DISTRIBUTION OF STRIPED BASS EGGS AND LARVAE IN THE SAVANNAH RIVER ESTUARY

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Abstract: A tide gate on the Savannah Back River, constructed by U.S. Army Corps of Engineers, might decrease survival of the striped bass (*Morone saxatilis*) eggs and larvae spawned near Savannah, Georgia. An initial season of sampling, with the tide gate held open, yielded striped bass eggs and larvae both up- and downstream from the gate. The distribution of eggs and larvae under normal conditions was established. Maximum numbers of striped bass eggs did not reveal $2/m^3$. Spawning occurred at temperatures between 17 and 23 C but 3 spawning peaks coincided with temperatures between 19.5 and 21 C. Slightly more eggs were found farther upstream during the last spawning peak. All stations sampled yielded eggs or larvae at some time, but stations in Back River generally produced the most eggs. Significant numbers of eggs were found in sections of the river flanked by industry but many of these eggs originated in other areas of the river. Because it alters river flow patterns, the tide gate: 1) may increase the likelihood that striped bass eggs and larvae will move into polluted sections of the river, 2) may increase the distance which striped bass eggs and larvae are transported downstream, and 3) will increase the likelihood that eggs will encounter waters of higher salinities.

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The striped bass population in the Savannah River provides the basis for a sport fishery and is the major source of brood fish for the Richmond Hill fish hatchery which supplies striped bass for stocking reservoirs throughout Georgia. The Savannah River population is primarily riverine, rather than anadromous (Dudley et al. 1976), and reproduces in the various river channels near Savannah. Recently, the U.S. Corps of Engineers completed construction of a tide gate on the Savannah Back River to control sedimentation in the Savannah shipping channel. When operating, the gate allows water to move upstream in the Back River but not downstream. There is concern that reproductive success of striped bass may be adversely affected since operation of the tide gate has modified water flow patterns in the area and forces more water, eggs and larvae through the industrial section of Savannah which flanks the Front River (Fig. 1). Changes in the salinity patterns within the estuary may also decrease egg and larval survival.

The striped bass has been extensively studied on both the east and west coasts of North America, but relatively little of this work involves natural striped bass populations in rivers south of North Carolina. Smith's (1970) report helped delineate the spawning area of striped bass in the Savannah River. His observations and those of McBay (1968) and Rees (1973, 1974) indicate that the primary spawning area is in the tidally influenced zone 30 to 40 km upstream from the river mouth near Savannah, although eggs are found as far upstream as 80 km.

Our study was undertaken to help predict the effects of the tide gate on the distribution and survival of eggs and larvae of striped bass. Additionally, this information will aid in making decisions concerning the effects of dredging in this area.

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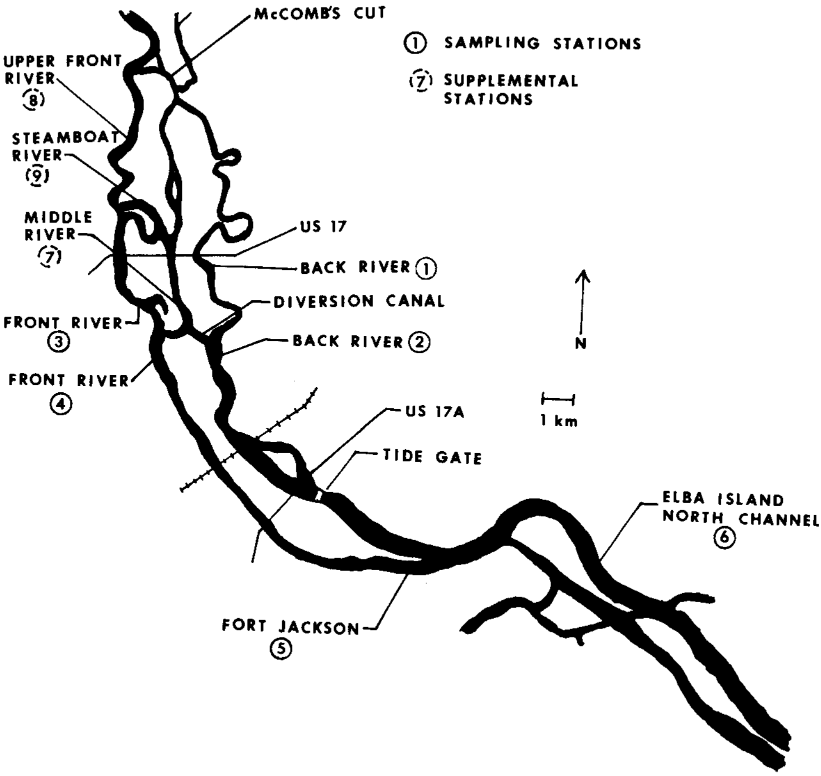

Fig. 1. The Savannah River in the vicinity of Savannah, GA. Numbers in closed circles indicate standard sampling areas. Broken circles indicate supplemental sampling stations. Names refer to river channels or nearby landmarks. Station 6 is approximately 12 km upstream from the river mouth. Station 8 is 40 km upstream from the river mouth.

views expressed herein do not necessarily coincide with those of the U.S. Army Corps of Engineers.

METHODS

The tidally influenced sector of the Savannah River is composed of 3 main channels with several cross connections (Fig. 1). The largest and deepest channel is the Front River which carries the main flow and is maintained as a 10-12 m deep shipping channel. The Front River is bordered by industries, shipping facilities and downtown Savannah. The Middle and Back Rivers are relatively shallow (1-3 m at mean low water) and are bordered by marsh vegetation and cypress forest of the Savannah Wildlife Refuge. The Corps of Engineers' tide gate is located on the Back River. The tide gate remained open during this study.

Sampling stations were established for collecting eggs and larvae and water quality data. The stations were established in consultation with Corps of Engineers and State of Georgia fishery personnel, taking into consideration time and equipment limitations. Six regular stations were established and 3 others were sampled when time permitted (Fig. 1).

Salinity at stations 1 through 3 and at supplemental stations 7 through 9 was zero. At high tide station 4 had a salinity of 1 ppt. Station 5 had a high tide salinity of 3 ppt. Salinity at station 6 ranged from 2 ppt at low tide to 15 ppt at high tide.

From 1 April through 13 May 1977, 209 plankton samples were collected in the Savannah River. Prior to 13 April a single 50-cm diameter plankton net was used. Subsequently a pair of 50-cm diameter nets were towed in a rectangular frame. Both the single net and one of the pair were fitted with a flowmeter. The plankton nets were constructed of 0.57-mm nylon mesh. Each plankton tow, both paired and unpaired, normally lasted 15 min. On a few occasions nets were left in the water for only 10 min to avoid excessive accumulation of detritus. All catches of eggs and larvae were subsequently calculated on a per $100m^3$ basis. A 15 min tow filtered between 30 and 300 m^3 of water, but normally filtered between 60 and 120 m^3.

Because of the shallow nature of Back and Middle Rivers (Stations 1, 2, 7, and 9), tows there were normally made at 1 m or just below the surface while tows in the main channel (Stations 3, 4, 5, 6, and 8) were normally made at 3 m.

Normally a sample was taken at least once per day at each of the 6 stations. When time permitted additional samples were taken: 1) at supplemental stations, 2) to examine depth distribution (1, 3, 5 m) within a station, and 3) to compare catches at different times and tides within a station. Striped bass eggs and larvae were identified using the criteria established by Lippson and Moran (1974) and Hogne, et al (1976).

Due to the significant correlation of the sample variance with the mean number of eggs or larvae, standard regression and analysis of variance techniques could not be used. T-tests utilizing unequal variances and the Wilcoxon rank sum statistic were used to examine differences among means.

RESULTS

During the 1977 sampling period 3 distinct peaks in striped bass spawning occurred. The first of these occurred between 4 and 6 April when water temperatures rose about 19 C. However, no larvae were found during this peak. A second peak in egg numbers occurred on 20 through 22 April. This peak undoubtedly lasted longer but sampling was interrupted on 15 through 19 April by an equipment breakdown. Again this peak was associated with a rise in water temperature. Larvae were found during this period. A third peak in egg and larval numbers occurred during 2-6 May. Water temperatures rose from 19.5 to 22 C during this period. Eggs and larvae were considerably less abundant at other times (Table 1, Fig. 2).

During the first spawning peak, samples from station 1 had the largest mean number of eggs because of the catch of 146 eggs/100 m^3 on 4 April. Since the subsequent day's catch was only 1.6 eggs/100 m^3 the standard error on the mean catch of station 1 precluding finding it statistically different from any other station. During this period one sample in Middle River (station 7) yielded as many eggs as stations 1, 2, and 4 on that day. In general, during 4-6 April more eggs were found in Back (stations 2 and 1) and Middle Rivers (station 7) and in Front River downstream from the confluence of Middle River (station 4) than other stations. Few eggs were found downstream as far as Fort Jackson (station 5) and none were found at Elba Island (station 6) where only 2 samples were taken. No larvae were collelcted during this period. Rank sum tests were not used to analyze data from this period (Table 2).

During period 2 (14 - 22 April) the Back River upstream from the diversion canal (station 1) again had the highest mean number of eggs, but again the significance of this high mean was unclear since its standard error was quite large. The rank test, which

Table 1. Number of striped bass eggs/100m³. Data for 1 to 13 April derived from one net. Subsequent data derived from one or more paired samples. Stations 1-6 were regular sampling stations; 7-9 supplemental stations.

Date	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*mean* (1-6)
April										
1	0	1.5	.5	7.5	0	0				1.6
2	1.6		4.3	6.5	0	0				2.4
3										
4	146.0	31.7	0	14.1	0	0				32.0
5	1.6	47.2		39.5						29.5
6	47.9	27.5	.5	28.4	1.0	1.2	33.2			20.0
7	0	0	0	1.7	0					.3
8										
9										
10										
11	0	0	0	0	1.1	0	6.1			.2
12	0	0	0	0		0				0
13	0	.7	.2	5.3	5.4	0	2.3			1.9
14	1.5	14.6	.8	10.4	12.6	.5	0			6.7
15										
16										
17										
18										
19										
20	159.2	45.7	2.3	6.1	16.1	7.2				39.4
21	0	22.5	0	1.0	8.6	2.4				5.8
22	4.9	11.5	3.2	5.5	0					5.1
23										
24										
25	0	0	0	0	1.6	0				.3
26	0	.4	0	.3	0	0				.1
27	3.4	.7	1.1	2.6	2.3	0				1.7
28	0	.8	0	0	1.5	0				.4
29	0	0	0	0	0	0				0
30										
May										
1	0	27.3	3.2	17.9	.6	0				8.2
3	11.6	135.7	58.3	43.8	0	0				41.6
4	1.0	17.2	21.3	11.5	2.4	0	4.44	28.6	28.6	8.9
5	3.6	1.5	14.4	7.4	0	0		5.6	11.1	4.5
6	5.4	10.9	1.1	10.4	.7					5.7
7										
8										
9										
10	0	0	1.6	2.5	0	0		2.5	0	.7
11	0	0	0	0	0			2.5	0	0
12	0	0	1.3	0	0	0	1.5	0	0	.2
13	0	0	0	0	0	0				0

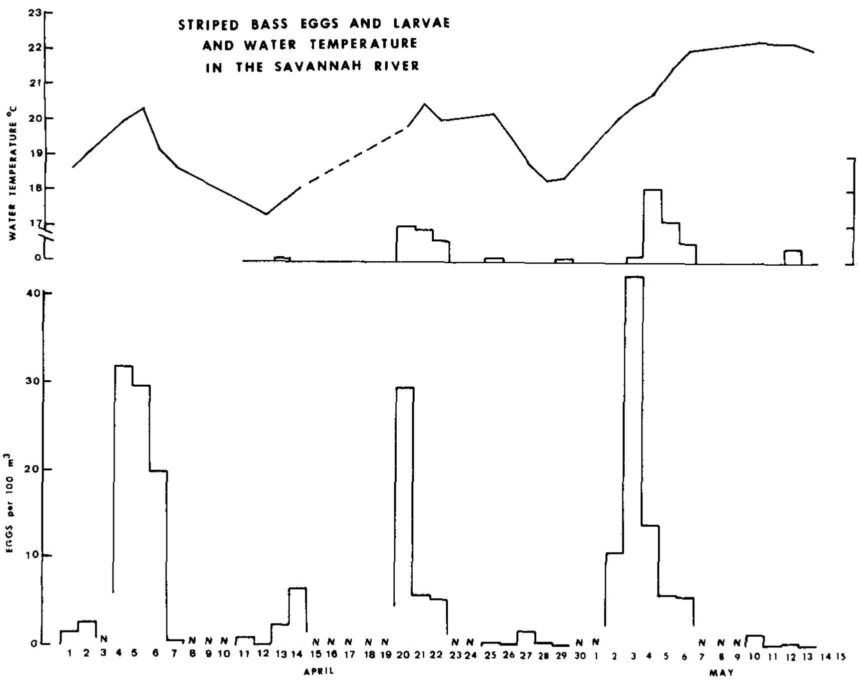

Fig. 2. Mean numbers of striped bass eggs and larvae captured per 100m³ per day, all stations combined, during April and May 1977. The upper curve indicates mean water temperature. N's indicate no data were collected on those dates.

indicates the consistencyof a station's yield of eggs as well as the number of eggs, indicated that the Lower Back River (station 2) yielded more eggs than other stations. Presumably, most of these eggs were spawned in the area of Back River between stations 1 and 2. Upper Back River (station 1) and stations in the main shipping channel downstream from the inflow of Middle River (stations 4, 5, and 6) produced intermediate numbers of eggs while the Front River upstream of Middle River (station 3) produced the fewest. These statements are supported by both t and rank tests (Table 2).

With the exception of 1 larva caught at station 2 and 1 at station 4 all larvae caught during this period were found at station 5 (1.2/100 m^3) and 6 (1.9/100 m^3) downstream from downtown Savannah. The greatest number of larvae found in any particular sample during this period was on a falling tide at Alba Island (station 6) on 20 April (7.2 larvae/100 m^3). The same tide and date produced the most larvae found at Fort Jackson (station 5) during this period (4.5/100 m^3).

Catches of eggs during the third spawning period (2-6 May) differed somewhat from those made during periods 1 and 2. The mean number of eggs caught at station 1 was quite low but the catch remained high at station 2 (Table 2). However, the catch at station 2 was more variable in period 3 than during periods 1 and 2. Station 2 ranked higher than station 1 during periods 2 and 3. The increase in eggs found in the Front River upstream from its confluence with Middle River (station 3) and the decrease in eggs downstream at stations 5 and 6 indicated that increased spawning took place in the upper reaches of

Front River. This finding is supported by high catches of eggs in upper Front River (station 9) on 4 (28.6/100 m^3) and 5 (11.2/100 m^3) May. Egg catches in Steamboat River (station 8) on the same dates (44.4 and 5.6 eggs/100 m^3) also indicate spawning upstream from station 3.

More larvae were captured during period 3 than during period 1 and 2. Some larvae were found at each station. Although station 6 produced the most (4.2 larvae/100 m^3) this was due entirely to a catch of 16.9/100 m^3 on 4 May on a falling tide. A sample just upstream in the Front River (station 5) yielded only .6 larvae/100 m^3 on the rising tide 6 hours earlier at 0900, and at 1000 station 4 yielded 3.6 larvae/100 m^3. Presumably the larvae found at station 6 were washed downstream from the downstream reaches of the Back River.

Larvae were more numerous during period 3 in areas upstream from station 5 than during periods 1 and 2, but the lower reaches of the river continued to produce significant numbers of larvae.

As noted above, catches of larvae sometimes differed with tidal stage. The same was true of egg catches, especially at Fort Jackson (station 5) and Elba Island (station 6), the most downstream sampling areas. In Front River, (at station 4) samples taken on rising and falling tides on the same date did not differ significantly. But at station 5 and 6 falling tides yielded more eggs than rising tides (Table 3). This indicates that eggs taken at these stations are undoubtedly spawned in areas farther upstream. Although a difference in depth distribution of the eggs at various tidal stages could have caused similar differences related to tides, a test of depth distribution at station 4 indicated such was not the case (Table 4). However, the higher salinities at high tide at stations 5 and 6 might cause a depth dependent difference in egg numbers.

Large numbers of eggs were associated with peaks in water temperature (Fig. 2). Significantly more eggs were found at a water temperature of 20 C (Table 5). Larvae were most abundant during the same periods.

DISCUSSION

The 3 spawning peaks observed in 1977 appear to be correlated with water temperatures of 20 and 21 C. This is considerably warmer than the temperatures reported by Smith (1970) but both these and Smith's values are well within the range of spawning temperatures expected (Stevens 1964, Turner 1976, Raney 1952). Kornegay and Humphries (1975) found most striped bass in the Tar River, North Carolina, spawned at water temperatures between 17.8 and 20 C.

Although the spawning peaks were associated with water temperatures between 19.5 and 21 C, the tidal cycle was also similar during each of these peaks with a high tide occurring between 1900 and 2200 EST. The peaks found in our data are not necessarily a typical spawning characteristic. In fact, workers familiar with the striped bass in the Savannah River generally report considerable variation in spawning time from year to year (Smith 1970; Dudley et al. 1976; Rees 1973, 1974). Three spawning peaks in the Tar River in 1975 were associated with rises in water temperatures. In 1965, when water temperatures rose more rapidly, only 1 spawning peak was found (Kornegay and Humphries 1975).

Striped bass eggs are widely distributed in the Savannah River estuary at times of peak spawning. Every location sampled yielded eggs and/or larvae at 1 time or another. No location produced eggs in the abundance found by Johnson and Koo (1975) in the Chesapeake and Delaware Canal (up to 23/m^3). Even the largest catches in the Savannah were about 2/m^3. Nevertheless, significant differences in egg and larval abundance among stations were readily apparent. Consistent with previous findings (Smith 1970; McBay 1968; Rees 1973, 1974) sampling locations in Back River produced the largest numbers of eggs.

Table 2. Comparison of stations within each spawning period. Two ranking methods were used: T-tests utilizing unequal variances were used to test the significance of the difference between each pair of means. The Wilcoxon rank sum statistic was used to test differences in the rank between each pair of stations. Both methods utilize an error rate per comparison of .05. Underlinings connect values deemed not significantly different.

	T-Tests						*Rank Tests*
STATION	1	2	4	6	5	3	not used due to small sample sizes.
Mean Number of eggs	65.2[a]	35.5	27.3	0.6	0.5	3	
S. E.	42.6	6.0	7.3	0.5	0.5	0.2	
N	3	3	3	2	2	2	
	Second Spawning Period (April 14-22)						
Station	1	2	5	4	6	3	2 5 4 1 6 3
Mean Number of eggs	41.4[a]	23.6	10.9	6.5	3.4	1.4	
S. E.	26.4	5.5	2.9	1.3	1.8	0.4	
N	8	8	14	14	10	10	
	Third Spawning Period (May 2-6)						
Station	2	4	3	1	5	6	2 4 3 1 5 6
Mean Number	35.0[b]	19.4	19.7	3.8	0.7	0.0	
S. E.	14.4	3.3	7.3	1.3	0.5	0.0	
N	12	26	10	12	10	8	

[a]Due to the large standard error the station 1 mean does not differ significantly from the other means.

[b]Station 2 differs significantly only from stations 5 and 6.

During the first 2 spawning peaks there was some indication that numbers of eggs in Back River did not differ greatly from Front River downstream from the Middle River confluence. Evidently a portion of eggs produced in Back and Middle Rivers subsequently flow via the diversion canal and Middle River to Front River. Thus, it is quite possible that movement of eggs toward Front River will occur even if the tide gate is left open as it was during this study. This movement was made possible by the construction of the diversion canal (Fig. 1) and increases the probability that eggs and larvae will encounter industrial pollutants. With the tide gate in operation eggs which normally would move down Back River will be even more likely to cross to the industry-flanked Front River since the gate will prevent downstream movement. Presumably operation of the tide gate will deepen the Back River channel somewhat. This would then permit increased flow of water and eggs downstream in Back River if the gates were held open.

It should be noted that a portion of the eggs found in Front River downstream from Middle River originated in Middle River and probably the diversion canal as well.

During the third spawning period eggs in Front River were found in equal abundance up and downstream from the mouth of Middle River. Some must have originated farther upstream in Front River.

Table 3. Differences in eggs/100m^3 found on rising and falling tides in the Savannah Front River and North Channel. Means within each station-date-tide combination are based on 1 paired sample (2 nets). Overall means within station 4 and 5 are based on 4 paired samples. Analysis was restricted to rising-falling pairs obtained when eggs were relatively abundant (period 2 plus 13 April).

Station	*Date*	*Mean Number of Eggs* *Rising tide*		*Falling tide*
4	13 APR	1.04		9.7
	14 APR	12.7		8.2
	20 APR	1.2		11.0
	22 APR	7.4	not	3.7
		5.6	different	8.1
5	13 APR	3.0		10.9
	14 APR	6.6		18.6
	20 APR	0.0		32.2
	22 APR	0.0	$p = .01$	10.5
		1.7		18.1
6	20 APR	0.6	$p = .05$	13.7

Table 4. Mean eggs/100m^3 caught at 3 depths at station 4. Each mean is based on 1 paired sample. No significant differences were found.

Date	*Tide*	*Depth (m)* *1*	*3*	*5*
2 MAY	F	13.3	24.6	15.9
3 MAY	F	57.9	21.5	51.9
4 MAY	R	6.3	11.0	17.3

Table 5. Mean numbers of striped bass eggs caught at different temperatures, stations 1 through 6 combined. Only samples taken at stations 1 through 6 at normal depths are included.

	Temperature C *17*	*18*	*19*	*20*	*21*	*22*	*23*
Mean Number of Eggs	1.7	2.7	3.3	14.9[a]	11.4[b]	1.6	0.0
S. E.	1.0	0.7	1.1	3.5	4.5	0.5	0.0
N	13	55	56	81	43	50	10

[a]Significantly larger than all other means except 21 C. $p = .05$.

[b]Significantly larger than means at 17, 22 and 23 C.

Another means of examining the relative proportions of eggs moving down Back and Front Rivers is to compare catches at stations upstream (5) and downstream (6) of the confluence of Front and Back Rivers. If significant numbers of eggs moved down Back River catches at station 6 would be larger than catches at station 5. Unfortunately the effect of tidal currents is great here and eggs rarely reached station 6. Catches at station 5 and 6 were rarely different indicating that, on the average, significant numbers of eggs did not reach station 6 via Back River. There were exceptions to this general rule, however, as indicated by the high catch of larvae at station 6 on 4 May (16.9/100 m^3), when few were caught in Front River at station 5 (0.6/100 m^3).

Any predictions of the effects of the tide gate on striped bass spawning should be prefaced with the comment that natural changes in the Savannah River channels have presumably occurred with regularity. However, the changes which will be caused by operation of the tide gate differ from possibly natural changes in 3 important ways: 1) striped bass eggs and larvae will be more likely to come in contact with industrial pollutants, 2) eggs and larvae will be more likely to encounter sudden changes in salinity, and 3) the flow pattern created by the tide gate will increase the flushing action of the tides in parts of both Back and Front Rivers which in turn may result in an increased downstream movement of eggs and larvae. It is, therefore, conceivable that eggs and larvae could reach waters of a higher salinity than they would normally encounter.

The effect on eggs and larvae if they encounter saline water is unclear. Albrecht (1964) reported better egg survival at salinities up to .9 ppt and poorer survival above 5 ppt. At higher temperatures, 18 to 22 C, salinities as low as 1 ppt may decrease survival, especially if the eggs are not water hardened in fresh water (Turner and Farley 1971). Downstream transport of eggs into waters of higher salinities apparently limited spawning success in the Potomac in 1974 (Polgar et al. 1976). Rees (1977) working with Savannah River striped bass, found no overall difference in hatching success of fry survival among groups of eggs hatched at salinities of 0, 1 and 3 ppt at 18.9 C. However, he found that eggs from particular females sometimes survived better at specific salinities. Lal, et al. (1977) found that striped bass fry survived better at salinities betwen 3.4 and 17 ppt, than in fresh water. They also found that eggs survived best at salinities of 3.4 ppt or less. The possible changes in salinity pattern and their potential effect on striped bass egg and larval survival in the Savannah River need further study.

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