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FEEDING, DIET, AND REPEAT SPAWNING OF BLUEBACK HERRING, *ALOSA AESTIVALIS*, FROM THE CHOWAN RIVER, NORTH CAROLINA

Current knowledge of the frequency of feeding among spawning blueback herring, *Alosa aestivalis* Mitchill, is limited. Other aspects of the blueback herring's life history have been more extensively studied: feeding of juveniles (Davis and Cheek 1966; Nichols 1966; Burbidge 1974; Domermuth and Reed 1980; Crecco and Blake 1983), distribution at sea (Hildebrand 1963; Holland and Yelverton 1973[1]; Neves 1981), and spawning range (Bigelow and Schroeder 1953; Hildebrand 1963; Scott and Crossman 1973). However, determination of the occurrence of feeding by adults in freshwater has received little attention despite the fact that spawning bluebacks are common in rivers from southern New England (Bigelow and Schroeder 1953) to the St. Johns River, FL (Hildebrand 1963). Throughout this extensive range only Frankensteen (1976) has studied feeding among adult bluebacks in freshwater. Furthermore, no attempt has been made to correlate feeding with length, weight, and sex of individual fish, distance upstream, or the number of seasons a blueback has spawned.

The objective of this study is to enhance our knowledge of the freshwater feeding of blueback herring. In this paper I describe the occurrence of feeding, diet, and percentage of repeat spawning among adults collected in the Chowan River, NC. I also examined, by multiple regression analysis, the relation between feeding activity in freshwater and length, weight, sex, the number of repeat spawnings, and the distance travelled upstream.

Materials and Methods

Collection of Data

Bluebacks were collected at two sites in the lower Chowan River system during April 1980 and 1981. Williams' Fishery, where five collections were made in 1980, is located on the lower Meherrin River near its junction with the Chowan River, 90 km upstream from the Chowan River's mouth. Rocky Hock Creek, where bluebacks were sampled twice in 1980 and once in 1981, is roughly 20 km from the mouth of the Chowan River. Bluebacks at Williams' Fishery were still migrating upstream while those at Rocky Hock Creek, a known spawning ground,[2] were preparing to spawn.

Bluebacks were caught in chicken-wire dip nets and fixed gill nets with 58 mm stretched mesh at Rocky Hock Creek. A drift gill net of similar mesh size and a haul seine were used at Williams' Fishery. None of the fish collected had spawned yet.

Bluebacks were measured, weighed, and sexed, and scales were removed for aging. The foregut and midgut regions of the stomach anterior to the pyloric caeca were removed and placed in 15% Formalin[3] within 10-15 min of capture.

Stomach contents were examined in the laboratory under a dissecting scope. First, fullness of the foregut and midgut, which are separate sections, was estimated visually following Hynes (1950) and Yoshiyama (1980). Five levels of fullness were used: half full (1/2), full (1), and distended with food (2) (as in Yoshiyama 1980), plus one quarter full (1/4), and empty or with traces of food (0). Contents of each section were then placed in a petri dish, identified, and counted. Also, the presence or absence of prey items was noted.

Scales were viewed at 50× through an EPO LP-2 Profile Projector and marks were interpreted following Marcy (1969).

[1]Holland, B. F., Jr., and G. F. Yelverton. 1973. Offshore anadromous fish exploratory fishing program. Completion report, Project AFC-5, 123 p. North Carolina Department of Natural and Economic Resources, Division of Commercial and Sports Fisheries, Raleigh, NC 27611.

[2]S. Winslow, North Carolina Division of Marine Fisheries, Elizabeth City, NC 27909, pers. commun. February 1980. S. Winslow had determined the previous year (1979) that blueback herring collected at this site on Rocky Hock Creek were spawning. Also, a dam upstream prevented blueback herring from moving any further than 150 m above my collection site.

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Statistical Analysis

To obtain a single index of stomach fullness, values for the foreguts and midguts were combined by using a weighted average. In calculating mean volumes each gut section was assumed to be approximately cylindrical. The foregut to midgut volume ratio, determined from five randomly chosen stomachs, was 3.16:1. The following equation was used to calculate the overall gut fullness:

$$\frac{F \times 3.16 + M}{4.16}$$

with F and M representing the foregut and midgut values, respectively.

A multiple regression (General Linear Model-Statistical Analysis Systems) was initially employed to determine which of the variables collected for each fish (i.e., distance upstream, length, weight, sex, and number of repeat spawnings) was most strongly correlated with stomach fullness, the dependent variable. Significant variables identified through multiple regression analysis were further analyzed with chi-square and F-tests.

Results

Presence of Food

Nearly all (91 of 103 or 88%) fish sampled in April 1980 contained food (Table 1) as did all 15 fish collected in April 1981. High percentages of the fish collected on each date in 1980 had food in their stomachs (Table 1). About 53% (48 of 91) of the bluebacks in 1980 (Table 1) and 73% (11 of 15) of the bluebacks in 1981 had either foregut and/or midgut fullnesses of 1/4 or greater. Approximately half of the fish from each date in 1980, with the exception of 13 April, had either foregut and/or midgut fullnesses of 1/4 or greater (Table 1).

Diet

The diet of the bluebacks collected in 1980 at both sites was composed of zooplankters, benthos, and terrestrial insects (Table 2). Chydorid cladocerans were the only zooplankters consumed in large numbers at either location (Figs. 1, 2). Insects, which accounted for 8.1% of the organisms consumed, occurred in about half of the fish. Ephemeroptera (*Baetis*), Coleoptera (Dytiscidae), and Heleidae larvae, as well as chironomid larvae and pupae, were the most conspicuous of the identifiable benthic insects. Most insects, benthic and terrestial, were unidentifiable. Chironomids occurred more frequently than other insect groups, but they accounted for only 2.7% of the total prey items. Several terrestrial insects were found in stomachs of bluebacks, particularly at Williams' Fishery. Insects, both benthic and terrestrial, increased in importance with time at Williams' Fishery, reaching about 22% during later collections (Fig. 1). Insects represented a smaller proportion of the diet at Rocky Hock Creek (Fig. 2). Fish eggs (probably from alewives or bluebacks), which occurred in the stomachs of several bluebacks in 1980 (Figs. 1, 2), were the most abundant food item in that year although their importance decreased with time. Varying amounts of sand and detritus occurred in many stomachs.

In 1981 the diet of bluebacks from Rocky Hock Creek was much less diverse (Table 3). Cladocerans, the predominant prey items, comprised 84.1% of the diet. Almost half of the prey items were daphnid

TABLE 1.—Incidence of feeding and stomach fullness in male and female blueback herring collected at Williams' Fishery (WF) and Rocky Hock Creek (RH) during April 1980.

Station and date of collection	No. fish collected per station	No. males (M) and females (F)		No. fish (n) with animal matter in stomach		No. of fish with ≥1/4 fullness for the foregut, midgut or both							
						Males			Females			Males + Females	
	N	M	F	n	% F	Fore	Mid	Both	Fore	Mid	Both	Total	% N
WF-4-5-80	16	8	8	12	75.0	0	1	0	1	2	3	7	43.6
RH-4-6-80	9	3	6	9	100.0	0	0	0	2	1	2	5	55.6
WF-4-7-80	17	8	9	15	88.2	1	3	0	0	2	3	9	52.9
WF-4-11-80	17	10	7	15	88.2	2	2	0	1	2	1	8	47.1
RH-4-12-80	7	6	1	7	100.0	1	1	0	0	0	1	3	42.9
WF-4-13-80	23	9	14	20	87.0	2	1	0	0	4	1	8	34.8
WF-4-19-80	14	10	4	13	92.9	0	5	0	0	2	1	8	57.1
Total	103	54	49	91	88.4	6	13	0	4	13	12	48	

cladocerans (Table 3). Few copepods were consumed, although they occurred in about half the fish. Ostracods were important numerically and in occurrence, as were daphnid ephippia. Benthic prey, terrestrial insects, fish eggs, detritus, and sand were rare.

TABLE 2.—Diets of 103 blueback herring collected at Williams' Fishery and Rocky Hock Creek during April 1980.

Prey taxon	Frequency of occurrence: No. of fish observed in	Frequency of occurrence: %	Proportions of prey items in diet: No. of prey	Proportions of prey items in diet: %
Copepoda				
Calanoida	1	1.0	1	(1)
Harpacticoida	5	4.9	12	0.4
Cyclopoida	35	33.9	80	2.8
Unidentifiable	7	6.8	21	0.7
Cladocera				
Chydoridae	61	59.2	839	29.6
Other families	14	13.6	26	0.9
Ostracoda	15	14.6	58	2.0
Insecta				
Miscellaneous	54	52.4	133	4.7
Diptera				
Chironomidae larvae	25	24.3	67	2.4
Chironomidae pupae	5	4.9	7	0.3
Other families	12	11.7	20	0.7
Oligochaeta	1	1.0	1	(1)
Mollusca				
Sphaeriidae	7	6.8	21	0.7
Fish eggs	43	41.8	1,273	44.9
Bryozoan statoblasts	20	19.4	178	6.3
Colonial hydrozoan pieces	16	15.5	96	3.4
Hydracarina	5	4.9	5	0.2
Total			2,838	100.0

[1]<0.1%.

TABLE 3.—Diets of 15 blueback herring collected at Rocky Hock Creek on 18 April 1981.

Prey taxon	Frequency of occurrence: No. of fish observed in	Frequency of occurrence: %	Proportions of prey items in diet: No. of prey	Proportions of prey items in diet: %
Copepoda				
Calanoida	5	33.3	8	0.1
Harpacticoida	7	46.6	7	0.1
Cyclopoida	7	46.6	23	0.4
Cladocera				
Daphnidae	15	100.0	3,191	48.7
Daphnidae ephippia	12	80.0	1,825	27.9
Chydoridae	13	86.6	493	7.5
Bosminidae	2	13.3	5	(1)
Ostracoda	13	86.6	929	14.2
Insecta				
Miscellaneous	5	33.3	6	0.1
Diptera				
Chironomidae larvae	5	33.3	8	0.1
Fish eggs	1	6.6	7	0.1
Bryozoan statoblasts	11	73.3	42	0.6
Hydracarina	3	20.0	3	(1)
Fish larvae	1	6.6	1	(1)
Total			6,548	99.8

[1]<0.1%.

Number of Repeat Spawnings

About 85% (87 of 103) of the fish in 1980 and 71% (10 of 14) in 1981 had spawned before (Table 4). Although some bluebacks in 1980 had spawned as many as six times, most (72%) had spawned only once or twice before (Table 4). Almost equal numbers of males (44) and females (43) were repeat spawners in 1980.

TABLE 4.—Number of previous years that 103 blueback herring collected at Williams' Fishery and Rocky Hock Creek during April 1980 had spawned.

	No. of years spawned					
	1 (first time)	2	3	4	5	6
Male	10	25	14	3	1	1
Female	6	22	13	6	2	0
Total	16	47	27	9	3	1

Relation Between Feeding Activity and Length, Weight, Sex, Number of Repeat Spawnings, and Distance Upstream

Sex was the only independent variable that contributed significantly to variance in feeding rate (Table 5). Female bluebacks fed more actively than males. The full model explained only 21% of the variance in gut fullness but this was significant ($F = 2.87, P > F = 0.005$, 102 df). The near significant contributions of length and weight to the reduction of variance in the model is believed to have resulted primarily from sex related differences in mean size ($\bar{x}$ length females = 305.1 mm, $\bar{x}$ length males = 289.4 mm; $\bar{x}$ weight females = 258.0 g, $\bar{x}$ weight males = 212.5 g). Further analysis of the feeding activity of male and female bluebacks with a chi-

TABLE 5.—Summary of the contribution of each of the independent variables to the multiple regression model for data from 103 blueback herring collected in 1980. Type IV F values and probability levels are shown. $P < 0.05$ significance level used.

Independent variable	F value	Probability
Site	2.64	0.1078
Sex	7.14	0.0089
No. of repeat spawnings	1.65	0.1818
Length	3.85	0.0527
Weight	3.81	0.0540

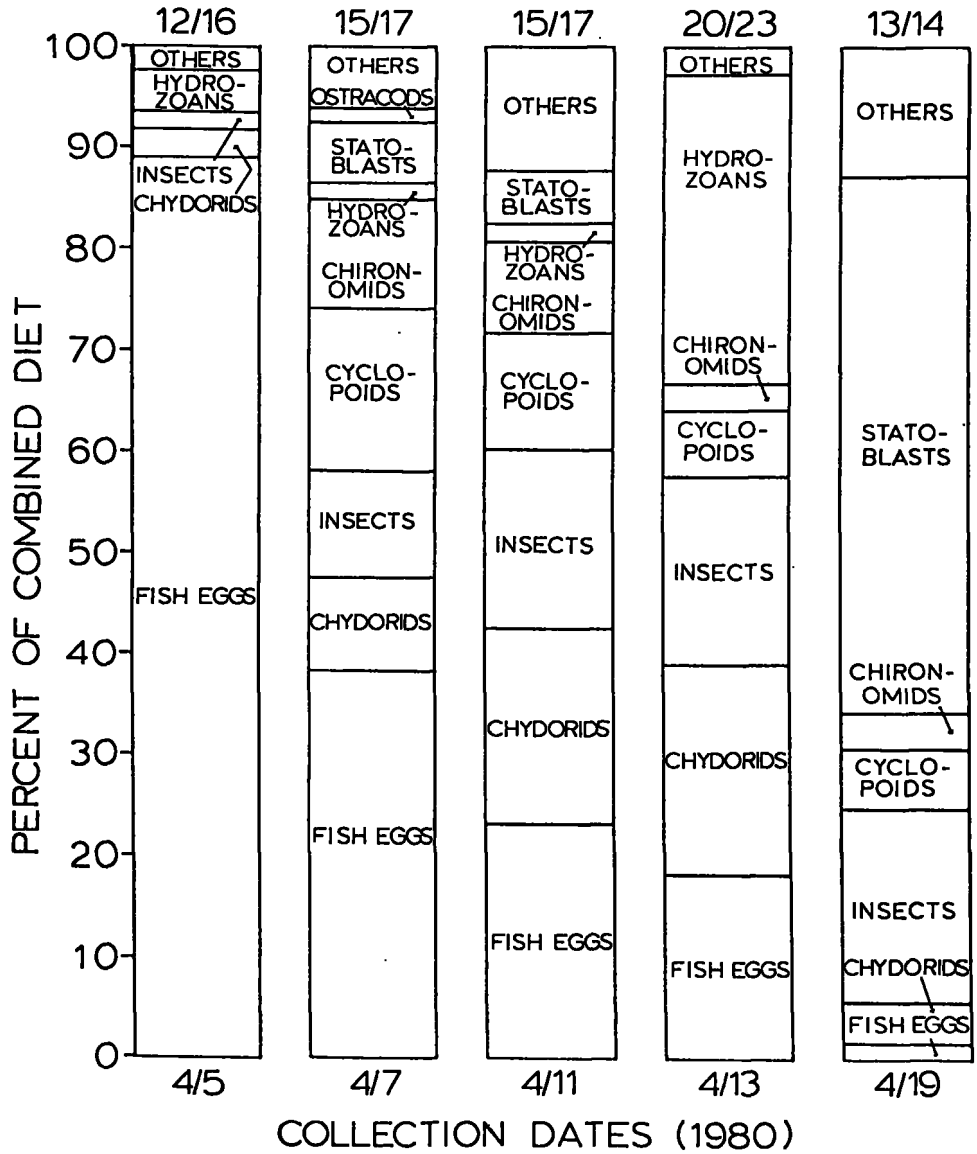

FIGURE 1.—Changes in the composition of the combined diet (both males and females) over the five collection dates at Williams' Fishery in April 1980. Numbers above each bar graph indicate number of stomachs with food/total number of stomachs examined.

square 2 × 2 contingency table also found significantly greater levels of feeding activity among females (χ^2 value = 5.86, $P < 0.025$). The difference in 1980, however, may depend on site. More females had stomach fullnesses ⩾1/4 than males at Rocky Hock (χ^2 value 6.349, $P < 0.025$), but the difference was not significant at Williams' Fishery.

For the three most abundant food items females consumed significantly greater numbers of chydorid cladocerans ($F = 6.02$, $P > F = 0.0001$), insects ($F = 7.64$, $P > F = 0.0001$), and fish eggs ($F = 90.15$, $P > F = 0.0001$) than males in 1980.

Discussion

Blueback herring spawning in the Chowan River do not stop feeding during their freshwater migrations. Williams' Fishery and Rocky Hock Creek are

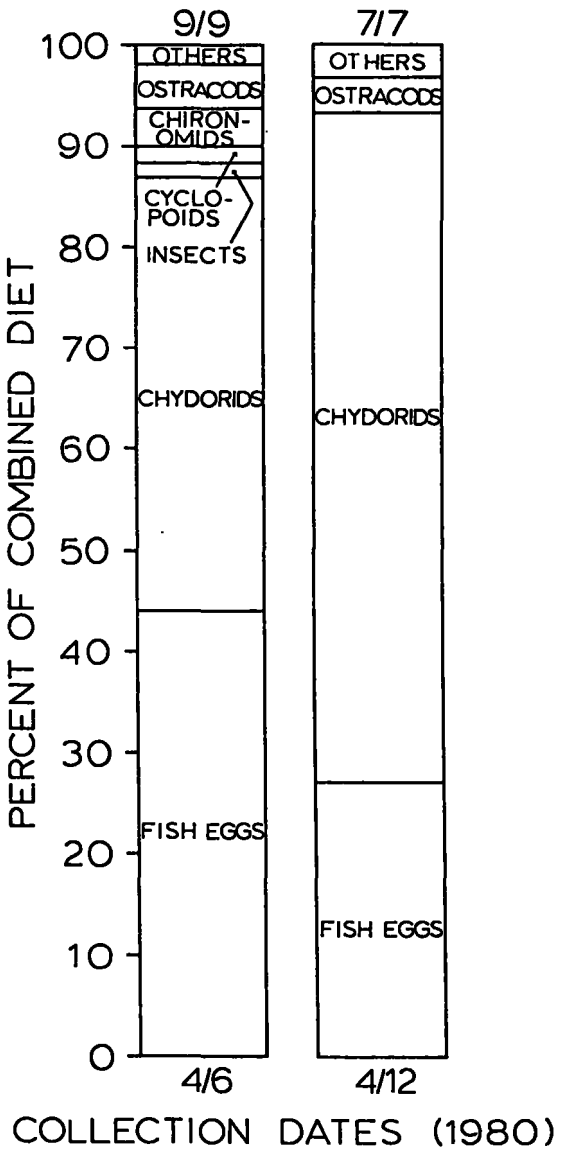

FIGURE 2.—Changes in the composition of the combined diet (both males and females) over the two collection dates at Rocky Hock Creek in April 1980. Numbers above each bar graph indicate number of stomachs with food/total number of stomachs examined.

too far from the estuary for bluebacks to travel to saltwater for daily feeding. It is important to note, also, that the interface between freshwater and saltwater often extends far out into Albemarle Sound due to the spring discharge of both the Chowan and Roanoke Rivers. This was the case in the spring of 1980.[4] Moreover, the prey were exclusively of freshwater origin. There is, therefore, little doubt that these bluebacks were feeding in freshwater.

The wide diversity of food items consumed was unexpected since bluebacks have previously been reported to be primarily planktivorous (Bigelow and Schroeder 1953; Hildebrand 1963). The limited 1981 data suggest that prey other than zooplankters are consumed infrequently if sufficient zooplankters (or large zooplankters such as *Daphnia*) are present. However bluebacks are also capable, as the 1980 data demonstrate, of foraging opportunistically on other riverine fauna and terrestrial insects, which could also explain Frankensteen's (1976) unusual finding that chironomids were the dominant prey of blueback herring in the Tar River. Consumption of benthic prey probably accounts for the presence of detritus and sand in the guts.

My data show a difference between male and female feeding activity. There are two possible explanations for this difference. First, females may require more energy than males during the spawning migration thus they consume more prey. Neither this study nor other studies of bluebacks have produced data to either support or refute this idea. However, moderate to severe weight loss is common among other spawning anadromous fishes (e.g., Atlantic salmon, American shad) with females suffering greater weight loss than males (Belding 1934; Chittenden 1976; Glebe and Leggett 1981). Glebe and Leggett (1981) found that development of ovaries in female shad required more energy and time than the male shads' testes. Consequently, female shad entering freshwater, particularly southern rivers, often do not have fully developed ovaries. Thus, not only must females expend energy for swimming but for gonad development as well. The same difference in gonad development may exist between male and female bluebacks and could explain the different levels of feeding activity observed in this study.

The second explanation for the difference in feeding activity is that all bluebacks, regardless of sex, stop feeding while spawning. However, males might remain on the spawning grounds longer than females. Thus, if females leave the area immediately after they spawn and are replaced by newly arrived females with relatively full guts, this could cause the gut samples to be biased. This explanation appears to be ruled out by the 1981 data, however, since half the fish with stomachs ≥1/4 full collected at Rocky Hock were males.

While previous researchers have found food in bluebacks' stomachs (Williams et al. 1975 as cited

[4]R. Holmes, Department of Natural Resources and Community Development, Division of Environmental Management, Raleigh, NC 27611, pers. commun. March 1984.

in Rulifson et al. 1982; Frankensteen 1976), my finding of a regular occurrence of significant volumes of food in blueback stomachs is unprecedented. Further research is needed to determine the extent to which feeding in freshwater is common among spawning bluebacks in other river systems, and possibly other anadromous species, and to determine if a relationship exists between freshwater feeding and spawning energetics.

Acknowledgments

I am grateful to Seth Reice and Edward Kuenzler for providing assistance, materials, and workspace for this study. I also wish to thank Jerry Diamond, Seth Reice, William Leggett, Angela Arthington, Rob Edwards, Brad Foster, and three anonymous reviewers for their careful readings of the manuscript. Assistance from Mr. and Mrs. Williams and the staff of Williams' Fishery, Sara Winslow, Harrel Johnson, and Michael Street of the North Carolina Division of Marine Fisheries, David Hammer, Chris Nations, Ernie Patterson, and Diana Hyland, as well as thought-provoking discussions with many other people, is greatly appreciated.

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