DISTRIBUTION OF SPAWNING BLUEBACK HERRING ON THE WEST BRANCH OF COOPER RIVER AND THE SANTEE RIVER, SOUTH CAROLINA

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Abstract: The distribution of spawning blueback herring was determined on the West Branch of Cooper River and on the Santee River, South Carolina. On the West Branch of Cooper River, the main river channel and abandoned ricefields were utilized for spawning. The use of tributaries for spawning was limited. On the Santee River, the main river channel and tributaries were utilized for spawning. Ranges for selected physical and chemical water quality characteristics associated with the distribution of spawning blueback herring were determined from 9 Cooper River and 15 Santee River sampling stations during the herring run. Those ranges were: surface water temperature, 11 - 20 C; dissolved oxygen, 6 - 11 mg/l; dissolved carbon dioxide, 5 - 25 mg/l; pH, 6.0 - 7.5; and depth, 0.4 - 3.1 m.

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The blueback herring (*Alosa aestivalis*) is an anadromous clupeid ranging from St. Johns River, Florida, to Cape Breton, Nova Scotia (Hildebrand and Schroeder 1928, Bigelow and Schroeder 1953). The life history and taxonomic description of blueback herring has been previously reported by Bigelow and Schroeder (1953), Davis and Cheek (1966), Godwin and Adams (1969), Loesch (1969), Street (1970) and Scherer (1972).

Blueback herring, one of the most numerous and most important anadromous fish species to enter South Carolina waters, support both a commercial and live-bait fishery in the Santee and Cooper Rivers, South Carolina. Commercially harvested blueback herring are used as bait in crab (*Callinectes sapidus*), eel (*Anguilla rostrata*), and catfish (*Ictalurus* spp.) traps. Live herring are used by sport fisherman to catch striped bass (*Morone saxatilis*), which prey on blueback herring in the Santee-Cooper system (Stevens 1961, Curtis 1977, Bulak and Christie 1980).

Since the completion of the Santee-Cooper lakes in 1941, the West Branch of the Cooper River, with its strong flow, has become an important spawning area for blueback herring. Bulak and Curtis (1977) found that while blueback herring spawned along the entire West Branch of Cooper River, the majority of the spawning occurred on the upper end of the West Branch. They found evidence to indicate herring utilized abandoned ricefields and tributaries of the West Branch of Cooper River as spawning areas, but the extent of the use of those areas was not determined. The Santee River has been only moderately successful in attracting

blueback herring, possibly because of the low flow rate (Curtis 1977). Bulak and Curtis (1977) found that while blueback herring spawned throughout much of the Santee River, the majority of spawning occurred near Weetee Branch (river km 72). Sampling data indicated herring spawned in tributaries of the Santee, but the degree of utilization was not determined.

To predict effects of alterations in spawning habitat resulting from future environmental changes, the present spawning areas of blueback herring in the Santee and Cooper Rivers needed to be identified. The collection of certain water quality characteristics would help define blueback herring spawning habitat. Specific objectives of this study were to 1) determine the geographical distribution of spawning blueback herring on the West Branch of Cooper River and the Santee River, South Carolina, 2) identify blueback herring spawning habitat by capture of herring eggs and larvae, and 3) determine certain water quality characteristics associated with the distribution of spawning blueback herring in the study area.

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METHODS

The West Branch of Cooper River originates at the tailrace of Lake Moultrie (Pinopolis Dam) and terminates at its confluence with the East Branch of Cooper River, 47 km from the Atlantic Ocean. River depths range from 1 - 20 m and widths vary from 91 - 304 m. The mean monthly discharge, during the study period, was 569,000 l/s. The West Branch is bordered by approximately 2,430 ha of abandoned ricefields (U. S. Army Corps of Engineers 1975). These ricefields are highly productive, shallow, lentic habitats, and support a variety of wildlife (Bulak and Curtis 1977). Two main tributaries, Wadboo Creek and Molly Branch, converge with the West Branch. These tributaries and many secondary tributaries drain extensive hardwood swamp areas.

The Santee River drainage from Lake Mattassee to Wambaw Creek courses through extensive cypress-oak swamplands. The main river channel depths range from 1 - 7 m and widths vary from 50 - 91 m. Monthly discharge averaged 123,500 l/s during the study period. Bottom substrate consists mainly of sand and silt, with submerged stumps and rock outcrops. The Santee River divides into 2 channels, the North Santee and South Santee Rivers, about 24 km from the Atlantic Ocean. Eleven major tributaries converge with the Santee River in the study area. Many of the tributaries drain heavily logged swamps and often carry a large silt load. These tributaries are shallow and water flow is often obstructed by fallen trees.

The geographical distribution of spawning blueback herring on the West Branch of Cooper River and the Santee River was determined by fishing various length gill nets (3.18-cm bar mesh, 1.8 m deep) from early February through late May 1978.

Gill netting was conducted at least once during the peak of the herring run at 30 Cooper River and 31 Santee River stations. Fishing locations included ricefields, tributaries, and the main channel of the West Branch of Cooper River as well as tributaries and the main channel of the Santee River. Nets, set overnight for a 14 - 18-hour period, were fished the entire tributary width. Main channel locations were fished on both rivers using drift gill nets. Nets were randomly placed in ricefields. Gill netting was discontinued at a sampling station when adult herring were captured.

To identify spawning habitat, 0.5-m plankton nets (0.5-mm mesh, 1.8 m long) were anchored and fished at gill netting sites. In areas of minimal flow, nets were towed for a distance of 10 - 20 m. Additionally, substrate and submerged vegetation were routinely examined for the presence of attached herring eggs. Captured eggs and larval fish were preserved in 5% buffered formalin and later identified.

Water quality measurements were recorded weekly at 6 Cooper River and 9 Santee River gill net locations from 13 February through 16 May 1978. On Cooper River, 2 ricefield stations adjacent to the main channel and 4 tributary stations located on Wadboo Creek were sampled. On the Santee River, water quality measurements were recorded at 4 stations on each of 2 tributaries, Wambaw Creek and Weetee Branch, and 1 main channel station. Water quality characteristics measured were surface water temperature (C), dissolved oxygen (mg/l), dissolved carbon dioxide (mg/l), pH, and depth. Also, surface water temperature (C), dissolved oxygen (mg/l), dissolved carbon dioxide (mg/l) and pH were recorded at 38 of the 46 remaining gill net stations at least once during the peak of the spawning season. A 2-tailed T-test was used to determine if statistically significant differences existed between the means of each of the water quality characteristics measured at stations where herring were and were not captured. All statistical tests were performed at the 0.05 significance level.

RESULTS

Adult blueback herring were captured from 1 March through 16 May 1978 at 56.7% (17 of 30) of the gill net stations on the West Branch of Cooper River (Table 1). Adult herring were caught at all 5 of the West Branch main channel stations located between Pinopolis Dam and the confluence of the East Branch and in all 8 abandoned ricefields sampled. The utilization of tributaries by adult herring was limited. Herring were captured in 4 of 10 tributaries and at 23.5% (4 of 17) of the tributary gill net stations. Adult herring captured in tributaries were always caught at stations within 2 km of the main channel. On the Santee River, adult herring were captured from 16 February through 26 April 1978 at 54.2% (14 of 31) of the gill net stations (Table 1). Herring were captured at both main channel sampling stations and 40.0% (12 of 30) of the tributary gill net stations. Adult herring were caught in 9 tributaries on the Santee. Most of the sampling stations where herring were captured were within 0.3 km of the main channel, but herring were captured 5 km from the main channel in Weetee Branch and 12 km from the main channel in Wambaw Creek.

Blueback herring eggs were captured only at stations where adult herring had been caught. On the West Branch, eggs were captured at 26.7% (8 of 30) of the sampling stations. Herring eggs were captured in the 0.5-m plankton net at 1

Table 1. Distribution of blueback herring adults, eggs, and larvae captured on the West Branch of Cooper River and the Santee River, South Carolina, during the 1978 spawning run. X indicates presence of adults, eggs, or larvae.

Station (Code)	Adults	Eggs	Larvae
Cooper River			
Tailrace Canal (C-1)	X		
Tailrace Canal (C-2)	X	X	X
Biggin Creek (C-3)	X	X	X
Wadboo Creek (C-4)	X	X	X
Cooper River (C-5)	X		
Berkeley Country Club (C-6)	X		X
Cooper River (C-8)	X		
Wappola Swamp (C-9)	X		X
Mepkin Ricefield (C-11)	X	X	X
Pimlico Ricefield (C-12)	X		X
Durham Creek (C-14)	X		X
Ricehope Ricefield (C-15)	X	X	X
Tee's Ricefield (C-16)	X		X
Cooper River (C-17)	X		X
Mulberry Ricefield (MRF-1)	X	X	X
Mulberry Ricefield (MRF-2)	X	X	X
Wadboo Creek (WC-4)	X	X	X
Santee River			
Lake Mattassee (S-1)	X		
Wedboo Creek (S-3)	X		
Weetee Lake (S-5)	X	X	X
Weetee Lake (S-6)	X		X
Fairy Lake (S-7)			X
Savanna Creek (S-8)	X		
Echaw Creek (S-13)	X	X	X
Chicken Creek (S-15)	X		
South Santee River (S-19)	X		X
Wadmacon Creek (S-20)	X	X	X
Wadmacon Creek (S-21)	X	X	X
Santee River (STR-1)	X	X	X
Weetee Branch (WTB-4)	X	X	X
Weetee Branch (WTB-3)	X	X	X
Wambaw Creek (WBC-3)	X		

tributary station, and eggs were collected from aquatic vegetation at 1 main channel location, 4 ricefield sampling stations, and 2 tributary stations (Table 1). Except for the eggs captured in the plankton net, eggs were only found attached to rooted aquatic vegetation near shore. On the Santee River, herring eggs were collected from one of the main channel stations and 20.0% of the tributary stations sampled. Eggs were found attached to decaying leaves in Weetee Branch, and on exposed filamentous algae in Wadmacon Creek.

Blueback herring larvae, in all cases but one, were captured at sampling stations where adult herring had been caught. On the West Branch, blueback herring larvae were captured at 46.7% (14 of 30) of the gill net stations (Table 1). Larvae were collected at 2 of the main channel locations, all of the ricefield locations and 4 of the tributary locations. Herring larvae were captured from both of the main channel sampling stations and 26.7% (8 of 30) of the tributary stations on the Santee (Table 1). Larval herring were captured at Fairy Lake, but adults were not.

The ranges of water quality parameters measured weekly throughout the sample period at the 6 Cooper River stations were: surface water temperature, 4 - 20 C; dissolved oxygen, 3 - 11 mg/l; dissolved carbon dioxide, 5 - 30 mg/l; pH 5.0 - 7.5; and depth 0.4 - 3.1 m (Table 2). Ranges of water quality values measured on the Santee River at 9 gill net stations were: surface water temperature, 1 - 22 C; dissolved oxygen, 6 - 12 mg/l; dissolved carbon dioxide, 5 - 35 mg/l; pH, 5.0 - 7.0; and depth 0.4 - 2.6 m.

Adults, eggs, or larval herring were captured at 9 of 22 Cooper River gill net stations where water quality was measured at least once during the peak of the herring run. The ranges of water quality values measured at the 9 stations where herring were captured were: surface water temperature, 11 - 18 C ($\overline{X}$ = 14.4); dissolved oxygen, 6 - 11 mg/l ($\overline{X}$ = 8.2); dissolved carbon dioxide, 10 - 20 mg/l ($\overline{X}$ = 10.5); and pH, 6.5 - 7.5 ($\overline{X}$ = 7.2). Ranges of water quality values recorded from 13 Cooper River gill net stations where herring were not captured were: surface water temperature 7 - 15 C ($\overline{X}$ = 11.2); dissolved oxygen, 3 - 10 mg/l ($\overline{X}$ = 7.0); dissolved carbon dioxide, 5 - 30 mg/l ($\overline{X}$ = 15.3), and pH, 5.0 - 7.5 ($\overline{X}$ =6.3). The means of the variables surface water temperature, dissolved carbon dioxide, and pH from stations where herring were captured were found to be significantly different than mean values of those variables from stations were herring were not captured. No significant difference was found between the mean concentration of dissolved oxygen measured at stations where herring were and were not captured.

On the Santee River, adults, eggs or larval herring were caught at 15 of 31 stations where water quality measurements were recorded at least once during the spawning peak. The water quality ranges from stations where herring were captured were: surface water temperature, 14 - 20 C ($\overline{X}$ = 15.5); dissolved oxygen, 6 - 11 mg/l ($\overline{X}$ = 8.7); dissolved carbon dioxide, 5 - 25 mg/l ($\overline{X}$ = 12.4); and pH 6.0 - 7.5 ($\overline{X}$ = 6.7). Those ranges recorded at 16 stations where herring were not captured were: surface water temperature, 13 - 22 C ($\overline{X}$ = 16.8); dissolved oxygen, 6 - 11 mg/l ($\overline{X}$ = 8.9); dissolved carbon dioxide, 5 - 35 mg/l ($\overline{X}$ = 19.3); and pH, 4.5 - 7.0 ($\overline{X}$ = 5.9). The mean values of the variables dissolved carbon dioxide and pH from stations where herring were caught were statistically different than the mean values of those variables from stations where herring were not caught. No significant differences were found between the mean value of surface water temperature or dissolved oxygen at stations where herring were and were not caught.

Water quality was also determined at 3 spawning sites on the West Branch of Cooper River. Spawning was observed at those sites and verified by the collection of herring eggs. At sites where spawning was observed, the water quality ranges were: surface water temperature, 15 - 17 C; dissolved oxygen, 7 - 10 mg/l; dissolved carbon dioxide, 10 mg/l; pH, 7.0; depth, 0.8 - 1.0 m. Spawning occurred over dense aquatic vegetation (*Egeria densa* and *Jussiaea diffusa*) in all instances. No spawning was observed on the Santee River.

Table 2. Ranges of weekly water quality characteristics measured at 6 Cooper and 9 Santee River, South Carolina, gill net stations and the number of herring captured at each station from 13 February - 16 May 1978.

Station (Code)	Surface Water Temperature (C)	Dissolved Oxygen (mg/l)	Dissolved Carbon Dioxide (mg/l)	pH	Water Depth (m)	Number of Herring Captured
Cooper River						
Wadboo Creek (WC-1)	6-15(18)[a]	3- 8	15-30	5.0-6.0	0.4-0.5	0
Wadboo Creek (WC-2)	6-16(18)	4- 9	10-20	6.5-7.5	0.6-0.7	0
Wadboo Creek (WC-3)	5-15(18)	4-10	10-20	7.0-7.5	0.7-1.0	0
Wadboo Creek (WC-4)	4-16(20)	6-11	10-20	6.5-7.5	1.2-3.1	81
Mulberry Ricefield (MRF-1)	5-20(20)	8-11	5-20	7.0-7.5	0.8-2.4	152
Mulberry Ricefield (MRF-2)	5-19(20)	8-11	5-20	7.0-7.5	1.3-2.8	225
Santee River						
Weetee Branch (WTB-1)	2-10(9)	6-12	10-25	5.5-6.0	0.5-0.6	0
Weetee Branch (WTB-2)	2-18(12)	8-12	10-20	5.5-6.0	0.4-0.8	0
Weetee Branch (WTB-3)	3-18(12)	6-10	5-20	6.5-7.0	0.5-0.7	22
Weetee Branch (WTB-4)	3-20(12)	8-11	5-20	6.5-7.0	1.1-1.5	126
Wambaw Creek (WBC-1)	1-22(9)	6-11	10-35	5.0-6.0	0.5-0.6	0
Wambaw Creek (WBC-2)	1-18(10)	7-11	15-30	6.0-7.0	0.4-0.6	0
Wambaw Creek (WBC-3)	3-18(10)	7-10	10-25	6.5-7.0	1.3-2.1	2
Wambaw Creek (WBC-4)	3-20(12)	8-10	10-15	6.5-7.0	1.8-2.6	0
Santee River (STR-1)	3-18(12)	8-10	5-10	6.5-7.0	1.3-1.6	114

[a] Number in parentheses indicates number of measurements recorded at each station.

DISCUSSION

The importance of abandoned ricefields and tributaries on the West Branch of Cooper River, and tributaries on the Santee River, to spawning blueback herring, have not been investigated previously. In southern coastal rivers, blueback herring have utilized river channels, tributaries and swamp drainages for spawning (Adams and Street 1969, Frankensteen 1976).

On the West Branch of Cooper River, adult blueback herring were captured in the main channel, abandoned ricefields and tributary mouths. This distribution was expected because of the large numbers of herring that annually enter Cooper River during spawning migrations. Spawning habitat, as determined by the collection of herring eggs and larvae, was confined to those areas where adult herring were captured. The main channel, with favorable water quality and shallow, vegetated shorelines, had been identified previously as spawning habitat (Bulak and Curtis 1977). Abandoned ricefields were also utilized for spawning. Compared to the main channel, the shallow, vegetated ricefields generally had warmer water temperatures and as favorable or more favorable water chemistry. Ricefields, because of their large area (2,430 ha) and favorable water quality, appeared to be primary spawning areas for blueback herring on the West Branch. The utilization of tributaries by spawning blueback herring was limited to within a short distance of the tributary mouth. No herring were captured in a tributary further than 2 km from the main channel. This finding may have been due to the unfavorable water quality associated with the tributary drainages. The water quality associated with tributary drainages of the West Branch generally had lower surface water temperature, lower pH, and higher dissolved carbon dioxide than the main channel. These water quality characteristics generally became more unfavorable as the distance from the main channel increased. Collins (1952) observed selective behavior when herring were offered a choice of water temperatures, dissolved carbon dioxide, and pH in 2 branches of a Massachusetts tributary. He found that 77% of the herring chose the warmer branch when the temperature difference between the branches was 0.5 C or greater. Also, 72% of the herring chose the branch with lower dissolved carbon dioxide when there was a difference exceeding 0.3 mg/l. No preference was shown when pH was varied 0.8 pH units from 6.5 to 7.3.

The water quality values associated with the distribution of spawning blueback herring on the West Branch of Cooper River were: surface water temperature, 11 - 18 C; dissolved oxygen, 6 - 11 mg/l; dissolved carbon dioxide, 10 - 20 mg/l; and pH, 6.5 - 7.5. These values compared favorably with previously documented findings (Frankensteen 1976, O'Dell et al. 1976, Johnson et al. 1978). Water temperature, dissolved carbon dioxide, and pH seemed to be important water quality characteristics determining spawning habitat on Cooper River.

On the Santee River, adult blueback herring were captured in the main channel and in tributaries. Their occurrence in the main channel was expected because of the annual herring spawning migrations (Bulak and Curtis 1977). Spawning habitat, identified by the capture of eggs and larval herring, was restricted in all cases but one, to those areas where adults were captured. In 1 instance (Fairy Lake S-7) larval herring were captured when adults were not. Spawning at the Fairy Lake stations probably occurred several days before gill netting was conducted. Tributaries of the Santee were used more extensively for spawning by blueback herring

than tributaries of the West Branch of Cooper River. Eggs and larval herring were captured in Weetee Branch, Weetee Lake, Echaw Creek and Wadmacon Creek. The reason blueback herring utilized tributaries more extensively for spawning on Santee River than on Cooper River may have been because the tributaries provided spawning habitat similar to the habitat found in the main channel. The main channel and tributaries had stump and debris littered shorelines with limited aquatic vegetation growth. Unlike Cooper River, water quality in tributaries on the Santee was more similar to water quality in the main channel and became unfavorable only near the tributary headwaters. Adults, eggs, or larval herring were never captured at stations located near tributary headwaters, but were caught at many downstream locations.

The water quality characteristics associated with habitat utilized by spawning blueback herring on the Santee River were: surface water temperature, 14 - 22 C; dissolved oxygen, 6 - 11 mg/l; dissolved carbon dioxide, 5 - 25 mg/l; and pH, 6.0 - 7.5. These values compared favorably with those values recorded from the Cooper River. Dissolved carbon dioxide and pH may have been particularly important in defining spawning area.

In this study adult blueback herring were never captured at a sampling station where dissolved oxygen was less than 6 mg/l, dissolved carbon dioxide greater than 25 mg/l, or pH less than 6.0 or greater than 7.5. These limited ranges of dissolved oxygen, dissolved carbon dioxide, and pH, measured during the peak of the herring run at stations where herring were captured, and at 3 observed spawning sites, may indicate that spawning habitat was restricted with respect to those parameters.

The results of this study have delineated the distribution of blueback herring on the West Branch of Cooper River and the Santee River, South Carolina, during the 1978 spawning run. Those areas utilized for spawning are important for the maintenance of blueback herring populations and should be protected from unnatural change. Water quality ranges from selected characteristics associated with the adult spawning distribution and spawning habitat on the Santee and Cooper Rivers were established. Further studies should be encouraged to determine which, if any, of the water quality parameters studied are most important in delineating blueback herring distribution.

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