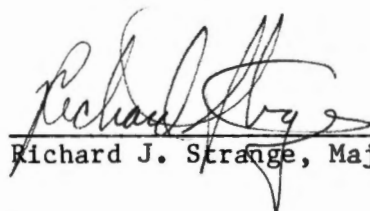
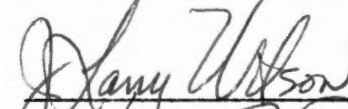
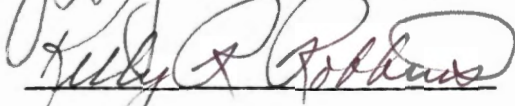
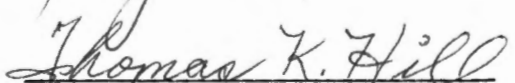


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NUTRIENT CONTENT OF CLUPEID FORAGE FISHES
IN TENNESSEE RESERVOIRS

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

Janice R. Carmichael

June 1985

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ABSTRACT

Gizzard, threadfin, and hybrid shad, and alewives were collected from Cherokee, Dale Hollow, and Old Hickory Reservoirs, Tennessee, from January 1984 through December 1984. Collections of fish were analyzed for proximate composition (moisture, ash, protein, and lipids) and gross energy content. Overall ranges of nutrients for all collections were: moisture, 69.7 - 84.9%; ash, 12.0 - 32.5%; protein, 45.4 - 79.1%; lipids, 3.3 - 31.5%; and gross energy, 3.92 - 6.06 kcal/g. Changes in protein, ash, and moisture percentages within an age class of a species were primarily the result of changes in lipid percentage. In general, lipid content increased through the summer, peaked during the fall, and declined during the winter. Seasonal variations in feeding level and reproductive condition, and differences in reservoir productivity, age, and sex were causes of variations in body composition within a species. Proximate composition and gross energy content of the clupeids examined were similar; however, young-of-year and adult alewives exhibited the highest individual gross energy values in their respective age classes.

Hybrids of gizzard and threadfin shad comprised 3.2% of shad collected from Cherokee Reservoir from August 1983 through August 1984. They exhibited intermediate and high morphometric and meristic values when compared with the parent species.

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CHAPTER I

INTRODUCTION

Some of the smaller members of Clupeidae, the herring family, serve as important sources of food for the piscivorous game fishes in Tennessee reservoirs, such as striped bass (Morone saxatilis), white bass (M. chrysops), and largemouth bass (Micropterus salmoides). These small clupeids include gizzard shad (Dorosoma cepedianum), threadfin shad (D. petenense), gizzard shad and threadfin shad hybrids, and alewives (Alosa pseudoharengus). These fishes are a vital link in the food chain of reservoirs due to their ability, as plankton feeders, to consume the minute plants and animals in the aquatic environment. Thus, a vast source of nutrients that would otherwise remain unavailable to higher predators, is converted into edible biomass.

Gizzard shad are widespread from Minnesota to the St. Lawrence River and from New Jersey south to the Gulf of Mexico; they are, therefore, native to the Tennessee River system (Eddy 1977). A littoral species, most of its diet is comprised of plankton and detritus (Kutkuhn 1958; Baker and Schmitz 1971; Shelton 1972; Hendricks and Noble 1980). Gizzard shad mature in one year or less (Noble 1981); spawning is initiated in late spring when the water temperature exceeds 16-17 C (Shelton 1972). They produce numerous young that can serve as prey for game fishes. However, they rapidly grow too large to be eaten by most predators (Dendy 1946; Pflieger 1975; Fagan and Fitzpatrick 1978). Noble (1981) indicated gizzard shad can reach lengths of over 400 mm in southern impoundments; therefore, food and space that would otherwise be

available for production of game fishes are utilized by these larger individuals (Jenkins 1957).

Threadfin shad are not native to the Tennessee River system since their original range extended along the Gulf coast from Florida into Mexico (Eddy 1977). However, they have been stocked into many Tennessee reservoirs to serve as an alternative prey species. They are pelagic fish which feed primarily on plankton, aquatic insects and their larvae, and invertebrate eggs (Miller 1967; Baker and Schmitz 1971; Shelton 1972; Hendricks and Noble 1980). Threadfin shad can become sexually mature at an age of several months (Noble 1981); spawning begins in the spring when water temperature rises above 19-20 C (Shelton 1972). Threadfin shad do not grow as large as gizzard shad (Parsons and Kimsey 1954; Bryant and Houser 1968; Pflieger 1975); they seldom exceed 175 mm in southern reservoirs, and thus remain vulnerable to predation throughout life (Noble 1981). The threadfin shad is very sensitive to low water temperatures, however, and extensive die-offs and/or a high incidence of impingement at electric power generating plants can occur at temperatures below about 7 C (Parsons and Kimsey 1954; Strawn 1963; Pflieger 1975; Griffith and Tomljanovich 1976; Griffith 1978).

Hybridization between gizzard and threadfin shad can occur in natural populations (Shelton and Grinstead 1973; McLean et al. 1980). Minckley and Krumholz (1960) documented the collection of the first known hybrids from the Ohio River. Hybrid fry were produced in the laboratory by crosses between gizzard shad males and threadfin shad females, but the reciprocal cross was a failure (Shelton and Grinstead 1973). Shelton and Grinstead (1973) believed there were two means by

which hybrids were produced in natural populations: either by the accidental union of eggs and sperm due to the overlapping spawning conditions and behavior of the parent species, or due to smaller gizzard shad males mistakenly participating in threadfin shad spawning.

In 1976, the Tennessee Wildlife Resources Agency stocked alewives into Watauga and Dale Hollow Reservoirs in an effort to increase forage (Sudheimer 1983; Daniel 1984). Originally an anadromous species, the alewife is found along the Atlantic coast from Florida to Labrador and throughout the St. Lawrence drainage (Eddy 1977; McClane 1978). In recent years, this forage species has entered the Great Lakes through the Welland Canal, resulting in a highly productive salmonid fishery (McClane 1978; Kohler and Ney 1980). Landlocked populations have been established through introductions with the oldest known population of this nature found in Lake Hopatcong, New Jersey (Boaze 1974). This population served as the source of the alewives stocked into Tennessee reservoirs (Sudheimer 1983). Alewives are pelagic, and their diet consists primarily of zooplankton, aquatic insects, and crustacean eggs (Lackey 1970; Hutchinson 1971; Kohler and Ney 1980; Daniel 1984). They mature at age 2 (Rothschild 1966; Lackey 1970; Daniel 1984); spawning occurs in late spring when water temperature exceeds 16 C (Edsall 1970). Alewives seldom surpass 130 mm in length in the cool water reservoirs in Tennessee into which they have been stocked (Daniel 1984). The ultimate lower lethal temperature of alewives is considered to be approximately 3 C (Stanley and Colby 1971; Otto et al. 1976). Therefore, they are more tolerant of low water temperatures than threadfin shad, and thus, more suited to the cooler waters of Watauga and Dale Hollow Reservoirs.

Although the alewife appears promising as a potential freshwater forage fish under suitable conditions, questions remain as to the impact this non-native species can have on resident game fish populations (Kohler and Ney 1980; Daniel 1984).

Kohler and Ney (1980) characterize an ideal forage species as one which is: 1) prolific and self-sustaining, 2) trophically efficient, 3) desirable and available to predators, 4) vulnerable to predation throughout its life cycle, 5) non-emigrating, 6) devoid of adverse interspecific impact, and 7) a positive influence on sportfish growth. In keeping with this last quality, the nutritional value to game fishes of a forage species should be considered extremely relevant.

Much work has been done in regard to the food habits of the piscivorous sport fishes of southern impoundments (e.g., Mullan and Applegate 1967; Ball and Kilambi 1972; Cannamela et al. 1978; Combs 1978). Research studies of this nature have determined the incidence of forage fishes, as well as other food items, in the diets of game fishes. However, not only is the quantitative value of a food item of significance, but also the qualitative or nutritional value of that item to the consumer. With this information in hand, the fisheries biologist can gain better insight into the actual nutrient intake of the predator, and thus the level of nutrients ultimately available to the fish for maintenance, growth, and reproduction. A nutritionally-poor food base could be a contributing factor to low production in a gamefish population.

A means of determining the nutritional value of a food item is through proximate analysis and bomb calorimetry. Proximate analysis

involves chemical and physical determinations for moisture, ash or total mineral, protein, fat or lipid, fiber, and starch and sugar contents (Cullison 1982). Only moisture, ash, protein, and fat analyses are of importance when examining fish since fiber is found only in plant sources and other carbohydrates are present at very low levels.

The proximate composition of fish varies widely from species to species. Moisture, ash, and protein levels can differ by three to five times; fat levels can differ by as much as three hundred times (Stansby and Olcott 1976). Within the same species, proximate composition can vary from one individual to another; the fat content of one individual may be more than ten times that of another. Individual variation is the result of differences in season of the year in which fish were collected, geographical location of collection, or fish age or sex.

The total number of calories contained in a material is its caloric content or gross energy, and it can be determined through measurement of the heat energy released upon combustion of the material in a bomb calorimeter (Maynard et al. 1979). Only proteins and fats contribute calories to the gross energy of fish, with proteins producing 5.7 kcal/g (Brody 1945), and fats, 9.5 kcal/g (Brody 1945; Souci et al. 1981).

Fish, in general, are an excellent source of food for other fish. Because of the close taxonomic relationship between predator and prey, the body composition of the prey species approximates that of the predator species. Thus, the nutrient requirements of the predator, including those for vitamins, minerals, and the 10 essential amino acids (Wilson and Robinson 1982) are met in a highly efficient manner. Aquaculturists have determined that the protein requirements of

carnivorous fishes for maximum growth range from 40 to 50% of the dry diet (Stickney 1979). Forage-sized fishes contain protein in excess of this range on a dry basis, and so can more than meet this need of predators. Lipid content should, therefore, be considered the primary determinant of a forage fish's nutritional value. The higher the lipid content of the prey species, the greater is the amount of energy that is available to the consumer. Thus, the forage species that contain higher levels of fat are able to produce fatter, deeper-bodied game fishes, which have the potential for greater reproductive success.

A limited amount of research has been done to determine whole body proximate composition and caloric content of gizzard shad, threadfin shad, and alewives. Pierce et al. (1980) studied seasonal changes in ash, lipid, and caloric contents of gizzard shad from Acton Lake, Ohio. Adams et al. (in press) determined moisture, ash, lipid, and caloric contents of adult gizzard shad from Watts Bar Reservoir, Tennessee. Gizzard and threadfin shad from West Point Reservoir, Georgia, were analyzed for ash and protein contents (Davis and Boyd 1978). Minton and McLean (1982) determined the caloric content of gizzard and threadfin shad from Watts Bar Reservoir, Tennessee. Dugal (1962) determined moisture, ash, protein, and lipid contents of gizzard shad and alewives from the Great Lakes. Alewives from Lake Michigan were analyzed for moisture, ash, protein, lipid, and/or caloric contents (Travis 1966; Ackman et al. 1967; Rottiers and Tucker 1982).

The primary objective of this study was to examine the nutritional value (proximate composition and gross energy content) of gizzard, threadfin, and hybrid shad, and alewives from selected Tennessee

reservoirs during the course of a year. Because hybrids were to be collected and analyzed for nutrient content, questions arose as to how significant these shad were as forage fish, and how they could be most readily distinguished from the parent species. Therefore, two corollary objectives of this study were to (1) determine the incidence of hybrid shad in the shad population of Cherokee Reservoir, Tennessee, during the collection period, and (2) compare selected physical characteristics of hybrid shad with those of the parent species.

CHAPTER II

DESCRIPTION OF THE STUDY AREAS

Fish for this study were obtained from three Tennessee reservoirs: Cherokee, Dale Hollow, and Old Hickory. The reservoirs were selected due to the composition of their clupeid forage fish populations.

Cherokee Reservoir is a multipurpose storage impoundment on the Holston River in northeast Tennessee which inundates portions of Grainger, Hamblen, Hawkins, and Jefferson Counties (Figure 1). The reservoir was formed in 1941 following completion of Cherokee Dam by the Tennessee Valley Authority (TVA) at Holston River Mile 52.3 (Waddle et al. 1980). Cherokee Reservoir's primary purposes are flood control, hydroelectric power generation, and recreation.

It is a warm water, eutrophic reservoir with a drainage area of 8,879 km² (Schaich and Coutant 1980). At full summer pool elevation (327 m), the reservoir is 87 km long, and has a surface area of 12,222 ha and 745 km of shoreline (Schaich and Coutant 1980; Humphreys 1983). At normal winter minimum pool elevation (311 m) the surface area is reduced to 5,002 ha (Schaich and Coutant 1980).

Throughout the winter, Cherokee Reservoir is isothermal and dissolved oxygen is plentiful at all depths (Waddle et al. 1980). However, thermal stratification begins in March and continues into September, resulting in depletion of dissolved oxygen in the hypolimnion. During the fall turnover in late September, water temperatures decrease and dissolved oxygen levels increase. By October, thermal stratification is slight.

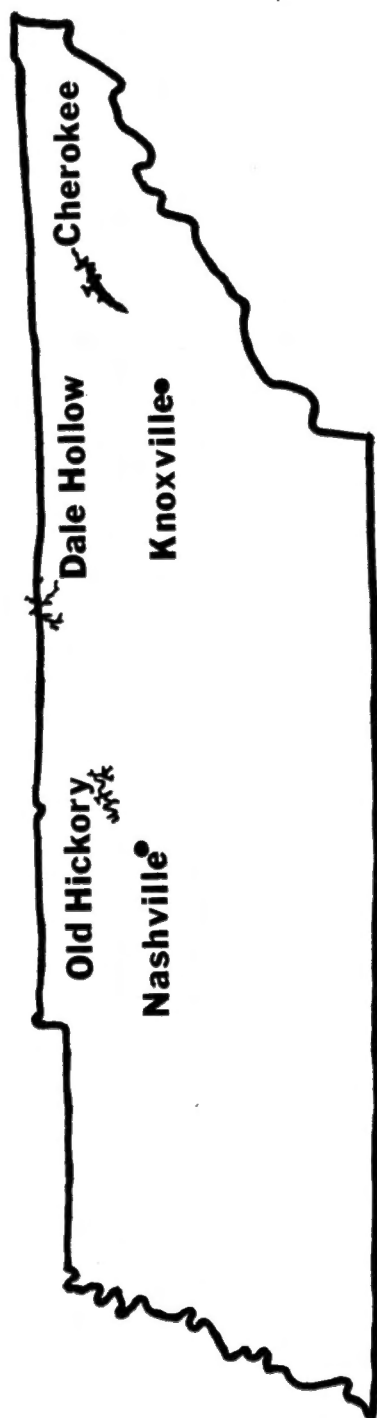


Figure 1. Map of Tennessee showing locations of Cherokee, Dale Hollow, and Old Hickory Reservoirs.

The predominant sport fishes in Cherokee Reservoir are striped bass, white bass, smallmouth bass (Micropterus dolomieu), largemouth bass, sauger and walleye hybrids (Stizostedion canadense and S. vitreum), crappie (Pomoxis spp.), bluegill (Lepomis macrochirus), and catfish (Ictalurus spp.). The clupeid forage fishes in Cherokee Reservoir are gizzard, threadfin, and hybrid shad.

Dale Hollow Lake is a multipurpose storage impoundment on the Obey River which covers portions of Clay, Fentress, Overton, and Pickett Counties, Tennessee, and Clinton and Cumberland Counties, Kentucky (Figure 1). Dale Hollow Lake was formed in 1943 by the construction of Dale Hollow Dam by the United States Army Corps of Engineers on the Obey River 11.7 km above its confluence with the Cumberland River (Ragsdale 1972). The lake's primary purposes are flood control, hydroelectric power generation, and recreation.

It is a cool water, mesotrophic lake, with a drainage area of 2,422 km² (United States Army Corps of Engineers). At maximum pool elevation (202 m), Dale Hollow Lake is 98 km long, and has a surface area of 12,541 ha and 998 km of shoreline. At minimum pool elevation (192 m) the surface area is reduced to 8,855 ha.

During the summer months, Dale Hollow Lake stratifies into a warm upper layer and a cool lower layer (Ragsdale 1972). However, high concentrations of dissolved oxygen remain in the lower layer, resulting in a two-story reservoir. Depletion occurs only briefly near the bottom during late summer.

Dale Hollow Lake supports a diverse sport fishery including rainbow trout (Salmo gairdneri), lake trout (Salvelinus namaycush), smallmouth

bass, largemouth bass, white bass, muskellunge (Esox masquinongy), walleye, crappie, and bluegill. Clupeid forage fishes found in Dale Hollow Lake include gizzard shad and alewives; however, the introduction of the alewife may have resulted in the displacement of the gizzard shad since very few small gizzard shad have been collected in recent years (A. I. Myhr, Tennessee Wildlife Resources Agency, pers. comm.). Threadfin shad have been repeatedly stocked into this reservoir, but due to the species' sensitivity to low water temperatures it has suffered severe winterkills (Wynn 1970). It is believed that threadfin shad are no longer present in Dale Hollow Lake (A. I. Myhr, Tennessee Wildlife Resources Agency, pers. comm.).

Old Hickory Lake is a multipurpose storage impoundment on the Cumberland River in northcentral Tennessee, and it extends into Sumner and Davidson Counties (Figure 1). The lake was formed in 1957 upon completion of Old Hickory Lock and Dam by the United States Army Corps of Engineers at Cumberland River Mile (CRM) 216.2 (United States Army Corps of Engineers). Old Hickory Lake's primary functions are improved navigation, flood control, hydroelectric power generation, and recreation.

Old Hickory is a warm water, eutrophic reservoir with a total drainage area of 30,236 km² (Byerley and Ridley 1980). At maximum pool elevation (137 m), the lake is 156 km long, and has a surface area of 11,109 ha and approximately 708 km of shoreline (United States Army Corps of Engineers). At minimum pool elevation (135 m), the surface area is reduced to 7,912 ha. Gallatin Steam Plant is located on Old Hickory Lake near Gallatin, Tennessee, at CRM 243.

Popular sport fishes in Old Hickory Lake are largemouth bass, white bass, striped bass, walleye, sauger, crappie, bluegill, and catfish. Clupeid forage fishes found in this lake include gizzard, threadfin, and hybrid shad, and alewives. The alewife has immigrated to Old Hickory Lake from Dale Hollow Lake.

CHAPTER III

MATERIALS AND METHODS

Nutrient Content

Field Collections

Clupeid forage fishes were collected from Cherokee, Dale Hollow, and Old Hickory Reservoirs during the period January 1984 through December 1984. Fish less than 100 mm total length (forage-sized) were obtained whenever possible. All fish were stored frozen in the laboratory until analyzed.

Collection of gizzard, threadfin, and hybrid shad was attempted monthly from Cherokee Reservoir (Appendix A). The primary collection method was nighttime shoreline and deepwater electrofishing with a boat-mounted, boom-type, 230-V generating unit. On occasion, fish were obtained by shoreline seining with a 1.8 x 15.7 m straight seine having 9.5 mm mesh. Fish were transported to the laboratory in plastic bags placed in an ice-filled cooler.

Collections of alewives were made quarterly from Dale Hollow Reservoir during the months of March, June, September, and December (Appendix B). No threadfin shad were found, and insufficient numbers of gizzard shad were obtained for analysis. The primary collection method was nighttime shoreline and deepwater electrofishing. However, the use of sinking horizontal gill nets (45.7 x 1.8 m with mesh sizes of 12.7 and 19.1 mm), and vertical gill nets (3.0 x 30.5 m with mesh sizes of 9.5 and 12.7 mm) in conjunction with electrofishing proved successful on

occasion. Fish were transported to the laboratory in plastic bags on dry ice.

A limited number of gizzard, threadfin, and hybrid shad, and alewives were collected by TVA fisheries biologists during March impingement counts at Gallatin Steam Plant on Old Hickory Reservoir. These fishes were frozen in plastic bags at the TVA facilities until they could be transported on ice to the laboratory.

Laboratory Analyses

Collections of fish were analyzed for moisture, ash, protein, lipid, and gross energy contents. The collections were comprised of individuals of one species and age class, collected from one reservoir during one month. The majority of age classes 1+ or higher were separated by sex also.

While still partially frozen, each selected fish was blotted dry, measured for total length (mm), and weighed (0.01 g). At least three individuals from each collection were aged by scale examination. Scales were removed from the left side of the fish at the midline just above the anal fin insertion (Rothschild 1963). They were cleaned, mounted between two glass slides, and examined in a microfiche reader. In order to determine sex, a sample of gonadal tissue was placed between two glass slides and examined under a dissecting microscope. Conservation of body moisture was of primary concern throughout all collection preparations.

Whenever possible, enough fish were used to constitute a wet weight of at least 120 g. Selected fish were placed in a stainless-steel blender. In order to obtain homogeneity, it was necessary to add an

exact weight of distilled water (50-100% of the collection weight). Fish and water were thoroughly blended until the slurry was uniform.

Three oven-dried, porcelain crucibles were weighed to 0.0001 g on a Mettler mechanical analytical balance. They were filled with the slurry and weighed again. Remaining slurry was poured into unweighed crucibles, and all crucibles were placed in a gravity convection oven at 60 C for 24 hours and then at 105 C overnight. The three original crucibles were cooled in a dessicator prior to reweighing. The dry matter level of the collection was then determined (following correction for the addition of water).

Some authors (Meakins 1976; Foltz and Norden 1977; Craig et al. 1978; Pierce et al. 1980) used lower drying temperatures for fish samples in order to avoid volatilization of lipids. An experiment was performed to determine whether the higher drying temperature of 105 C would reduce gross energy content. Dry matter and gross energy content results from samples that were dried at 60 C for 48 hours were compared with those of samples dried at 60 C for 24 hours and 105 C overnight (Appendix C). Samples dried at 60 C for 48 hours did not lose 100% of their moisture. This resulted in higher dry matter percentages when compared with the percentages of samples prepared using the other drying schedule. Because these samples contained some moisture, lower gross energy values were obtained per gram of material. Therefore, since drying at 60 C only resulted in inaccurate values, and since drying at 105 C did not appear to adversely affect gross energy content, 105 C was used as a final drying temperature.

Upon determination of dry matter content, all of the dried material for a collection was finely ground together using a mortar and pestle. The ground collection was dried again at 105 C for three hours. After removal from the oven and cooling in a dessicator, samples for each analysis were weighed.

All analyses were performed in triplicate; all weights were to 0.0001 g. If an inadequate number of the appropriate fish was available for a collection, it was not possible to perform all analyses. In this case, the order of precedence was moisture, gross energy, protein, ash, and lipid determinations.

The method of ash determination was essentially that of the Association of Official Analytical Chemists (AOAC) (AOAC 1980). Samples of 2.0 g were ashed in a muffle furnace at 600 C for three hours, cooled for two hours, and weighed. In order to determine protein content, 0.5 g samples were analyzed for total nitrogen content using standard Kjeldahl digestion, distillation, and titration procedures (AOAC 1980). Protein was estimated as Kjeldahl nitrogen X 6.25. The method of ether extract, or lipid, determination was essentially that of the AOAC (AOAC 1980). Samples of 1.5 g were continuously extracted for four hours in a Goldfish fat extractor. Gross energy was determined by igniting 0.8 g samples in a Parr adiabatic oxygen bomb calorimeter (Parr Instrument Company 1981).

Data Analyses

Most of the fish collected during this study were too small to be analyzed as individuals so it was necessary to pool fish. This procedure was satisfactory in determining the mean level of each

nutrient that the population as a whole offered to predators during a given month. However, because variability within the population was not determined, it was not possible to perform statistical comparisons between samples of fish based on individual variability.

Regression equations and correlation coefficients (r) were used to ascertain overall linear relationships among moisture, ash, protein, lipids, and gross energy. Correlation was used to determine the strength of the linear relationship between total calculated dry matter content and calculated gross energy content as a percent of determined gross energy content. Nutrient level differences between age classes and sexes were determined with Student's t-test. The mean coefficient of condition, K, for selected collections was calculated by use of the formula:

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

where: W = weight (g), and

L = length (mm) (Lagler 1956).

Correlation coefficients were used to determine the strength of the linear relationship between mean condition factor and lipid percentage and between mean condition factor and gross energy level. Data analyses were performed with the aid of The University of Tennessee Computing Center's DECsystem-10 computer and the Statistical Analysis System (SAS) 1982 software package.

Hybrid Shad

Population Incidence

Shad were collected either monthly or bimonthly from Cherokee Reservoir during the period August 1983 through August 1984. The sampling method involved nighttime shoreline electrofishing for a 30-minute period. Only fish less than 100 mm total length (forage-sized) were retained and preserved in the field in 10% formalin. They were later soaked in water at the laboratory and transferred to 40% isopropanol.

Monthly collections were separated into gizzard, threadfin, and hybrid shad. Gizzard and threadfin shad were separated primarily by examining the shape of the snout and the length of the dorsal filament. Also of importance were the presence or absence of yellow pigmentation in the fins, and the number of anal fin rays. Hybrids were distinguished from the parent species by examination of a combination of physical characteristics, including the shape of the snout and head, the length of the dorsal filament and upper jaw, body shape, the incidence of black pigment on the chin and floor of the mouth, and the number of anal fin rays. The number of each kind of shad in each monthly collection was ascertained, and the percentage composition of the total collection was determined.

Physical Characteristics

To determine physical differences among gizzard, threadfin, and hybrid shad, selected measurements were taken on 30 representative individuals of each kind. Predorsal length, upper jaw length, mandible

length, caudal peduncle depth, dorsal filament length, and body depth were determined to 0.1 mm using dial calipers. Each measurement for an individual fish was then divided by that fish's standard length and multiplied by 1,000. Also, the number of rays in the anal fin of each of the 90 fish was counted under a dissecting microscope. Dyeing the fins in a rose bengal solution made rays more readily visible. Total length (mm) and body weight (0.01 g) were taken on 30 fish of each kind from the January and February 1984 collections. These fish were selected using a table of random numbers. Means for each physical characteristic were compared using Duncan's multiple range test.

CHAPTER IV

RESULTS

Nutrient Content

Securing the desired fish species of the appropriate age from Cherokee and Dale Hollow Reservoirs during each collection month proved more difficult than anticipated. Problems arose primarily from (1) the harshness of the winter and the resultant fish kill, (2) limitations of the collection methods (e.g., fish depths exceeded collection method effectiveness), (3) infrequency of visits to, and thus, unfamiliarity with seasonal forage fish locations in, Dale Hollow Reservoir, and (4) scarcity or nonexistence of a species in a reservoir (e.g., gizzard and threadfin shad in Dale Hollow Reservoir). Originally only forage-sized fish were to be collected. However, due to the difficulty encountered in obtaining this size, older age classes were at times collected for supplemental data.

Overall ranges of nutrients for all collections of fish analyzed were: moisture, 69.7 - 84.9% (mean = 78.3%, n = 52); ash, 12.0 - 32.5% (mean = 18.2%, n = 49); protein, 45.4 - 79.1% (mean = 63.4%, n = 55); lipids, 3.3 - 31.5% (mean = 14.5%, n = 39); and gross energy, 3.92 - 6.06 kcal/g (mean = 4.97 kcal/g, n = 57) (Appendixes D - H). Results for ash, protein, lipids, and gross energy are and will be expressed on a dry basis unless otherwise specified.

Protein percentages of young-of-year clupeids showed approximately the same variability when expressed on a dry, fat-free basis as when expressed on a dry basis. Mean protein percentage on a dry, fat-free

basis was 77.4% (standard error, SE = 1.00) as compared to a mean protein percentage of 69.2% (SE = 1.20) on a dry basis. Protein percentages of adult fish were less variable when expressed on a dry, fat-free basis than when expressed on a dry basis. Mean protein percentage on a dry, fat-free basis was 76.5% (SE = 0.86); when expressed on a dry basis, the mean was 62.3% (SE = 1.77). The method of collection preparation (i.e., pooling of fish) did not allow determination of individual variability among fish. The above standard errors and those that follow are standard errors of samples of mean values from collections rather than of samples of nutrient values from individual fish. Thus, less variability would be expected.

Regression equations and correlation coefficients revealed close linear relationships between some nutrients (Table 1). Positive correlations existed between gross energy and lipid levels, and between protein and moisture levels. Negative correlations were found between protein and lipid, gross energy and ash, moisture and lipid, gross energy and protein, and gross energy and moisture levels.

Under the assumption that starches and sugars are present at negligible levels in fish, the sum of the mean percentages of ash, protein, and lipids for each collection (total calculated dry matter content) should have equaled 100%. In actuality, this sum averaged 95.6% (SE = 0.42), with a range of 88.0 - 101.8%. Under the same assumption, the calculated gross energy content of a collection $[(\% \text{ protein} \times 5.7 \text{ kcal/g}) + (\% \text{ lipid} \times 9.5 \text{ kcal/g})]$ should have equaled the mean determined gross energy content of that collection. In fact,

Table 1. Regression equations and correlation coefficients (r) between proximate composition and gross energy (GE) content for gizzard, threadfin, and hybrid shad, and alewives collected from Cherokee, Dale Hollow, and Old Hickory Reservoirs, Tennessee, January 1984 through December 1984.

Regression Equation	r ^a	n
GE (kcal/g) = 4.31 + 0.05(% lipid)	+0.88*	39
% Protein = -73.38 + 1.75(% moisture)	+0.86*	52
% Protein = 73.52 - 0.76(% lipid)	-0.80*	39
GE (kcal/g) = 6.95 - 0.11(% ash)	-0.79*	49
% Moisture = 83.35 - 0.37(% lipid)	-0.78*	39
GE (kcal/g) = 7.46 - 0.04(% protein)	-0.62*	55
GE (kcal/g) = 11.03 - 0.08(% moisture)	-0.61*	52
% Ash = 20.91 - 0.16(% lipid)	-0.36	39
% Ash = 7.70 + 0.14(% moisture)	+0.14	48
% Protein = 60.51 + 0.12(% ash)	+0.06	49

^ar values marked with an asterisk (*) are significantly different from zero at a significance level of 0.01; unmarked r values are not significantly different from zero at a significance level of 0.01.

calculated gross energy content averaged 98.9% of determined gross energy content (SE = 0.47) with a range of 92.6 - 106.5%.

Seasonal changes in body composition of young-of-year clupeids were marked (Figures 2 - 6). Depicted data are from two distinct year classes. The 1983 year class is represented by data from January through March 1984; winterkill resulted in unavailability of fish of that year class after that time. Data for the months of July through December 1984 are from the 1984 year class. Calculated values shown in Figure 3 were derived in the following manner:

$$\% \text{ lipid} = \frac{[\text{determined gross energy content} - (\% \text{ protein} \times 5.7 \text{ kcal/g})]}{9.5 \text{ kcal/g}} .$$

These values are meant to provide probable data points during months when lipid percentage data were not available. The collection of gizzard shad made during September was highly aberrant in its proximate composition, resulting in extreme values for some nutrients for that collection.

In general, levels of lipids and gross energy were low in young-of-year clupeids following hatching. These levels increased throughout the summer and into the fall. At that time, they began a decline which continued through the winter. Moisture and protein percentages, and to a lesser degree, ash percentage, tended to vary inversely with lipid percentage.

Young-of-year alewives had the highest individual values of young-of-year clupeids for protein (79.1%) and gross energy (5.52 kcal/g) during the study period. Alewives of this age were consistently higher in protein percentage (mean = 11.2% higher) than their counterparts.

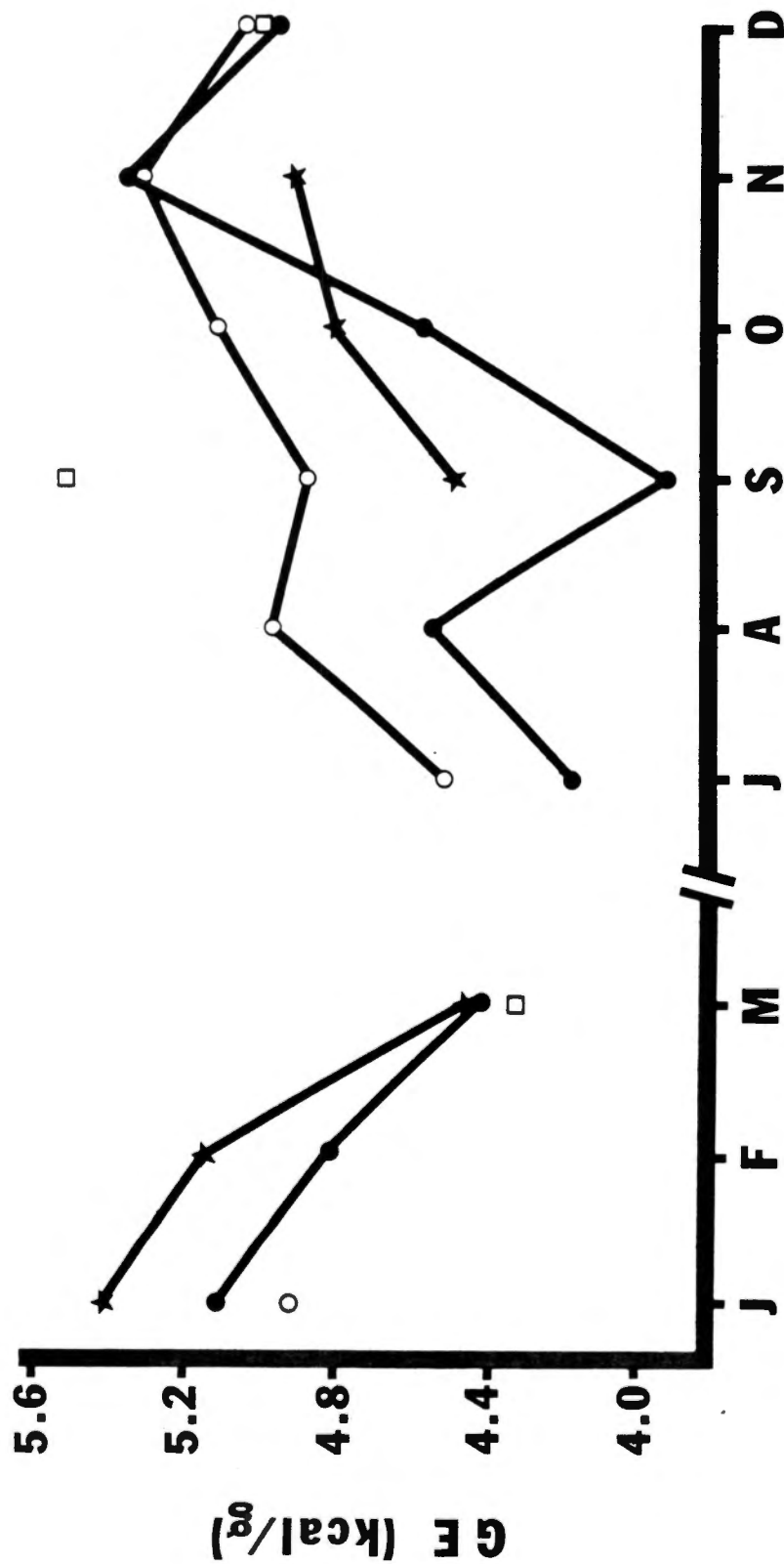


Figure 2. Seasonal variation in mean gross energy (GE) content (dry basis) of young-of-year gizzard, threadfin, and hybrid shad, and alewives collected from Cherokee and Dale Hollow Reservoirs, Tennessee, January 1984 through December 1984. Data are from 1983 and 1984 year classes. ● = gizzard shad, ○ = threadfin shad, ★ = hybrid shad, □ = alewife.

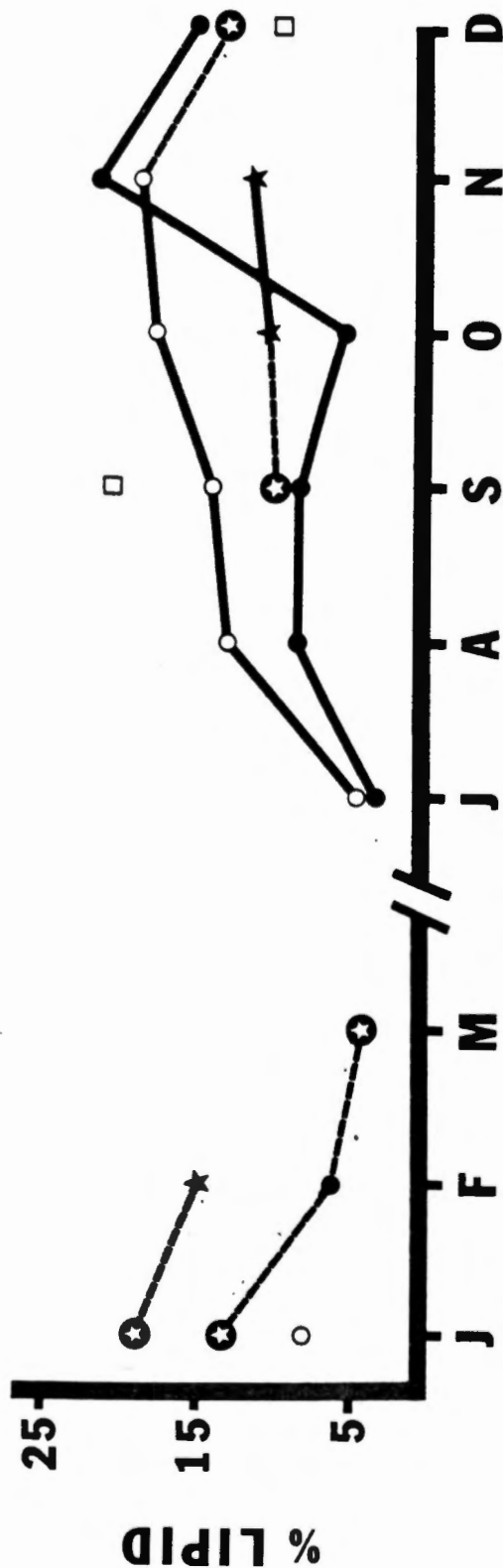


Figure 3. Seasonal variation in mean lipid percentage (dry basis) of young-of-year gizzard, threadfin, and hybrid shad, and alewives collected from Cherokee and Dale Hollow Reservoirs, Tennessee, January 1984 through December 1984. Data are from 1983 and 1984 year classes. Dashed lines indicate probable changes during those months for which data are missing. ● = gizzard shad, ○ = threadfin shad, ★ = hybrid shad, □ = alewife, ●★ = calculated values.

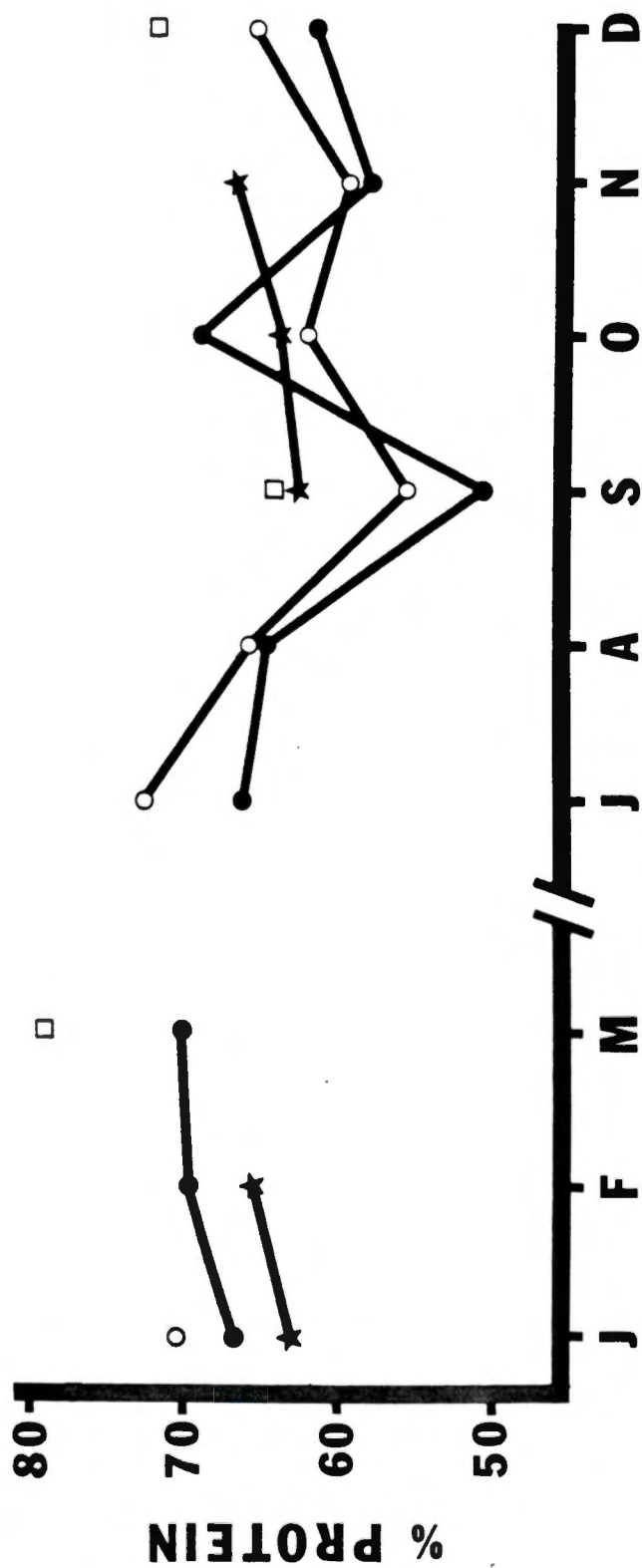


Figure 4. Seasonal variation in mean protein percentage (dry basis) of young-of-year gizzard, threadfin, and hybrid shad, and alewives collected from Cherokee and Dale Hollow Reservoirs, Tennessee, January 1984 through December 1984. Data are from 1983 and 1984 year classes. ● = gizzard shad, ○ = threadfin shad, ★ = hybrid shad, ◻ = alewife.

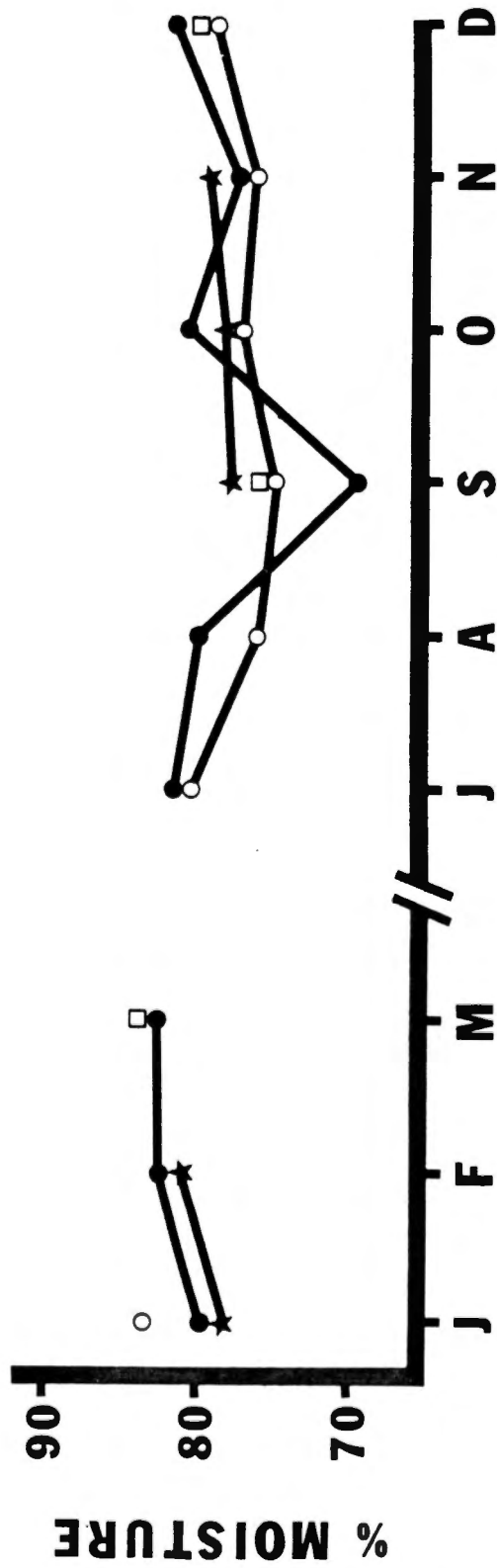


Figure 5. Seasonal variation in mean moisture percentage of young-of-year gizzard, threadfin, and hybrid shad, and alewives collected from Cherokee and Dale Hollow Reservoirs, Tennessee, January 1984 through December 1984. Data are from 1983 and 1984 year classes. ● = gizzard shad, O = threadfin shad, ★ = hybrid shad, □ = alewife.

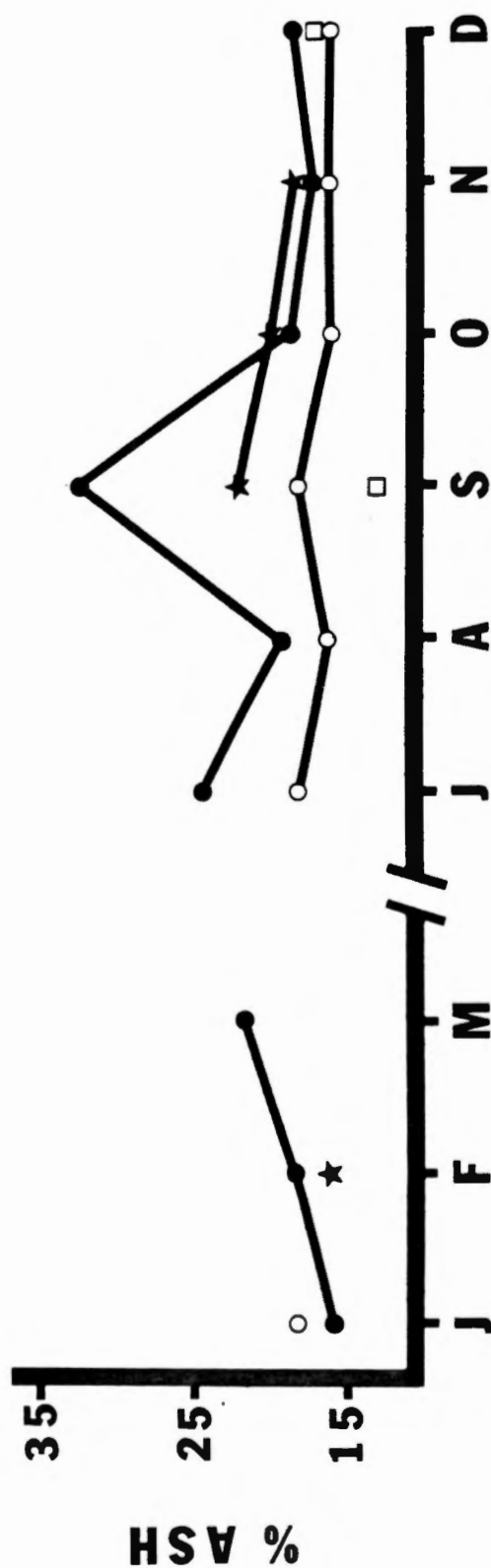


Figure 6. Seasonal variation in mean ash percentage (dry basis) of young-of-year gizzard, threadfin, and hybrid shad, and alewives collected from Cherokee and Dale Hollow Reservoirs, Tennessee, January 1984 through December 1984. Data are from 1983 and 1984 year classes. ● = gizzard shad, ○ = threadfin shad, ★ = hybrid shad, □ = alewife.

They were generally lower in ash percentage (mean = 21.1% lower) and variable in their moisture, lipid, and gross energy levels in relation to the other clupeids. The onset of their seasonal fat depletion appeared to occur earliest in the year.

Gizzard shad had the highest individual values for moisture (84.9%), ash (32.5%), and lipids (21.5%) when compared with other young-of-year clupeids. Threadfin shad were generally higher in protein percentage (mean = 3.4% higher) than gizzard shad. Lipid and gross energy levels of threadfin shad were higher than those of gizzard shad through the summer and into the fall (lipids, mean = 90.7% higher; gross energy, mean = 13.6% higher). Although it appears that threadfin shad showed a more rapid reduction in fat stores during early winter, it is difficult to draw a conclusion based on the limited data available. Threadfin shad were usually lower in moisture (mean = 0.5% lower) and ash (13.6% lower) percentages when compared with gizzard shad.

Hybrid shad were highly variable in their nutrient percentages in relation to gizzard and threadfin shad. However, mean gross energy content of young-of-year hybrids (4.80 kcal/g) was intermediate between those of gizzard shad (4.67 kcal/g) and threadfin shad (4.92 kcal/g). Only gross energy values from those months in which all three kinds of fish were collected were used to calculate means. It is interesting to note that hybrids had a higher remaining energy level than the parent species in January (5.9% greater than the level in gizzard shad; 10.3% greater than the level in threadfin shad) and February (6.8% greater than the level in gizzard shad).

Seasonally, adult gizzard shad showed an increase in protein percentage during the spawning period followed by an increase in lipid percentage that lasted until the beginning of fall (Figures 7 - 9). Calculated values in Figure 8 were derived as for Figure 3. Adults peaked in their fat stores earlier in the year than young-of-year, and the onset of the depletion occurred sooner. One+ and 2+ year-old alewives together showed an increase in gross energy content each collection month; no decline in fat stores was noted into December (Figure 7).

Collections of young-of-year gizzard and hybrid shad were available from both Cherokee and Old Hickory Reservoirs during the month of March. Only a very slight difference in gross energy content of these fishes between reservoirs existed, with those fish from Cherokee Reservoir being higher (gizzard shad, 2.0% higher; hybrid shad, 1.4% higher). However, young-of-year alewives collected from Old Hickory Lake in March were notably higher in gross energy content than those collected from Dale Hollow Lake (6.1% higher).

A comparison between year classes of gizzard shad revealed that body composition was dependent to some extent on age. Young-of-year were significantly higher in mean protein percentage and significantly lower in mean lipid and gross energy levels than adult (2+ and 3+ year-old) fish (significance level = 0.05) (Table 2). No significant differences in moisture or in ash percentages existed. Only nutrient values from those months in which collections of both age classes were obtained were used to calculate means. Insufficient data were available for statistical age class comparisons within other species. However, an

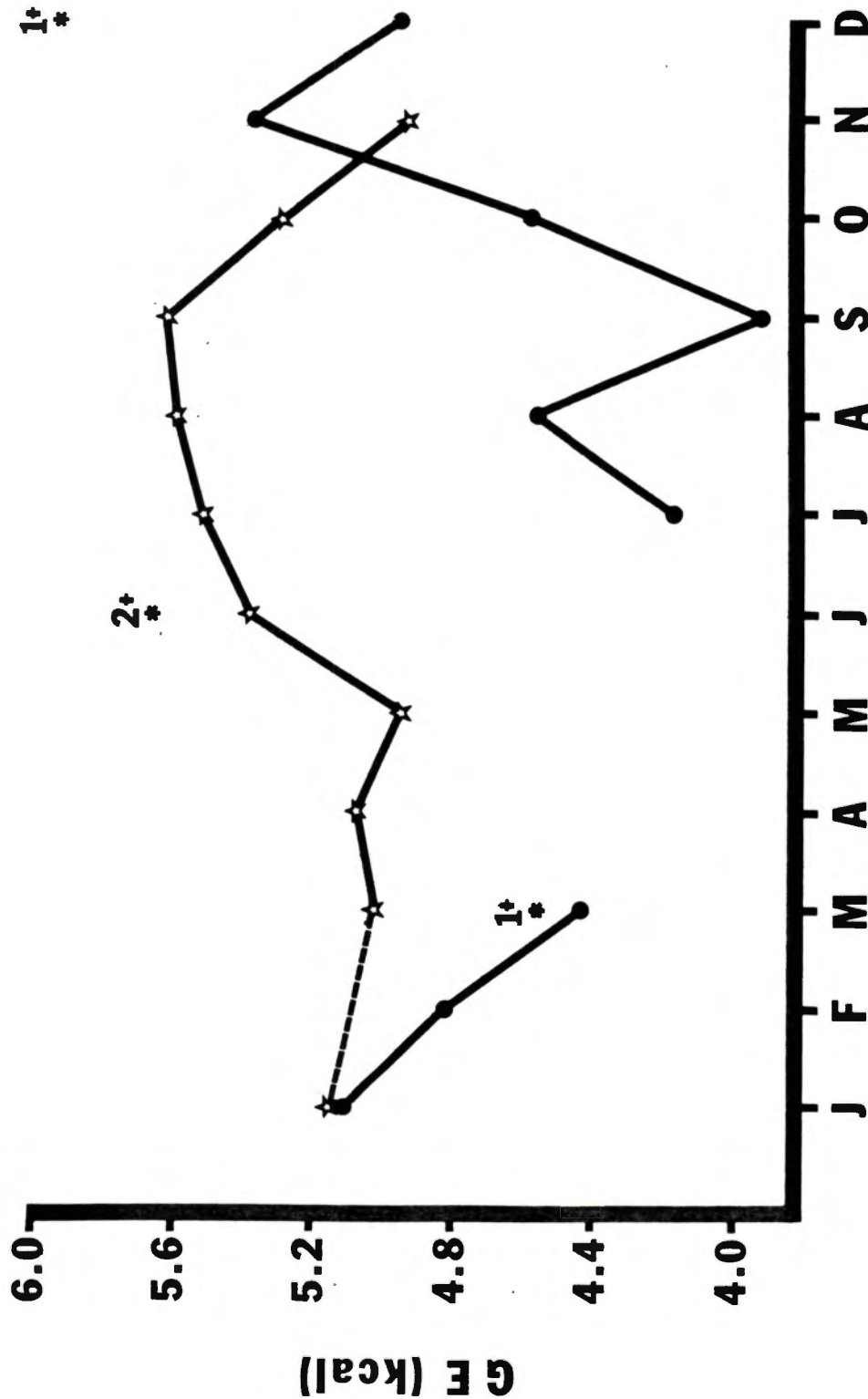


Figure 7. Seasonal variation in mean gross energy (GE) content (dry basis) of young-of-year and adult gizzard shad collected from Cherokee Reservoir, Tennessee, and 1+ and 2+ year-old alewives collected from Dale Hollow Reservoir, Tennessee, January 1984 through December 1984. The dashed line indicates probable change during the month for which data are missing. ● = young-of-year gizzard shad, ★ = adult gizzard shad, * = alewife.

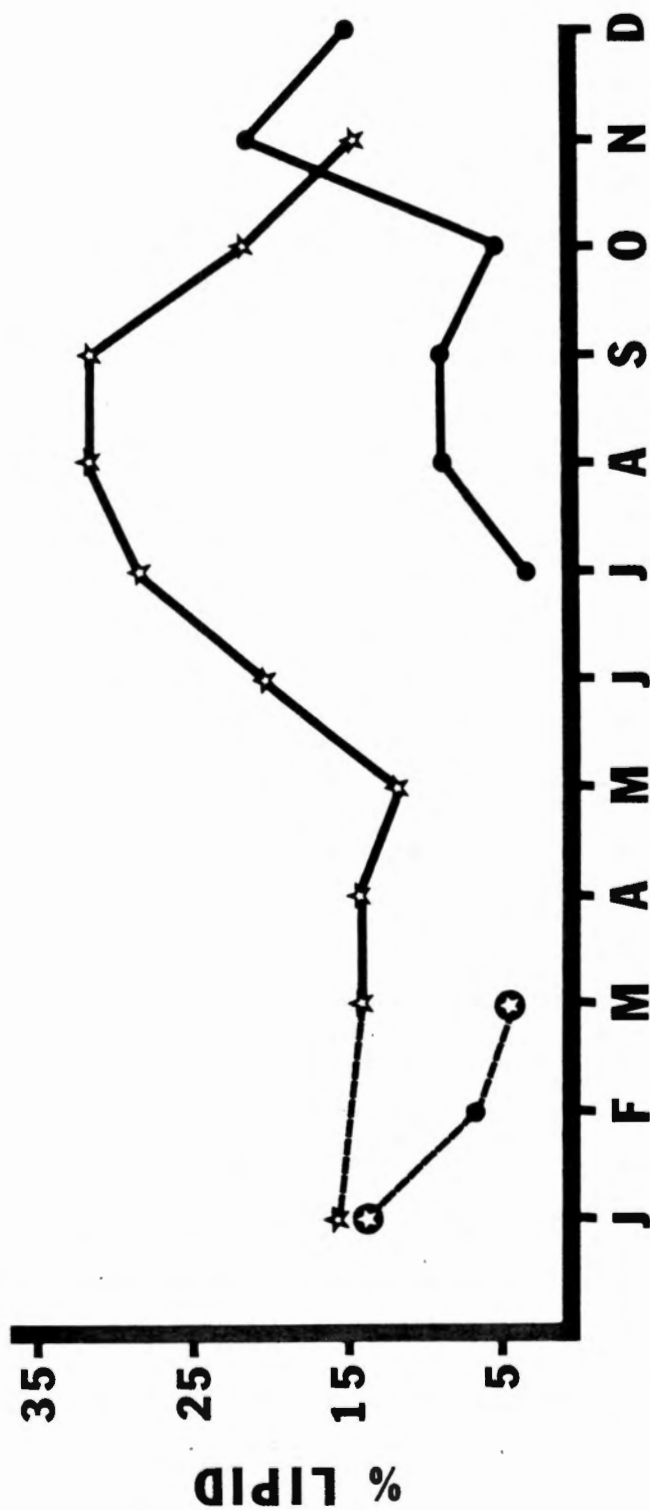


Figure 8. Seasonal variation in mean lipid percentage (dry basis) of young-of-year and adult gizzard shad collected from Cherokee Reservoir, Tennessee, January 1984 through December 1984. Dashed lines indicate probable changes during those months for which data are missing. ● = young-of-year, ★ = adult, ⬤ = calculated values.

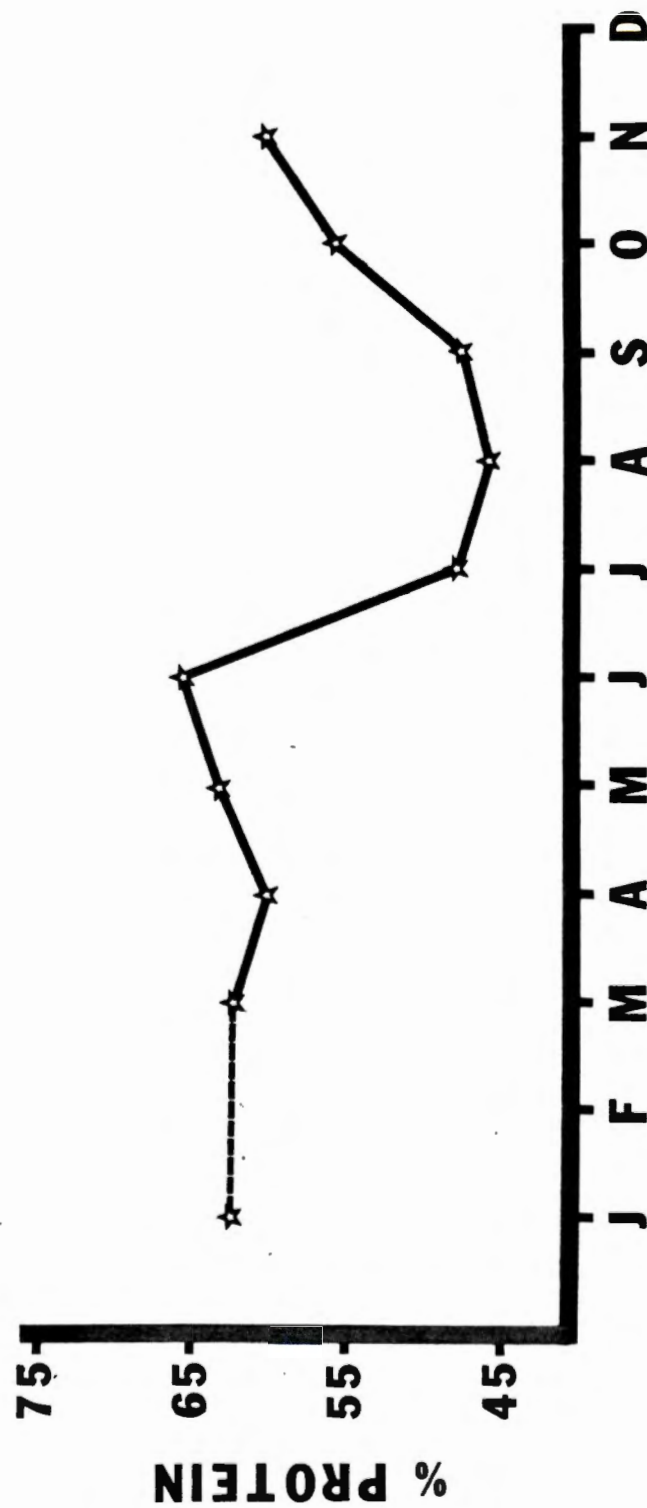


Figure 9. Seasonal variation in mean protein percentage (dry basis) of adult gizzard shad collected from Cherokee Reservoir, Tennessee, January 1984 through December 1984. The dashed line indicates probable change during the month for which data are missing.

Table 2. Mean proximate composition and gross energy (GE) content of young-of-year and adult gizzard shad collected from Cherokee Reservoir, Tennessee. Only nutrient values from months during the period January 1984 through December 1984 in which collections of both age classes were obtained were used to calculate means. Values in columns marked with an asterisk (*) are significantly different at a significance level of 0.05 as determined by Student's t-test. Standard errors are in parentheses.

Age Class	%Moisture n=7	%Ash n=7	%Protein* n=7	%Lipid* n=5	GE(kcal/g)* n=7
Y-O-Y	78.9 (1.65)	21.4 (2.14)	63.9 (2.60)	9.7 (3.12)	4.59 (0.19)
Adult	75.1 (1.19)	19.1 (0.43)	54.5 (2.84)	25.5 (3.30)	5.29 (0.10)

examination of these limited data indicated that young-of-year threadfin shad and alewives had higher protein percentages (mean = 14.0% higher) than adult fish. Young-of-year alewives from Dale Hollow Lake had lower gross energy contents (mean = 8.5% lower) than adult fish.

No significant differences in mean nutrient values were found between male and female adult gizzard shad (significance level = 0.05) (Table 3). Only nutrient values from those months in which collections of both sexes were analyzed were used to calculate means. Because proximate analysis had indicated only very minor body composition differences between the sexes on a monthly basis during the first half of the year (and through the spawning period), and since the gross energy determinations for male and female collections from July had revealed no marked differences, separation of the sexes was discontinued with the August collection. Because it was necessary to accumulate samples so that a large number of protein and fat determinations could be made at one time, it was not discovered until later that slight differences in protein and fat percentages in males and females from July did exist.

In contrast, it appears that body composition differences in male and female adult alewives existed year round. Gross energy values for males were consistently higher (3.9 - 4.6% higher) than those for females in March, June, and December.

Correlation coefficients between mean condition factor and lipid percentage were low and quite variable (young-of-year gizzard shad, $r = +0.42$, $n = 8$; adult gizzard shad, $r = +0.05$, $n = 10$; young-of-year threadfin shad, $r = +0.59$, $n = 8$). This was also the case with

Table 3. Mean proximate composition and gross energy (GE) content of male and female adult gizzard shad collected from Cherokee Reservoir, Tennessee. Only nutrient values from months during the period January 1984 through July 1984 in which collections of both sexes were analyzed were used to calculate means. No significant difference existed between values for each nutrient at a significance level of 0.05 as determined by Student's t-test. The number of observations for each sex for each comparison was six. Standard errors are in parentheses.

Sex	%Moisture	%Ash	%Protein	%Lipid	GE(kcal/g)
M	76.3 (1.38)	17.6 (0.79)	60.1 (3.03)	17.6 (2.86)	5.19 (0.09)
F	76.7 (0.99)	17.6 (0.62)	60.4 (2.23)	17.4 (2.16)	5.16 (0.08)

correlation coefficients between mean condition factor and gross energy level (young-of-year gizzard shad, $r = -0.07$, $n = 10$; adult gizzard shad, $r = +0.17$, $n = 10$; young-of-year threadfin shad, $r = +0.52$, $n = 10$).

Hybrid Shad

The total collection consisted of 3630 shad; the percentage composition was 6.2% gizzard shad, 3.2% hybrids, and 90.6% threadfin shad (Table 4). In general, hybrids had a rounded snout shape similar to that of gizzard shad, but with a more terminal mouth (Figure 10). However, they also had the elongated dorsal filament and yellow pigmentation in the fins in life that are characteristic of threadfin shad.

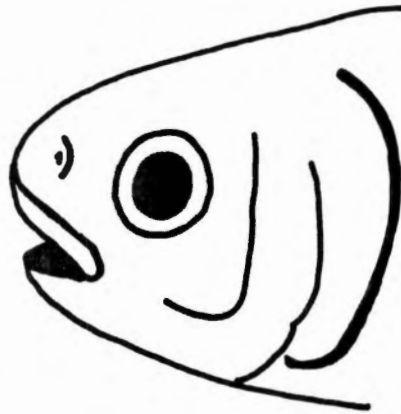
Hybrids were found to be intermediate between gizzard and threadfin shad in their predorsal length, upper jaw length, and mandible length (Table 5). Gizzard shad had the greatest predorsal length, while threadfin shad had the greatest upper jaw and mandible lengths.

Hybrids were found to have the greatest values of the three kinds of fish for caudal peduncle depth, dorsal filament length, and body depth (Table 5). There was no significant difference in caudal peduncle depth between gizzard and threadfin shad, and although hybrids had the greatest value for dorsal filament length, this value was not significantly different from that of threadfin shad. Threadfin shad had the least body depth in relation to standard length.

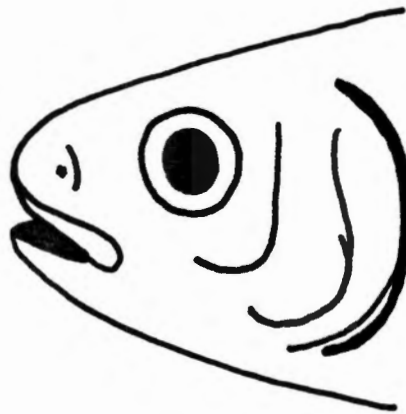
The mean anal fin ray count of hybrids was significantly different from those of the parent species (significance level = 0.05). Hybrids

Table 4. Numbers of shad less than 100 mm total length collected during hybrid shad study from Cherokee Reservoir, Tennessee, August 1983 through August 1984.

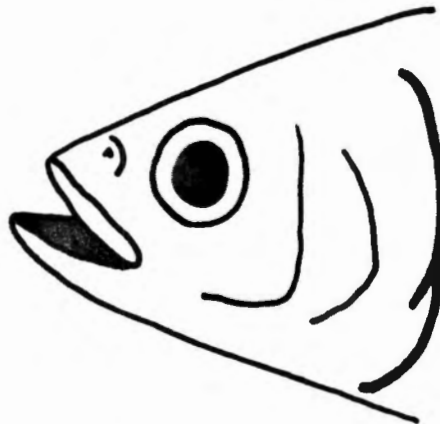
Month	Gizzard	Hybrid	Threadfin	Total
Aug 83	0	0	159	159
Sep 83	15	3	18	36
Oct 83	11	3	571	585
Nov 83	0	0	0	0
Dec 83	5	9	894	908
Jan 84	22	11	1296	1329
Feb 84	111	44	12	167
Mar 84	9	1	0	10
Apr 84	3	1	0	4
May 84	0	0	0	0
Jun 84	0	0	0	0
Jul 84	---	---	---	---
Aug 84	48	43	341	432
TOTAL	224	115	3291	3630
PERCENT OF TOTAL	6.2	3.2	90.6	100.0



A



B



C

1.0 mm $\approx$ 0.3mm

Figure 10. Representative snouts of gizzard shad (A), hybrid shad (B), and threadfin shad (C) from Cherokee Reservoir, Tennessee.

Table 5. Mean proportional body measurements and ranges of 30 representative specimens each of gizzard, hybrid, and threadfin shad collected from Cherokee Reservoir, Tennessee, August 1983 through August 1984. Measurements are expressed as whole numbers calculated as thousandths of standard length. Values with the same superscript are not significantly different at a significance level of 0.05 as determined by Duncan's multiple range test. Standard errors are in parentheses.

Character	Gizzard	Hybrid	Threadfin
Predorsal length	508 ^a (2.34) 484-547	496 ^b (1.47) 481-516	487 ^c (1.63) 471-513
Upper jaw length	92 ^c (0.90) 82-102	110 ^b (1.01) 98-122	118 ^a (0.69) 113-126
Mandible length	120 ^c (1.41) 106-138	140 ^b (0.81) 132-150	162 ^a (0.81) 154-169
Caudal peduncle depth	89 ^b (0.73) 80-95	93 ^a (0.67) 84-99	90 ^b (0.76) 80-103
Dorsal filament length	215 ^b (4.88) 175-277	330 ^a (3.40) 284-366	325 ^a (2.14) 305-348
Body depth	326 ^b (1.36) 311-342	330 ^a (1.49) 311-343	311 ^c (1.27) 298-325

had an intermediate value of 26.1 (SE = 0.25), with a range of 24 - 29. Values and ranges for gizzard and threadfin shad were 31.9 (SE = 0.26) and 22.7 (SE = 0.18), and 29 - 34 and 21 - 25, respectively. Mean total length and body weight of hybrids collected during January and February 1984 were found to be approximately equal to those of gizzard shad, but greater than those of threadfin shad (Table 6).

Table 6. Mean total lengths and weights and ranges of 30 randomly selected specimens each of gizzard, hybrid, and threadfin shad collected from Cherokee Reservoir, Tennessee, January and February 1984. Values with the same superscript are not significantly different at a significance level of 0.05 as determined by Duncan's multiple range test. Standard errors are in parentheses.

	Gizzard	Hybrid	Threadfin
Total length (mm)	71.9 ^a (1.77) 59-97	71.5 ^a (0.91) 61-81	55.0 ^b (0.91) 48-64
Weight (g)	2.82 ^a (0.21) 1.44-6.50	2.67 ^a (0.11) 1.38-4.02	1.14 ^b (0.05) 0.72-1.76

CHAPTER V

DISCUSSION

Other studies of the proximate composition and gross energy content of clupeid forage fishes have yielded variable results (Table 7). This would be expected since the season of the year in which fish were collected, the geographic location of collection, and the size of fish analyzed differed. Rottiers and Tucker (1982) analyzed alewives from Lake Michigan and determined correlation coefficients between selected nutrients. Their results were similar to those of the present study (Table 8).

The mean of the total calculated dry matter contents (% ash + % protein + % lipid) of all collections was 95.6%. An explanation for the fact that the mean was not closer to 100% is that carbohydrates were present but unaccounted for in collections. Carbohydrates constitute less than 1% of whole body composition (Stansby and Olcott 1976; Maynard et al. 1979); however, when expressed on a dry basis, this percentage could increase to 2 to 3%. Also, carbohydrates could have been present in plant and animal material in the digestive tract.

These unaccounted for carbohydrates could have been the cause of low calculated gross energy contents $[(\% \text{ protein} \times 5.7 \text{ kcal/g}) + (\% \text{ lipid} \times 9.5 \text{ kcal/g})]$ when compared with determined gross energy contents. Carbohydrate levels were not ascertained during proximate analysis; however, any carbohydrates that were present in collections would have contributed to gross energy determinations (4.2 kcal/g; Brody 1945). A high positive correlation ($r = +0.84$) existed between the

Table 7. Proximate composition and gross energy (GE) values for gizzard and threadfin shad, and alewives. Data for ash, protein, lipid, and GE are expressed on a dry basis.

Species	% Moisture	% Ash	% Protein	% Lipid	GE (kcal/g)
Gizzard shad					
Dugal (1962)	61.5-65.4	6.6- 7.0	41.8-44.2	49.3-51.2	
Davis and Boyd (1978)		16.1	54.3		
Pierce et al. (1980)		11.8-38.1		5.0-30.0	
Adams et al. (in press)	79.7	25.6		6.8	4.06
Present study	69.7-84.9	15.0-32.5	45.4-70.1	3.3-31.5	3.93-5.61
Threadfin shad					
Davis and Boyd (1978)		16.0	65.3		
Present study	75.1-83.3	15.9-21.2	55.9-72.7	3.8-19.0	4.35-5.32
Alewife					
Dugal (1962)	58.5-79.9	6.5-13.4	32.3-67.2	14.4-61.9	
Travis (1966)	66.5-74.6	8.5-14.5	41.5-57.5	29.4-49.3	
Ackman et al. (1967)	76.8	7.3	50.9	41.4	
Rottiers and Tucker (1982)	71.5-74.4	9.8-12.1		19.5-35.4	5.82-6.14
Present study	71.6-84.0	12.0-23.5	52.7-79.1	5.8-20.8	4.32-6.06

Table 8. Correlation coefficients between selected nutrients from Rottiers and Tucker (1982) and from the present study. Data from Rottiers and Tucker pertain to alewives only; data from the present study are from all clupeids analyzed.

Nutrients	Correlation coefficient	
	Rottiers and Tucker (1982)	Present Study
Gross energy/lipids	+0.83	+0.88
Gross energy/ash	-0.65	-0.79
Moisture/lipids	-0.76	-0.78
Gross energy/moisture	-0.63	-0.61

total calculated dry matter content of a collection (% ash + % protein + % lipid), and the calculated gross energy content as a percent of determined gross energy content for that collection. Thus, the greater the difference between total calculated dry matter content and 100%, the greater was the difference between calculated gross energy content and determined gross energy content. This suggests that carbohydrates were present at low levels and were contributing to gross energy content. Analytical error probably also contributed to the discrepancies in total dry matter content and gross energy content since at times total calculated dry matter content exceeded 100%, and calculated gross energy content exceeded determined gross energy content.

Changes in protein, ash, and moisture percentages within an age class of a species were primarily the result of changes in lipid content rather than the result of real changes in the body contents of these nutrients. For example, an increase in body lipid content would obviously result in an increase in lipid percentage. A lower remaining percentage (100% minus lipid percentage) would consequently be available for protein, ash, and moisture to occupy. Proportional decreases dependent on the relative percentage level of each of these nutrients would occur.

Other factors could have caused real changes in body content of protein, ash, and moisture. Protein percentages of young-of-year clupeids were as variable when expressed on a dry, fat-free basis, as when expressed on a dry basis, probably as a result of slight increases in protein content through growth. Protein percentages of adult fish were more stable when expressed on a dry, fat-free basis than when

expressed on a dry basis; the same situation is found in adult domestic mammals (Maynard et al. 1979). An increase in protein percentage of sexually mature gizzard shad during the spawning period was noted. This increase was probably due to a true increase in body content of protein as a result of gonadal development. Protein content of herring roe was 81.3% on a dry basis (Souci et al. 1981). Starvation during winter and early spring might be expected to result in a reduction in true protein content through metabolism (Moyle and Cech 1982), but this did not appear to have occurred during the present study.

Even though true body content of ash probably remained fairly stable, with perhaps a slight increase due to growth, changes in the ash level in the digestive tract could have resulted in changes in ash percentage. An extreme example of this was the September collection of young-of-year gizzard shad. The ash percentage of this collection (32.5%) was much higher than those of the preceding (68.2% higher) and following (72.8% higher) months. It was also higher than the ash percentages of young-of-year threadfin shad (80.7% higher), hybrid shad (48.2% higher), and alewife (147.6% higher) collections during September. A explanation for this might be that a change in food habits and/or feeding behavior of young-of-year gizzard shad occurred during that month that resulted in a higher consumption of soil particles along with food items. An examination of the contents of the digestive tracts of September young-of-year gizzard shad revealed that there was indeed a high concentration of sand present as compared with digestive tract contents of August and October fish.

During periods of starvation in fish, losses in body fat or protein are rarely reflected in significant body weight changes (Moyle and Cech 1982). Instead, metabolized fat and protein are replaced by water to make up the body weight difference, resulting in a true change in moisture content. It is possible that this occurred during the present study during fat stores depletion. However, any true change in moisture content that may have occurred would have been obscured by the inverse relationship between lipid percentage and the percentages of the other nutrients described previously.

Seasonal variation in a number of factors can potentially contribute to seasonal variation in lipid content within a species. One of these factors is feeding level. Feeding activity of many freshwater fish species ceases or is negligible during the winter months due to low water temperatures. Therefore, it becomes necessary for fish to mobilize energy reserves for use in body maintenance. As occurred in the clupeids examined during the present study, gizzard shad from Acton Lake, Ohio (Pierce et al. 1980), and alewives from Lake Michigan (Travis 1966), declined in lipid content during the winter months.

Cessation of feeding apparently occurred earlier in the year in young-of-year alewives from Dale Hollow Reservoir (September) than in the other young-of-year clupeids from Cherokee Reservoir (November or later). It is possible that the decline in fat stores of alewives did not actually begin until October or November, rather than in September. Since no collections were made during October and November it was not possible to determine if this was the case. However, it is unlikely that this occurred since the gross energy level of alewives was higher

than those of the other clupeids in September, but was approximately equal to those of the other clupeids in December. An extremely rapid rate of depletion would have been necessary if fat stores had continued to increase into October or November. A contributing factor to cessation of feeding in September by alewives might have been a difference in seasonal abundance of plankton between Dale Hollow and Cherokee Reservoirs. Pennak (1946) found great variation in seasonal plankton production among seven Colorado lakes. Another factor may have been a more rapid overall cooling of Dale Hollow during the fall turnover due to the presence of a cooler, more extensive hypolimnion as compared with Cherokee Reservoir (Ragsdale 1972; Schaich and Coutant 1980). Alewives are apparently quite sensitive to rapid changes in water temperature (Otto et al. 1976). Results from adult alewives contradict the results for young-of-year since adults did not show the same early cessation of feeding.

Adult gizzard shad from Cherokee Reservoir peaked in their fat content earlier in the year than young-of-year, indicating a cessation of feeding earlier in the year. A similar difference in onset of fat depletion between sexually immature and mature gizzard shad existed in Acton Lake, Ohio (Pierce et al. 1980).

The reproductive cycle can contribute to seasonal variation in lipid content of sexually mature fish. Dahlberg (1969) found an inverse relationship between fat stores and gonad maturity in Brevoortia spp. Although fat stores may show a decline, an increase or at least a stabilization of whole body caloric content prior to spawning would be expected since feeding has resumed and food energy is being directed

toward gonadal development. Caloric content of gravid ovaries of sexually mature gizzard shad from Lake Lewisville, Texas, was 6.20 kcal/g, while caloric content of spent ovaries was 4.78 kcal/g (Fagan and Fitzpatrick 1978). During the actual spawning period, a decline in whole body lipid content might occur since the level of activity is high while the level of food intake is generally low (Dahlberg 1969; Pierce et al. 1980).

During the present study, 1+ and 2+ year-old alewives together showed a continual increase in gross energy content from March through December. However, since alewives apparently do not reach maturity until age 2 (Rothschild 1966; Lackey 1970; Daniel 1984), this seasonal variation likely does not reflect that of sexually mature fish. Adult gizzard shad were fairly stable in gross energy content prior to and during spawning; an increase in gross energy content followed this period. Lake Michigan alewives showed a decline in lipid content through the winter and spring until June; lipid content was stable through the spawning period (Travis 1966). Acton Lake gizzard shad experienced a decline in lipid and caloric contents through the spawning period (Pierce et al. 1980).

Another factor which could contribute to seasonal variation in lipid content is seasonal variation in the amount of food available. In both fresh water and marine environments, plankton undergoes seasonal variation in abundance. In general, maximum abundance occurs in the spring and fall months, while minimum abundance occurs during the winter and summer (Davis 1955). Fat content varied directly with seasonal plankton abundance in menhaden (Brevoortia spp.) (Dahlberg 1969) and

mackerel (Rastrelliger kanagurta) (Venkataraman and Chari 1951). Seasonal variation in plankton abundance in Cherokee and Dale Hollow Reservoirs during the present study is not known. Humphreys' (1983) data indicated seasonal zooplankton abundance in Cherokee Reservoir was quite variable among collection sites and years; in general, maximum abundance was in the spring and minimum abundance was in the winter. Any variation in lipid content of Dorosoma spp. during the present study that might have been associated with a spring abundance of plankton was probably obscured by the influences of gonadal development and spawning activity on lipid content.

Seasonal variation in the energy content of the food supply also can lead to seasonal variation in lipid content of fish. A decline in caloric content during mid-summer of bottom sediments grazed by gizzard shad in Acton Lake, Ohio, contributed to a decline in lipid and caloric contents of young-of-year gizzard shad (Pierce et al. 1980). Venkataraman and Chari (1953) found that seasonal variation in the fat content of mackerel could be attributed to seasonal variation in the fat content of plankton. The fat content of zooplankters varies considerably on a seasonal basis, depending upon the amount and kind of food available to them, their physiological condition, and the period in their life cycle (Davis 1955). Fat content of clupeids examined during the present study could not be correlated with the energy content of the food supply since seasonal energy content data for food items were not collected.

Seasonal variation in energy content of the forage fishes examined has both advantage and disadvantage to game fishes. In order to survive

the winter, forage and game fishes alike must store energy in excess of that needed for normal maintenance and growth during the late summer and fall months. The high caloric content of the clupeids during this critical time provides game fishes with the high energy supply they need for fat deposition. However, during the late winter and spring months when game fishes need energy for gonad maturation and spawning activity, their food supply is relatively low in caloric content. Therefore, this time of the year may be a "negative" foraging period for game fishes; although food is being consumed, it may not be able to supply the energy needed, and fish may have to rely on fat reserves that were built up the previous fall.

In addition to the seasonal influences discussed above, lipid content within a species is also dependent on reservoir productivity, and on fish age and sex. Cherokee and Old Hickory are both eutrophic reservoirs; thus, one would expect that the level of plankton abundance in them would be similar. March collections of young-of-year gizzard shad and hybrid shad from these two reservoirs had approximately the same gross energy contents. Dale Hollow Lake, on the other hand, would be expected to support a lower standing crop of plankton due to its mesotrophic condition; young-of-year alewives collected from Dale Hollow Lake during March were lower in caloric content than those collected from the more nutrient-rich Old Hickory Reservoir during March.

Lipid content is also dependent on age; young-of-year gizzard shad had higher protein and lower lipid and gross energy levels than adult fish. Studies of body composition of domestic mammals have yielded similar results (Maynard et al. 1979). The percentage of fat normally

increases with age; this increase consequently reduces the percentages of the other body constituents.

No difference in body composition existed between male and female gizzard shad during the present study. Seven species from three families and six genera collected from Lake Michigan did not differ in proximate composition and caloric content between the sexes (Rottiers and Tucker 1982). However, differences apparently do exist within some species; as in the present study, Rottiers and Tucker (1982) found male alewives to be higher in mean caloric content than female alewives.

Extreme differences in body composition among the clupeids examined during the present study would not be expected since the fishes are so closely related taxonomically. One cause of any existing differences may have been differences in the energy content of the food consumed. Caloric contents on an ash-free dry basis of phytoplankton and zooplankton ranged from approximately 4.98 to 5.96 kcal/g and from 5.25 to 7.11 kcal/g, respectively (Davis 1955). Detritus grazed by gizzard shad in Acton Lake ranged from 0.85 to 5.52 kcal/g on an ash-free dry basis. Food habits studies have shown that, while the majority of the alewife's diet consists of zooplankton (Lackey 1970; Hutchinson 1971; Kohler and Ney 1980; Daniel 1984), threadfin and gizzard shad primarily consume both phytoplankton and zooplankton (Kutkuhn 1958; Miller 1967; Baker and Schmitz 1971; Hendricks and Noble 1980). Gizzard shad also rely on organic detritus as a food source (Baker and Schmitz 1971). Since differences in the energy content of the food items eaten by these clupeids exist, it follows that differences in body composition would result. During the early fall of the present study (September),

following a period of fat storage and prior to onsets of fat depletion, young-of-year clupeids did indeed show comparative lipid and gross energy contents that would be consistent with the energy levels of the diets described above. Alewives had the highest values, threadfin shad were intermediate, and gizzard shad had the lowest values.

Differences in species-specific fat storage capacity could also contribute to differences in lipid content among species. Alewives might be expected to exceed the other species in lipid content due to their anadromous nature. Dahlberg (1969) found Atlantic menhaden (Brevoortia tyrannus), a migratory species, to be higher in fat content than yellowfin menhaden (B. smithi), an inshore, non-migratory species. During the present study, adult alewives were, in fact, higher in caloric content than adult gizzard shad during three of four collection months, and they had the highest individual value of all adult fish (6.06 kcal/g). Young-of-year alewives were variable in their energy content in relation to other young-of-year clupeids. However, they did exhibit the highest individual value of all young-of-year (5.52 kcal/g).

Young-of-year hybrid shad were variable in caloric content in relation to the parent species; however, their overall mean caloric content was intermediate. Dahlberg (1969) found hybrid menhaden (B. smithi X B. tyrannus) to be intermediate in fat storage capacity between the parent species; he felt this intermediacy was evidence of genetic control of fat storage capacity in the parent species.

The clupeids examined during the present study appear to be intermediate in nutritional value in comparison with other forage fishes. Mean lipid percentage of Dorosoma spp. (24.2%) exceeded those

of Lepomis spp. (15.2%) and fathead minnows (Pimephales promelas) (19.1%), but was less than those of mosquitofish (Gambusia affinis) (25.8%) and golden shiners (Notemigonus crysoleucas) (34.8%) (Davis and Boyd 1978). Bluegill had lower caloric contents (1.06 kcal/g on a wet basis) than gizzard and threadfin shad (1.17 kcal/g on a wet basis) (Minton and McLean 1982); preliminary data collected for the present study also showed Lepomis spp. to be lower in caloric content than the clupeids. The primary reason for the lower energy content of Lepomis spp. is probably a higher true ash content, rather than a lower lipid content. Mean ash content of Lepomis spp. was 23.8%; the mean for Dorosoma spp. was 16.1% (Davis and Boyd 1978). Scales of Lepomis spp. are larger and thicker than those of Dorosoma spp., and their skeletal structure may be more substantial. Scales are about 30 to 35% ash on a dry basis (Lagler et al. 1977).

Although differences in nutritional value among forage species have been ascertained, these differences likely do not lead to differences in growth among game fishes which consume them. This is because the nutrient content of the diet is only one of many interacting factors (e.g., food availability, water temperature, dissolved oxygen level, reservoir productivity, and photoperiod) which act upon game fishes in reservoirs to determine their ultimate rate of growth.

Condition factors are considered to be indicators of the "degree of well-being, relative robustness, plumpness or fatness" of fish (Lagler 1956). Thus, one would expect that lipid and caloric contents would have a strong positive correlation with condition factor. This was not the case in the present study; r values were low and quite

variable. Therefore, condition factors cannot always be considered reliable indicators of the true "plumpness or fatness" of fish. Seasonal variation of condition factors did correspond to fat cycles in menhaden (Brevoortia spp.) (Dahlberg 1969), and in Pacific herring (Clupea harengus) (Hart et al. 1940).

The percentage composition of the collection made during the hybrid shad study was 6.2% gizzard shad, 3.2% hybrid shad, and 90.6% threadfin (Table 4). Data from the TVA's cove rotenone operations from 1955 through 1984 revealed that an extremely high percentage of threadfin shad in the shad population of Cherokee Reservoir is not uncommon (Table 9). Cove rotenone collections made during the summer preceding the collection period of the present study yielded a percentage for threadfin shad of the same order (97.5%) as that determined during the present study. Therefore, the percentage composition of the collection made during the present study, if not totally accurate, was likely representative of the true shad percentages present in Cherokee Reservoir during the collection period.

Population percentages of hybrid shad similar to that obtained during the present study (3.2%) were reported from Lake Texoma, Oklahoma (1.7 and 2.5%; Shelton and Grinstead 1973). Bennett (1962) indicated that production of hybrids rarely exceeds 1 or 2% in natural populations. It is unknown whether the hybrids in this study were F1 hybrids or if they were possibly members of subsequent generations, since the reproductive capacity of hybrids remains in question (Shelton and Grinstead 1973; McLean et al. 1980).

Table 9. Percentages of young-of-year shad collected by the Tennessee Valley Authority during cove rotenone operations on Cherokee Reservoir, Tennessee, 1955-1984 (Tennessee Valley Authority 1985).

Year	Gizzard	Threadfin	Year	Gizzard	Hybrid ^a	Threadfin
1955	7.97	92.03	1975	60.11	0.37	39.52
1956	46.50	53.50	1976	76.51	0.00	23.49
1957	0.16	99.84	1977	99.97	0.03	0.00
1958	98.08	1.92	1978	100.00	0.00	0.00
1959	1.63	98.37	1979	100.00	0.00	0.00
1960	0.18	99.82	1980	99.68	0.00	0.32
1963	18.22	81.78	1981	91.33	0.02	8.65
1972	15.07	84.93	1982	59.76	0.01	40.23
1973	9.18	90.82	1983	2.55	0.00	97.45
1974	50.46	49.54	1984	55.12	0.00	44.88

^aIt has only been recent years that the TVA has made an effort to identify hybrid shad during its cove rotenone operations.

During the present study, hybrid shad were intermediate between gizzard and threadfin shad in their predorsal, upper jaw, and mandible lengths (Table 5). They had the greatest caudal peduncle depth, dorsal filament length, and body depth (Table 5). Minckley and Krumholz (1960) measured physical characteristics of 6 hybrid specimens and 25 specimens each of gizzard and threadfin shad from the Ohio River Basin. Their results were of the same order as those of the present study; however, they did find hybrids to be intermediate in body depth between the parent species.

One of the definitive ways to separate gizzard and threadfin shad is to count their anal fin rays, since these counts for the two species are mutually exclusive, with gizzard shad usually having 29 - 34 rays and threadfin shad, 21 - 25 rays. Although the range for hybrids in this study extended into those of the parent species, anal fin ray count could sometimes serve as a valuable aid in identifying an individual hybrid if the fish's count fell between the ranges of gizzard and threadfin shad (26 - 28). Minkley and Krumholz (1960) reported mean anal fin ray counts similar to those of the present study. Their mean counts were 30.4 for gizzard shad, 27.2 for hybrids, and 23.2 for threadfin shad, while those from the present study were 31.9, 26.1, and 22.7, respectively.

The mean length and weight comparisons made during the present study indicated forage-sized hybrid shad were approximately equal in size to gizzard shad, but greater in size than threadfin shad. Mean weight of young-of-year hybrid shad (10.2 g) collected by the TVA during cove rotenone operations on Cherokee Reservoir greatly exceeded those of

gizzard shad (5.9 g) and threadfin shad (2.8 g) (Tennessee Valley Authority 1985). In reality, this extreme value for hybrids was probably a result of the difficulty encountered in identifying very small hybrids that might have been present during the summer collection months. Smaller hybrids were likely mistaken for one or the other of the parent species. Thus, a bias toward larger individuals may have existed. Fish collected during the months of January and February were used for the mean length and weight comparisons made during the present study. These young-of-year were older than those collected by the TVA, and, therefore, were more readily identifiable.

Maximum length of adult hybrids is unknown, but it appears that, like gizzard shad, they continue to surpass threadfin shad in size throughout life. Adult hybrid shad collected by the TVA during the above cove rotenone operations were intermediate in their mean weight (32.3 g) between gizzard shad (41.1 g) and threadfin shad (29.6 g) (Tennessee Valley Authority 1985). Most hybrid shad collected from Lake Texoma were larger than threadfin shad and were greater than 150 mm total length (Shelton and Grinstead 1973). Mean standard length of hybrids (146.3 mm) collected by Minckley and Krumholz (1960) greatly exceeded that of threadfin shad (102.7 mm).

Threadfin shad constituted over 50% of the shad collected during the TVA's cove rotenone operations in 9 of the 20 collection years from 1955 through 1984, and over 90% in 6 of those years (Table 9). Some of these years were ones in which the shad forage base as a whole was poor. If an extensive winterkill of this thermally-sensitive species occurred during years when it was the most populous forage, the amount of food

available to game fishes prior to and during the spawning season or to those species that feed year round would be severely reduced. Hybrid shad made up only 3.2% of the total collection during the present study; however, in the month following a severe winterkill of threadfin shad, hybrids were a notable percentage of the remaining shad forage (26.3%) as a result of their apparent greater tolerance of low water temperatures (Griffith 1978). Consequently, hybrid shad could prove to be an asset to the forage base, since the potential exists for them to become a key component of the meager food supply remaining following a harsh winter. The thermal tolerance of hybrids may offset to some degree a detrimental aspect of excessive growth.

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APPENDIX

APPENDIX A

Table 10. Date and location of field collections for nutrient content study from Cherokee Reservoir, Tennessee, January 1984 through December 1984, and surface water temperature at time of collection.

Date	Location	Water Temperature (C)
Jan 12	Twin Churches	4.5
Feb 14	Oak Grove, Twin Churches	6.0
Mar 14	County Line	11.0
Apr 12	Fall Creek	15.5
May 16	Quarryville	16.0
Jun 7	Quarryville	24.0
Jul 24	County Line	30.0
Aug 14	Quarryville	30.0
Sep 12	County Line	25.0
Oct 9	County Line	21.0
Nov 13	County Line	14.5
Dec 10	Oak Grove	8.5

APPENDIX B

Table 11. Date and location of field collections for nutrient content study from Dale Hollow Reservoir, Tennessee, March 1984 through December 1984, and surface water temperature at time of collection.

Date	Location	Water Temperature (C)
Mar 20	Pleasant Grove	10.0
Jun 22	Lillydale	28.0
Sep 18	Pleasant Grove	24.0
Dec 13	Pleasant Grove	11.5

APPENDIX C

Table 12. Mean dry matter (DM) percentages and gross energy (GE) contents of two collections of 3+ year-old gizzard shad obtained from Cherokee Reservoir, Tennessee, May 1984. Collections were dried at 60 C/24 hours and 105 C/overnight (Treatment A), and at 60 C/48 hours (Treatment B).

Sex	Treatment	DM (%)	GE (kcal/g)
M	A	23.2	5.13
	B	24.1	5.01
F	A	21.9	4.97
	B	22.9	4.89

APPENDIX D

Table 13. Mean proximate composition and gross energy (GE) content of young-of-year gizzard shad collected from Cherokee (CH) and Old Hickory (OH) Reservoirs, Tennessee, January 1984 through December 1984. Standard errors are in parentheses. Standard errors for nutrient means are estimates of the precision of the analyses, and were obtained by using data from triplicate samples.

Reservoir	Month	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
CH	Jan	M&F	13	75 (2.99) 60-95	3.32 (0.40) 1.64-6.45	79.8 (0.05)	15.9 (0.05)	66.9 (0.99)	-----	5.12 (0.009)
CH	Feb	M&F	34	82 (0.98) 66-89	4.10 (0.13) 2.34-5.28	82.4 (0.02)	18.3 (0.07)	69.8 (0.24)	6.5 (0.07)	4.82 (0.021)
CH	Mar	M&F	14	83 (1.89) 68-89	4.13 (0.25) 2.13-5.32	82.5 (0.01)	21.5 (0.08)	70.1 (0.43)	-----	4.43 (0.008)
CH	Jul	M&F	91	59 (0.47) 49-68	1.73 (0.04) 0.95-2.53	81.9 (0.10)	24.5 (0.10)	66.4 (0.45)	3.6 (0.03)	4.16 (0.011)
CH	Aug	M&F	91	56 (0.64) 43-73	1.57 (0.06) 0.73-3.41	80.2 (0.05)	19.3 (0.14)	65.6 (0.43)	8.8 (0.03)	4.56 (0.008)
CH	Sep	M&F	38	76 (0.71) 63-84	4.02 (0.11) 2.40-5.57	69.7 (0.10)	32.5 (0.07)	50.9 (0.10)	9.0 (0.26)	3.92 (0.009)
CH	Oct	M&F	25	90 (1.23) 74-104	6.05 (0.23) 3.70-9.23	80.7 (0.16)	18.8 (0.04)	69.0 (0.21)	5.6 (0.14)	4.57 (0.014)
CH	Nov	M&F	41	75 (0.79) 63-85	3.54 (0.09) 2.19-4.98	77.3 (0.01)	17.1 (0.02)	58.1 (0.50)	21.5 (0.03)	5.36 (0.004)
CH	Dec	M&F	69	63 (0.81) 49-78	2.15 (0.08) 0.98-4.08	81.5 (0.13)	8.2 (0.06)	61.6 (0.10)	15.1 (0.08)	4.96 (0.003)
OH	Mar	M&F	36	82 (1.10) 68-95	3.44 (0.15) 1.88-5.37	84.9 (0.26)	22.8 (0.10)	70.0 (0.34)	3.3 (0.12)	4.35 (0.007)

APPENDIX E

Table 14. Mean proximate composition and gross energy (GE) content of adult (2+ and 3+ year-old) gizzard shad collected from Cherokee Reservoir, Tennessee, January 1984 through November 1984. Standard errors are in parentheses. Standard errors for nutrient means are estimates of the precision of the analyses, and were obtained by using data from triplicate samples.

Reservoir	Month	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
CH	Jan	M	8	130 (2.21) 122-139	17.38 (1.07) 13.76-22.06	77.1 (0.15)	17.7 (0.09)	63.9 (0.73)	14.9 (0.20)	5.14 (0.004)
CH	Jan	F	8	127 (1.66) 118-133	16.01 (0.59) 12.31-17.30	76.7 (0.09)	18.2 (0.09)	61.1 (0.59)	16.5 (0.09)	5.14 (0.020)
CH	Mar	M	8	131 (0.79) 127-133	17.19 (0.44) 15.44-19.10	79.1 (0.06)	18.4 (0.11)	62.4 (0.22)	13.7 (0.03)	5.04 (0.006)
CH	Mar	F	8	130 (0.90) 126-135	16.78 (0.47) 14.78-18.99	78.7 (0.03)	19.0 (0.03)	62.4 (0.74)	14.3 (0.14)	5.00 (0.013)
CH	Apr	M	4	136 (0.75) 135-138	22.18 (0.40) 21.47-23.26	78.0 (0.20)	16.1 (0.18)	60.4 (0.35)	15.0 (0.81)	5.10 (0.005)
CH	Apr	F	5	140 (1.44) 136-144	24.29 (0.89) 21.88-26.84	78.5 (0.11)	16.9 (0.13)	59.8 (0.75)	13.6 (0.15)	5.04 (0.007)
CH	May	M	7	153 (1.62) 147-157	33.22 (1.16) 29.00-37.05	78.0 (0.25)	18.0 (0.12)	62.6 (0.88)	11.0 (0.20)	4.90 (0.017)
CH	May	F	6	145 (2.64) 138-153	28.72 (1.15) 25.59-32.22	78.1 (0.09)	17.6 (0.10)	63.9 (0.22)	12.6 (0.06)	4.97 (0.006)
CH	Jun	M	6	139 (1.12) 134-142	25.85 (0.66) 23.61-27.58	75.5 (0.44)	15.1 (0.06)	66.0 (0.22)	20.7 (0.06)	5.40 (0.011)
CH	Jun	F	6	141 (2.22) 134-147	27.25 (1.39) 22.70-31.35	75.8 (0.07)	15.0 (0.12)	65.4 (0.74)	20.6 (0.08)	5.34 (0.005)

Table 14 (Continued)

Reservoir	Month	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
CH	Jul	M	6	154 (2.58) 145-163	32.01 (1.96) 26.75-39.45	69.8 (0.07)	20.6 (0.07)	45.4 (0.06)	30.4 (0.08)	5.52 (0.006)
CH	Jul	F	5	151 (3.54) 143-162	30.46 (1.78) 27.62-37.33	72.3 (0.14)	19.0 (0.12)	50.0 (0.12)	26.5 (0.19)	5.48 (0.006)
CH	Aug	M&F	6	141 (1.62) 134-145	24.03 (0.87) 20.01-25.55	71.0 (0.47)	18.7 (0.28)	45.6 (0.17)	31.5 (0.13)	5.58 (0.007)
CH	Sep	M&F	6	154 (1.09) 152-158	29.82 (0.84) 27.64-32.87	74.3 (0.21)	19.2 (0.05)	47.3 (0.44)	31.5 (0.03)	5.61 (0.009)
CH	Oct	M&F	6	153 (4.29) 143-166	29.99 (2.85) 24.91-39.03	75.5 (0.11)	18.3 (0.09)	55.7 (0.11)	21.8 (0.13)	5.28 (0.013)
CH	Nov	M&F	6	155 (4.65) 145-176	29.72 (2.82) 25.06-43.28	77.9 (0.42)	21.3 (0.12)	60.2 (0.21)	14.4 (0.08)	4.92 (0.011)

APPENDIX F

Table 15. Mean proximate composition and gross energy (GE) content of threadfin shad collected from Cherokee (CH) and Old Hickory (OH) Reservoirs, Tennessee, January 1984 through December 1984. Standard errors are in parentheses. Standard errors for nutrient means are estimates of the precision of the analyses, and were obtained by using data from triplicate samples.

Reservoir	Month	Age	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
CH	Jan	Y-O-Y	M&F	86	58 (0.44) 50-67	1.42 (0.03) 0.83-2.11	83.3 (0.05)	18.1 (0.15)	70.7 (0.34)	8.0 (0.07)	4.92 (0.026)
CH	Jul	Y-O-Y	M&F	135	48 (0.67) 31-68	1.00 (0.05) 0.21-2.70	80.8 (0.03)	18.1 (0.08)	72.7 (0.99)	4.9 (0.02)	4.52 (0.020)
CH	Aug	Y-O-Y	M&F	66	64 (0.85) 48-75	2.28 (0.09) 0.86-3.80	76.3 (0.07)	16.3 (0.09)	65.7 (0.24)	13.1 (0.16)	4.98 (0.002)
CH	Sep	Y-O-Y	M&F	60	64 (1.01) 48-80	2.44 (0.12) 0.97-4.53	75.1 (0.06)	18.0 (0.13)	55.9 (0.31)	14.1 (0.17)	4.89 (0.003)
CH	Oct	Y-O-Y	M&F	60	66 (0.46) 57-71	2.40 (0.05) 1.52-3.35	77.6 (0.09)	15.9 (0.03)	62.3 (0.42)	17.8 (0.21)	5.12 (0.003)
CH	Nov	Y-O-Y	M&F	34	77 (0.88) 67-92	3.62 (0.13) 2.41-6.16	76.4 (0.02)	16.4 (0.06)	59.5 (0.27)	19.0 (0.003)	5.32 (0.001)
CH	Dec	Y-O-Y	M&F	18	66 (1.41) 56-76	2.25 (0.15) 1.33-3.47	79.2 (0.06)	16.4 (0.02)	65.7 (0.33)	-----	5.04 (0.0001)
OH	Mar	Y-O-Y	M&F	35	85 (2.06) 61-100	3.90 (0.28) 1.20-7.17	83.0 (0.41)	21.2 (0.06)	71.8 (0.17)	3.8 (0.03)	4.35 (0.013)
CH	Jan	1+	M&F	24	89 (0.83) 79-98	5.28 (0.15) 3.22-6.44	81.5 (0.05)	19.9 (0.09)	68.8 (0.81)	8.3 (0.09)	4.80 (0.006)
CH	Feb	1+	M&F	7	91 (1.59) 87-100	5.05 (0.32) 4.28-6.86	80.5 (0.07)	-----	69.6 (0.35)	-----	4.64 (0.007)

APPENDIX G

Table 16. Mean proximate composition and gross energy (GE) content of young-of-year hybrid shad collected from Cherokee (CH) and Old Hickory (OH) Reservoirs, Tennessee, January 1984 through November 1984. Standard errors are in parentheses. Standard errors for nutrient means are estimates of the precision of the analyses, and were obtained by using data from triplicate samples.

Reservoir	Month	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
CH	Jan	M&F	8	73 (2.02) 67-82	2.83 (0.26) 2.20-4.13	78.0 (0.16)	-----	63.3 (0.20)	-----	5.42 (0.007)
CH	Feb	M&F	40	73 (0.84) 64-90	2.84 (0.11) 1.86-5.29	81.1 (0.03)	16.2 (0.09)	65.7 (0.15)	15.4 (0.22)	5.15 (0.011)
CH	Mar	M&F	3	75 (5.93) 66-86	2.99 (0.66) 2.03-4.25	-----	-----	-----	-----	4.45 (0.009)
CH	Sep	M&F	10	77 (3.16) 64-94	4.05 (0.54) 2.26-7.20	78.0 (0.02)	21.9 (0.09)	63.8 (0.45)	-----	4.49 (0.004)
CH	Oct	M&F	20	93 (1.31) 78-101	6.87 (0.25) 4.74-8.62	78.6 (0.03)	20.0 (0.01)	64.1 (0.64)	10.5 (0.04)	4.80 (0.003)
CH	Nov	M&F	11	94 (1.36) 85-100	6.71 (0.28) 5.06-8.26	79.2 (0.30)	18.3 (0.02)	66.9 (1.12)	11.7 (0.22)	4.91 (0.014)
OH	Mar	M&F	3	95 (1.76) 92-98	5.88 (0.14) 5.65-6.14	-----	-----	67.2 (0.46)	-----	4.39 (0.008)

APPENDIX H

Table 17. Mean proximate composition and gross energy (GE) content of alewives collected from Dale Hollow (DH) and Old Hickory (OH) Reservoirs, Tennessee, March 1984 through December 1984. Standard errors are in parentheses. Standard errors for nutrient means are estimates of the precision of the analyses, and were obtained by using data from triplicate samples.

Reservoir	Month	Age	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
DH	Mar	Y-O-Y	M&F	17	70 (1.60) 58-81	1.71 (0.13) 0.88-2.93	83.6 (0.17)	-----	79.1 (0.35)	-----	4.32 (0.003)
DH	Sep	Y-O-Y	M&F	78	54 (0.42) 37-63	1.11 (0.02) 0.35-1.65	75.5 (0.01)	13.1 (0.01)	64.0 (0.19)	20.7 (0.07)	5.52 (0.004)
DH	Dec	Y-O-Y	M&F	89	61 (0.37) 55-72	1.40 (0.03) 0.94-2.27	80.1 (0.07)	16.8 (0.08)	72.0 (0.08)	9.7 (0.11)	5.02 (0.004)
OH	Mar	Y-O-Y	M&F	19	76 (1.28) 63-87	2.13 (0.10) 1.27-2.96	83.7 (0.12)	20.2 (0.04)	74.6 (0.17)	-----	4.58 (0.011)
DH	Mar	1+	M&F	15	113 (1.27) 105-124	7.63 (0.31) 5.73-10.35	81.6 (0.03)	23.5 (0.04)	70.0 (1.01)	5.7 (0.07)	4.56 (0.009)
DH	Jun	2+	M	3	110 (5.51) 100-119	10.88 (0.93) 9.20-12.42	71.6 (0.03)	12.0 (0.04)	57.2 (0.54)	-----	5.76 (0.007)
DH	Jun	2+	F	13	114 (2.34) 100-128	12.13 (0.43) 9.46-14.46	75.4 (0.03)	13.2 (0.05)	64.3 (0.20)	19.4 (0.09)	5.54 (0.004)
DH	Sep	1+	F	3	108 (5.20) 99-117	8.85 (0.81) 7.27-9.95	-----	13.9 (0.16)	52.7 (0.16)	-----	5.79 (0.009)
DH	Dec	1+	M	5	94 (0.92) 92-96	5.09 (0.17) 4.68-5.55	73.9 (0.09)	13.1 (0.08)	53.6 (0.13)	-----	6.06 (0.009)
DH	Dec	1+	F	8	95 (1.07) 90-100	5.24 (0.15) 4.65-5.97	75.9 (0.02)	14.2 (0.07)	57.3 (0.24)	-----	5.80 (0.012)

Table 17 (Continued)

Reservoir	Month	Age	Sex	n	Mean Length Range (mm)	Mean Weight Range (g)	%Moisture	%Ash	%Protein	%Lipid	GE (kcal/g)
OH	Mar	1+	M	2	112 (3.00) 109-115	6.82 (0.04) 6.78-6.85	-----	-----	-----	-----	4.61 (0.017)
OH	Mar	1+	F	5	111 (1.39) 106-114	6.62 (0.35) 5.53-7.57	84.0 (0.17)	-----	72.6 (0.14)	-----	4.42 (0.004)

VITA

Janice R. Carmichael was born in Baton Rouge, Louisiana, on 24 May 1956. Her elementary and secondary school years were spent in Baton Rouge; Zurich, Switzerland; Polk City, Florida; New Canaan, Connecticut; St. Croix, U. S. Virgin Islands; Sevierville, Tennessee; and St. John's, Newfoundland, Canada. She attended Memorial University of Newfoundland and Tennessee Technological University prior to receiving her Bachelor of Science degree in Wildlife and Fisheries Science from the University of Tennessee, Knoxville, in June 1978.

Following graduation, Ms. Carmichael was employed by the U. S. Fish and Wildlife Service Young Adult Conservation Corps and the National Park Service at Great Smoky Mountains National Park. She returned to the University of Tennessee in September 1982 to pursue a graduate degree in Wildlife and Fisheries Science; a Master of Science degree was awarded to her in June 1985.