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A STUDY OF RIVER HERRING SPAWNING AND WATER QUALITY IN CHOWAN RIVER, N.C.

by

C. W. O'Rear

Department of Biology

East Carolina University

Greenville, N.C. 27834

July 1983

Completion Report for Project AFC-17

This project was conducted under the Anadramous Fish Conservation Act (PL 89-304) and funded, in part, by the U.S. Department of Commerce, National Marine Fisheries Service.

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INTRODUCTION

The commercial catch of river herring (Alewife, *Alosa pseudoharengus*, Blueback Herring, *Alosa aestivalis*) in North Carolina has declined from approximately 11 million pounds in 1972 to 4 million pounds in 1981 (North Carolina Division of Marine Fisheries data). Approximately 76% of this catch is from the Chowan River pound net fishery.

The Chowan River system has experienced major blooms of nuisance algae and water quality changes that are symptomatic of advanced eutrophication since about 1970. These water quality changes are suspected of causing declines in the river herring fishery (N.C.N.R.C.D. 1982).

This river, a tributary of Albemarle Sound, is bordered by extensive swamps extending into the lower reaches of its tributaries. Two major tributaries, Wiccacon and Meherrin Rivers, enter the Chowan from the west. The east side of the river has several tributaries, the largest being Bennetts Creek. The swamps bordering the river and the lower reaches of the tributaries have a mean elevation of approximately 1.5 m and are subject to periodic flooding. These swamps are usually inundated during the summer because of wind tides. The swamps bordering the tributaries that have an altitude of more than 1.5 m are usually inundated during the late winter and spring (Daniel 1977; Giese *et al.* 1979).

The entire Chowan River system in North Carolina is considered a river herring spawning and nursery area based on studies conducted by the North Carolina Division of Marine Fisheries (NCDMF). However, the distribution of planktonic and nektonic river herring larva (5-25 mm) within the Chowan River system has not been adequately defined. A major objective of this study is to obtain quantative information on the distribution of planktonic larvae (5-15 mm) within the Chowan system.

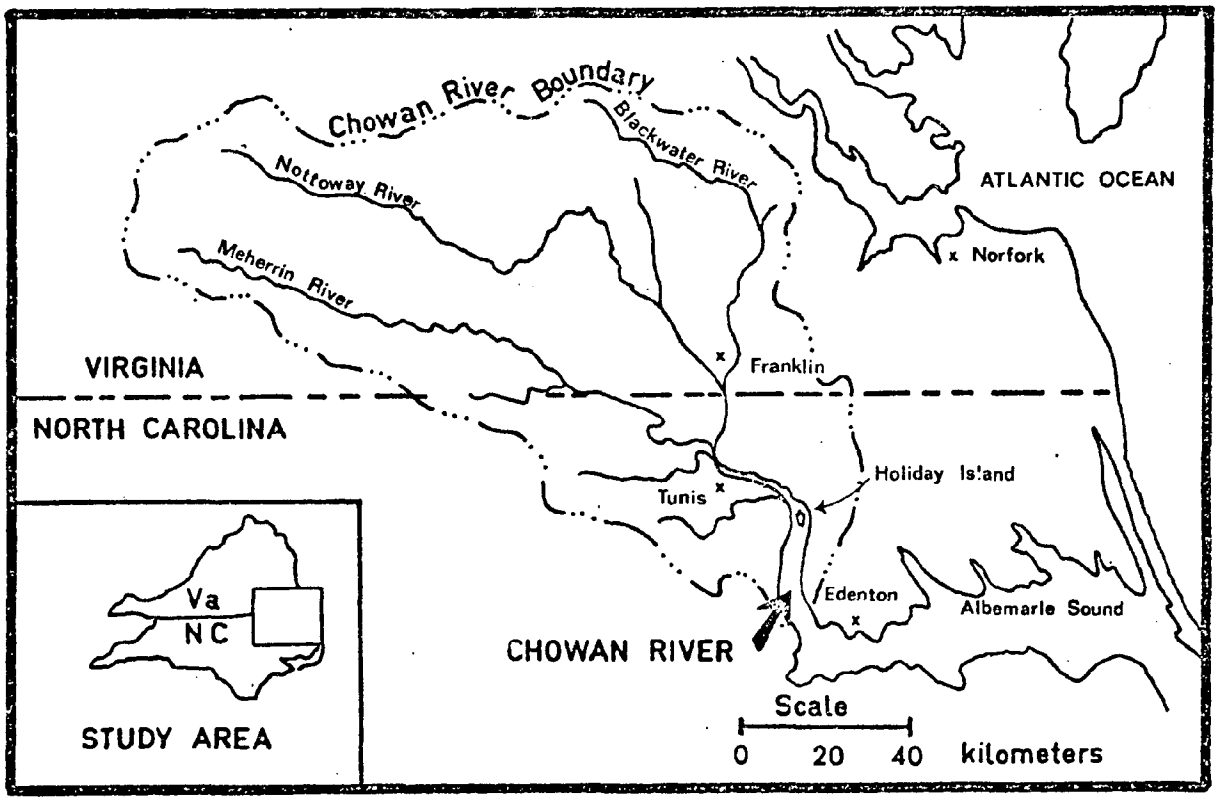

Figure 1. Chowan River Watershed in Virginia and North Carolina

River herring usually spawn in the Chowan system during February-May. The majority of the Alewife spawn before the Bluebacks. Both species usually spawn along the edges of the inundated floodplains of the tributary streams. Frankensteen (1976) reported that river herring larva were found in slow flow situations in the lower reaches of two Tar River tributaries, Grindle and Chicod Creeks in Pitt County, North Carolina. This hypothesis was also tested in this study.

NCDMF personnel had observed during sampling in the Chowan system during spring, 1979 that dissolved oxygen levels were depressed and that larvae did not appear to be as vigorous as they had during previous seasons and in other known spawning areas in the Albemarle region. Therefore, the second major objective of this study was to determine the effects of water quality on the reproductive success of the spawning river herring.

METHODS AND MATERIALS

Larval Sampling

All larval sampling was performed using a 1/2 m, 0.5 mm mesh plankton net. This net was rigged on a wooden frame with a rigid hoop. The frame kept the net at the surface and the hoop vertical. A low speed current meter was suspended in the mouth of the net. This net fished with the top of the hoop at the water surface. The net and frame were guided from the bow of the boat with a pole to keep the net in front of the bow wave and to keep the net as close as possible to the edge. The same rig was used for center samples.

It was necessary to divide the larval sampling program into two phases because of inadequate information on the location of planktonic larvae within the Chowan River system. Phase I consisted of surveys to establish the location of larvae in selected tributaries and the river. The results of this phase were used to establish strata for Phase II sampling. Phase I locations were picked to determine if the 5-15 mm larvae would be found in the following:

A. Low flow or high flow areas of tributaries.

B. Open water or edge areas of tributaries and the river.

Current meters to determine catch-per-unit-effort (CPUE) were not available during the preliminary sampling. This phase was completed in 1980.

Based on the preliminary sampling, each stream was subdivided into substrata with sampling sites. Each substrata was approximately 1,500 m and a 50 m segment of a substra was used as a sample. Strata and substrata locations used during 1981 and 1982 are shown in Table 1. These locations were in the areas of the tributaries with no preceptable flow. The number of samples taken during 1981 and 1982 is given in Table 2.

Table 1. Locations of substra used for larval sampling, Chowan River system, 1981-1982.

Stream	Description of Location
Wiccacon	1. 1,500 m downstream from state secondary road 1427 bridge. 2. 1,500 m upstream in Chinkipin Creek from its confluence with Wiccacon Creek. 3. 1,500 m downstream in Wiccacon Creek from its confluence with Chinkipin Creek. 4. 1,500 m upstream from N.C. 45 bridge. 5. 1,500 m downstream from N.C. 45 bridge.
Rockyhock	1. 1,500 m downstream from state secondary road 1222 bridge. 2. 1,500 m upstream from state secondary road 1207 bridge.
Catherine	1. 1,500 m upstream from mouth. 2. 1,500 m downstream from confluence of Trotman & Warwick Creeks.
Warwick	1. 1,500 m upstream from confluence with Catherine Creek.
Trotman	1. 1,500 m upstream from confluence with Catherine Creek. 2. 3,000 m upstream from confluence with Catherine Creek.
Bennetts	1. 1,500 - 3,000 m upstream from mouth. 2. 1,500 - 3,000 m downstream from N.C. 37 bridge. 3. 1,500 m upstream from N.C. 37 bridge.
Indian	1. 1,500 m upstream from mouth.
Sarem	1. 1,500 m upstream from mouth.
Chowan	1. 1,500 m upstream from confluence with Meherrin River. 2. Between Spikes and Buckhorn Creeks. 3. West shore opposite Catherine Creek. 4. West edge of Holiday Island. 5. Between Harris Landing and Rockyhock Creek.

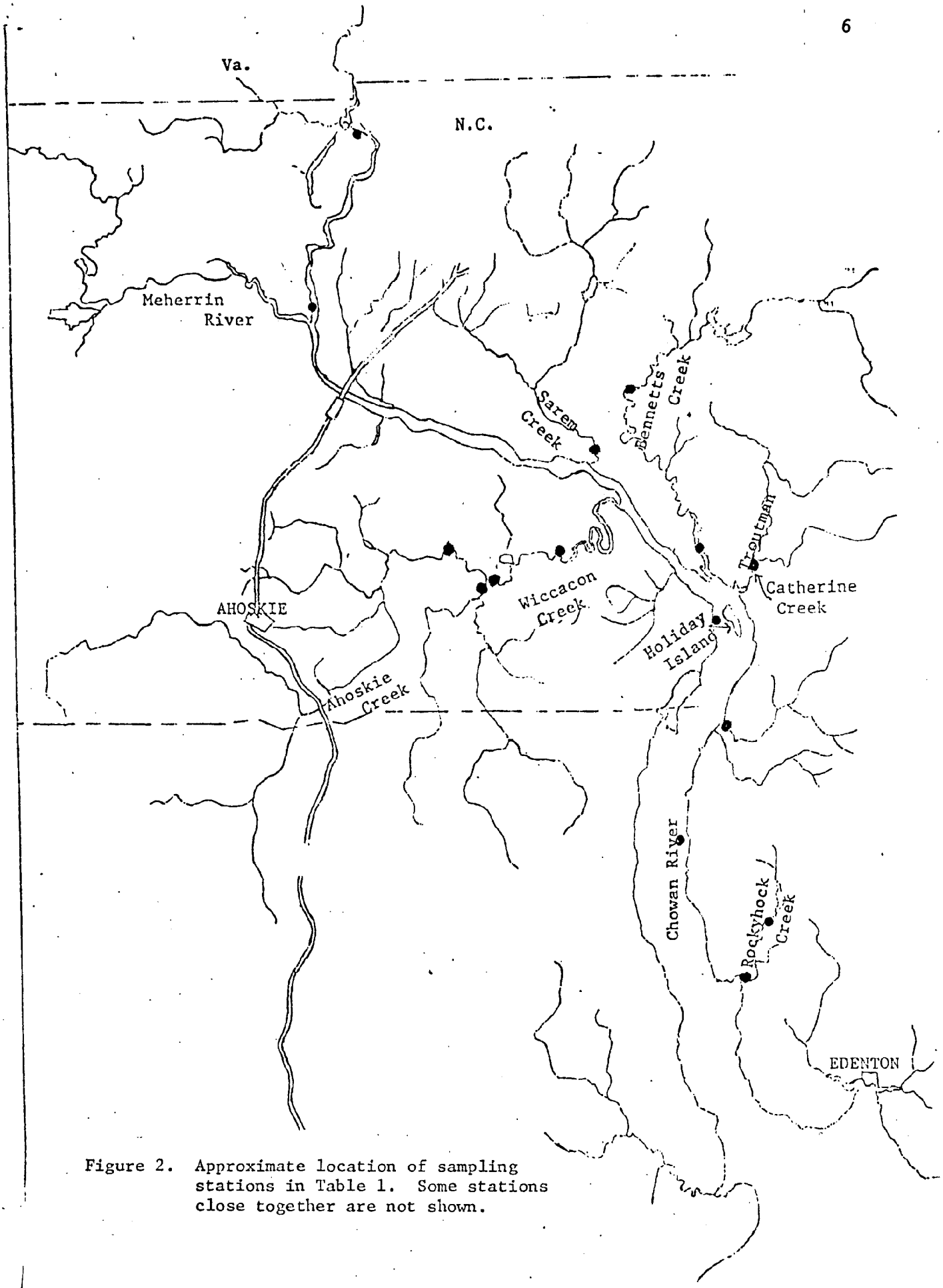

Figure 2. Approximate location of sampling stations in Table 1. Some stations close together are not shown.

Table 2. Number of samples taken in each stream 1981-1982.

Stream	Number of Samples			
	1981		1982	
	Center	Edge	Center	Edge
Chowan River	21	26	5	6
Catherine Creek & Tributaries	21	15	10	11
Wiccacon Creek	20	21	6	5
Bennetts Creek	12	12	6	5
Rockyhock Creek	8	9	3	3
Total	82	83	30	30

Egg and Larval Bioasseys

During the 1981 spawning season, 0.75 m X 1.5 m nitex cylinders with a mesh size of 1.00 mm were suspended from styrofoam floats for testing as in-stream bioassey containers. These were placed in Wiccacon Creek. Larval fish were successfully reared in two of three containers. Approximately 25 fish larva that had been field identified as river herring were placed in one container and a mixed sample of approximately 75 larval fish were placed in the second container. The third container contained approximately 100 ml of fertilized Blueback Herring eggs. Dissolved oxygen temperature and pH were the same inside and outside the containers.

In 1982, four sites were used in the Chowan system. The sites were: Wiccacon Creek at the N.C. 45 bridge, Catherine Creek, Bennetts Creek approximately 3,000 m upstream from the mouth, and the first channel marker north of Holiday Island in the Chowan River. The construction of the bioassey bags was the same as used in 1981 with the addition of welded wire fencing to protect the bags from predation. Bags and floats were constructed so that two replicates could be attempted. During the third week in March, Blueback Herring were dipnetted in the mouth of Bennetts Creek where these fish were observed spawning. Ripe fish running with milt and roe were spawned into a dish pan. After approximately 5 minutes the spawn was rinsed with river water and transferred to 4 l glass jars for transportation to the bioassey sites. The transportation time was approximately 5 minutes for Bennetts Creek, 10 minutes for Catherine Creek, and 2.5 hours to the Wiccacon site. The container in the Chowan River had been destroyed by heavy weather during the interim. A second bioassey was started at the end of April using fish obtained from a pound net operator. This attempt was completely unsuccessful.

Water Quality Analysis

Standard measurements for dissolved oxygen, temperature, pH, conductivity, and ammonia were made during 1980, 1981, and 1982. Dissolved oxygen, temperature, pH, and conductivity measurements were made in the field with meters calibrated in the laboratory and periodically checked in the field. Data was collected in each substratum sampled. Water samples for ammonia analysis were collected in 500 ml bottles, stored on ice and returned to the laboratory for analysis.

RESULTS AND DISCUSSION

Larval Sampling and Analysis

Preliminary Sampling-1980

The summary of the results of the preliminary sampling are shown in Tables 3 and 4. Since the average number of river herring was larger (Table 2) and approximately one-half the samples from the low swamp sections of the two comparison streams (Table 3) contained river herring larvae, the remainder of the sampling was performed in the low swamp areas.

Sampling-1981, 1982

During the 1981 spawning season efforts were concentrated on obtaining a quantative sample of the river herring larva. A total of 165 samples were taken of which 83 were edge and 82 were center samples (Table 2). The average length of all edge samples was 59 m; the average length of all center samples was 66 m. The results of this sampling are shown in Table 5 and 6. A population projection based on Caughly (1977) was prepared to estimate larval populations for single line edge and center transects in each stream and for the system as a whole. These projections are shown in Tables 7 and 8. These projections indicated the large variance and non-normal distribution that result from the spawning practices of river herring and consequential distribution of the herring larva. The shore line distances and stream length as well as the river herring biology effectively prevent economical sampling in a single year or two for population projections. Chi-square analysis of the combined frequency distributions of larva from all stream systems sampled indicated there was no difference ($p > 0.1$) between the distribution of larval catches from edge and center transects. This differed from the results of the 1980 survey and could result from better coverage in 1981 or the extremely low flow conditions in 1981 making it easier for the poor swimming larva to

Table 3. Summary of larval catch data, 1980.

Stream	Number of samples with river herring		Number of samples without river herring		Average number of river herring/sample	
	Edge	Center	Edge	Center	Edge	Center
Catherine-Trotman	5	4	5	6	100	10
Rockyhock	4	2	9	11	50	5
Bennetts	3	2	1	2	25*	5
Wiccacon	3	1	7	6	25	5
Chowan River	3	1**	8	8	50	0
Others	0	3	5	8	0	25
Total	18	12	35	39		

*1 sample contained over 5,000 river herring.

**This sample was a traverse sample across the river approximately 1500 m downstream from Holiday Island during a 10-15 K northwest wind and contained approximately 10,000 larvae.

Table 4. Summary of catch data from upstream vs low swamp areas - Wiccacon and Catherine Creeks, 1980.

Stream	Upstream river herring present		Total samples	Low swamp river herring present		Total samples
	Edge	Center		Edge	Center	
Wiccacon*	1	0	8	2	1	12
Catherine	1	0	10	4	4	10

*Includes Ahoskie and Chinkapin Creeks in upstream area.

Table 5. Total clupeid larva/meter sampled 1981.

Stream	Center			Edge		
	Mean	S.D.	Number of Samples	Mean	S.D.	Number of Samples
Chowan River	0.49	1.97	21	0.7	1.94	26
Catherine Creek & Tributaries	0.01	0.04	21	0.22	0.75	15
Wiccacon Creek	0.11	0.02	20	0.53	1.23	21
Bennetts Creek	0.11	0.20	12	0.11	0.3	12
Rockyhock Creek	1.19	3.13	8	0.29	0.71	9
Total			82			83

Table 6. Frequency distribution for larval river herring sampling, Chowan River system, spring 1981.

Stream \ Number of larvae/ sample	0	1 to 9.99	10 to 99.9	100 to 199.9	Above 200
		Center Transects			
Chowan River	14	3	4	0	0
Catherine Creek	15	1	1	0	0
Bennetts Creek	9	1	3	0	0
Wiccacon Creek	14	6	0	0	0
Rockyhock Creek	6	1	0	0	1
		Edge Transects			
Chowan River	13	5	7	0	2
Catherine Creek	11	2	1	1	0
Bennetts Creek	9	2	1	0	0
Wiccacon Creek	14	0	4	2	1
Rockyhock Creek	6	1	1	1	0

Table 7. Sample statistics and population projection for edge transect Chowan River area, spring 1981.

Stream	Sampling units	Sampled units	Sample mean larve/sample	Sample variance	Population estimate
Chowan River	3,627	27	42.9	13,153	155,562
Catherine Creek	388	15	13.1	2,097	5,094
Bennetts Creek	8,542	12	6.3	335	53,815
Wiccacon Creek	1,525	21	32.1	5,743	48,952
Rockyhock Creek	249	9	17.1	1,979	4,258
			Population Projection		267,681
			Confidence Interval		190,320

Table 8. Sample statistics and population projection for center transect Chowan River area, spring 1981.

Stream	Sampling units	Sampled units	Sample mean larve/sample	Sample variance	Population estimate
Chowan River	1,288	21	6.38	214	8,217
Catherine Creek	116	17	0.82	6.97	95
Bennetts Creek	271	13	6.69	185	1,813
Wiccacon Creek	500	20	0.7	2.11	350
Rockyhock Creek	74	8	78.5	48,762	5,809
			Population Projection		16,284
			Confidence Interval		13,776

Table 9. Total clupeid larva/meter sampled in the Chowan River system, spring 1982.

Stream	Center			Edge		
	Mean	S.D.	Number of Samples	Mean	S.D.	Number of Samples
Chowan River	0.12	0.24	5	0.17	0.37	6
Catherine Creek & Tributaries	0.34	0.59	10	1.18	4.88	11
Wiccacon Creek	0.31	0.44	6	1.68	2.05	5
Bennetts Creek	0.004	0.009	6	2.6	4.79	5
Rockyhock Creek	0	0	3	1.9	2.69	3
Total			30			30

Table 10. Frequency distribution for larval river herring, all streams combined, Chowan River system, spring 1982.

Number of larva/sample	Frequency (number of samples) Edge	Center
0	16	21
1-9.99	2	3
10-99.9	6	5
100-199.9	2	1
Above 200	4	0
Total	30	30

move into the open water areas of the streams.

The larval sampling program during 1982 was reduced to obtain more information on the larval bioassey experiments. Sixty larval samples were made with 30 center and 30 edge samples. The average length of all edge samples was 49 m, the average center sample length was 66 m. Analysis by T-test showed no differences between the length of center samples for 1981 and 1982 ($p > .5$) in either edge or center sample distribution for the two years.

The large variation and non-normal distribution of CPUE for the larval sampling makes it extremely difficult to determine differences between the 1981 and 1982 data. Since logorithmic and natural log transformations did not compensate for the variation and distribution, non-parametric statistical analysis was used. Two types of non-parametric analysis were used: the Mann-Whitney U-test and the Wilcoxan paired sign rank test (Zar 1974). Comparisons of mean larva/meter for edge samples and for center samples by stream between 1981 and 1982 was made using the U-test. This test indicated there was no difference in mean larva/meter for either edge or center samples for the two years. This was checked by combining both edge and center samples for 1981 and comparing them with the combined samples for 1982. This analysis also showed no differences, in neither test was the probability for chance less than 0.25. Comparisons for each individual stream, center and edge, were made using the Wilcoxan paired sample test. This analysis also indicated no differences ($p > .4$) between 1981 and 1982 sampling results.

Preliminary sampling in 1981 indicated the larva caught in the center samples were larger than those along the edge. This hypothesis was confirmed in the 1982 sampling. Any edge or center sample with five or more larva was used to obtain larval length measurements, except for Bennetts Creek. If the sample contained more than ten larva, ten were selected randomly. The results of these measurements is shown in Tables 11 and 12. The unequal numbers

Table 11. Summary of total length (cm), larval river herring, Chowan River system, spring 1982.

Stream	Center			Edge		
	Mean	S.D.	N	Mean	S.D.	N
Chowan River	0.7	0.10	20	0.67	0.12	20
Catherine Creek & Tributaries	0.81	0.31	61	0.77	0.26	65
Wiccacon Creek	1.05	0.46	42	0.92	0.32	55
Bennetts Creek	0.75	0.07	2	0.67	0.12	35
Rockyhock Creek	----	----	--	0.71	0.07	25
Total			125			200

Table 12. Frequency distribution of total lengths for larval river herring, all streams combined, Chowan River system, spring 1982.

Length (cm) Intervals	Frequency Edge	Frequency Center
0.3-0.399	1	0
0.4-0.499	4	3
0.5-0.599	23	18
0.6-0.699	42	31
0.7-0.799	63	22
0.8-0.899	25	12
0.9-0.999	12	4
1.0-1.099	5	1
1.1-1.199	5	4
1.2-1.299	5	6
1.3-1.399	3	5
1.4-1.499	5	3
1.5-1.599	2	7
1.6-1.699	3	6
1.7-1.799	2	2
1.8-1.899	0	1
Total	200	125

result from the number of larvae that could be adequately measured in each sample.

Mean length of larva from edge samples was less than center samples of combined measurements from all streams as indicated by T-test ($p < 0.05$). Analysis of variance by stream for edge and center samples showed differences between streams ($p < .05$). Individual comparisons of streams by the Student-Newman-Kuels procedure (Zar 1974) indicated both edge and center caught larva from the Wiccacon were longer than other streams ($p < 0.05$) and there were no differences between any other stream for either edge or center samples in total length.

Bioassey

Trial bioasseys during 1980 indicated that the technique used was practical. Larval herring were successfully reared in two of the three containers. Twenty-two Blueback Herring larvae lived 21 days with an average length of 14.6 mm.

In 1982, five fish were collected from the bioassey bags. The first and second collections were made with small dip nets to minimize stress to the remaining larva, if any. Fifteen days after fertilization, one larva was obtained from the Bennetts Creek bag. No larva were obtained from the Wiccacon bag. The Catherine Creek bag was completely emptied and checked, no larva were found. Two larva were obtained from the Bennetts Creek bag 33 days after fertilization. No larva were found in the Wiccacon bag. At 45 days after fertilization, both the Bennetts Creek bag and the Wiccacon bag were emptied. Two larva were found in the Wiccacon bag. The information on these larva is shown in Table 13. The lengths at age appear to be on the low end of the normal range (Heinrich 1981). The techniques used for observing daily growth rings of the otiliths were those of the Beaufort National Marine

Table 13. Daily otilith ring counts and length of known age Blueback Herring larva from Chowan River system, 1982.

Herring #	Total Length	Age (Days)	Otolith A Ring Count	Otolith B Ring Count
1	11mm	15	12	12
2	18mm	33	32 ??	32
3	22mm	33	37 ??	34
4	23mm	49	47	38
5	20mm	49	46	44

?? Indicates questionable ring counts.

Fisheries Laboratory. Those techniques worked well and with an adequate sample of known age fish, growth rates and length at age could be determined on collected larva. This information could then be used to assess growth rates in the Chowan system and to document subtle effects of the eutrophication in the Chowan system.

As a simple check on the validity of using the growth rings as an age measure, correlation analysis were made of the five larval samples. A correlation analysis were made of the five larval samples. A correlation coefficient was calculated using both otiliths A and B. Even with using the unclear otiliths, a coefficient of 0.93 ($p < 0.05$) was obtained. If the two unclear otiliths were removed from the calculations, a coefficient of 0.98 ($p < 0.05$) was obtained. If only the B otiliths are used a correlation coefficient of 0.98 ($p < 0.05$) was obtained. This analysis, even with the limited numbers, indicates this method can be used for ageing and determining growth rates in larval river herring.

The only obvious problem that was associated with the use of the bioassey bags was the buildup of aufwuchs on the surface. Dissolved oxygen and pH were identical both inside and outside the bags. All live larva were artifically spawned but problems with the technique could have resulted in the relatively unsuccessful bioassey as well as many other possibilities.

Water Quality

The results of the water quality measurements for 1981 and 1982 are shown in Tables 14 and 15. Problems with field meters prevented complete coverage in all sampling locations in 1982. The data for that year are presented combined for all locations. A more detailed presentation of water quality data, problems, and implications can be found in the Chowan River water management plans (Dec. 1982) from the N.C. Division of Environmental Management.

Table 14. Summary of selected chemical data, Chowan River system, spring 1981.

Stream	Mean ± Std. error	Range	Number of observations
	Dissolved Oxygen - 1/2 meter below surface		
Chowan River	6.8 ± 0.3	3.3 - 8.9	24
Catherine Creek	6.0 ± 0.5	2.4 - 10.2	21
Wiccacon Creek	5.9 ± 0.3	1.8 - 8.6	27
Bennetts Creek	6.2 ± 0.69	1.5 - 8.9	14
Rockyhock Creek	8.9 ± 0.64	5.4 - 12.3	12
	Dissolved Oxygen - 1 meter off bottom		
Chowan River	5.9 ± 0.3	2.8 - 7.9	24
Catherine Creek	4.9 ± 0.5	1.3 - 9.2	21
Wiccacon Creek	5.1 ± 0.4	1.0 - 7.8	27
Bennetts Creek	5.5 ± 0.67	1.0 - 8.4	14
Rockyhock Creek	7.5 ± 0.72	2.7 - 11.2	12
	Temperature - 1/2 meter below surface		
Chowan River	20.9 ± 0.7	16 - 28	24
Catherine Creek	16.2 ± 1.3	10 - 28	21
Wiccacon Creek	14 ± 1.3	10 - 28	27
Bennetts Creek	15.3 ± 1.6	9 - 27	14
Rockyhock Creek	14.5 ± 1.4	10 - 23	12
	pH - 1/2 meter below surface		
Chowan River	6.6 ± 0.08	5.8 - 7.1	24
Catherine Creek	5.8 ± 0.14	5 - 6.9	19
Wiccacon Creek	6.3 ± 0.06	6 - 6.8	27
Bennetts Creek	6.0 ± 0.15	5.4 - 7.0	12
Rockyhock Creek	6.8 ± 0.12	6.3 - 7.5	12
	NH_3 - 1/2 meter below surface		
Chowan River	0.14 ± 0.03	0.01 - 0.28	7
Catherine Creek	0.15 ± 0.06	0.03 - 0.46	8
Wiccacon Creek	0.08 ± 0.03	0.04 - 0.12	4
Bennetts Creek	0.16 ± 0.06	0.05 - 0.42	7
Rockyhock Creek	0.14 ± 0.02	0.07 - 0.21	8

Table 15. Summary of selected water quality data, all streams combined, Chowan River system, 1982.

	Mean	S.D.	N
Dissolved oxygen-surface	4.79	3.06	19
Temperature-surface	15.03	4.71	31
Ammonia	0.12	0.15	27

Differences between 1981 and 1982 in dissolved oxygen and ammonia probably reflect the greater precipitation and subsequent runoff in 1982 (NOAA 1982, 1983). Average rainfall in the Chowan basin was greater both before and during the spawning season.

Visual observation of net caught larva in both 1981 and 1982 did not indicate any obvious differences. The larva were kept for several days in large, shallow finger bowls in the laboratory and appeared to move normally and feed on available zooplankters in the neted sample.

CONCLUSIONS

1. Larval river herring are distributed in the tributaries of the Chowan system in areas of minimum flow. These areas are the lower reaches of the smaller streams but may be much further upstream in tributaries such as the Wiccacon.

2. Smaller larva are found on the stream edges with larger larva in open water.

3. Otilith ring counts with associated length measurements would be a valid method of determining larval age and growth rates.

4. Water quality in the system did not appear to affect the larva directly but the more subtle effects on the larval food chain were not assessed.

RECOMMENDATIONS

1. No further attempts should be made in sampling for population projections. If larval sampling is initiated, locations should be sampled to establish relative abundance information in several streams. After several years, this information would serve as a data base for comparisons with young-of-the-year sampling, commercial catch, and water quality information.

2. Studies should be initiated to assess the effects of eutrophication on the larval food chain.

3. Young-of-the-year sampling should be continued since most clupeids have a high mortality rate between the larval and juvenile stages.

4. Larval growth studies should be initiated. This information, together with information on food habits and food availability, would better document any water quality effects on the larval river herring.

LITERATURE CITED

Caughly, C.
1977. Analysis of Vertebrate Populations. John Wiley & Sons, New York, 234p.

Daniel, C.C., III
1977. Digital flow model of Chowan River Estuary, North Carolina. U.S.G.S. Water Resources Investigations 77-63, 84p.

Frankensteen, E.D.
1976. Genus *Alosa* in a channelized and an unchannelized creek of the Tar River basin, North Carolina. M.S. thesis, East Carolina University, Greenville, N.C., 123p.

Giese, G.L., H.B. Wilder, G.G. Parker, Jr.
1979. Hydrology of major estuaries and sounds of North Carolina. U.S.G.S. Water Resources Investigations 79-46, 175p.

Hinrich, J.W.
1981. Culture, feeding, and growth of alewives hatched in the laboratory. Prog. Fish Cult. 43:3-7.

N.C. Dept. Nat. Resources Comm. Devel.
1982. Chowan River water quality management plan. N.C. Dept. Nat. Resources Comm. Devel., Div. Envir. Mgt., 122p.

National Oceanic and Atmospheric Administration, U.S. Dept. Commerce.
1980-1982. Local climatological data, monthly bulletin. Environmental Data Service.

Zar, J.H.
1974. Biostatistical Analysis. Prentice Hall, Englewood Cliffs, N.J., 620p.

APPENDIX

Master of Science Thesis in Progress

Smith, R.A. Biochemical markers in Blueback Herring subpopulations.

Wynne, M.B., Jr. Potential relationships between some broad-based climatological fctors and the commercial catch of river herring in Chowan River, N. C.

These theses will be completed during the 1983-84 academic year.

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