but definite conclusions cannot be reached in the absence of fisheries data to weight the results.

The net distance traveled was not related to size, time at liberty, or season. During the period of this study, the abundance of sablefish was believed to have been decreasing from overfishing (International North Pacific Fisheries Commission 1980). It is possible that behavior and migration tendencies could be different when the population is stable or increasing. Recently, a relatively strong year class of sablefish has been noted in most areas (International North Pacific Fisheries Commission 1980). Some of these fish had been tagged in 1979 and 1980 (Hughes 1980[3]). It will be interesting to see if movement patterns of adults alter in response to the presence of a large year class.

Acknowledgments

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Literature Cited

BEAMISH, R. J., AND D. E. CHILTON.
In press. A preliminary evaluation of a method to determine the age of sablefish (*Anoplopoma fimbria*). Can. J. Fish. Aquat. Sci.

BEAMISH, R. J., C. HOULE, AND R. SCARSBROOK.
1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. Manuscr. Rep. Fish. Aquat. Sci. 1588, 194 p.

EDSON, Q. A.
1954. Premilinary report on the Alaska sablefish fishery. Pac. Mar. Fish. Comm., Bull. 3:73-85.

HIPKINS, F. W.
1974. A trapping system for harvesting sablefish *Anoplopoma fimbria*. U.S. Dep. Commer., Natl. Mar. Fish. Serv., Fish. Facts 7, 20 p.

HOLMBERG, E. K., AND W. G. JONES.
1954. Results of sablefish tagging experiments in Washington, Oregon, and California. Pac. Mar. Fish. Comm., Bull. 3:103-119.

INTERNATIONAL NORTH PACIFIC FISHERIES COMMISSION.
1980. Proceedings of the 27th Annual Meeting—1980, Anchorage, Alaska, November 4 to 7, 1980. Int. North Pac. Fish. Comm., Vancouver, B.C., Canada, 352 p.

NIE, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER, AND D. H. BRENT.
1975. SPSS - Statistical Package for the Social Sciences. 2d ed. McGraw-Hill, N.Y., 675 p.

NOVIKOV, N. P.
1968. Tagging of the coalfish (*Anoplopoma fimbria* Pall.) in the Bering Sea and on the Pacific coast of Kamchatka. [In Russ.] Vopr. Ikhtiol. 8(5):955-957. (Transl. *In* Probl. Ichthyol. 8:762-764.)

PASQUALE, N.
1962. Notable migration of sablefish tagged in Puget Sound. Wash. Dep. Fish., Fish. Res. Pap. 2(3):68.

PATTIE, B.
1970. Two additional long-range migrations of sablefish tagged in Puget Sound. Wash. Dep. Fish., Tech. Rep. 5:22-23.

PRUTER, A. T.
1959. Tagging experiments on sablefish at Holmes Harbor, Wash. Wash. Dep. Fish., Fish. Res. Pap. 2(2):66-70.

SOKAL, R. R., AND F. J. ROHLF.
1969. Biometry. The principles and practice of statistics in biological research. W. H. Freeman and Co., San Franc., Calif., 776 p.

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[3]Hughes, S. 1980. Pacific west coast and Alaska research plan on sablefish, 1980-84. Unpubl. manuscr., 17 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

WINTER AND ALTERED SPRING MOVEMENTS OF STRIPED BASS IN THE SAVANNAH RIVER, GEORGIA

The striped bass, *Morone saxatilis*, population of the Savannah River supports a small sport fishery and provides all the brood fish for the Richmond Hill, Ga., striped bass hatchery. Information on the biology and management of Savannah River striped bass also has application for management of similar populations in coastal rivers of Georgia, South Carolina, and Florida.

Previous studies of striped bass in the Savannah River have shown that the population is primarily riverine rather than anadromous. Spawning takes place in the freshwater, tidally influenced zone 30-40 km upstream from the river mouth during late March through early May, normally at water temperatures of 16°-20°C (Dudley and Black 1978). After spawning, striped bass in the Savannah River move upstream and remain in the river until the following autumn (Dudley et al. 1977). The fish may then move downstream to overwinter in estuarine areas, although, until now, no direct evidence for this assumption has been available except for the existence of a small and unpredictable sport fishery in the estuary during November through January. This note summarizes additional information about striped bass movements during the winter and during the spring spawning season.

Study Area

The study area extends from the mouth of the Savannah River to the Augusta city dam 370 km upstream and has been described by Dudley et al. (1977). The tidally influenced section of the river is composed of three branches. Front River, the main shipping channel, flows through the industrial part of Savannah, Ga., and is 10-12 m deep downstream from Highway 17. Back River and Middle River flow through the Savannah National Wildlife Refuge, are bordered by cypress forest and extensive grassy marshlands, and are 1-3 m deep at mean low water (Fig. 1).

The tide gate, completed by the U.S. Army Corps of Engineers in 1977, was built to control sedimentation in the shipping channel. The gate allows the incoming tide to flow upstream in Back River but closes when the tide starts to drop, preventing downstream flow. Tidal brackish water and freshwater flowing down upper Back River pass through the diversion canal and increase water velocities in Front River. The gate has changed flow patterns and has increased salinity in parts of Back and Front Rivers. Salinity in Back River from the tide gate to Highway 17 is 1-3‰ higher than without tide gate operation, when salinity upstream from the diversion canal is usually zero. With gate operation, salinity in Back River at Highway 17 can reach 3‰ (Dudley and Black[1]).

During studies conducted in 1973-75 (Dudley et al. 1977), Back River was blocked at the site of tide gate construction. During the present study the tide gate was operating.

Methods

In freshwater a boom-type electrofishing boat with alternating or pulsed direct current was used to capture striped bass. During November through March, attempts were made to capture striped bass with gill nets of 24.3 and 15 cm stretch mesh 30-100 m long. These nets were fished primarily in the Savannah Back River, especially near the tide gate, and in other areas of the downstream 80 km of the river. A 10 cm mesh net was also used but caught mostly smaller fish. Gill nets were checked for fish every 30 min.

Both ultrasonic and radio transmitters were used. The ultrasonic transmitters (manufactured by Smith-Root[2] of Vancouver, Wash.) are easily detected in the estuary, but difficult to track in upstream areas due to noise generated by water currents and by sand moving along the bottom. Ultrasonic transmitters used in the spring of 1979 weighed 54 g, measured 20 mm in diameter and 100 mm long, and had a life expectancy of 6 mo. Those used in the winter of 1979-80 and in the spring of 1980 weighed 40 g, measured 20 mm in diameter and 110 mm long, and had a 1-yr life expectancy.

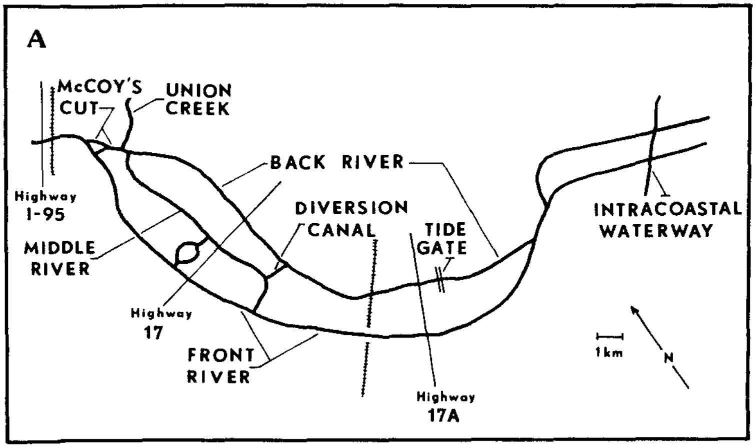
Radio transmitters (manufactured by AVM Electronics of Champaign, Ill.) are easily detected in freshwater but not in saline water. Radio tags measure $70 \times 25 \times 20$ mm, weigh 23 g, and transmit for more than 1 yr. The surgical tagging procedure followed that of Dudley et al. (1977).

In our studies of winter movements, the downstream 100 km of the river was searched for tagged striped bass at about weekly intervals. During this time we also tried to capture and tag additional fish. In our studies of spring movements, the downstream 60 km, including most side channels, was searched about five times per week. The river in the vicinity of the spawning grounds was divided into nine sections to facilitate comparison of 1980 movements with those observed in earlier studies (Dudley et al. 1977) (Fig. 1B).

We used a chi-square test of independence to compare sections used by striped bass in 1980 with sections frequented by striped bass tracked in the earlier, pretide gate study. In that test, river sections E through H were combined, because of the small number of sightings made in them.

[1]Dudley, R. G., and K. N. Black. 1979. Effect of the Savannah River tide gate on striped bass eggs and larvae. Final report to the U.S. Army Corps of Engineers on contract DACW21-78-C-0073, 46 p. + app.

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.



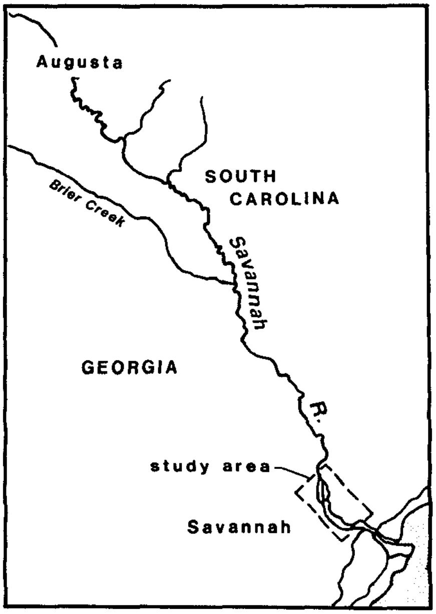
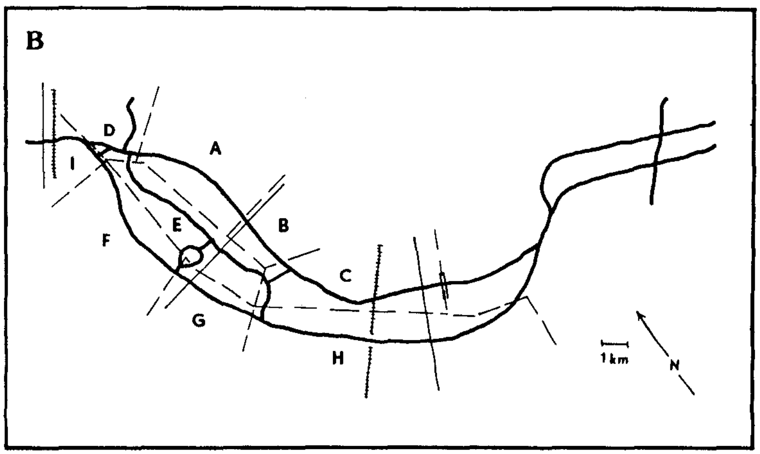


FIGURE 1.—A) Schematic of the Savannah River near Savannah, Ga., from Interstate 95 (km 45) to the Intracoastal Waterway (km 10). Meanders, small islands, etc., are not shown. The river mouth is approximately 10 km southeast of the Intracoastal Waterway. B) Savannah River near Savannah, Ga., showing river segments (A through I) used in analyzing striped bass distribution patterns during the spawning season.



A Hydrolap Surveyor was used to measure temperature, dissolved oxygen, pH, conductivity, and redox potential at each site where a tagged fish was located. Additional sites were sampled on a regular basis during March through May of 1980. No unusual water chemistry readings were noted, and only temperature and salinity are cited in the text as needed.

Results

Thirteen fish were successfully tagged with transmitters and tracked. Six of these were found periodically for more than 100 d, while two were found for more than 1 yr.

Three fish tagged during March and April 1979 provided useful information during the following fall, winter, and spring. During a single search of the entire study area in July 1979, fish F1, F2, and F3 were found at km 257, 222, and 246, respectively. Fish F2 never moved from km 222 and was presumed dead. On 26 September only fish F1 was found (km 234) although only areas upstream from km 107 were searched. Neither fish F1 nor F3 could be found during the winter, but both were found on the spawning grounds the following spring. There is considerable question regarding the whereabouts of these two fish during the winter. Since neither fish had an operating ultrasonic transmitter, they could not have been found in saline waters. If these fish remained in freshwater sections of the river, they would have been detected. The whole river extending to Augusta was searched twice in October, and numerous searches to km 75 were made between October and March. The apparent absence of these fish from the river, and their sudden reappearance in March (fish F3) and early April (fish F1) when they were found without difficulty, indicate that they probably were in saline water during the winter.

Three fish (F4, F5, and F6) were tagged with ultrasonic transmitters in mid-December in saline water (5‰) immediately upstream from the tide gate. Fish F5 was also tagged with a radio transmitter. These fish remained within a few kilometers upstream from the tagging site for 2, 25, and 100 d, respectively. They subsequently left that area and could not be found for extended periods (117, 89, and 19 d, respectively) in spite of numerous searches which reached to the river mouth. They all were later found in upper Back River in April. None of the three fish used freshwater segments of the river during winter.

Seven additional fish were tagged in April 1980. Four were tagged on 4 April with ultrasonic transmitters and three on 17 April with radio transmitters. Thus a total of 12 fish (all except fish F2) yielded movement data during the 1980 spawning season (Table 1).

There was considerable variation among the movement patterns of individual fish (Table 2). Fish F4, F8, and F9 exhibited abnormal patterns. Fish F4 remained at the mouth of Union Creek at the end of the study. Prior to 6 May it shifted its position on occasion but later it apparently died. Fish F8 and F9

TABLE 1.—Striped bass successfully tagged and tracked in the Savannah River, Ga., during 1979 and 1980. Tag type: R = radio; U = ultrasonic. Capture method: G = gill net; DC = direct current; AC = alternating current. Track duration indicates time period during which useful data were obtained. In upstream areas, fish tagged with ultrasonic transmitters were not tracked.

Fish			Tagging			Found on spawning grounds 1980		Upstream location late May 1980 (river km)	Track duration (d)
ID	Weight (kg)	Sex	Date	Tag type	Capture method	First date	Last date		
				Back River, Spring 1979					
F1	7	M	4 Mar 79	R	G	3 Apr	7 May	Not found[1]	429
F2	9	M	10 Mar 79	RU	DC	[2]	—	—	120
F3	10	M	28 Apr 79	RU	AC	21 Apr	29 Apr	196	396
				Tide Gate, December 1979					
F4	6	—	16 Dec 79	U	G	14 Apr	[3]	—	156
F5	8	—	17 Dec 79	RU	G	10 Apr	11 Apr	227	163
F6	6	—	17 Dec 79	U	G	21 Mar	25 Apr	—	129
				Back River, Spring 1980					
F7	15	F	4 Apr 80	U	AC	—	15 Apr	—	11
F8	12	F	4 Apr 80	U	AC	—	9 May	—	35
F9	11	M	4 Apr 80	U	AC	—	9 May	—	35
F10	13	F	4 Apr 80	U	AC	—	11 Apr	—	7
F11	5	M	17 Apr 80	R	DC	—	23 Apr	301	42
F12	8	F	17 Apr 80	R	DC	—	25 Apr	Not found	8
F13	7	M	17 Apr 80	R	DC	—	2 May	241	41

[1]Radio transmitter of fish F1 may have stopped working by late May 1980.
[2]Fish F2 apparently died at km 222, summer 1979.
[3]Fish F4 apparently died in Back River, April 1980.

TABLE 2.—Movement patterns of individual tagged striped bass during spring 1980 in the Savannah River, Ga., as compared with a pretide gate study (Dudley et al. 1977). Fish observed more than once in a given section on a given day are counted as one observation.

	No. days observed/river section									
Fish	A	B	C	D	E	F	G	H	I[1]	Total
F1				14	1				2	15
F3	4			6		1			10	11
[2](F4)	(1)			(18+)						(19+)
F5				3						3
F6	1		2	3		1	1			8
F7	2			1			1			4
[2](F8)	(2)							(12)		(14)
[2](F9)	(1)		(4)					(11)		(16)
F10	1			4						5
F11				3					5	3
F12	1		1							2
F13	12			1						13
Totals excl. fish F4, F8, F9	21 32%	0 0%	3 5%	35 55%	1 2%	2 3%	2 3%	0 0%		64
Totals incl. fish F4, F8, F9	25 22%	0 0%	7 6%	53+ 47%	1 1%	2 2%	2 2%	23 20%		113+
Totals previous study	90 43%	67 32%	19 9%	24 12%	5 2%	1 0.5%	0 0%	1 0.5%		207

[1]This river section was not used in calculating totals or percents since it was not used in the pre-tide gate study.
[2]These fish exhibited unusual movement patterns which may have been caused by tagging.

remained in river segment H from 22 April until 9 May. These fish continued to move about in that segment and later left. Only one other fish in our earlier study (Dudley et al. 1977) entered that area.

Eighty-seven percent of our observations of striped bass were in river segments A and D during the 1980 spawning season. None were found in segment B, although in our previous study (Dudley et al. 1977) 32% of our observations of fish were in that segment. The distribution of our observations among river segments in 1980 differed significantly ($P = 0.005$) from that found in 1973, 1974, and 1975 (Dudley et al. 1977). The difference is due to the increased use by 1980 of segment D by striped bass, and a decreased use of segment B. In 1980, with the tide gate in operation, striped bass were more likely to be found further upstream in Back River.

Five striped bass (F1, F3, F4, F5, F6) tagged prior to the start of the 1980 spawning season gave an indication of the first arrival of the fish on the spawning grounds. Although gill nets set in upper Back River captured some smaller striped bass as early as mid-February, our tagged fish did not enter upper Back River until late March. Four of our five fish first entered this area between 21 March and 14 April when the river temperature was between 17° and 18°C. The other fish (F6) did not enter this area until 22 April after residing in segments C and G.

Each of the 12 tagged fish (all except fish F2) left the spawning area between 11 April and 9 May. The mean date of departure was 26 April (±10 d), similar to the mean date of departure (25 April ±5 d) found in our earlier work. As expected, the fish moved upstream after spawning. Four of the six striped bass carrying radio transmitters were subsequently found as far upstream as km 301, even though only one incomplete search of the river was made in late May (Table 1).

Discussion

The Savannah tide gate has caused significant alterations in both flow and salinity regimes. Our data regarding the location of adult striped bass during the spawning season showed that these fish are found farther upstream when the gate is in operation. This observation is consistent with that of an earlier study (Dudley and Black footnote 1) that striped bass eggs occur farther upstream when the tide gate is operating. Thus the tide gate apparently causes an upstream shift in striped bass spawning. This shift possibly reflects an alteration in salinity patterns. Savannah River striped bass spawn in freshwater and would thus move farther upstream to avoid increased salinity. The overall effect on spawning success from this upstream shift is probably minimal, although in combination with altered flow patterns its ultimate effect on striped bass eggs and larvae is unclear.

Our data concerning movements at other times of the year supplement earlier finds (Dudley et al. 1977). Savannah River striped bass are primarily riverine, ascending the river following spawning. Movements of fish F1 and F3 revealed that fish residing upstream during the summer will return to the spawning grounds the following spring, and then reascend the river after spawning. Factors responsible for this behavior, quite different from that in northern populations, are not positively known.

Dudley et al. (1977) suggested temperature preference may be a reason for riverine behavior, and recent studies by Coutant and Carroll (1980) and Coutant et al.[3] further support this idea. Cooler, more preferable temperatures are likely to be found upstream in the Savannah River in late spring and summer. In late May 1980 the temperature at km 301 was 16°C, while the river temperature at Savannah (km 35) was 24°C. Four striped bass were found upstream on 28 and 29 May in waters of between 16° and 19°C. While Coutant and Carroll (1980) found that small (3.1 kg) striped bass preferred temperatures of 20°-24°C, striped bass of 5 kg or greater preferred temperatures of 16°-22°C (Coutant et al. footnote 3). All our tagged fish exceeded 5 kg. Both Orsi (1971), working in California, and Nichols and Miller (1967), working in Chesapeake Bay, found that larger striped bass were more likely to move to cooler ocean waters.

Available evidence suggests that striped bass use the saline portions of the Savannah River estuary and adjacent waters during the winter. Of five fish known to have working transmitters during the winter, only one could be regularly located and it was in saline water. The other four could not be found in freshwater or saline reaches of the river. These fish likely moved to nearby marine or estuarine waters during January and February. Fish known to be in the river in summer had already departed by October.

Although our tagged fish probably inhabited the lower estuary or marine waters during the winter of 1980, Savannah River striped bass sometimes remain in areas 250-330 km from the river mouth during the winter (Dudley et al. 1977). The differences in these findings could reflect variations among individual fish or among years, caused, perhaps, by winter temperature or flow regimes. The small number of fish tagged during the winter precludes investigating this problem, but observations made during attempts to collect striped bass suggest that year-to-year variations in wintering areas do occur. In some years (e.g., 1974) large striped bass were commonly sighted in upstream areas (Dudley et al. 1977). In other years (1979, 1980) none were seen there in spite of intensive efforts to collect them.

[3]Coutant, C. C., H. R. Waddle, and B. A. Schaich. 1980. Temperature and habitat selection by striped bass. Underwater Telem. Newsletter 10(1):1-4. Available from Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830.

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Literature Cited

COUTANT, C. C., AND D. S. CARROLL.
1980. Temperatures occupied by ten ultrasonic-tagged striped bass in freshwater lakes. Trans. Am. Fish. Soc. 109:195-202.

DUDLEY, R. G., AND K. N. BLACK.
1978. Distribution of striped bass eggs and larvae in the Savannah River estuary. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 32:561-570.

DUDLEY, R. G., A. W. MULLIS, AND J. W. TERRELL.
1977. Movements of adult striped bass in the Savannah River, Georgia. Trans. Am. Fish. Soc. 106:314-322.

NICHOLS, P. R., AND R. V. MILLER.
1967. Seasonal movements of striped bass *Roccus saxatilis* (Walbaum) tagged and released in the Potomac River, Maryland, 1959-61. Chesapeake Sci. 8:102-124.

ORSI, J. J.
1971. The 1965-67 migrations of the Sacramento-San Joaquin estuary striped bass population. Calif. Fish Game 57:257-267.

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