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Dietary composition and habitat preferences of Blueback herring, Alosa aestivalis, including observations on their role in the trophic ecology of Lake Chatuge NC/GA

Billy C. Goodrich

To the Graduate Council:

I am submitting herewith a thesis written by Billy C. Goodrich entitled "Dietary composition and habitat preferences of Blueback herring, Alosa aestivalis, including observations on their role in the trophic ecology of Lake Chatuge NC/GA." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson, Major Professor

We have read this thesis and recommend its acceptance:

Marshall Adams, Mark Bevelhimer

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Acceptance for the council:

Vice Provost and Dean of Graduate Studies

Dietary Composition and Habitat Preferences of Blueback Herring, *Alosa aestivalis*, including Observations on their Role in the Trophic Ecology of Lake Chatuge NC/GA

A Thesis Presented for the Master of Science Degree

The University of Tennessee, Knoxville

Billy C. Goodrich

August 2002

DEDICATION

This thesis is dedicated to the true constants in my life: my wife Jenni, and our new son David 'Wyatt'. The support and love they give is like no other known to man, fulfilling my life. I dedicate this thesis to my mother Carolyn Goodrich, my hero for 38 years, and my grandmother, Mary W. Morrison, who always believed in me no matter what. I cannot forget my in-laws John D., Becky L., Anne C. Waddell, and Heather L. Smith who have encouraged and supported me. I especially wish to dedicate this thesis to memory of my 'pop' William D. Goodrich (the best friend I ever had) and my grandfather (pap) Charles D. Morrison (the greatest granddad ever); they were my heroes. Lastly, I dedicate this thesis to the rest of my family and friends, present and past. Though there are too many to list; they too have made profound impacts on my life, making me the person I am and the person I want to be.

Thank you, one and all.

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I wish to thank David Yow (NCWRC), Reggie Weaver (GADNR), and Anthony Rayburn (GADNR), who were instrumental in obtaining the project, information, and blueback herring at times during the study. I thank Dr. David Etnier, for his information and his teachings. I thank Cherry Gong, Aggie Vanderpool, Jeff Highfill, Frank Yancey, Chris Cooper, Jay Howell, Randy Cooper, and my wife Jenni for their help in setting and pulling nets, and sacrificing their time to help me complete this project. Thank you!. Thank you is so little in return for so much.

I wish to thank Dr. Larry Wilson for all his teachings, encouragement, support, and belief, especially for being my mentor. I extend great thanks to Dr. Marshall Adams and Dr. Mark Bevelhimer, of the Oak Ridge National Laboratories, for serving on my committee, being my teachers, and being my friends.

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ABSTRACT

Blueback herring, *Alosa aestivalis*, were collected during a 15-month period from Lake Chatuge, NC/GA, to determine food habits, evaluate sampling methods, and determine habitat preferences. Experimental and standard gill nets were fished horizontally, obliquely, and vertically at different depths, while electrofishing efforts employed 30-minute transects along designated shoreline areas. Larval light traps were fished at alternating sites and depths to sample available plankton and larval blueback herring. Blueback herring were determined to be obligate planktivores; the primary prey items included cladoceran species from the genera *Daphnia*, *Bosmina*, *Chydorus*, and *Leptodora*, calanoid copepods, and dipterans (chironomids, chaoborids, and ceratopogonids). The larger specimens also utilized aquatic insects as well as juvenile black basses (*Micropterus* sp.) and bluebacks. Piscivory was recorded from July through September 1998 and December 1998 with a peak in September (50% of sample, n=2, contained fish). Piscivory also occurred during 1999 in May (6.7% of all fish examined, n=30) and June (23.3%, n = 30). The best sampling method for blueback herring was gill netting with mesh sizes ranging from 0.95-2.54 cm. Electrofishing was effective only in mid-December when fish were in riverine portions of the lake. Only three larval blueback were collected in light traps during the study, proving that light traps were ineffective for collecting larval and juvenile blueback herring. Blueback herring were found to have an upper thermal preference of 25° C and can tolerate dissolved oxygen levels as low as 1.4 mg/L. as well as pH levels of 4.4.

TABLE OF CONTENTS

LIST OF TABLES

Table # Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Blueback herring (*Alosa aestivalis*) were first recorded in 1996 in Lake Chatuge, a storage reservoir located on the border of southern North Carolina and northern Georgia. They were discovered during the annual shad census collections conducted by the North Carolina Wildlife Resources Commission (NCWRC). The presence of bluebacks raised concerns about how they got into Lake Chatuge and what impacts could be realized as a result of their introduction. According to David Yow (NCWRC, personal communication), the introduction of blueback herring (BBH) was a result of incidental stockings. They were introduced as young of the year (YOY) with stocks of YOY threadfin shad, (*Dorosoma petenense*), which were intended to bolster the existing forage population after severe winter kills in 1993. It was also hypothesized that additional introductions occurred by way of angler introductions, i.e., bait-bucket stocking, since Chatuge is known to possess a trophy hybrid-striped bass (*Morone saxatilis* x *M. chrysops*) fishery (A. Rayburn and R. Weaver, Georgia Department of Natural Resources (GADNR), personal communication; D. Yow, NCWRC, personal communication).

The blueback herring is an anadromous clupeid closely related to the alewife, *Alosa pseudoharengus*. It is a sight feeder (Janssen 1982) and displays a size selective feeding behavior (Guest and Drenner 1991; Davis 1987). It is indigenous to the North American Atlantic coast from Nova Scotia to north Florida (Hildebrand 1963; Scott and Crossman 1973) with no historical records of land-locked populations. Populations of land-locked blueback herring can now be found in North and South Carolina (Prince and

Barwick 1981), Georgia and Tennessee (A. Brown, Tennessee Valley Authority (TVA), personal communication), and Virginia (Jenkins and Burkhead 1993). These populations of land-locked blueback most probably resulted from angler introductions, incidental introductions, and intentional stocking. New York, Vermont, and Virginia also possess land-locked populations of blueback herring (Fuller et al. 1999).

The introduction of an exotic fish species raises questions concerning the potential ecological impacts of that species on the body of water into which it was introduced. Exotic species of fish may facilitate impacts such as, but not limited to, the introduction of parasites and diseases, overcrowding, habitat changes, excessive competition for food resources, and predation of indigenous species (Taylor et al. 1984). In October 1995, the first record of blueback herring from Lake Ontario was documented with two juvenile blueback herring being collected (Owens et al. 1998). The authors voiced concern that colonization of blueback herring would possibly impede the recovery of native fishes, echoing the concerns of Taylor et al. (1984), through larval or juvenile predation and interspecific competition (Owens et al. 1998). Adding the variable of planktivory, different questions arise.

Should the introduced species be a planktivorous fish, impacts by that species could negatively affect the zooplankton community of a body of water by restructuring the zooplankton community's composition and size as reported for alewives (Warshaw 1972) and blueback herring (Guest and Drenner 1991). The introduction of a planktivorous fish may also affect the productivity of a body of water by altering the existing trophic interactions should a population be established (Carpenter et al. 1985). This follows the idea of 'cascading trophic interactions' where lakes having comparable nutrient supplies but possessing dissimilar food webs, have varying levels of productivity due to decreased or increased levels of piscivorous, planktivorous, herbivorous, or phytoplankton biomass (Carpenter et al. 1985). The authors explain by stating, "...a rise in piscivore biomass brings decreased planktivore biomass, increased herbivore biomass, and decreased phytoplankton biomass..." (Carpenter et al. 1985).

In the event the exotic species is a forage fish, new questions arise; however, the same basic, ecological undertones remain as stated by Kohler and Ney (1981). The authors stated that for a forage fish to be desirable, the species had to possess certain characteristics. The exotic species should be: (1) self-sustaining, (2) trophically efficient, (3) desirable and available to predators, (4) having positive effects on sport fish growth, (5) available as prey all it's life cycle, (6) non-emigrating, and (7) lacking of adverse interspecific impact. One example of negative forage fish characteristics occurred in 1982-83 in Watauga Reservoir, Tennessee. Stocked alewives collected from the reservoir were found to be preying on zooplankton species used by YOY game fishes (Strange et al. 1985) thus violating Kohler and Ney's (1981) seventh characteristic. The Watauga alewives were also found to have three age classes (0+, 1+, 2+) of which only one age class (age 2) was reproducing, thus presenting a "...potentially unstable population" (Strange et al. 1985). Bulak and Walker (1979) reported the ability of blueback herring to consume juvenile largemouth bass (*Micropterus salmoides*). These facts contribute to the consensus that BBH are not a desirable forage introduction.

If forage fish display piscivorous behavior, either obligatory or opportunistic, the reproduction and recruitment of indigenous fishes, both game and non-game species, could suffer due to additive mortality (Kohler and Ney 1980). In past studies blueback herring have been shown to display piscivorous behavior (Bulak and Walker 1979; Davis 1987; and Goodrich and Wilson 2000). In an unpublished study conducted by the Georgia Department of Natural Resources (GADNR) and the University of Tennessee at Knoxville (UTK), adult blueback herring, YOY bluegill (*Lepomis macrochirus*), and YOY largemouth bass (LMB) were collected from Lakes Nottley and Burton during 1998-99 and 1999, respectively (Goodrich and Wilson 2000). The purpose of that study was to determine the composition and similarities of the three species' diets after the numbers of age 0 largemouth bass began to decline in 1996 and 1997 (R. Weaver, GADNR, personal communication). The study revealed that blueback herring from Lakes Nottley and Burton preyed on LMB and BBH juveniles from April through June 1999, with opportunistic piscivorous behavior being displayed by individuals averaging 137 mm total length (TL) (Goodrich and Wilson 2000); these fish were estimated to be two-year-old fish (A. Rayburn and R. Weaver, GADNR, personal communication) which agreed with the lengths at age observations of Pardue (1983). An increase in piscivory on Lake Nottley from 0.07 percent in 1998 to 6.8 percent in 1999 while piscivory in Lake Burton was recorded at 18.6 percent in 1999 (Goodrich and Wilson 2000). The study also found that the bluebacks consumed many of the same prey items that were consumed by the YOY bluegill and YOY largemouth bass suggesting possible interspecific competition for food resources.

Questions concerning economic impacts cannot be overlooked since many states generate funding for their natural resources programs through the sales of fishing licenses and gain tax revenue through sale of equipment (Balon and Bruton 1986). Fishing and aquatic businesses also provide salaries to residents for products and services rendered, as suggested by Balon and Bruton (1986).

Due to the limited literature sources concerning the land-locked blueback herring's food habits and ecology, managers and biologists have little documented information on which to plan management strategies. Information concerning the management of blueback herring, the potential problems presented by their presence, and methods of collecting blueback herring is, at best, limited. Most of that information is derived and extrapolated from studies and experiences involving anadromous blueback herring and alewife and not land-locked blueback herring (Domermuth 1972; Scherer 1972; Pardue 1983).

When a biologist suspects that BBH are present in a body of water, do they have the technical information and resources required to sample the perspective body of water effectively? To better manage exotic and native fish species, answers to questions concerning interspecific competition for food resources among larval, juvenile, and adult fishes are needed. Information concerning niche competition between exotic and native species, impacts on the planktonic community, and the effects of the exotic species on indigenous communities also needs to be available for better management. However, due to the limitations of funding for studies and research, the previous questions are not always addressed; therefore, the objectives for this project were clear.

The purpose of this project was to gain a further understanding of blueback herring biology in its land-locked form. The specific objectives were as follows: (1) to document dietary composition of blueback herring, (2) to document habitat preferences of blueback herring, including water quality parameters affecting their presence or absence, (3) to provide information about the best sampling methods for larval and adult blueback herring, and (4) to provide insight on the role blueback herring play in the trophic ecology of Lake Chatuge.

CHAPTER II

DESCRIPTION OF STUDY AREA

Lake Chatuge is a located on the southwest border of North Carolina and northeast Georgia in the counties of Clay and Townes, respectively (Figure 1). Construction of Chatuge Dam began on 17 July 1941 and the reservoir began filling on 12 February 1942 (Townes County GA, Chamber of Commerce 2001). Chatuge Dam is located on the Hiwassee River, approximately 6.4 km (4 miles) southeast (upstream) of Hayesville, NC, at river kilometer 194.7 (HRM 121) (TVA 1941). It can be described as a dendritic, monomictic, oligotrophic mountain reservoir typical for the region. Lake Chatuge has 170.6 km (106 miles) of main shoreline and an area of 2853 hectares (7,050 acres) at an average summer pool elevation of 587.7 m (1928 ft) above mean sea level (TVA 1941). The drainage area for Lake Chatuge is 304 square kilometers (189 square

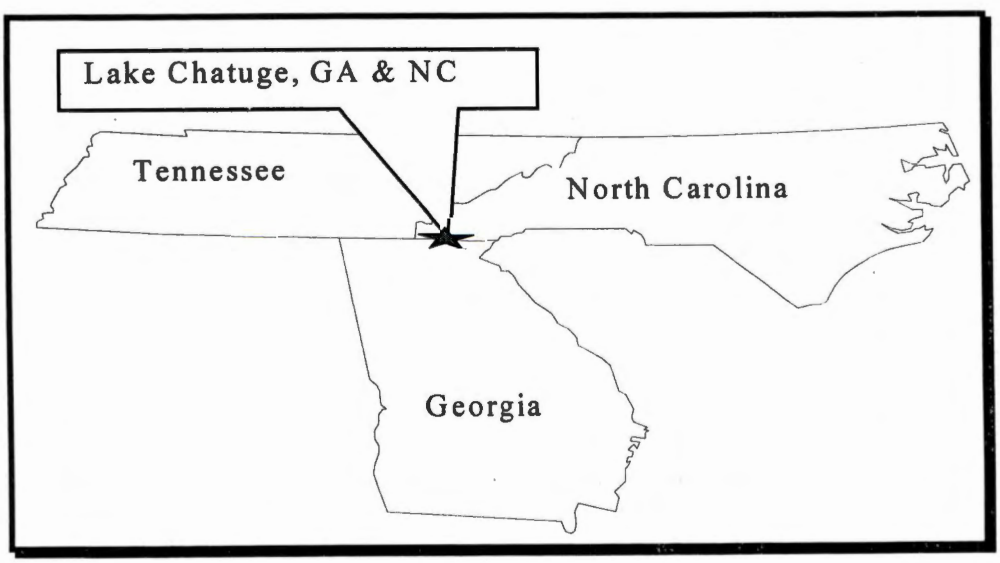


Figure 1. Location of Lake Chatuge on the border of North Carolina and Georgia.

miles) at the dam (TVA 1941). Water level fluctuates on average 4.6 m (15 ft) during a typical year, between summer and winter pool (TVA 2001).

Most of the blueback herring collections were taken from the North Carolina portion of the lake. However, periodic collections from the Georgia portion of the reservoir were made when personnel from the GADNR were collecting fish and/or were available to help with our collections.

A total of 24 sites were sampled during the project from April 1998 through June 1999 (Table 1 and Figure 2), which included 12 existing shad census sites (primary sites) used by the GADNR and NCWRC to successfully collect blueback herring. Twelve additional sites (alternative sites) were added in July 1998 in an effort to increase numbers of blueback herring collected and to document the blueback herring's spatial preferences (vertical distribution, temperature requirements, and substrate choice) in Lake Chatuge, due to their proximity to deeper water and other substrate types. The shad census sites were designated as N 1-8 for the North Carolina sites and GA 1-4 for the Georgia sites. The additional sites were designated by adding the letter A (for adjacent to) to a census site designator or using the name of the branch, cove, creek, or the area from which the sample came.

Table 1. Primary and alternate sites locations of the North Carolina Wildlife Resources Commission annual shad census sites:

Primary Sites:	
1. N-1 Chamber's Cove	7. N-7; Burrell Cove
2. N-2 Shooting Creek	8. N-8; Sneaking Ck at McIntosh Cove
3. N-3 Jackrabbit Cove	9. GA-1; Bell Creek area
4. N-4 Philadelphia Church Cove	10. GA-2; Hog Creek, west of Pt. 12
5. N-5 Chatuge Saddle Dam 2	11. GA-3; Long Bullet Creek
6. N-6 Clay County Park	12. GA-4; Woods Creek
Alternative Sites:	
1. N-2A; NC	7. Gibby Island; NC
2. Towns County Park; GA	8. Hog Creek; GA
3. Armstrong Cove; NC	9. Brown Island; NC
4. Point 5; GA	10. Sutton Branch; GA
5. Merry Island; NC	11. Chatuge Dam; NC
6. Mouth of Hog Creek; GA	12. Woodring Branch; GA

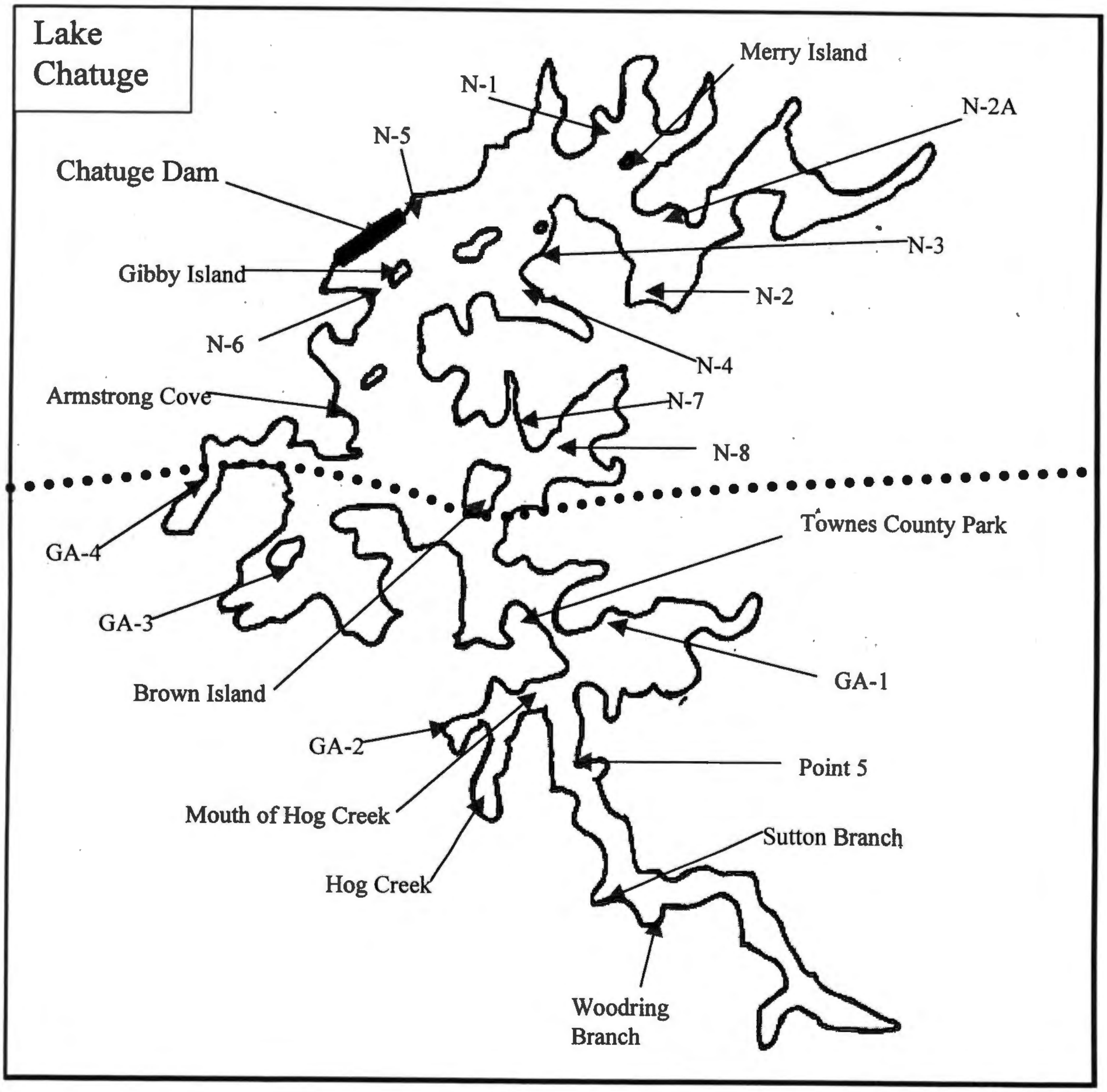


Figure 2. Locations of Lake Chatuge sample areas used during the study. Areas above the dotted line are located in North Carolina, with the dam facing northwest, while those below the line are located in Georgia.

CHAPTER III

METHODS

Sampling was initiated on a monthly basis in 1998. The sampling period was April through October for 1998, with the April samples being collected by the NCWRC during their annual shad census. However, after no collections in May 1998 due to equipment failure and limited catch success during June, it was decided to conduct future sampling on a bi-weekly basis beginning in July. In September 1998, the sampling period was extended through December, with collections reverting back to a monthly basis, due to low numbers of BBH collected up to that time. It was also decided, after examining the 1998 data, to continue collections during 1999 from March through June due to low funding and lesser occurrences of BBH during mid- and late-summer months.

Equipment

Due to their passive collection nature and their ability to collect numerous target organisms at one time, gill nets are a common method used by most state and federal resource agencies for the purpose of monitoring fish populations. This method has been used in fisheries for a range of purposes including population analysis and niche partitioning. The use of gill nets in this study, as the primary collection method, provided greater efficiency by allowing a crew to set several nets in different locations, conduct electro-shocking collections when feasible, and then return to pull the nets in the same day.

Two types of experimental gill nets and three different sizes of standard gill nets, Type 3, were used in the collections (Table 2). The Type 1 net were provided by the NCWRC and was used during the March through August 1998 collections. The Type 2 net was used during the 1998 and 1999 collections while Type 3 nets were used only during the 1999 collections. Larval light traps were provided by the courtesy of the Tennessee Valley Authority (TVA). The light traps were circular in design utilizing a 0.476-cm gap opening for organism entrance and a 20.32 cm chemical light stick (yellow-green) as the light source. Electrofishing was conducted as an expedient search method using a 5000-kilowatt generator and a Smith-Root converter box. Shocking was conducted using 30-minute blocks of time along shoreline and littoral areas. Water quality parameters were measured using a Hydro-lab (Datasonde Surveyor II) and turbidity was measured using a Secchi disk.

Table 2. Physical measurements and numbers (No.) of gill nets used during 1998-99 on Lake Chatuge.

Net Type Year Used	Length (m)	Depth (m)	No. Used	Bar Mesh (cm)	Number Panels
Experimental 1998-1999					
1	53	2.42	8	0.95, 1.59, 2.22, 2.86, 3.49, 4.13, 4.76, 5.40	8
2	30	1.82	6	1.27, 1.91, 2.54, 3.18, 3.81	5
Standard 1998					
1	53*	2.42	2	1.27	1
2	53*	2.42	2	1.91	1
3	53*	2.42	2	2.54	1

* Nets were used in vertical sets during the summer 1999 sampling period.

Gill Nets

Gill nets were selected as the primary collection method for adult blueback herring as a result of their versatility and efficiency in determining spatial data. The only possible negative effect of gill netting would be stress-induced regurgitation, thus biasing the data from our project towards those fish with empty stomachs. Therefore, the duration of the net sets were based on the observed fullness of the blueback stomachs. Inclement weather and water temperature were also limiting factors in determining set duration.

Gill nets were set along the bottom, within the water column (suspended), and on the surface to locate those areas and depths used by bluebacks were using. Nets set in the water column were suspended diagonally and horizontally with exception of those set vertically from the surface to the bottom. All nets were marked with 35.6-cm orange bullet floats and tethered to concrete anchors weighing 1 to 3 kg by 30-m lengths of 0.635-cm cotton-poly rope attached to a rope caddy. The 30-m ropes allowed for fishing the nets in deeper waters along the main channel area of the reservoir. Experimental nets were set with the smallest mesh being alternated from the shallow to the deep end of the set. Nets were also set horizontally and perpendicularly in relation to banks of the sample sites.

Light Traps

Larval light traps were used to evaluate their ability to collect larval and juvenile (young of the year) blueback herring. The light traps were selected for their ease of use and less intensive sampling characteristics. In addition, they could be deployed in a static manner and the collected organisms were subjected to minimal stress. The use of light traps also provided an opportunity to gain a further understanding of the planktonic and invertebrate organisms available in the study areas.

Light traps were set randomly among those sites sampled during each effort at various depths to collect larval and juvenile BBH and to avoid patchy blueback herring and prey occurrence by sampling one area. The light traps were set only in the littoral areas of the lake where YOY bluebacks had previously been collected (D. Dennerline, Georgia Cooperative Fish and Wildlife Research Unit, personal communication) during the summer in shallow coves of other lakes using haul seines. Set duration for the light traps was similar to that of the gill nets.

Electroshocking

Due to the pelagic behavior of blueback herring, electroshocking would be utilized as an accessory collection method if the blueback herring were reported or noted in water suitable for shocking. Suitable water was defined as, for the purpose of this study and due to the equipment available, less than 2.5 m in depth with a surface temperature of less than 27° C. Shocking runs were conducted using 30-minute shoreline transects. Fish collected during electroshocking were placed in a 379-L live well to recover and for holding purposes until positive identification was made and preservation of BBH was completed.

Hydro-Lab and Secchi Disk

Basic water quality parameters associated with those areas and depths where the BBH were collected were documented in order to possibly define those factors limiting the distribution of the blueback herring. Water quality parameters typically affecting the absence or presence of fishes are dissolved oxygen (DO), temperature, and pH. A

Datasonde Surveyor II Hydro-Lab (courtesy of the Oak Ridge National Laboratory, Environmental Sciences Division) was used to measure levels of DO, temperature, and pH. Water quality parameters were measured and recorded for each area sampled during the study; a standard Secchi disk was used to measure turbidity. Values obtained were averaged for each month.

Sample Preservation and Preparation

Blueback Herring

Blueback herring were placed immediately on ice once they were removed from the gill net or dip net. After returning to the launch area a small incision was made just anterior of the gut and posterior of the opercle in the abdomen to facilitate formalin dispersal for maximum preservation. Fish were then placed in 10% formalin for 1 to 2 hours. Fish were not stored in formalin for long periods of time to prevent changes in weight and lengths (Anderson and Neumann 1996). The bluebacks were then removed from the formalin, rinsed in fresh water, blotted dry, placed in labeled freezer bags, and frozen until further processing in the laboratory.

Once the fish were in the lab and processing was initiated, the freezer bags of bluebacks were placed in 17 L of fresh water and thawed. By thawing the fish in the freezer bags, the possibility of water absorption was eliminated thus reducing the biasing of fish weights. When the fish were completely thawed (usually approximately 8 hours in water), they were removed and blotted dry, thereby trying to simulate the same conditions as when they were stored. Lengths and weights were then taken and recorded.

Total lengths to the nearest 0.1 mm were recorded for each month's sample to establish size classes, i.e., 100 to 109 mm, etc. Representatives from each size class would then be proportionately selected to make up the 30-fish sample for each month. The working sample would then be weighed to the nearest 0.01g, lengths re-measured, and those data recorded. The bluebacks would then be ready for evisceration, otolith removal, and scale removal.

Light Trap Samples

Organisms collected from the light traps were washed into 1.0-L jars using lake water. The water was then strained off and contents of the light trap were placed in 10% formalin to preserve the collected organisms (Bowen 1996). Once the light trap samples were returned to the lab, the formalin was strained off and the samples were rinsed several times in fresh water and replaced in 50% propanol for storage and handling purposes (Bowen 1996).

Sample Processing

Scales

Scales were collected from each fish for scale age analysis prior to evisceration and otolith removal. The scales were taken from just below the lateral line and beneath the tip of the pectoral fin as recommended by DeVries and Frie (1996). Scales were pressed between acetate slides for aging purposes. However, if slides were unreadable, the use of a dissecting microscope and reflected light on the scales were used to determine the age. Age analysis from scales, for the purpose of the study, was to provide information for future age analysis using the otoliths collected from the samples.

Otoliths

To remove the sagittal otoliths and stomachs from each fish, three cuts on three different transects were made (Figure 3). The Isthmus Cut severed the isthmus just ventral to the spine; the Operculum Cut allowed removal of the opercles covering the gills; and the Abdominal Cut oriented diagonally along the mid-line of the abdominal cavity from the esophagus to the anal opening allowed for complete evisceration. After cuts 1 and 2 were made, the ventral portion of the skull was accessible for otolith removal. Fine point scissors were used to make a transverse cut on the ventral portion of the skull, where it flares slightly, allowing the head to be removed, exposing the otoliths. Otoliths were then placed in 5.0-ml vials containing glycerin to enhance the clearing process for future age analysis.

Stomach Contents

The Abdominal Cut facilitated complete visceral extraction; all viscera were visually examined for abnormalities. The esophagus and stomach were separated from the pyloric cecum and other viscera, and then stored in 50% propanol in numbered 40-ml

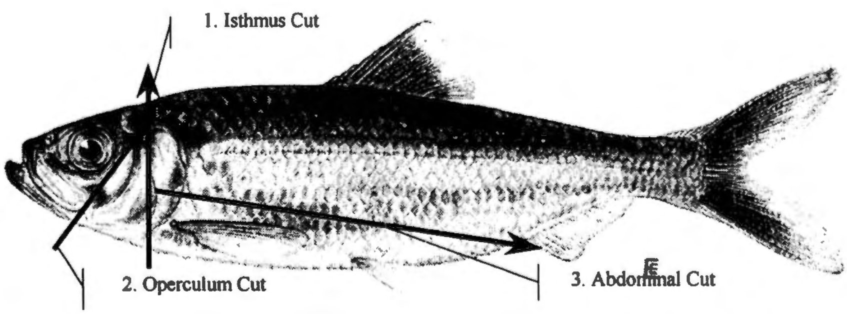


Figure 3. Diagram of the Isthmus, Operculum, and Abdominal Cuts used in collecting the otoliths and stomachs. Modified from New York State Department of Environment and Conservation's website.

vials. During further examination, stomachs were removed from each vial, blotted dry, and weighed to the nearest 0.01 g. Each stomach and associated esophagus was cut longitudinally using a pair of fine point dissecting scissors or safety razor. The contents were removed and examined, using a Cambridge Instruments Stereo-zoom 4 (0.7 – 3X magnification) dissecting microscope and a 2X magnifier, to document basic composition and fish remains. Stomach contents were then replaced in their respective vial with fresh 50% propanol until detailed analysis could be conducted. It was thought that replacing the contents in fresh propanol would help loosen and promote separation of the prey organisms that were occasionally clumped together. When fish remains and unknown food items were encountered, those items or were placed in a separate vial numbered correspondingly to the fish from which it came.

Quantification of Sub-Samples

Due to the possibility of adult BBH having thousands of organisms in their stomachs (Davis 1987; Goodrich and Wilson 2000), a method for sub-sampling each stomach was needed. In his master's thesis, Davis (1987) developed a regression equation for "Estimated Counts" of organisms per stomach for BBH after establishing that using a multiplier of 10 (by taking a 10-mL sub-sample from a 100-mL sample) gave inaccurate estimations due to the sample being over-sampled (inflated numbers of some organisms). Consultation with a University of Tennessee statistician (Dr. A. Saxton, personal communication) revealed after reviewing Davis' (1987) methods and regression equation, that using a sample volume of 100 mL per stomach gave too much volume to sub-sample accurately due to the different densities (how each type of prey would float or sink in the suspension medium) of each taxa of organisms. Dr. Saxton suggested using a 20-mL sample volume and a 1.0- or 2.0-mL sub-sample volume. After a battery of 1.0- and 2.0-mL sub-sample pre-tests, it was determined that the 1.0-mL sub-sample was the most numerically accurate. Variation between estimated numbers and total counts of the test stomachs averaged +/- 5.0 percent.

Sub-samples were taken using a 1.0-mL Henson-Stemple pipette from a 50-mL beaker filled with 20 mL of 50% propanol. The contents of each stomach or group of stomachs was placed in 20 mL of propanol and stirred to mix well. The 1.0-mL sample was removed while the solution was still swirling and placed in a 7.62-cm petrie dish with approximately 5.0 mL of additional alcohol for emersion purposes. Sub-samples were viewed using the dissecting microscope and the 2X magnifier previously mentioned, and counted using a hand held, four digit, clicker counter to count each organism from each taxon in the sub-sample.

Identification of Prey Items

Prey organisms were identified to the lowest possible taxon using various references except for copepods, which were identified to suborder. Juvenile fish were identified using *The Fishes of Tennessee* (Etnier and Starnes 1993), zooplankton were identified using the 3rd edition of *Fresh-Water Invertebrates of the United States* (Pennak 1989). Aquatic insects were identified using *Aquatic Insects and Oligochaetes of North and South Carolina* (Brigham et al. 1982) and *Nymphs of North America Stonefly Genera (Plecoptera)* (Stewart and Stark 1988).

Dietary Composition

The dietary composition of blueback herring was determined by inspection and identification of whole organisms and digested remains. Whole and slightly digested organisms did not present a problem in counting and identification. However, to document numbers and taxa of organisms in a more advanced stage of digestion, a method for accurately identifying and counting each organism was needed. During the initial examination of the gut contents, it was noted that the hard parts of organisms, such as the carapace, head capsule, scales, other sclerotized pieces, and vertebrae, were common in the stomachs containing prey items that were moderately to highly digested. Therefore, a prey organism was identified only if there were discernible parts available. If the contents of a stomach were completely digested, the identification was documented as unidentifiable. The presence of scales, vertebrae, other bony parts, as well as whole or partially digested fishes, determined fish presence; the presence of antenna, carapace, fifth leg, and the whole organism determined cladoceran presence; the presence of antenna, metasome, urosome, and the whole organism determined copepod presence; the presence of head capsule, body segments, and whole bodies determined dipteran presence; the presence of gills, cerci, head capsule, and the whole organism determined the presence of ephemeropterans; the presence of cerci, head capsule, and the whole organism determined the presence of plecopterans; the presence of head capsule and the whole organism determined the presence of odonates; the presence of a prosternum, meso- and metasternum, abdomen, elytron, and whole organisms defined the presence of coleopterans; and the presence of other organisms was defined by the presence of whole organisms and cases, such as conchostracans, decopods, gastropods, hydracharinids (water mites), ostracods, and Trichoptera cases.

Light Trap Samples

All organisms in the light trap samples were identified to the lowest possible taxon identified in the stomach samples. All organisms were enumerated to determine percentages of each taxon present in order to compare to the percentages of taxa found in the stomachs. Numbers and percentages of organisms were recorded by month for the duration of the study.

CHAPTER IV

RESULTS AND DISCUSSION

A total of 792 blueback herring were collected from April 1998 to June 1999 from Lake Chatuge, GA/NC, using gill nets and electroshocking. Of the 236 BBH collected in 1998 from April to December, the majority (n=199) were collected with gill nets; in 1999 during the four-month collecting period (March through June), all BBH (556) were collected with gill nets, even though some electroshocking collections were made. The only time that electroshocking was effective was during December 1998 in the more riverine portions of the reservoir. Numbers of blueback herring collected and the net type in which they were collected in presented in Table 3.

This study obtained much-needed information concerning the sampling efficiency of gill nets and electroshocking for landlocked blueback herring in Lake Chatuge, as well as documenting their diet and habitat preferences within the reservoir. To facilitate a clearer understanding of how blueback herring fit into the ecology of the reservoir, the 1998 and 1999 data will be reported and discussed together.

Gill Nets

1998

Blueback herring collected from April through June 1998 were captured in the Type 1 experimental gill nets provided by the NCWRC. Type one gill nets were 53 m long and had eight panels with one panel each of 0.95, 1.59, 2.22, 2.86, 3.49, 4.13, 4.76, and 5.40-cm bar mesh netting. Collections of BBH from July through October 1998 and December 1998 incorporated both Type 1 and Type 2 experimental gill nets. The Type 2

Table 3. Numbers of blueback herring collected during 1998-99 and the net types used. Bold characters indicate fish caught using Type 3 nets as vertical gill nets.

Month	No. Fish	Type 1	Type 2	Type 3 (1.27 cm)	Type 3 (1.91 cm)	Type 3 (2.54 cm)
1998						
April	80	80	N/A			
May	0	0	N/A			
June	13	13	0			
July	10	5	5			
August	8	0	8			
September	2	0	2			
October	17	17	0			
November	0	0	0			
December	80	18	62			
Total	210	133	77			
1999						
March	145	0	79	28	36	2
April	332	274	58	0	0	0
May	46	0	37	3	6	0
June	33	0	13	**7**	**12**	**1**
Total	556	274	187	38	54	3

nets were 30 m in length and had five panels with one panel each of 1.27, 1.91, 2.54, 3.18, and 3.81-cm bar mesh netting. November was the only month during the 1998 season in which Type 2 nets were exclusively used. The physical measurements of net Types 1 and 2 are presented in Table 2, found on page 12.

Gill net collections in 1998 indicated that panels 1, 2, and 3 of Type 1 nets, with bar mesh lengths of 0.95, 1.59, and 2.22 cm, respectively, were the only panels containing blueback herring, which ranged from 84 to 206 mm TL. The addition of Type 2 nets in July 1998, with panels 1, 2, and 3 having a bar mesh length of 1.27, 1.91, and 2.54 cm, respectively, also collected bluebacks ranging in length from 92 to 206 mm TL. Two collections were made during October in which the only BBH collected came from panels 1, 2, and 3 of net Type 1. The November sampling was conducted using only Type 2 nets with no BBH captures. The December sampling was conducted using Type 1 and Type 2 gill nets, the former furnished and fished by the GADNR. Blueback herring netted during the December sample were caught in panels 1, 2, and 3 of Type 1 and Type 2 nets. Bar mesh sizes of each panel for net Types 1 and 2 and the size range of BBH collected by that panel are listed in Table 4.

1999

Collections of blueback herring from March through June 1999 were similar to the 1998 collections with the addition of net Type 3. Net Type 3 was 53 m with one continuous panel. There were three mesh sizes of Type 3 nets: 1.27-, 1.91-, and 2.54-cm bar mesh. The physical measurements of gill net Types 1, 2, and 3 are presented in Table 2 located on page 12.

Collections of blueback herring from March through June 1999 were made using net Types 2 and 3 nets, while April 1999 was the only month where Type 1 nets were used. Collections from March through April indicated that only panels 1, 2, and 3 of net Types 1 and 2, and each size of net Type 3, were the only panels that collected bluebacks. These findings suggested that gill net panels having bar mesh lengths of 0.95, 1.27, 1.59, 1.91, 2.22, and 2.54-cm were most effective in collecting blueback herring from Lake Chatuge in 1999. Blueback herring netted from March through June 1999 were collected using the same size bar mesh lengths as those bluebacks collected in 1998. Bar mesh sizes and size ranges of BBH collected in 1999 for each panel of net Types 1, 2, and 3 are also listed in Table 4.

Observations from the 1999 sample season also indicated that gill net panels

Table 4. Bar mesh sizes (cm) and size ranges of blueback herring collected in 1998 and 1999 for each respective panel for net Types 1, 2, and 3.

1998			1998		
Type 1			Type 2		
Panel	Bar Mesh (cm)	Size Range (mm)	Panel	Bar Mesh (cm)	Size Range (mm)
1	0.95	84 - 102	1	1.27	92 - 102
2	1.59	126 - 177	2	1.91	126 - 185
3	2.22	186 - 206	3	2.54	186 - 206
4	2.86	-	4	3.18	-
5	3.49	-	5	3.81	-
6	4.13	-	-	-	-
7	4.76	-	-	-	-
8	5.4	-	-	-	-
1999			1999		
Type 1			Type 2		
Panel	Bar Mesh (cm)	Size Range (mm)	Panel	Bar Mesh (cm)	Size Range (mm)
1	0.95	84 - 102	1	1.27	92 - 102
2	1.59	126 - 177	2	1.91	126 - 185
3	2.22	186 - 206	3	2.54	186 - 206
4	2.86	-	4	3.18	-
5	3.49	-	5	3.81	-
6	4.13	-	-	-	-
7	4.76	-	-	-	-
8	5.4	-	-	-	-
1999					
Type 3					
Panel	Bar Mesh (cm)	Size Range (mm)			
Net 1	1.27	100-200			
Net 2	1.91	124-198			
Net 3	2.54	195-226			

having a bar mesh length of greater than 2.54 cm were ineffective for collecting the landlocked BBH. Net panels 1, 2, and 3 of Type 1 nets having bar mesh lengths of 0.95, 1.59, and 2.22 cm collected BBH ranging from 84 to 206 mm TL. Net Panels 1, 2, and 3 of Type 2 nets having bar mesh lengths of 1.27, 1.91, and 2.54 cm collected specimens ranging from 92 to 206 mm TL. It should be noted that panels 1, 2, and 3 of net Type 2 and the Type 3 nets had similar mesh sizes. However, Type 3 net collections showed a wider range in total lengths of blueback herring collected except for panel 3. The 1.27-cm Type 3 net collected BBH ranging from 100 to 120 mm TL rather than 92–102 mm as collected in panel 1 of Type 2 nets. The 1.91-cm Type 3 net collected blueback herring 124 to 198 mm TL rather than the 126–185 mm bluebacks collected in panel 2 of Type 2 nets. Lastly, the 2.54-cm Type 3 nets collected fish ranging from 195 to 226 mm in TL rather than the 186–206 mm bluebacks collected in panel 3 of Type 2 nets. Panels having bar mesh lengths of 0.95, 1.27, 1.59, 1.91, 2.22, 2.54 cm were the most effective for collecting BBH in Lake Chatuge during 1999.

In summary, observations from the 1998 and 1999 sample seasons indicated that gill net panels having a bar mesh of greater than 2.54 cm were ineffective for collecting the landlocked BBH in Lake Chatuge. During 1998-99 seasons, the experimental gill net panels having bar mesh sizes of 0.95, 1.59, and 2.22 cm collected blueback herring ranging from 84 to 206 mm TL while panels having bar mesh lengths of 1.27, 1.91, and 2.54 cm collected BBH ranging from 92 to 206 mm TL. The Type 3 nets (standard gill nets) collected bluebacks ranging from 100 to 226 mm TL. This study indicated that net Types 1, 2, and 3 were proficient in collecting blueback herring at different times of the year, depending on the size of the herring. Don Dennerline (Georgia Cooperative Fish and Wildlife Research Unit, personal communication) related that due to the blueback's rapid growth rate, the use of only one mesh size net for his collections would have missed catchable fish. Therefore, optimal collections would be made using an experimental gill net having one panel each of 0.95-, 1.27-, 1.59-, 1.91-, 2.22-, and 2.54-cm bar mesh.

CPUE 1998-1999

The catch per unit effort (CPUE) values varied greatly from April through December 1998; they ranged from 0.0 (November) to a high of 0.65 in December. The higher value for April was attributed to pre-spawn movements (Skjeveland 1982; Pardue 1983) while December value was attributed to winter migrations (A. Rayburn and R. Weaver, GADNR, personal communication). The (CPUE) values for March through June 1999 were 1.59, 0.72, 0.34, and 0.07, respectively. The higher values for March and April are attributed to pre-spawn and spawning movements (Skjeveland 1982; Pardue 1983). The low values from June through November 1998, and the declining values for March through June 1999 prompt questions about the strength of the blueback population. Catch per unit effort for 1998 and 1999 are presented in Table 5.

Collections from a population, using passive collection methods, that is abundant would have lesser numbers collected in the beginning and increasing with familiarity and proficiency of collecting until the target population began to suffer from over-harvest (Hubert 1996). Hubert (1996) also stated that populations that are not abundant are often times identified by a greater beginning collection frequency and tailing off rapidly with each additional collection. Therefore, based on Hubert's (1996) writings, the results of the 1998-99 collections suggest that the blueback herring population in Lake Chatuge

Table 5. Number of fish collected, net types used, bar mesh sizes, depth sampled, net hours, and CPUE values for collections during 1998 and 1999.

Gill Nets							Electroshocking		
Month	No. Fish	Net Type	Bar Mesh Sizes (cm)	Depth (m)	Net Hours	CPUE	No. Fish	Hours	CPUE
Apr-98	80	1	0.95, 1.59, 2.22	0 - 3	128	0.63	-	-	-
May-98	-	-	-	-	-	-	-	-	-
Jun-98	13	1	0.95, 1.59, 2.22	0 -20	72	0.18	-	-	-
Jul-98	10	1 and 2	0.95, 1.27, 1.59, 1.91, 2.22, 2.54	0 - 21	272	0.04	-	-	-
Aug-98	8	1 and 2	1.27, 1.91, 2.54	5 - 20	356	0.02	-	-	-
Sep-98	2	2	1.27, 1.59	4 - 19	52	0.04	-	-	-
Oct-98	17	1	0.95, 1.59, 2.22	0 - 20	204	0.08	-	-	-
Nov-98	0	1	1.27, 1.91, 2.54, 3.18, 3.81	0 - 12	80	0	-	-	-
Dec-98	69	1 and 2	0.95, 1.27, 1.59, 1.91, 2.22, 2.54	0 - 17	124	0.65	37	2	18.5
Mar-99	145	2 and 3	1.27, 1.91, 2.54	0 - 3	91	1.59	-	-	-
Apr-99	332	1, 2, 3	0.95, 1.27, 1.59, 1.91, 2.22, 2.54	0 - 3	463	0.72	-	-	-
May-99	46	2 and 3	1.27, 1.91, 2.54	0 - 12	135	0.34	0	2.5	0
Jun-99	33	2 and 3	1.27, 1.91, 2.54	0-15	463	0.07	-	-	-

was, at best, not abundant and possibly poorly established during both years. The declining CPUEs for June through November 1998 as well as May through June 1999 may best be explained by the post-spawn movements of BBH to cooler and deeper waters (Pardue 1983).

Electroshocking

1998

As stated earlier, electroshocking was only an accessory method of collecting blueback herring should the fish be reported or noted in suitable waters i.e., less than 2.5 m in depth and having a surface temperature less than 27° C. Four 30-minute shoreline transects were conducted in December, two each in Bell Creek and Hog Creek, yielding 37 BBH; all bluebacks collected were found in areas having woody cover in the backs of creeks. This catch per unit effort (CPUE) of 18.5 fish per hour was related to increased blueback presence in the riverine areas as a result of winter migrations (R. Weaver, GADNR, personal communication). Numbers of blueback herring collected in December and their respective CPUE values are listed in Table 5 found on Page 28.

1999

In an effort to collect juvenile blueback herring, electroshocking was conducted for 2.5 hours during the month of May in 1999. The littoral areas of Sneaking Creek (N-7 and N-8), Philadelphia Church Cove, and Chatuge Dam were electroshocked with no success. Numbers of threadfin shad were found, but no bluebacks were seen.

The limited success during both the 1998 and 1999 electroshocking efforts suggested that this collection method was not very efficient for the collection of blueback herring in Lake Chatuge. This may be due, in part, to the pelagic nature of the adult BBH and the potential pelagic nature of juvenile BBH (Hewett and Stewart 1989); seining in littoral areas may be more effective for larval and juvenile BBH as suggested by Domermuth (1972), Scherer (1972), and Crecco and Blake (1983).

Light Traps

1998

Light traps were used from July through December in the 1998 samples. The use of traps for collection of blueback herring larvae and juveniles proved ineffective, only collecting three blueback juveniles in July which averaged 17 mm in length and weighed 0.5, 0.47, and 0.41 g. However, light traps did collect zooplankton and other larval and juvenile fishes from the areas sampled. Numbers of organisms, percent occurrence, and species composition of all 1998 light trap samples are presented in Appendix 1.

Results from the light trap study (Table 6) indicated that during July, dipterans (42.2%), miscellaneous organisms (31.8%), and cladocerans (13.2%) were most common types of organisms collected; BBH juveniles collected in July, represented 0.5% of the total collections. August collections were quite similar with dipterans (50%), miscellaneous organisms (32.2%), and cladocerans (11.3%) ranking 1st, 2nd, and 3rd in order of occurrence. In September, a shift in occurrence to cladocerans (69.1%), miscellaneous organisms (21.2%), and dipterans (9.6%) was seen with only those three groups being collected. The October sample documented miscellaneous organisms constituting 37.2% of the sample, with cladocerans constituting 35.4%, and dipterans

Table 6. Numbers (N) and percent occurrences (% OCC) of organisms collected in light traps during the 1998 Lake Chatuge sampling.

1998	N	% OCC	N	% OCC	N	% OCC
Organism	Jul-98		Aug-98		Sep-98	
Copepoda	53	8.2	17	1.6	-	-
Cladocera	85	13.2	122	11.3	381	69.1
Diptera	273	42.4	538	50.0	53	9.6
Coleoptera	-	-	-	-	-	-
Ephemeroptera	3	0.5	-	-	-	-
Odonata	4	0.6	-	-	-	-
Plecoptera	2	0.3	-	-	-	-
Trichoptera	3	0.5	-	-	-	-
Fish	16	2.5	53	4.9	-	-
Misc. organisms	205	31.8	346	32.2	117	21.2
Total	644	100.0	1076	100.0	551	100.0
1998	N	% OCC	N	% OCC	N	% OCC
Organism	Oct-98		Nov-98		Dec-98	
Copepoda			73	21.6	136	48.2
Cladocera	58	35.4	118	34.9	79	28.0
Diptera	45	27.4	96	28.4	34	12.1
Coleoptera	-	-	-	-	-	-
Ephemeroptera	-	-	-	-	-	-
Odonata	-	-	-	-	-	-
Plecoptera	-	-	-	-	-	-
Trichoptera	-	-	-	-	-	-
Fish	-	-	-	-	-	-
Misc. organisms	61	37.2	51	15.1	33	11.7
Total	164	100.0	338	100.0	282	100.0

registering 27.4%; in November, cladocerans were the most often collected organism (34.9%).

1999

Light traps were used from March through June in the 1999 samples. The use of light traps for collection of blueback herring larvae and juveniles proved ineffective since no blueback herring were collected during the 1999 season. However, light traps did collect zooplankton as well as other larval and juvenile fishes, which provided an idea of the prey base available. Percentages, numbers, and species composition of all 1999 light trap samples are presented in Appendix 3.

Results from the light trap collections indicated that during March, cladocerans (45.1%), miscellaneous organisms (23.4%), and copepods (16.0%) were the three most abundant organisms present. In April, the study found cladocerans (44.8%) again ranked first in abundance with dipterans (29.6%) and miscellaneous organisms (21.5%) ranking second and third. There was a shift in rankings in May with miscellaneous organisms (64.2%) ranking first followed by cladocerans (31.6%) and dipterans (3.1%). Cladocerans regained the first ranking in June (39.8%) with miscellaneous organisms (25.8%) and dipterans (19.2%) following. Numbers and percent occurrences, by order of organisms collected in light traps from Lake Chatuge are presented in Table 7.

The scarcity of juvenile BBH in the collections may be attributed to their being less than 'positively phototropic' as stated by Jessop (1990). For collections of larval and juvenile BBH, the author suggests the use of bag seines as described by Domermuth (1972), Scherer (1972), and Crecco and Blake (1983) as primary collection methods.

Table 7. Numbers and percent occurrences (% OCC), of organisms collected in light traps during the 1999 Lake Chatuge sampling.

Organism	N Mar-99	% OCC	N Apr-99	% OCC	N May-99	% OCC	N Jun-99	% OCC
Copepoda	39	16.0	49	3.8	111	0.9	457	13.8
Cladocera	110	45.1	578	44.8	3717	31.6	1314	39.8
Diptera	35	14.3	381	29.6	360	3.1	634	19.2
Coleoptera	-	-	-	-	-	-	2	0.1
Ephemeroptera	-	-	2	0.2	-	-	1	0.0
Plecoptera	-	-	-	-	-	-	1	0.0
Trichoptera	-	-	-	-	1	0.0	5	0.2
Fish	3	1.2	2	0.2	30	0.3	36	1.1
Miscellaneous	57	23.4	277	21.5	7556	64.2	851	25.8
Total	244	100.0	1289	100.0	11775	100.0	3301	100.0

Jessop (1990) found that using a bow-mounted pushnet with an opening of 1.5 m^2 with a 12.7-mm stretch mesh collected juvenile BBH in the St. John River.

Water Quality

Temperature, dissolved oxygen (DO), pH, and Secchi disk measurements were taken during each sampling effort July through December 1998 in an effort to distinguish possible limiting factors concerning the presence of blueback herring. Water quality measurements were taken at the surface and at 1.0-m increments to a depth of 10 meters; beyond 10 m, readings were taken every 2.0 m or until the bottom reading was recorded. Measurements taken for each site sampled were averaged and recorded by month. Gill nets were set accordingly and depths (both inshore and offshore) were noted. As nets were retrieved, the panels containing fish were noted and the depths at which blueback herring were collected were recorded. No readings were taken April through June while the Hydrolab was being reconditioned.

1998

The 1998 results indicated that a maximum surface temperature of 28.4° C occurred in August while the minimum-recorded surface temperature of 13.3° C occurred in December. Water quality measurements recorded during July through December 1998 are presented in Tables 8, 9, and 10. Monthly thermocline depths in Lake Chatuge (from July to December) occurred at the following depths: July, 8 m; August, 9 m; September, 12 m; October, 18 m; and November, 12 m. No thermocline was found in December, indicating complete mixing of reservoir waters. Levels of DO at the greatest depths (ranging from 12 to 21 m) varied greatly with a high of 9.3 parts per million (ppm) in December and a low of 0.2 ppm in September. The levels for pH ranged from a surface high of 7.0 in November to a surface low of 5.5 in September. The pH levels at the greatest depths (ranging from 12 to 21 m) ranged from a high of 6.5 in December to a low of 4.3 in August. The low pH values may be attributed to density drifts having acid precipitation entrained within.

1999

Data collection during 1999 indicated that a maximum surface temperature of 25.5° C occurred in June while the minimum recorded surface temperature of 10.7° C occurred in March. Physical measurements of the water quality parameters are shown in Table 11. Thermoclines in Lake Chatuge from April to June were recorded at the following depths: 8 m, 3 m, and 4 m, respectively; there was no thermocline found in March. Levels of DO at the greatest depths sampled, 10 to 15 m, varied greatly with a high of 12.1 ppm in May and a low of 7.2 ppm in June. The levels for pH ranged from a surface high of 7.8 in May to a surface low of 7.2 in March with high and low pH levels

Table 8. Average temperature, DO, pH, and water transparency values (Secchi disk) taken from Lake Chatuge in July and August 1998, including numbers (No.) of blueback herring collected at noted depths.

Jul-98	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH	Aug-98	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH
Depth						Depth					
0	27.7	8.5	6.5	2.84	-	0	28.4	8.5	6.1	2.81	-
1	27.8	8.5	6.5		-	1	28.3	8.5	6.1		-
2	27.7	8.4	6.5		-	2	27.7	8.6	6.3		-
3	27.7	8.4	6.5		-	3	27.5	8.6	6.3		-
4	27.6	8.4	6.4		-	4	27.4	8.6	6.3		-
5	27.5	8.3	6.4		-	5	27.2	8.5	6.1		-
6	26.7	8.7	6.1		-	6	27.0	8.3	5.8		-
7	24.6	8.4	5.7		-	7	26.5	7.7	5.4		-
8*	23.3	7.8	5.4		3	8	25.2	6.8	5.1		-
9	21.6	6.0	5.2		3	9*	23.8	5.4	4.8		2
10	19.5	4.5	5.1		2	10	22.3	4.5	4.7		4
12	18.0	3.9	5.0		2	12	19.9	3.1	4.5		3
14	16.2	3.8	5.0		-	14	18.4	3	5		1
16	15.6	3.1	5.0		-	16	17.4	2.4	4.3		-
18	14.8	3.7	5.2		-	18	17.5	2.6	4.3		-
20	14.1	3.3	5.2		-	20	17.0	2	4.3		-
21	13.9	3.0	5.2		-						

* Denotes thermocline.

Table 9. Average temperature, DO, pH, and water transparency values (Secchi disk) taken from Lake Chatuge in September and October 1998, including numbers (No.) of blueback herring collected at noted depths.

Sep-98	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH	Oct-98	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH
Depth	Temp C°					Depth					
0	26.2	8.8	5.5	2.35	-	0	23.2	7.3	5.9	2.67	-
1	26.1	8.6	5.5		-	1	23.2	7.2	5.9		5
2	26.1	8.5	5.5		-	2	22.8	7.2	5.9		7
3	25.9	8.4	5.5		-	3	22.7	7.1	5.9		5
4	25.8	8.4	5.5		-	4	22.7	6.9	5.9		-
5	25.6	8.3	5.5		-	5	22.7	6.7	5.8		-
6	25.2	8.3	5.4		-	6	22.6	6.6	5.8		-
7	25.1	8.3	5.4		-	7	22.6	6.5	5.8		-
8	25	8.3	5.4		-	8	22.6	6.5	5.8		-
9	25	8.2	5.4		-	9	22.6	6.3	5.8		-
10	24.9	7.9	5.2		-	10	22.6	6.3	5.8		-
12*	23.1	1.4	4.4		2	12	22.6	6.1	5.7		-
14	21.5	0.6	4.3		-	14	22.4	5.0	5.6		-
16	20.1	0.7	4.3		-	16	21.2	5.2	5.4		-
18	18.9	0.2	4.4		-	18*	20.4	5.1	5.4		-
19	18.4	0.2	4.4		-	20	20.1	5.1	5.4		-

* Denotes thermocline.

Table 10. Average temperature, DO, pH, and water transparency values (Secchi disk) taken from Lake Chatuge in November and December 1998, including numbers (No.) of blueback herring collected at noted depths.

Nov-98	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH	Dec-98	Temp °C	DO (ppm)	pH	Secchi (meters)	No. BBH
Depth						Depth					
0	17.4	10.4	7	1.73	0	0	13.3	9.9	6.7	2.5	-
1	17.3	10.3	7		0	1	13.3	9.7	6.7		15
2	17.3	10.2	7		0	2	13.1	9.7	6.7		22
3	17.2	10.2	7		0	3	13.1	9.6	6.7		10
4	17.2	10.0	6.9		0	4	13.2	9.5	6.7		7
5	16.9	9.9	6.8		0	5	13.2	9.5	6.7		3
6	16.9	9.7	6.8		0	6	13.2	9.4	6.7		8
7	16.9	9.7	6.8		0	7	13.2	9.4	6.7		4
8	16.8	9.6	6.7		0	8	13.2	9.4	6.7		9
9	16.8	9.5	6.7		0	9	13.2	9.3	6.7		5
10	16.2	9.6	6.7		0	10	13.2	9.3	6.7		8
12	14.8	8.9	6.4		0	12	13.2	9.3	6.6		7
						14	13.1	9.3	6.5		8
						16	13.1	9.3	6.5		-
						17	13.1	9.3	6.5		-

Table 11. Average temperature, DO, pH, and Secchi disk values, for depths sampled, taken from Lake Chatuge in March and April 1999 with numbers of blueback herring and collection depths. An asterisks denotes presence of the thermocline.

March 99	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH	April 99	Temp °C	DO (ppm)	pH	Secchi (m)	No. BBH
Depth						Depth					
0	10.7	12.5	7.2	1.82		0	15.9	10.2	7.6	2	
1	10.5	12.4	7.2		72	1	15.8	10.0	7.6		166
2	10.4	12.3	7.2		73	2	15.2	10.1	7.6		166
3	10.3	12.3	7.2			3	15.0	10.0	7.7		
4	9.9	12.3	7.1			4	14.7	9.9	7.6		
5	9.0	12.2	7.1			5	14.5	9.9	7.5		
6	8.1	12.2	7.1			6	14.1	9.6	7.4		
7	8.0	12.1	7.1			7	14.0	9.5	7.3		
8	7.9	12.1	7.0			8	13.7	9.4	7.3		
9	7.8	12.1	7.2			9*	12.7	9.3	7.1		
10	7.7	12.1	7.2			10	10.7	9.1	7.0		
						12	9.9	8.9	6.8		
May 99						June 99					
Depth						Depth					
0	22.3	9.4	7.8	1.9	3	0	25.5	9.2	7.7	2.53	
1	21.9	9.4	8.0		8	1	25.5	9.1	7.8		
2	21.5	9.5	8.0		5	2	25.4	9.1	7.9		
3	20.7	9.7	8.2		4	3	24.8	9.1	7.9		4
4*	19.4	10.0	8.3		3	4	24.1	9.1	7.8		3
5	18.0	9.7	7.7		5	5*	22.9	9.0	7.7		1
6	17.0	9.2	7.3		7	6	20.7	9.2	7.5		2
7	16.2	8.9	7.1		2	7	18.3	8.5	7.0		2
8	15.1	8.6	7.0		4	8	16.8	7.5	6.7		4
9	14.4	8.4	6.9		3	9	15.7	6.4	6.6		3
10	13.5	8.3	6.8		2	10	14.6	5.9	6.5		12
11	13.4	7.5	6.8			11	13.3	4.3	6.4		2
12	11.6	7.5	6.6			12	13.2	7.0	6.4		
						14	11.5	7.0	6.4		
						15	11.1	7.2	6.4		

at the greatest depths sampled, 10 – 15 m, ranging from a high of 7.2 in March to a low of 6.4 in June.

Limiting Factors

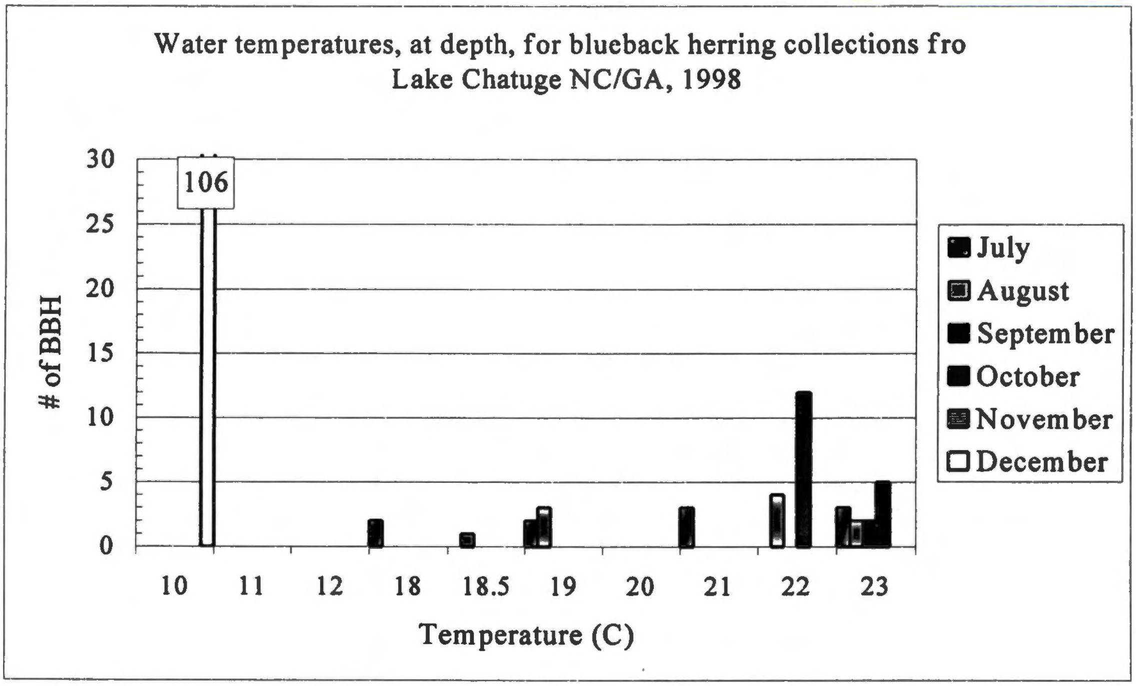
No blueback herring were collected from water temperatures greater than 23.8° C at any time during the 1998 collections. In addition, BBH were collected in waters having as little as 1.4 ppm DO, corroborating the Dennerline and Van Den Avyle (1998) study concerning longitudinal and vertical distribution of bluebacks as related to the temperature and DO squeeze associated with southern reservoirs. Two blueback herring were collected from water with a pH of 4.4, a DO level of 1.4 ppm, and a temperature of 23.1° C in September when surface temperatures were in excess of 26° C. Other collections of BBH in lower pH water (4.5 to 5.4) occurred in July and August when surface temperatures were in excess of 27° C. BBH were also collected at depths of 0-14 m having more normal pH levels (5.9 in October and 6.7 in December) and water temperatures less than 23.8° C.

Observations of the data reveal that no blueback herring were collected from water temperatures of greater than 24.8° C at any time during the 1999 collections. Since the DO levels did not get lower than 7.2 ppm (at 15 m in June), limitations placed on the bluebacks by lack of suitable DO were nonexistent. The lowest pH value (pH 6.4), during the 1999 collections, was recorded at a depth of 15 m during June, thus pH limitations were negligible. Blueback herring were collected at depths of 0–3 meters deep during March and April and at depths of 1-14 m during May and June 1999.

In summary, the results of the study indicated that Lake Chatuge blueback herring typically exhibited an aversion to water temperatures in excess of 25° C (Pardue 1983; Dennerline and Van Den Avyle 1988; Hewett and Stewart 1989; A. Rayburn, GADNR, personal communication). The only water quality parameter having a direct effect on the location of BBH in Lake Chatuge, during the present study, was water temperature greater than 23.8 to 24.8° C for 1998 and 1999, respectively. Levels of dissolved oxygen and pH appeared to have little effect on location in 1998 due to the only blueback herring being collected in September 1998 (n = 2) being collected from water having a pH of 4.4 and a DO level of 1.4ppm suggesting that BBH will sacrifice levels of DO and pH for suitable water temperatures in the water column. This suggests that blueback herring seek out deeper, cooler water during the months of stratification. Due to the higher values of dissolved oxygen at the greatest depth (7.2 ppm @ 15 m) and near neutral values of pH (6.6 – 8.3), DO and pH values appeared to have little effect on fish distribution in the water column during 1999. These findings strongly agree with the study by Nestler et al. (2002) in which the authors stated that temperature was first in order of importance, i.e., the proportionate amount of time (45%) that a nonrandom variable contributed to the movement of blueback herring) They also determined the vertical distribution of bluebacks by using a coupled Eulerian-Lagrangian hybrid model (CE-QUAL-W2) and comparing the results to field observations. Numbers of BBH collected and their associated depths are presented in Figure 4.

Habitat Preference

Physical habitat preferences for blueback herring were not defined during the 1998-99 gill net collections. However, during the 1998 December electroshocking, BBH



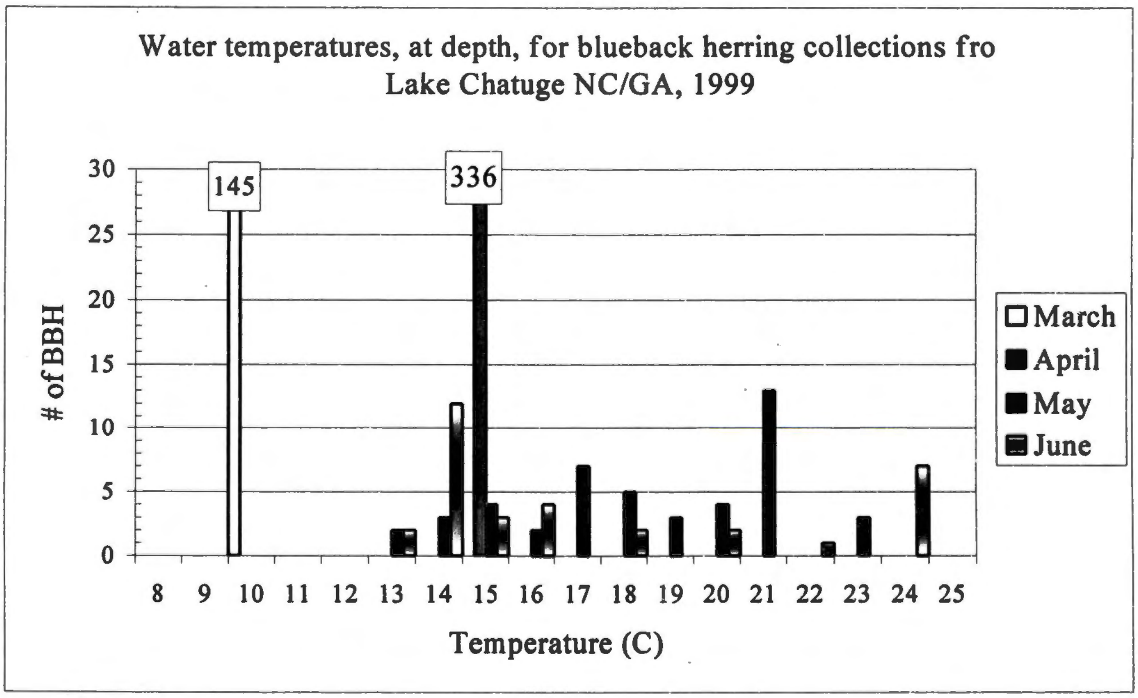


Figure 4. Numbers of blueback herring and the associated temperature at depth of collection during 1998 and 1999.

were found in association with woody cover in Bell and Hog Creeks. It was also noted that the further upstream a sample site was from Chatuge Dam, the more bluebacks that were collected. This finding corroborated the observations of Reggie Weaver (GADNR, personal communication) that bluebacks migrated upstream to the riverine area of the Hiwassee River during winter. The 1999 electroshocking efforts did not add any information concerning habitat preference.

Diet Composition

During the study, the blueback herring were found to be primarily planktivorous consuming larger species of cladocerans, copepods, and dipterans. They were also found to be capable of consuming juvenile fishes (BBH and LMB). Other prey organisms encountered were from the orders Ostracoda, Hydracarina, and Bryozoa, and, for the purpose of this study, were classified as 'miscellaneous' organisms due to speculation that these organisms were ingested while the bluebacks were foraging for other prey.

1998

Blueback herring collected in 1998 were found to be primarily planktivorous and displaying occasional piscivory throughout the 1998 portion of the study (nine months). Utilization of cladocerans (50.0-100.0% of the stomachs examined), copepods (20.0-100.0%), and dipterans (50.0-100.0%) were most frequent from April through December. Consumption of ephemeropterans (10.0-15.4%), coleopterans (7.7-10.0%), and fish (3.3-50.0%) occurred sporadically during June through July for benthic organisms, and June through September and December for fish. The 1998 results show that BBH are capable of utilizing a wide range of prey items, based on size and trophic standing, Appendix 2.

1999

The 1999 results again indicated blueback herring to be an obligate planktivore with occasional piscivorous behavior with fish collected from March through June consuming cladocerans (96.7-100.0% of stomachs with prey items), copepods (53.3-96.7%), and dipterans (70.0-83.3%) in greater numbers for all four months. Ephemeropterans (3.3-23.3%), coleopterans (3.3% for both March and May), and fish (6.7-23.3% for May and June) were also consumed on a less frequent basis. The 1999 results also documented that BBH utilize a wide diversity of prey items similar to the 1998 results, Appendix 4.

The results indicate that Blueback herring collected during 1998-99 were primarily planktivorous (Table 12) throughout the 1998 portion of the study (nine months), agreeing with Domermuth (1972), Creed (1985), Davis (1987), and Guest (1991). Blueback herring utilized cladoceran, copepod, and dipteran species in order of occurrence from April through October 1998; the exception was in December 1998, when bluebacks utilized more copepods than cladocerans. During March, April, and June 1999, blueback herring utilized cladocerans, copepods, and dipterans in order of precedence, while May 1999, the order of exploitation was cladocerans, dipterans, and copepods. These results agreed with Scherer's (1972) study of blueback herring in Massachusetts on the Connecticut River where he found that juvenile BBH primarily consumed cladoceran species. In a study by Crecco and Blake (1983), the results showed that BBH greater than 13 mm in length displayed a preference for *Bosmina* species and suggested that intra-specific competition among BBH may outweigh impacts of inter-specific competition between BBH and other species. Adult blueback herring from the

Table 12. Diet composition of BBH analyzed in 1998 and 1999, including most frequently occurring organisms ingested and frequency of occurrence (%). Percentages indicate the number of BBH analyzed for a given month having the particular organism in the gut. An asterisks denotes no fish collected.

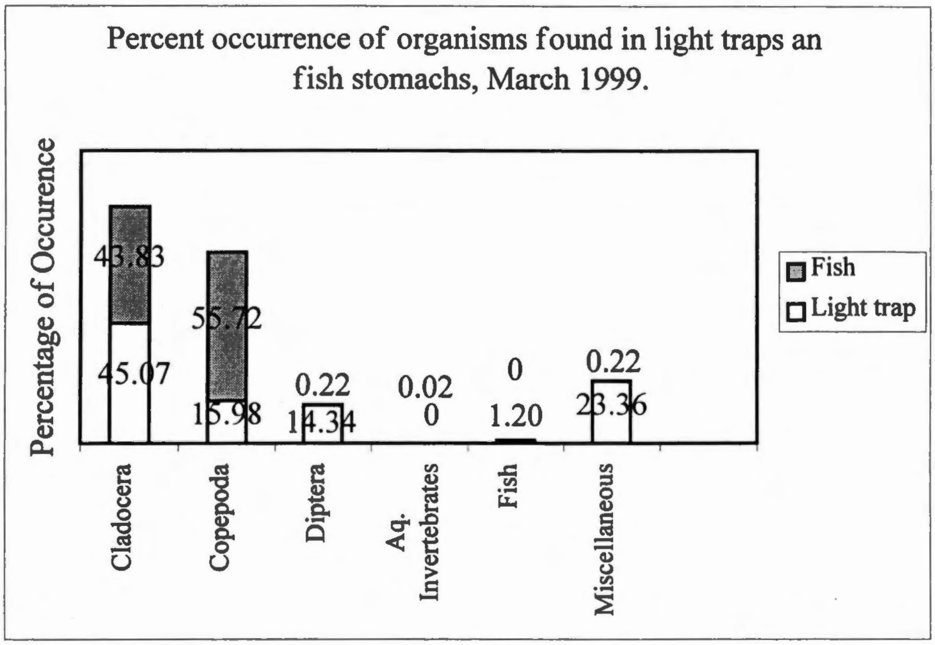
		Organisms Ingested (%)					
Month 1998	No. BBH	Cladocera	Copepoda	Diptera	Ephemeroptera	Coleoptera	Fish
Apr	30	83.3	66.7	53.3	-	-	-
May	-	-	-	-	-	-	-
June	13	84.6	69.2	61.5	15.4	7.7	7.7
July	10	60.0	20.0	50.0	10.0	10.0	10.0
Aug	8	100.0	100.0	100.0	-	-	12.5
Sept	2	50.0	50.0	-	-	-	50.0
Oct	17	82.4	88.2	55.8	-	-	-
Nov*	0	0	0	0	0	0	0
Dec	30	93.3	83.3	83.3	-	-	3.3
		Organisms Ingested (%)					
Month 1999	No. BBH	Cladocera	Copepoda	Diptera	Ephemeroptera	Coleoptera	Fish
March	30	100.0	96.7	73.3	3.3	3.3	-
April	30	93.3	93.3	70.0	16.7	-	-
May	30	83.3	53.3	83.3	23.3	3.3	6.7
June	30	96.7	90.0	76.7	6.7	-	23.3

Chowan River in North Carolina were found to prey primarily on cladocerans, copepods, and dipterans (Creed 1985), thus validating our study. Guest and Drenner (1991) found that BBH in Lake Theo, TX, selected for larger zooplankton when smaller species of cladocerans and copepods were more abundant, thus validating concerns that alosid species can be capable of restructuring the zooplankton communities in an aquatic system (Warshaw 1972).

Diet preference was not initially planned for this study; however, the collection of potential prey organisms in light traps from the areas of BBH collections this study provided some insight about BBH prey selection (Figures 5 and 6). It should be noted that not all organisms observed in the stomach samples were observed in the light traps. Blueback herring in Lake Chatuge during 1998 and 1999 appeared to select for cladocerans and copepods, even when miscellaneous organisms made up approximately two-thirds of the light trap samples (May 1999). Observations from the study also indicate that bluebacks prefer larger cladocerans such as *Daphnia* and *Leptodora,* while *Chydorus*, *Holopedium*, and *Bosmina* were also utilized. The data does not support any inferences about selection for other organisms collected in the light traps.

Piscivory

Piscivory was documented in blueback herring during the 1998-99 sampling years. It was discovered that BBH 150 mm TL, typically age 2 fish, could consume fish having lengths of 10-30 mm, which approximated 6.7 to 20 percent of the size of the predator BBH. With occurrence of both juvenile BBH and LMB, respectively, in BBH stomachs, observations as related to selectivity of fish species would be speculation. The



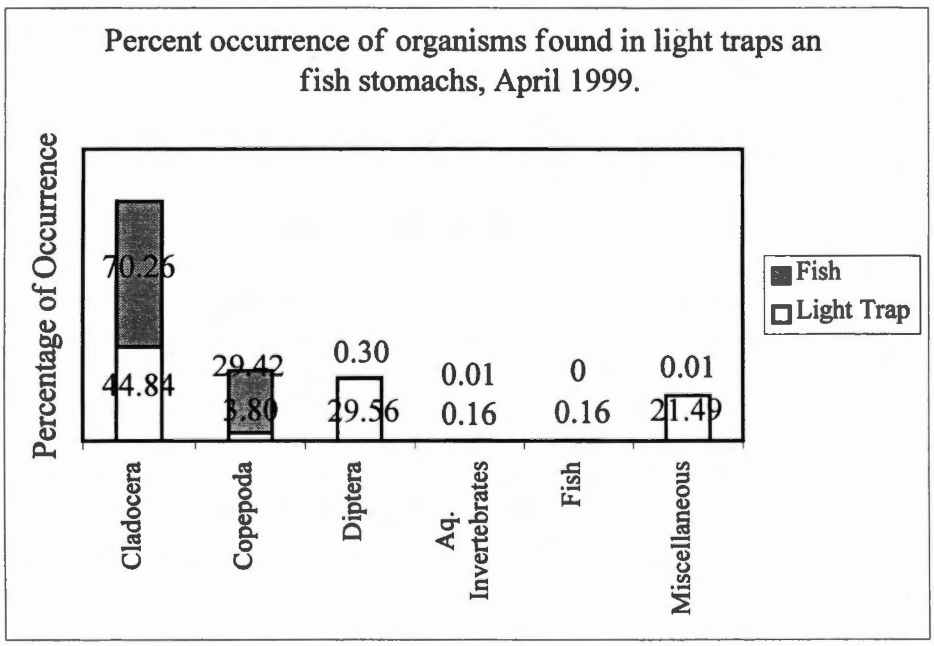


Figure 5. Percent occurrences of organisms found in light traps and fish stomachs during March and April 1999.

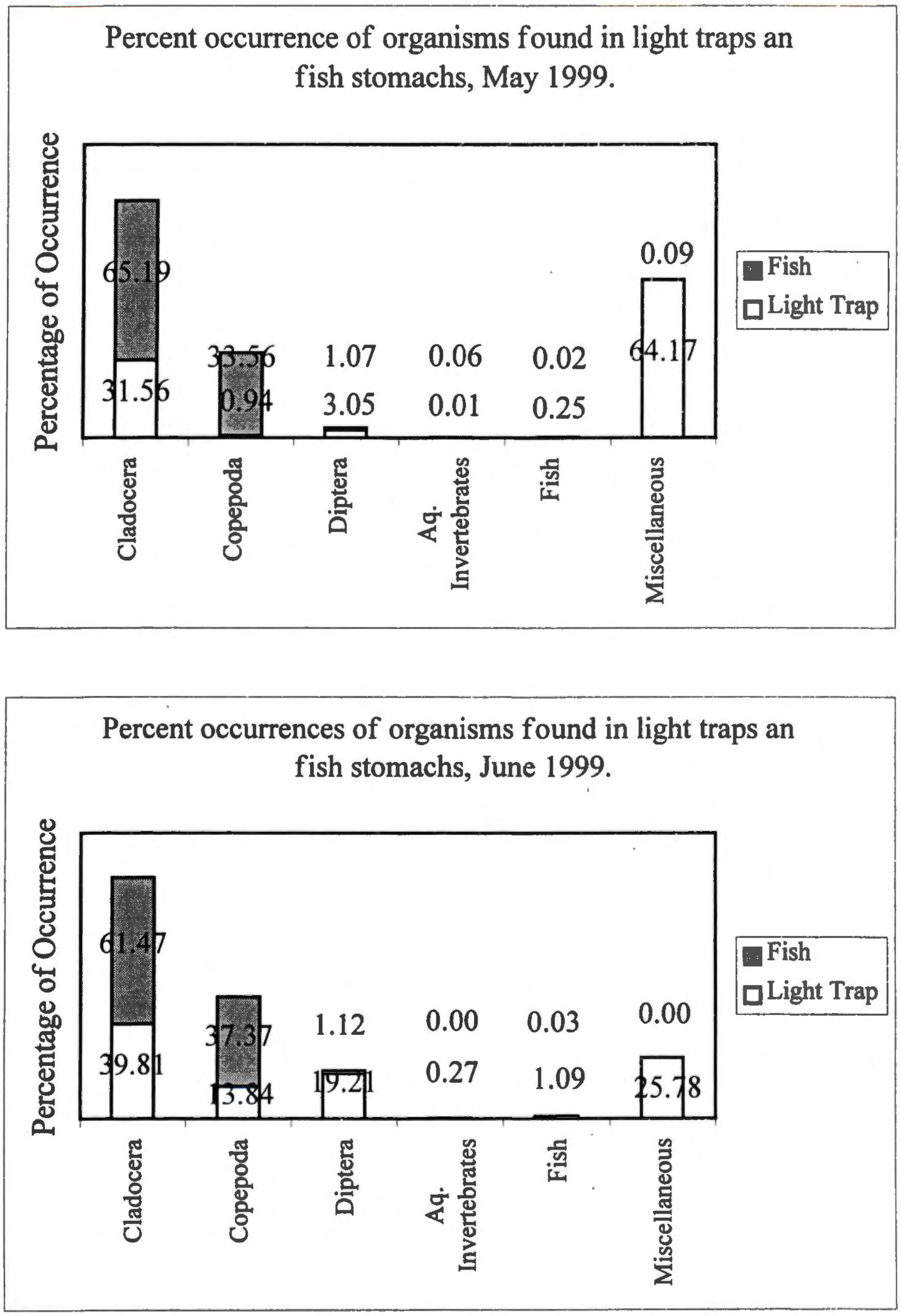


Figure 6. Percent occurrences of organisms found in light traps and fish stomachs during May and June 1999.

presence of both species suggested that blueback herring and largemouth bass, in Lake Chatuge, have overlapping spawn times and may share the spawning areas. These results concur with the findings of the food habits study of BBH, largemouth bass, and bluegill from Lakes Nottley and Burton (Goodrich and Wilson 2000) in that Lake Chatuge BBH consumed both BBH and LMB juveniles.

Blueback's Role in Trophic Ecology

During this study, information was obtained which provided insight to the blueback's role in the trophic ecology of Lake Chatuge. This study provided information describing how the blueback herring impacts Lake Chatuge by their presence, enabling managers and biologists to develop management strategies that follow best management practices prescribed by each agency.

Blueback herring in Lake Chatuge were found to be obligate planktivores. The Chatuge bluebacks also displayed piscivorous behavior that was best described as opportunistic, with 3.6 % and 7.5 % of the 1998 and 1999 samples, respectively, containing fish remains. Although active spawning of the blueback herring was not detected, it has been reported that they spawn in shallow coves, in and around submerged woody structures (A. Rayburn and R. Weaver, GADNR, personal communication), and on submerged aquatic vegetation (Bozeman and Van Den Avyle 1989). Habitat preference for the Lake Chatuge bluebacks, as determined by gill net collections, was found to be water temperature less than 25° C during 1998-99. No specific preference for substrate type and cover, related to spawning and distribution, was defined. Fish collected in December 1998 during electroshocking, were found to be associated with woody cover in the upper reaches of coves, while no bluebacks were collected in 1999 during spring electroshocking efforts.

Lake Chatuge bluebacks preyed primarily on larger cladocerans, calanoid copepods, and dipterans (ceratopogonids, chaoborids, and chironomids) during 1998 and 1999. Other prey items encountered during the study were bryzoans, coleopterans, conchostracans, ephemeropterans, fish (both juvenile LMB and BBH), hydracarinids, ostracods, plecopterans, and trichopterans. Because alewife larvae, which have feeding habit similar to larval blueback herring, have been reported to consume 10% of the zooplankton community annually in Lake Michigan (Hewett and Stewart 1989), a concern has been raised relative to the potential impact of BBH larvae on the zooplankton community in Lake Chatuge. For Lake Michigan, it was postulated that larval and young of the year alewives could annually consume 50% of the zooplankton community (Hewett and Stewart 1989). Based on the results of the present study, the wide diversity of prey items consumed by adult blueback herring, in both size and trophic ranking, suggests that herring could compete with other planktivorous and omnivorous fishes, by switching preference of consumed prey items according to abundance. Young clupeids, such as age 0 gizzard shad (*Dorosoma cepedianum*) switched from species of *Daphnia* spp. to algae and detritus after a collapse of the Daphnidae population in Lake Oneida, New York (Shepherd and Mills 1996). Increased competition for planktonic resources among species of larval and juvenile fishes, not just clupeids, could result in reduced growth and less recruitment of larval fish into the juvenile and adult population. Species in Lake Chatuge dependent on zooplankton as larvae and juveniles are blueback herring, threadfin and gizzard shad, largemouth bass, smallmouth bass (*Micropterus dolomieu*), spotted bass (*M. punctulatus*), crappies (*Pomoxis* spp.), bluegill, blue catfish (*Ictalurus furcatus*), and the channel catfish (*I. punctatus*) (Jenkins and Burkhead 1993). Allen and DeVries (1993) suggested that threadfin and gizzard shad could suppress the planktonic communities of a reservoir thus limiting recruitment of other fishes including game, forage and rough species. Because blueback herring utilize larger cladocerans (Domermuth 1972; Scherer 1972; Warshaw 1972; Davis 1987; Guest and Drenner 1991), copepods, and dipterans which are also consumed by YOY largemouth bass and bluegills (Goodrich and Wilson 2000), managers and biologists need to pay particular attention to the potential impact of BBH relative to the numbers and diversity of the planktonic communities and other important fish species in the respective reservoirs. It is the opinion of the author that the blueback herring, if in sufficient abundance, could negatively impact the zooplankton community, thus limiting the recruitment of other species and following the principle of cascading trophic interactions (Carpenter et al. 1985).

Piscivory found in the Chatuge bluebacks was not as great as expected. During the 1998 sample year, 3.6% (4 out of 110 BBH examined) of the sample contained remains of fish, while 7.5% (9 out of 120 BBH examined) of the 1999 samples contained fish remains, giving a total of 5.9%, collectively, of the all blueback herring examined displaying piscivorous behavior. A total of two LMB, five BBH, and one unidentifiable fish were found in the 1998 bluebacks. The 1999 bluebacks examined revealed the remains of three LMB, 17 BBH, and one unidentifiable fish. Being as that blueback herring are known to prey on larval and juvenile fishes (Bulak and Walker 1979; Pardue 1983; Creed 1985; Davis 1987; Goodrich and Wilson 2000) impacts on game species within a reservoir from 'additive piscivory' could be a possibility.

A plausible explanation for piscivory as related to the blueback herring is the overlapping of spawning and feeding areas of the blueback herring and other fish species. Blueback herring have been observed spawning in water temperatures as low as 13° C (Bozeman and Van Den Avyle 1989) with fecundity rates of 120,000 to 400,000 eggs per female, and at 14° C with fecundity of females ranging from 45,000 to 349,000 eggs (Loesch and Lund 1977). Jenkins and Burkhead (1993) list several species of forage, game, and rough fish as spawning at temperatures higher than 13° C with threadfin and gizzard shad, spotted bass, smallmouth bass, and largemouth bass, crappies, bluegills, and channel as well as blue catfish spawning between 14.4° C and 28.9° C. In the case of Lake Chatuge, the piscivory noted in blueback herring is thought to occur due to the close proximity of the adult blueback to the larval and juvenile LMB and BBH. Simply stated, piscivory by BBH on other species may be resultant of the spawning times, temperatures, and locations of those species being similar. Lake Chatuge is characterized by having only a few shallow water areas, proportionately, where segregation of the species can occur during the spring and spawning times. Piscivory in blueback herring could be a function of overlapping spawning times and a lack of adequate shallow-water, spawning habitat.

Habitat preferences for the Lake Chatuge blueback herring were found to be primarily related to water temperature. The only period blueback herring were found to display a habitat preference other than water temperature was in December 1998 while electroshocking. They were found to be associated with woody cover in the upper reaches of reservoir coves. The physical features of Lake Chatuge are such that there is a rapid transition zone between deep open water areas and the shallow littoral areas because of steep rock and clay banks. The lake is characterized as dendritic, much the same as many upland storage reservoirs found in the Appalachian region of the southern US. Because of this rapid transition zone, premium shallow-water habitats for spawning and reproduction are limited; this results in competition for space and crowding of larvae of many species into limited areas. Such a situation could result in piscivory on other species by adult blueback herring.

During the study BBH were found to prey on larger organisms used by larval and juvenile fishes of other species suggesting that interspecific competition could be a concern. They were found to prey on larger zooplankton, suggesting that this selectivity for those larger species of zooplankton could alter the zooplankton community in Lake Chatuge. Blueback herring were capable of consuming juvenile BBH and LMB suggesting that, in conjunction with the possibility of interspecific competition for other organisms, piscivory of larval and juvenile could increase at any time depending on the strength of the zooplankton community. Also, the occurrence of juvenile LMB, as well as juvenile BBH, in the blueback's diet suggests that the two species spawning habits overlap, at least partially, in Lake Chatuge.

Aging of Blueback Herring

1998

Scale analysis indicated the presence of three age classes for the fish collected from April through December 1998 (n=110); the age classes documented were 0, 1, and 2 with the majority of fish in the age 0 and 1 year classes. This analysis suggested that all age classes of the Lake Chatuge BBH population were represented during 1998, but not enough aging data were gathered for a valid documentation. The lengths for the 0 age class fish ranged up to 150 mm TL, having a median total length of 111-120 mm. Lengths for the age class 1 BBH ranged from 151-180 mm TL with a median length of 161-170 mm. The age class 2 BBH had ranged from 181 to 210 mm in length while having a median length of 191-200 mm. It should be noted that the range in lengths, for median length values of the age classes, was associated with differences of growth among the individual fishes. The primary reason age analysis was conducted was to provide data to the NCWRC for future comparative aging studies of BBH using otoliths.

1999

Scale analysis indicated three age classes of blueback herring collected in 1999. The age classes displayed were 1, 2, and 3 with the majority of fish in the age 1 and 2 classes, which was similar to the 1998 data. The size of age 1 class BBH ranged up to 150 mm. This included one year-old fish with and without the annular ring, suggesting that similar to BBH in the Savannah River basin (Boltin 1995) the annulus for Lake Chatuge BBH is laid down in April of each year. The age 2 class peaked at 161-170 mm and ranged from 151-180 mm, while all but one of the age class 3 fish ranged from 181-210 mm and had a median length of 191-200 mm, agreeing with Scherer (1972) and Jenkins and Burkhead (1993). The unusually large blueback from the age 3 class was 226 mm in TL and was the only blueback in this size range collected in either year of the study.

Results of the study indicated that age 0 class BBH (1998) and age 1class BBH (1999) ranged up to 150 mm. The age 2 class BBH peaked at 161-170 mm and ranged from 151-180 mm, while all but one BBH (226 mm) of the age class 3 fish ranged from

181-210 mm and had a median length of 191-200 mm. The ages documented for the Lake Chatuge blueback herring suggested the life span of landlocked BBH is considerably shorter than anadromous BBH (Scherer 1972; Boltin 1995). However, results of length and age do not agree with the findings of Boltin's (1995) study in which blueback herring collected from five Savannah River basin reservoirs were found to be up to eight years old and having a maximum length of less than 230mm. Based on differences between Boltin's (1995) study and reports of Jenkins and Burkhead (1993) and Scherer (1972), different ages and lengths reported for blueback herring may be reservoir dependent. Back calculation to determine length at age was not conducted due to the inaccuracies of scale analysis for blueback herring (Schramm et al. 1991). Boltin (1995) also cited the possibility of annular formation not occurring, and differences in annular formation being lake specific.

CHAPTER V

SUMMARY

1. Blueback herring from Lake Chatuge appeared to be obligate planktivores, but will ingest fish when larval and juvenile fishes are abundant and in close proximity to areas where the blueback herring are feeding.
2. Cladocerans were usually the most frequently ingested zooplankton organisms in both 1998 and 1999, including *Bosmina longirostris*, *Daphnia* sp., *Chydorus* sp., and *Leptodora kindti*. Copepods typically ranked second in frequency of occurrence, but on occasions (December 1998, March 1999) were the most abundant organism in blueback stomachs. Dipterans (chironomids and *Chaoborus punctipennis*) were the third most abundant organism consumed. Ceratopogonids and culicids occurred occasionally, as did several other taxa, including Ostracoda, Conchostraca, Hydracarina, and Bryzoa.
3. Piscivory by blueback herring was observed but did not appear to be significant; in 1998, stomachs from five BBH, ranging from 150-190 mm, contained two juvenile largemouth bass, four juvenile alosids, and unidentified fish remains, respectively. A fourth BBH collected in June 1998 had fish eggs in the gut. In 1999, nine BBH ingested 17 juvenile bluebacks, 3 largemouth bass juveniles, and unidentified fish remains; fish eggs were also found in two BBH in May.
4. The role of blueback herring in the trophic ecology of Lake Chatuge was that of an obligate planktivore capable of consuming, having attained 150 mm TL; primarily two year old fish, larval and juvenile fishes (BBH and LMB). Blueback

herring have the potential to negatively affect the zooplankton community, by restructuring, and recruitment of larval fishes by means of direct competition for food items and predation of larval and juvenile fishes

5. This study found that no BBH were collected from water at temperatures greater than 23.8 °C in 1998 and 24.8 °C in 1999, suggesting that temperature is a determining factor in the vertical distribution of blueback herring. Dissolved oxygen and pH levels appeared to have little or no bearing on their distribution, since BBH were collected at DO levels of 1.4 mg/L and at a pH of 4.4. Physical habitat preference was not identified during the study.
6. Gill nets were more efficient in collecting blueback herring than electroshocking. Experimental gill nets with panels having bar mesh sizes less than 2.54 cm collected fish during 1998 and 1999; larger mesh sizes were not effective. Also, standard gill nets with a bar mesh size of less than 2.54 cm was an effective collection tool. Based on these results, best collection methods for blueback herring would be the experimental gill net having one panel each of the following bar mesh sizes: 0.95, 1.27, 1.59, 1.91, 2.22, and 2.54 cm. To allow for larger specimens we recommend two additional panels, one each of 2.86 and 3.18 cm. In addition, based on the results spring samples should be made in shallow-water areas in the main lake area using gill nets. Fall and winter collections should be made in the riverine areas using gill nets. Summer collections should be made using horizontal or vertical nets, set in waters having a temperature of less than 25° C with DO levels of at least 1 ppm.

7. A total of 37 fish were collected during four hours of electroshocking during 1998 and 1999. The bluebacks collected were collected, during December 1998, in the backwater portions of Bell and Hog Creeks over areas of woody debris. The limited success during both electroshocking efforts suggested that this method was not very efficient and may be due, in part, to the pelagic nature of the adult fish.
8. The use of light traps as a collection method for larval and juvenile blueback herring proved to be inadequate. No blueback herring were collected at any time during the study using light traps.
9. Scale analysis of BBH indicated at least three age classes present during 1998 and 1999. Mean length ranges were similar in both years for the ages represented and were: Age 1, 111-120 mm; Age 2, 161-170 mm; and Age 3, 191-200 mm.

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APPENDICES

Table A 1.1. Numbers of organisms and percent occurrences from the July 1998 light trap collections on Lake Chatuge.

July 1998 Organisms				No.	% Occ
Copepoda					
	Calanoida			53	8.2
Cladocera					
	Chydoridae	*Chydorus*	sp.	3	0.5
	Daphnidea	*Daphnia*	spp.	82	12.7
Miscellaneous					
	Hydracarina			205	31.
Diptera					
	Chaoboridae	*Chaoborus*	*punctipennis*	60	9.3
	Chironomidae		pupae	212	32.9
	Culicidae			1	0.2
Ephemeroptera					
	Ephemeridae	*Hexagenia*	spp.	3	0.5
Odonata					
	Corduliidae	*Epicordulia*	spp.	3	0.5
		Neurocordulia	spp.	1	0.2
Plecoptera					
	Unidentified Adults			2	0.3
Trichoptera					
	Unidentified Adults			3	0.5
Fish					
	Ictaluridae	*Ictalurus*	*punctatus*	1	0.2
	Centrarchidae	*Micropterus*	*salmoides*	9	1.4
	Clupeidae	*Alosa*	*aestivalis*	3	0.5
	Centrarchidae	*Lepomis*	*auritus*	2	0.3
	Unidentified Centrarchidae			1	0.2
Total				644	100.0

Table A 1.2 Numbers of organisms and percent occurrences from the August 1998 light trap collections on Lake Chatuge.

August 1998 Organisms				No.	% Occ
Copepoda					
	Calanoida			17	1.6
Cladocera					
	Chydoridae	*Chydorus*	sp.	6	0.6
	Daphnidae	*Daphnia*	spp.	110	10.2
	Leptodoridae	*Leptodora*	*kindti*	6	0.6
Crustacea					
	Hydracarina			346	32.2
Diptera					
	Chaoboridae	*Chaoborus*	*punctipennis*	242	22.5
	Chironomidae		pupae	296	27.5
Fish					
	Clupeidae	*Dorosoma*	*petenense*	53	4.9
Total				1076	100.0

Table A 1.3. Numbers of organisms and percent occurrences from the September, October, and December 1998 light trap collections on Lake Chatuge.

Organisms				Sept-No.	% Occ	Oct-No.	% Occ	Dec-No.	% Occ
Copepoda									
	Calanoida							73	21.6
Cladocera									
	Chydoridae	*Chydorus*	sp.			17	10.4	2	0.6
	Daphnidae	Daphnia	spp.	381	69.1	41	25.0	63	18.6
	Holopedidae	*Holopedium*	sp.					53	15.7
Miscellaneous									
	Hydracarina			117	21.2	61	37.2	51	15.1
Diptera									
	Chaoboridae	*Chaoborus*	*punctipennis*	14	2.5	14	8.5	89	26.3
	Chironomidae		larvae	12	2.2				
			pupae	27	4.9	31	18.9	7	2.1
Total				551	100.0	164	100.0	338	100.0

Table A 2.1. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1998.

April-98 Sample n = 30 Fish w/Prey 25 - 83.3% Fish w/o Prey 5 - 16.7%

ORDER									
Cladocera	Unld'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* sp.	*Leptodora kindti*	Total	Fish w/Order	% sample	% Fish with Prey
# Organisms	4440	340	64	161	16	5021			
% of Cladocera	88.4	6.8	1.3	3.2	0.3	100.0			
Fish w/Taxon	14	18	10	12	5		25	83.3	100.0
% of Sample	46.7	60.0	33.3	40.0	16.7				
Copepoda	Unld'ed	Calanoida	Cyclopoida	Nauplii					
# Organisms	147	185	22	1792		2146			
% of Copepoda	6.8	8.6	1.0	83.5		100.0			
Fish w/Taxon	9	14	1	5			20	66.7	80.0
% of Sample	30.0	46.7	3.3	16.7					
Diptera	*Chaoborus punctipennis*	Chironomidae	Culicidae						
# organisms	4	62	2			68			
% of Diptera	5.9	91.2	2.9			100.0			
Fish w/Taxon	2	15	2				16	53.3	64.0
% of Sample	6.7	50.0	6.7						
Misc.	Ostracoda								
# organisms	3					3			
% of Misc.	100.0					100.0			
Fish w/Taxon	3						2	6.7	8.0
% of Sample	10.0								

Table A 2.2. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1998.

ORDER	June-98	Sample n=13	Fish w/Prey	11 - 84.6%	Fish w/o Prey	2 - 15.4%				
Cladocera		UnId'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* sp.	*L. kinditi*	Total	Fish w/Order	% sample	% Fish with Prey
	# Organisms	1008	125	25	316	108	1582			
	% of Cladocera	63.7	7.9	1.6	20.0	6.8	100.0			
	Fish w/Taxon	7	9	3	10	4		11	84.6	100.0
	% of Sample	53.8	69.2	23.1	76.9	30.8				
Copepoda		UnId'ed	Calanoida							
	# Organisms	104	1282				1386			
	% of Copepoda	7.5	92.5				100.0			
	Fish w/Taxon	4	6					9	69.2	81.8
	% of Sample	30.8	46.2							
Diptera		*Chaoborus punctipennis*	Chironomidae							
	# organisms	24	24				48			
	% of Diptera	50.0	50.0				100.0			
	Fish w/Taxon	5	5					8	61.5	72.7
	% of Sample	38.5	38.5							
Aq. inverts		Coleoptera	Ephemerellidae							
	# organisms	1	10				11			
	% of Aq. Inverts	9.1	90.9				100.0			
	Fish w/Taxon	1	2					3	23.1	27.3
	% of Sample	7.7	15.4							
Fish		Eggs								
	# organisms	1					1			
	% of Fish	100.0					100.0			
	Fish w/Fish	1						1	7.7	9.1
	% of Sample	7.7								
Misc.		Ostracoda	Hydracarina							
	# organisms	3	2				5			
	% of Misc.	60.0	40.0				100.0			
	Fish w/Taxon	2	2					5	38.5	45.5
	% of Sample	15.4	15.4							

Table A 2.3. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1998.

ORDER	July-98	Sample = n 10	Fish w/Prey 9 - 90%	Fish w/o Prey 1 - 10%					
Cladocera		UnId'ed	*Bosmina longirostris*	*Chydorus* sp.		Total	Fish w/Order	% sample	% Fish with Prey
	# Organisms	74	30	7		111			
	% of Cladocera	66.7	27.0	6.3		100.0			
	Fish w/Taxon	4	6	4			6	60.0	66.7
	% of Sample	40.0	60.0	40.0					
Copepoda		Nauplii							
	# Organisms	96				96			
	% of Copepoda	100.0				100.0			
	Fish w/Taxon	2					2	20.0	22.2
	% of Sample	20.0							
Diptera		Ceratopogonidae	*Chaoborus punctipennis*	Chironomidae	Culicidae				
	# organisms	1	6	8	1	16			
	% of Diptera	6.3	37.5	50.0	6.3	100.0			
	Fish w/Taxon	1	2	3	1		5	50.0	55.6
	% of Sample	10.0	20.0	30.0	10.0				
Aq. inverts		Coleoptera	Polymitarcidae	Perlodidae					
	# organisms	1	1	2		4			
	% of Aq. Inverts	25.0	25.0	50.0		100.0			
	Fish w/Taxon	1	1	1			4	40.0	44.4
	% of Sample	10.0	10.0	10.0					
Fish		LMB							
	# organisms	2				2			
	% of Fish	100.0				100.0			
	Fish w/Taxon	1					1	10.0	11.1
	% of Sample	10.0							

Table A 2.4. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1998.

August-98	Sample = n 8	Fish w/Prey 8 - 100.0%	Fish w/o Prey 0						
ORDER									
Cladocera		UnId'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* sp.	Total	Fish w/Order	% sample	% Fish with Prey
	# Organisms	132	47	12	5	196			
	% of Cladocera	67.3	24.0	6.1	2.6	100.0			
	Fish w/Taxon	6	6	1	2		8	100.0	100.0
	% of Sample	75.0	75.0	12.5	25.0				
Copepoda		UnId'ed							
	# Organisms	65				65			
	% of Copepoda	100.0				100.0			
	Fish w/Taxon	8					8	100.0	100.0
	% of Sample	100.0							
Diptera		Chironomidae							
	# organisms	56				56			
	% of Diptera	100.0				100.0			
	Fish w/Taxon	5					5	62.5	62.5
	% of Sample	62.5							
Fish		*A. aestivalis*							
	# organisms	1				1			
	% of Fish	100.0				100.0			
	Fish w/Taxon	1					1	12.5	12.5
	% of Sample	12.5							

Table A 2.5. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1998.

September-98		Sample n = 2		Fish w/Prey 2 - 100%		Fish w/o Prey 0		
ORDER								
Cladocera		*Bosmina longirostris*	*Daphnia* sp.	*Leptodora kindti*	Total	Fish w/Order	% sample	% Fish w/Prey
	# Organisms	6	15	4	25			
	% of Cladocera	24.0	60.0	16.0	100.0			
	Fish w/Taxon	1	1	1		1	50.0	50.0
	% of Sample	50.0	50.0	50.0				
Copepoda		UnId'ed						
	# Organisms	9			9			
	% of Copepoda	100.0			100.0			
	Fish w/Taxon	1				1	50.0	50.0
	% of Sample	50.0						
Fish		*A. aestivalis*						
	# Organisms	4			4			
	% of Fish	100.0			100.0			
	Fish w/Taxon	1				1	50.0	50.0
	% of Sample	50.0						

Table A 2.6. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1998.

October-98 Sample n = 17	Fish w/Prey 15 - 88.2%		Fish w/o Prey 2 - 11.8%				
ORDER							
Cladocera	UnId'ed	*Bosmina longirostris*	*Daphnia* sp.	Total	Fish w/Order	% sample	% Fish with Prey
# Organisms	200	61	58	319			
% of Cladocera	62.7	19.1	18.2	100.0			
Fish w/Taxon	8	7	3		14	82.4	93.3
% of Sample	47.1	41.2	17.6				
Copepoda	UnId'ed	Calanoida					
# Organisms	166	9		175			
% of Copepoda	94.9	5.1		100.0			
Fish w/Taxon	15	1			15	88.2	100.0
% of Sample	64.7	5.9					
Diptera	*Chaoborus punctipennis*	Chironomidae pupae					
# organisms	12	147		159			
% of Diptera	7.5	92.5		100.0			
Fish w/Taxon	4	10			10	58.8	66.7
% of Sample	23.5	58.8					

Table A 2.7. Numbers and percent occurrences of 1998 prey organisms consumed by blueback herring in Lake Chatuge.

December-98 Sample n = 30		Fish w/Prey	29 - 96.7%		Fish w/o Prey 1 - 3.3%				
ORDER									
Cladocera		UnId'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* sp.	Total	Fish w/Order	% sample	% Fish w/Prey
	# Organisms	2998	1920	487	696	6101			
	% of Cladocera	49.1	31.5	8.0	11.4	100.0			
	Fish w/Taxon	24	24	12	15		28	93.3	96.6
	% of Sample	80.0	80.0	40.0	50.0				
Copepoda		UnId'ed	Calanoida	Harpacticoida					
	# Organisms	3683	1755	1198		6636			
	% of Copepoda	55.5	26.4	18.1		100.0			
	Fish w/Taxon	23	16	19			25	83.3	86.2
	% of Sample	76.7	53.3	63.3					
Diptera		*Chaoborus punctipennis*	Chironomidae						
	# organisms	27	55			82			
	% of Diptera	32.9	67.1			100.0			
	Fish w/Taxon	14	21				25	83.3	86.2
	% of Sample	46.7	70.0						
Fish		UnIdentifiable							
	# organisms	1				1			
	% of Fish	100.0				100.0			
	Fish w/Taxon	1					1	3.3	3.4
	% of Sample	3.3							
Misc		Ostracoda	Hydracarina	Bryozoa					
	# organisms	49	6	23		78			
	% of Misc	62.8	7.7	29.5		100.0			
	Fish w/Taxon	15	3	3			17	56.7	58.6
	% of Sample	50.0	10.0	10.0			56.7		

Table A 3.1. Numbers and percentages of organisms collected in light traps during March through June 1999. Values were rounded to the nearest 0.1 percent.

				March-99		April-99		May-99		June-99	
ORGANISM				No.	%	No.	%	No.	%	No.	%
Copepoda	Calanoida			39	16.0	49	3.8	111	0.9	457	13.8
Cladocera	Bosminidae	*Bosmina*	*longirostris*	1	0.4						
	Chydoridae	*Chydorus*	sp.	12	4.9	121	9.4	219	1.9	52	1.6
	Daphnidae	*Daphnia*	spp.	95	38.9	457	35.5	1563	13.3	409	12.4
		D.	*lumholtsi*	-	-	-	-	-	-	1	0.0
	Holopedidae	*Holopedium*	sp.	2	0.8	-	-	-	-	1	0.0
	Leptodoridae	*Leptodora*	*kindti*	-	-	-	-	1935	16.4	851	25.8
Crustacea	Conchostraca			-	-	-	-	-	-	1	0.0
	Ostracoda			-	-	-	-	-	-	1	0.0
	Hydracarina			57	23.4	277	21.5	7556	64.2	849	25.7
Diptera	Ceratopogonidae	*Palpomyia*	sp.	-	-	-	-	-	-	3	0.0
	Chaoboridae	*Chaoborus*	*punctipennis*	14	5.7	210	16.3	302	2.6	302	9.1
	Chironomidae		larvae	-	-	-	-	21	0.2	64	1.9
			pupae	21	8.6	171	13.3	-	-	-	-
Coleoptera	Elmidae	*Stenelmis*	spp.	-	-	-	-	-	-	2	0.1
Ephemeroptera	Ephemeridae	*Hexagenia*	spp.	-	-	2	0.2	-	-	1	0.0
Plecoptera	UI Adults			-	-	-	-	-	-	1	0.0
Trichoptera	UI Adults			-	-	-	-	1	0.0	5	0.2
Fish	Clupeidae	*Dorosoma*	*petenense*	2	0.8	2	0.2	-	-	1	0.0
	Ictaluridae	*Ictalurus*	*punctatus*	-	-	-	-	-	-	2	0.1
	Centrachidae	*Micropterus*	*punctulatus*	-	-	-	-	21	0.2	15	0.5
		M.	*salmoides*	-	-	-	-	8	0.1	1	0.0
	UnIdentifiable			1	0.4			1	0.0	16	0.5
Total				244		1289		11775		3301	

Table A 4.1. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1999.

Mar-99	Sample = n	Fish w/Prey	Fish w/o Prey						
ORDER	30	30 - 100%	0						
Cladocera		UnId'ed	*Bosmina longirostris*	*Daphnia* sp.		Total	Fish w/Order	% sample	% Fish w/ Prey
	# Organisms	7607	5131	4720		17458			
	% of Cladocera	43.6	29.4	27.0		100.0			
	Fish w/Taxon	28	30	14			30	100.0	100.0
	% of Sample	93.3	100.0	46.7					
Copepoda		UnId'ed	Calanoida	Cyclopoida	Harpacticoida				
	# Organisms	11976	8421	240	1560	22197			
	% of Copepoda	54.0	37.9	1.1	7.0	100.0			
	Fish w/Taxon	30	30	4	14		29	96.7	96.7
	% of Sample	100.0	100.0	13.3	46.7				
Diptera		Chironomidae	Culicidae						
	# organisms	82	4			86			
	% of Diptera	95.3	4.7			100.0%			
	Fish w/Taxon	22	2				22	73.3	73.3
	% of Sample	73.3	6.7						
Aq. inverts		Ephemerellidae	Coleoptera						
	# organisms	4	2			6			
	% of Aq. Inverts	66.7	33.3			100.0%			
	Fish w/Taxon	1	1				2	6.7	6.7
	% of Sample	3.3	3.3						
Misc.		Ostracoda	Isopoda						
	# organisms	84	4			88			
	% of Misc	95.5	4.5			100.0%			
	Fish w/Taxon	13	3				7	23.3	23.3
	% of Sample	43.3	10.0						

Table A 4.2. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1999.

Apr-99 ORDER	Sample = n 30	Fish w/Prey 28 - 93.3%	Fish w/o Prey 2 - 6.7%							
Cladocera		Unld'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* spp.	*Leptodora kindti*	Total	# of Fish w/Order	% sample	% Fish w/Prey
	# Organisms	20492	8280	86	9939	100	38897			
	% of Cladocera	52.7	21.3	0.2	25.6	0.3	100.0			
	Fish w/Taxon	27	26	3	22	4		28	93.3	100.0
	% of Sample	90.0	86.7	10.0	73.3	13.3				
Copepoda		Unld'ed	Calanoida	Harpacticoida	Nauplii					
	# Organisms	3912	9333	3	3040		16288			
	% of Copepoda	24.0	57.3	0.0	18.7		100.0			
	Fish w/Taxon	25	27	1	9			28	93.3	93.3
	% of Sample	83.3	90.0	3.3	30.0					
Diptera		*Chaoborus punctipennis*	Chironomidae	Chiron. pupae	Culicidae					
	# organisms	22	123	11	9		165			
	% of Diptera	13.3	74.5	6.7	5.5		100.0			
	Fish w/Taxon	7	18	2	3			21	70.0	70.0
	% of Sample	23.3	60.0	6.7	10.0					
Aq. inverts		Ephemerellidae								
	# organisms	7					7			
	% of Aq. Inverts	100.0					100.0			
	Fish w/Taxon	5						5	16.7	16.7
	% of Sample	16.7								
Misc.		Ostracoda								
	# organisms	8					8			
	% of Misc.	100.0					100.0			
	Fish w/Taxon	1						1	3.3	3.3
	% of Sample	3.3								

Table A 4.3. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1999.

ORDER	May-99	Sample n = 30	Fish w/Prey 27 - 90.0%		Fish w/o Prey 3 - 10.0%					
Cladocera		UnId'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* sp.	*Leptodora kindti*	Total	# of Fish w/Order	% sample	% Fish w/Prey
	# Organisms	13037	2828	305	3047	22	19239			
	% of Cladocera	67.8	14.7	1.6	15.8	0.1	100.0			
	Fish w/Taxon	21	18	8	17	1		25	83.3	92.6
	% of Sample	70.0	60.0	26.7	56.7	3.3				
Copepoda		UnId'ed	Calanoida	Cyclopoida	Harpacticoida	Nauplii				
	# Organisms	4228	3135	0	20	2520	9903			
	% of Copepoda	42.7	31.7	0.0	0.2	25.4	100.0			
	Fish w/Taxon	15	15	0	1	9		16	53.3	59.3
	% of Sample	50.0	50.0	0.0	3.3	30.0				
Diptera		Ceratopogonidae	*C. punctipennis*	Chironomidae	Culicidae					
	# organisms	10	139	137	31		317			
	% of Diptera	3.2	43.8	43.2	9.8		100.0			
	Fish w/Taxon	4	16	20	8			25	83.3	92.6
	% of Sample	13.3	53.3	66.7	26.7					
Aq. inverts		Coleoptera	Ephemerellidae							
	# organisms	2	15				17			
	% of Aq. Inverts	11.8	88.2				100.0			
	Fish w/Taxon	1	7					7	23.3	25.9
	% of Sample	3.3	23.3							
Fish		Eggs								
	# organisms	7					7			
	% of Fish	100.0					100.0			
	Fish w/Taxon	2						2	6.7	7.4
	% of Sample	6.7								
Misc.		Conchostraca	Ostracoda	Hydracarina						
	# organisms	10	16	1			27			
	% of Misc.	37.0	59.3	3.7			100.0			
	Fish w/Taxon	4	8	1				11	36.7	40.7
	% of Sample	13.3%	Fish w/o Prey							

Table A 4.4. Numbers and percent occurrences of prey organisms consumed by blueback herring in Lake Chatuge during 1999.

ORDER	June-99	Sample n = 30	Fish w/Prey	29 - 96.7	Fish w/o Prey	1 - 3.3					
Cladocera		Unld'ed	*Bosmina longirostris*	*Chydorus* sp.	*Daphnia* sp.	*Holopedium* sp.	*L. kinditi*	Total	Fish w/ Order	% sample	% Fish w/Prey
	# Organisms	19605	68	168	19081	100	9243	48265			
	% of Cladocera	40.6	0.1	0.3	39.5	0.2	19.2	100.0			
	Fish w/Taxon	27	3	8	17	5	26		29	96.7	100.0
	% of Sample	90.0	10.0	26.7	56.7	16.7	86.7				
Copepoda		Unld'ed	Calanoida	Nauplii							
	# Organisms	6527	22289	526				29342			
	% of Copepoda	22.2	76.0	1.8				100.0			
	Fish w/Taxon	21	24	5					27	90.0	93.1
	% of Sample	70.0	80.0	16.7							
Diptera		Ceratopogonidae	*Chaoborus punctipennis*	Chironomidae	Culicidae						
	# organisms	8	844	28	2			882			
	% of Diptera	0.9	95.7	3.2	0.2			100.0			
	Fish w/Taxon	5	20	11	2				23	76.7	79.3
	% of Sample	16.7	66.7	36.7	6.7						
Aq. inverts		*Ephoron Sp.*									
	# organisms	2						2			
	% of Aq. Inverts	100.0						100.0			
	Fish w/Taxon	2							2	6.7	6.9
	% of Sample	6.7									
Fish		*A. aestivalis*	*M. salmoides*	Unidentified							
	# organisms	17	3	1				21			
	% of Fish	81.0	14.3	4.8				100.0			
	Fish w/Taxon	5	3	1					7	23.3	24.1
	% of Sample	16.7	10.0	3.3							
Misc.		Ostracoda									
	# organisms	1						1			
	% of Misc.	100.0						100.0			
	Fish w/Taxon	1							1	3.3	3.4
	% of Sample	3.3									

Vita

Billy C. Goodrich was born in Greeneville, TN, on 27 December, 1963. He was raised in Greeneville and Wharton TX, and attended Boling High School in Boling, TX, where he graduated in 1982. After graduation, he worked in auto parts sales until 1987. He joined the US Army in 1987 and served in Korea and at Ft. Bragg, NC. He also served in Operation Desert Shield/Storm as an airborne engineer combat leader responsible for mobility and counter mobility measures. He began his college education in late 1992 and received a B.S. in Wildlife and Fisheries Science in 1997 from the University of Tennessee. He received his M.S. in Wildlife and Fisheries Science in August 2002, and is currently working in the field of environmental consulting.