Effect of the Savannah Tide Gate on Striped Bass Egg Distribution and Survival During 1977 and 1978

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Abstract: A comparison of striped bass, *Morone saxatilis,* egg abundance, distribution and survival during 2 years in the Savannah River estuary gave some indications of the possible effects of the Savannah River Tide Gate on the spawning success of this species. Eggs are more likely to be found farther upstream when the tide gate is in operation. Apparently striped bass respond to increased salinities by spawning farther upstream. By using egg stage as a measure of age, survivorship curves based on relative abundance of the different egg stages were calculated. While the 1977 data were of limited use for this purpose, the excellent fit of the 1978 data indicates that this technique could be used to advantage to estimate in-river egg survival rates. Adjusted mortality to hatching was 0.984 in 1977 and 0.999 in 1978.

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Striped bass spawn in the tidally-influenced reaches of the Savannah River 30 to 40 km upstream from the river's mouth (Dudley et al. 1977). A tide gate completed by the United States Army Corps of Engineers in 1976 altered river flow patterns in the estuary and may have adversely affected survival of striped bass eggs and larvae. Upon completion of the tide gate the Corps of Engineers agreed to keep

[1] Most of the field work for this project was carried out by Ken Black while he was working toward his master's degree at the School of Forest Resources of the University of Georgia. Shortly after his field work was completed Ken was beset by medical problems which prevented the completion of his degree. Ken died in the autumn of 1984 having had only a limited chance to show our professional world his abilities and ideas.

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it open during the striped bass spawning season at the request of the Georgia Department of Natural Resources. However, the effect it would have if left in operation was not well known.

During 1977, preliminary sampling revealed the distribution of striped bass eggs in the estuary when the gate was held open (Dudley and Black 1978). Subsequently, arrangements were made to leave the gate in operation during the 1978 spawning season to allow a comparison with the relatively natural situation of 1977. Collections from 1978 are compared to those reported by Dudley and Black (1978) for 1977 to more accurately investigate the potential effects of the tide gate on striped bass spawning.

Methods

The region of the Savannah River where striped bass spawn is composed of 3 channels (Fig. 1). The main channel, Front River, flows through the industrial part of Savannah, Georgia, and is dredged to a depth of 12 m. The other channels, Back River and Middle River, are meandering, flow through the Savannah National Wildlife Refuge, and are bordered by tidewater swamp, river marsh, and freshwater marsh environments. These channels are 1 to 3 m deep at mean low water.

The tide gate is located on the downstream section of Back River. On incoming tides the hydraulically operated gates are held open allowing water to move upstream. As the tide turns the gates are closed and the tidal water flows upstream, through the diversion canal, and downstream in Front River (Fig. 1). The purpose of the gate is to increase water velocity in Front River in order to decrease sedimentation.

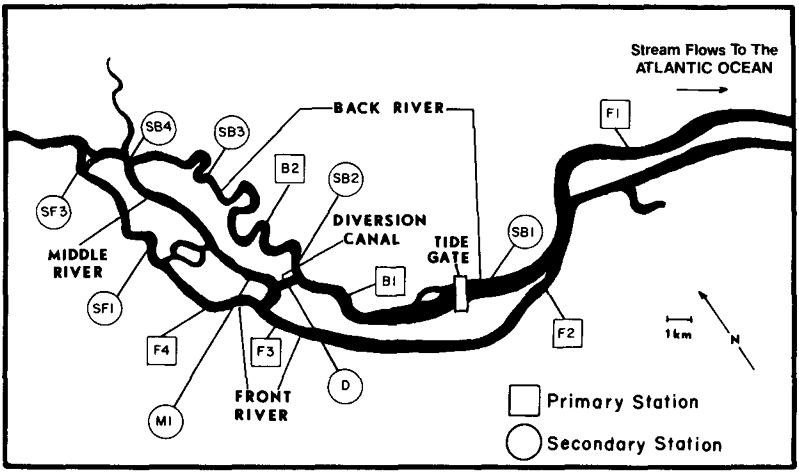

Figure 1. Map of the Savannah River estuary showing the major river channels and primary and supplemental sampling stations.

We established sampling stations throughout the Savannah River estuary. Our 6 primary sampling stations in Front River and Back River were identical to those used by Dudley and Black (1978). Supplemental (secondary) stations were established in Front and Back rivers and in the Diversion Canal (Fig. 1).

Our sampling procedure followed that of Dudley and Black (1978). A pair of 50-cm, 0.57-mm nylon mesh plankton nets mounted in a rectangular frame were towed for 15 minutes at a depth of 1 m. One of the nets utilized a flow meter to estimate the volume of water filtered.

We took samples on 40 of the 57 days between 28 March and 23 May in both 1977 and 1978. On most days, we sampled the 6 primary stations at least once. Additional tows were made at the primary stations and at supplemental stations when time and weather permitted.

The contents of each net were preserved in 5% formalin. Eggs and larvae of striped bass were later identified using criteria established by Lippson and Moran (1974). We determined the state of development of each egg using categories based on Bayless (1972) as follows: S0–eggs dead, S1–not more than 10 hours old, S2–10 to 19 hours old, S3–19 to 26 hours old, S4–25 to 33 hours old, S5–33 to 44 hours old These ages assume an incubation temperature of 18.9° C.

All egg and larval catches were subsequently converted to a per 100 cubic meter basis (100 m^3). Each net actually filtered between 85 and 150 m^3 (mean = 118 m^3).

After each tow we measured water temperature and specific conductance with a Hydrolab Surveyor. We also collected this water quality information at several stations during a full tidal cycle between 22 and 25 May 1978 with the tide gate operating and between 8 and 10 June with the gate held open. This allowed a reasonably accurate measurement of change in salinity due to gate operation.

In order to convert our specific conductance readings to salinity values, 21 water samples of differing conductance below 25×10^3 umhos cm^{-1} were collected. The salinity of each sample was determined with an induction salinometer and a linear regression of salinity versus specific conductance calculated. The resulting relationship (Salinity = 6.067×10^{-4} conductance - 0.1734) had an R^2 of 0.998.

We estimated the survival rate of eggs by using egg stage as a measure of age in hours, and fitting the data to a negative exponential survivorship curve of the form $N_t = N_0e^{zt}$. Although 18.9° C is quite close to river temperatures measured in 1977 and 1978, we also calculated survival rates adjusted for actual river temperature. In calculating survival rates we used data summarized by Bonn et al. (1976) to determine the age in hours of each egg stage at the weighted mean river temperature. Weighted temperatures were calculated by weighting each temperature (to the nearest degree) by the number of eggs found at that temperature. In 1977 the weighted river temperature was 20.0° C and in 1978 it was 19.9° C.

Table 1. Surface and bottom salinities (ppt) at high and low tide with tide gate operating and held open in 1978. The difference shown is the salinity with the gate in operation minus the salinity with the gate held open.

	High tide						Low Tide					
	Gate operating		Gate open		Difference		Gate operating		Gate open		Difference	
Station	S	B	S	B	S	B	S	B	S	B	S	B
B1	2.7	4.0	0.2	1.9	2.5	2.1	2.8	2.9	0.0	0.0	2.8	2.9
B2	0.8	0.8	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
F1	13.2	20.7	11.4	24.3	1.8	−3.6	1.6	4.8	5.0	19.3	−3.4	−14.5
F2	3.7	10.7	5.7	16.8	−2.0	−6.1	0.9	1.0	1.3	12.0	−0.4	−11.0
F3	0.9	1.0	0.0	0.0	0.9	1.0	0.0	0.9	0.0	0.0	0.0	0.9
F4	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0

Results

The change in flow pattern has caused changes in salinity within the estuary. Because saline water is trapped on the upstream side of the tide gate, salinity in Back River has increased with tide gate operation (Table 1). As the tide starts to drop the saline water moves upstream. Some of it reaches our station B2 (Fig. 1) prior to moving into Front River.

From 28 March through 23 May 1978 we collected 4,197 eggs and 14 larvae of striped bass in 464 paired samples. Our most upstream station (SF5) yielded only 3 eggs indicating that our stations adequately covered the river segment in which striped bass spawn. Eggs were never more abundant than 353 per 100 m^3.

During the 1978 spawning season water temperatures were relatively stable. This resulted in a peak of egg abundance in late March and early April followed by a constant lower level of egg numbers. We did not find peaks in egg abudance associated with peaks in water temperature like those found in 1977 (Fig. 2)

On 29 March 353 eggs per 100 m^3 were found in Back River (B2), but few eggs were found at other stations on that date. During 4 through 7 April we found eggs at every primary sampling station. The numbers of eggs collected per 100 m^3 ranged from about 60 in Middle River to 100 in upper Front River and over 200 in

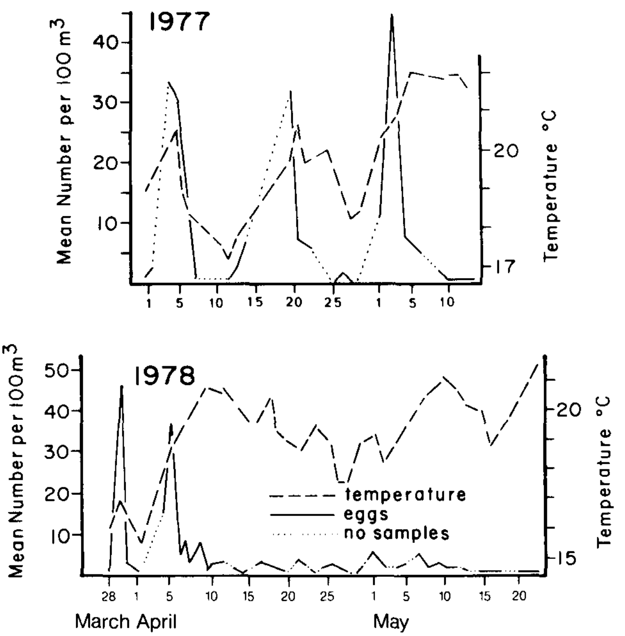

Figure 2. Water temperatures and mean number of eggs sampled per day in 1977 and 1978. Data from 1977 is the same as that presented in Dudley and Black (1978).

Table 2. Comparison of the mean number of eggs per 100 m collected each day at the 6 primary sampling stations within each year. The Wilcoxin rank test was used to indicate significant differences among stations ($P = 0.05$ in 1977 and 0.0001 in 1978). Underlining shows the results of pairwise tests between stations using an error rate of 0.05.

	1977					
Station	F3	B1	F2	F4	B2	F1
Mean Number of Eggs	7.6	15.5	3.1	5.0	16.8	1.5

	1978					
Station	F3	B2	F4	F2	F1	B1
Mean Number of Eggs	6.9	20.1	5.1	0.37	0.33	0.02

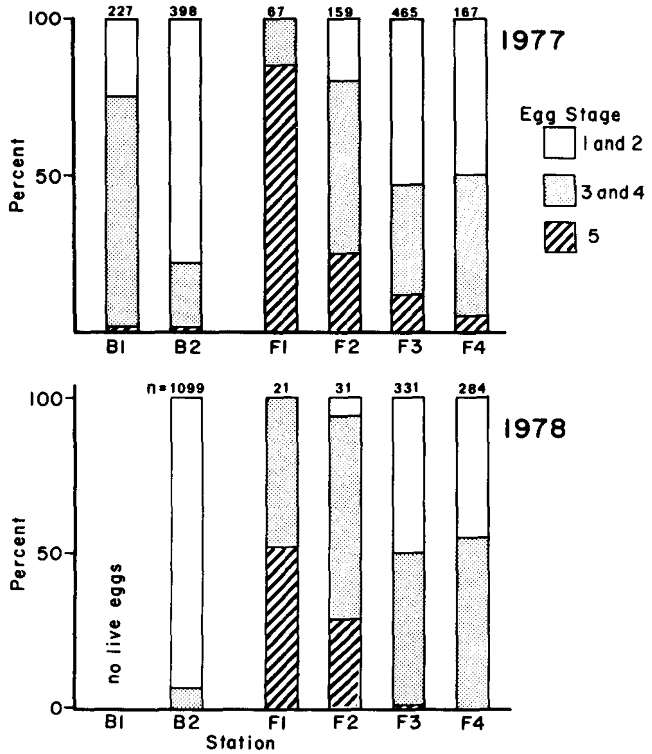

Figure 3. Proportion of eggs of different ages found at the 6 primary sampling stations during 1977 and 1978. Numbers at the top of each bar indicate the total number of eggs from that station for which age could be determined.

Table 3. Survival rates of striped bass eggs in the Savannah River estuary assuming water temperatures of 18.9° C and 20.0° C. Adjusted Z values were calculated using corresponding changes in the time needed to reach each egg stage at that temperature.

	Hourly Z	Hourly mortality	Daily mortality	Hours to hatching	Mortality prior to hatching
1977 data egg stages 3, 4, 5					
Assuming T = 18.9°	0.094	0.090	0.895	44	0.984
Adjusted T = 20.0°	0.103	0.098	0.916	40	0.984
1978 data					
Assuming T = 18.9°	0.159	0.147	0.978	44	0.999
Adjusted T = 20.0°	0.140	0.131	0.965	50	0.999

Back River. During the following 6 weeks egg numbers in only 9 samples exceeded 20 per 100 m^3. No eggs were found downstream from the tide gate in Back River (SB1) and only 2 were found between the tide gate and the Diversion Canal (B1).

Rank tests indicated that eggs were significantly more abundant at stations in upper Back River (B2) and upper Front River (F3 and F4) (Table 2). Eggs were also relatively abundant at supplemental stations in Front and Back rivers. Differences among the primary stations were more pronounced in 1978 than in 1977. During 1978 downstream stations F1 and F2 had significantly fewer eggs than upstream stations. This difference was not as pronounced in 1977. The distribution of eggs among stations differed significantly between the two years. This difference was due primarily to the decreased proportion of eggs caught at stations B1, F1, and F2 in 1978. A corresponding increase in egg abundance was found at station B2 in Back River (Table 2).

In both 1977 and 1978 older eggs were generally found at downstream stations (Fig. 3). However, in 1978 significantly fewer eggs were found at the downstream stations and fewer stage 5 eggs were found at all locations.

We were able to estimate the survival of eggs by comparing the relative abundance of the 5 developmental stages. Stage 1 eggs were apparently not sampled in proportion to their abundance and were not used in the calculations. The data for 1978 provided an excellent fit to the standard survivorship curve giving a daily mortality rate of 0.978 (Fig. 4, Table 3). Data from the 1977 samples did not provide as good a fit. Using 1977 relative abundance of stages 2 through 5 we calculated a daily mortality of 0.763 (Fig. 4). Since our sampling in 1977 missed the beginning of each of the 3 peaks in egg abundance (Dudley and Black 1978) we may not have adequately sampled egg stages 1 and 2. We therefore recalculated the survivorship for 1977 based only on data for egg stages 3, 4, and 5. This method gave a daily mortality rate of 0.895 (Table 3) although there was substantial variation among the 3 periods of egg abundance (Fig. 5).

Because water temperatures between the 2 years differed, we calculated survival rates adjusted for mean weighted water temperatures (Table 3). Estimated survival during 1977 was somewhat higher than during 1978 resulting in a theoreti-

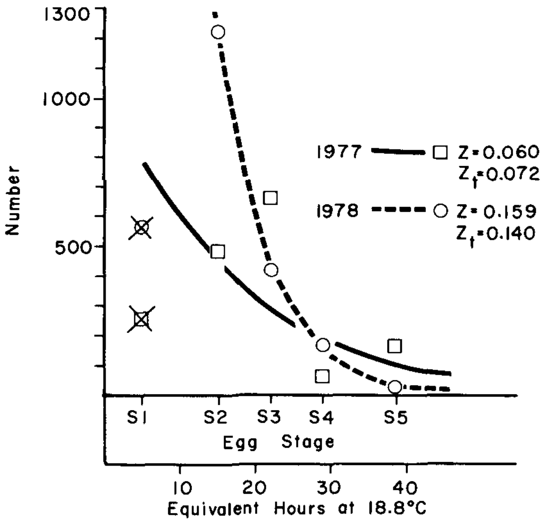

Figure 4. Survivorship curve for striped bass eggs collected in 1977 and 1978. Z refers to an instantaneous mortality rate calculated using adjusted ages. Revised values for 1977 are shown in Figure 5.

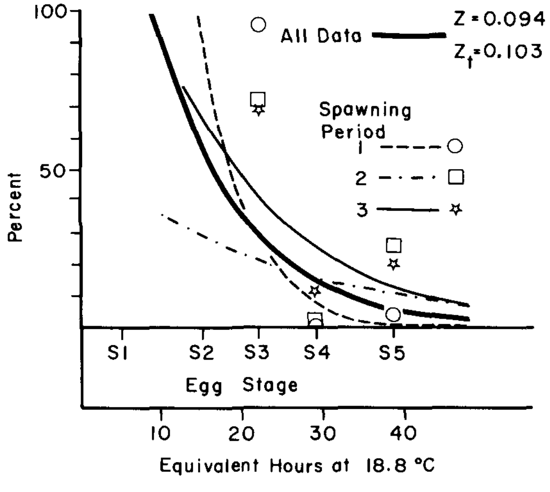

Figure 5. Revised survivorship curve for eggs collected in 1977 using only egg stages 3, 4, and 5.

cal sixteenfold improvement in survival through the last egg stage in 1977. Because many factors affect striped bass spawning and egg survival it is impossible to state that tide gate operations significantly affected striped bass survival, however, this technique of estimating egg survival may provide helpful information if used over several years.

Literature Cited

Bayless, J. D. 1972. Artificial propagation and hybridization of striped bass *Morone saxatilis*. S.C. Wildl. and Mar. Resour. Dep., Charleston. 135pp.

Bonn, E. W., W. M. Bailey, J. D. Bayless, K. E. Erickson, and R. E. Stevens, eds. 1976. Guidelines for striped bass culture. Am. Fish. Soc., South. Div. 103pp.

Dudley, R. G., A. W. Mullis and J. W. Terrell. 1977. Movements of adult striped bass (*Morone saxatilis*) in the Savannah River, Georgia. Trans. Am. Fish. Soc. 106:314–322.

——— and K. N. Black. 1978. Distribution of striped bass eggs and larvae in the Savannah River Estuary. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies. 32:561–570.

Lippson, A. J. and R. L. Moran. 1974. Annual for identification of early development stages of fishes of the Potomac River Estuary. Environ. Techn. Ctr., Martin Marietta Corp., Baltimore, Md. 282pp.