Occurrence and Distribution of Larval Fish in a Coastal Plain River System[1]

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Abstract: Twenty-two larval fish taxa were collected from Wee Tee Lake, a backwater tributary of Santee River, South Carolina, and 2 adjacent main river sites during the spring of 1981 and 1982. *Pomoxis* spp., *Alosa aestivalis, Dorosoma petenense, D. cepedianum,* and *Perca flavescens* were the most abundant species collected in both Wee Tee Lake and Santee River during both years. These species were significantly ($P < 0.05$) more abundant in the lake than in the river, indicating a better spawning habitat in the lake. *A. aestivalis* and *D. cepedianum* appeared to spawn concurrently and exhibited similar patterns of diel periodicity. *D. petenense* spawned later and exhibited a different diel pattern. Flood control operations in the Santee River prior to the detection of larvae in 1982 appeared to alter time and duration of spawning and reduce species diversity and abundance of larval fish.

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In 1938, the Santee-Cooper Project was initiated for the purpose of hydroelectric power generation and increased flood control in the coastal plain of South Carolina. Two impoundments, Lake Marion (40,500 ha) created by Wilson Dam on the Santee River and Lake Moultrie (27,000 ha) by Pinopolis Dam on the Cooper River, resulted from this project. The drop in elevation at Pinopolis Dam on the Cooper River was approximately 15 m greater than that on the Santee River at Wilson Dam. To take advantage of this elevation difference, a 12-km diversion canal was constructed between Lake Marion and Lake Moultrie. After completion of the project in 1942,

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annual average flow in the lower Cooper River increased from approximately 2 m^3/second to 442 m^3/second (U.S. Army Corps of Eng. 1975).

Increased silt load accompanied increased flow in the Cooper River and Charleston Harbor. Silt removal from the harbor had become so costly that a Santee-Cooper Rediversion Project was proposed. This project would redivert water from Lake Moultrie to the Santee River through a second canal. Rediversion, scheduled for completion in 1984, is projected to increase average daily flow in the lower Santee River to approximately 413 m^3/second (U.S. Army Corps of Eng. 1975). Flow after rediversion should be 80% of the original flow in Santee River (i.e. before diversion). Flow will also fluctuate with the operation of a peaking hydroelectric unit at the base of the rediversion canal.

Altered flow may affect abundance and distribution of fish in coastal river systems. This study was conducted to provide baseline information for the proposed rediversion project and examine the effects of flood spillage (discharge) on larval fish abundance and distribution.

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Methods

Abundance of larval fish was sampled at 3 sites in the Santee River system during the spring of 1981 and 1982. Two sample sites were located in Santee River, immediately upstream and downstream from the outlet of Wee Tee Lake. In this area, the Santee River is a broad (50 to 65 m) and shallow (1 to 3 m), slow-moving (15 m^3/second) river except during flood control discharges from Wilson Dam. The third sample site was located in Wee Tee Lake approximately 7 km above the outlet. Wee Tee Lake, fed by drainage from an extensive oak-cypress swamp, is a narrow (10 to 25 m) and shallow (1 to 10 m) backwater lake. Three sample stations were selected within each site; two samples were taken at each station.

Larval fish were collected with a 0.5 m diameter plankton net (0.526 mm mesh) mounted in an adjustable metal frame attached to the bow of a 4.3-m aluminum jon boat. The net was pushed just below the surface for 5 minutes at a constant speed of approximately 1 m/second. Constant speed was maintained using a Frahm vibration tachometer. A digital flowmeter

(General Oceanics Model 2030) was mounted within the rim to measure volume of water filtered (Marcy and Dahlberg 1980).

Sampling was conducted from approximately 1000 to 1600 hours for safety reasons and to minimize the effect of changing light intensity on larval distribution. No attempt was made to compare littoral and main channel areas due to numerous obstructions and the shallow nature of the 3 sites. Therefore, only the main channel of each site was sampled. All stations were sampled moving downstream. The order in which sites were sampled was randomly determined each week. An attempt was made to sample each site 4 times a week. Surface water temperature was measured at each site each day.

In 1981, 246 samples from Wee Tee Lake and 504 samples from Santee River were collected between 3 March and 13 May. During the 1982 sampling period (8 March to 1 May) 132 samples were collected from Wee Tee Lake and 272 from Santee River. Four more samples were collected from the upstream river site than from the downstream river site in 1982.

Larval fish samples were preserved and stored in 5% buffered formalin until larvae could be sorted. All fish were identified to the lowest practical taxon using keys by Mansueti and Hardy (1967), Lippson and Moran (1974), and Wang and Kernehan (1979). Identification of larval clupeids was based on myomere counts and diagnostic morphological characters described by Meador and Eversole (1982). A larval fish was defined as a fish with a visible yolk sac or fish whose yolk had been absorbed, but without a full complement of fin rays (Hubbs 1943).

Larval fish/sample was divided by volume of water filtered (m^3) and expressed as number of larvae/100 m^3 of water as a measure of abundance. Analysis of variance using the general linear model of SAS (Barr et al. 1979) was employed to compare abundances among sites and years. Student's *t*-tests were used for further comparisons of larval fish abundance when analysis of variance indicated significant differences ($P < 0.05$). Statistical tests were only run on those larval fish taxa with total abundance greater than 1.0 and the detection of individual differences among sites or years was only attempted when larvae of a particular taxon occurred in each (site or year).

Diel distribution of larval fish was determined during two 24-hour periods (144 samples) on 13 April and 5 May 1981. Samples were collected at 6-hour intervals, corresponding to dawn (0400–1000 hours), daytime (1000–1600 hours), dusk (1600–2200 hours), and night (2200–0400 hours). Catch data for both 24-hour periods were combined to yield a sample size large enough to permit analysis. Analysis of variance was used to detect significant differences ($P < 0.05$) in abundance between time intervals.

Results

Twelve taxa ($N = 7{,}369$) were collected in Wee Tee Lake and 19 taxa ($N = 15{,}318$) in Santee River in 1981 (Table 1). No significant differences

Table 1. List of taxa, total number (N), and abundance ($N/100m^3$) of larval fish collected in Wee Tee Lake and Santee River during 1981 (3 March to 13 May) and 1982 (8 March to 1 May).

Taxa	1981				1982			
	Wee Tee Lake		Santee River		Wee Tee Lake		Santee River	
	N	$N/100m^3$	N	$N/100m^3$	N	$N/100m^3$	N	$N/100m^3$
Brevoortia tyrannus			12,187	41.1[b]			2	<0.1
Alosa aestivalis	1,842	12.9[ab]	1,789	6.0[b]	327	4.2[a]	186	1.2
Dorosoma petenense	3,566	24.9[ab]	297	1.0[b]	51	0.7[a]	4	<0.1
Pomoxis spp.	710	4.9[ab]	39	0.1[b]	50	0.6[a]	2	<0.1
Dorosoma cepedianum	482	3.4[a]	12	<0.1	282	3.7[a]	4	<0.1
Perca flavescens	428	3.0[a]	44	0.1	76	1.0[a]	28	0.2
Morone spp.	1	<0.1	35	0.1[a]	1	<0.1	396	2.5[ab]
Gobiidae			349	1.2				
Lepomis spp.	267	1.9[a]	10	<0.1			1	<0.1
Catostomidae	7	<0.1	232	0.8[ab]			29	0.2
Alosa sapidissima			112	0.4	5	0.1	31	0.2
Menidia beryllina	58	0.4	71	0.2	1	<0.1	1	<0.1
Anguilla rostrata	1	<0.1	68	0.2	1	<0.1		
Cyprinidae	6	<0.1	35	0.1				
Esox niger					13	0.2		
Other[c]	1	<0.1	38	0.2	1	<0.1		
Total	7,369	51.5	15,318	51.5	808	10.5	684	4.4

[a] Significant difference ($P < 0.05$) between lake and river within year.
[b] Significant difference ($P < 0.05$) between years within lake or river.
[c] Species accounting for <0.1 ($N/100m^3$) in both areas in both years include: Belonidae, *Cottus* spp., *Elops saurus*, *Etheostoma* spp., *Micropterus salmoides*, *Mugil cephalus*, *Trinectes maculatus*.

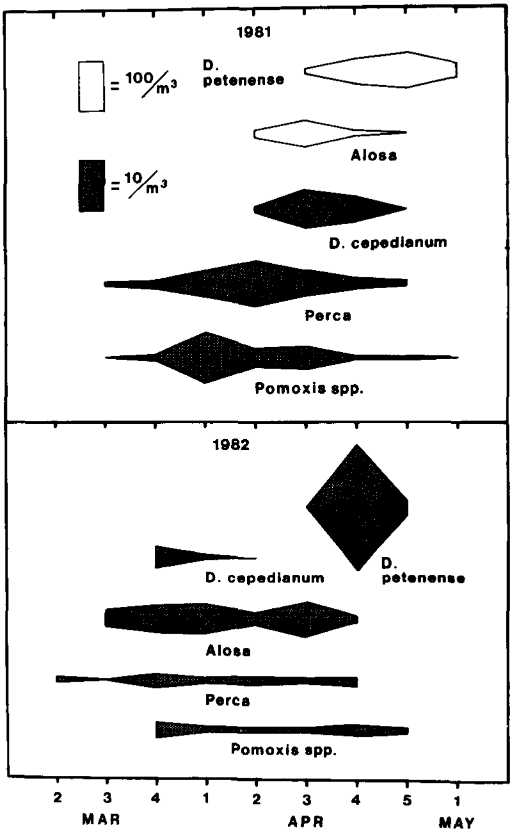

Figure 1. Abundance of the 5 most abundant larval fish in Wee Tee Lake by sample week in 1981 and 1982. Vertical scale is indicated by the height of the rectangles in the upper-left corner of the figure.

($P > 0.05$) were detected in total abundance between upstream and downstream river sites, therefore these data were combined. Total abundances in the river and lake were identical, although densities for particular taxa differed significantly.

Larval *Brevoortia tyrannus,* the most abundant species collected, were only collected in Santee River samples (Table 1). *Dorosoma petenense,* second in abundance, were collected both in river and lake samples. Abundance of *D. petenense, D. cepedianum, Alosa aestivalis, Perca flavescens, Pomoxis* spp., and *Lepomis* spp. in 1981 was significantly greater ($P < 0.05$) in the lake than in the river, while abundance of *Morone* spp. and catostomids was significantly greater ($P < 0.05$) in the river.

Although salinity in the area of the Santee River sampled (river km 62) was low (<1 g/liter), some tidal influence was observed. On 5 May 1981 a spring tide increased water levels in the river by approximately 1 m. *Elops saurus* and gobiids were collected only at this time.

In 1982, no statistical difference was detected in total abundance be-

Table 2. Mean number of larvae/100m^3 of 5 most abundant taxa in Wee Tee Lake during 2 24-hour sampling periods (48 samples) in 1981.

	Time intervals			
Taxa	Dawn (0400–1000 hours)	Daytime (1000–1600 hours)	Dusk (1600–2200 hours)	Night (2200–0400 hours)
Pomoxis spp.	25.3AB[a]	1.6A	3.8A	35.9B
Perca flavescens	4.1A	3.4A	2.6A	5.1A
Alosa aestivalis	64.6A	16.3B	13.5B	32.2B
Dorosoma cepedianum	28.4A	0.3B	2.7B	11.9B
Dorosoma petenense	55.9A	8.4A	25.7A	155.4B

[a] Values followed by the same letter are not significantly different ($P > 0.05$).

tween river sites so the data were combined as in 1981 (Table 1). A total of 11 taxa ($N = 808$) was collected in Wee Tee Lake and 11 taxa ($N = 684$) in the river. Total abundance in the lake was approximately 2.5 times that of the river.

A. aestivalis and *Morone* spp. were the most abundant taxa in 1982 in lake and river samples, respectively. As in 1981 abundances of *D. petenense, D. cepedianum, A. aestivalis, P. flavescens,* and *Pomoxis* spp. were significantly greater ($P < 0.05$) in the lake than in the river. In 1982 the catch of *Morone* spp. in the river was again significantly greater ($P < 0.05$) than in the lake.

Fifteen of 19 taxa collected in the river and 9 of 15 taxa in the lake were more frequently encountered in 1981 than 1982. Eight taxa were significantly ($P < 0.05$) more abundant in 1981 than 1982. *Morone* spp. was the only taxon with significantly greater abundance in 1982 (Table 1).

Temporal distribution of the 5 most abundant taxa in Wee Tee Lake is presented in Fig. 1 and Table 2. Similar results based on lower abundances of these taxa were obtained for Santee River. Abundances were greatest at dawn (0400–1000 hours) for *A. aestivalis* and *D. cepedianum* and the greatest at night (2200–0400 hours) for *D. petenense* (Table 2). *Pomoxis* spp. were significantly more abundant ($P < 0.05$) at dawn and night than daytime (1000–1600 hours) or dusk (1600–2200 hours). Abundances of *Pomoxis* spp. at dawn and night were not significantly different ($P > 0.05$). No significant difference ($P > 0.05$) was detected in the abundance of *P. flavescens* over a 24-hour period.

A. aestivalis and *D. cepedianum* appeared 2 and 3 weeks earlier in 1982 than in 1981 (Fig. 1). *D. petenense,* which appeared at similar times in both years, were not collected until after peak abundance of *A. aestivalis* and *D. cepedianum. Pomoxis* spp. exhibited similar diel patterns to *D. petenense* (Table 2), but appeared to spawn much earlier.

Discussion

Faber (1967) observed that even though larval fish abundance can be quite variable, particular species remain dominant from year to year. *Morone* spp., *Pomoxis* spp., *A. aestivalis, D. petenense, D. cepedianum,* and *P. flavescens* were the most abundant taxa at the surface at all 3 sample sites in the Santee River system. All of these taxa except *Morone* spp. were more abundant in Wee Tee Lake than in the Santee River. Tributaries and backwater areas such as Wee Tee Lake appear to meet the spawning habitat requirements of these species (Scott and Crossman 1973, Pfleiger 1975, Collette et al. 1977, Rulifson et al. 1982) while the main channel of the river appears more suited for *Morone* spp. (Rulifson et al. 1982).

B. tyrannus spawn in the ocean and move into estuaries as larvae. Wilkens and Lewis (1971) reported that larval *B. tyrannus* transform into juveniles in brackish water areas (0.0 to 1 g/liter, salinity). In the Santee River during periods of low rainfall and no flood control discharges, as in 1981, this brackish mixing zone may appear as far upstream as river km 62 (location of river sampling sites). *B. tyrannus* was the most abundant species collected in this area of the river in 1981. Greater abundance of *B. tyrannus* and presence of other euryhaline species in 1981 were the major species differences between the river and Wee Tee Lake. In 1982, *B. tyrannus* was the only euryhaline species collected in this area of the river and abundance was considerably less than in 1981. With rediversion, this low salinity zone (0.0 to 1 g/liter) is expected to occur near the mouth of the Santee River (Kjerfve 1976). It is unclear from the present study what effect change in location of this zone will have on the population of *B. tyrannus* in this river system.

Water levels and temperatures are considered to be very important in determining time of spawning (Rawson 1945, Hassler 1970, Hynes 1970). When water levels in Lake Marion are high, excess water is released into Santee River through flood control gates. During 1981, flood gates remained closed and discharge was constant at 14.5 m^3/sec. In 1982, discharge into Santee River averaged 323.3 m^3/sec from 4 January until 15 March when flood control operations were discontinued (Barry Inabinette, S.C. Public Service Authority, pers. commun.). This discharge increased water levels approximately 1 to 2 m until 17 March 1982 when water levels returned to the 1981 levels. Discharge was constant at 14.5 m^3/sec from 16 March to 1 May 1982 (same as in 1981) when sampling was terminated. Walberg and Nelson (1966) reported that rising water levels enhance spawning of some species, but greater larval abundance was not observed for 5 of the 6 dominant taxa collected in 1982. These 5 taxa spawn in the shallows (Scott and Crossman 1973, Pfleiger 1975) and are probably affected more by fluctuating water levels than *Morone* spp., the only taxon found more abundant in 1982.

Surface water temperatures in the river ranged from 13.0° to 22.5° C in 1981 and 11.0° to 20.0° C in 1982. A rapid increase in temperature occurred shortly after flood control discharges were discontinued in 1982. This appeared to have triggered the spawning of *A. aestivalis, P. flavescens* and *D. cepedianum* which occurred earlier in 1982 than in 1981.

Increased discharge as a result of altered flow from rediversion is expected to expand tributaries and backwater areas along Santee River, increasing spawning and nursery habitat (U.S. Army Corps of Eng. 1975). Increased larval fish production should result. However, fluctuating discharges created by operation of the peaking hydroelectric unit on the rediversion canal and the associated changes in water temperature may alter time and duration of spawning, species composition, and abudance of larval fish in the Santee River system. Additional research on larval fish distribution, particularly under conditions of varying flow, will help to predict impacts of ecosystem alteration projects and aid in proposing cautionary steps or mitigative measures before such projects are approved.

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