranged in length from 192 to 886 mm (Figure 12). Of the 4,476 drum collected from inshore waters, only 16 (0.4%) were longer than 800 mm. Lengths of red drum

Table 16. Comparison of empirical lengths recorded during February and March and back-calculated lengths derived from scale analyses for the biological year (April - March) for red drum collected in Georgia from February and March, 1984-1990

Age		Empirical Lengths (mm) for Red Drum Collected During February and March and Back-calculated Lengths from Scales for Biological Year (April - March)													
		1984		1985		1986		1987		1988		1989		1990	
Annual Marks	Estimated (months)	Emp	Cal	Emp	Cal	Emp	Cal	Emp	Cal	Emp	Cal	Emp	Cal	Emp	Cal
1	18	415	363	405	413	435	434	429	418	397	434	394	425	392	402
2	30	604	598	632	610	625	625	609	612	607	603	597	616	633	594
3	42	713	724		711	733	714	736	-	718	-	745	721	728	690
Sample Size		25	5	27	176	49	135	136	65	193	4	43	37	29	203

NOTE: The letters "Emp" denotes empirical and "Cal" denotes back-calculated.
A dash (-) denotes none collected.

Table 17. Comparison of growth rates derived from weighted mean back-calculated lengths for February 1984 through March 1990 and empirical lengths for the month of March 1984 through 1990 for red drum collected in Georgia.

Method of Length Determination	Biological Age / Estimated Age (months)		Length (mm) 1 / 18	2 / 30	3 / 42
Back-calculated:	Scale	Weighted Mean	415	609	703
		Annual Growth	415	194	94
		Monthly Growth	23.1	16.2	7.8
		Daily Growth	0.76	0.53	0.26
	Otolith	Weighted Mean	436	604	701
		Annual Growth	436	168	97
		Monthly Growth	24.2	14.0	8.1
		Daily Growth	0.80	0.46	0.27
Empirical:	Fish Collected During March	Mean Length	430	617	723
		Annual Growth	430	187	106
		Monthly Growth	23.9	15.6	8.8
		Daily Growth	0.79	0.51	0.29
Methods Combined:		Mean Length	427	610	709
		Annual Growth	427	183	99
		Monthly Growth	23.7	15.3	8.3
		Daily Growth	0.78	0.50	0.27

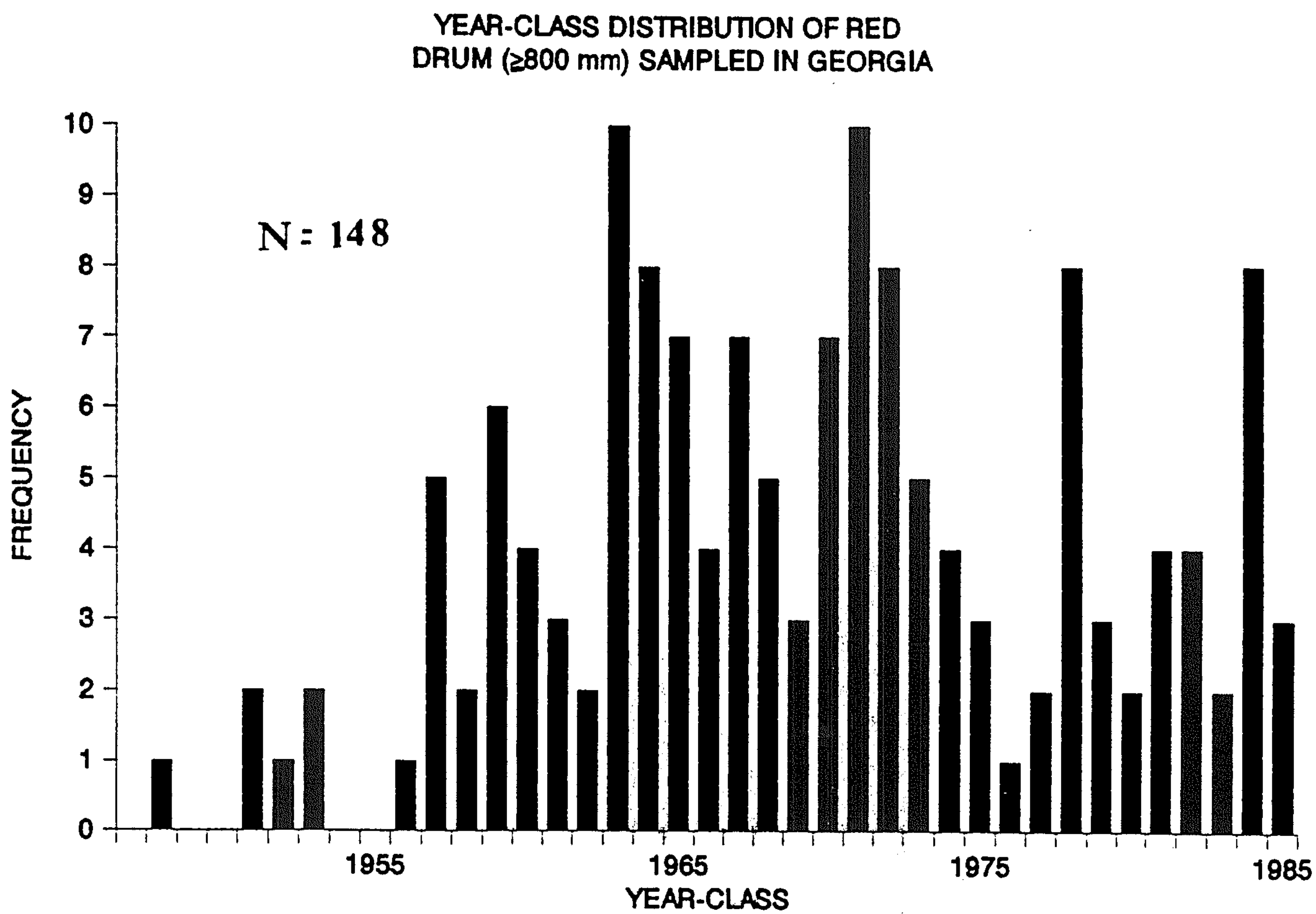

Figure 11. Year-class frequency distributions for red drum (≥800 mm) collected in Georgia, 1988-1989.

Table 18. Comparison in growth rates between tag recapture and length frequency data for red drum collected during monthly monitoring or tagged and released during the month of July, 1984 through 1988 in Georgia.

Method of Information	Mean Length For Month of July	(Months) (Days)	Mean Recapture Length and Daily Growth Rate For Time At Large (mm) SEP 31 - 60	OCT 61 - 90	NOV - DEC 91 - 180	JAN - MAR 181 - 270	APR - MAY 271 - 335	JUN - JUL 336 - 395
Tag Recaptures Released In July	283		340	364	469	425	466	535
			1.28	1.08	1.01	0.63	0.58	0.69
Mean Monthly Length Frequency Beginning With July	271		329	353	396	430	558	525
			1.29	1.09	0.93	0.71	0.59	0.72

collected from offshore waters ranged from 265 to 1,149 with 426 (65.1%) greater than 800 mm.

Utilizing otoliths, spatial distribution based on age was determined from 257 red drum. Ninety-seven of these fish were collected from inshore waters, with only one (1.1%) older than age 4 (Figure 13). This was an 852 mm, age 6 male caught in August 1989 approximately 5 km inside the St. Andrew estuary. Of the 160 red drum collected from nearshore and offshore waters, 133 (83.1%) were older than four years.

Meristic Relationships

Length and weight measurements were taken for 379 red drum ranging from 348-1,105 mm and 341-16,571 g. The length-weight relationship was $W = 0.00000066\ L^{3.06}$ ($r^2 = 0.99$, Figure 14). The age-headgirth relationship was examined for 120 red drum ranging from age 0 to 36 and the variation in this relationship was similar to that in the age-length relationship (Figure 15). Headgirth was significantly related to both length and weight ($P<0.05$) (Figures 16 and 17).

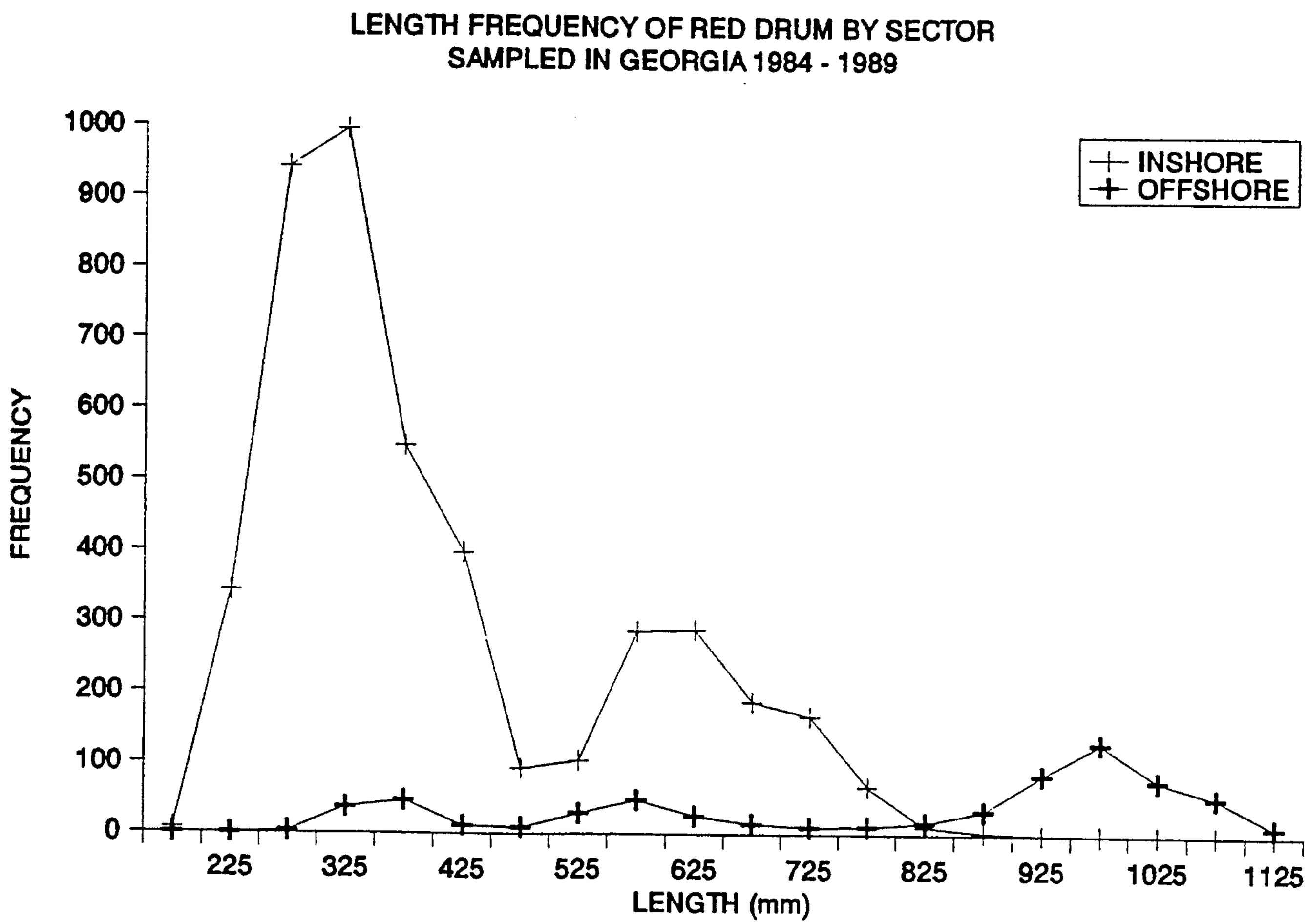

Figure 12. Length frequency distributions for red drum (≥800 mm) collected in Georgia's inshore and offshore waters, 1984-1989.

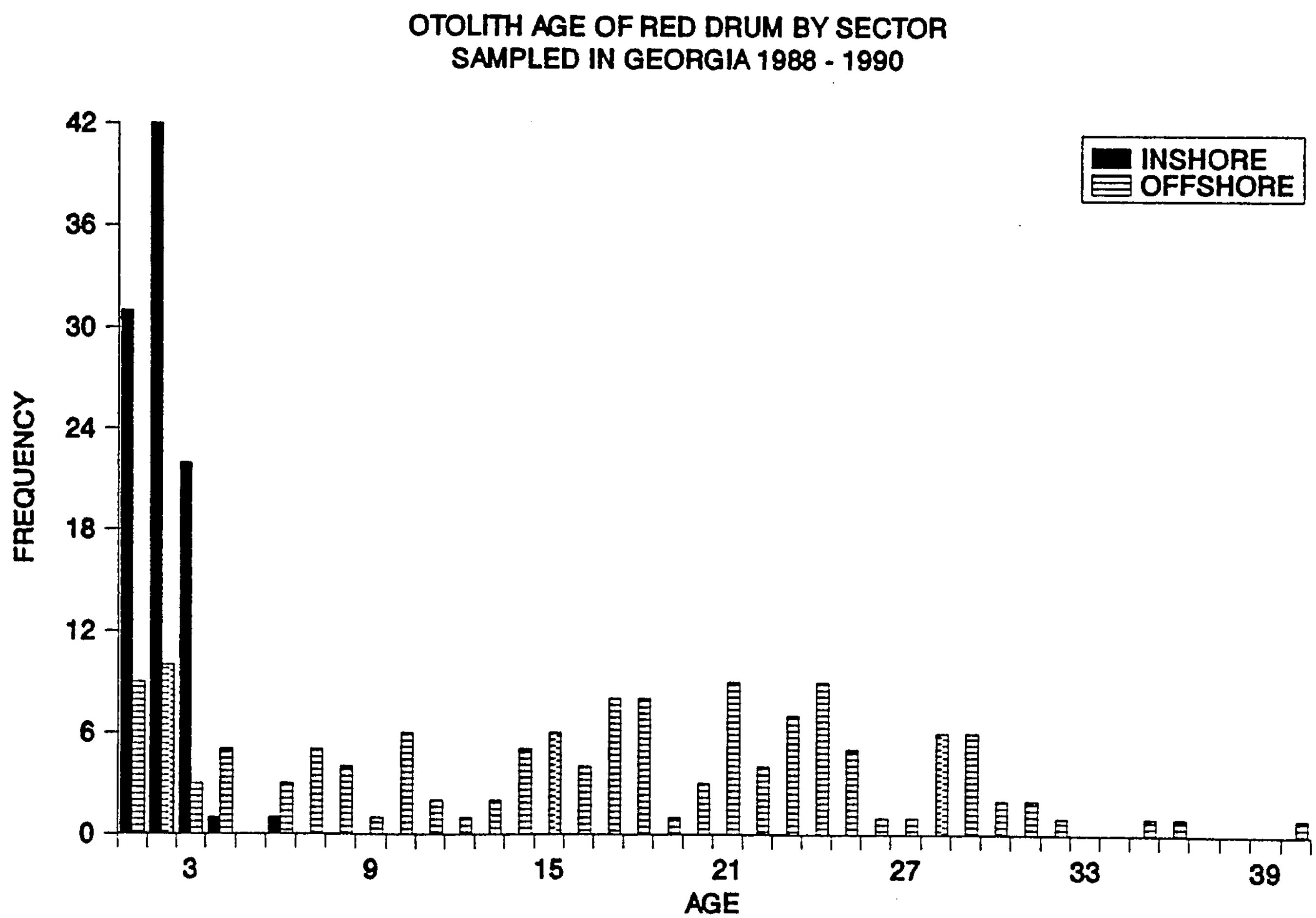

Figure 13. Otolith age frequency distributions for red drum collected in Georgia's inshore and offshore waters from September 1988 through March 1990.

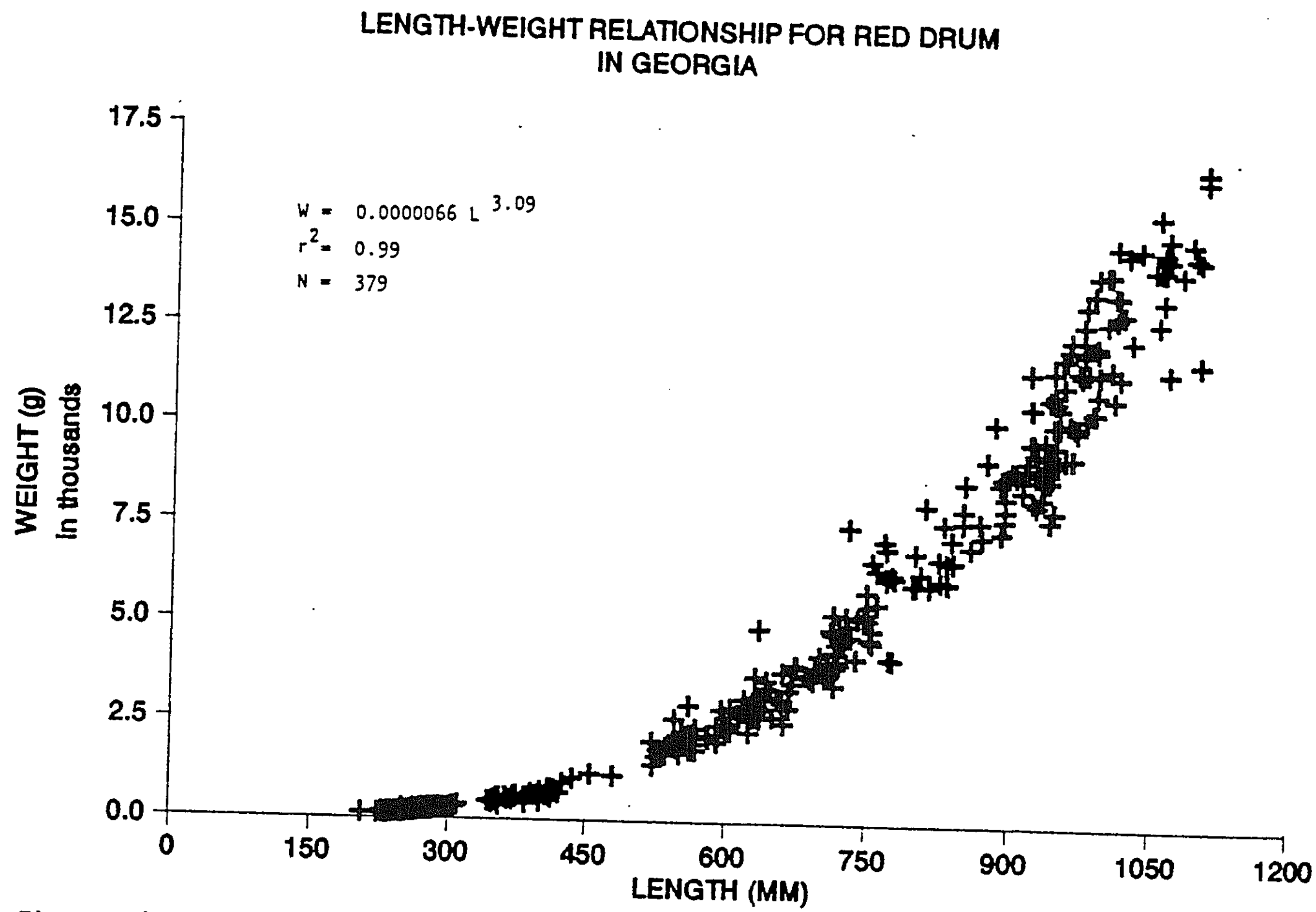

Figure 14. Length and weight relationship for red drum collected in Georgia.

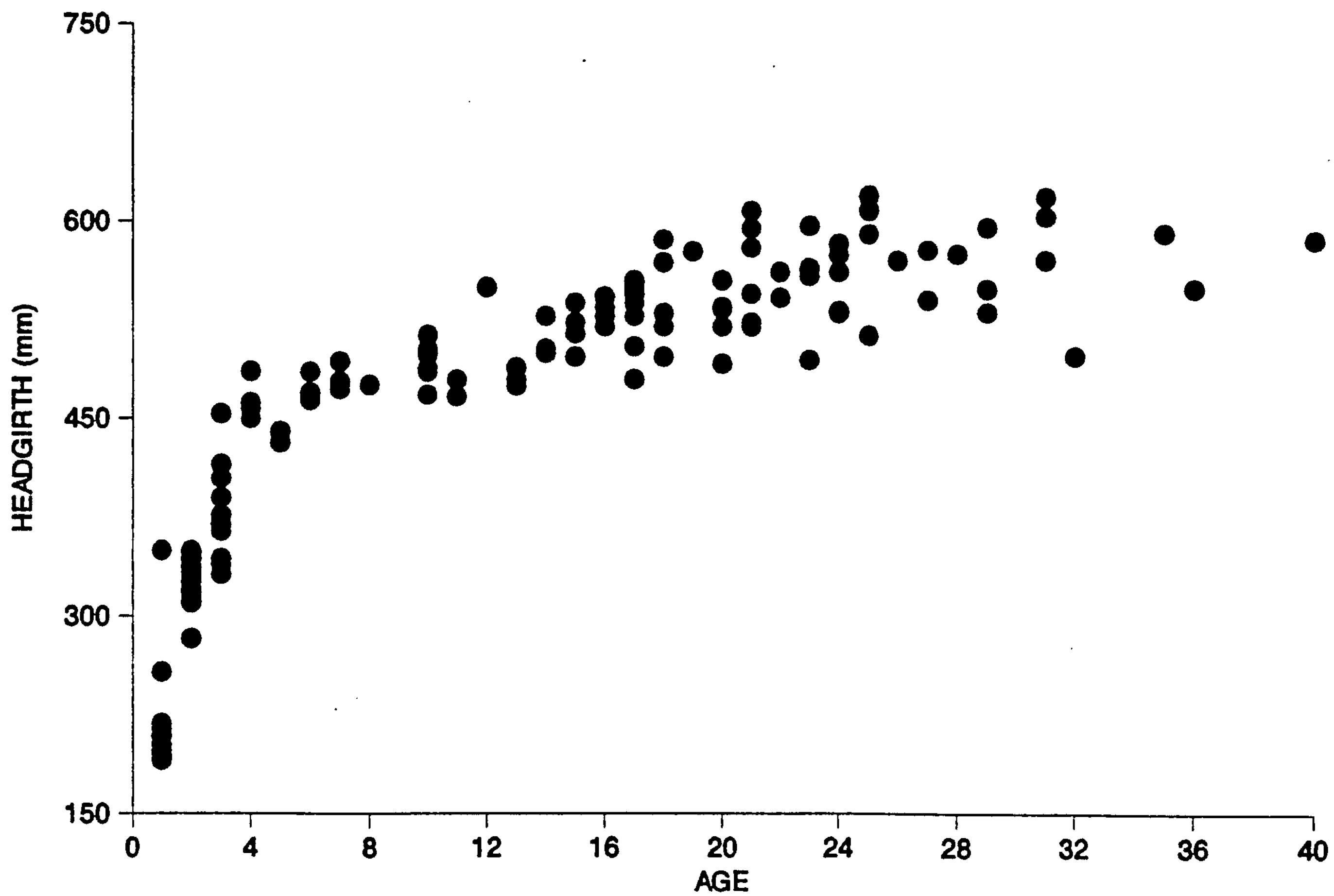

Figure 15. Headgirth and age relationship for red drum collected in Georgia, 1989.

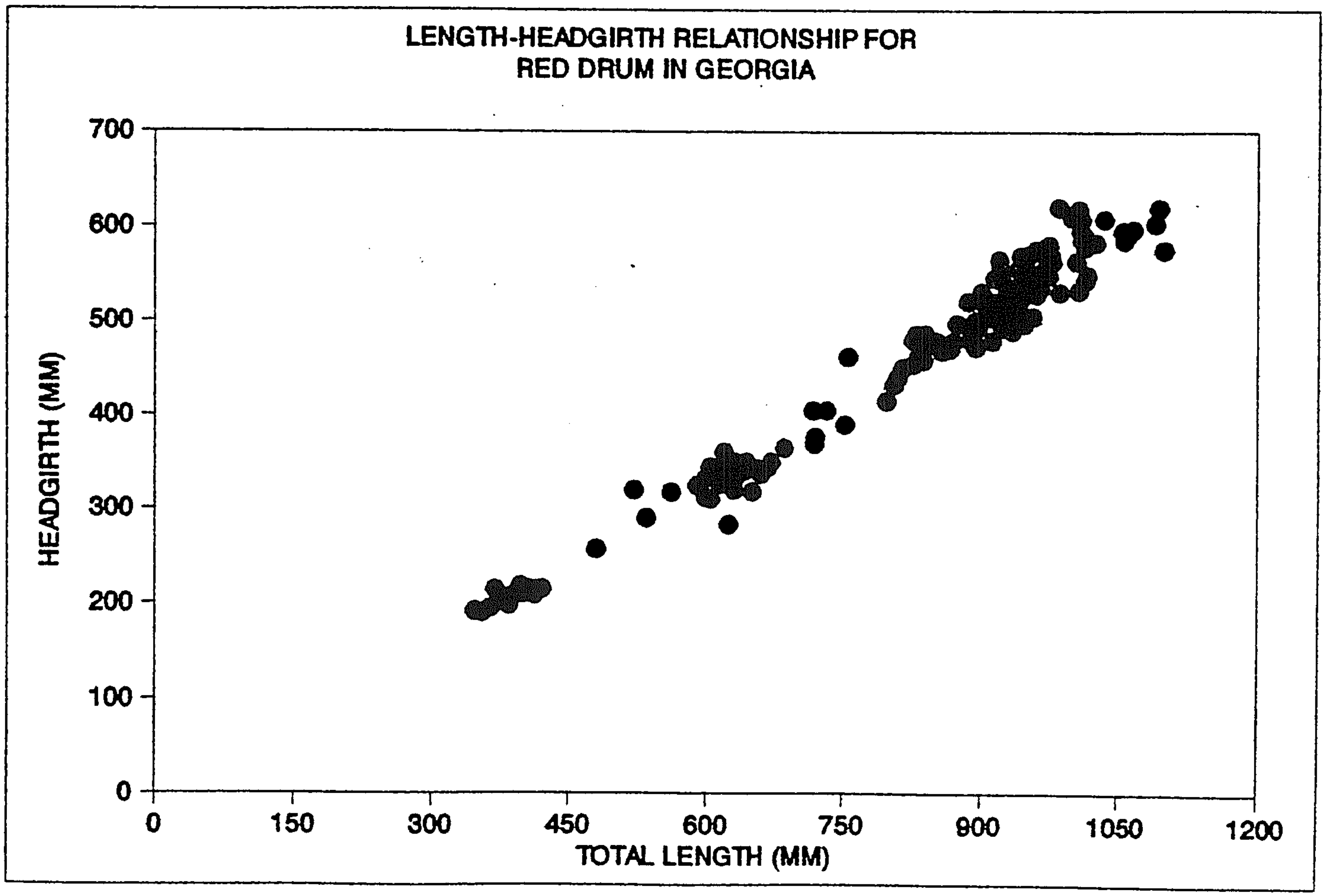

Figure 16. Length and headgirth relationship for red drum collected in Georgia.

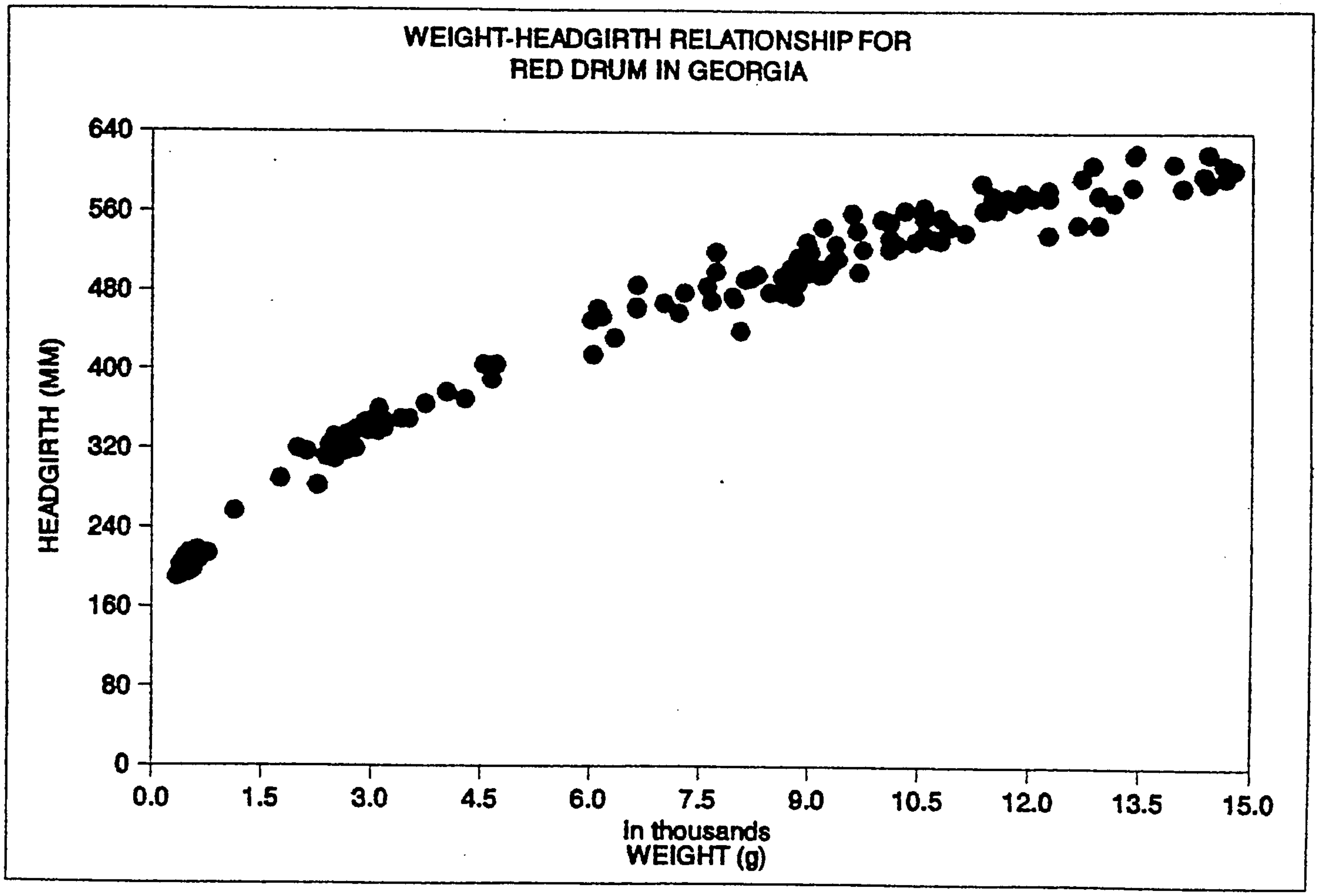

Figure 17. Weight and headgirth relationship for red drum collected in Georgia.

DISCUSSION

Exploitation, Mortality, and Survival

The results of this study indicate that Georgia's juvenile and sub-adult red drum are subject to intense angling pressure in estuarine waters. Heavy exploitation of these immature fish and possible recruitment overfishing pose a serious threat to the reproductive stability of Georgia's red drum stock. Traditionally, most red drum were caught incidentally by anglers targeting spotted seatrout, with most fish harvested being age 0 individuals. However, the popularity of this fish with recreational anglers, the widespread distribution of angling effort, and increased abundance of larger red drum has resulted in more harvest of sub-adults. If this trend continues, the current protection afforded to juvenile red drum during peak vulnerability may not be sufficient to ensure adequate survival of a cohort to adulthood.

Fishing effort peaks in coastal Georgia during the months of June-September (Pafford and Nicholson 1989). Concurrently, young juvenile red drum or "school bass" will move into areas in the lower estuary where they become extremely susceptible to angling. These small red drum (10-12 inches) can be caught readily by even novice anglers as they will take virtually any bait presented. Often times large schools of juvenile red drum will remain in a restricted area for several weeks and anglers will repeatedly remove fish from these aggregations.

Exploitation of age 0 red drum varied from 63-82% during 1984-1986. During the fall of 1986 the 14-in minimum size limit was implemented and exploitation of age 0 red drum decreased to 55% in 1987 and 39% in 1988. Exploitation of age 1 red drum was high (41%) in 1984, decreased (24-26%) during the next three years but increased again to 34% in 1988. Exploitation of age 2-3 red drum was quite variable during the study period. The low number of fish tagged and released in these age classes probably contributed to this variation. However, a greater number of both older age classes were removed by anglers in 1988 than in previous years. The increase in exploitation of age 2-3 red drum in 1988 may be illustrative of a change in angling patterns due to increased abundance of these larger fish, as well as the overall increase and homogeneity of angling effort.

Release location had a considerable impact on exploitation of red drum during our study. The implications of this in terms of estimating mortality and survival will be discussed later. The temporal and spatial aspects of tagging were such that released fish were often immediately subject to intense fishing pressure. During this study over 50% of the tagged red drum were recovered within 90 days of release with several juvenile red drum recaptured within a week of the release date. If the release location was readily accessible then fishing pressure would remain high until sufficient numbers of red drum had been removed to reduce fishing efficiency or the school moved to another area.

During this study, over 250 red drum (350-750 mm) were tagged and released in the Jekyll Creek area of St. Simons estuary during a two week period in December 1988. An adjacent commercial marina, public boat ramp, and bridge catwalk provided both boating and non-boating angling access to the release site. Although fishing effort in coastal Georgia is usually reduced during this season, the tagging event was observed by several individuals and the fishing pressure and exploitation rate of tagged red drum of all sizes was considerable (>30%) for several weeks following the release period. Although this was a worst case situation, it stimulated a concern that sub-adult red drum could be exploited just as heavily as the young juveniles if access was available and fishing pressure was high. If survival to sub-adulthood is already limited by the intense harvest of juveniles, the high exploitation of age 2-3 fish could further jeopardize the stability of Georgia's red drum stock.

Exploitation of adult red drum in Georgia appears to be minimal as only 1 tagged adult was recaptured during the study period. This individual was captured in a sturgeon net approximately 1 mile from the site where it had been released over a year before. Over 230 adult-size red drum ($\geq$800 mm) were tagged by cooperative recreational anglers and DNR personnel during this study. Large red drum occur infrequently in Georgia's inshore waters where fishing pressure is the most intense. These larger fish are found seasonally along the shoals and bars at the inlets; however, these areas are subject to constant change and inaccessible to most anglers. Regulations were implemented in 1986 to protect Georgia's adult red drum from overharvest. Consideration must be given to modifications of the maximum-size regulations, both length and quantity, if angling pressure on sub-adult and adult-size red drum increases.

Annual survival of juvenile and sub-adult red drum in coastal Georgia appears to be very low. Red drum tagged in the summer had annual survival rates of 4-16%, while estimates of annual survival for red drum released during the fall/winter months were somewhat greater (15-31%). Although the survival rates determined during this study may seem unrealistically low for a long-lived species such as red drum, they are similar to the rates of 15-32% estimated for young red drum in Texas bays (Matlock and Weaver 1979, Green et al. 1985). Green et al. (1985) also found that survival rates were lowest for red drum released in the summer. These investigators suggested intense recreational fishing pressure and possible increased predation as causes for this low survival. A similar situation likely exists in Georgia since fishing pressure and availability of the more vulnerable juvenile red drum peak concurrently during the summer months.

Estimates of instantaneous total mortality (Z) in the St. Simons system varied from 1.26-3.23 during the study period. Values of Z were greatest for fish released during the summer months and lowest for those tagged during the fall/winter period. Estimates of Z determined from catch-curves (1.13-2.96) based on fishery-independent collections of red drum in Georgia were comparable to those determined from mark-recapture data. The similarities in estimates of Z among the two methods indicates that the disappearance rates (mortality + emigration) of juvenile and sub-adult red drum are very high.

Instantaneous total mortality rates have been estimated for red drum in several South Atlantic states using a variety of methods (Pugliese 1990); however, few investigators have used mark-recapture data. These regional estimates are quite variable depending on the geographical location and specific methodology used in determining the estimates. Murphy and Taylor (1986) utilized catch curves and found considerable variation (0.68-1.35) in their estimates of Z for red drum in the Mosquito Lagoon/Indian River complex. Rago and Goodyear (1986) utilized mark-recapture data and found Z values of 0.62-0.96 for red drum in the Everglades National Park, Florida. Tilmant et al.(1989) utilized a virtual population analysis (VPA) and estimated a Z of 1.87 for red drum in the same area. Vaughan and Helsner (1989) in their stock assessment of red drum in the South Atlantic examined mortality of red drum in several areas using cohort-based catch curves. Their estimates of Z for Georgia using data from fishery-independent sampling were also quite variable (0.84-1.78). Green et al. (1985) utilized mark-recapture data and estimated a Z of 1.89 for immature red drum in Texas bays. Estimates of Z determined during the current study are as high as any reported for red drum in the United States. While these estimates are subject to some bias due to emigration they are reflective of the intense angling pressure on Georgia's red drum stocks.

Estimates of instantaneous fishing mortality (F) were highest for tagged red drum released in the summer, particularly during the early part of the study. The imposition of minimum length regulations appeared to impact fishing mortality during the summers of 1987 and 1988 as estimates of F decreased from 2.97 in the summer of 1984 to 0.93 in the summer of 1988. F also comprised a smaller percentage of the instantaneous total mortality during those years.

Instantaneous natural mortality rates (M) of red drum determined in this study varied tremendously (0.26-1.27) and often comprised over 50% of the total instantaneous mortality. Natural mortality was always a major portion of the total mortality estimated for red drum released during the fall/winter period; however, during the latter years of the study M values were equal to or exceeded F values for red drum released in the summer period.

The estimates of M determined during this study were inordinately large for a long-lived species such as red drum. Red drum can live for over 50 years (Ross and Stevens 1989) and one individual collected in Georgia during this study had more than 40 otolith marks. Previous investigators have followed Pauly's (1980) method and utilized a Von Bertanlanffy growth model to estimate natural mortality (Vaughan and Helsner 1989). These investigators determined a M value of 0.44 for sub-adults and 0.13 for adult red drum. All but one of the estimates for M in our study exceeded the value determined by these investigators for sub-adult red drum.

There are several factors which can influence estimates of exploitation, mortality, and survival derived from mark-recapture data. Movement of tagged fish, tag loss, tagging mortality, and incomplete reporting of recovered tags can all impact the accuracy and validity of tagging data. Ricker (1975) discussed these factors as Type A, B, and C errors in the interpretation of mark-recapture data. It is likely that all these factors influenced the results of this study to some extent.

In the latter period of this study estimates of Z and M remained high in spite of apparent reductions in fishing mortality of young juveniles. If one assumes that the true likelihood of a death by natural causes (i.e. predation, environmental factors, etc.) remained constant throughout the study period, then emigration of early maturing individuals could be an explanation for the persistently high Z and M values observed during 1987 and 1988. The effects of this behavior would result in a Type B error which would effect greatly estimates of total mortality.

Data indicate that red drum can become reproductively active as early as age 2; however, 100% of a cohort is usually not mature until age 4 (Vaughan and Helsner 1989). Previous studies suggest that once red drum reach sexual maturity they leave the estuarine waters and move to nearshore ocean waters. Music and Pafford (1984) found no sexually mature or reproductively active red drum in Georgia's estuarine waters during a four-year study. Pearson (1929) suggested that red drum in Texas move into the Gulf of Mexico at the onset of maturity. Recently, Beckman et al. (1989)

documented age 2 individuals in offshore aggregations of adult red drum in the northern Gulf of Mexico. Consequently, the disappearance of sub-adult red drum from estuarine waters is the cumulative result of intense harvest of young juveniles and emigration. If Type B error is a significant source of bias, then Ricker (1975) suggest using independent estimates of Z and A (i.e. catch curves) for the population. Unfortunately, estimates of mortality from catch curves based on fishery-dependent and -independent sampling are subject to the same error since red drum are emigrating from the sampling area, as well as the angling area. The similarity in estimates of Z from mark-recapture and catch curves is illustrative of this problem.

Non-random distribution of marked fish in a population (Type C error) can affect estimates of total mortality and rate of fishing (exploitation) utilizing recaptures in the first year (Ricker 1975). In Georgia, fishing effort within estuaries is not uniform as anglers concentrate their efforts on specific locations depending of tide stage, prevailing winds, and season of the year. The fact that tagged red drum will often remain in the immediate area of release for extended periods of time, makes them particularly vunerable when anglers locate them. Consequently, removal rates in these areas could be disproportionate to angler harvest in an estuary as a whole. While this is a source of bias, it is important to consider that harvest of juveniles during the first year following recruitment to the fishery is the source of most of the fishing mortality during the 3-4 year period when these fish are resident in estuarine waters. Therefore, while the non-random distribution of marked red drum and periodic non-random distribution of angling effort does influence estimates of exploitation, this bias should not cause unrealistic distortion in these values.

Another possible bias in mark-recapture studies is tag loss. This Type A error can affect estimates of exploitation and fishing mortality (Ricker 1975). Observations during this study and a review of literature suggests that short-term tag loss is less of a problem than long term loss. Elam (1971) found that abdominally tagged red drum placed in hatchery ponds loss only 13% of the tags over a 20 month period. In this study there were over 260 abdominally tagged red drum recovered during fishery-independent sampling efforts. Few of these fish had completely loss their tags; however, there were some red drum in which the streamer portion of the internal anchor tag was eroded to the extent that it would be undetectable to most anglers. Most of these individuals had been at-large for over two years. An additional problem with detectability of tags was revealed during this study. When internal anchor tags were used in larger sub-adult red drum (>600 mm), often times the streamer of the tag would be drawn into the abdominal cavity before the disk portion could be anchored by the peritoneal lining. These aforementioned problems prompted the current use of plastic dart tags and modified internal anchor tags with longer streamers for tagging of red drum.

When mortality and survival are estimated from the ratio of tags recovered in consecutive years, the number of recoveries during the second year following release could be affected by long-term tag loss. This would result in an underestimate of survival and an overestimate of total mortality. During this study instantaneous mortality rates and survival were estimated for red drum with tags recovered within two years of release. Therefore, it is likely that, with the data used and the 5% reduction in numbers released, tag loss had minimal impacts on estimates of mortality and survival during this study.

Failure of anglers to report recovered fish tags (Type A error) can lead to underestimates of exploitation and fishing mortality. Green et al. (1985) suggested using surreptitiously tagged fish inserted in angler's creels to estimate fish tag nonreporting rates. Woodward (1989) utilized a similar methodology and found that nonreporting rates in Georgia varied from 38-87%. Although the small sample size in that study compromised the accuracy of the estimates, the results demonstrated that nonreporting was a significant source of variation in analysis of mark-recapture data. Therefore, tag return numbers were adjusted by 50% to compensate for bias caused by nonreporting.

There is little published work on tagging mortality of red drum. The internal anchor and dart tags used in this study appeared to have little deleterious effects on red drum. Investigations in Georgia (Schaffer, unpub. data) indicated that juvenile red drum (250-350 mm) suffered no short-term mortality (2 weeks) following insertion of internal anchor tags. Additionally, both internal anchor and dart tags were used to mark fish during a recent hooking mortality study in Georgia (Jordan 1990). Neither tag appeared to cause any short-term mortality in sub-legal (<355 mm) red drum. Consequently, tagging mortality should have had little impact on the results of our estimates of mortality and survival.

Movement

Movement of immature juvenile and sub-adult red drum in Georgia's estuaries is minimal and appears to be largely random. Over 75% of the recaptured red drum in this study were recovered within 10 km of the release location with most fish recaptured within 6 months of release. There were no significant relation ships between fish length at release, days-at-large, season of release, and distance traveled from the release site.

If a percentage of sub-adult red drum are becoming sexually mature and leaving estuarine waters, older red drum should exhibit a greater net movement than younger juveniles. While an examination of distance traveled vs. age at release for recaptured red drum suggested that this may be the situation, the low number of returns reduced the validity of this analysis. Over 30% of the age 2 red drum traveled more than 30 km before recapture. However, 90% of the age 3 red drum were recaptured within 5 km of the release site. The extremely low fishing effort for red drum in nearshore areas greatly reduces the probability of angler recapture of tagged red drum once they leave inshore estuarine waters. A large number of sub-adult red drum must be tagged before sufficient recaptures will be made to provide accurate data on temporal and spatial aspects of the movement of older red drum.

There were no evident trends in direction moved vs. season of release. More red drum moved north; however, the magnitude of this movement prior to recapture was such that most of these fish were recovered in either the estuary of release or a system immediately adjacent. There are few published studies of red drum movement in the South Atlantic. However, investigations in that region and the Gulf of Mexico have not revealed any distinct patterns of directional movement (Osburn et al. 1982, Ross and Stevens 1989).

During this study the estuarine area of recapture for red drum was examined to provide insight on habitat utilization on a seasonal basis. Unlike spotted seatrout in Georgia, red drum do not appear to have seasonal intra-estuarine migrations. Food habits studies in Georgia and other areas (Pearson 1929, Yokel 1980, Music and Pafford 1984) indicate that white shrimp, (Penaeus setiferus), is the predominant food of juvenile red drum. However, these investigators also found that immature red drum feed readily on other decapods such as mud crabs (Panopeus spp.) and fiddler crabs (Uca spp.). These decapods are ubiquitous in Georgia's estuaries and, although there are seasonal peaks in abundance, they do not exhibit estuarine-ocean migration patterns like those documented for penaeid shrimp. Since red drum are opportunistic omnivores and apparently do not rely as heavily on penaeid shrimp and juvenile finfish as do spotted seatrout, their movement patterns may not be as strongly linked to the seasonal migrations of prey species such as white shrimp. It is likely that intra-estuarine movement of juvenile and sub-adult red drum is related to seasonal changes in estuarine water temperatures, salinities, and prey availability; however, more detailed examinations of red drum behavior will be necessary to quantify these relationships.

Inter-estuarine movement of red drum was minimal during this study and suggests that, while estuarine-specific sub-populations of red drum may exist in coastal Georgia, they are not as restricted as seen in other investigations (Beaumariage 1969,Osburn et al. 1982). In this study, it appeared the extent of inter-estuarine movement was related to the number of fish released. There were over 3000 red drum released in the St. Simons estuarine system of which 690 returns had sufficient information to ascertain area of recapture. Tagged red drum released in St. Simons were recovered in all of Georgia's estuaries and in the coastal waters of the adjacent states of South Carolina and Florida. The next greatest number of tagged red drum was in the Wassaw system. Red drum released in this system were recovered in all but two of Georgia's estuaries and in South Carolina. The number of recaptures in the remaining two systems examined was considerably less and the extent of inter-estuarine movement was further restricted in those systems.

Although the low number of returns for systems other than St. Simons compromises the results, they do suggest that once red drum recruit to an estuarine system as larvae they generally remain in that system until maturity and/or emigration. The limited inter-estuarine movement also indicates that locally heavy patterns of exploitation could greatly reduce the potential contribution of estuarine-specific populations to the adult component of the red drum stock.

Unfortunately, the results of this study provided little information on the movements of adult red drum in coastal Georgia and adjacent Federal waters. Efforts to manage the South Atlantic red drum as one unit may be unrealistic if reproductively and behaviorly isolated sub-stocks exist in the region. Communications with fishery managers indicate that population dynamics and exploitation of red drum vary tremendously throughout the South Atlantic states. The probability of recovering tagged adult red drum in nearshore and offshore waters is very low and a moratorium on harvest exists in the Exclusive Economic Zone (3-200 miles). Therefore, a large number of adult red drum must be tagged before valid data on stock identity and migration can be obtained.

Immature red drum demonstrate a tendency to remain in schools or aggregations while occupying inshore estuarine waters. There were numerous occasions where several red drum tagged within a limited period of time and released in the same location would be recaptured by anglers the same location several days, weeks, or even months later. This propensity for schooling allows immature red drum to be heavily exploited by a limited number of anglers.

During this study there was one incident where a single angler removed over 200 juvenile and sub-adult red drum from the same estuarine creek mouth over a three day period. This example is illustrative of the possible impacts that anglers can have on red drum populations in Georgia. Continued implementation of the 14 inch minimum length limit and further reductions in the creel limit should help prevent the excessive harvest of vulnerable young juveniles.

The schooling behavior observed in this study has been documented in one other investigation (Osburn et al. 1982). They suggested both angling and more efficient commercial gear such as trammel nets could effectively remove local populations of red drum in Texas. Matlock et al. (1977) documented that catch rates of red drum were lower in bays open to commercial netting than in those closed to netting. Fortunately, Georgia outlawed the harvest of red drum with nets in the 1950s or, given the coastal morphology of Georgia and the heterogenous distribution of red drum, it is possible that this species could have been extirpated from the state's coastal waters within a few decades.

Age and Growth

Length-frequencies, scales, and otoliths have been applied as ageing methods for young red drum (Pearson 1929; Gunter 1945; Miles 1950 and 1951; Simmons and Breuer 1962; Theiling and Loyacano 1976; Rohr 1980; Music and Pafford 1984). In these studies, the length-frequency method for determination of age was applicable for ageing red drum during the early years of life, but older red drum must be aged with structures such as otoliths to provide reliable estimates.

The rapid growth rate of young red drum results in sufficient uniformity of monthly length-frequency data to determine occurrence and monitor growth rate of a single cohort of red drum for approximately the first 45 months of life. Most of the red drum collected during this study were collected with a trammel net which most effectively sampled red drum > 250 mm. Therefore, age 0 red drum did not recruit to the sampling gear until June-July of the first year of life. The is also the time when recreational fishermen would harvest large numbers of young red drum before Georgia established a 14 inch minimum size limit in 1986. This high exploitation of young juvenile red drum would continue from June through September. Monthly growth rates for these young red drum averaged approximately 30 mm during June through October. However, as water temperatures declined in the fall, growth rates decreased to approximately 15 mm per month. Therefore, the minimum size limit of 14 inches delayed harvest of red drum for approximately three months until approximately 12 to 13 months of age. During the winter months at 16 to 18 months of age, growth rates slowed to approximately 6 mm a month. A minimum size of 16 inches would have delayed harvest until approximately December. A minimum of 18 inches would have delayed harvest until spring of the following year when the cohort would be approximately 20 months old. Growth rates again increased to 20-25 mm a month during the following summer when red drum were approximately 22 to 24 months old.

Although length-frequencies were useful for estimating time of occurrence and age for the first three years of life, the variation in length-at-age beyond the 4th or 5th year of life makes it impossible to accurately estimate age of adult-size red drum using length. Similar results were found in the reliability of estimating age of red drum from headgirth measurements. However, the potential exists to apply length and headgirth to determine trends in age-composition.

Calculation of mean monthly marginal increments and evaluation of new annuli on scales of recaptured red drum indicated a single annulus was formed on scales each year during February and March for at least the first three years of life. Red drum apparently deposit a mark on their scales during the first winter of life. However, otoliths do not exhibit a similar mark. Data in this study indicated that formation of the first detectable annulus in scales and otoliths is relatively simultaneous.

Red drum are a long-lived species, and unfortunately, scales are reliable for determing age only during the first 3 or 4 years. Otoliths have been used by several investigators to estimate ages of larger red drum. However, until recently, no studies had been conducted to validate the number of marks formed annually in otoliths of adult-size red drum. For many years, some investigators theorized that after age 4 or 5, several sciaenids, including red and black drum, may form more than one annulus-like mark each year on otoliths (Richards 1973; Rohr 1980). However, Beckman et. al. (1989) documented a single peak per year in marginal increment plots derived from otoliths indicating that one mark was formed each year in adult red drum in the Gulf of Mexico. Investigators in Florida (Murphy and Taylor, unpubl. data) have documented single annual mark formation in otoliths taken from oxytetracycline-injected red drum from 955-1,100 mm.

Of all the techniques applied in this study, otoliths proved to be the most satisfactory in precisely and reliably estimating the age of red drum. The oldest red drum collected in Georgia was a 40 year old, 1,057 mm male. The oldest female was 36 years and

1,105 mm. The largest female red drum aged measured 1,105 mm, while the largest male was 1,100 mm. Maximum ages of Atlantic coast red drum range from 33 years in Florida (Murphy and Taylor 1986), 37 for South Carolina (Wenner et al. 1990), to 55 for North Carolina (Ross and Stevens 1989). The largest length reported for the Atlantic coast was 1,499 mm for 52 year old red drum in North Carolina (Ross and Stevens 1989).

Tremendous variability in survival is indicated by the age composition of red drum in the adult stock. Although abundance was low for red drum from the 1966 and 1969 cohorts, survival from 1963-1972 appeared to be the highest for any ten year period in the past 40 years. The low abundance of red drum spawned before 1960 may be attributed to natural mortality of older fish and/or possible harvest by the gill net fishery. It is interesting to note that red drum from the 1957 cohort were substantially more abundant in the adult stock that those from previous years. This is the same year when Georgia established regulations restricting gill netting activities to only sturgeon and shad. The low abundance of adult red drum in cohorts since 1972 indicates that the stability of the adult spawning stock may be jeopardized if survival of immature red drum in estuarine waters is not adequate to compensate for losses of adults due to attrition and natural mortality. Beckman et al. (1989) found that adult red drum in cohorts produced since the mid-1970s were less abundant that those prior to that period. These investigators suggested several possible explanations for this distribution of ages including: poor year classes, incomplete recruitment to the offshore spawning populations, and high fishing pressure on inshore red drum. While the fluctuations in abundance of red drum older than 15 years in this study may be influenced by poor year-class strength, it is likely that the high harvest of immature red drum and/or incomplete recruitment of young adults (< age 10) explains the low abundance of adults from cohorts of recent years.

In the past 30 years, the majority of the estuarine harvest of immature red drum can be attributed to the hook and line fisherman. Commercial landings of red drum in Georgia have historically been the result of sales by "recreational" anglers catching quantities greater than needed for their personal consumption. Red drum commercial landings have averaged approximately 2,000 pounds annually for the past 10 years and account for less than 2% of the total harvest of red drum in Georgia (Pafford and Nicholson 1989). From 1979 through 1985, approximately 70% of all red drum harvested by recreational fishermen in Georgia were less than 14 inches in length. A 14 inch minimum length limit and a 10 fish bag limit were implemented during the late 1980s to help reduce fishing mortality of the vunerable young juvenile red drum.

The low abundance of adult red drum from cohorts spawned in years preceding severe winters indicates that year-class strength may be greatly impacted by such environmental events. Since 1959, there have been several periods where low abundance of adults in a birth-year coincided with a severe winter following the reproductive period of that year. The distributions of abundance versus birth-year suggest that these severe winters were most deleterious to the age 0 fish. The low abundance of sub-adults which would have been resident in the estuarine waters at the time of the winter-kill also indicates that, while smaller red drum are more susceptible to cold-shock (Procarione and Neill 1987), these events may have caused appreciable mortality in these older fish as well. The most severe winter conditions occurred in 1962, 1976-77, and 1980 with lesser freezes in 1966 and 1969. The birth-years with the lowest abundance preceded years of drastic declines in shrimp landings associated with severe cold fronts and estuarine shrimp and fish kills (1962-63, 1976-77, 1977-78, and 1980-81). Although the 1966-67 and 1969-70 winters were not considered as "shrimp disaster" years, the water temperatures dropped to near lethal levels for penaeid shrimp. Although observations of dead red drum were reported immediately following many of these severe winter events, the indirect impact to young red drum from diminished food availability is unknown. Mortality of immature red drum during severe winters could be a major factor contributing to the apparent low recruitment of some cohorts into the adult stock.

Sex Ratio

Data available for determination of sex ratio was restricted to red drum greater than ≥800 mm. Consequently, availability of length and sex information were limited. Histological analyses of gonads from red drum collected in South Carolina indicated males were mature by 713 mm and females by 830 mm (Wenner et al. 1990). Therefore, the sex ratio derived for red drum >800 mm may not be representative of the overall sex ratio for Georgia's red drum stock. Sex ratio for red drum ≥800 indicated a greater abundance of females than males (2.6:1). The ratio for females to males increased dramatically for larger red drum. The female:male ratio increased from 3.9:1 for red drum ≥900 mm to 6.8:1 for drum ≥1,000 mm. The preponderance of females in the collections of large red drum may be attributed to larger size at age for females and possible behavioral differences among the sexes. Over 95% of the red drum were collected with hook and line during September through November, months immediately following peak spawning (Wenner et al. 1990). Due to the physical demands and limited feeding of females during spawning, the tendency of females to move into beach and shoal areas to feed following spawning may be greater than for males. If such a behavior pattern exists, this may possibly explain the greater abundance of females in these collections. However, a single sample of 14 red drum collected with hook and line approximately 13 km offshore during November 1989 had a female to male ratio of 4.7:1. Beckman et al. (1989) reported a similar sex ratio for red drum captured by purse seine from offshore waters of the northern Gulf of Mexico.

RECOMMENDATIONS

As coastal populations expand and development continues to escalate, pressure on Georgia's red drum will likely increase. The immediate challenge confronting coastal fishery managers in Georgia is protecting red drum populations to ensure the existence of an adequate spawning stock. This requires management actions which will reduce fishing mortality of immature red drum, identify and protect crucial spawning and nursery habitat, and evaluate the necessity of gamefish or no sale status for this species. Fishery-dependent and -independent sampling suggest that red drum are recruitment overfished in Georgia. Formulation of effective management programs to prevent overfishing necessitates a knowledge of this species abundance, age composition, movement, reproduction, and mortality.

The results of this study indicate that estuarine populations of immature red drum are subject to high fishing mortality. While the majority of the fishing mortality occurs during the first year of life, increasing exploitation of sub-adult red drum suggests that survival to adulthood may be further compromised by expanding fishing pressure. Although exploitation of adults appears to be minimal, a revision of the length and bag limit on large red drum is necessary to ensure protection of sub-adults. The current maximum size limit should be decreased to 27 inches and the allowable take over this size should be reduced to one fish per angler per day.

Recognizing the possible impacts of emigration on the disappearance rate of sub-adult red drum from estuarine waters, the persistent high exploitation of juveniles seen in this study indicates that further reductions in the bag limit of immature red drum may be needed. Vaughan and Helsner (1989) modeled the effects of several combinations of minimum and maximum length limits, daily bag restrictions, and seasonal closures on survival of immature red drum. These investigators suggested that a 14 inch minimum size limit with a 2 fish daily bag would barely meet the 30% escapement rate recommended by the South Atlantic Fishery Management Council. Georgia DNR recently (1989) implemented a 10 fish daily bag for immature red drum; however, it will be 2-3 years before the success of this limit for reducing fishing mortality on the juveniles of the 1990 cohort can be evaluated. With high exploitation documented in the current study, consideration should be given to further reductions in the bag limit for immature fish (14-27 in) to 5 per angler per day.

Throughout the Gulf of Mexico and South Atlantic regions, fishery managers have utilized gamefish or no sale status to reduce the harvest of red drum. This has resulted in a decline in the availability of red drum for legal sale. In Georgia, the reported commercial harvest of red drum is minimal, with most fish harvested by hook and line anglers. If bag limits are further reduced and ex-vessel values of red drum increase, the financial incentive may develop for individual anglers to harvest illegal quantities. Any decision to reduce bag limits must be tempered with the acknowledgment that this situation could develop in the future.

Georgia should continue both fishery-dependent and -independent monitoring of red drum in Georgia's coastal waters. This will provide vital information on the abundance and age composition of immature and adult red drum. Detailed analysis of this data with techniques such as a virtual population analysis (VPA) will provide insight on age-specific abundance and fishing mortality. Results from this type of analysis will allow fishery managers to assess the effectiveness of current bag limits for reducing fishing mortality on juveniles and providing adequate recruitment to the spawning stock.

Evaluation of exploitation and fishing mortality rates of red drum can be accomplished by continuing mark-recapture studies in Georgia's estuarine and nearshore ocean waters. Results of the current study indicates there are several sources of error which may invalidate tagging data. These sources of bias must be addressed to ensure the accuracy and validity of future mark-recapture data. The following research and monitoring activities will be necessary to meet these goals: 1) continue mark-recapture to determine estuarine-specific rates of exploitation, mortality, and survival; 2) conduct double-tagging experiments to quantify tag loss and evaluate alternative tag designs to improve long-term retention; 3) assess the extent of tag nonreporting in Georgia to improve the accuracy of estimates of fishing mortality; 4) increase the numbers of red drum tagged to determine emigration of juveniles and sub-adults and movement and migration of adults; and 5) assess the effects of emigration on estimating mortality and survival from tagging and fishery-dependent and -independent data .

Information on the reproductive biology of red drum along the Atlantic coast is extremely limited. The general consensus of fishery managers is that Atlantic red drum spawn during July through October. However, there is a paucity of information on specific spawning requirements including location, water temperature, and salinity. Additionally, there is sparse data on age at maturity and fecundity for red drum in Georgia. Future investigations should emphasize the quantitative sampling of sub-adult and adult red drum to determine temporal and spatial aspects of maturity and reproduction.

Although numerous adult-size red drum have been tagged in Georgia, only one individual has been recovered. With a closure of the red drum fishery in Federal waters and the current minimal angling effort for adults, considerable numbers of adult red drum must be tagged to increase the probability of recoveries. Recaptures of marked adults will provide much needed information on stock identity, migration, and mortality rates. Current biotelemetry investigations should be expanded to further document the temporal and spatial distribution of sub-adult and adult red drum and assist in identifying crucial habitat in Georgia's estuarine and nearshore waters.

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LITERATURE CITED

Anderson, W. W. 1968. Fishes taken during shrimp trawling along the South Atlantic coast of the United States, 1931-1935. U. S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 570. 60 p.

Bagenal, T. 1978. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publs., Ltd. Oxford, England. 365 p.

Barger, L. E., and A. G. Johnson. 1980. An evaluation of marks on hardparts for age determination of Atlantic croaker, spot, sand seatrout, and silver seatrout. U.S. Dept.Commer.,Natl.Mar. Fish. Serv.,S.E. Fish. Center, NOAA Tech. Memo. 22. 5 p.

Beaumariage, D. S., and A. C. Wittich. 1966. Returns from the 1964 Schlitz tagging program. Fla. Bd. Conserv. Tech. Ser.47. 51 p.

Beaumariage, D. S. 1969. Returns from the 1965 Schlitz tagging program including a cumulative analysis of previous results. Fla. Dept. Nat. Res., Mar. Lab., Tech. Ser. 59. 38 p.

Beckman, D. W., C. A. Wilson, and A. L. Stanley. 1989. Age and growth of red drum, Sciaenops ocellatus, from off shore waters of the northern Gulf of Mexico. Fish. Bull.87(1):17-28.

Elam, L. 1971. Salt water pond research, Marine Fisheries Research Station. Pp. 1-62A in: Coastal Fisheries Project Reports, 1971. Texas Parks and Wildlife Department, Austin, Texas.

Fischer, W. Editor. 1978. FAO species identification sheets for fishery purposes. FAO, UN, Rome, Vols. I-VII.

Green, A.W., H.R. Osburn, G.C. Matlock, and H.E. Hegen. 1985. Estimated survival rates for immature red drum in Northwest Gulf of Mexico bays. Fisheries Research 3:263-277.

Gunter, G. 1945. Studies of marine fishes of Texas. Publ. Inst. Mar. Sci. Univ. Tex. 1:1-190.

Jordan, S.R. 1990. Mortality of hook-caught sub-legal red drum and spotted seatrout. Georgia Dept. Nat. Res., Coast. Res. Div. Federal Aid Report. Proj. F-31. 33 p.

Klima, E. F., and D. C. Tabb. 1959. A contribution to the biology of the spotted weakfish, Cynoscion nebulosus (Cuvier), from northwest Florida with a description of the fishery. Fla. Bd. Conserv. Tech. Ser. 30. 24 p.

Knowlton, C. J. 1972. Fishes taken during commercial shrimp fishing in Georgia's close inshore ocean waters. Ga. Dept. Nat. Res., Game & Fish Div., Coastal Fish. Ofc., Brunswick, Ga., 42 p.

Lux, F. E. 1971. Age determination of fishes. U.S. Dept. Commer., NOAA, Natl. Mar. Fish. Serv. Leaflet 637. 7 p.

Mahood, R. K., C. D. Harris, J. L. Music and B. A. Palmer. 1974. Survey of the fisheries resources in Georgia's estuarine and inshore ocean waters. Part IV. Coastal Georgia - southern, central and northern sections. Ga. Dept. Nat. Res., Game and Fish Div., Coastal Fish. Ofc., Brunswick, Contrib. Ser. 25. 201 p.

Matlock, G.C., J.E. Weaver, and A.W. Green. 1977. Trends in spotted seatrout and red drum abundance in Texas coastal waters influenced by commercial netting activities. Proc. Annu. Conf. S.E. Assoc. Game Fish Comm. 31:477-483.

Matlock, G.C. and J.E. Weaver. 1979. Fish tagging in Texas bays during Nov. 1975-Sept. 1976. Coast. Fish. Brnch, Tex. Pks. Wild. Dept., Manage. Data Ser. 1. 135 p.

Miles, D. W. 1950. The life histories of spotted seatrout, Cynoscion nebulosus, and the redfish, Sciaenops ocellatus. Tex. Game, Fish & Oyster Comm., Mar. Lab. Annu. Rep. (1949-1950). pp. 66-103.

Miles, D. W. 1951. The life histories of the seatrout, Cynoscion nebulosus, and the redfish, Sciaenops ocellatus. Sexual development. Tex. Game & Fish Comm., Mar. Lab. Annu. Rep. (1950-1951). 11 p.

Miller, E. E. 1966. Age and growth determinations. In: Inland fisheries management, edited by Alex Calhoun. State of California. The Resources Agency, Dept. Fish and Game, pp. 57-69.

Moffett, A.W. 1961. Movements and growth of spotted seatrout, Cynoscion nebulosus (Cuvier), in west Florida. Fla. Bd. Conserv. Mar. Res. Lab., Tech. Ser. 36. 35 p.

Murphy, M.D. and R.G. Taylor. 1986. Reproduction, growth, and mortality of red drum, Sciaenops ocellatus, in Florida. Fl. Dept. Natl. Res. 76 p.

Music, J. L., Jr., and J. M. Pafford. 1984. Population dynamics and life history aspects of major marine sport fishes in Georgia's coastal waters. Ga. Dept. Natl. Res., Coastal Res. Div., Contrib. Ser. 38. 382 p.

Nicholson, N., J.M. Pafford, and A.G. Woodward. 1990. An assessment of relative abundance of finfish in coastal Georgia, January 1984-June 1989. GA. Dept. Natl. Res., Coastal Res. Div. Fed. Aid Report, Project F-31. 60 p.

Osburn, H.R., G.C. Matlock, and A.W. Green. 1982. Red drum (Sciaenops ocellatus) movement in Texas bays. Contr. Mar. Sci. 25:85-97.

Overstreet, R.M. 1983. Aspects of the biology of the red drum, Sciaenops ocellatus, in Mississippi. Gulf Res. Reps. Suppl 1: 45-68.

Pafford, J. M., and N. Nicholson. 1989. Georgia marine recreational fisheries survey, 1985-1987. Ga. Dept. Nat. Res., Coastal Res. Div., Brunswick, Ga., Contrib. Ser. No. 45. 157 p.

Pauly,D. 1980. On the interrelationships between mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39:175-192.

Pearson, J. C. 1929. Natural history and conservation of the redfish and other commercial sciaenids of the Texas coast. Bull. U.S. Bur. Fish. 44:129-214.

Procarione, L. and B. Neill. 1987. Cold tolerance limited. Coastal Aquaculture 3(3):9.

Pugliese, R. 1990. The Atlantic coast red drum fishery management plan. SAFMC. Charleston, SC. 116 p.

Qualia, N.S. 1987. Tagging offshore pelagic species (TOPS) tournament and Fish Trackers, Inc. tag and release program. pages 275-282 in: R.A. Barnhart and T.E. Roelofs, editors. Catch-and-Release Fishing a Decade of Experience. Proc. Humboldt St. Univ. CA. 299 p.

Rago, P.J. and C.P. Goodyear. 1986. Estimation of mortality rates and population size from tagging studies in Everglades National Park, 1984-1985. U.S. Fish. Widl. Ser. Gainesville, Fl.

Richards, C.E. 1973. Age, growth and distribution of black drum (Pogonias cromis) in Virginia. Trans. Amer. Fish. Soc 102: 584-590.

Ricker, W.E. 1975. Computation and interpretation of biologi cal statistics of fish populations. Bulletin. Fish. Res. Bd. Canada. No. 191. 382 p.

Rohr, B. A. 1980. Use of hard parts to age Gulf of Mexico red drum (Abstract). In: Proceedings of the Red drum and Seatrout Colloquium, Oct. 19-20, 1978. Gulf states Mar. Fish. Comm., Ocean Springs, Miss., Report No. 5.

Ross, J.L. and T.M. Stevens. 1989. Marine fisheries research: red drum. Annual progress report, Project F-29 - Study IV. N.C. Dept. Natl. Res. Comm. Development, Div. Ma rine Fish. Morehead City, NC. 36 p.

Schmeid, R.L. and E.E. Burgess. 1987. Marine recreational fisheries in the southeastern United States: an overview. Mar. Fish. Rev. 49(2):2-7.

Simmons, E. G., and J. P. Breuer. 1962. A study of redfish, Sciaenops ocellata Linnaeus, and black drum, Pogonias cromis Linnaeus. Publ. Inst. Mar. Sci. Univ. Tex. 8:184-211.

Sokal, R.F. and F.J. Rohlf. 1981. Biometry. W.H. Freeman, San Francisco, California. 776 p.

Theiling, D. L., and H. A. Loyacano, Jr. 1976. Age and growth of red drum from a saltwater marsh impoundment in South Carolina. Trans. Amer. Fish. Soc. 105(1):41-44.

Tilmant, J.T., E.S. Rutherford, and E.B. Thue. 1989. Fishery harvest and population dynamics of red drum (Sciaenops ocellatus) from Florida Bay and adjacent waters. Bull. Mar. Sci. 4(1):126-138.

Vaughan, D.S. and T.E. Helsner. 1989. Status of the red drum stocks of the Atlantic coast: stock assessment report for 1989. NMFS, SEFC. 169 p.

Wenner, C. A., W. A. Roumillat, J. E. Moran, M. Maddox, L. B. Daniel, III, and J. W. Smith. 1990. Investigations on the life history and population dynamics of marine rec reational fishes in South Carolina: part 1. manuscript. S.C. Wildl. Mar. Res. Dept. Charleston, SC.

William, T., and B. C. Bedford. 1974. The use of otoliths for age determination. pages 114-123, In: Proceedings of an International Symposium on the Ageing of Fish, T.B. Bagenal, editor. Univ. Reading, England. Unwin Bros. Ltd., Surrey, England.

Wilson, C.A., D.W. Beckman, D.L. Neiland, and A.L. Stanley. 1988. Age, growth rate and reproductive biology of red drum landed in Louisiana. Final rept. 1987-1988 LA. Dept. Wildl. Fish. MARFIN, LSU-CFI-88-18. 29 p.

Woodward, A.G. 1989. Nonreporting of recaptured tagged fish by recreational anglers in Georgia. manuscript. GA. Dept. Natl. Res., Coastal. Res. Div. 3 p.

Woodward, A.G. 1990. Attitudes and opinions of Georgia's resident saltwater anglers. GA. Dept. Nat. Res., Coastal Res. Div. Contr. Ser. No. 47. 32 p.

Yokel, B. 1980. A contribution to the biology and distribu tion of the red drum, Sciaenops ocellata. (Abstract). Proc. Red Drum and Seatrout Colloq., Oct. 19-20, 1978. GSMFC 5. 118 p.