BLUEBACK HERRING OVIVORY AND PISCIVORY IN TRIBUTARY ARMS OF HIWASSEE RESERVOIR, NORTH CAROLINA

Final Report

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Abstract.—We examined blueback herring *Alosa aestivalis* diets in Hiwassee Reservoir, in response to observed declines in recruitment of walleye *Sander vitreus* and known negative impacts of river herrings *A. spp*. on reservoir fisheries in other states. We hypothesized that the spatial and temporal overlap between blueback herring and gamefish larvae and eggs during spring spawning activities could encourage ovivory and piscivory. We collected blueback herring by boat electrofishing from two tributaries, Hanging Dog Creek and Hiwassee River, that have known spawning runs of walleye and white bass *Morone chrysops*. We sampled from 24 March until 12 May to coincide with spring spawning activities. Ovivory occurred during a 19-d period in both tributaries which began on 17 April and concluded on 5 May. During the 19-d period on Hanging Dog Creek, 92.8% of the blueback herring diets contained prey items. Fish eggs occurred in 55.6% of the diets containing prey items. The majority (98.0%) of the 9,232 identified eggs were white bass. During the 19-d period on Hiwassee River, 79.7% of the blueback herring diets contained prey items. Fish eggs occurred in 32.9% of the diets containing prey items. The majority (98.8%) of the 1,796 identified eggs were white bass. Piscivory was rarely observed during this study. Although larval fish predation has been suggested as a mechanism by which river herring may reduce reservoir game fish populations, we found very little evidence of larval fish predation by blueback herring in Hiwassee Reservoir. However, this study has shown that the predation of blueback herring on fish eggs can be considerable and may be a mechanism by which blueback herring reduce gamefish recruitment.

The recent appearance of blueback herring *Alosa aestivalis* into Hiwassee Reservoir has raised concerns due to negative impacts of river herrings *A. spp*. on reservoir fisheries in other states. Blueback herring introduction into Lake Burton, Georgia coincided with decreased abundance of black crappie *Pomoxis nigromaculatus*, largemouth bass *Micropterus salmoides*, and white bass *Morone chrysops* (Rabern 2000). In addition, failures in walleye *Sander vitreus* recruitment followed the introduction of alewife *A. pseudoharengus* in several Tennessee reservoirs (Irwin-Larrimore 1989; Schultz 1992). The appearance of blueback herring in Hiwassee Reservoir coincided with reductions and failures in walleye recruitment (Wheeler et al. 2004a). Although several mechanisms have been proposed, the relationship between river herring and reduced sport fish recruitment remains unknown. One potential mechanism, suggested by biologists in Tennessee (Irwin-Larrimore 1989) and Georgia (A. Rabern, Georgia Department of Natural Resources, personal communication), is larval fish predation.

Previous investigations of larval fish predation by blueback herring have yielded conflicting results. Bulak and Walker (1979) observed that adult blueback herring fed on juvenile largemouth bass in South Carolina aquaculture ponds. Davis and Foltz (1991) examined 120 blueback herring diets collected in February, May, August, and December, from Jocassee Reservoir, South Carolina and found piscivory only during August. The 30 fish collected in August consumed 80 juvenile clupeids and 1 juvenile centrarchid. Goodrich (2002) found low occurrence of piscivory (average frequency of occurrence 6%) throughout the year on Chatuge Reservoir, North Carolina/Georgia. In contrast, other researchers have found no evidence of piscivory. Winkleman and Van Den Avyle (2002) found no piscivory in 266 blueback herring collected throughout the year from J. Strom Thurmond Reservoir, South Carolina/Georgia. In addition, Guest and Drenner (1991) collected quarterly samples from Lake Theo, Texas and reported no piscivory.

Wheeler et al. (2004b) evaluated the use of electrofishing for collecting blueback herring for diet characterization and found no catch rate differences between day and night. They examined the diet contents of 1,147 blueback herring and found larval fish in <1% of the 815 diets containing prey items. However, because they sampled bimonthly, they may have missed brief pulses of piscivory.

Blueback herring are present in tributaries of Hiwassee Reservoir during white bass and walleye spawning periods (Wheeler et al. 2004b). We hypothesized that this spatial and temporal overlap between adult blueback herring and gamefish larvae and eggs could encourage ovivory and piscivory. The goal of this study was to determine if blueback herring consume larval fish and fish eggs during of spring tributary spawners. Specific objectives were 1) to quantify the frequency of occurrence of larval fish and fish eggs in blueback herring diets and 2) to identify the species of larval fish and fish eggs consumed.

Methods

We collected blueback herring from two Hiwassee Reservoir tributaries, Hanging Dog Creek and Hiwassee River, that have known spawning runs of walleye and white bass (Figure 1) and timed our sampling to coincide with spring spawning activities. A preliminary investigation found that day electrofishing was an effective technique for collecting blueback herring and that there was little diel difference in stomach contents (Wheeler et al. 2004b); therefore, we sampled only during daylight. We electrofished the two tributaries (Smith-Root 7,500-W generator; 3-4 A pulsed DC) between 0900 and 1200 hours; sampling occurred every Monday beginning 24 March 2003 until larval fish or fish eggs appeared in blueback herring diets, and every Monday and Thursday thereafter. Sampling ceased when fish and fish eggs had not been observed in diets for two consecutive samples. Because reservoir water levels varied among sample dates, we standardized sampling by navigating up each tributary as far as possible and shocking downstream, covering a range of water depths approximately 0.3-3.0 m. We sampled each site for 30 minutes or until 25 blueback herring were collected.

All blueback herring were placed on ice immediately after collection. The fish were returned to the lab, where they were measured and eviscerated. Stomach contents were examined under a dissecting microscope and the presence or absence of fish and fish eggs was recorded. All lab work, except expert taxonomic identification, occurred on the same date as collection. Larval fish and eggs were preserved in 10% formalin and identified to the lowest possible taxon, except for those collected on 28 April and 1 May; for these samples, only the presence or absence of larval fish, fish eggs, and other prey items was recorded. Ovivory and piscivory were quantified as the frequency of occurrence among diets containing prey items.

Results

Diet samples were collected between 24 March and 12 May 2003 (Table 1). A larval fish was found in diet contents on 14 April; thereafter, semiweekly sampling continued until 12 May, when fish and fish eggs had not been observed in diets for two consecutive samples. Rainfall caused the reservoir water levels to increase rapidly between the 5 May and 8 May samples. After this water level increase, blueback herring were difficult to collect, and diet data no longer indicated ovivory or piscivory. We collected 281 blueback herring ranging in size from 72-266 mm TL from Hanging Dog Creek and 285 ranging from 72-118 mm TL from Hiwassee River (Figure 2).

Ovivory occurred over a 19-d period in both tributaries, beginning on 17 April and concluding on 5 May (Table 1). We collected 153 blueback herring from Hanging Dog Creek during the ovivory period and 92.8% of these contained prey items. Fish eggs occurred in 55.6% of the diets containing prey items. The majority (98.0%) of the 9,232 identified eggs were white bass, 2.0% were shad *Dorosoma sp.*, and 1 egg was a darter *Etheostoma* or *Percina*. The shad eggs were probably gizzard shad *D. cepedianum*. The one darter egg was probably a greenside darter *E. blennioides*.

During the period of ovivory on Hiwassee River, we collected 143 blueback herring of which 79.7% contained prey items. Fish eggs occurred in 32.9% percent of the diets containing prey items. The majority (98.8%) of the 1,796 identified eggs were white bass, 0.5% were shad, and 0.7% were unidentifiable. The shad eggs were probably gizzard shad. The unidentifiable eggs were possibly redhorse *Moxostoma* or another Catostomid.

Piscivory was rarely observed during this study and too infrequently to report a meaningful time period or frequency of occurrence on Hanging Dog Creek. The diets of only two blueback herring from Hanging Dog Creek contained a total of 15 larval fishes (Table 1). The first occurrence was from 14 April and the diet contained six darter larvae and eight unidentifiable larvae. Of the eight unidentifiable larvae, seven were possibly darters and one was possibly a walleye. The second occurrence was from 28 April, when the diet contained one larval darter.

Piscivory occurred over three consecutive samples (28 April-5 May) in Hiwassee River, when the diets of seven blueback herring contained a total of 16 larval fish (Table 1). We collected 68 blueback herring during this period of which 72.1% contained prey items and the frequency of occurrence of piscivory was 14.3%. Two diets from 28 April contained a total of three larval darters. Two diets from 1 May both contained one larval sucker and an additional diet contained five larval suckers and four unidentifiable larval fish. One diet from 5 May contained a larval sucker and another diet contained one unidentifiable larval fish.

Discussion

Although larval fish predation has been suggested as a mechanism by which river herring may reduce reservoir game fish recruitment, we found very little evidence of larval fish predation by blueback herring in Hiwassee Reservoir. However, this study has shown that the predation of blueback herring on fish eggs can be substantial. A literature review (Wheeler et al. 2004b), found no previous studies documenting ovivory in blueback herring. Ovivory may be an important, but unexplored, mechanism by which blueback herring limit game fish recruitment.

With the exception of one possible larval walleye, we found no evidence that blueback herring were consuming walleye eggs or larvae. However, we observed very few walleye during the sampling. Poor recruitment after 1996 has reduced the walleye population in Hiwassee Reservoir (Wheeler et al. 2004a) and we may have failed to observe spawning walleye because we shocked during daylight hours. Although Wheeler et al. (2004b) observed walleye in tributaries during a preliminary study, the tributaries had lower turbidity than in the preliminary study throughout most of this study. When tributaries have low turbidity, walleye may avoid the shallow areas where boat electrofishing is effective during daylight and move up into shallow areas to spawn at night (C. Vandergoot, personal communication).

The feeding success of blueback herring on white bass eggs may not reflect their ability to consume walleye eggs. Although both species make annual spring spawning runs up tributaries, white bass and walleye have different spawning strategies. These strategic differences may result in walleye eggs being less vulnerable to blueback herring predation than white bass eggs. White bass spawning occurs at the water's surface. Their eggs are demersal and permanently adhere to the substrate surface (Jenkins and Burkhead 1993). In contrast, walleye broadcast eggs over the bottom and eggs adhere briefly (approximately one hour) to the substrate and then settle into crevices, where they may be somewhat protected from predators (Colby et al. 1979; Jenkins and Burkhead 1993). We anticipated that blueback herring would be able to consume larval fish and fish eggs that were drifting in the water column; however, the volume of white bass eggs in their diets suggest that they may forage directly on the substrate (R. Wallus, personal communication). In addition, the darter egg found in a blueback herring diet was likely a greenside darter which also attaches its eggs to the surface of substrate (Jenkins and Burkhead 1993). We observed sand and many benthic invertebrates in blueback herring stomachs during this study, also suggesting that blueback herring are effective at foraging directly on the substrate. However, if blueback herring are less effective at retrieving eggs from within the substrate, the vulnerability of walleye eggs may be limited to the short adhesive period.

This study identified ovivory in tributaries as a possible mechanism by which blueback herring may negatively impact fish recruitment. However, it is unlikely that ovivory in tributaries is the ultimate mechanism by which river herring suppress gamefish recruitment. Because alewife and blueback herring are similar species that exhibit similar effects on walleye recruitment, it is likely that they do so through a common mechanism. However, an important behavioral difference between alewife in Tennessee reservoirs and blueback herring in Hiwassee Reservoir is in Tennessee tributaries alewife are not present in the spring. Thus, the mechanism of tributary ovivory is restricted to blueback herring. Future studies should attempt to isolate the mechanism or mechanisms by which river herring reduce game fish recruitment focusing on behavioral similarities among river herring in different reservoirs with similar recruitment declines. Considering only potential mechanisms by which both species may reduce game fish recruitment may help future studies to more quickly isolate causes. In addition, comparisons of zooplankton communities of western North Carolina reservoirs with and without blueback herring are needed to determine how introduced blueback herring alter trophic dynamics of these systems.

Recommendations

1. Investigate factors affecting vulnerability of walleye eggs to consumption by blueback herring.
2. Compare behavioral patterns of blueback herring among reservoirs exhibiting declines in walleye recruitment.
3. Compare zooplankton community composition and densities between western North Carolina reservoirs with and without blueback herring populations.

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TABLE 1.—The sample dates, number (N_C) and size range of blueback herring collected from Hanging Dog Creek (HD) and Hiwassee River (HR) during this study. Ovivory and piscivory are expressed as the frequency of occurrence (FO) and mean number of fish larvae or eggs ($\bar{x}$) for the number of individuals that contained prey items (N_P).

				Piscivory	Ovivory				
				Total	Total	Moronidae	Clupeidae	Percidae	Unid.
Date	Site	N_C	N_P	FO ($\bar{x}$)	FO ($\bar{x}$)	FO ($\bar{x}$)	FO ($\bar{x}$)	FO ($\bar{x}$)	FO ($\bar{x}$)
3/24	H.D.	26	26	0.0	0.0				
	H.R.	29	20	0.0	0.0				
4/01	H.D.	1	1	0.0	0.0				
	H.R.	25	23	0.0	0.0				
				0.0					
4/07	H.D.	25	23	0.0	0.0				
	H.R.	25	18	0.0	0.0				
4/14	H.D.	25	25	4.0 (14.0)	0.0				
	H.R.	25	19	0.0	0.0				
4/17	H.D.	25	22	0.0	100.0 (99.5)	84.0 (95.5)	9.1 (0.5)		
	H.R.	25	24	0.0	25.0 (9.5)	25.0 (9.5)			
4/21	H.D.	25	25	0.0	80.0 (229.8)	80.0 (224.3)	40.0 (5.4)	4.0 (<0.1)	
	H.R	25	24	0.0	58.3 (48.1)	54.2 (47.9)	8.3 (0.2)		
4/24	H.D.	28	24	0.0	4.2 (15.2)	4.2 (14.9)	4.2 (0.3)		
	H.R.	25	16	0.0	0.0				
4/28	H.D.	25	24	4.2 (1.0)	100.0	a	a	a	a
	H.R.	25	24	8.4 (1.5)	100.0	a	a	a	a
5/01	H.D.	25	23	0.0	69.6	a	a	a	a
	H.R.	18	10	30.0 (3.7)	10.0	a	a	a	a
5/05	H.D.	25	24	0.0	8.3 (1.9)	8.3 (1.9)			
	H.R.	25	15	8.0 (1.0)	13.3 (2.1)	6.7 (2.7)			6.7 (0.9)
5/08	H.D.	25	18	0.0	0.0				
	H.R.	13	12	0.0	0.0				
5/12	H.D.	26	24	0.0	0.0				
	H.R	25	17	0.0	0.0				

[a] Fish eggs from diets collected on 4/28 and 5/01 were not identified or counted.

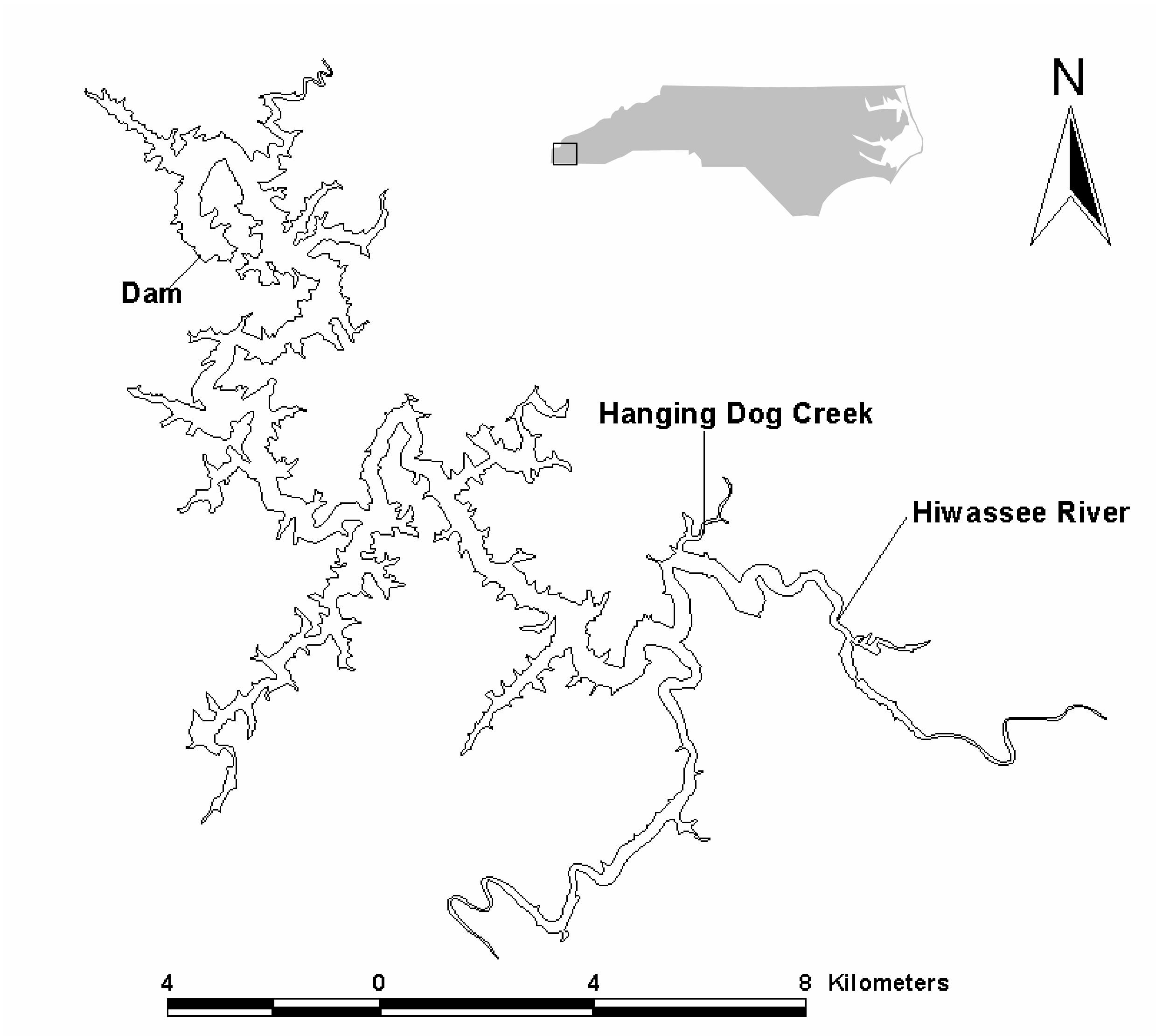

FIGURE 1.—Map of Hiwassee Reservoir showing the location of Hanging Dog Creek and Hiwassee River.

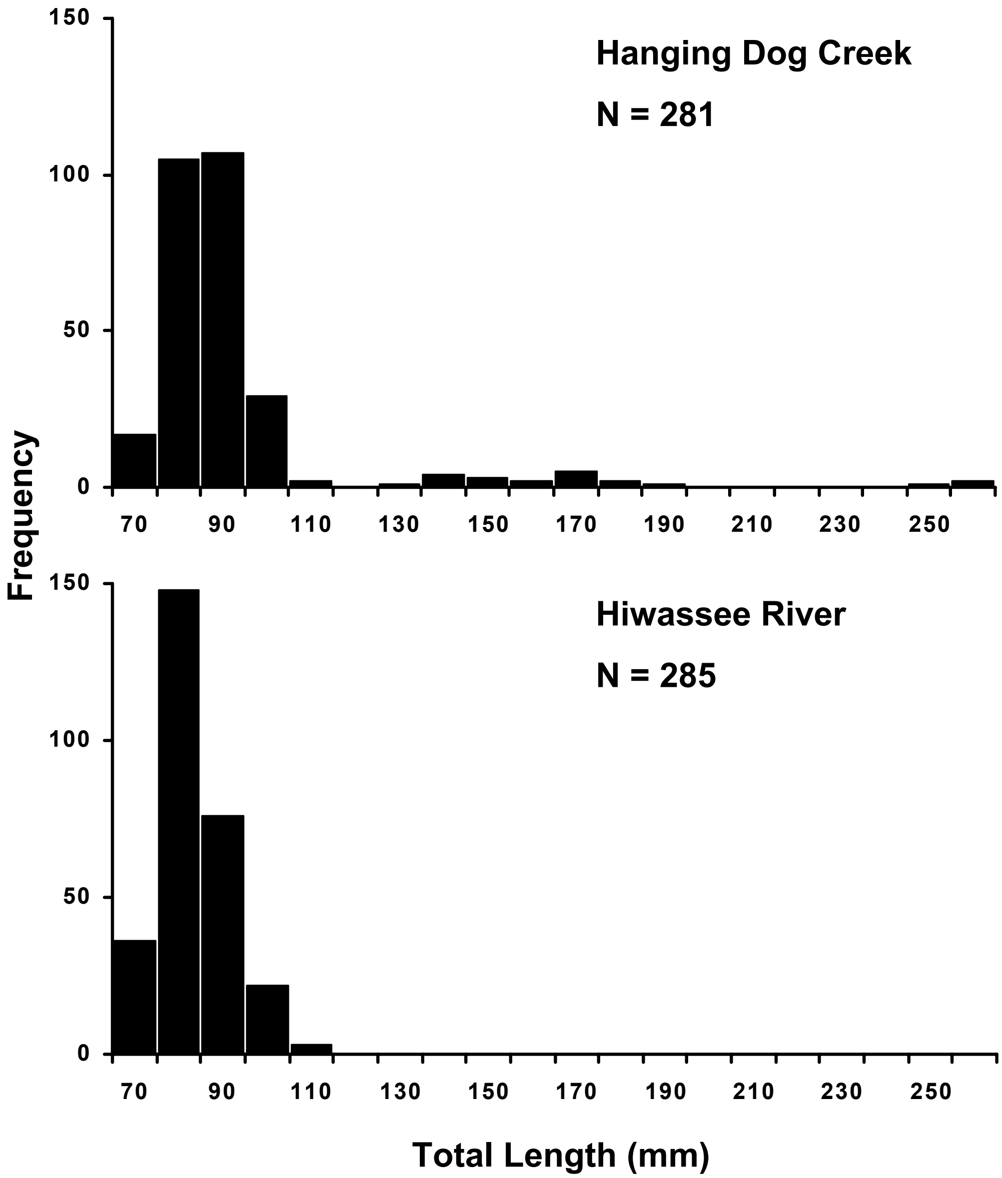

FIGURE 2.—Length-frequency distributions of blueback herring collected from Hanging Dog Creek and Hiwassee River, 2003.