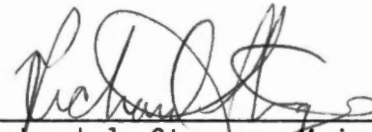
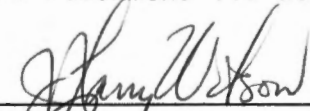
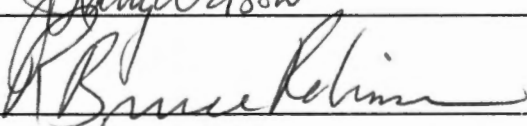


To the Graduate Council:

I am submitting herewith a thesis written by Karen L. Daniel entitled "Food Habits, Age and Growth, and Forage Value of the Alewife in Watauga Reservoir, Tennessee." I have examined the final 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.


Richard J. Strange, Major Professor

We have read this thesis
and recommend its acceptance:


Accepted for the Council:


The Graduate School

4

FOOD HABITS, AGE AND GROWTH, AND FORAGE VALUE OF THE
ALEWIFE IN WATAUGA RESERVOIR, TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Karen L. Daniel

March 1984

ACKNOWLEDGEMENTS

Many individuals have contributed to the completion of this thesis. I sincerely appreciate the advice, encouragement, and understanding of my major professor, Dr. Richard J. Strange. I would also like to thank my other committee members, Dr. J. Larry Wilson, Dr. Bruce Robinson, and Douglas C. Peterson of the Tennessee Wildlife Resources Agency, for their instruction, cooperation, and support.

Special thanks are extended to Ronald Jenkins, J. N. Marklin, Duane Oyer, and Douglas Peterson, all from the Tennessee Wildlife Resources Agency, for their invaluable help in field collections and support of the project. I would also like to thank my fellow students for their help in the field and laboratory: David Routledge, T. Michael Walker, Steve Green, Jeff Durniak, Glenn Thomas, Michael Humphreys, Bruce Saul, and Alan Polk. Also, I would like to thank Dr. Melbourne Whiteside for his help in identification and information regarding zooplankton analyses. Appreciation is extended to Glenn Plungis, graduate research assistant, for the initial work done on the alewife study. I would also like to thank Dr. Thomas Hill for his advice and encouragement. Time and patience of Joyce Quickle in the typing of my manuscript is greatly appreciated.

Computer analyses were made with the assistance of Paul Wright. Special acknowledgement is extended to Danny C. Lee for his computer analyses and interpretation of the alewife diet by the

use of factor analysis and analysis of covariance, and use of regression analyses for age and growth.

Special thanks are extended to my family and friends for their support and encouragement during the entire study.

ABSTRACT

In 1976, the alewife (Alosa pseudoharengus) was stocked in Watauga Reservoir, Tennessee, by the Tennessee Wildlife Resources Agency in an attempt to strengthen the forage base. To assess ecological impacts of the introduction, both food habits and age and growth of alewives were evaluated along with food habits of game fishes and age and growth of walleye. Alewives and game fishes were collected using electrofishing, horizontal and vertical gill netting and "borrowing" from angler creels.

Alewives fed primarily on cladocerans, copepods, and crustacean eggs in both littoral and limnetic regions. Piscivory in alewives was not found to be a significant problem due to the small size of age 2 alewives (103 mm) and the low occurrence of piscivory (0.6%). The alewife population was composed of three age classes (0+, 1+, and 2+). Back-calculated lengths were 70 mm at annulus I and 103 mm at annulus II. No significant differences between sexes were found with back-calculated lengths or with the length-weight relationship ($\alpha = 0.05$).

Alewives contributed to the diets of walleye, smallmouth bass, crappie, rainbow trout, and Ohrid trout. Only in largemouth bass, were there no identifiable alewives found, though unidentified clupeids (alewives and/or gizzard shad) occurred. Age classes of walleye identified by the collection procedures included age 2 through 6. Back-calculated growth at annuli were I-183 mm, II-315 mm, III-395 mm,

IV-442 mm, V-475 mm, and VI-534 mm. Females were found to be significantly heavier than males of the same length and longer at age than males, by length-weight relationships and back-calculated lengths, respectively. Condition factor of walleye was 1.04 indicating sufficient forage for the population size of walleye in Watauga Reservoir. Predator-prey analyses supports a hypothesis that the alewife population in Watauga (maximum size 131 mm) is available to the piscivorous game fishes in the system.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. DESCRIPTION OF THE RESEARCH PROBLEM	10
III. MATERIALS AND METHODS	14
Collection Procedures	14
Laboratory Techniques	15
Diet Analyses	17
Age and Growth Analyses	18
IV. RESULTS	21
Alewife: Age and Growth	21
Alewife: Diet Analyses	26
Walleye: Age and Growth	33
Game Fishes: Diet Analyses	33
V. DISCUSSION	50
VI. SUMMARY	61
VII. RECOMMENDATIONS	64
Positive Attributes from the Study	64
Negative Attributes from the Study	64
Positive Attributes from the Literature Review	65
Negative Attributes from Literature Review	66
LIST OF REFERENCES	69
APPENDICES	76
Appendix A. Tennessee Wildlife Resources Agency Region IV	77
Appendix B. Zooplankton Collection Procedures	82
Appendix C. Results from Factor Analysis and Analysis of Covariance	85
VITA	93

LIST OF TABLES

TABLE	PAGE
1. Comparisons of Total Length at Each Year of Life of Alewives in Watauga Reservoir, Tennessee, 1982-83, and Other Inland Bodies of Water	6
2. Back-calculated Growth at Each Annulus for Alewives from Watauga Reservoir, Tennessee, 1982-83	22
3. Estimated Relationship Between Total Length (mm) and Weight (g) $\pm$ Standard Error for Alewives, by Sex, in Watauga Reservoir	23
4. Gonosomatic Indexes (GSI) for Female and Male Alewives in Watauga Reservoir	25
5. Relative Frequency of Occurrence (%) of Food Items Found in 148 Alewife Stomachs by Season	28
6. Percentage Composition by Number of Food Items in Alewives for the Sampling Period (March 1982 through June 1983) and by Season	29
7. Relative Frequency of Occurrence (%) of Food Items in Alewives Collected in Littoral and Limnetic Regions of Watauga Reservoir from March 1982 through June 1983	30
8. Food Items Associated with Each Factor	32
9. Back-calculated Growth at Each Year of Life for Walleye from Watauga Reservoir, Tennessee, 1982-83	35
10. Estimated Relationship Between Total Length (mm) and Weight (g) $\pm$ Standard Error for Walleye, by Sex, in Watauga Reservoir	36
11. Coefficient of Condition (K) for Walleye in Watauga Reservoir for the Collection Period of June 1982 through June 1983	38
12. Relative Frequency of Occurrence (%) of Food Items for Crappie, Largemouth Bass (LMB), Smallmouth Bass (SMB), Walleye, Rainbow Trout (RBT), and Ohrid Trout (OT) from Watauga Reservoir Collected from March 1982 to June 1983	43

TABLE

PAGE

13.	Relative Frequency of Occurrence (%) of Food Items in Crappie, Largemouth Bass (LMB), Smallmouth Bass (SMB), Walleye, Rainbow Trout (RBT), and Ohrid Trout (OT) from Watauga Reservoir, March 1982 to June 1983	44
14.	Percentage Composition by Number of Food Items in Crappie, Largemouth Bass (LMB), Smallmouth Bass (SMB), Walleye, Rainbow Trout (RBT), and Ohrid Trout (OT) in Watauga Reservoir, March 1982 to June 1983	45
15.	Relative Frequency of Occurrence (%) of Food Items in Walleye and Smallmouth Bass by Season in Watauga Reservoir	46
16.	Relative Frequency of Occurrence (%) of Food Items by Season in Largemouth Bass, Crappie, Rainbow Trout, and Ohrid Trout (OT) in Watauga Reservoir, March 1982 to June 1983	48
17.	Predator-prey Relationship in Watauga Reservoir . . .	49
18.	Comparisons of Back-calculated Lengths of Walleye in Watauga Reservoir and Other Bodies of Water . . .	56
19.	Comparisons of Coefficient of Condition (K) for Walleye in Watauga Reservoir to Other Bodies of Water and Various Size Groups	58
A-1.	Results from Analysis of Covariance with Date as Class Variable and Length of Fish as Covariate . . .	92

LIST OF FIGURES

FIGURE		PAGE
1.	Map of Watauga Reservoir, Tennessee	12
2.	Predicted Length-Weight Relationship for Alewives from Watauga Reservoir	24
3.	Relative Frequency of Occurrence of Food Items in Alewives Collected from March 1982 to June 1983 in Watauga Reservoir	27
4.	Composite Plots of Mean Factor Scores for Each Month . .	34
5.	Predicted Length-Weight Relationship for Walleye in Watauga Reservoir	37
6.	Relative Frequency of Occurrence (%) of Food Items for Walleye and Smallmouth Bass from Watauga Reservoir Collected from 1982 to June 1983	39
7.	Relative Frequency of Occurrence (%) of Food Items for Largemouth Bass and Rainbow Trout from Watauga Reservoir Collected from 1982 to June 1983	40
8.	Relative Frequency of Occurrence (%) of Food Items for Ohrid Trout and Crappie from Watauga Reservoir Collected from 1982 to June 1983	41
A-1.	Mean Factor Scores for Each Month	89

CHAPTER I

INTRODUCTION

Energy flow through trophic levels in biotic ecosystems is influenced by species composition. Food relationships between different species help determine population levels, rates of growth, and condition of fish (Lagler 1956). Manipulation of the forage base has been used to manage mid-level energy transfer in an effort to increase production of carnivorous game fishes (Ney 1981; Nobel 1981). One of the key problems involved in forage fish management is maintaining adequate stocks of prey of size ranges that are vulnerable to predators (Nobel 1981). The introduction of an exotic prey species is one of the most common forage fish management practices and is most prevalent in reservoirs which lack open water forage species. Criteria for an ideal forage species reflects a combination of both biotic potential and ecological constraints (Ney et al. 1982). The criteria for considering an ideal forage species drawn up from guidelines for particular situations (Kimsey 1957; Kohler and Ney 1980a), case histories, and ecological principles as listed by Ney (1981) are: 1) prolific, 2) stable, 3) trophically efficient, 4) vulnerable to predation, 5) non-emigrating, and 6) innocuous. These characteristics should all be considered in the selection of a species for forage fish management.

Planktonic feeding members of Clupeidae, the herring family, have often been used in fisheries management as a forage species. Due

to their high fecundity and small size, they strengthen the food chain length between the plankton and piscivorous game fishes (Boaze 1974). Gizzard shad (Dorosoma cepedianum) and threadfin shad (D. petenense) are clupeids which have the widest natural distribution through the southern United States. Both have been introduced widely as a prey species. Although young gizzard shad are frequently the major source of prey in southern reservoirs, they quickly reach lengths of over 400 mm and are too large for most predator consumption. Consequently, gizzard shad often have the largest standing crop among the forage species. There is some evidence that gizzard may have negative effects on other species when they become overpopulated (Nobel 1981). Cases presented by Nobel (1981) include work by Jenkins and by Swingle. Jenkins compared two nearby lakes, one system having 560 kg/hectare of gizzard shad and the other system in which gizzard shad were absent. Game fishes in the system containing gizzard shad were found to have a lower standing crop; centrarchids had a slower growth rate, poorer condition, and smaller average size when compared to the system lacking gizzard shad. Swingle found a reduction or prevented production of forage-size bluegills (Lepomis macrochirus) and gizzard shad in a system where gizzard shad were overpopulated with larger individuals that were unavailable to predation. The decrease in the populations of forage-size bluegill and gizzard shad negatively affected the growth and survival of largemouth bass (Micropterus salmoides) (Nobel 1981).

Threadfin shad, unlike the gizzard shad, seldom exceed 175 mm and consequently remain vulnerable, throughout their life, to

predators (Nobel 1981). Threadfin shad are limited in their northern range as a result of their inability to withstand temperatures below 9 C for prolonged periods (Strawn 1963). Consequently threadfin shad are subject to winter die-offs in reservoirs which exceed its lower lethal temperature. In considering diet requirements, both the gizzard shad and threadfin shad feed primarily on algae, detritus, and benthos (Kulkun 1957; Baker and Schmitz 1971; Jude 1973).

The alewife (Alosa pseudoharengus) is receiving widespread consideration as an alternative forage species for United States lakes and reservoirs (Ney et al. 1982). Northern populations of landlocked alewives have a desirable trait as a forage species, in that the adults (which have an average attainable size of 120 mm) are small enough to be eaten by predators (Kircheis and Stanley 1981). As a forage species, the alewife has been used for both cold and warm water fishes (Boaze 1974). It was originally an anadromous species confined to the northern Atlantic coast of the United States. Landlocked populations of alewives have been established through introduction and by natural dispersal through the canal systems in the northeastern United States and Canada. The oldest known population of landlocked alewives is in Lake Hopatcong, New Jersey (Boaze 1974).

Further introductions of landlocked alewives have been of interest as a result of the recent success of the Great Lakes fisheries, which now rely heavily on alewives as an abundant forage base. Interest in the alewife focuses on its introduction as a possible solution for lakes and reservoirs that are perceived to have

inadequate pelagic forage populations. Landlocked populations of alewives were generally limited to the Great Lakes system and lakes in southeastern Canada and the northeastern United States (Nigro and Ney 1982) prior to the 1960's. Introductions of landlocked alewives have since been made south of this northeastern region. Among the initial introductions were New Creek Lake, West Virginia, in 1965 (Lewis 1981) and Claytor Lake, Virginia, in 1968 and 1969 (Nigro and Ney 1982). In New Creek Lake, landlocked alewives were stocked to provide an important prey species for brown trout (Salmo trutta) (Lewis 1981). The alewife was stocked in Claytor Lake in an effort to provide pelagic forage species (Nigro and Ney 1982).

The alewife has been found to be beneficial in the diets of a variety of game fish species. Alewives have served as a food source for pelagic species, and when moving inshore to spawn, for littoral piscivorous game fishes (Wagner 1972). In Maine, alewives were found to be an important component of the diet of Atlantic salmon (Salmo salar) (Speirs 1974). Brown trout, rainbow trout (Salmo gairdneri), brook trout (Salvelinus fontinalis), and largemouth bass consumed alewives in West Virginia (McCaig 1980; Lewis 1981). In the Great Lakes system, lake trout (Salvelinus namaycush), chinook salmon (Oncorhynchus tshawytscha), coho salmon (O. kisutch), northern pike (Esox lucius), burbot (Lota lota), bowfin (Amia calva), walleye (Stizostedion vitreum), and smallmouth bass (Micropterus dolomieu) were all found to consume alewives (Wagner 1972; Rhodes and McComish 1975; Stewart et al. 1981). Both walleye and smallmouth bass along

with white bass (Morone chrysops), black crappie (Pomoxis nigromaculatus), white crappie (P. annularis), channel catfish (Ictalurus punctatus), flathead catfish (Pylodictis olivaris), and yellow perch (Perca flavescens) were found to feed upon alewives in Clayton Lake, Virginia (Boaze and Lackey 1974). Kohler and Ney (1980a) found alewives to be a major component in the diet of introduced striped bass (Morone saxatilis) in Claytor Lake. Species found to consume alewives vary from pelagic to shore oriented predators. Variations are also found in the extent of utilization of alewives by individual predator species from system to system.

Life history characteristics (including the range of expression of each characteristic) are important in the consideration of any introduced species. The growth rate of the alewife will vary with geographical location and the individual system. Total length attained by age 1 alewives ranges from 58 mm in New Creek Lake, West Virginia (Lewis 1981) to 94 mm in Lake Michigan (Norden 1967) to 162 mm in Claytor Lake, Virginia (Ney et al. 1982). Age 1 alewives in Lake Michigan and Lake Hopatcong are small enough in size to be eaten by piscivorous game fishes, but their rapid growth rate in Claytor Lake reduces the time in which they are available to piscivorous game fishes. In addition to the differences in expression of growth rate in alewife populations are differences in year class structures. Lake Hopatcong is composed of four year classes, Claytor Lake five (Ney et al. 1982), and Lake Michigan with eight (Brown 1972). Back-calculated lengths at each age for several alewife populations are listed in Table 1.

Table 1. Comparisons of total length at each year of life of alewives in Watauga Reservoir, Tennessee, 1982-83, and other inland bodies of water. Data from Lake Hopatcong, NJ, Lake Ontario, and Echo Lake, MA compiled from Ney et al. 1982. (Total lengths in mm at each annulus.)

Water and Source	I	II	III	IV	V
Watauga Reservoir, TN (Present study) ^a	70	103			
Claytor Lake, VA (Boaze and Lackey 1974) ^a	145	179	222		
Claytor Lake, VA (Ney et al. 1982) ^a	162	194	207	213	
New Creek Lake, WV (Lewis 1981) ^a	58	91	119	140	170
Lake Hopatcong, NJ (Gross 1958) ^b	76	108	150		
Seneca Lake, NY (Ode11 1934) ^a	68	144	151	168	172
Cayuga Lake, NY (Rothschild 1965) ^b	102	121	130	138	144
Lake Ontario (Graham 1956) ^a	77	134	156	161	184
Lake Michigan (Norden 1967) ^a	94	140	159	173	
Echo Lake, MA (Lackey 1970) ^a	114	175			

^aBack-calculation

^bLength frequency

Age at sexual maturity also varies with the individual system. In Lake Hopatcong, Gross found 83% of age 2 alewives are sexually mature (Ney et al. 1982). Fifty-four percent of age 2 alewives are sexually mature in Lake Michigan (Norden 1967). In Claytor Lake sexual maturity occurred at an earlier age, with 86% at age 1 (Ney et al. 1982). The age at sexual maturity in any system will affect the dynamics of the alewife population in both recruitment and year class structure.

Temperature regimes of a system are an important consideration in that they affect age and growth, and the onset, duration and success of the spawn for a particular species. Esdall (1970) found spawning was initiated by alewives at 16 C and was interrupted at 28 C. He also found the minimum temperature at which hatching would occur was 6.9 C. Preferred temperature for alewives was found to be 21 C (Coutant 1977). The critical maximum has been reported as 33 C for adult and juveniles life stages (Otto et al. 1976). Alewives are sensitive to extremely cold temperatures. Resulting seasonal die-offs from cold temperatures can be a common occurrence as exhibited in Lake Michigan, Lake Wononskopomuc, Connecticut, and Claytor Lake (Warshaw 1972; Kohler and Ney 1980a).

Jannsen (1976) studied the feeding behavior of the alewife and determined that it was possible for three different modes of feeding to be exhibited. The first, expressed principally by the smaller fish (≤ 114 mm), was particulate feeding on individual prey items. Only one prey item was taken per mouth opening. The second feeding

mode was exhibited by the largest fish observed (178 to 180 mm). They were capable of filtering prey items with the mouth held agape, accompanied by strong swimming action. Always more than one prey item was taken per mouth opening. The third feeding mode was exhibited by the observed intermediate size fish, and was termed "gulping." The mouth opened and closed more slowly than in particulate feeding, yet more rapidly than during filtering. A swimming action accompanied the "gulping," but more slowly than if filter feeding. In "gulping" more than one prey item was taken per mouth opening. The filtering mode was non-size selective, "gulping" was size selective, and particulate feeding was the most size selective feeding mode. If prey are very small and in dense numbers (i.e., diatoms) even the small fish may filter feed, and in the presence of large prey, particulate feeding may be exhibited by the larger fish. The diet of the alewife is still undergoing examination. They have been found to feed primarily on cladocerans and copepods (Davis and Check 1966; Wells 1970; Hutchinson 1971; Warshaw 1972; Kohler and Ney 1980a; Crowder et al. 1981; Nigro and Ney 1982). In the 1980 study on Claytor Lake, Virginia, larval fish were found in alewife stomachs. This occurrence coincided with mainly nocturnal feeding, was more littoral than limnetic, and also coincided with a precipitous decline in zooplankton densities (Kohler and Ney 1980b). In the Great Lakes alewives have been observed to feed on mixed schools of larval smelt and alewives (Smith 1970). The degree of

alewife piscivory is of concern and current interest in assessing potential impacts on the resident fish communities. Impacts on zooplankton communities from introductions of the alewife have been and are being studied. As a result of the alewife's highly size selective feeding behavior and its efficiency as a foraging predator on zooplankton, shifts in size and species composition (toward smaller forms) have been recorded for several systems into which alewives have been introduced (Wells 1970; Hutchinson 1971; Warshaw 1972; and Kohler and Ney 1981). The highly size selective feeding of the alewife on zooplankton populations could adversely affect cohabitating planktivores including young-of-year game fish (Kohler and Ney 1981).

CHAPTER II

DESCRIPTION OF THE RESEARCH PROBLEM

Watauga Reservoir was impounded in 1948 and initially a satisfactory yield of fishes was produced. In the late 1960's fish production had declined. The Tennessee Wildlife Resources Agency (TWRA) studied the problem of declining production to identify causes and possible solutions. TWRA biologists suggested that efforts should be made to strengthen the forage base and thereby provide more food for piscivorous game fishes. An effort to strengthen the forage base in Watauga was also suggested by biologists from the Tennessee Valley Authority based on cove rotenone studies (Tennessee Valley Authority 1971). Stockings of threadfin shad were made by TWRA in an attempt to supplement the predominantly gizzard shad forage base. A reproducing population of threadfin shad could not be established due to large winter die-offs resulting from cold temperatures. TWRA personnel suggested the alewife as a possible solution to strengthen the forage base. A landlocked population of alewives from Lake Hopatcong, near Sussex, New Jersey, was used as the source. On October 1, 1976 TWRA stocked 1,000 alewives into Watauga Reservoir. One month later, on November 4, 1976, TWRA stocked 6,000 alewives into Dale Hollow Reservoir. Survival of alewives in Watauga was documented on July 17, 1979. In an effort to assess the management decision made by TWRA, to stock the alewife into reservoir systems in the state of Tennessee, TWRA commissioned The University of Tennessee, Knoxville,

to conduct a two-year study on the contribution of the alewife to the forage base in Watauga Reservoir. This study was initiated July 1981. The graduate research assistant, Glenn Plungis, started field collections and laboratory analyses, but left the project in October 1981 (Appendix A). I started on the study in January 1982 and continued through December 1983. The results of this study (January 1982-December 1983) on alewife introduction to Watauga Reservoir are the subject of this report. Primary objectives of this study were to: 1) determine the extent to which alewives are eaten by game fishes (e.g. walleye, smallmouth bass, rainbow trout, and Ohrid trout (Salmo letnica)), 2) evaluate the food habits of alewives, and 3) to measure the growth rate of alewives in Watauga Reservoir. This study was sponsored by TWRA with funds provided by Dingell-Johnson Project F-67 which are administered by the United States Fish and Wildlife Service.

The study area, Watauga Reservoir, is a cool water, mesotrophic, storage reservoir (Figure 1). The reservoir extends into both Carter and Johnson counties in northeast Tennessee. Flood control, power generation, downstream navigation, and recreation are primary functions of the reservoir. Watauga Dam is located on river kilometer 57.6. The reservoir itself is 26.9 km long with a maximum width of 1.3 km. Surface area of the lake is 2,602 ha and the reservoir has 171 km of shoreline. Summer maximum elevation is 597.1 m above sea level, enclosing a volume of 7.01×10^8 cubic meters. Maximum depth at the dam during summer maximum is 87.2 m. Elevation during the winter lies at 583.7 m above sea level with a volume of 3.98×10^8

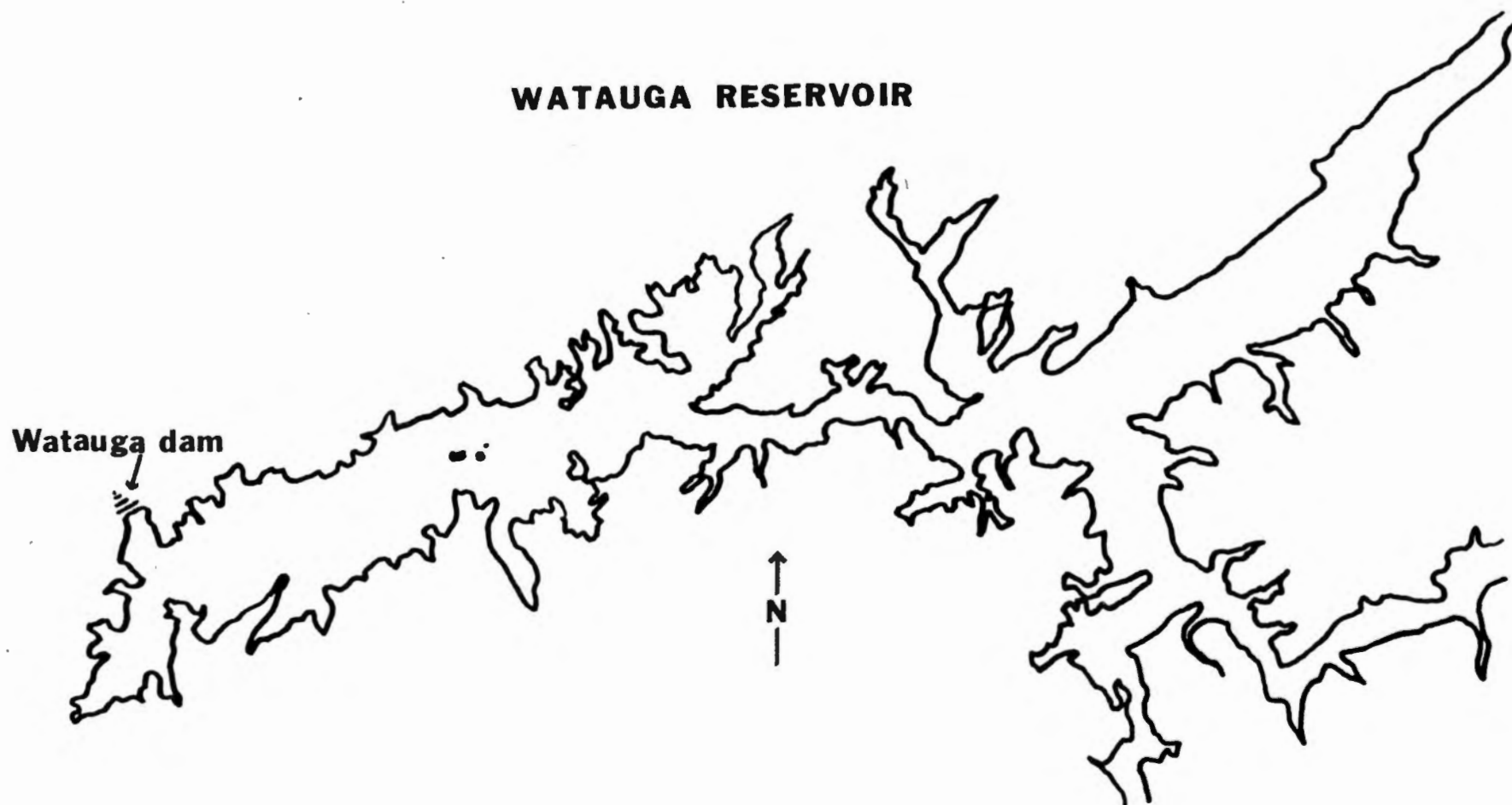


Figure 1. Map of Watauga Reservoir, Tennessee.

cubic meters. Two main tributaries, Watauga and Elk Rivers, feed Watauga Reservoir. During winter months ice forms over the upper section of the reservoir including portions of the tributaries. Dissolved oxygen is present in the hypolimnion throughout the year.

Watauga Reservoir contains a diversity of game fish species. White and black crappie, largemouth and smallmouth bass, walleye, rainbow trout, and channel catfish are present in the reservoir. Stockings of Ohrid trout have been made into the reservoir, though a reproducing population has not been documented.

CHAPTER III

MATERIALS AND METHODS

Collection Procedures

Data analyzed in this study focused on the collection period of March 1982 to June 1983. Alewives and game fish stomachs were collected during monthly sampling trips. Collection goals of 30 game fish per month and 30 alewives from each littoral and limnetic regions were set. Additionally, to meet collection goals, some game fish stomachs were obtained by "borrowing" from angler creels. Collections of alewives were made at dusk and at night since members of the genus Alosa have been found to be negatively phototrophic (Loesch et al. 1982). Landlocked alewives, specifically, have been found to avoid surface waters during the day, but not at night, and therefore are not vulnerable to day-time gill netting (Lindenburg 1976). Attempts were made to collect at both littoral and limnetic sites during the sampling trips. Several sampling techniques were used for the collections. Alewives from limnetic sites were collected with vertical gill net sets, using mesh sizes of 9.5 mm and 12.7 mm. Littoral collections of alewives were collected by electrofishing and horizontal gill net sets with mesh sizes of 9.5 mm and experimental (9.5 to 76.2 mm). All nets used for the collection of alewives were checked two hours after setting to avoid digestion of their stomach contents. Gannon (1976) found that invertebrates were digested beyond recognition in alewife stomachs in 2.5 to 4.5 h at 15 C. Upon collection of

the alewives, an incision was made into the body cavity to facilitate preservation of the stomach contents. The fish were then preserved in 10% formalin. Attempts were made to collect zooplankton samples from areas in which alewives were captured, but were unsuccessful (Appendix B). Game fish samples were collected by electroshocking, horizontal, and vertical gill net sets (50.8 mm, 76.2 mm, and experimental mesh). The fish were weighed, measured, and sexed. Scale samples were collected from the left side of the fish below the lateral line at the top of the pectoral fin. The stomachs were removed from each fish, wrapped with an identification number and preserved in 10% formalin.

Laboratory Techniques

Stomach contents were analyzed for game fishes and alewives. Twenty-five game fish per month were analyzed when available. A minimum of nine alewives per month, representing collections from littoral and limnetic regions, were randomly selected and analyzed. Game fish stomach contents were identified and enumerated for numerical analysis (Lagler 1956; Windell and Bowen 1978). Food items were identified to the lowest taxonomic level permitted by digestion. Length of ingested prey species was measured, or estimated when possible. Alewives were weighed and measured. For alewives, the body cavity was opened to remove the stomach, intestine, and gonadal tissue. Weights were taken for the gonadal tissue. The digestive tract (stomach and intestine) was opened and rinsed free of food items. A general survey was made to identify all food items present. A dilution of

stomach contents was made to a known volume and a subsample withdrawn, using a Henson-Stimple pipet. The subsampled organisms were identified and counted. The subsample count was then expanded by the dilution factor to get an estimate of the total number of organisms per stomach.

Age and growth analyses of the walleye were made by conventional techniques (Lagler 1956; Bagenal and Tesch 1978). Scales of alewives were analyzed by the conventional techniques (Lagler 1956; Bagenal and Tesch 1978) with the addition of information on the characteristics of the cycloid scale of the alewife (Cating 1953; Judy 1961; Rothschild 1963; Norden 1967). Scale samples from the alewives were taken from the left side of the fish, three and four rows below the posterior end of the dorsal fin (Norden 1967). Cycloid scales of the alewife differ from ctenoid scales in several respects. The cycloid scale is more round, with annuli and transverse grooves in the anterior field. The first transverse groove closest to the posterior (exposed) portion of the scale is taken as the baseline, and annuli are measured from this reference line. Spawning marks differ from annuli formed before sexual maturity in appearance, yet are also used as an indication of a year's growth. As the alewife scales were analyzed, annuli, spawning marks, and number of transverse grooves per annulus were recorded. Age was assigned on the basis of these data. Scales from alewives and walleye were examined at 20X magnification in a modified Microfishe reader.

Diet Analyses

Two numerical analyses were used to assess the diets of game fish and alewives. The occurrence of one or more given food items in the diet was defined by the number of stomachs it occurred in relation to the total number of stomachs that contained food. This ratio was expressed as a percentage indicating the relative frequency of occurrence of the given food item:

$$\text{relative frequency of occurrence} = \frac{\text{number of stomachs in which the food item occurred}}{\text{total number of non-empty stomachs examined}} \times 100.$$

The number of food items of a given type occurring in all stomachs examined was expressed as a percentage of the total number of all food items to estimate the relative abundance of that type of food item in the diet (Lagler 1956; Windell and Bowen 1978):

$$\text{percentage composition by number} = \frac{\text{number of food items of a given type}}{\text{total number of all food items}} \times 100.$$

In the analysis of the predator-prey relationship, prey ingested by the game fishes were measured or estimated when possible. Data included predator species, predator length, prey species and length of prey.

The diet of alewives was examined through the use of factor analysis. Multivariate techniques have been used to reduce diet information to a lesser number of components which are linear combinations of the original variables (Desselle et al. 1978; Ross 1978;

Dolman 1982). Variables used for the alewife diet analysis included date of capture, length of fish, and number of individual prey items per stomach sample for each fish. A total number of food items were identified as occurring in at least one stomach sample. Through the use of factor analysis, this total number of food items was reduced to lesser number of factors or diet components. As an initial step, descriptive statistics for each food item were calculated. Frequency of occurrence was used to estimate relative importance. Those items occurring in only one sample or which were perfectly correlated with other items were omitted from further analyses. Log transformation ($\log_e(x+1)$) of food item counts were performed as variance appearance proportional to the means (Kleinbaum and Kupper 1978). Factor analysis using a promax rotation was used to reduce the matrix of food items to nine factors or diet components. Factor scores for each factor were calculated for all individual fish and used in an analysis of covariance using date of capture as a class variable and length of fish (mm) as the covariate. Average factor scores were calculated for each month, regardless of year, and plotted using a spline interpolation. All computations, analyses, and plotting were performed using SAS procedures (SAS 1981; SAS 1982).

Age and Growth Analyses

Calculations based on scale data were made to estimate previous growth of alewives and walleye. Total scale radius and distance from the focus (baseline for alewives) to each annulus were

measured. The measured distance to each annulus was assumed to be directly proportional to the length of the fish at the time the annulus was formed. This body length:scale length relationship was used to back-calculate length during each year of life, utilizing Lea's (1910) formula (Bagenal and Tesch 1978):

$$L_n = \frac{S_n}{S} L$$

where: L_n = length of the fish when annulus 'n' was formed

L = length of the fish when the scale sample was obtained

S_n = radius of annulus 'n' (at fish length 'n')

S = total scale radius

Back-calculated lengths were computed for alewives and walleye. Differences between sexes for each species were tested for significance using the Student's t-test at $\alpha = 0.05$.

The length-weight relationship in fishes can usually be represented by $W = aL^b$. A logarithmic transformation of this equation yields the straight line relationship (Bagenal and Tesch 1978):

$$\log w = \log a + b \log L$$

Regression analysis, utilizing PROC REG (SAS 1982), was used to estimate length-weight relationships for both alewives and walleye. Differences between sexes for each species were tested for significance at $\alpha = 0.05$.

The hypothesis that heavier fish of a given length are in better condition is used to compare the "condition," "fatness" or "well-being" of fish. The condition of walleye was calculated using the coefficient of condition, K, or Fulton's condition factor (Lagler 1956; Bagenal and Tesch 1978):

$$K = \frac{W 10^5}{L^3}$$

where: W = weight in grams

L = length in mm

and 10^5 is a factor used to bring the value of K near unity.

The condition factor was tested for significant differences between sexes using the Student's t-test at $\alpha = 0.05$.

The gonosomatic index (GSI) was used to indicate spawning periods. It was calculated as a percentage based on the formula of Vladykov (1956) as Ney et al. (1982):

$$GSI = \frac{\text{weight of both ovaries}}{\text{total body weight} - \text{ovary weight}} \times 10$$

During a 12-month period the highest GSI levels indicate maximum spawning activity with the lowest levels indicating the end of spawning activity.

Computations, analyses, and plotting of most age and growth, and food habit analyses were performed using the UTCC Decsystem-10 and SAS procedures (SAS 1981; SAS 1982).

CHAPTER IV

RESULTS

Alewife: Age and Growth

Sampling of the alewife population from 1982-1983 identified three year classes (0+, 1+, and 2+). Total lengths at annulus I and II were back-calculated (Table 2). No significant difference was found between males and females for back-calculated lengths ($\alpha = 0.05$). Analysis of the length-weight relationship in alewives indicated no significant differences ($\alpha = 0.05$) between sexes for "a" (log a is the y-intercept) or "b" (regression coefficient). Analysis of the length-weight relationship in alewives indicated no significant differences ($\alpha = 0.05$) between sexes for "b" (regression coefficient) or "a" (log a is the y-intercept) (Table 3). Differences in "a" or "b" between sexes would reflect sex related differences in body shape. Figure 2 shows the predicted length-weight relationship for alewives in Watauga Reservoir.

Examination of scales revealed annulus formation from the end of March through the first of June. Transverse groove counts were made for each annulus. Number of transverse groove counts per annulus by age were: age 0+, 2.8; age 1+, 1.5; age 2+, 1.2. In 46% of age 2 or 2+ alewives ($n = 57$), the second annulus was an identifiable spawning mark. Calculations of gonosomatic indexes (GSI) were made for both female and male alewives (Table 4) to define the spawning period of alewives in Watauga Reservoir.

Table 2. Back-calculated growth at each annulus for alewives from Watauga Reservoir, Tennessee, 1982-83. (Total lengths in mm at each annulus.)

Sex	I				II			
	N	$\bar{X}$	S.E.	Range	N	$\bar{X}$	S.E.	Range
Combined	145	70	0.09	44 - 98	54	103	0.18	88 - 123
Male	62	70	0.13	44 - 98	22	103	0.22	88 - 120
Female	80	70	0.11	46 - 96	31	105	0.18	88 - 123

Table 3. Estimated relationship between total length (mm) and weight (g) $\pm$ standard error for alewives, by sex, in Watauga Reservoir. Model $W = a (\text{Total length})^b$.

Coefficient	Sex	
	Male	Female
a	$9.83 \times 10^{-6} \pm 1.10 \times 10^{-5}$	$9.83 \times 10^{-6} \pm 9.99 \times 10^{-6}$
b	2.91 ± 0.16	2.91 ± 0.10
R ²	0.86	0.86

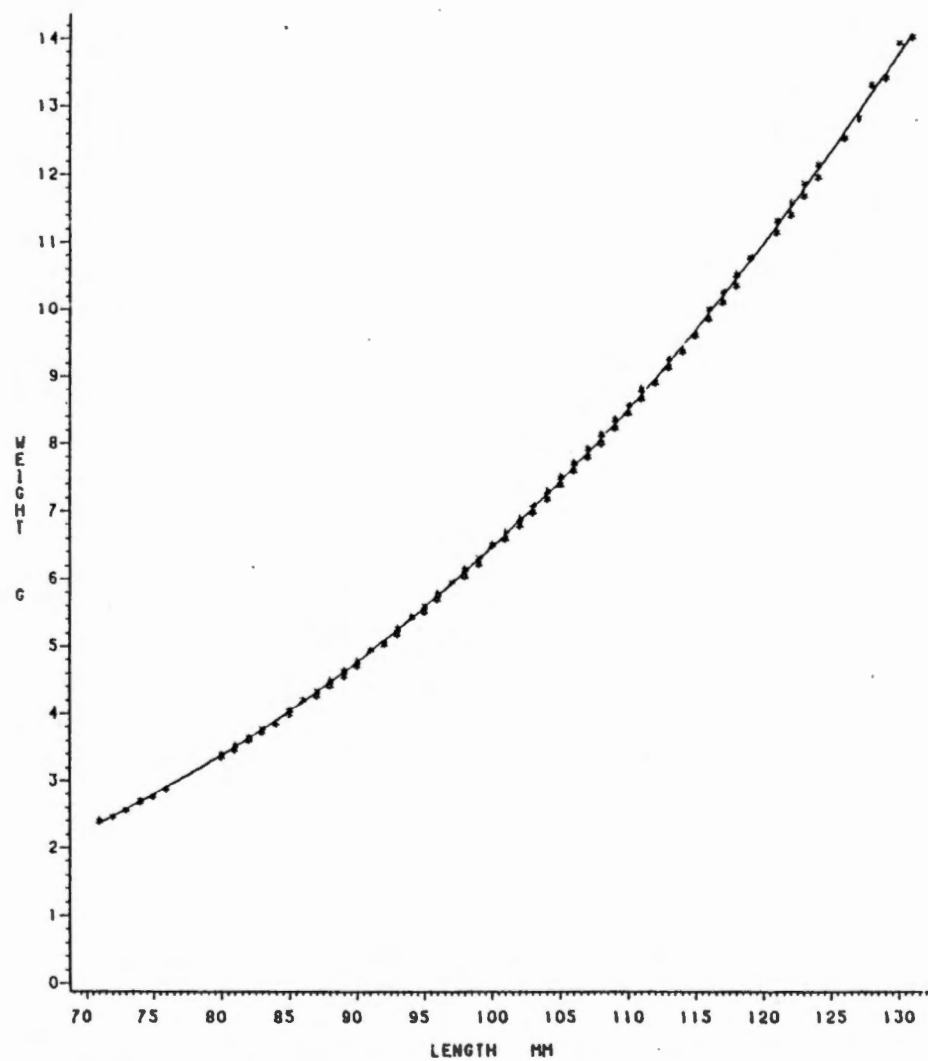


Figure 2. Predicted length-weight relationship for alewives from Watauga Reservoir.

Table 4. Gonosomatic indexes (GSI) for female and male alewives in Watauga Reservoir.

Date	Gonosomatic Index (GSI) ^a									
	Female					Male				
	N	$\bar{X}$	S.E.	MIN	MAX	N	$\bar{X}$	S.E.	MIN	MAX
Mar 82	7	3.5	0.6	1.9	6.0	3	1.5	0.3	0.9	1.9
Apr 82	7	4.3	0.6	0.4	11.3	3	2.1	1.4	0.3	4.8
May 82	4	6.0	3.4	0.8	16.0	5	4.1	0.5	2.2	5.7
Jun 82	7	8.0	2.8	0.8	21.2	6	3.1	0.6	1.8	5.2
Jul 82	6	7.6	2.2	1.1	15.8	3	1.5	0.6	0.7	2.7
Aug 82	6	1.3	0.4	0.4	3.2	3	0.8	0.4	0.4	1.6
Sep 82	6	1.1	0.2	0.4	1.5	3	1.0	0.3	0.6	1.6
Oct 82	6	1.0	0.1	0.5	1.3	2	0.9	0.1	0.8	1.0
Nov 82	5	1.8	0.1	0.8	2.3	2	0.6	0.3	0.3	0.9
Dec 82	5	1.8	0.3	0.8	2.4	4	0.7	0.1	0.3	0.9
Jan 83	5	2.1	0.4	1.0	3.3	2	0.6	0.3	0.3	0.9
Feb 83	4	2.2	0.6	0.8	3.8	5	1.4	0.3	0.7	1.9
Mar 83	8	4.8	1.3	0.8	9.9	5	3.2	0.6	1.6	4.2
Apr 83	4	1.6	1.2	0.3	5.1	1	5.1	-	-	-
May 83	4	6.6	3.4	0.5	13.5	5	3.5	0.9	0.5	5.9
Jun 83	6	7.5	1.6	2.4	14.0	4	2.6	1.0	0.9	4.5

$$^a \text{GSI} = \frac{\text{weight of gonads (g)}}{\text{total weight of fish-gonadal weight}} \times 100$$

Maximum GSI values of female alewives were used in the determination of the spawning period, instead of mean GSI values, because of the small sample size per month. Spawning began in April, peaked in June, and terminated in August.

Alewife: Diet Analyses

Principal components of the alewife diet by relative frequency of occurrence were cladocerans, copepods, and crustacean eggs for the period of March 1982 through June 1983 (Figure 3). Effects of season on the alewife diet were examined by relative frequency of occurrence of food items (Table 5). Cladocera occurred in all alewives analyzed throughout the year. Copepods were found in alewives throughout the year, increasing in occurrence in the summer and fall. Crustacean eggs increased from 39% in the winter to 59% in the fall. Ostracods were consumed during the spring (10%) and summer (12%). During the spring dipterans occurred in 14% of alewives examined decreasing to 7% in the summer to 4% in the fall. Percentage composition by number was also used to examine effects of season on the alewife diet (Table 6). Cladocerans were again the dominant component by number (90.9 to 97.7%). Though dipterans and hymenoptera were a small percent by number, they were an important component in the diet when found due to their size in comparison to cladocerans (0.1 to 2.0 mm). Relative frequency of occurrence was used to compare diets of alewives collected in littoral and limnetic regions (Table 7). Bosminidae comprised the majority of cladocerans found in both littoral (98.3%) and limnetic (100%)

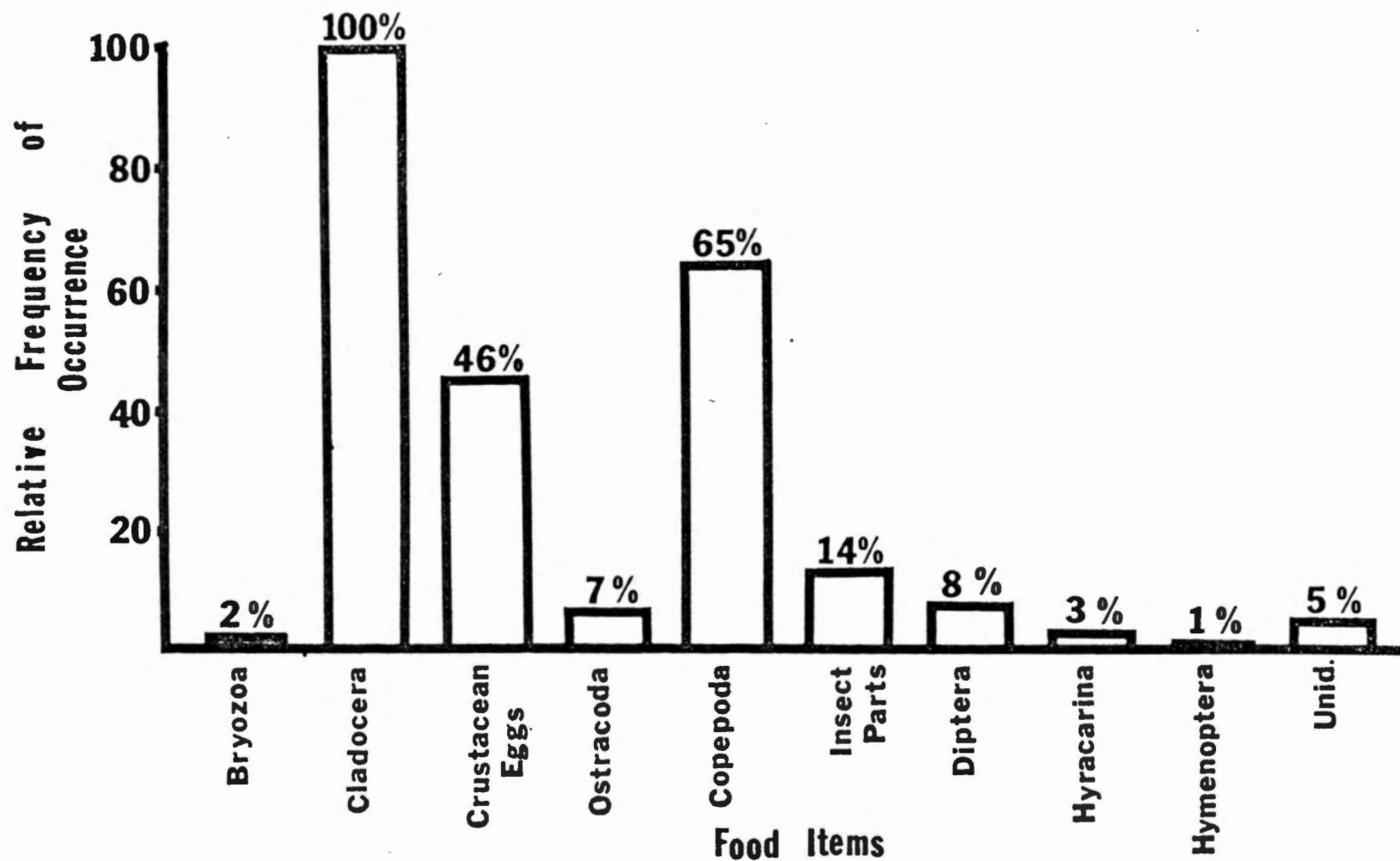


Figure 3. Relative frequency of occurrence of food items in alewives collected from March 1982 to June 1983 in Watauga Reservoir.

Table 5. Relative frequency of occurrence (%) of food items found in 148 alewife stomachs by season.

Food Item	Relative Frequency of Occurrence			
	Winter ^a	Spring ^b	Summer ^c	Fall ^d
Bryozoan floatoblast	0	3	0	4
Cladocera	100	100	100	100
Crustacean eggs	39	45	44	59
Ostracoda	0	10	12	0
Copepoda	57	59	71	78
Insect fragments	11	17	17	7
Diptera	0	14	7	4
Hydracarina	0	0	10	0
Hymenoptera	0	0	2	4
Unidentified	0	12	2	0
No. of fish with food	28	58	37	25

^aWinter = December-February

^bSpring = March-May

^cSummer = June-August

^dFall = September-November

Table 6. Percentage composition by number of food items in alewives for the sampling period (March 1982 through June 1983) and by season.

Food Item	Mar '82-June '83	Season			
		Winter ^a	Spring ^b	Summer ^c	Fall ^d
Bryozoan floatoblast	0.01	0.00	0.02	0.00	0.02
Cladocera	94.40	97.73	96.28	92.13	90.91
Crustacean eggs	1.74	0.73	1.61	2.11	2.47
Ostracoda	0.02	0.00	0.03	0.01	0.00
Copepoda	3.69	1.49	1.82	5.64	6.47
Insect fragments	0.07	0.05	0.12	0.04	0.11
Diptera	0.04	0.00	0.10	0.01	0.00
Hydracarina	0.01	0.00	0.00	0.03	0.00
Hymenoptera	0.01	0.00	0.00	0.02	0.00
Unidentified	0.01	0.00	0.02	0.00	0.00
No. of fish with food	148	28	58	37	25

^aWinter = December-February

^bSpring = March-May

^cSummer = June-August

^dFall = September-November

Table 7. Relative frequency of occurrence (%) of food items in alewives collected in littoral and limnetic regions of Watauga Reservoir from March 1982 through June 1983.

Food Item	Region		Food Item	Region	
	Littoral	Limnetic		Littoral	Limnetic
Bryozoa			Copepoda		
Plumatellidae			Calanoida	3.4	7.3
floatoblast	3.3	1.2	Cyclopoida	54.2	35.4
Cladocera			Harpacticoida	16.9	8.5
Unid. cladocera	13.6	11.0	Unid. copepods	64.4	45.1
Leptodoridae			Crustacean eggs	52.5	47.6
<u>Leptodora kindti</u>		1.2	Ostracoda	8.5	2.4
Sidiidae			Hydracarina	3.4	
<u>Sida crystallina</u>	1.7	1.2	Diptera		
Daphnidae			Chironomidae		
<u>Daphnia</u> spp.	8.5	2.4	Chironomid larvae	6.8	1.2
Ephippium	3.4	3.7	Chironomid pupa	1.7	1.2
Bosminidae			Chaoborinae		
Bosmina spp. ^a	98.3	100.0	Chaoborus spp.	5.1	
Chydorinae			Unid. dipterans	5.1	
Unid. chydorids	13.6	3.7	Insect fragments	15.3	11.0
Graptoleberis			Hymenoptera		1.2
<u>testudinaria</u>	1.7		Unid. material	10.2	2.4
<u>Leydigia</u> spp.		1.2			
<u>Alona</u> spp.	3.4	3.7			
<u>Chydorus sphaericus</u>	10.1	1.2	No. of fish with food	59	82

^aPrincipally Bosmina longirostris.

regions. Alewives were feeding in both littoral and limnetic regions, as shown by the presence of littoral species Leydigia spp. and Alona spp., in alewives collected in limnetic areas, and Chaoborus sp., a limnetic species, found in alewives collected in littoral areas. In littoral areas alewives fed in the water column as indicated by the presence of Daphnia spp. and cyclopoid copepods, and over the bottom, indicated by the presence of harpacticoid copepods, ostracods, chironomids, and Leydigia spp. Presence of Graptoleberis testudinaria and Alona spp. indicate the feeding of alewives among weeds. In 154 alewives analyzed for food habits, one stomach contained an unidentified partially digested fish (0.6%). The alewife (140 mm TL) was collected at night in a vertical gill net set under lights for 1.5 h, in June 1983.

Factor analysis of the alewife diet reduced 24 food items, occurring in more than one fish, to nine linear components or factors (Table 8). Food items which share similar high loadings on the same factor are simultaneously being utilized by alewives (Appendix C). Food items with high oppositely signed loadings on the same factor are inversely related to the diet (example: factor 5). The nine factor solution accounted for 65.6% of the total variation and no less than 43% of any individual food item. Results from the analysis of covariance of generated factor scores for individual fish indicated significant interaction between date of capture and fish length for factors 1, 2, 3, 6, and 9. This significance indicates that the variation in utilization of these components, associated with length, is date dependent. Only for factor 5 does length appear to

Table 8. Food items associated with each factor.

Factor	Food Items
Factor 1.	Dipterans, chironomid larvae, chydorids, Ostracoda, and unidentified remains
Factor 2.	Bryozoan floatoblast, <u>Alona</u> spp., insect fragments, and chydorids
Factor 3.	<u>Sida</u> sp., <u>Pleuroxus</u> spp., and <u>Chydorus sphaericus</u>
Factor 4.	<u>Leydigia</u> spp., Ostracoda, chironomid pupa, insect fragments, and <u>Alona</u> spp.
Factor 5.	<u>Bosmina</u> spp. (negative correlation), cyclopoid copepods, Copepoda, and <u>Chaoborus</u> larvae
Factor 6.	Calanoid copepods, harpacticoid copepods, Hymenoptera, and Acari
Factor 7.	<u>Daphnia</u> spp., crustacean eggs, and cyclopoid copepods
Factor 8.	Tricoptera, Hymenoptera, and Acari
Factor 9.	Ephippium, and <u>Chaoborus</u> larvae (negative correlation)

have a significant, consistent effect. Date apparently has the highest degree of association with the utilization of all diet components. Mean factor scores plotted for each month illustrate seasonal utilization of each diet component (Figure 4).

Walleye: Age and Growth

Sampling of the walleye population from 1982 to 1983 identified five age classes (age 2 to age 6). Total lengths at each annulus were back-calculated (Table 9). Females were found to be significantly greater in length for back-calculated lengths at ages 2 through 5 ($\alpha = 0.05$). Annulus information occurred in March and April in Watauga Reservoir. Analysis of the length-weight relationship in walleye indicated significant differences ($\alpha = 0.05$) between sexes for "a." Resultant coefficients are in Table 10. Females were heavier than males of the same length (Figure 5). The condition factor (or K) calculated for 210 walleye over a 13-month period was 1.04. No significant difference ($\alpha = 0.05$) in condition between sexes was found. Condition factors calculated by month did not reveal any distinct trends in seasonal variation (Table 11).

Game Fishes: Diet Analyses

Game fish species represented in the collection period of March 1982 through June 1983 were walleye, smallmouth bass, largemouth bass, crappie, rainbow trout and Ohrid trout. Diet analyses were made for 272 walleye, 66 smallmouth bass (Figure 6), 14 largemouth bass, 6 rainbow trout (Figure 7), 19 crappie and 6 Ohrid trout (Figure 8). Relative frequency

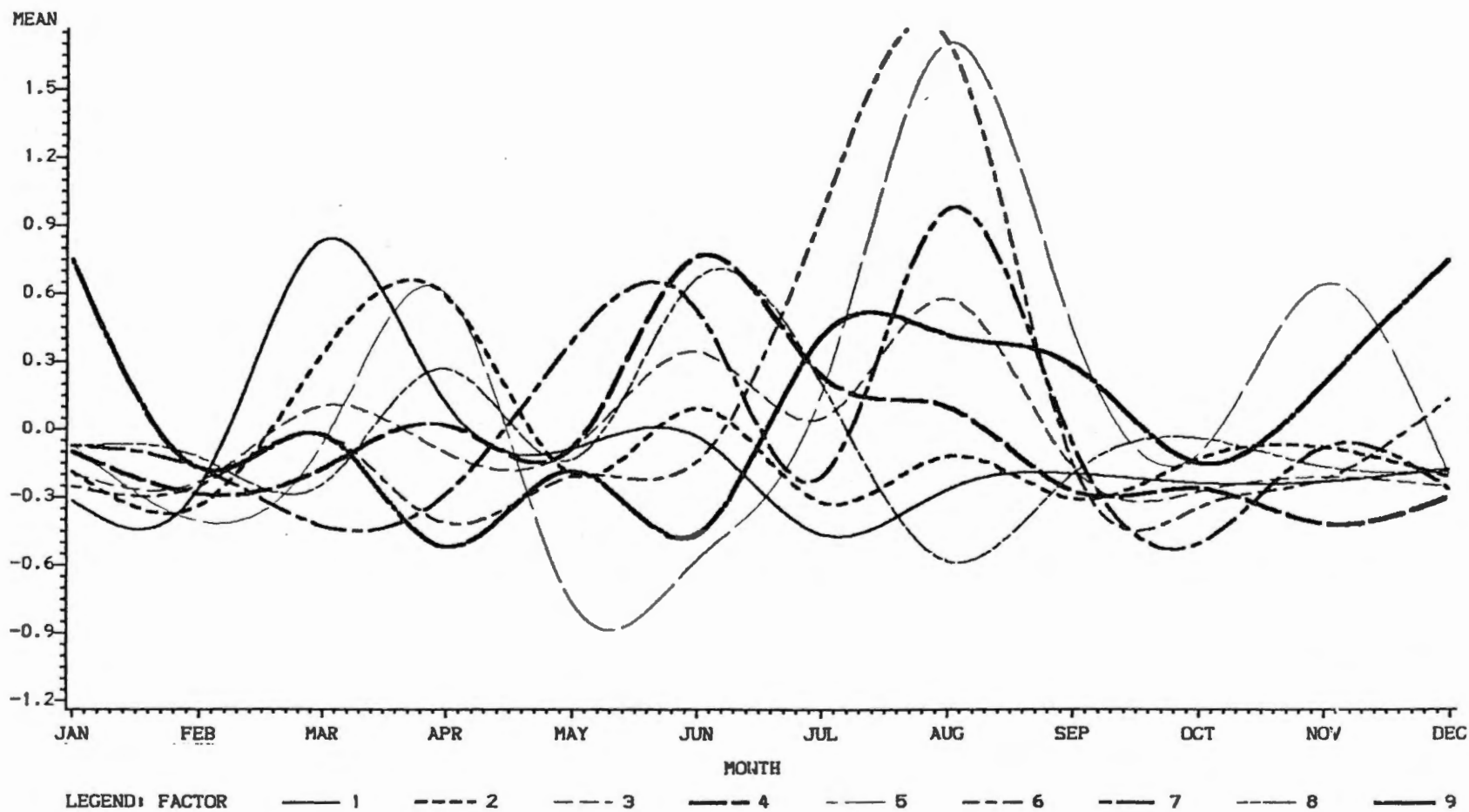


Figure 4. Composite plots of mean factor scores for each month.

Table 9. Back-calculated growth at each year of life for walleye from Watauga Reservoir, Tennessee, 1982-83. Ranges are in parentheses. (Total lengths in mm at each annulus.)

Sex	N	I	II	III	IV	V	VI
M,F	208	185 (66-292)	315 (129-394)	395 (235-478)	442 (319-554)	475 (410-552)	534 (490-564)
M	157	183 (108-270)	311 (225-381)	390 (304-453)	431 (374-520)	446 (410-530)	490 (490)
F	46	192 (66-292)	327 (129-394)	412 (236-478)	465 (319-554)	504 (441-552)	556 (549-564)

Table 10. Estimated relationship between total length (mm) and weight (g) $\pm$ standard error for walleye, by sex, in Watauga Reservoir. Model $W = a (\text{Total length})^b$.

Coefficient	Sex	
	Male	Female
a	$4.62 \times 10^{-4} \pm 1.42 \times 10^{-3}$	$3.26 \times 10^{-4} \pm 6.64 \times 10^{-4}$
b	2.38 ± 0.23	2.44 ± 0.18
R ²	0.79	0.79

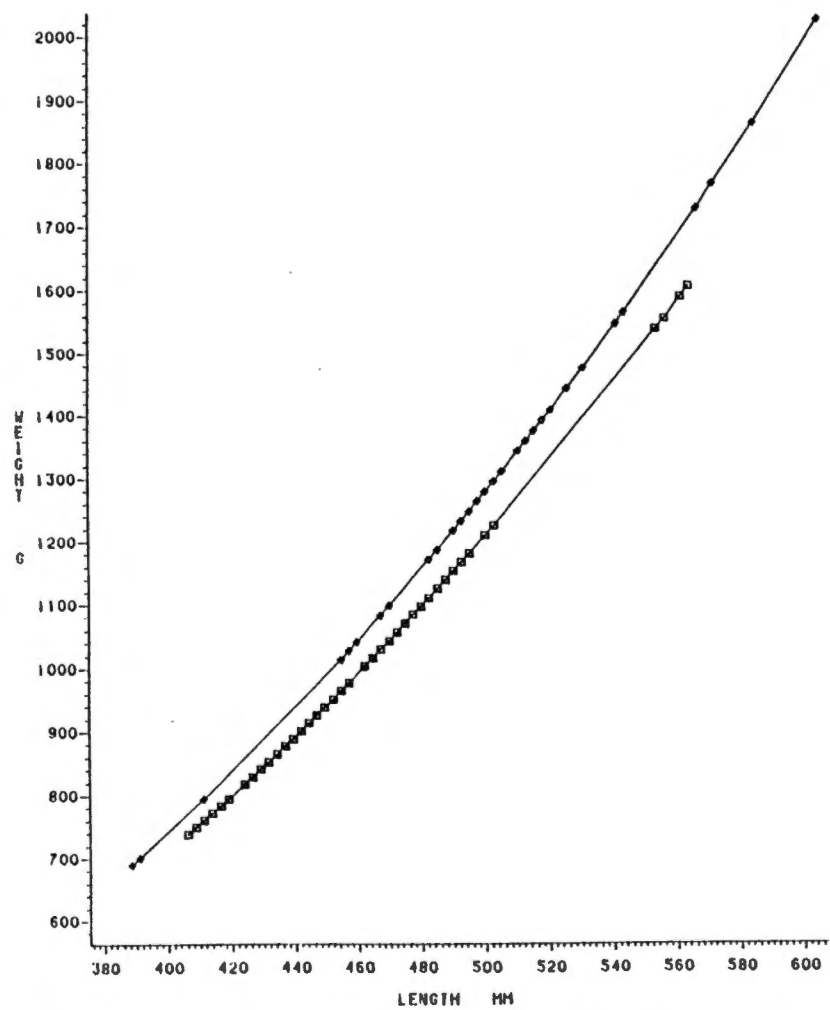


Figure 5. Predicted length-weight relationship for walleye in Watauga Reservoir.

Females = □ and males = ◇

Table 11. Coefficient of condition (K) for walleye in Watauga Reservoir for the collection period of June 1982 through June 1983.

Date	N	$\bar{X}$	S.E.	Minimum	Maximum
Jun 82	19	0.98	0.03	0.68	1.18
Jul 82	16	1.03	0.03	0.85	1.35
Aug 82	23	1.02	0.02	0.86	1.13
Sep 82	5	0.97	0.03	0.89	1.07
Oct 82	11	1.00	0.02	0.89	1.18
Nov 82	21	1.02	0.01	0.90	1.13
Dec 82	20	1.02	0.02	0.83	1.14
Jan 83	20	1.09	0.03	0.92	1.42
Feb 83	20	1.19	0.02	1.02	1.37
Mar 83	19	1.06	0.04	0.93	1.78
Apr 83	15	0.96	0.02	0.80	1.06
May 83	8	1.00	0.05	0.85	1.26
Jun 83	13	1.06	0.02	0.93	1.21
Jun 82- Jun 83	210	1.04	0.01	0.68	1.42

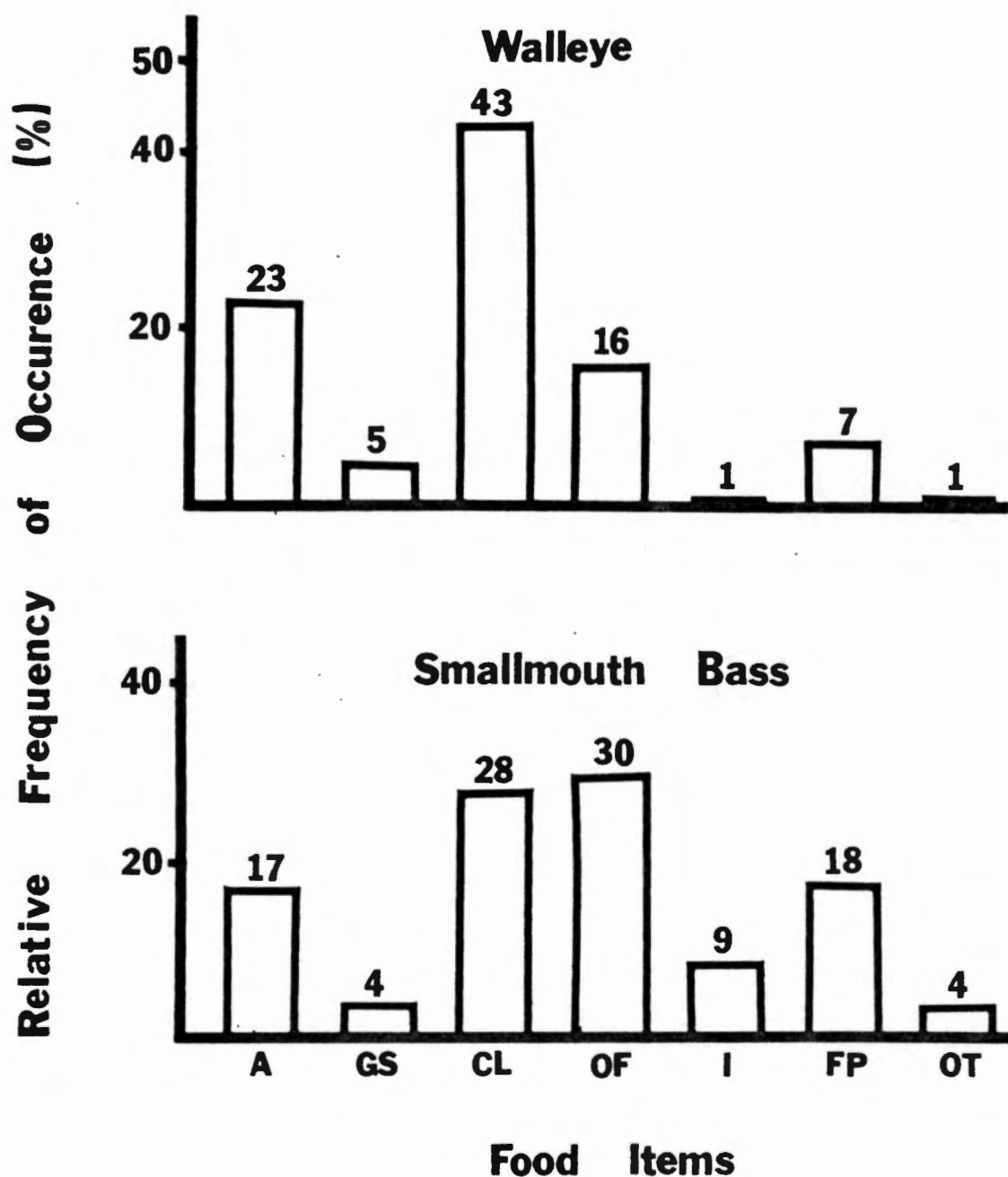


Figure 6. Relative frequency of occurrence (%) of food items for walleye and smallmouth bass from Watauga Reservoir collected from 1982 to June 1983. A = alewife, GS = gizzard shad, CL = clupeid, OF = other fish, I = insects, FP = fish parts, OT = 'other.'

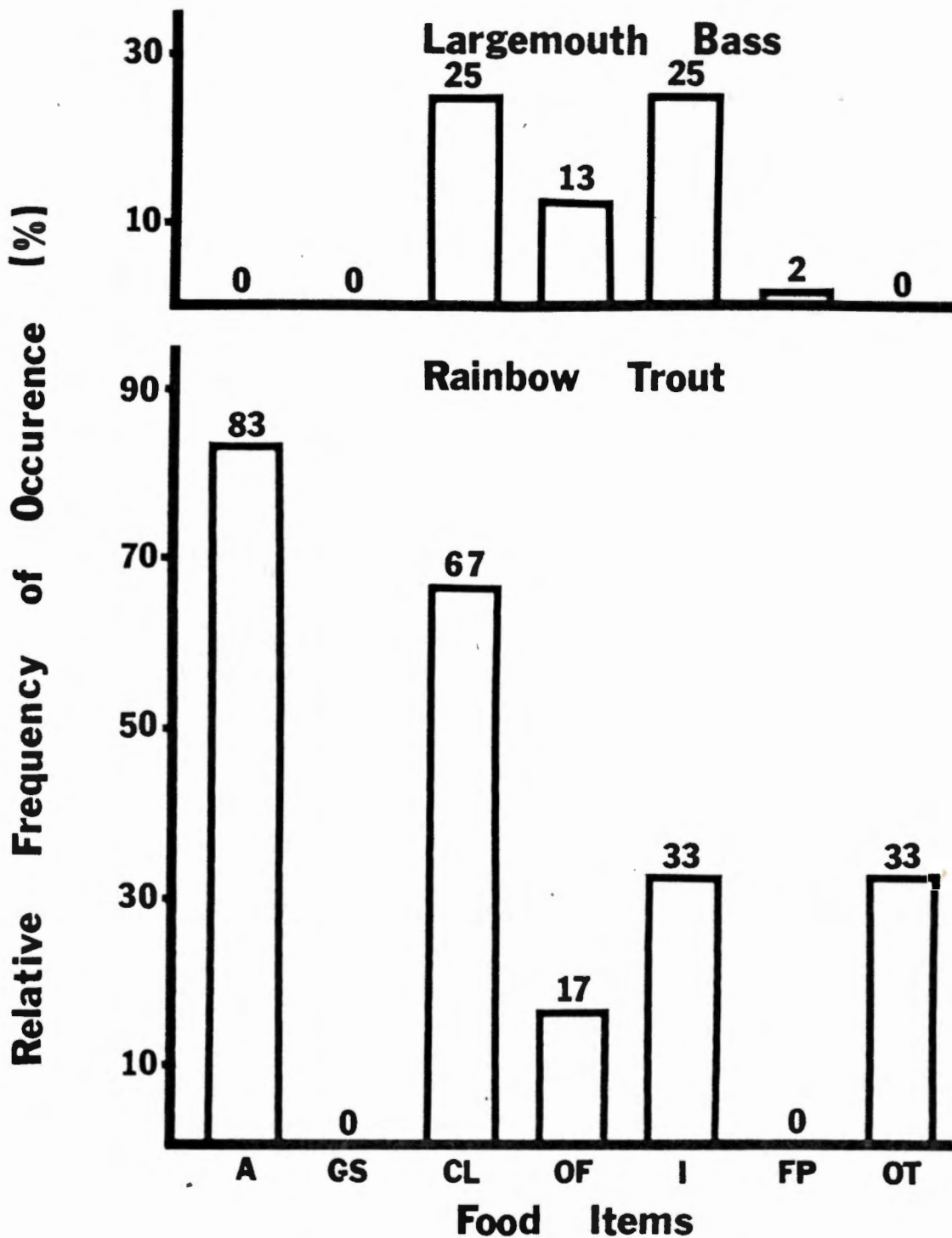


Figure 7. Relative frequency of occurrence (%) of food items for largemouth bass and rainbow trout from Watauga Reservoir collected from 1982 to June 1983. A = alewife, GS = gizzard shad, CL = clupeid, OF = other fish, I = insects, FP = fish parts, OT = 'other.'

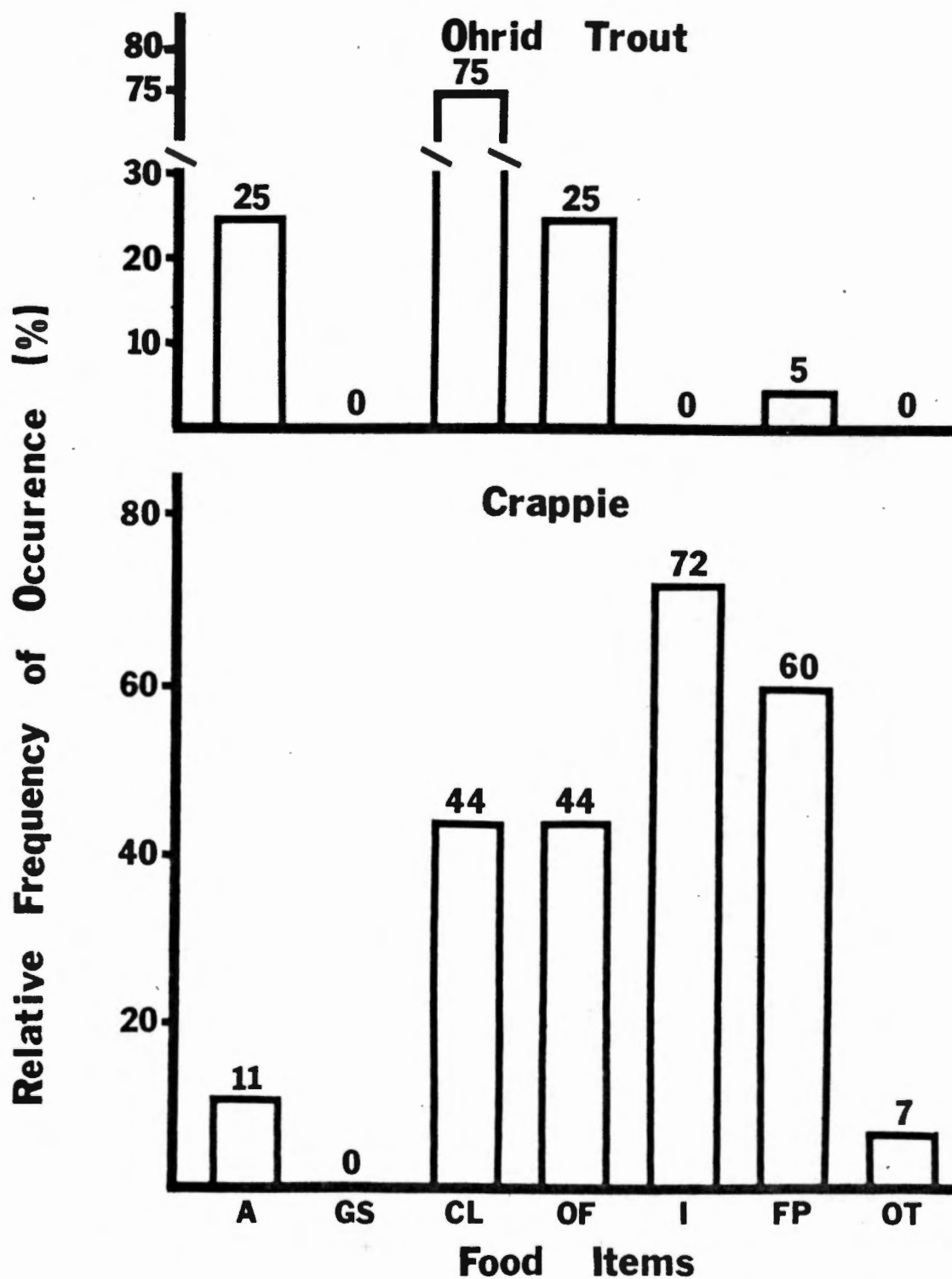


Figure 8. Relative frequency of occurrence (%) of food items for Ohrid trout and crappie from Watauga Reservoir collected from 1982 to June 1983. A = alewife, GS = gizzard shad, CL = clupeid, OF = other fish, I = insects, F = fish parts, OT = 'other.'

of occurrence was used to assess categories of food items in the game fish diets (Table 12). Alewives were consumed by all species analyzed (crappie, 11.1%; smallmouth bass, 17.4%; walleye, 22.7%; rainbow trout, 83.3%; and Ohrid trout, 25%) with the exception of largemouth bass in which no alewives were identified. Gizzard shad were identified in smallmouth bass (4.3%) and walleye (4.5%) at a lower relative frequency of occurrence in comparison to alewives. All species contained unidentified clupeids (either alewives or gizzard shad). Seventy-two percent of crappie examined contained invertebrates compared to 33.3% in rainbow trout, 25% in largemouth bass, 8.7% in smallmouth bass, and 0.5% in walleye. The diets of game fish were further assessed by individual food items by relative frequency of occurrence (Table 13). Species comprising the "other fish" category are listed along with individual food items of crustaceans and insects. Zooplankton were found in crappie, with crayfish occurring in largemouth and smallmouth bass. Insects primarily were components of crappie and rainbow trout diets. Percent composition by number of individual food items for game fish were calculated (Table 14). Percent composition by number of alewives consumed were crappie, 1%; smallmouth bass, 16.5%; walleye, 18.7%; rainbow trout, 11.6%; and Ohrid trout, 13.3%. Though crappie consumed 1% by number of alewives and 50.8% ephemeropterans, an alewife is the larger mass in comparison to one ephemeropteran. Effects of season on the game fish diets were assessed by relative frequency of occurrence. Alewives were consumed by walleye throughout the year, by smallmouth bass (Table 15), largemouth bass,

Table 12. Relative frequency of occurrence (%) of food items for crappie, largemouth bass (LMB), smallmouth bass (SMB), walleye, rainbow trout (RBT), and Ohrid trout (OT) from Watauga Reservoir collected from March 1982 to June 1983.

Food Item	Gamefish Species					
	Crappie	LMB	SMB	Walleye	RBT	OT
Alewife	11.1		17.4	22.7	83.3	25.0
Gizzard shad			4.3	4.5		
Clupeid	44.4	25.0	28.3	42.9	66.7	75.0
Other fish	44.4	12.5	30.4	15.7	16.7	25.0
Invertebrates	72.2	25.0	8.7	0.5	33.3	
Fish parts	59.5	1.6	17.8	7.2		4.5
Other	7.4		4.4	1.3	33.3	
No. stomachs with food	18	8	46	198	6	4
No. empty	1	6	20	74		2

Table 13. Relative frequency of occurrence (%) of food items in crappie, largemouth bass (LMB), smallmouth bass (SMB), walleye, rainbow trout (RBT), and Ohrid trout (OT) from Watauga Reservoir, March 1982 to June 1983.

	Gamefish Species					
	Crappie	LMB	SMB	Walleye	RBT	QT
Pisces						
<u>Alosa pseudoharengus</u>	11.1		17.4	22.7	83.3	25.0
<u>Dorosoma cepedianum</u>			4.3	4.5		
<u>Unid. clupeids</u>	44.4	25.0	28.3	42.9	66.7	75.0
<u>Campostoma anomalum</u>		12.5				
<u>Notropis sp.</u>	5.5					
<u>Unid. cyprinids</u>				0.5		
<u>Lepomis macrochirus</u>				1.5		
<u>Unid. fish</u>	38.9		30.4	13.6	16.7	25.0
Eye lenses	38.9	12.5	6.5	7.6		50.0
Cycloid scales	11.1		2.2	0.5		
Ctenoid scales	5.6			0.5		
Unid. scales	5.6					
Crustacea						
Bryozoan floatoblast	11.1					
Cladocera	5.6					
Ostracoda	16.7					
Crayfish		12.5	4.3			
Insecta						
Plecoptera					16.7	
Ephemeroptera	55.6		2.2	0.5	33.3	
Hemiptera					16.7	
Megaloptera	16.7					
Tricoptera	5.6					
Coleoptera	11.1				16.7	
Diptera						
Chironomid larvae	11.1					
Chironomid pupa	11.1					
Insect fragments	11.1	12.5			33.3	
Plants				0.5	33.3	
Seeds	5.6		2.2		16.7	
Unid. material	5.6	37.5	32.6	39.9		
Unid. eggs				1.0		
No. with food	18	8	46	198	6	4
No. empty	1	6	20	74		2

Table 14. Percentage composition by number of food items in crappie, largemouth bass (LMB), smallmouth bass (SMB), walleye, rainbow trout (RBT), and Ohrid trout (OT) in Watauga Reservoir, March 1982 to June 1983.

Food Items	Crappie	LMB	SMB	Walleye	RBT	OT
Pisces						
<u>Alosa pseudoharengus</u>	1.0		16.5	18.7	11.6	13.3
<u>Dorosoma cepedianum</u>			2.4	2.2		
<u>Unid. clupeids</u>	8.7	42.9	27.1	40.0	7.5	46.7
<u>Campostoma anomalum</u>		7.1				
<u>Notropis sp.</u>	0.5					
<u>Unid. cyprinids</u>				0.5		
<u>Lepomis macrochirus</u>				1.0		
<u>Unid. fish</u>	4.1		16.5	6.6	0.6	6.7
Eye lenses	16.4	7.1	10.6	8.4		33.3
Cycloid scales	2.1		2.4	0.2		
Ctenoid scales	2.6			0.2		
Unid. scales	1.0					
Crustacea						
Bryozoan floatoblast	1.0					
Cladocera	0.5					
Ostracoda	1.5					
Crayfish		7.1	3.5			
Insecta						
Plecoptera					15.6	
Ephemeroptera	50.8		1.2	0.2	53.2	
Hemiptera					0.6	
Megaloptera	3.6					
Tricoptera	0.5					
Coleoptera	1.0				0.6	
Diptera						
Chironomid larvae	1.0					
Chironomid pupa	1.0		1.2			
Insect fragments	1.0	14.3			1.2	
Plants				0.2	5.8	
Seeds	1.0		1.2		3.5	
Unid. material	0.5	21.4	17.6	19.4		
Unid. eggs				2.2		
No. with food	18	8	46	198	6	4
No. empty	1	6	20	74		2

Table 15. Relative frequency of occurrence (%) of food items in walleye and smallmouth bass by season in Watauga Reservoir.

Food Item	Smallmouth Bass				Walleye			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Alewife		23.1	23.8		38.5	16.9	17.1	7.4
Gizzard		15.4			4.6	3.1	2.4	11.1
Clupeid		38.5	28.6	22.2	53.9	35.4	43.9	33.3
Other fish	33.3	15.4	42.9	22.2	7.7	20.0	24.4	11.1
Invertebrates	33.3	15.4		11.1			2.4	
Fish parts			91.3		20.5	6.5	11.9	
Other		3.0				6.5		
No. with food	3	13	21	9	65	65	41	27
No. empty	7	7	5	1	21	35	11	7

crappie, and rainbow trout (Table 16), in the spring and summer, and by Ohrid trout in the spring. Gizzard shad were consumed by smallmouth bass in the spring and by walleye throughout the year. Gizzard shad were consumed by smallmouth bass (15.4%) at a lower percentage in comparison to alewives at 23.1%. Walleye consumed more alewives than gizzard shad during the winter, spring, and summer, but consumed more gizzard shad than alewives in the fall (11.1% gizzard shad, 7.4% alewives). Invertebrates (including zooplankton, crayfish, and aquatic insects) were consumed in the spring and summer by largemouth bass, crappie, and rainbow trout, in the winter and spring by smallmouth bass, and during the summer by walleye.

Total lengths of ingested alewives were measured or estimated from the analysis of game fish stomachs (Table 17). Actual total lengths of alewives measured ranged from 53 to 86 mm in walleye and 80 to 97 mm in rainbow trout. Estimated total lengths of alewives ranged from 45 to 134 mm in walleye, 61 to 99 mm in smallmouth bass, and 75 to 132 mm in rainbow trout. Four entire gizzard shad were identified in the stomach analysis of game fish. Three gizzard shad ranging from 53 to 78 mm were consumed by walleye (381 to 493 mmTL). One gizzard shad (93 mmTL) was consumed by a 310 mm smallmouth bass.

Table 16. Relative frequency of occurrence (%) of food items by season in largemouth bass, crappie, rainbow trout, and Ohrid trout (OT) in Watauga Reservoir, March 1982 to June 1983.

Food Item	Largemouth Bass			Crappie		Rainbow Trout		OT
	Winter	Spring	Summer	Spring	Summer	Spring	Summer	Spring
Alewife				7.7	20.0	50.0	100.0	25.0
Gizzard shad								
Clupeid		33.3	33.3	38.5	60.0		100.0	75.0
Other fish	50.0			53.8	20.0		25.0	
Invertebrates		33.3	33.3	76.9	60.0	50.0	25.0	
Fish parts				79.3	60.0			
Other					20.0	50.0	25.0	
No. with food	2	3	5	13	5	2	4	6
No. empty	0	4	2	1	0	0	0	0

Table 17. Predator-prey relationship in Watauga Reservoir. Total lengths are in mm. Total lengths and estimated total lengths, prior to digestion, of alewives consumed by walleye, small-mouth bass and rainbow trout.

Species	Length (mm)					
Walleye						
Predator range (TL = mm):	381-405	406-430	431-455	456-480	481-505	506-526
Number of predators:	2	10	8	11	4	1
Prey species: Alewife						
Number of prey:	1	0	0	2	1	0
Actual prey length	60	0	0	53-86	70	0
Number of estimated prey:	1	11	11	13	5	1
Estimated prey length	86	45-132	63-124	61-113	86-134	76
Smallmouth Bass						
Predator range (TL = mm):	221-245	246-270	271-295	296-320	321-345	346-358
Number of predators:	2		1		1	2
Prey species: Alewife						
Number of estimated prey:	2		1		1	3
Estimated prey length	83-99		89		83	61-73
Rainbow Trout						
Predator range (TL = mm):	307-331	332-356	357-381	382-406	407-417	
Number of predators:	1	1	1		2	
Prey species: Alewife						
Number of prey:	2	0	0		6	
Actual prey length	80-96				83-97	
Number of estimated prey:	1	1	2		8	
Estimated prey length	132	108	99-111		75-129	

CHAPTER V

DISCUSSION

Growth rate of alewives is affected by geographical location and the characteristics of the individual system. Back-calculated growth in length of alewives in Watauga Reservoir was 70 mm (44 to 98 mm) at annulus I and 103 mm (83 to 123 mm) at annulus II. Comparisons of the alewife growth rate attained by each year of life, with other inland bodies of water (Table 1, page 6) revealed a slower growth rate than in most places. Only New Creek Lake, West Virginia, was lower than Watauga for total lengths of both age 1 and age 2 alewives (Lewis 1981). The lower growth rate in Watauga is advantageous for predators. Maximum total length of alewives collected in Watauga (1982-83) was 131 mm. Wagner (1972) found walleye of only 300 to 390 mm have consumed alewives 140 mm and smallmouth bass at 200 to 290 mm have consumed alewives of 150 mm TL. Nigro and Ney (1982) calculated that 300 mm largemouth bass could consume 160 mm alewives, based on the predator-prey relationship described by Jenkins and Morais (1978). These data on lengths of ingestible alewives suggests the alewife population sampled in Watauga (maximum 131 mm) is morphologically available to the predator population in the reservoir.

Predator length and ingested prey length from stomach analysis was used to examine the predator-prey relationship in Watauga. Walleye (481 to 505 mm) consumed alewives with an estimated total length

of 134 mm prior to digestion. Smallmouth bass (271 to 295 mm) consumed alewives estimated to be 89 mm and rainbow trout of 307 to 331 mm consumed alewives estimated at 132 mm. These results support the hypothesis that the alewife population sampled in Watauga (1982-83) is available to piscivorous game fishes in the system.

Survival and reproduction of the introduced alewives in 1976 in Watauga was documented in July 1979, with the collection of alewives (127 to 152 mm TL) assumed to be progeny of the originally stocked fish. Whether these progeny were age 1+ or 2+, growth was still greater than for age 2+ in 1981-83 (103 mm; range 83 to 123 mm). Reductions in average lengths attained by specific age classes and in number of age classes have resulted from increasing density of alewife populations (Brown 1972; Kohler and Ney 1981).

Sampling of the alewife population from 1982-83 revealed only 3 age classes (0+, 1+, and 2+) with a maximum total length of 131 mm, as compared to eight age classes in Lake Michigan (Brown 1972). The reduction in attainable size and presence of only three age classes in Watauga indicates a high density alewife population, and possibly, a high degree of intraspecific competition. Alewife populations fluctuate in year class composition and abundance, and are subjected to massive die-offs (Rothschild 1965; Brown 1972; Warshaw 1972; Kohler and Ney 1981). Though a massive die-off of the alewife population has not been reported for Watauga Reservoir, fluctuations in year class strength in a population containing only three age classes could alter their abundance, resulting in instability of the forage base available to piscivorous game fishes.

Male and female alewives in Watauga did not differ significantly in back-calculated lengths. The predicted length-weight relationship of alewives in Watauga also did not detect significant differences between sexes ($\alpha = 0.05$).

Annuli were formed from the end of March through the first part of June. Scale examination revealed that alewives in Watauga did not spawn until age 2 (83 to 123 mm). Sexual maturity is similarly attained at age 2 for alewives in Lake Hopatcong (102 to 142 mm), Lake Ontario (127 to 145 mm) (Nigro and Ney 1982), Lake Michigan (130 to 189 mm) (Norden 1967), and Cayuga Lake (122 mm) (Rothschild 1966). In contrast to Watauga and other inland systems, a reported 86% of age 1 (160 mm) alewives were sexually mature in Claytor Lake (Nigro and Ney 1982). Edsall (1970) found alewives to initiate spawning at 16 C. Spawning by alewives in Watauga started in April, peaked in June, and declined to the first of August, as indicated by maximum female GSI values. Spawning of alewives, in Watauga (indicated by maximum female GSI values), starting in April and continuing to August, is similar to the 13-week spawning period of Claytor Lake (early May through July). The similar spawning periods of alewives in Watauga and Claytor Lake are longer in comparison to the nine week period in Cayuga Lake and Lake Michigan, and the four week period in Lake Hopatcong (Nigro and Ney 1982). Nigro and Ney (1982) suggested the possibility of fractional spawning of alewives (repeated egg deposition within the spawning season) indicated by GSI values for females during the long spawning period in Claytor Lake.

Alewives in Watauga were found to feed primarily on cladocerans, copepods, and crustacean eggs as in other inland waters (Odell 1934; Hutchinson 1971; Warshaw 1972; Rhodes and McComish 1975; Kohler and Ney 1980a; Crowder et al. 1981). Factor analysis of the alewife diet reduced 24 food items to nine linear "factors." Only for factor 5 (Table 8, p. 32) did length of fish have a significantly consistent factor. Food items in factor 5, sharing high opposite loadings, have an inverse relationship in the diet. Bosmina spp., a small cladoceran (0.1 mm), was negatively correlated with the larger zooplankton forms (copepods, cyclopoid copepods, and Chaoborus spp.) composing the factor. This indicated selective feeding by alewives, in that larger alewives tended to select large zooplankton and fewer smaller species (e.g., Bosmina spp.), and the smaller alewives tended to select the smaller Bosmina spp. instead of the larger zooplankton. The remaining 8 factors were each composed of food items which shared similar high loadings. Food items composing each factor were simultaneously being utilized by alewives. Plots of mean factor scores over a period of time (Figure 4, p. 34) suggested that each factor reflected a diet component with a particular temporal pattern. This is evidence that the variation in diet of alewives was largely due to seasonal fluctuations in the zooplankton community. Factor analysis of the alewife diet indicated that larger alewives increased their selectivity for larger zooplankton forms (copepods) over Bosmina spp. This is similar to work at Lake Michigan where the frequency of occurrence of copepods in the diet increased from Y-0-Y to adult alewives and a corresponding

decrease in frequency of occurrence of cladocerans from Y-0-Y to adult alewives (Crowder et al. 1981).

In Lake Michigan, Wells (1980) found alewives consumed 4 to 11% (relative frequency of occurrence) fish eggs, all of which were alewife eggs. Crowder et al. (1981) found no consumption of fish eggs by alewives in Lake Michigan. No identifiable fish eggs were found in alewives examined in Watauga Reservoir. Alewives in Watauga feed in both littoral and limnetic regions. Alewives have been found to consume larval fish (Smith 1970; Kohler and Ney 1980b). In Claytor Lake fish composed up to 4% by volume of alewife diets in limnetic regions and up to 21% by volume in littoral regions. Alewives have consumed young of five fish species; largemouth bass, white bass, Lepomis spp., yellow perch (Perca flavescens), golden shiner (Not emigunus crysoleucas) along with their own young (Kohler and Ney 1980b). Based on results of alewife piscivory, Kohler and Ney (1980b) supported the idea that alewife predation could have a detrimental effect on the resident fish populations. Alewives in Claytor Lake that were found to consume larval fish species (12.8 to 21 mm) were of a mean length of 171 to 209 mm, though the range encompassed 100 to 209 mm TL. Piscivory in alewives in Watauga may not be a serious problem due to the fact that the oldest age class of alewives collected (age 2) had a mean length of 103 mm and a range of 88 to 123 mm (maximum captured, 131 mm) versus the occurrence of alewives in Claytor Lake up to 209 mm (Kohler and Ney 1980b). In fact, of 154 alewives examined from Watauga, only one contained any fish remains (0.6%). The alewife was collected in a

vertical gill net, set under lights, which tended to attract juvenile fish.

Comparisons of growth attained by each year of life of walleye in Watauga (1982-83) were made to other bodies of water (Table 18). Comparisons of walleye growth rate in Watauga prior to and following the introduction of alewives in 1976 cannot be made because there are no published growth rate data prior to the introductions. Growth in Watauga is similar to Hiwassee, North Carolina, and Spirit Lake, Iowa. Compared to other reservoirs in Tennessee, Watauga has the lower growth rate and Center Hill Reservoir the highest. Analysis of the length-weight relationship for walleye by sex revealed that females were heavier than males of the same length. Significant differences between sexes have also been found for Center Hill Reservoir, Tennessee (Muench 1966; Scott 1976). Sampling of the walleye population in Watauga identified six age classes, age 2 through 6. Two-hundred and eight walleye were used for age and growth analyses. Only three of the 208 walleye aged were age 2. Gear used for collection included electrofishing and horizontal gill netting. The lack of collection of Y-0-Y, age 1, and few age 2 walleye have been of concern. Colby et al. (1979) reported that few walleye less than 2 years old are captured because of the selectivity of all types of gear toward larger forms. The absence may in part, be attributed to the selectivity of the gear used.

Growth rate of adult walleye appeared to be affected by both temperature and the amount of food consumed (forage abundance and

Table 18. Comparisons of back-calculated lengths of walleye in Watauga Reservoir and other bodies of water. Data compiled from Scott (1976) with the exception of the present study. (TL = mm at each annulus.)

Water and Source	Sex	N	I	II	III	IV	V	VI	VII	VIII	IX	X
Watauga Reservoir, TN (Present Study)	M	157	183	311	390	431	446	490				
	F	46	193	327	412	465	504	556				
	M,F	208	185	315	395	442	475	534				
Norris Reservoir, TN	M		249	409	460	485	498	505	564			
	F		272	432	498	551	602	610	744	765		
	M,F		272	416	483	513	528	533	561	632		
Melton Hill Reservoir, TN	M,F		249	330	368							
Dale Hollow Reservoir, TN	M,F	325	264	409	488	546	602	638	645			
Center Hill Reservoir, TN	M,F		248	438	494	521	563	608				
	F		281	466	537	573	622	675	683	715		
	M,F		255	444	511	545	590	666	683	715		
Center Hill Reservoir, TN	M	417	257	406	456	480	502	522	544			
	F	374	278	434	502	538	570	592	621	644	709	716
	M,F	791	267	421	480	508	533	559	592	644	709	716
Hiwassee, NC	M,F		193	310	371	404	429					
Claytor Reservoir, VA	M,F	254	251	386	503	580	663	701	759	818		
Lake Gogebic, MI	M	252	112	236	300	353	386	414	429	439	450	457
	F	267	124	239	315	368	414	455	480	503	518	533
Pike Lake, WI	M	443	173	287	358	401	432	457				
	F	203	178	292	376	439	480	433	574	630	653	701
Spirit Lake, IA	M,F	321	183	282	366	445	505	564	602	632	660	706
Hoover Reservoir, OH	M	269	254	369	424	451	464	487	502			
	F	258	259	372	429	460	489	497	508	515	535	570

population density) (Colby et al. 1979). Colby et al. (1979) cited established condition factor ratings as shown in Table 19. The calculated value of 1.04 from this study falls into the "excellent" range. In systems where forage is scarce condition has been found to be low; on the other hand, in systems with abundant forage, it has been found to be high (Colby et al. 1979). The calculated K of 1.04 indicates that during the period of the study, sufficient forage was available for the population size of walleye in this system.

Alewives represented a sizeable percentage of the diet in all species analyzed (walleye, 22.7; rainbow trout, 83.3; Ohrid trout, 25; smallmouth bass, 17.4; and crappie, 11.1) with the exception of largemouth bass in which no identifiable alewives were found. Walleye consumed alewives, 22.7%, at a higher relative frequency of occurrence than gizzard shad at 4.3%. In Claytor Lake walleye were found to consume 36.6% alewives and 4.8% insects (0.5% insects in Watauga), which is similar to that in Watauga (Kohler and Ney 1981). Walleye consumed 42.9% of unidentifiable clupeids (either alewives or gizzard shad), 0.5% unidentified cyprinids, and 1.5% bluegill. Seasonally, walleye consumed alewives throughout the year in greater percentage than gizzard shad (winter: 38.5% alewives (A) to 4.6% gizzard shad (GS); spring: 16.9% A to 3.1% GS, summer: 17.1% A to 2.4% GS), with the exception of fall (7.4% A to 11.1% GS). The decrease in alewife consumption in the fall may be attributed to the movement of alewives from littoral areas out into deeper, warmer waters. Consumption of alewives increasing from fall to winter indicates that walleye

Table 19. Comparisons of coefficient of condition (K) for walleye in Watauga Reservoir to other bodies of water and various size groups. Data, excluding that of Watauga Reservoir, Tennessee, were compiled from Colby et al. 1979. (Weight in g and TL in mm; ranges, where known, in parentheses.)

Location	Condition Factor ^a		
	Male	Female	Combined
Watauga Reservoir, TN (Present Study)	1.04	1.04	1.04 (0.68-1.78)
Mississippi River (IA)	1.02	1.16	1.11
Canton Reservoir, OK			1.03
Lake Winnebago, WI	0.80	0.82	0.81
Red Lakes, MN			0.89 (0.86-0.91)
Lake Erie (Sandusky Bay)	1.08	1.07	1.10 (0.98-1.23)

^aExcellent >1.02; average 0.89-0.97; poor >0.83 (Colby et al. 1979).

"follow" the alewives with the change of season. Smallmouth bass consumed alewives (17.4%) at a greater percentage than gizzard shad (4.3%). Smallmouth have also been found to consume alewives in Lake Michigan and Claytor Lake (Wagner 1972; Boaze and Lackey 1974). In Watauga other fish consumed by smallmouth bass were unidentified clupeids 28.3% and other unidentified fish at 30.4%. Crayfish were consumed at 4.3%. Seasonally smallmouth bass consumed alewives in the spring (23.1%) and summer (23.8%). Gizzard shad were consumed by smallmouth bass only during the spring (15.4%), and at lower levels than alewife consumption (23.1%). Rainbow trout were found to consume 83.3% alewives, no identifiable gizzard shad, 66.7% unidentified clupeids, and 16.7% other fish, and 33.3% invertebrates. Seasonally rainbow trout were collected only in the spring and summer. During the spring rainbow trout consumed 50% alewives, subsequently increasing to 100% during the summer. Along with the increase in alewife consumption in the spring and summer was a decline of invertebrates from 50% to 25% possibly indicating food preference of rainbow trout shifted from insects to fish from the spring to summer, but due to small sample size ($n = 6$) no definite conclusions can be made. Ohrid trout were collected only in the spring. During this time alewives composed 25% of the diet, and unidentified clupeids at 75%. Crappie were found to consume 11.1% alewives, 44.4% unidentified clupeids, 44.4% other fish, and 72.2% invertebrates. Seasonally, crappie consumed 7.7% alewives in the spring increasing to 20.0% in the summer. Consumption of insects

decreased slightly in the summer but shifts occurred in unidentified clupeid and other fish consumption also, making any determination of shifts in food preference difficult to assess. Largemouth bass consumed 25% unidentified clupeids (alewives and/or gizzard shad) and 25% invertebrates. Along with the consumption of clupeids by largemouth bass were Campostoma anomalum at 12.5%. Because clupeids consumed by largemouth bass could not be identified as alewives and/or gizzard shad, the possible contribution of alewives to their diet could not be assessed in this study. Largemouth bass have been found to consume alewives (Lewis 1981), but were concluded by Kohler and Ney (1981) to be seldom eaten in Claytor Lake by Micropterus spp. Alewives did contribute to the diets of walleye, smallmouth bass, crappie, rainbow trout and Ohrid trout in Watauga.

CHAPTER VI

SUMMARY

1. Collections of alewives from March 1982 through June 1983 revealed the presence of three age classes (0+, 1+, and 2+). Back-calculated lengths at annuli I and II were 70 mm (44 to 98 mm) and 103 mm (88 to 123 mm), respectively. Annulus formation occurred from March through June.

2. In Watauga Reservoir alewives do not spawn until age 2. Scale examination revealed that in 46% of age 2 or 2+ ($n = 57$), the second annulus was an identifiable spawning mark. Maximum GSI values indicated that alewives begin spawning in April, peak in June, and continue to the first of August.

3. Principal components of the alewife diet by relative frequency of occurrence were cladocerans, copepods, and crustacean eggs. Other food items in their diet included bryozoan floatoblasts, ostracods, insect fragments, dipterans, hydracarina, and Hymenoptera.

4. Factor analysis followed by analysis of covariance indicated size selectivity in alewives. As fish length increased selectivity for copepods over cladocerans increased and conversely the smaller fish length the higher the occurrence of cladocerans over copepods. Factors or "diet components" plotted overtime indicated seasonal variation in the diet.

5. Sampling of the walleye population in Watauga from 1982 through June 1983 revealed the presence of five age classes (age 2

through age 6). The lack of collection of 0+, 1+, and only a few 2+ walleye was of concern, but may be in part attributed to selectivity of collection gear. Back-calculated lengths at annuli were I-185 mm, II-315 mm, III-395 mm, IV-442 mm, V-475 mm, and VI-534 mm. Females were significantly ($\alpha = 0.05$) longer than males for back-calculated lengths of age 2 through 6. Analysis of the length-weight relationship revealed that females were significantly heavier than males of the same length ($\alpha = 0.05$). Annulus formation occurred in March and April. Condition factor for walleye was 1.04. This indicates that for the population size of walleye in Watauga there is sufficient forage available.

No fish eggs were found in alewife stomachs. Of 154 fish analyzed, only one (0.6%) contained the remains of a fish that could not be identified because of the state of digestion. Piscivory in alewives in Watauga may not be a serious problem because maximum size collected (131 mm) is below the mean length of alewives (171 to 209 mm) that consumed larval fish in Claytor Lake, though their range did encompass 100 to 209 mm (Kohler and Ney 1980b).

6. Alewives were found to occur in the diets of walleye with a frequency of 22.7%, smallmouth bass 17.4%, crappie 11.1%, rainbow trout 83.3%, and Ohrid trout 25%. Gizzard shad were only identified in walleye and in smallmouth bass and at a lower relative frequency of occurrence than alewives on an annual basis. Alewives were consumed by walleye throughout the year and by smallmouth bass in the spring and summer. Only largemouth bass did not contain any

identifiable alewives, but did contain 42.9% unidentified clupeids (alewives and/or gizzard shad).

7. Analysis of the predator-prey relationship examining length of prey consumed indicated that the alewife population in Watauga (maximum size 131 mm) is available to piscivorous predators in the system.

CHAPTER VII

RECOMMENDATIONS

Results from this study on the age and growth, and forage value of the alewife in Watauga Reservoir identified both positive and negative attributes of this exotic forage species:

Positive Attributes from the Study

1. Collection of alewives in Watauga from 1982-1983 revealed a maximum size of 131 mm TL. This small size attained is advantageous in that the alewife population in Watauga is available to the piscivorous predators in the system.

2. In Watauga, alewife piscivory was found to be 0.6%. Piscivory by alewives may not be a significant problem since piscivory in alewives appears to be positively correlated with size and the oldest age class in Watauga (age 2) had a mean length of 103 mm with a maximum length of 131 mm. Mean length of piscivorous alewives, documented previously, were 171 to 209 mm though the range encompassed 100 to 209 mm (Kohler and Ney 1980b).

3. Alewives in Watauga were found to contribute to diets of walleye, smallmouth bass, crappie, rainbow trout, and Ohrid trout.

Negative Attributes from the Study

1. Principal components of the Watauga alewife diet were cladocerans, copepods, and crustacean eggs. Size selectivity of

alewives for larger zooplankton forms was found to be related to increase in total length of the fish. Zooplankton species consumed by alewives are also consumed by Y-O-Y walleye (Colby et al. 1970) and other Y-O-Y game fishes, thus the potential exists for inter-specific competition.

2. Sampling of the alewife population revealed the presence of only three age classes (0+, 1+, and 2+) in Watauga. With only one reproducing age class (age 2), this population structure may result in a potentially unstable forage base as a result of changes in year class strength.

The alewife has emigrated downstream from Watauga and has been found in Boone and Cherokee Reservoirs.

Supplemental information on the positive and negative attributes of alewives have been compiled from the literature:

Positive Attributes from the Literature Review

1. Alewives are highly fecund (Kohler and Ney 1980a).
2. After alewife introduction into Claytor Lake, Virginia, growth rates of white bass and walleye increased (Kohler and Ney 1980a).
3. Dietary overlaps tested by Levin's method between alewives, largemouth bass, smallmouth bass, white bass, crappie, and yellow perch were found significant only between alewives and yellow perch (Kohler and Ney 1980a).

Negative Attributes from Literature Review

1. After alewife introduction growth rate of black basses and crappie in Claytor Lake, Virginia (Kohler and Ney 1980a), and rainbow trout and brown trout in Massachusetts (McCaig 1980) generally decreased.

2. Alewives have been found to consume larval fishes and fish eggs, though in one study, fish eggs consumed were alewife eggs (Smith 1970; Warshaw 1972; Kohler and Ney 1980b; Wells 1980).

3. Alewives are subject to massive die-offs due to extremely cold winters (Brown 1972; Warshall 1972; Kohler and Ney 1980a).

4. Alewife populations have been shown to fluctuate in structure resulting from changes in year class strength (Rothschild 1965).

5. Alewives have been found to be highly size selective zooplanktivores and have caused shifts in zooplankton communities toward smaller forms. This may potentially have significantly adverse effects on cohabitating planktivores including Y-O-Y game fishes (Hutchinson 1971; Wells 1970; Brown 1972; Warshaw 1972; Kohler and Ney 1981).

6. Alewife introduction has been blamed for the decrease of native forage species possibly because of interspecific competition and/or predation on early life history stages of native species (Smith 1968; Wells 1968; Smith 1970; Brown 1972; Crowder et al. 1981).

7. Alewives are an emigrating species (Kohler and Ney 1980a).

The fisheries manager must weigh these positive and negative attributes in the light of specific management objectives, and the unique characteristics of the individual system in question to make a decision regarding the stocking of alewives. Additional information to be considered are management recommendations suggested by Kohler and Ney (1980a)

Kohler and Ney (1980a) have suggested management recommendations based on the work done on the alewife in Claytor Lake, Virginia. They suggest that the introduction of alewives be limited to systems too cold for threadfin shad, and such systems which are managed primarily for pelagic predators on a put-grow-take basis. In systems where self-sustaining populations of pelagic predators exist, they suggested consideration of all alternatives before introducing the alewife. In Claytor Lake, it was found that the alewife was rarely consumed by black basses and they proposed that bass recruitment and growth may be hindered by alewife interspecific trophic interactions. They suggest that alewife introductions should be avoided in systems managed primarily for black basses. They recommend that the use of the alewife as a pelagic forage species should involve regional rather than site-specific planning as a result of the emigrating nature of the alewife.

Though the concept of an ideal forage fish is an attractive, in reality however, no such fish exists. The decision to introduce any forage fish must be based on the characteristics of the individual body of water with consideration of neighboring systems.

Based on the results of this study, information from the literature, and recommendations from Kohler and Ney (1980a), at this time, I cannot recommend further stocking of alewives into rivers and reservoirs of the southeast where self-sustaining populations of game fishes exist. Since the alewife was introduced into Watauga Reservoir in 1976, it has emigrated downstream of Watauga into Boone, followed by Patrick Henry, and in Cherokee Reservoir. Now that the alewife is established in the Tennessee River Valley, population dynamics of the alewife and potential problems with inter- and intraspecific competition needs to be assessed in order to evaluate more fully the ecological impact of the alewife.

LIST OF REFERENCES

LIST OF REFERENCES

- Bagenal, T. B. and F. W. Tesch. 1978. Age and Growth. Pages 101-136 in T. B. Bagenal, editor. Methods of assessment of fish production in fresh waters, 3rd edition, IBP Handbook No. 3. Blackwell Scientific Publications, Oxford, England.
- Baker, C. D. and E. H. Schmitz. 1971. Food habits of adult gizzard shad and threadfin shad in two Ozark reservoirs. Pages 3-11 in G. E. Hall Reservoir Fisheries and Limnology. Special Publication No. 8. American Fisheries Society. 511 pp.
- Boaze, J. L. 1974. New Hope for Claytor Lake. Virginia Wildlife. October 1974. Vol. 35 (10): 8.
- Boaze, J. L., and R. T. Lackey. 1974. Age, Growth, and Utilization of Landlocked Alewives in Claytor Lake Virginia. Progressive Fish-Culturalist 36 (3): 163-164.
- Brooks, J. L., and S. I. Dodson. 1965. Predation, body sizes, and composition of plankton. Science (Washington, District of Columbia) 150: 28-35.
- Brown, E. H., Jr. 1972. Population biology of alewives, Alosa pseudoharengus, in Lake Michigan, 1949-70. Journal of the Fisheries Research Board of Canada 29: 477-500.
- Cating, James P. 1953. Determining age of Atlantic shad from their scales. U. S. Fish and Wildlife Service, Fishery Bulletin 54 (85): 187-199.
- Colby, P. J., R. E. McNicol, and R. A. Ryder. 1979. Synopsis of Biological Data on the Walleye Stizostedion v. nitreum (Mitchill 1818). Food and Agriculture Organization of the United States. Synopsis No. 119.
- Coutant, C. C. 1977. Compilation of temperature preference data. Journal of Fisheries Research Board of Canada 34: 739-746.
- Crowder, L. B., J. J. Magnuson, and S. B. Brandt. 1981. Complementarity in the use of food and thermal habitat by Lake Michigan fishes. Canadian Journal of Fisheries and Aquatic Sciences 38: 662-668.
- Davis, J. R., and R. P. Cheek. 1966. Distribution, food habits, and growth of young clupeids, Cape Fear River System, North Carolina. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 20: 250-260.

- Desselle, W. J., M. A. Poirrier, J. S. Rogers, and R. C. Cashner. 1978. A discriminant functions analysis of sunfish (Lepomis) food habits and feeding niche segregation in the Lake Ponchartrain, Louisiana estuary. Transactions of the American Fisheries Society 107: 713-719.
- Dolman, W. B. 1982. The feeding ecology of juvenile Atlantic croaker (Micropogonias undulatus) in two habitats of a Louisiana brackish marsh. Masters Thesis. Louisiana State University, Baton Rouge, Louisiana, USA.
- Esdall, T. A. 1970. The effect of temperature on the rate of development and survival of alewife eggs and larvae. Transactions of the American Fisheries Society 99 (2): 376-380.
- Gannon, J. E. 1976. The effects of differential digestion rates of zooplankton by alewife, Alosa pseudoharengus, on determinations of selective feeding. Transactions of the American Fisheries Society 105: 89-95.
- Graham, J. J. 1956. Observations of the alewife, Pomolobus pseudoharengus (Wilson), in fresh water. Univ. Toronto Stud., Biol. Ser. 62. Ont. Fish. Res. Lab. Publ. 74: 1-43.
- Gross, R. W. 1959. A study of the alewife Alosa pseudoharengus (Wilson) in some New Jersey lakes, with special reference to Lake Hopatcong. Master's Thesis. Rutgers State University, New Brunswick, New Jersey, USA.
- Hutchinson, B. P. 1971. The effect of fish predation on the zooplankton of ten Adirondack lakes, with particular reference to the alewife, Alosa pseudoharengus. Transactions of the American Fisheries Society 100: 325-335.
- Janssen, J. 1976. Feeding modes and prey size selection in the alewife (Alosa pseudoharengus). Journal of Fisheries Research Board of Canada 33: 1972-1975.
- Jenkins, R. M., and D. I. Morair. 1978. Prey-predator relations in the predator-stocking-evaluation reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 30: 141-157.
- Jude, D. J. 1973. Food and feeding habits of gizzard shad in Pool 19, Mississippi River. Transactions of the American Fisheries Society 102(2): 378-383.
- Judy, M. H. 1961. Validity of age determination from scales of marked American shad. U. S. Fish and Wildlife Service, Fishery Bulletin 61 (185): 161-170.

- Kimsey, J. B. 1957. Fisheries problems in impounded waters of California and the lower Colorado River. Transactions of the American Fisheries Society 87: 319-332.
- Kircheis, F. W., and J. E. Stanley. 1981. Theory and practice of forage fish management in New England. Transactions of the American Fisheries Society 110: 729-737.
- Kleinbaum, D. G., and L. L. Kupper. 1978. Applied Regression Analysis and other Multivariate Methods. Duxbury Press, Belmont, CA.
- Kohler, C. C., and J. J. Ney. 1980a. Suitability of alewife as a pelagic forage fish for southeastern reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 34: 137-150.
- Kohler, C. C., and J. J. Ney. 1980b. Piscivory in a landlocked population of alewife (Alosa pseudoharengus). Canadian Journal of Fisheries and Aquatic Sciences 37(8): 1314-1317.
- Kohler, C. C., and J. J. Ney. 1981. Consequences of an alewife dieoff to fish and zooplankton in a reservoir. Transactions of the American Fisheries Society 110: 360-369.
- Kutkuhn, J. H. 1957. Utilization of plankton by juvenile gizzard shad in a shallow prairie lake. Transactions of the American Fisheries Society 87(1): 80-103.
- Lackey, R. T. 1970. Observations on newly introduced landlocked alewives in Maine. New York Fish and Game Journal 17: 110-116.
- Lagler, K. F. 1956. Freshwater Fishery Biology, 2nd edition. Wm. C. Brown Company, Publishers. Dubuque, Iowa, USA.
- Lewis, G. E. 1981. Characteristics of alewives in a small West Virginia impoundment. The Progressive Fish-Culturalist 43(4): 224.
- Lindenberg, J. G. 1976. Seasonal depth distribution of landlocked alewives, Alosa pseudoharengus (Wilson), in a shallow, eutrophic lake. Transactions of the American Fisheries Society 105(3): 395-399.
- Loesch, J. G., W. H. Kriete, Jr., and E. J. Foell. 1982. Effects of light intensity on the catchability of juvenile anadromous Alosa species. Transactions of the American Fisheries Society 111(1): 41-44.

- McCaig, R. S. 1980. Effect of sea-run alewives on rainbow trout and brown trout in reclaimed ponds. *The Progressive Fish-Culturalist* 42(1): 59-63.
- Muench, K. A. 1966. Certain aspects of the life history of the walleye, Stizostedion vitreum vitreum (Mitchill), in Center Hill Reservoir, Tennessee. Masters Thesis. Tennessee Technological University, Cookeville, Tennessee, USA.
- Ney, J. J. 1981. Evolution of forage fish management in lakes and reservoirs. *Transactions of the American Fisheries Society* 110: 725-728.
- Ney, J. J., C. C. Kohler, and A. A. Nigro. 1982. Landlocked alewife in Claytor Lake, Virginia: Evaluation as a forage species for inland waters. Management Publication No. 4, Dept. of Fisheries and Wildlife Sciences. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA. Report January 1982.
- Nigro, A. A., and J. J. Ney. 1982. Reproduction and early life accommodations of landlocked alewives Alosa pseudoharengus to a southern range extension. *Transactions of the American Fisheries Society* 111(5): 559-569.
- Nobel, R. L. 1981. Management of forage fishes in impoundments of the southern United States. *Transactions of the American Fisheries Society* 110: 738-750.
- Norden, C. R. 1967. Age, growth, and fecundity of the alewife, Alosa pseudoharengus (Wilson) in Lake Michigan. *Transactions of the American Fisheries Society* 96(4): 387-393.
- Odell, T. T. 1934. The life history and ecological relationships of the alewife (Pomolobus pseudoharengus) (Wilson) in Seneca Lake, New York. *Transactions of the American Fisheries Society* 64: 118-126.
- Otto, R. G., M. A. Kitchel, and J. O'H. Rice. 1976. Lethal and preferred temperatures of the alewife (Alosa pseudoharengus) in Lake Michigan. *Transactions of the American Fisheries Society* 105(1): 96-106.
- Rhodes, R. J., and T. S. McComish. 1975. Observations on the adult alewife's food habits (Pisces: Clupeidae: Alosa pseudoharengus) in Indiana's water of Lake Michigan in 1970. *Ohio Journal of Science* 75: 50-55.
- Ross, S. T. 1978. Trophic ontogeny of the leopard searobin, Prionotus scitulus (Pisces: Triglidae). U. S. Fish and Wildlife Service. *Fishery Bulletin* 76: 225-234.

- Rothschild, B. J. 1963. A critique of the scale method for determining the age of the alewife, Alosa pseudoharengus (Wilson). Transactions of the American Fisheries Society 92(4): 409-413.
- Rothschild, B. J. 1965. Aspects of the population dynamics of the alewife, Alosa pseudoharengus (Wilson), in Cayuga Lake, New York. The American Midland Naturalist 74(2): 479-496.
- Rothschild, B. J. 1966. Observations on the alewife (Alosa pseudoharengus) in Cayuga Lake. New York Fish and Game Journal 13: 188-195.
- SAS Institute Inc. 1982. SAS/Graph User's Guide. SAS Institute Inc., Cary, North Carolina, USA.
- SAS Institute Inc. 1982. SAS User's Guide: Statistics. SAS Institute Inc., Cary, North Carolina, USA.
- Scott, E. M. 1976. Dynamics of the Center Hill Walleye Population. Masters Thesis. Tennessee Technological University, Cookeville, Tennessee, USA.
- Smith, S. H. 1970. Species interactions of the alewife in the Great Lakes. Transactions of the American Fisheries Society 99: 754-765.
- Spiers, G. D. 1974. Food habits of landlocked salmon and brook trout in a Maine lake after introduction of landlocked alewives. Transactions of the American Fisheries Society 103: 396-399.
- Stewart, D. J., J. F. Kitchell, and L. B. Crowder. 1981. Forage fishes and their salmonid predators in Lake Michigan. Transactions of the American Fisheries Society 110: 751-763.
- Strawn, K. 1963. Resistance of threadfin shad to low temperature. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 17: 290-292.
- Tennessee Valley Authority. 1971. Fish inventory data, Watauga Reservoir. Fisheries and Waterfowl Resources Branch. 14 pp.
- Vladykov, V. D. 1956. Fecundity of wild speckled trout (Salvelinus fontinalis) in Quebec Lakes. Journal of the Fisheries Research Board of Canada 13: 799-841.
- Wagner, W. C. 1972. Utilization of alewives by inshore piscivorous fishes in Lake Michigan. Transactions of the American Fisheries Society 101(1): 55-63.

- Warshaw, S. J. 1972. Effects of alewives (Alosa pseudoharengus) on zooplankton of Lake Wononskopomuc, Connecticut. *Limnology and Oceanography* 17: 816-825.
- Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U. S. Fish Wildl. Service. Fish Bull. 67(1): 1-15.
- Wells, L. 1970. Effects of alewife predation on zooplankton populations in Lake Michigan. *Limnology and Oceanography* 15: 556-565.
- Wells, L. 1980. Food of alewives, yellow perch, spottail shiners, trout perch, and slimy and fourhorn sculpins in southeastern Lake Michigan. U. S. Fish Wildl. Service. Tech. Paper 98. 12 pp.
- Windell, J. T., and S. H. Bowen. 1978. Methods for study of fish diets based on analysis of stomach contents. Pages 219-226 in T. Bagenal, editor. *Methods for assessment of fish production in fresh waters*, third edition. Blackwell Scientific Publishers, London, England.

APPENDICES

APPENDIX A

TENNESSEE WILDLIFE RESOURCES AGENCY REGION IV

Quarterly Report
1 July 1981 - 30 September 1981
Alewife Study - Watauga Lake

Glenn Plungis
Graduate Research Assistant
The University of Tennessee, Knoxville

This report encompasses the collection dates, of July 29-30, August 10-11, and September 8-10, 1981. The methods of collection included 2-6 hour sets of conventional 1.5 inch nylon gill nets and experimental 5-2.5 inch and 5-1.5 inch monofilament gill nets, cove rotenone, and data collected from angler's creels. For the July collection, only gill nets were set. In August, gill nets were set on the collection dates and creel data was collected throughout the month. In September, two coves were rotenoned and creel data was collected throughout the month. Lab analysis of data was conducted for the July data only. Scales were analyzed for age and growth. Stomach contents were also analyzed. A species by species account follows:

Walleye--A total of 65 walleye were collected during the period, all in gill nets. None were collected during September. The size of the fish ranged from 378 mm, 499 g to 610 mm, 2070 g. The average size was 431 mm, 786 g. Age and growth information from scales revealed that age II walleye (1) averaged 389 mm in total

length; age III (10), 436 mm; age IV (12), 446 mm; and age V (3) averaged 527 mm in total length. Of the 27 stomachs examined, 12 (46%) contained food. Of the stomachs containing food, 1 (8%) contained only insects (Ephemeroptera), 2 (17%) contained fish and insects, and 9 (75%) contained only fish. Of the stomachs containing fish, one is known to contain an alewife and several others are highly suspect. Most of the fish found in the walleye stomachs were highly digested and it was difficult to make a positive identification. I am currently studying the skeletal anatomy of the alewife and gizzard shad in the hope of somewhat alleviating this problem in the future.

Gizzard shad--A total of 142 gizzard shad were collected during the period. Most (114) of these fish were collected during the September cove rotenones. The fish collected ranged in size from 60 mm, 2 g to 462 mm, 936 g. The average size of the fish collected was approximately 149 mm, 145 g. Age and growth information from scales revealed that age II gizzard shad (14) averaged 217 mm in total length; age III (1), 256 mm; age V (2) 396 mm; age VII (1), 447 mm; and age IX averaged 323 mm in total length. No age IV, VI, or VIII gizzard shad have been analyzed yet. The bulk of the fish collected during the September rotenone are suspected to be age 0 and I, but have not been analyzed as such yet. Stomach analyses of twelve shad taken in July revealed that zooplankton constituted a large percentage of the diet of those fish collected in July. The Cladoceran Bosmina and the Rotifer Keratella sp. were

the most prevalent organisms found in the stomachs. As gizzard shad increased in size, their stomachs contained increasingly greater proportions of plant matter. The algae class Chlorophyta was the most frequently found. Also, various bits and pieces of what is suspected to be Bryozoa were found in nearly all gizzard shad stomachs analyzed.

Alewife--A total of 216 alewives were collected during the period. The bulk of these fish (211) came from the September cove rotenones. The fish ranged in size from 50 to 132 mm. The average size of alewives collected was 76 mm. Stomach analyses of two of the alewives revealed that one was feeding on hatching Ephemeroptera in addition to small numbers of Bosmina sp. and unidentified copepods. The other alewife consumed small numbers of Bosmina sp., other unidentified cladocera, and unidentified copepods.

Ohrid trout--Lengths, weights, scales, and stomachs were taken from 9 fish caught by fishermen during August and September. None were taken during July. The fish ranged in size from 315 mm, 363 g to 521 mm, 1769 g. The average size was 412 mm, 884 g. Data from these fish awaits analyzation.

Rainbow trout--Data from 5 fish caught by fishermen during August and September was collected. None was collected during July. The fish ranged in size from 236 mm, 136 g to 478 mm, 1406 g. The average size was 380 mm, 681 g. Data from these fish also awaits analyzation.

Smallmouth bass--Nine of these fish, or data from them were taken. Two fish were collected in gill nets during July. Data from the remaining 7 fish was taken from fish caught by fishermen during August and September. The fish ranged in size from 152 mm, 84 g to 400 mm, 816 g. The average size of the bass was 346 mm, 606 g.

Other species--Other species collected included 2 Channel catfish, 4 crappie, 2 rock bass, and 2 bluegill.

APPENDIX B

ZOOPLANKTON COLLECTION PROCEDURES

Attempts were made to collect zooplankton samples at sites where alewives were captured. A kemmerer water bottle with a 1.2 liter volume was used. The kemmerer was not of sufficient volume to collect a representative sample from the water column. Analysis of samples revealed only shells of organisms and detritus. Vertical pulls using a Wisconsin plankton net was later used with better results. Because of a lack of satisfactory samples, analyses could not be made. Possible solutions for future collections have been suggested by Dr. Melbourne Whiteside, The University of Tennessee, Knoxville. They include sampling of both littoral and limnetic areas with "bongo" or "twin" nets, each net with a diameter of 20 cm. This "twin" net allows the collection of duplicate samples. Sampling should be done at a specified time after sunset (e.g., 2 hours after sunset), consistently throughout the sampling period. In limnetic regions only one vertical pull is needed using "twin" nets, and should start with 3 m of the bottom. For littoral samples a transect should be made perpendicular from the shoreline. If sampling is to include 3 m in depth, three samples should be taken using twin nets. Starting from the shoreline, along the transect, one should be made at 1 m depth, then further out one at 2 m depth, and

then further out, the last at 3 m of depth. This composite sample is used to represent the zooplankton community at the time collected.

APPENDIX C

RESULTS FROM FACTOR ANALYSIS AND ANALYSIS OF COVARIANCE

INITIAL FACTOR METHOD: PRINCIPAL COMPONENTS

PRIOR COMMUNALITY ESTIMATES: ONE

EIGENVALUES OF THE CORRELATION MATRIX: TOTAL = 24.000000 AVERAGE = 1.000000

	1	2	3	4	5	6	7	8	9	10	11	12
EIGENVALUE	3.339419	2.391901	2.060056	1.831268	1.390530	1.309106	1.204062	1.164676	1.055426	0.948764	0.911132	0.817396
DIFFERENCE	0.947518	0.331845	0.228788	0.440738	0.081423	0.105045	0.039385	0.109250	0.106662	0.037632	0.093736	0.079543
PROPORTION	0.1391	0.0997	0.0858	0.0763	0.0579	0.0545	0.0502	0.0485	0.0440	0.0395	0.0380	0.0341
CUMULATIVE	0.1391	0.2388	0.3246	0.4009	0.4589	0.5134	0.5636	0.6121	0.6561	0.6956	0.7336	0.7677
	13	14	15	16	17	18	19	20	21	22	23	24
EIGENVALUE	0.737853	0.720861	0.607278	0.585256	0.497198	0.470483	0.436384	0.387118	0.341241	0.319512	0.277021	0.196057
DIFFERENCE	0.016993	0.113583	0.022023	0.088057	0.026715	0.034099	0.049267	0.045877	0.021729	0.042490	0.080965	
PROPORTION	0.0307	0.0300	0.0253	0.0244	0.0207	0.0196	0.0182	0.0161	0.0142	0.0133	0.0115	0.0082
CUMULATIVE	0.7984	0.8284	0.8537	0.8781	0.8988	0.9184	0.9366	0.9528	0.9670	0.9803	0.9918	1.0000

9 FACTORS WILL BE RETAINED BY THE NFACTOR CRITERION

VARIANCE EXPLAINED BY EACH FACTOR IGNORING OTHER FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9
2.633226	2.371585	1.975074	2.030973	1.933466	1.870332	1.592422	1.431793	1.218080

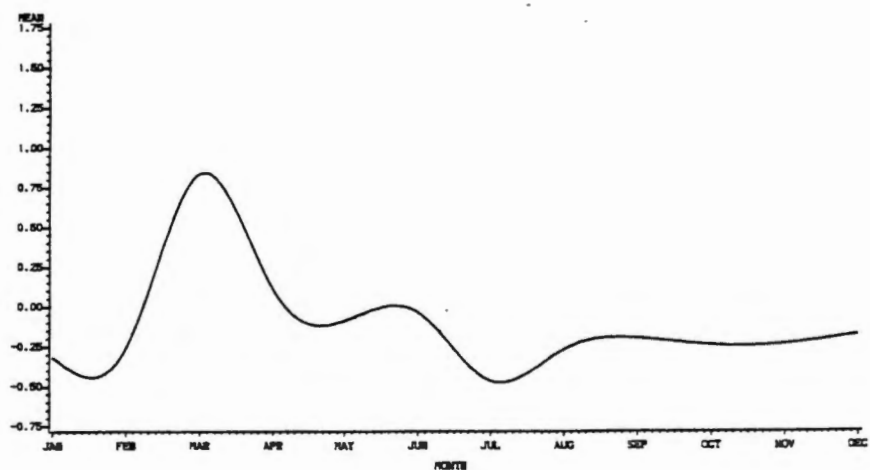
FINAL COMMUNALITY ESTIMATES: TOTAL = 15.746445

C1	C2	C3	C4	C5	C8	C9	C10	C11	C12	C13	C14
0.812697	0.735623	0.707772	0.482860	0.584613	0.790003	0.725504	0.517540	0.647543	0.710924	0.721826	0.660811
C15	C16	C20	C21	C22	C23	C25	C26	C28	C29	C30	C31
0.650564	0.681263	0.763945	0.510025	0.690683	0.429843	0.680964	0.605817	0.648763	0.705545	0.645782	0.635535

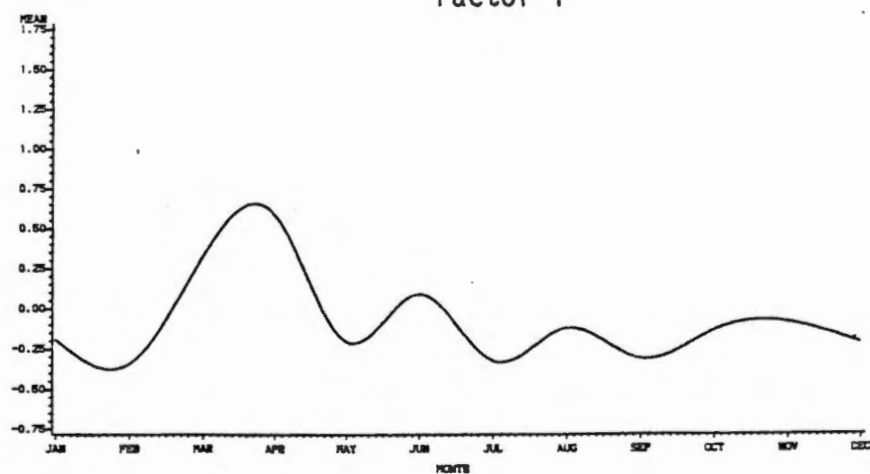
ROTATION METHOD: PROMAX

ROTATED FACTOR PATTERN (STD REG COEFS)

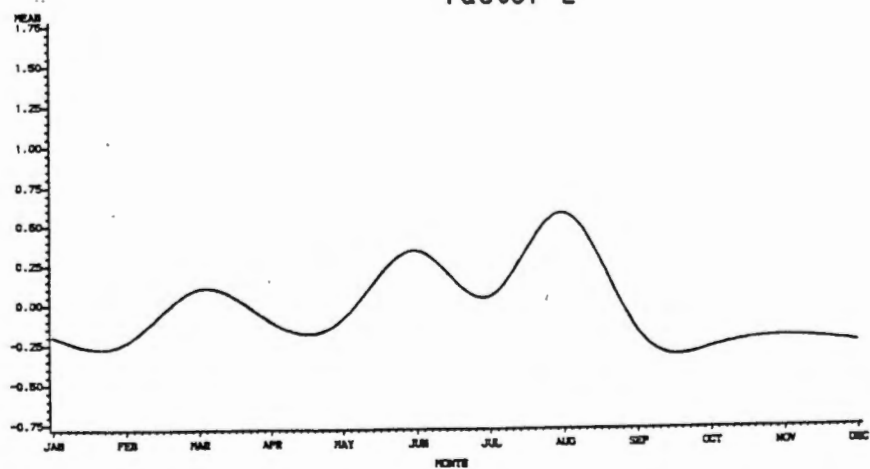
	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	
C1	0.04788	0.90236	-0.10784	-0.18015	0.02218	0.05158	0.01580	-0.11784	0.00226	BRYZOAN FLT.
C2	-0.01512	-0.06942	0.85307	-0.00450	0.05453	0.07115	-0.02615	0.02892	0.03611	SIDA
C3	0.02294	0.00341	-0.07448	-0.04003	-0.07222	-0.09576	0.84825	0.02515	-0.08729	DAPHNIA
C4	-0.03093	0.01827	0.03593	-0.15179	0.07435	-0.21040	-0.02269	0.02519	0.70298	EPHIPIUM
C5	-0.13413	-0.03799	-0.00452	0.04960	-0.69889	0.00325	0.21941	-0.03114	-0.13100	BOSMINA
C6	-0.18387	0.70761	0.06883	0.40606	0.01510	-0.05167	-0.01406	0.08102	-0.06026	ALONA
C9	0.12601	-0.04979	0.85803	-0.09943	-0.01178	-0.11069	-0.07075	0.05243	-0.03433	PLEUROXUS
C10	0.06105	0.18193	0.44421	0.04818	-0.36425	-0.03929	0.30642	-0.07178	-0.04760	CHYDORUS SPHAERICUS
C11	-0.12959	-0.01169	0.32819	0.48413	0.07968	0.37774	-0.01524	-0.08803	0.19239	LEYDIGIA
C12	0.42615	-0.05425	-0.02752	0.72774	-0.20738	0.00200	-0.07993	-0.05241	-0.17361	OSTRACODA
C13	-0.10103	-0.02060	0.01404	0.04094	0.03136	0.85352	0.03504	0.11472	-0.10990	CALONOID COPE.
C14	0.01402	0.02668	-0.03611	0.03340	0.57928	-0.00482	0.41790	0.08099	-0.36893	CYCLOPOID COPE.
C15	0.36559	0.08743	-0.13649	-0.05175	0.09854	0.62529	-0.12983	-0.12108	-0.10986	HARPACTOID COPE.
C16	0.15630	-0.01626	-0.01385	0.11712	0.68495	0.19141	0.19402	-0.08863	0.00316	COPEPODA
C20	0.14197	-0.00937	0.05712	0.02952	0.06455	-0.12158	0.01081	0.84696	0.06139	TRICOPTERA
C21	0.55004	0.20567	-0.03262	0.06042	0.16619	-0.05423	0.04886	0.00241	0.28633	DIPTERANS
C22	0.78368	0.01756	0.15576	-0.07180	0.02300	-0.00109	0.01068	-0.07910	-0.10255	CHIRONOMID LARVAE
C23	-0.17207	0.04009	0.13712	0.00994	0.42797	-0.18239	-0.14375	0.01584	-0.45035	CHABORUS LARVAE
C25	-0.07903	0.00717	-0.01267	-0.13020	-0.03899	0.54303	-0.01945	0.70791	-0.06666	HYMENOPTERA
C26	0.00795	-0.04292	0.08969	-0.13438	0.08232	0.15499	0.61491	-0.05502	0.31374	CRUSTACEAN EGGS
C28	0.06596	0.51143	-0.12501	0.40089	-0.04774	-0.06173	0.01486	0.15576	0.21953	INSECT FRAGMENTS
C29	0.84800	-0.17354	-0.04717	0.11594	0.08268	-0.03226	0.06096	0.17899	0.06700	WHO KNOWS?
C30	0.45450	0.46876	0.18298	-0.10544	0.01558	0.08926	-0.09288	0.05882	-0.13667	CHYDORIDS
C31	-0.09446	-0.02611	-0.07985	0.80432	0.14615	-0.00579	-0.04785	-0.03264	-0.13588	CHIRONOMUS PUPA



Factor 1

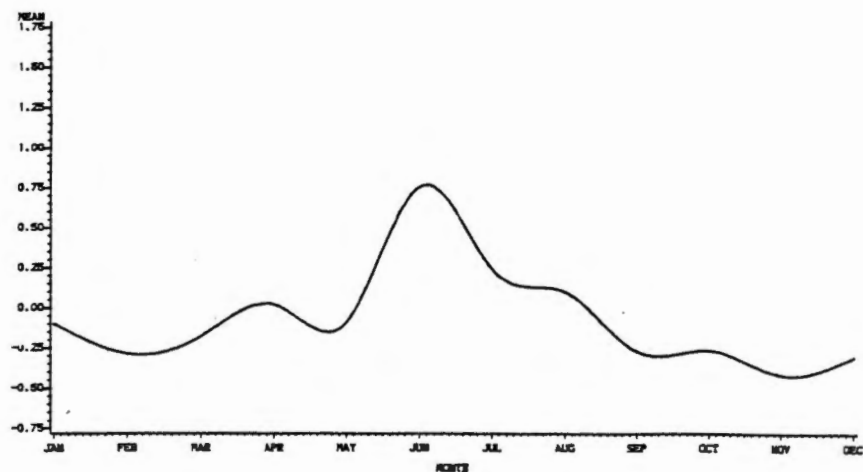


Factor 2

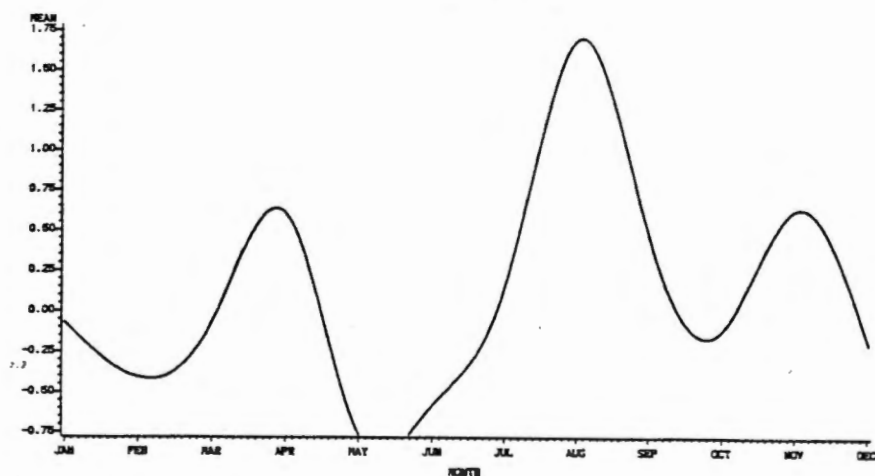


Factor 3

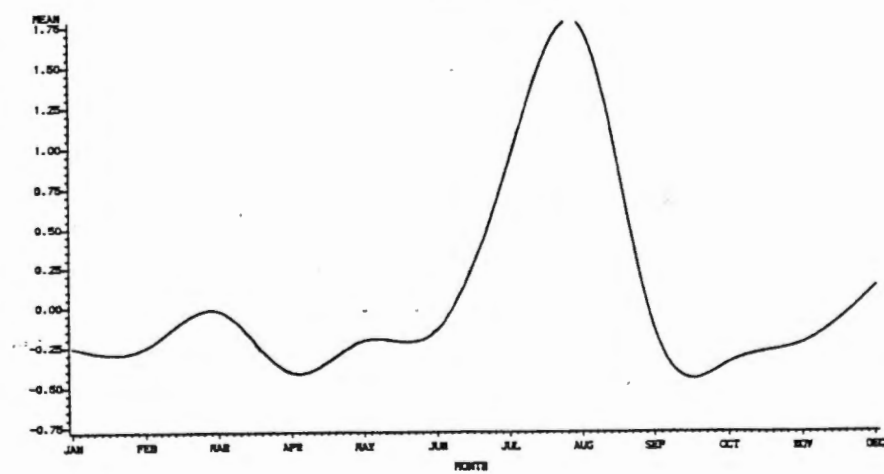
Figure A-1. Mean factor scores for each month.



Factor 4

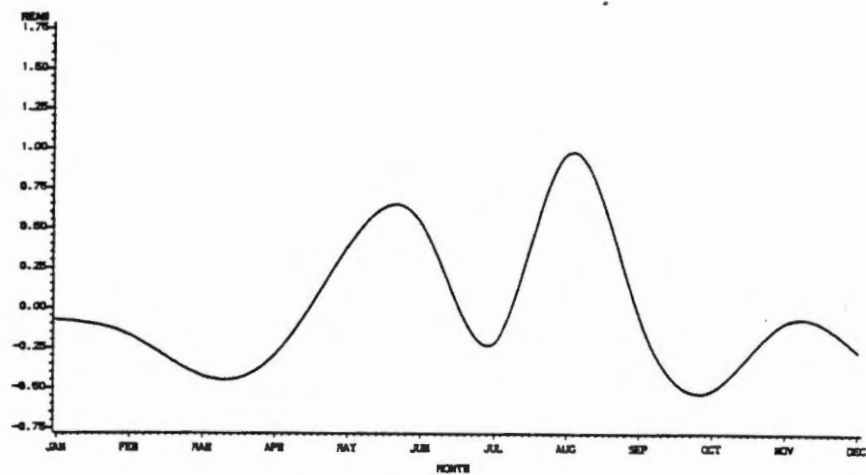


Factor 5

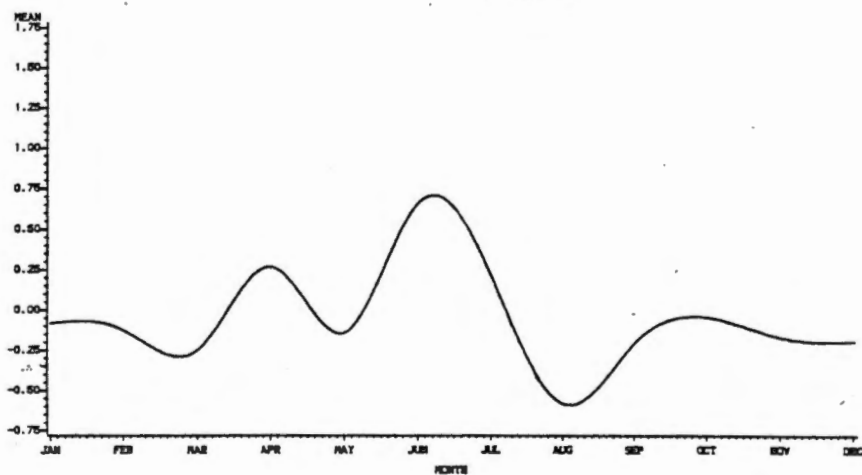


Factor 6

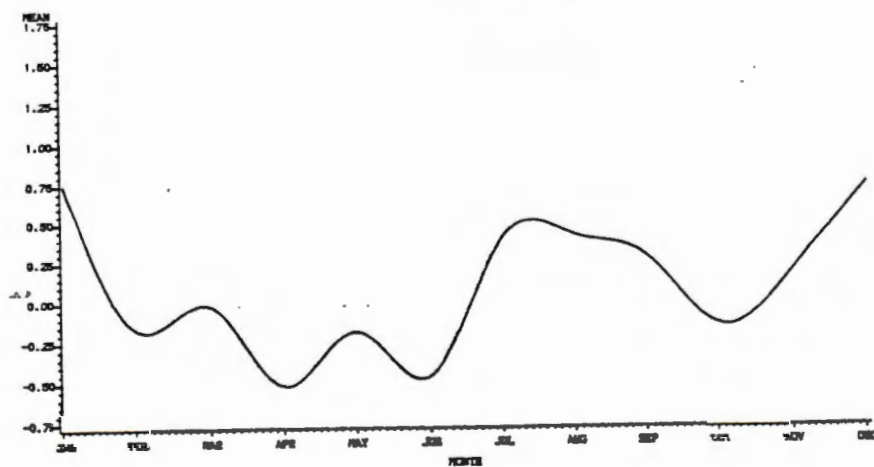
Figure A-1 (continued)



Factor 7



Factor 8



Factor 9

Figure A-1 (continued)

Table A-1. Results from analysis of covariance with date as class variable and length of fish as covariate.

Factor	Source	DF	Type I SS	F value
1	Length	1	0.573	1.25
	Date	24	70.100	6.43*
	Length*Date	24	32.098	3.09*
2	Length	1	2.853	5.59*
	Date	24	52.387	4.28*
	Length*Date	24	45.091	3.68*
3	Length	1	1.233	2.00
	Date	24	23.848	1.95*
	Length*Date	24	59.517	4.03*
4	Length	1	1.682	2.27
	Date	24	46.752	2.63*
	Length*Date	24	28.151	1.58
5	Length	1	4.656	12.61*
	Date	24	100.107	11.30*
	Length*Date	24	10.207	1.15
6	Length	1	2.113	3.44
	Date	24	48.088	3.26*
	Length*Date	24	39.403	2.67*
7	Length	1	0.318	0.48
	Date	24	61.335	3.85*
	Length*Date	24	22.735	1.43
8	Length	1	1.047	1.15
	Date	24	42.823	1.96*
	Length*Date	24	15.423	0.71
9	Length	1	1.860	2.64
	Date	24	47.679	2.82*
	Length*Date	24	30.703	1.82*

*Significant, $\alpha = 0.05$.

VITA

Karen L. Daniel was born in Bossier City, Louisiana on August 22, 1958. She attended elementary school in Chattanooga, Tennessee and graduated from Central High School in June 1976. The following September she entered Tennessee Technological University in Cookeville, Tennessee. During completion of her degree, Karen completed two co-operative education assignments with the U. S. Army Corps of Engineers including both Louisville and Nashville Districts. Karen graduated in December 1981 from Tennessee Technological University with a Bachelor of Science degree in Biology. From January 1982 through March 1984, Karen attended The University of Tennessee, Knoxville, serving as a graduate research assistant. There in March 1984, she received her Master of Science degree in Wildlife and Fisheries Science with an emphasis in fisheries. The author is a member of Gamma Sigma Delta, Beta Beta Beta, The American Fisheries Society, The World Mariculture Society, and the Wildlife Society.