INTRODUCTION OF STRIPED BASS X WHITE BASS HYBRIDS IN TWO OKLAHOMA RESERVOIRS: EFFECTS ON EXISTING FISH POPULATIONS

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PREFACE

Striped bass x white bass hybrids were stocked in two Oklahoma reservoirs to evaluate their impact on population structures and growth rates of existing fish populations. Population parameters analyzed were: relative abundances, mean and median weights and total lengths, and length-weight relationships for each species. Growth rates of centrarchids, clupeids and basses were estimated. Diets of largemouth bass, white bass and striped bass x white bass hybrids were analyzed to determine the relative importances of various forages, diet selectivity and diet overlap between populations of predators.

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CHAPTER I

INTRODUCTION

Fish populations in reservoirs commonly change after impoundment. After an initial period of high growth rates and strong year classes of most species, the fish community tends to become dominated by fishes occupying lower trophic levels (Carlander, 1955; Jenkins, 1958, 1961). Subsequent harvest of sport fish is usually reduced (Jenkins, 1961). Populations of primary consumers and detritivores in southeastern U.S. reservoirs are commonly dominated by clupeids such as gizzard shad, *Dorosoma cepedianum*, and threadfin shad, *Dorosoma petenense*, (Jenkins, 1957). These fish are highly fecund (Carlander, 1955; Kilambi and Baglin, 1969; Pierce, 1977) and "usurp nutrients and living space from the more desirable fishes" (Jenkins, 1957, p.58). It has also been suggested that juvenile threadfin shad may compete directly for food with fingerling largemouth bass, *Micropterus salmoides*, (von Geldern and Mitchell, 1975).

Exploitation of predators usually increases with time (Jenkins, 1976) and may result in reduced size ranges and growth rates (Favro, Kisa and McDonald, 1979) or severe reductions in population size (King, Davies and Shelton, 1969) and possible extermination of stocks or species (Larkin, 1977). Increased densities of clupeid forage and reductions of sport fishes are two of the major problems facing fishery managers.

Options available for manipulating fish populations in reservoirs include habitat improvement, forage control or reduction, and stocking of predators. Habitat manipulations are usually only marginally successful in increasing fish production in reservoirs with fluctuating water levels, although addition of substrate, such as sunken trees or artificial reefs, may concentrate fish near the structure (Prince and Maughan, 1979). Wege and Anderson (1979) found that size, density, and biomass of young-of-the-year largemouth bass and bluegills, *Lepomis macrochirus*, were not affected by presence of artificial structures in ponds, although overall carrying capacity may have been positively affected.

Results of control or reduction of forage fish populations are also mixed. Jenkins (1975) doubted that shad reductions would increase bass production, but sport fisheries for largemouth bass have improved after removal of gizzard shad (Lambou and Stern, 1959; Zeller and Wyatt, 1967). Native game fish were stocked to control shad populations in many reservoirs in the 1950's, but these programs were largely unsuccesful (Jenkins,1961). A landlocked population of striped bass, *Morone saxatilis*, was discovered in Santee Cooper Reservoir and introductions were initiated, with the hope that a large, pelagic predator would be more effective in controlling shad populations than native predators that are more restricted to littoral areas.

Introductions of adult striped bass were not always successful (Coutant and Carroll, 1980) and reproduction was often limited (Bailey, 1975; Stevens, 1975). Hatchery programs were thus initiated and during attempts to rear striped bass fry and fingerlings, a female striped bass was hybridized with male white bass, *Morone chrysops*, (Stevens, 1965). The hybrids survived and grew better than striped bass in both hatchery

(Logan, 1968) and field situations (Bishop, 1967; Ware, 1970; Bayless, 1968, 1972). Striped bass x white bass hybrids, Morone saxatilis x Morone chrysops, also produced greater returns to sport fisheries than striped bass (Ware, 1975; Stevens, 1975; Hanson and Dillard, 1976; Coutant and Carroll, 1980). Natural reproduction of hybrids has not been confirmed although they have been observed spawning (Bishop, 1967; Williams, 1971a).

Reports concerning control of forage populations through hybrid introductions are conflicting. Although the hybrid shows strong preference for clupeid forage (Williams, 1971b; Ware, 1975, 1977; Crandall, 1978), Bishop (1967) expressed uncertainty about the hybrids' ability to control shad. Bailey (1975) concluded that hybrids would not affect the stability of forage populations, while Ware (1977) found an 80% reduction in shad biomass subsequent to hybrid introduction in Florida, and Crandall (1978) believed hybrid growth was limited by reduction of shad in a heated Texas reservoir. Even though Ware (1975) stocked hybrids in bass-bluegill ponds and harvested 8-pound fish in 4 years, reduction of centrarchids in Crandall's (1978) study was negligible.

Introductions of striped bass have been generally assumed to have no effect on other predatory fishes (Bailey, 1975; Hanson and Dillard, 1976), although very little is known except that native predatory fishes are not commonly eaten by striped bass. However, hybrids are apparently more voracious predators than striped bass and Magnuson (1976) and others argue that introductions of exotics, when successful, often have greater impacts on resource utilization and species interactions (Kerr and Werner, 1980) than expected. This view is supported by fisheries research in reservoirs (Rainwater and Houser, 1975) and observations of an introduction of a riverine predator into a lacustrine environment (Zaret and Paine, 1973).

Total predator biomass can be limited by production of prey available to predators of all sizes (Rainwater and Houser, 1975), and predators in reservoirs in the southern United States may be commonly limited by forage (Jenkins and Morais, 1978). Gizzard shad is the most abundant forage species in many reservoirs and is an important food for largemouth (Anderson, 1976) and white bass (Miller and Robison, 1973), as well as striped bass and hybrids (almost the exclusive food in some reservoirs; Mensinger, 1970; Williams, 1971; Bailey, 1975; Ware, 1975). Availability of forage of appropriate size may be limiting for both largemouth bass (and other native predators) and striped bass x white bass hybrids (Bailey, 1975; Coutant and Carroll, 1980). Lawrence (1958) found that largemouth bass could consume forage fishes whose maximum body depth was equal to or slightly greater than the horizontal esophageal capacity of the bass, but that smaller prey were preferred. Similar results were found during a study of food habits of striped bass in Chesapeake Bay. The fish were capable of eating clupeids up to approximately 60% of their total length, but relied on shad 40% or less of total length (Bishop, 1967; Mensinger, 1970; Williams, 1971b; Ware, 1975).

In order to determine the effects of hybrid striped bass x white bass stocking programs on native fish communities, I studied the fish populations of Lakes Carl Blackwell and Hams, in Payne County, Oklahoma, for one year prior, and two years subsequent to introduction of striped bass x white bass hybrids. Populations of gizzard shad and centrarchid sunfishes were examined in both reservoirs, as were white bass in Lake Carl Blackwell.

The justification for this project was provided by the Oklahoma Department of Wildlife Conservation (ODWC) and various researchers. The ODWC is currently engaged in hybrid stocking programs which have the following objectives:

1. To provide sport fisheries where none currently exist.
2. To provide additional sport fish species.
3. To utilize excess shad populations.

CHAPTER II

DESCRIPTION OF STUDY AREAS

Hams Lake is a Soil Conservation Service flood detention reservoir located in the Permian Redbeds (Cobb and Hawker, 1918) approximately 8 km west of Stillwater. At spillway elevation of 287.0 m M.S.L. the lake has a surface area of about 40 ha and a capacity of 115 ha-m. Maximum depth is 9.5 m, and average depth is 3.0 m. The lake is usually thermally stratified during the summer with an anoxic hypolimnion at 3-4 m (Steichen, 1974). The lake is bordered on the east, south, and west sides by mixed hardwood forest. The north side of the lake is a rip-rap earthen dam.

Lake Carl Blackwell is also located in the Permian Redbeds (Cobb and Hawker, 1918), 11 km west of Stillwater. The reservoir was constructed as a recreational facility by the Works Progress Administation in 1938. The lake now serves as a municipal water supply for Stillwater. At spillway elevation of 283.2 m M.S.L., the maximum area is approximately 1400 ha, with a capacity of 6720 ha-m. Maximum depth is 11 m, and mean depth is 4.8 m (Orth, 1977). The watershed-to-surface-area ratio at spillway elevation is insufficient to maintain water level except during years of above average rainfall.

Watershed-to-surface-area ratio is probably able to maintain water levels near 280 m M.S.L. during years of average rainfall. At this elevation, surface area is approximately 850 ha, with an approximate volume of 1700 ha-m , and mean depth of 2.0 m (Norton, 1968). Turbidity ranges from about 20 J.T.U. in the deeper eastern portion to 180 J.T.U. in the shallow western end (Zweiacker and Summerfelt, 1973). The hypolimnion quickly becomes anoxic during stratification, but the thermocline is usually weak and is quickly destroyed by wind action (Zweiacker, Summerfelt and Johnson, 1972). The south shore of the lake is mostly mud flats and rock outcroppings; the north and west shores are principally mud flats, and the dam forms the east shore (Zweiacker and Brown, 1971).

CHAPTER III

METHODS AND MATERIALS

Fish populations in the reservoirs were studied from 1980 through 1982. Striped bass x white bass hybrid swim-up fry were stocked in both lakes on 22 May 1981 and 1982. Three hundred thousand fry were stocked in Lake Carl Blackwell on each date. Twenty thousand and 40,000 were stocked in Hams Lake in 1981 and 1982, respectively. The higher rate in 1982 was to compensate for possible mortality due to predation by centrarchids. Estimated mortality of the fry at stocking was from 1 to 5%. Approximately 5,000 striped bass x white bass hybrid young-of-the-year (YOY), 100 mm total length (TL), were stocked in Hams Lake in November, 1980. Estimated stocking mortality of the YOY hybrid bass was 40 to 50%.

To reduce the effect of size selectivity associated with a single collection method (Carlander, 1950), fish were collected by seining in summer, electrofishing from spring through fall, and by concurrent use of barrel, frame, and gill nets throughout each year (Powell, Bowden and Hagen, 1971). With the exception of seining sites, collection sites were randomly chosen on each date. Sample sites were randomized by dividing the lakes into quadrants 610 m and 152 m on a side in Carl Blackwell and Hams, respectively. Pairs of numbers were chosen from a random number table to identify "A" and "B" coordinates on the sampling maps. Coordinates were reported in the order chosen (i.e., 3/1 corresponds to A3/B1). Seining sites were selected on the basis of accessibility and included two replicates of each of the following habitat types:

sand substrate with no permanent cover [3/1 and 6/3 in Blackwell (Figure 1); none in Hams];

mud/sand substrate with macrophytes or flooded terrestrial vegetation [4/2 and 4/13 in Blackwell; 2/2 and 4/3 in Hams (Figure 2)];

mud/sandstone with submerged woody vegetation [5/6 and 5/8 in Blackwell; 3/1 and 2/9 in Hams].

A single haul of approximately 30.5 m was made at each site on each sample date. The seine was constructed of 3.17 mm mesh nylon, 9.1 m long x 1.8 m deep. All fish collected were placed in 10% formalin and were later identified, weighed and measured.

Electrofishing was conducted for 30-minute units of effort. Six hundred volt pulsed direct current was supplied by a 3750-watt, 240-volt alternator and a Coffelt VVP-15 variable voltage pulsating unit. The electrofishing apparatus was permanently mounted in a 4.9 m flat bottom aluminum boat, powered by a 40 horsepower outboard motor. Anodes were suspended from booms extending 3 m in front of the bow of the boat and the cathodes were suspended from the gunwales of the boat, 1.5 m behind the bow. Affected fish were attracted to the anodes for collection. Stunned fish were placed in an aerated circulating live well until they were processed and released.

Barrel, frame, and gill nets were placed in sample quadrants concurrently and fished for 12-hour units of effort. Barrel nets were constructed of 19 mm bar mesh nylon and were 1.5 m long and 0.9 m in diameter. Frame nets were constructed of 13 mm bar mesh nylon, with a 0.9 m x 14 m lead, a 0.9 m x 1.8 m x 1.5 m box and a 2.4 m x 0.75 m diameter cylindrical bag with a drawstring closure for fish removal (a cod end). Experimental gill nets were made from six panels of multifilament nylon, each 1.8 m deep x 7.6 m long, with mesh sizes ranging from 19-100 mm.

Data collected from each fish included total length (mm), weight (g) and greatest body depth (mm). Horizontal buccal gape (mm) was determined for largemouth bass, white bass, and striped bass x white bass hybrids. Stomach contents were removed from predator species by use of glass tubes inserted through the mouth into the stomach (Van Den Avyle and Roussel, 1980; Gilliland, Kleinholz and Clady, 1982). Scales were removed from centrarchids, gizzard shad and basses for determination of age composition and growth rates. Acetate slides containing scale impressions were viewed on an Eberbach projector. The distance (mm) from the scale origin to each annulus was measured perpendicular to the anterior edge of the scale. Only the terminal annulus for each scale was used to calculate total length at age (Ricker, 1969). The data were tabulated in this manner to reduce the effect of Lee's phenomenon (Carlander, 1969). Lee's phenomenon is the apparent reduction in growth rates with increasing age of a fish when all annuli on a scale are examined. Length of fish at age was calculated with the Dahl-Lea equation (Carlander, 1955):

$$L_n = \frac{S_n L_c}{S_c}, \text{ where}$$

L_n = total length at annulus n

S_n = scale radius at annulus n

S_c = total scale radius

L_c = total length at capture.

K, the index of condition (Carlander, 1955) was calculated for each species:

$$K = \frac{W \times 10^5}{L^3}, \text{ where}$$

W = weight (g)

L = total length (mm).

Logarithms of the dependent variables (weight, body depth, and horizontal buccal gape) were regressed on the independent variable log total length for various species of fish. Length-weight relationships were compared to those of other populations as indications of fish productivity in the study lakes. Regressions of body depth on total length of forage species were compared to regressions of buccal gape on total lengths of largemouth bass, white bass and striped bass x white bass hybrids to estimate size and relative abundance of suitable sizes of forage available to predators of various total lengths.

Diet items of the three predators studied were identified and ranked using a modification of the Index of Relative Importance (Pinkas, Oliphant and Iverson, 1971):

$$IRI = (N+W)F, \text{ where}$$

N = numeric percent of a diet item

W = weight percent

F = frequency of occurrence

Diet overlap of predators was determined by the Schoener (1970) index to indicate if food items were partitioned and if potential forage competition existed:

$$\alpha = 1 - 0.5 \left(|P_{xi} - P_{yi}| \right), \text{ where}$$

P_{xi} = importance of item i in the diet of predator x

P_{yi} = importance of item i in the diet of predatory y.

Our data were compared to data on peacock bass, Chichla ocellaris , (Zaret and Rand, 1971) in which it was concluded that values of the Schoener index less than 0.6 were not biologically important. Forage selectivity by the predators was determined by calculation of the linear Strauss (1979) index:

$L = r_i - p_i$, where

r_i = importance of forage i in the gut of a predator

p_i = importance of forage i in the reservoir.

The values of r_i and p_i were quantiles of relative importance data. Values of the Strauss index range from -1 to 1; negative values indicate prey were inaccessible or were avoided by the predators and positive values indicate predator selection for a forage item.

Annual selectivity values were obtained by comparison of dietary importance of forage items to environmental importance obtained from data on relative abundance and frequency of capture. Daily selectivity data were obtained by comparison of dietary importance of forage items to the environmental importance of suitable prey which were captured with each predator. Available prey/predator (AP/P) ratios were calculated as the weights of suitable-sized prey captured with each predator.

Additional analyses were performed to determine whether other parameters of the fish populations in each lake changed during the study. The nonparametric Mann-Whitney test (Conover, 1980) was performed to determine if changes in relative abundance of fish populations occurred. Chi-square contingency tables (Conover, 1980) were used to determine if Lee's phenomenon (Carlander, 1969) occurred in centrarchids, clupeids or basses in either reservoir and to compare differences in growth rates of the species.

CHAPTER IV

RESULTS

Hams Lake

Relative Abundance

The relative abundances of fish species in Hams Lake did not change statistically between any two of the years studied (1980/1981: Mann-Whitney, $n_1 = 11$, $n_2 = 13$, $T = 0.30$, $P = 0.62$; 1981/1982: Mann-Whitney, $n_1 = 13$, $n_2 = 14$, $T = -0.78$, $P = 0.22$; 1980/1982: Mann-Whitney, $n_1 = 11$, $n_2 = 14$, $T = -0.05$, $P = 0.48$). Bluegill sunfish was the dominant species during all three years (Table I). Bluegills produced a very strong year class in 1981 (Figure 3). Redear sunfish, *Lepomis microlophus*, was second in importance in 1980 and 1981, and third in 1982. Gizzard shad was third in 1980 and 1981, and second in 1982.

Changes in population structure of both gizzard shad and redear sunfish occurred during the study. Gizzard shad produced a very weak year class during 1981 and a strong year class in 1982. The mean total length and weight of gizzard shad were similar between 1980 and 1982 but the median total length increased from 100 mm to 250 mm and declined to 180 mm in 1980, 1981, and 1982, respectively (Figure 4). Redear sunfish produced a strong year class in 1980 but few YOY redear sunfish were found in 1981 and 1982 (Figure 5).

Changes also occurred in populations of largemouth bass and striped bass x white bass hybrids. Five YOY largemouth bass were collected in 1980, but a good year class was produced in 1981, and over half the 1982 collection of largemouth bass was YOY fish (Figure 6). Most adult largemouth bass were collected by electrofishing in 1981 and 1982. Few adult largemouth bass were collected in 1980 because of electrofishing equipment failure. Striped bass x white bass hybrids increased in size (Figure 7) and frequency of occurrence between 1981 and 1982. All of the physical characteristics tested for hybrid bass increased between 1981 and 1982.

Yellow bullheads, Ictalurus natalis, were similar in size in 1980 and 1982 (268 mm and 263 mm mean total length , respectively) but were smaller in 1981 (152 mm mean total length). The mean total length of channel catfish, Ictalurus punctatus, varied from 372 mm to 390 mm during the study. Both ictalurid populations remained numerically stable throughout the study.

Food Habits

Fish was the dominant food for largemouth bass during the study, comprising 46 - 82% of the diet. Food was present in 47, 63, and 54% of the largemouth bass collected in 1980, 1981, and 1982, respectively. Centrarchids comprised 11 - 61% of largemouth bass diets during the study and were dominant in two of the three years (Table II). Gizzard shad and unidentified fish comprised 10 - 14 and 8 - 24%, respectively, of largemouth bass diets. Chi-square comparisons showed no annual variations in importance of pairs of fish food items (centrarchids and gizzard shad, centrarchids and unidentified fish, gizzard shad and unidentified fish). The median total lengths of largemouth bass which consumed fish changed significantly (chi-square = 73.05, 2 d.f., $P < 0.01$) during the study (Table III) . In 1981, the median size of largemouth bass which consumed gizzard shad was 8 and 12% larger than in 1980 and 1982, respectively.

Ephemeropterans and odonata were the principal non-fish food items consumed by largemouth bass. In 1981, ephemeroptera and odonata were consumed primarily by YOY largemouth bass and comprised 48% of the diet of largemouth bass.

Forage selectivity by largemouth bass was influenced by abundance and size suitability of centrarchids. Centrarchids were selected by largemouth bass less than 250 mm total length in all three years and by all largemouth bass in 1982 (Table IV). No data are available for daily prey suitability in 1980. Sixty and 46% of the bluegills collected with largemouth bass were suitable for forage in 1981 and 1982, respectively. Suitability of redear sunfish was low in both 1981 and 1982 (4 and 18%, respectively). Black crappie, Pomoxis nigromaculatus, were also unsuitable as forage in 1981 (4%) but 44% of black crappie in 1982 could be consumed by largemouth bass from the same samples.

Gizzard shad were eaten randomly by largemouth bass throughout the study, except for 1981. In 1981, very few gizzard shad (0.16%) could be eaten by largemouth bass less than 250 mm total length, and only 1% of the gizzard shad could be consumed by all largemouth bass. Forty-one percent of the gizzard shad collected in 1982 could be eaten by all largemouth bass, and 29% were available to largemouth bass less than 250 mm total length.

Fish were 87 and 76% of the diet of striped bass x white bass hybrids in 1981 and 1982, respectively (Table V). Food was recovered from 52 and 77% of striped bass x white bass hybrids collected in 1981 and 1982, respectively. Variation within the fish food component of the diet was not significant between years (chi-square = 1.36, 2 d.f., P = 0.51). Unidentified fish (probably centrarchids) was the dominant food in 1981, but was replaced by gizzard shad in 1982. No gizzard shad of appropriate size were available to hybrid bass in 1981. Centrarchids declined in dietary importance from 12% in 1981 to 4% in 1982, but larger centrarchids were consumed in 1982. The median size of hybrid bass which ate centrarchids increased from 149 to 290 mm TL, and the centrarchids consumed increased from 17 to 32% of maximum size in 1981 and 1982, respectively. The median size of gizzard shad consumed by hybrid bass was 20% of the maximum size that could be consumed. The median size of striped bass x white bass hybrids that consumed gizzard shad was 254 mm TL. Dipterans (predominantly chaoborids) increased in dietary importance from 5 to 22% in 1981 and 1982, respectively. The median total lengths of hybrid bass consumers increased from 133 to 237 mm in the same time period. Dipterans were found in 20% of hybrid bass stomachs in 1981 and increased to 27% in 1982. Ephemeropterans declined from 4 to 1% of the diet in 1981 and 1982, respectively, but frequency of occurrence in stomachs increased from 13 to 20% in the two years.

Annual selectivity data indicated that centrarchids were inaccessible or avoided by hybrid bass in both years, but daily data shows that centrarchids were eaten randomly (Table VI). Centrarchids were found in 13 and 17% of hybrid bass stomachs in 1981 and 1982, respectively, which also indicates little selection by hybrids. Gizzard shad were found in 53% of hybrid bass stomachs in 1982, and little change was seen between annual and daily selectivity data. Hybrid bass in Hams Lake may forage selectively on ephemeropterans when gizzard shad are not available, and eat centrarchids incidentally.

Diet overlap between striped bass x white bass hybrids and all largemouth bass decreased by 52% between 1981 and 1982. Overlap between hybrid bass and largemouth bass with the same buccal gape was nearly constant between years (Table VII). In both years the greatest amount of overlap occurred with relatively unimportant prey types. In 1981 the greatest degree of diet overlap between all largemouth bass and hybrid bass occurred for *Lepomis* spp. Centrarchids were the second most important forage for hybrid bass in 1981, but were fourth in importance for largemouth bass. For predators in the gape overlap range, *Lepomis* forage contributed the least to diet overlap in 1981. Ephemeropterans were the largest component of diet overlap, and ranked 3 and 5 respectively, in the diets of largemouth bass and hybrid bass. In 1982, the greatest amount of overlap was again due to ephemeropterans, which ranked 7 and 5, respectively, in diets of largemouth bass and hybrid bass.

Age and Growth

Scale analyses of selected fish species are shown in Table VIII. None of the species showed differences in growth increments between years of the study, nor were there differences in increments between age "n" and "n+1" between years. Redear sunfish showed no differences in growth throughout the study. There were no differences in length-weight relationships among any of the fish species when compared to statewide averages. Growth of gizzard shad was greater during 1981 (Mann-Whitney, $n_1 = n_2 = 3$, $T = 11$, $P = 0.17$) than in 1979. No difference in growth of gizzard shad was observed between 1979 and 1980 or 1979 and 1981.

Black crappie was the only species that grew differently between 1979 and 1980 (Mann-Whitney, $n_1 = 3$, $n_2 = 5$, $T = 13$, $P = 0.12$). Black crappie growth was similar in 1980 and 1981.

Bluegill sunfish was the only species which grew differently in 1980 than 1981. In 1980, age I and V bluegills grew more, but age II-IV bluegills grew less than in 1981 (Mann-Whitney, $n_1 = n_2 = 5$, $T = 27$, $P = 0.08$). Bluegill sunfish showed no difference in growth between 1979 and 1980 or 1979 and 1981.

No difference in growth of largemouth bass occurred between 1979 and 1980, or between 1980 and 1981, but growth was less in 1981 than in 1979 (Mann-Whitney, $n_1 = 5$, $n_2 = 6$, $T = 30$, $P < 0.0001$).

Lee's phenomenon was observed throughout the study in all of the species examined ($P < 0.05$). Table IX indicates that with only two exceptions (redear sunfish), the largest growth increment occurred at age I. When the data were reanalyzed without age I, Lee's phenomenon was not apparent in black crappie and largemouth bass in 1979, or in bluegill sunfish in 1980. Redear sunfish showed the phenomenon regardless of the presence of age I data.

Lake Carl Blackwell

Relative Abundance

No changes occurred in the distributions of relative abundance of fish species between years in Lake Carl Blackwell (1980/1981: Mann-Whitney, $n_1 = 18$, $n_2 = 19$, $T = 321$, $P = 0.67$; 1981/1982: Mann-Whitney, $n_1 = 17$, $n_2 = 19$, $T = 293$, $P= 0.99$; 1980/1982: Mann-Whitney, $n_1 = 17$, $n_2 = 18$, $T = 308.5$, $P = 0.93$). Few hybrid bass were collected in Lake Carl Blackwell. In 1981, two hybrids (200 and 242 mm TL) were collected in September. Eighteen hybrids were collected in 1982, with total lengths ranging from 225 to 330 mm. Gizzard shad, inland silversides, Menidia beryllina, and white crappie, Pomoxis annularis, were numerically dominant throughout the study (Table X). Gizzard shad (Figure 8) and white bass (Figure 9) produced strong year classes in 1982, which caused changes in the population structures of both species. The relative abundance of gizzard shad increased from 20 to 53% and the median total length decreased from 150 to 30 mm in 1981 and 1982, respectively. The median total length of bluegill sunfish increased throughout the study (20, 90, and 105 mm in 1980, 1981 and 1982, respectively, Figure 10). In 1980, most bluegills were collected by seining, but the majority of bluegills were collected by electrofishing in 1981 and 1982. The data probably indicate differences in collection methods rather than changes in population structure of the bluegill population. The median total length of inland silversides was identical in 1980 and 1981 (52 mm), but decreased to 26 mm in 1982 (Figure 11). These data also indicate differences in collections rather than changes in population structure. Most of the silversides collected in 1980 and 1981 were taken in late July and early August, while collections in 1982 were made from mid-June to mid-July. During all three years, silversides were 65-85 mm TL by late August. More largemouth bass were collected in 1982 than in 1980 or 1981, but the length-frequency distributions were unchanged (Figure 12). The white crappie population was also unchanged throughout the study (Figure 13). Median total lengths of white crappie ranged from 150 mm in 1980 and 1981 to 130 mm in 1982. Median weight of white crappie was 30 grams throughout the study.

Food Habits

The dominant foods of largemouth bass were terrestrial insects, centrarchids and gizzard shad in 1980, 1981 and 1982, respectively. Food was present in 65, 53 and 47% of largemouth bass examined in 1980, 1981 and 1982, respectively. The distributions of food items in the diet of largemouth bass were different for each pair of years (1980/1981: Mann-Whitney, $n_1 = 4$, $n_2 = 6$, $T = 32$, $P < 0.01$; 1981/1982: Mann-Whitney, $n_1 = 4$, $n_2 = 7$, $T = 26$, $p < 0.01$; 1980/1982: Mann-Whitney, $n_1 = 6$, $n_2 = 7$, $T = 47$, $P < 0.01$). Terrestrial insects occurred in 47% of stomachs with food in 1980 (Table XI). Insects were eaten primarily by YOY largemouth bass. Centrarchids were second in dietary importance in 1980 and gizzard shad were third. Most largemouth bass that ate fish in 1980 were adults; the median TL of piscivorous largemouth bass was 290 mm.

Centrarchids were the most important food of largemouth bass in 1981, followed by gizzard shad and unidentified fish. Centrarchids were the dominant forage of largemouth bass in May, 1982 but were replaced by gizzard shad by June. In both 1981 and 1982, gizzard shad were eaten by largemouth bass of similar sizes (308 and 301 mm TL, respectively [Table XII]). The median total length of largemouth bass that ate centrarchids increased from 315 mm in 1981 to 451 mm in 1982. Throughout the study, largemouth bass ate centrarchids that were 45-50% of the maximum suitable size, but gizzard shad eaten by largemouth bass ranged from 29-56% of the maximum suitable size. Largemouth bass ate sizes of gizzard shad that were representative of the shad population but selected for the largest centrarchids. Median total lengths of gizzard shad eaten were the same as those of the gizzard shad population (140, 150 and 30 mm in 1980, 1981 and 1982, respectively). Median total lengths of bluegill sunfish eaten by largemouth bass were 235, 136 and 117% of the bluegill population medians in 1980, 1981 and 1982, respectively.

Annual selectivity data indicate that gizzard shad were selected over centrarchids by largemouth bass (Table XIII). Gizzard shad were selected in 1981 and 1982, while centrarchids were selected only in 1982. In 1980, centrarchids were eaten randomly and gizzard shad were avoided or inaccessible to largemouth bass. However, daily selectivity data show that both centrarchids and gizzard shad were selected and that centrarchids were selected more frequently than gizzard shad in 1980 and 1981.

Gizzard shad was the predominant food of white bass (Table XIV), but the distribution of food items in the diet of white bass was not different when any two of the three years were compared (1980/1981 Mann-Whitney: $n_1 = n_2 = 6$, $T = 38$, $P = 0.87$; 1981/1982 Mann-Whitney: $n_1 = n_2 = 6$, $T = 35$, $P = 0.52$; 1980/1982 Mann-Whitney: $n_1 = n_2 = 6$, $T = 36$, $P = 0.63$). The median total length of white bass that ate gizzard shad increased from 218 mm in 1980 to 295 mm in 1982. Mayflies were second in importance in 1980, but were fourth in 1981 and 1982. Dipterans were second in importance in 1981, and miscellaneous food items were second in 1982. The median total length of white bass that ate mayflies also increased throughout the study. The median total lengths of white bass that ate all but miscellaneous items increased from 1980 to 1981, and the median total lengths of predators decreased from 1981 to 1982 for all food items but gizzard shad and mayflies. Food was recovered from 77, 57 and 26% of the white bass collected in

1980, 1981 and 1982, respectively. The low percentage of stomachs with food in 1982 was representative of both YOY and adult fish. Food was found in 25% of YOY and 35% of adult white bass in 1982. In both YOY and adult size categories, several collections of spawning adults and YOY < 50 mm TL contained very few white bass with food.

Forage selectivity of white bass suggests the influence of forage reduction during 1981. Annual data indicate that gizzard shad were selected most heavily in 1981, but also indicate that centrarchids were inaccessible or avoided by white bass (Table XV). However, daily selectivity data show that centrarchids were eaten randomly and gizzard shad were strongly selected in 1981. Centrarchids were < 1% of the diet in 1980 (Table XIV), when no centrarchids were collected with white bass. These data indicate random foraging on centrarchids (Table XV).

Hexagenia naiads were the only food items found in striped bass x white bass hybrids in 1981. In 1982 food was recovered from 44% of the hybrid bass collected. Unidentified fish formed 42% of the diet and were found in 71% of the stomachs with food (Table XVI). *Hexagenia* naiads and gizzard shad were second and third in importance, respectively, and each was present in 29% of hybrid bass stomachs with food. No centrarchids were eaten by hybrid bass.

Annual selectivity of hybrid bass for gizzard shad was -0.13 but daily selectivity was 0.26. Available prey/predator (AP/P) ratios (Jenkins and Morais, 1978) were calculated for each sampling date by comparing the biomass of suitable-sized prey to the biomass of predators with which the prey were captured. The ratios indicated that in May 1982, sufficient gizzard shad forage was available to only those hybrid bass greater than 300 mm TL. Gizzard shad were also too large to be eaten by hybrids < 300 mm TL after mid-August, 1982 (Figure 14).

Daily AP/P ratios indicated that most size classes of white bass and largemouth bass were also forage-limited in Lake Carl Blackwell. Insufficient biomass of suitable sizes of bluegill sunfish forage for white bass occurred throughout the study. Bluegill sunfish were also insufficient to maintain the largemouth bass population in 1980. In 1981, only largemouth bass 100-199 mm TL or 300-399 mm TL had adequate bluegill forage, and then only in mid-June. In 1982, sufficient bluegill forage occurred only in mid-August for largemouth bass 100-199 mm TL.

Very few gizzard shad of suitable size for forage were captured with white bass in 1980. In 1981, gizzard shad were abundant during mid-May for white bass 200-499 mm TL. In 1982, gizzard shad forage was abundant for white bass 300-399 mm TL from late February through early May, for white bass 200-299 mm TL from late April through May and for white bass 0-99 mm TL from early June through mid-July (Figure 15).

Adequate gizzard shad forage was present from mid-May to mid-June, 1980 for largemouth bass 300-399 mm TL. In 1981 gizzard shad were abundant during mid-June for largemouth bass 200-399 mm TL and during mid-August for largemouth bass 100-299 and 400-499 mm TL. In 1982 sufficient gizzard shad forage was generally available from mid-May through October (forage was not adequate for bass from 200-299 mm TL in mid-August) (Figure 16). Too few gizzard shad were present to maintain largemouth bass ≥ 400 mm TL in 1982.

Diet overlap between all combinations of two of the three predators was evaluated to determine if there was potential competition for limited forage. In 1980 and 1981, diet overlap between largemouth bass and white bass increased when predators with the same buccal capacity were compared to the total population of predators (Table XVII).

In 1981, diet overlap between largemouth bass and white bass was dominated by ephemeropterans, followed by centrarchids, gizzard shad and unidentified fish. Gizzard shad were 64% and 77% of the diets of largemouth bass and white bass, respectively, in 1981. Gizzard shad were selected moderately by largemouth bass (L = 0.34, Table XIII) and strongly by white bass (L = 0.74, Table XV).

The only year in which sufficient data from all three predators was collected to perform pair-wise comparisons of diets was 1982. Diet overlap increased between largemouth bass and striped bass x white bass hybrids with the same buccal gape (Table XVIII), but decreased between largemouth bass and white bass (Table XVII) and between white bass and striped bass x white bass hybrids (Table XVIII). Diet overlap between largemouth bass and striped bass x white bass hybrids with the same gape size was limited to unidentified fish and gizzard shad.

In 1982 diet overlap between largemouth bass and white bass with the same buccal gape was dominated by centrarchids and unidentified fish, followed by ephemeropterans, gizzard shad and dipterans. Ephemeropterans were unimportant to largemouth bass but formed 13% of the white bass diet. Conversely, dipterans were 31% of the largemouth bass diet and only 2% of the white bass diet. Gizzard shad was important forage for both predators, forming 17 and 41% of the diets of largemouth bass and white bass, respectively. Largemouth bass selected gizzard shad (Table XIII) more frequently than did white bass (Table XV) in 1982, both on annual and daily bases.

Diet overlap between white bass and striped bass x white bass hybrids in 1982 was greatest for gizzard shad, followed by ephemeropterans and unidentified fish. All three items were important for hybrid bass (Table XV) and white bass (Table XIV).

Age and Growth

Growth and age composition of selected fish species are presented in Table XIX. Data for striped bass x white bass hybrids is not presented, since all hybrid bass scales exhibited false annuli. No other fish species examined showed differences in median TL at annulus in pairwise comparisons of growth between years. There were no differences in length-weight relationships among any of the fish species when compared to statewide averages.

Differences in median increment at annulus were apparent for bluegill sunfish (1980/1981: Mann-Whitney, $n_1 = 4$, $n_2 = 5$, $T = 15$, $P = 0.01$) and gizzard shad (1979/1980: Mann-Whitney, $n_1 = n_2 = 3$, $T = 6$, $P = 0.05$; 1980/1981: Mann-Whitney, $n_1 = n_2 = 3$, $T = 15$, $P = 0.05$; 1979/1981: Mann-Whitney, $n_1 = n_2 = 3$, $T = 6$, $P = 0.05$), white crappie (1979/1980: Mann-Whitney, $n_1 = 3$, $n_2 = 6$, $T = 24$, $P = 0.02$; 1979/1981: Mann-Whitney, $n_1 = n_2 = 3$, $T = 15$, $P = 0.05$) and largemouth bass (1979/1981: Mann-Whitney, $n_1 = 4$, $n_2 = 7$, $T = 10$, $P = 0.01$). White bass showed marginal differences (1979/1980: Mann-Whitney, $n_1 = 5$, $n_2 = 6$, $T = 39$, $P = 0.10$; 1980/1981: Mann-Whitney, $n_1 = 5$, $n_2 = 6$, $T = 27$, $P = 0.10$; 1979/1981: Mann-Whitney, $n_1 = n_2 = 5$, $T = 35$, $P = 0.12$) in median increment at annulus in all comparisons.

Growth of bluegill sunfish was not estimated for 1979 because of small sample sizes of adult fish (Figure 10). Growth in median increment at annulus of bluegill was less in 1980 than 1981 (Mann-Whitney, $n_1 = 4$, $n_2 = 5$, $T = 15$, $P = 0.01$).

Median growth increments of gizzard shad were greatest in 1980, followed by 1981 and 1979 (Table XIX). Growth of gizzard shad essentially ceases after age I. The data also indicate the abundant year-class in 1980 (Figure 8) did not grow in 1981, nor did 1981 age III gizzard shad (Table XIX). The comparison of median growth increment at annulus "n" to growth at annulus "n+1" in the succeeding year indicated that gizzard shad of comparable ages grew more in 1980 than 1979 or 1981 (1979/1980: Mann-Whitney, $n_1 = 2$, $n_2 = 3$, $T = 6$, $P = 0.08$; 1980/1981: Mann-Whitney, $n_1 = 2$, $n_2 = 3$, $T = 12$, $P = 0.08$). Gizzard shad exhibited Lee's phenomenon during all years of the study (chi-square = 30.1, 43.3, 128.8 in 1979, 1980 and 1981, respectively , 2 d.f., $P < 0.0001$) but when the data were analyzed without age I fish Lee's phenomenon was not present in 1980 (chi-square = 0.31, 2 d.f., $P = 0.58$).

Median growth increments of largemouth bass increased each year of the study but were statistically different only between 1979 and 1981 (Mann-Whitney, $n_1 = 4$, $n_2 = 7$, $T = 10$, $P = 0.008$). Comparisons of median growth increments between annulus "n" and annulus "n+1" indicated that growth in 1980 was slightly less than in 1979 and growth in 1981 was much less than in 1980 (Mann-Whitney, $n_1 = n_2 = 5$, $T = 40$, $P = 0.009$). These data indicate greater growth of younger age classes during all years of the study. The appearance of Lee's phenomenon was significant for all years of the study (chi-square = 34.6, 67.2 and 135.5 in 1979, 1980 and 1981, respectively, 2 d.f., $P < 0.001$), regardless of whether data from age I largemouth bass was included in the analysis.

Growth of white bass was greater in 1979 than in either 1980 (Mann-Whitney, $n_1 = 5$, $n_2 = 6$, $T = 39$, $P = 0.10$) or 1981 (Mann-Whitney,

$n_1 = n_2 = 5$, $T = 35$, $P = 0.12$) and growth of white bass in 1981 was greater than in 1980 (Mann-Whitney, $n_1 = 5$, $n_2 = 6$, $T = 27$, $P = 0.10$). Growth at annulus "n" vs. annulus "n+1" was less in 1980 than in 1979 (Mann-Whitney, $n_1 = n_2 = 5$, $T = 35$, $P = 0.12$) and was much less in 1981 than in 1980 (Mann-Whitney, $n_1 = 4$, $n_2 = 6$, $T = 45$, $P = 0.01$). With the exception of age I, white bass grew more in 1979 than in 1980 (Table XIX). However, during 1981 growth of age II-IV white bass was more than in 1980. Growth of age V white bass in 1981 may have been misrepresented due to the small sample size. White bass exhibited Lee's phenomenon during all years of the study. In 1979 and 1981 Lee's phenomenon was present regardless of whether age I growth was included in the calculations (chi-square = 102.3 and 57.7, respectively, 4 d.f., $P < 0.00$). In 1980 the phenomenon was also significant (chi-square = 10.3, 5 d.f., $P = 0.07$) but was more significant when age I data were not included (chi-square = 12.7, 4 d.f., $P = 0.01$). The data suggest that although age I white bass grew more in 1980 than in 1979 or 1981, the proportionate growth of age I fish was less than in the other two years of the study.

White crappie grew less in 1979 than 1980 (Mann-Whitney, $n_1 = 3$, $n_2 = 6$, $T = 24$, $P = 0.02$) or 1981 (Mann-Whitney, $n_1 = n_2 = 3$, $T = 15$, $P = 0.05$) but there was no difference in growth between 1980 and 1981 (Mann-Whitney, $n_1 = 3$, $n_2 = 6$, $T = 27$, $P = 0.44$). In all three years of the study, growth beyond age III was slower, but growth at age VI was above the statewide average (Table XX). Growth in 1980 at annulus "n+1" was greater than in 1979 at annulus "n" (Mann-Whitney, $n_1 = n_2 = 3$, $T = 6$, $P = 0.05$) and growth at annulus "n" in 1980 was greater than at annulus "n+1" in 1981, but the difference was not significant. The discrepency between growth increments in 1980 and 1981 was related to greater growth at ages II and III in 1980 than in 1981. The data indicated that white crappie benefitted from high water levels in 1980, and that growth was greatly reduced in 1981 when water levels again declined.

CHAPTER V

DISCUSSION

Hams Lake

Relative Abundance

The relative abundances of fish species in Hams Lake were statistically similar between any two of the years studied but the population structures of some species changed significantly. Gizzard shad produced a very small year class in 1981 and a large year class in 1982. In 1981, water levels in the reservoir declined 2-3 m, and approximately 30% of the littoral area was covered with dense mats of *Chara* and *Najas*. Bluegills comprised 70% of the fish collected in 1981 and it is possible that the gizzard shad year class was affected by bluegills. Bluegills prey heavily on fish eggs and fry and can limit reproductive success of other fish (Applegate, Mullan and Morais, 1966; Bickerstaff, Ziebell and Matter, 1984). Excessive macrophyte growth may also limit phytoplankton production and zooplankton production is independent of macrophyte production, but zooplankton may be concentrated by macrophytes (Wiley, Gorden, Waite and Powless,1984). The large population of bluegill YOY may also have competed with gizzard shad for available food.

Food Habits

The median total lengths of largemouth bass which consumed fish changed significantly (chi-square = 73.05, 2 d.f., $P < 0.01$) during the study (Table IV). In 1981, the median size of largemouth bass which consumed gizzard shad was 8 and 12% larger than in 1980 and 1982, respectively. The shift in size of largemouth bass consumers was due to the very weak year class of gizzard shad produced in 1981, which increased the median total length of gizzard shad to 250 mm (Figure 4) and reduced the suitability of gizzard shad as forage for largemouth bass. Strong year-classes of largemouth bass (Figure 6) and bluegill sunfish (Figure 3) in 1981 reduced the median total length of largemouth bass containing centrarchids and unidentified fish (predominantly larval forms).

In 1981, the largemouth bass diet shifted from fish to aquatic insects. The diet shift occurred after development of dense mats of vegetation, which may have reduced the accessibility of forage fish to largemouth bass. Savino and Stein (1980) found that bluegills disperse and become hard to find in thick vegetation. Ambrow, Lynch and Johnson (1983), found that bluegills 50-200 mm TL selected for openings about 40 mm in size in artificial structure, but YOY bluegills were not selective for structure size.

Bluegill sunfish were the dominant centrarchid forage throughout the study and were also the dominant forage fish for largemouth bass less than 250 mm TL. The data agree with Ambrow, Lynch and Johnson, (1983) since movement of largemouth bass longer than 250 mm TL would be hampered in thick vegetation. However, largemouth bass were still closely associated with vegetated areas, as evidenced by the large proportion of aquatic insects in the diet in 1981 (Table III), and low selectivity values for gizzard shad (Table V). In Smith Mountain Lake, Virginia, largemouth bass move offshore during summer (Prince and Maughan, 1979). Such movement should bring largemouth bass in closer contact with gizzard shad, but Timmons, Shelton and Davies (1980), found that gizzard shad were not important prey for largemouth bass less than 250 mm TL. The median total lengths of largemouth bass that ate gizzard shad exceeded 250 mm throughout this study (Table IV).

Diet analyses indicated that striped bass x white bass hybrids foraged in mostly littoral areas in 1981, and in open water in 1982. Unidentified fish was the dominant food in 1981, but the fish were probably centrarchids. Although less than 1% of black crappie and redear sunfish and 8% of bluegill sunfish were suitable as forage, centrarchids formed 93% of the fish collected in 1981. No gizzard shad of forage size were collected with hybrid bass in 1981, and no cycloid scales or shad gizzards were found in stomachs of hybrid bass. Aquatic insects in the diet also indicate that hybrid bass foraged in littoral areas in 1981. Hexagenia naiads and chironomid larvae were of equal dietary importance in 1981 (Table VI), but in 1982, chaoborid larvae replaced chironomids as the dominant dipteran forage, and consumption of Hexagenia also declined. Gizzard shad was the dominant food item of hybrid bass in 1982, although only 0.2% of the gizzard shad collected with hybrid bass were of forage size.

Diet overlap between largemouth bass and hybrid bass indicated that forage important to one predator was not important to the other. In 1981, Lepomis were eaten randomly by hybrid bass and largemouth bass > 250 mm TL, but were selected by largemouth bass < 250 mm TL. In 1982, Lepomis were selected by all sizes of largemouth bass and consumed randomly by hybrid bass. Hybrid bass selected gizzard shad, which were eaten randomly by all sizes of largemouth bass. Insects were the dominant food of hybrid bass in Sooner reservoir when gizzard and threadfin shad were unavailable (Gilliland, 1981). Gizzard and/or threadfin shad were also the domint forage of hybrid bass in other studies (Williams, 1971b; Ware, 1975, 1977; Crandall, 1978). Prince and Maughan (1979) found that largemouth bass were strongly attracted to underwater structure. As structural habitat diversity increases, largemouth bass spend more time remining motionless or searching for prey, and less time following (Savino and Stein, 1980). Larval gizzard shad occurred most frequently near 3 m depths in Lake Carl Blackwell (Downey and Toetz, 1983). No largemouth bass were collected in 3 m water in Hams lake, which may explain the low selectivity for gizzard shad.

Age and Growth

Fluctuations in water levels in Hams lake were accompanied by changes in growth rates of fish. Growth of gizzard shad was greater in 1981 than in 1979, and black crappie grew more in 1979 than in 1980 or 1981. Although this research was not initiated intil 1980, I suggest the same mechanism was in operation in 1979 and 1981. During periods of increased macrophyte density, macroinvertebrate populations also increase and zooplankton populations are concentrated (Wiley et al., 1984). YOY bluegill sunfish may have competed with black crappie for forage in 1981, causing a reduction in growth of both species. The presence of Lee's phenomenon in all species of fish examined indicated forage limitation in Hams Lake. Cohen and Brown (1969) found that the average size of young bluegills increased over winter in Oklahoma; the increase was ascribed to selective predation on smaller fish. Such a size increase would overestimate the average growth rate of younger fish, and give rise to Lee's phenomenon. My data suggest that size-selective mortality may have occurred, since Lee's phenomenon occurred in all species examined, but was not apparent in black crappie and largemouth bass in 1979, or in bluegill sunfish in 1980. Oliver, Holeton and Chua (1979), determined that caloric exhaustion occurred during winter in smaller fish in a year-class of smallmouth bass. Starvation of smaller fish in a cohort is the probable mechanism driving size-selective mortality/predation in Hams Lake. Growth of largemouth bass may be limited more by availability than abundance of forage.

Lake Carl Blackwell

Relative Abundance

Lake Carl Blackwell filled to capacity in the spring of 1982 and inundated shoreline vegetation. Both fish reproduction and vulnerability of fish to collection increased; the greatest number of adult largemouth bass captured during the study were taken in 1982 (Figure 10). Aggus and Elliot (1975) determined that survival of YOY largemouth bass was directly related ($R = 0.91$, $P = 0.01$) to the amount of flooded cover in Bull Shoals reservoir between 1 June and mid-August. Flooded cover reduced predation on YOY bass and increased production of clupeid forage. In Lake Carl Blackwell, fluctuations in water level from 1 October to 15 May accounted for 87% of the variation in instantaneous mortality on YOY largemouth bass. Growth of largemouth bass ages II, III and VI was correlated with variations in standing crop of gizzard shad, which was also affected by water level fluctuation

(Orth, 1977). High water levels in Lake Carl Blackwell are coincident with increased nutrient levels in the sediments. Increased nutrient loading benefits gizzard shad (Summerfelt, 1971; Ploskey and Jenkins, 1982) and benthic macroinvertebrates (Craven, 1967; Norton, 1968).

Food Habits

Largemouth bass diets changed with water level and forage fish abundance. The dominant forage in 1980 was terrestrial insects, which were eaten primarily by YOY largemouth bass. Centrarchids and gizzard shad were second and third in importance, respectively, in 1980. Centrarchids were the most important forage of largemouth bass in 1981, followed by gizzard shad. In 1982, centrarchids were again the dominant forage until June when gizzard shad became most important. Gizzard shad may be most valuable as forage during high water periods when sediments with high organic matter have been inundated or washed into the reservoir (Summerfelt, 1971). Most larval gizzard shad occur at depths near 3 m by July (Downey and Toetz, 1983) and may not be available to largemouth bass. A similar pattern of depressed gizzard shad use was observed in Norris River, Tennessee (Dendy, 1946). Zweiacker (1972) determined that gizzard shad and crayfish were the dominant food of all sizes of largemouth bass in Lake Carl Blackwell. However, Zweiacker's (1972) study occurred when centrarchid production was suppressed during the lowest water levels recorded for the reservoir. In 1982, the relative abundance of gizzard shad was double that in 1980 and 1981, and greater numbers of gizzard shad were available to largemouth bass than in 1980 or 1981. Absolute numbers of both white crappie and gizzard shad increased dramatically in 1982, while collections of bluegill sunfish remained stable (Table XI).

White bass diets were also influenced by water levels in the reservoir. In 1980 and 1982, Lake Carl Blackwell was full for most of the growing season, but in 1981 water level was approximately 3 m below spillway. Fish reproduction was limited in 1981, and white bass used more aquatic insects as food than in 1980 or 1982. During periods of high water, terrestrial vegetation is inundated and allochthonous organic material is imported with runoff. Decomposition of the organic matter increases nutrient loading in sediments. High nutrient levels in sediments support increased standing crops of mayflies and midges (Craven, 1967; Norton, 1968). Invertebrates, especially mayfly naiads, are consistently important in white bass diets from March to May, or until suitable forage fish become available (Mitzner, 1980; Day, 1981). In Lake Carl Blackwell the catch of white bass was positively correlated with abundance of mayflies ($P < 0.05$; Summerfelt, 1971). In 1980, mayflies were the dominant food of white bass until gizzard shad became available in mid-June. Gizzard shad reproduction in Lake Carl Blackwell occurred from mid-April to July and peaked in late May to early June (Downey and Toetz, 1983). Other authors have also shown that mayfly production is very important as forage when gizzard shad production is low (Aggus and Elliot, 1975; Ploskey and Jenkins, 1982). *Hexagenia* was the most important food of white bass in Shafer Lake, Indiana (Riggs, 1952). Chironomids, *Hexagenia* and culicids are important food for white bass in Lake Texoma in March, April, May, and during emergence of the adults in July (Moser, 1968). The same pattern of aquatic insect use was observed in this study.

Gizzard shad are the preferred food of white bass (Bonn, 1952; Riggs and Moore, 1958; Moser, 1968; Houser and Bryant, 1970) unless threadfin shad are also available (Moser, 1968). Houser and Bryant (1970) found a dramatic increase in growth of the first three age classes of white bass when threadfin shad became available in Bull Shoals reservoir.

Striped bass x white bass hybrids in Lake Carl Blackwell fed mainly on Hexagenia naiads during this study. Insects were also the predominant food of hybrid bass 451-600 mm TL in Sooner reservoir in spring, 1980, and of hybrids 151-300 mm TL in summer, 1980 (Gilliland, 1981). Mayflies were numerically dominant in the diet of hybrid bass in Lake Bastrop, Texas (Day, 1981). The absence of centrarchids in hybrid bass diets in this study may have been due to low suitability of centrarchid forage; 4% of the bluegill sunfish in the reservoir were suitable as prey for hybrid bass on an annual basis, and none were suitable on a daily basis. Available prey/predator ratios indicated that gizzard shad forage in Lake Carl Blackwell was insufficient to maintain hybrid bass < 300 mm TL. Since Hexagenia adults emerge during June through August, these data suggest that striped bass x white bass hybrids < 300 mm TL have only a 90-100 day period each year when forage of suitable size is available in the reservoir. Previous research has determined that while total forage biomass in reservoirs may indicate abundant food for predators, temporary shortages of suitable sizes of prey occur frequently (Rainwater and Houser, 1975; Noble, 1981; Ploskey and Jenkins, 1982). Striped bass x white bass hybrids may suffer high overwinter mortality as a result of forage limitation. Coble (1970) found that 21 days of starvation was sufficient to cause false annulus formation in bluegill sunfish scales, and all hybrid bass examined from Lake Carl Blackwell exhibited false annuli. Both smallmouth bass

(Oliver, Holeton and Chua, 1979) and largemouth bass (Timmons, Shelton and Davies, 1980) lose the smallest members of year classes to overwinter starvation. Largemouth bass maximize caloric growth and store visceral fat in the fall to sustain winter energy needs (Adams, McLean and Parotta, 1982). Since gizzard shad in Lake Carl Blackwell are too large for age 0 hybrid bass to eat during the fall, and *Hexagenia* are too small to be of value, starvation of the smallest hybrid bass appears inevitable.

Diet overlap data, when compared to that of Zaret and Rand (1971) suggested intense competition for food between white bass and largemouth bass. However, in 1980 diet overlap was confined to unidentified fish and gizzard shad. Neither of the food items was a major portion of the diet of largemouth bass (Table XI), and only gizzard shad was of major importance to white bass (Table XIV). In 1981, diet overlap between largemouth bass and white bass included ephemeropterans and gizzard shad. Gizzard shad were 64% and 77% of the diets of largemouth bass and white bass, respectively, in 1981 and were selected moderately by largemouth bass and strongly by white bass. The abundance of *Hexagenia* could not be determined, so selectivity was not calculated. However, competition for forage was also suggested by the coefficient of condition, K, for both predators. Condition of largemouth bass (1.68) was greater in 1981 then either 1980 (1.34) or 1982 (1.18), but condition of white bass was lower in 1981 (1.18) than 1980 (1.43) or 1982 (1.42). The distribution of food items in the diet of white bass was no different in 1981 than 1980 or 1982.

In 1982, diet overlap was compared for all pair-wise combinations of largemouth bass, white bass, and hybrid bass. The potential existed for competition between largemouth bass and hybrid bass for gizzard shad forage. Gizzard shad were important food for both predators, but largemouth bass did not appear to be adversely affected by the diet overlap. Centrarchids and unidentified fish formed another 39% of the largemouth bass diet in 1982. Hybrid bass appeared to have been affected by insufficient forage, since the condition of hybrids in 1982 (1.08) was less than in 1981 (1.27). Diet overlap between largemouth bass and white bass showed no effects in 1982. However, diet overlap between white bass and striped bass x white bass hybrids occurred for gizzard shad, ephemeropterans and unidentified fish. All three items were important forage for both predators. However, gizzard shad were eaten by larger white bass and small hybrids (median TL of 295 and 175 mm, respectively), and unidentified fish were recovered from small white bass (95mm TL) and larger hybrid bass (275 mm TL). Ephemeropterans were eaten by larger white bass and smaller hybrid bass (median TL of 262 and 218 mm, respectively). Insects were also the predominant food of hybrid bass 151-300 mm TL in Sooner reservoir (Gilliland, 1981).

Age and Growth

All striped bass x white bass hybrid scales from Lake Carl Blackwell had false annuli, which were attributed to forage limitations (Coble, 1970). Changes in growth rates of other fish species were affected by environmental factors. The water level was 3-5 m below spillway in 1979. Heavy spring rains in 1980 filled the reservoir to capacity. Spawning was disrupted for most fish species and high turbidity temporarily reduced primary production. Limnetic predators were most affected, while littoral species and detritovores were aided by the allochthonous inputs. In 1981 water levels again declined 2-3 m. Fish species dependent on submerged vegetation for reproduction were less successful during 1981 than 1980, while some other fish benefitted from the drawdown.

Growth of bluegill sunfish was statistically different between 1980 and 1981, but the biological differences in growth may not have been as important. Bluegill growth was nearly identical for ages II and III in both 1980 and 1981. Age I bluegills grew more, and age IV bluegills grew less in 1981 than in 1980. The differences were probably related to the increased turbidity and rapid rise in water level in 1980. Since reproduction in 1980 was disrupted, YOY fish had a shorter growing season and less food from primary production than in 1981, when the reservoir level remained stable in spring and turbidity was less than in 1980. Feeding by bluegills is reduced by high turbidity (Gardner, 1981). Reduced growth of YOY fish in 1980 probably provided age IV bluegills with more abundant forage than was present in 1981.

Data for gizzard shad indicated the Lake Carl Blackwell population was chronically forage-limited for older age classes. Gizzard shad grew fastest during a high water year in 1980. Mitzner (1980) also observed greater growth of gizzard shad at low population densities. Lee's phenomenon was present in all years of the study, but was not present in 1980 when data from age I fish was omitted, which also indicated forage limitation in 1979 and 1981.

Largemouth bass grew more each year of the study. The differences in growth increments were related to steady increases in growth of age I fish during the study and to increases in the number of age classes of fish sampled each year. Few largemouth bass were collected in 1980 because of electrofishing gear failure. More adult largemouth bass were captured in 1981 when the electrofisher was operating properly. In 1982, largemouth bass concentrated in inundated shoreline vegetation, which further aided collection efforts.

Growth of white bass was inversely related to water levels in the reservoir. During 1981 white bass foraged heavily on gizzard shad, which formed 77% of the diet (Table XIV). In 1980 gizzard shad were less than half of the white bass diet and Hexagenia naiads were nearly as important as gizzard shad. However, white bass switched from Hexagenia to gizzard shad forage in June, 1980, when gizzard shad of suitable size became available. White bass feed primarily by sight (Greene, 1962) and foraging may be negatively affected by turbidity, as are bluegills (Gardner, 1981). The partial dependence on Hexagenia as forage, and the associated reduced growth rates of the predator indicated that white bass were more forage-limited in 1980 than in 1979 or 1981.

CHAPTER VI

CONCLUSIONS

Hams Lake

The relative abundance and importance of centrarchid forage in Hams Lake remained stable throughout the study, but gizzard shad fluctuated in response to environmental factors. In 1981 these factors caused a very weak year class. Growth and condition of hybrid bass in Hams Lake were directly related to the abundance of forage-size gizzard shad. Largemouth bass were not strongly affected by changes in the gizzard shad population, but were affected by density of aquatic vegetation. The presence of aquatic insects and centrarchid forage in largemouth bass diets was related positively and negatively, respectively, to the density of aquatic vegetation.

Forage selectivity of largemouth bass in Hams Lake was influenced by the abundance and size suitability of centrarchid forage. Forage selectivity of hybrid bass was strongly influenced by abundance and size suitability of gizzard shad. Ephemeropterans may have been selected by hybrids when gizzard shad were unavailable. Diet overlap between largemouth bass and striped bass x white bass hybrids in Hams Lake was dominated by ephemeropterans and was nearly constant between 1981 and 1982. In reservoirs where gizzard shad is not a stable forage base, ephemeropterans may be an important food source for hybrid bass.

Growth of all fish in Hams Lake slowed after age I, suggesting that growth was limited by density dependent factors. However, growth of hybrid bass appeared to be related to the size of the gizzard shad population. Neither largemouth bass nor hybrid bass appeared to be adversely affected by the other, nor did any of the other fish species in the reservoir appear to be influenced by introduction of the hybrids.

Lake Carl Blackwell

Gizzard shad was the most abundant forage species throughout the study. Gizzard shad abundance was directly related to water level in the reservoir. Norton (1968) suggested a positive correlation between gizzard shad abundance and water level, since water level was positively correlated with sediment density and organic content of the sediment (Norton, 1968; Summerfelt, 1971). White bass and centrarchid populations remained stable during the study.

Centrarchids were the dominant forage of largemouth bass in 1980 and 1981 but gizzard shad were the dominant forage in 1982. Centrarchids were selected by largemouth bass in 1980 and 1981 and gizzard shad were selected in 1982. Centrarchids were probably preyed upon more efficiently than gizzard shad by largemouth bass. Gizzard shad was the selected forage of white bass throughout the study. Ephemeropterans and dipterans were important forage for white bass when forage-size gizzard shad were unavailable. Centrarchids were eaten randomly by white bass. Ephemeropterans and gizzard shad were the dominant forage of striped bass x white bass hybrids in Lake Carl Blackwell. Gizzard shad were suitable for hybrid bass < 300 mm TL for only 90-100 days in 1982. Since no centrarchids were eaten by hybrid bass, Hexagenia was probably the primary food source of hybrid bass. Hexagenia and other benthos are also important forage for white bass in the spring (Mitzner, 1980). Summerfelt (1971) found a greater relationship between catch of white bass and mayflies than white bass and gizzard shad during the summer of 1967 in Lake Carl Blackwell, and found that gizzard shad were not heavily utilized by white bass. Gizzard shad were hypothesized to be in deeper water than white bass (Summerfelt, 1971) but growth of gizzard shad in 1981 suggests that gizzard shad may have been too large for forage in 1967, when water levels were lower than in 1981.

Most size classes of all three predators were forage-limited during the study. Diet overlap data indicated that white bass may have been adversely affected by foraging of largemouth bass in 1981, and hybrid bass may have been affected in 1982. Different size classes of white bass and hybrid bass foraged on gizzard shad and Hexagenia.

Differences in growth rates of the various fish species between years appear to have been determined by environmental factors rather than density-dependent interactions, with the exception of gizzard shad, which essentially cease growth after age I. Largemouth bass growth rates increased throughout the study but were statistically different only between 1979 and 1981. Growth of white bass was greatest in 1979, followed by 1981 and 1980. Growth of striped bass x white bass hybrids could not be estimated because of false annuli on all hybrid scales. The false annuli were probably the result of recurrent forage scarcity for hybrid bass.

Introduction of striped bass x white bass hybrids in Lake Carl Blackwell has apparently caused no adverse reactions in other fish populations. Survival of the hybrids has been low. However, because of the largemouth bass/white bass interaction in Lake Carl Blackwell, hybrid bass could negatively interact with white bass as competitors for currently limiting *Hexagenia* and gizzard shad < 100 mm TL. A population of large hybrid bass could potentially place competitive pressure on largemouth bass for gizzard shad > 150 mm TL.

CHAPTER VII

RECOMMENDATIONS

Data from Hams Lake indicated that largemouth bass were not affected by hybrid bass when adequate centrarchid forage was available. In turbid, windswept reservoirs such as Lake Carl Blackwell, centrarchid standing crop may be cyclic, much as gizzard shad. In such reservoirs *Hexagenia* is not an acceptable alternate forage for the temperate basses. *Hexagenia* require fine silt and clay substrates (Baker, 1918; Norton, 1968), with high organic content (Norton, 1968; Summerfelt, 1971). Stable sediments are not often found in windswept Oklahoma reservoirs because of large fluctuations in water level (Shirley, 1975) and wind-generated currents which irregularly resuspend sediments (Norton, 1968). The high turbidities found in windswept reservoirs negatively affect primary production and sport fisheries (Summers, 1983). Numbers and biomass of *Hexagenia* also cycle, with few large individuals in spring and numerous small naiads by October (Craven, 1967). Heavy predation pressure and intense competition for gizzard shad forage is then likely. Therefore, I make the following recommendations:

1. Since survival/recruitment of hybrid bass in Lake Carl Blackwell is low, I recommend additional introductions accompanied by research to determine the patterns of forage use and limitations of striped bass x white bass hybrid YOY and determine if adult hybrid bass negatively impact white bass or largemouth bass.

2. In reservoirs similar to Lake Carl Blackwell, i.e., windswept, shallow, turbid reservoirs with low or no populations of largemouth bass or white bass, do not attempt to establish hybrid bass populations unless an adequate forage base of gizzard shad or threadfin shad < 100 mm TL can be established and sustained from mid-April through October of each year. Hybrid bass introductions in Oklahoma have been most successful in relatively clear reservoirs (90 cm median visibility) with good primary productivity (Kleinholz, 1983).

3. Alternate forage, such as inland silversides, should not be introduced in reservoirs such as Lake Carl Blackwell. Silversides have been reported to be important forage for small largemouth and white basses in lake Texoma (Mense, 1967) but although abundant, were consumed infrequently by all of the predators studied in Lake Carl Blackwell. Similar data have been reported for largemouth bass in Texas (Hall, 1977) and for largemouth bass, white bass and striped bass x white bass hybrids in Sooner Reservoir, Oklahoma (Gilliland, 1981). The high turbidities present in shallow windswept reservoirs such as Blackwell often depress primary production. Depression of primary production results in irregular food shortages for forage fishes, and such reservoirs may not be good candidates for introductions of additional species (Li and Moyle, 1981). Habitat modifications to decrease turbidity and increase productivity of the reservoirs could be of greater benefit to sport fisheries (Noble, 1981; Ploskey and Jenkins, 1982).

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APPENDIX A

TABLES

TABLE I

RELATIVE ABUNDANCE OF SELECTED FISH SPECIES IN HAMS LAKE

Species	Number 1980	1981	1982
Black crappie	0.02 (44)[1]	0.03 (172)	0.12 (306)
Bluegill sunfish	0.62 (1447)	0.70 (3552)	0.32 (821)
Channel catfish	0.02 (54)	0.02 (84)	0.03 (87)
Green sunfish	0.02 (62)	0.01 (56)	0.01 (24)
Gizzard shad	0.08 (211)	0.02 (91)	0.12 (296)
Lepomis spp. fry	-	0.11 (535)	0.18 (473)
Largemouth bass	0.03 (296)	0.03 (243)	0.09 (236)
Redear sunfish	0.17 (438)	0.05 (276)	0.08 (193)
Striped bass x white bass hybrid	-	0.01 (29)	0.02 (39)

[1] Numbers in parentheses are numbers of fish collected.

I Continued

	Weight		
	1980	1981	1982
Black crappie	0.05	0.09	0.10
Bluegill sunfish	0.13	0.11	0.13
Channel catfish	0.33	0.43	0.27
Green sunfish	0.04	<0.01	<0.01
Gizzard shad	0.08	0.13	0.10
Lepomis spp. fry	-	<0.01	<0.01
Largemouth bass	0.22	0.08	0.20
Redear sunfish	0.12	0.13	0.11
Striped bass x white bass hybrid	-	0.01	0.06

TABLE II

RELATIVE IMPORTANCE AND RANK OF FOOD ITEMS IN DIETS OF LARGEMOUTH BASS IN HAMS LAKE

Food item	Importance			Rank		
	1980	1981	1982	1980	1981	1982
Centrarchids	0.29	0.16	0.64	1	4	1
Gizzard shad	0.13	0.13	0.09	4	5	2
Unidentified fish	0.23	0.16	0.08	2	3	3
Odonata	0.02	0.20	0.08	7	2	4
Ephemeroptera	0.16	0.28	<0.01	3	1	7
Crayfish	0.06	0.01	0.04	6	8	6
Diptera	0.00	0.02	<0.01	N/A	7	8
Miscellaneous	0.11	0.04	0.05	5	6	5

TABLE III

MEDIAN TOTAL LENGTHS (MM) OF LARGEMOUTH BASS WHICH CONSUMED SPECIFIC FOOD ITEMS

Food items	Largemouth bass median total lengths		
	1980*	1981	1982
Centrarchids	250	218 (5.5)	264 (21.7)
Gizzard shad	267	289 +	259 (17.4)
Unidentified fish	222	71 +	213 (18.5)
Odonata	247	68 (3.6)	259 (10.5)
Ephemeroptera	245	50 +	278 (10.8)
Crayfish	263	281 (4.8)	261 (20.0)
Diptera			224 (2.3)
Miscellaneous	234	52 (4.6)	293 (11.6)

Values in parentheses indicate the percentage of maximum buccal capacity of largemouth bass for specific food items.

* Insufficient data was collected for estimates of percent maximum capacity in 1980.

+ Food items were too decomposed for accurate determinations.

TABLE IV

FORAGE SELECTIVITY OF LARGEMOUTH BASS IN HAMS LAKE

	Lepomis spp.		Gizzard shad	
	A	O	A	O
1980	-0.18	0.16	0.06	0.002
1981	-0.29	0.34	0.05	-0.003
1982	0.30	0.38	0.04	0.04

A - refers to all sizes of largemouth bass

O - refers to largemouth bass with the same buccal gape as striped bass x white bass hybrids

TABLE V

RELATIVE IMPORTANCE AND RANK OF FOOD ITEMS IN DIETS OF STRIPED BASS X WHITE BASS HYBRIDS IN HAMS LAKE

	Importance		Rank	
Food item	1981	1982	1981	1982
Centrarchids	0.12	0.04	2	3
Gizzard shad	0.00	0.68	N/A	1
Unidentified fish	0.75	0.04	1	4
Diptera	0.04	0.22	3	2
Ephemeroptera	0.04	0.01	5	5
Miscellaneous	0.04	<0.01	4	6

TABLE VI

FORAGE SELECTIVITY OF STRIPED BASS X WHITE BASS HYBRIDS IN HAMS LAKE

	Lepomis spp.		Gizzard shad	
	Annual	Daily	Annual	Daily
1981	-0.25	0.04	-1.00	-1.00
1982	-0.23	0.01	0.65	0.68

TABLE VII

DIET OVERLAP OF LARGEMOUTH BASS AND STRIPED BASS X WHITE BASS HYBRIDS IN HAMS LAKE

	A	0
1981	0.56	0.42
1982	0.27	0.43

"A" refers to all sizes of largemouth bass and hybrid bass, "O" refers to largemouth bass and hybrid bass with the same buccal gape.

TABLE VIII

GROWTH AND AGE COMPOSITION OF SELECTED FISH SPECIES IN HAMS LAKE

	I	II	III	IV	V	VI
Black crappie						
1979	108(4)	159(1)	204(1)			
1980	77(1)	124(5)	162(13)	198(7)	207(1)	
1981	56(1)	124(5)	166(10)	181(6)	205(1)	
Bluegill sunfish						
1979	91(11)	112(25)	112(17)	116(4)		
1980	84(1)	99(7)	115(9)	134(19)	155(4)	
1981	61(2)	111(7)	126(5)	141(3)	131(1)	
Gizzard shad						
1979	127(8)[1]	223(5)	231(3)			
1980	135(15)[1]	237(2)	253(12)	255(1)		
1981	184(8)	214(7)	225(6)			
Largemouth bass						
1979	124(13)	207(73)	270(25)	341(8)	434(1)	
1980	105(3)	206(54)	276(30)	288(9)		466(1)
1981	104(5)	191(4)	250(6)	314(1)	418(2)	460(1)
Redear sunfish						
1979	74(20)	104(22)	145(13)	153(1)		
1980	45(16)[1]	103(2)	189(7)	170(5)	178(2)	
1981	39(2)	144(3)	157(7)	168(10)	172(1)	

Data are reported as median TL (mm) at annulus and the number of fish in each sample (N).

[1] No age I fish were collected. These data are median TL at age I of all fish collected.

VIII Continued

	I	II	III	IV	V	VI
Striped bass x white bass hybrids						
1981	130(1)	199(12)	286(4)			

TABLE IX

GROWTH INCREMENTS OF SELECTED FISH SPECIES IN HAMS LAKE

	I	II	III	IV	V	VI
Black crappie						
1979	108(4)	51(1)	45(1)			
1980	77(1)	47(5)	38(13)	36(7)	9(1)	
1981	56(1)	68(5)	42(10)	15(6)	24(1)	
Bluegill sunfish						
1979	91(11)	21(25)	0(17)	3(4)		
1980	84(1)	15(7)	16(9)	19(19)	21(4)	
1981	61(2)	50(7)	15(5)	15(3)	-10(1)	
Gizzard shad						
1979	127(8)[1]	96(5)	8(3)			
1980	135(15)[1]	102(2)	16(12)	2(1)		
1981	184(8)	31(7)	10(6)			
Largemouth bass						
1979	124(13)	87(73)	63(25)	71(8)	92(1)	
1980	105(3)	101(54)	70(30)	12(9)		
1981	104(5)	87(4)	59(6)	64(1)	104(2)	42(1)
Redear sunfish						
1979	74(20)	29(22)	41(13)	8(1)		
1980	45(16)[1]	58(2)	86(7)	-19(5)	8(2)	
1981	39(2)	105(3)	13(7)	11(10	4(1)	

Data reported are median increment (mm) at annulus and number of fish (N) in each age class.

[1] No age I fish were collected. These data are the median TL at age I of all fish collected.

TABLE X

RELATIVE ABUNDANCES OF SELECTED FISH SPECIES IN LAKE CARL BLACKWELL

	Numbers					
	1980	(N)	1981	(N)	1982	(N)
Bluegill sunfish	0.10	(434)	0.10	(254)	0.04	(364)
Carp	0.02	(97)	0.01	(33)	0.01	(97)
Channel catfish	0.04	(169)	0.05	(132)	0.02	(183)
Freshwater drum	0.01	(66)	0.03	(71)	0.02	(152)
Gizzard shad	0.27	(1204)	0.20	(499)	0.53	(4550)
Inland silverside	0.20	(898)	0.16	(415)	0.08	(702)
Largemouth bass	0.01	(62)	0.02	(43)	0.02	(180)
Red shiner	0.14	(607)	0.02	(42)	0.04	(308)
River carpsucker	0.01	(34)	0.01	(30)	<0.01	(19)
Striped bass x white bass hybrid	-	-	<0.01	(2)	<0.01	(18)
White bass	0.01	(53)	0.03	(76)	0.02	(147)
White crappie	0.16	(705)	0.21	(539)	0.18	(1551)

X Continued

	Weight		
	1980	1981	1982
Bluegill sunfish	0.01	0.04	0.03
Carp	0.23	0.12	0.13
Channel catfish	0.23	0.18	0.17
Freshwater drum	0.02	0.01	0.03
Gizzard shad	0.10	0.09	0.11
Inland silverside	<0.01	<0.01	<0.01
Largemouth bass	0.06	0.10	0.21
Red shiner	<0.01	<0.01	<0.01
River carpsucker	0.12	0.15	0.05
Striped bass x white bass hybrid	-	<0.01	0.01
White bass	0.08	0.11	0.06
White crappie	0.10	0.16	0.15

TABLE XI

RELATIVE IMPORTANCE AND RANK OF FOOD ITEMS EATEN BY LARGEMOUTH BASS IN LAKE CARL BLACKWELL

Food item	Importance			Rank		
	1980	1981	1982	1980	1981	1982
Centrarchids	0.16 (290)	0.45 (315)	0.22 (451)	2	1	2
Gizzard shad	0.13 (290)	0.40 (308)	0.54 (301)	3	2	1
Unidentified fish	0.09 (75)	0.10 (118)	0.17 (226)	4	3	3
Ephemeroptera	0.06 (84)	<0.01 (96)	<0.01 (89)	5	4	7
Crayfish	0.04 (237)	N/A	0.01 (302)	6		5
Diptera	N/A	N/A	0.01 (37)			6
Terrestrial insects	0.51 (79)	N/A	0.03 (238)	1		4

Median total lengths of predators are shown in parentheses

TABLE XII

MEDIAN TOTAL LENGTHS (MM) OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL WHICH PREYED ON SPECIFIC FOOD ITEMS

	Largemouth bass total length		
	1980	1981	1982
Centrarchids	290[1]	315 (49)	451 (45)
Gizzard shad	136	308 (56)	301 (29)
Ephemeroptera	84	96 (27)	89
Astacidae	237	-	302 (18)
Diptera	-	-	37
Terrestrial insects	79	-	-

Numbers in parentheses give the median percentages of the maximum sizes of prey items which were eaten.

[1] No data on percent gape was available in 1980.

TABLE XIII

ANNUAL AND DAILY FORAGE SELECTIVITY OF LARGEMOUTH BASS IN LAKE CARL BLACKWELL

	1980		1981		1982	
Forage	Annual	Daily	Annual	Daily	Annual	Daily
Centrarchids	-0.030	0.158	0.054	0.441	0.157	0.210
Gizzard shad	-0.190	0.126	0.201	0.345	0.191	0.450

TABLE XIV

RELATIVE IMPORTANCE AND RANK OF FOOD ITEMS EATEN BY WHITE BASS IN LAKE CARL BLACKWELL

	Importance			Rank		
Food item	1980	1981	1982	1980	1981	1982
Gizzard shad	0.46 (218)	0.77 (238)	0.41 (295)	1	1	1
Diptera	0.08 (188)	0.09 (260)	0.02 (85)	3	2	5
Ephemeroptera	0.41 (196)	0.04 (230)	0.13 (262)	2	4	4
Unidentified fish	0.05 (192)	0.03 (221)	0.18 (95)	4	5	3
Centrarchids	<0.01 (194)	<0.01 (230)	<0.01 (69)	5	6	6
Other	<0.01 (200)	0.06 (72)	0.26 (75)	6	3	2

Median total lengths of predators are shown in parentheses

TABLE XV

ANNUAL AND DAILY FORAGE SELECTIVITY OF WHITE BASS IN LAKE CARL BLACKWELL

	1980		1981		1982	
Forage	Annual	Daily	Annual	Daily	Annual	Daily
Centrarchids	-0.083	-1.0	-0.374	-0.008	-0.038	-0.002
Gizzard shad	0.315	0.456	0.573	0.741	0.153	0.378

TABLE XVI

RELATIVE IMPORTANCE AND RANK OF FOOD ITEMS EATEN BY STRIPED BASS X WHITE BASS HYBRIDS IN LAKE CARL BLACKWELL DURING 1982

Food item	Importance	Rank
Unidentified fish	0.42 (275)	1
Ephemeroptera	0.30 (218)	2
Gizzard shad	0.27 (175)	3
Miscellaneous	0.01 (248)	4

Median total lengths (mm) of predators are given in parentheses.

TABLE XVII

DIET OVERLAP BETWEEN LARGEMOUTH BASS AND WHITE BASS IN LAKE CARL BLACKWELL

	All	Overlap
1980	0.57	0.77
1981	0.54	0.81
1982	0.75	0.58

"All" indicates all largemouth bass and white bass, and "overlap" refers to only those largemouth bass and white bass with the same buccal gape.

TABLE XVIII

DIET OVERLAP OF STRIPED BASS X WHITE BASS HYBRIDS WITH WHITE BASS AND LARGEMOUTH BASS IN 1982

Hybrid bass vs. White bass		Hybrid bass vs. Largemouth bass	
"A"	"O"	"A"	"O"
0.72	0.60	0.55	0.92

"A" refers to all sizes of predators and "O" refers to only those white bass and largemouth bass with the same buccal gape (29-41 mm) as striped bass x white bass hybrids.

TABLE XIX

GROWTH AND AGE COMPOSITION OF SELECTED FISH SPECIES IN LAKE CARL BLACKWELL

	I	II	III	IV	V	VI	VII
Bluegill sunfish							
1980	57 (4)	98 (6)	144 (6)	170 (3)	163 (3)		
Incr	57	41	46	26	-7		
1981	72 (7)	98 (21)	145 (4)	162 (1)			
Incr.	72	26	47	17			
Gizzard shad							
1979	74 (3)	85 (1)	158 (1)				
Incr.	74	11	73				
1980	141 (8)	188 (5)	243 (2)				
Incr.	141	47	55				
1981	140 (25)	137 (15)	171 (4)				
Incr.	140	-3	34				
Largemouth bass							
1979	93 (1)	215 (3)	337 (5)	384 (4)			
Incr.	93	122	122	47			
1980	119 (10)	192 (8)	231 (6)	360 (5)	395 (5)		
Incr.	119	73	39	129	35		
1981	124 (1)	224 (9)	225 (4)	306 (8)	426 (2)	464 (4)	499 (1)
Incr.	124	100	1	81	120	38	35

Data are reported as median TL (mm) at annulus and number of fish (N) in each sample.

TABLE XIX

CONTINUED

	I	II	III	IV	V	VI	VII
White bass							
1979	97 (17)	218 (27)	301 (12)	422 (1)	412 (1)		
Incr.	97	121	83	121	-10		
1980	113 (5)	206 (31)	278 (12)	335 (5)	406 (5)	441 (1)	
Incr.	113	93	72	57	71	35	
1981	104 (3)	224 (10)	283 (15)	338 (8)	339 (1)		
Incr.	104	120	59	55	1		
White crappie							
1979	104 (32)	125 (65)	142 (14)				
Incr.	104	21					
1980	75 (9)	131 (13)	157 (15)	182 (16)	274 (12)	337 (3)	
Incr.	75	56	26	25	92	63	
1981	77 (6)	109 (23)	135 (2)	- (0)	278 (2)		
Incr.	77	32	26				

Data are reported as median TL (mm) at annulus and number of fish (N) in each sample.

TABLE XX

STATEWIDE GROWTH RATES OF SELECTED SPECIES OF OKLAHOMA FISH.[1]

	I	II	III	IV	V	VI	VII
Black crappie							
TL	80.3	123.9	181.8	210.3	289.7		
Incr.	80.3	43.6	57.9	28.5	79.4		
Bluegill sunfish							
TL	64.3	107.0	132.0	149.7	165.6	184.5	
Incr.	64.3	42.7	25.0	17.7	15.9	18.9	
Gizzard shad							
TL	119.1	180.6	221.7	266.5	297.9	381.2	409.0
Incr.	119.1	61.5	41.1	44.8	31.4	83.3	27.8
Largemouth bass							
TL	133.1	231.3	308.0	386.1	423.0	465.4	517.7
Incr.	133.1	98.2	76.7	78.1	36.9	42.4	52.3
Redear sunfish							
TL	62.2	108.6	142.0	155.7	179.0		
Incr.	62.2	46.4	33.4	13.7	23.3		
White bass							
TL	130.2	237.9	309.5	366.8	394.0		
Incr.	130.2	107.7	71.6	57.3	27.2		
White crappie							
TL	77.3	139.5	195.9	230.7	290.4		
Incr.	77.3	62.2	56.4	34.8	59.7		

[1] Data taken from Mense 1976.

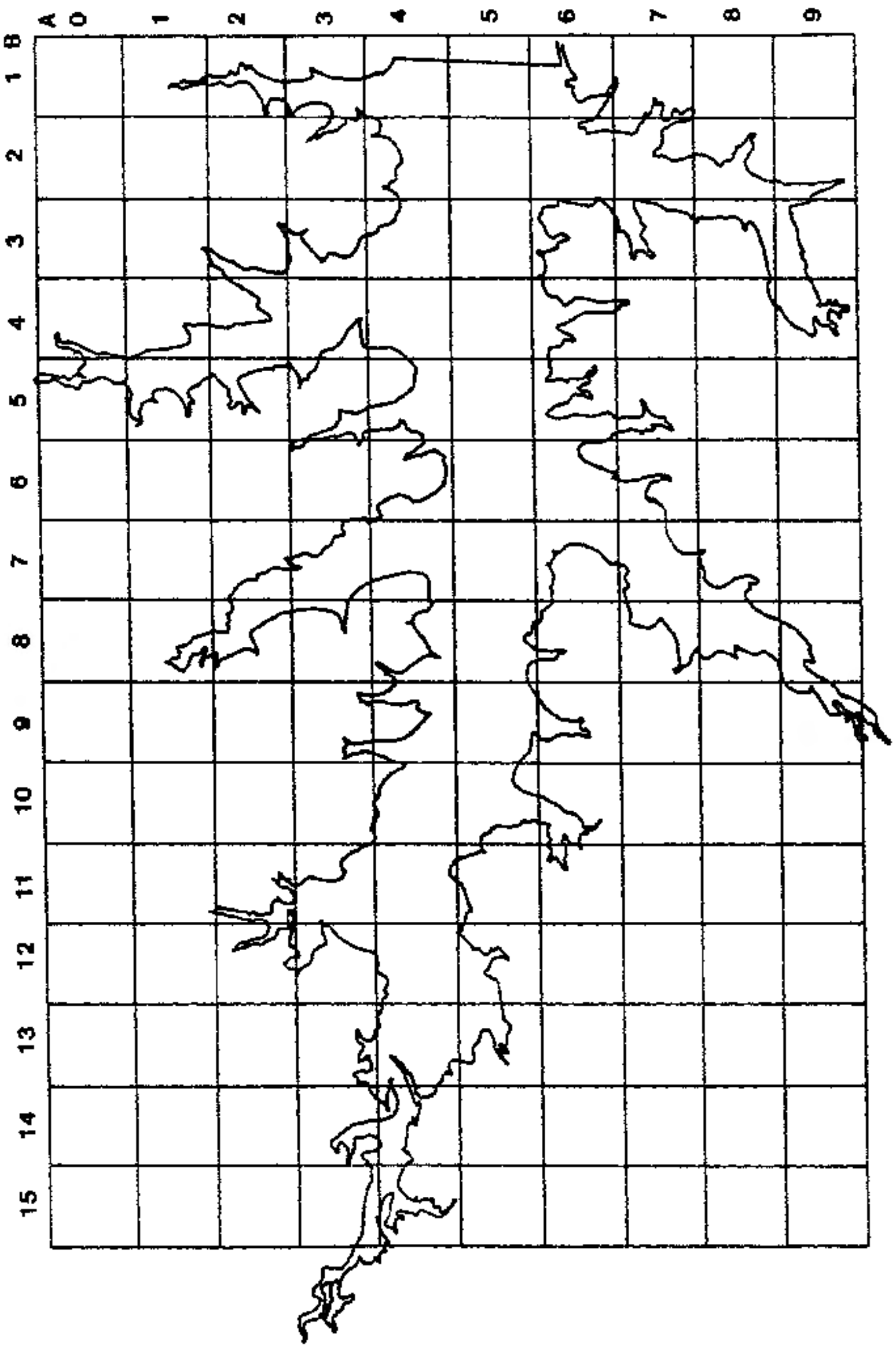

Figure 1. Lake Carl Blackwell

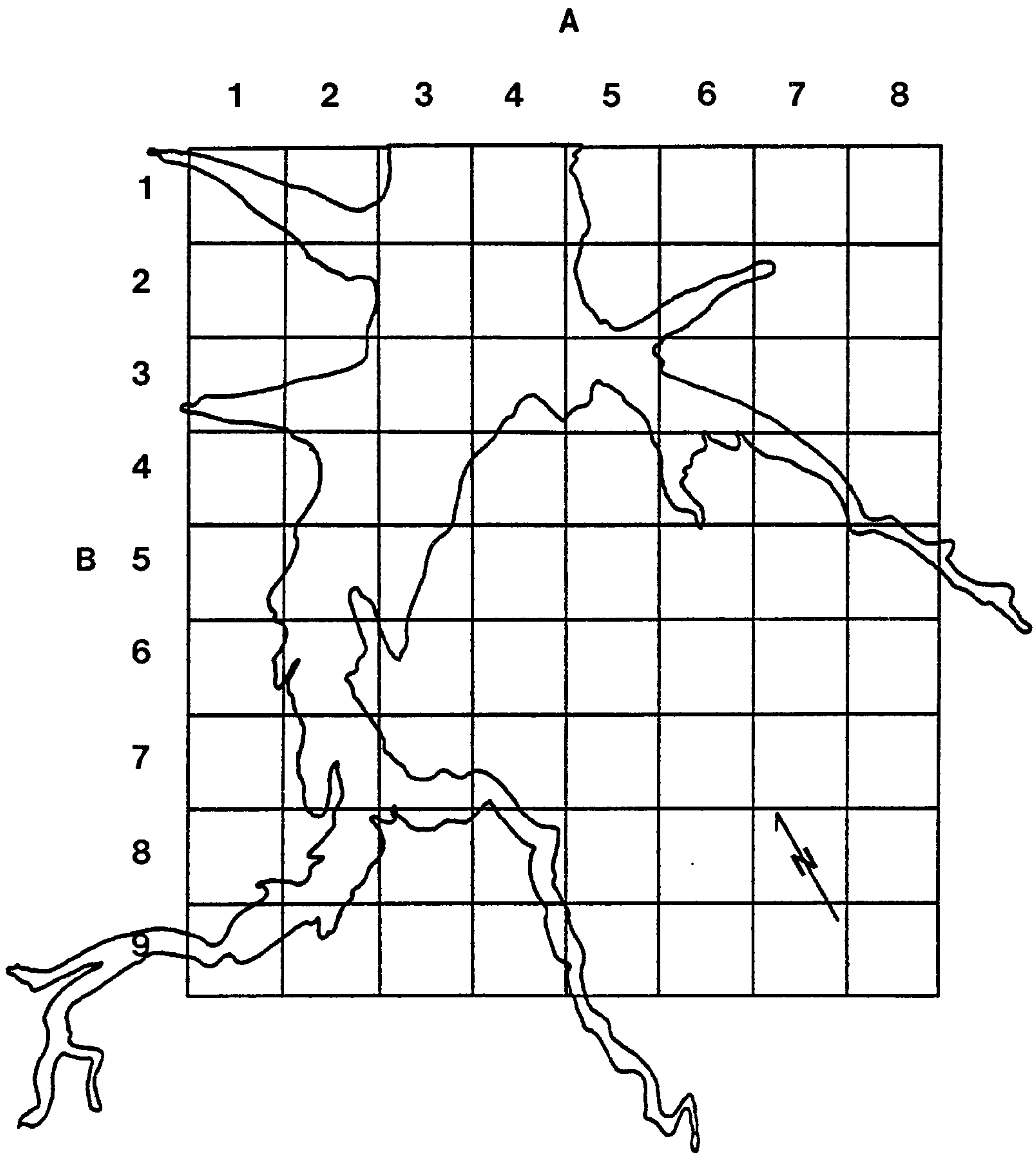

Figure 2. Hams Lake

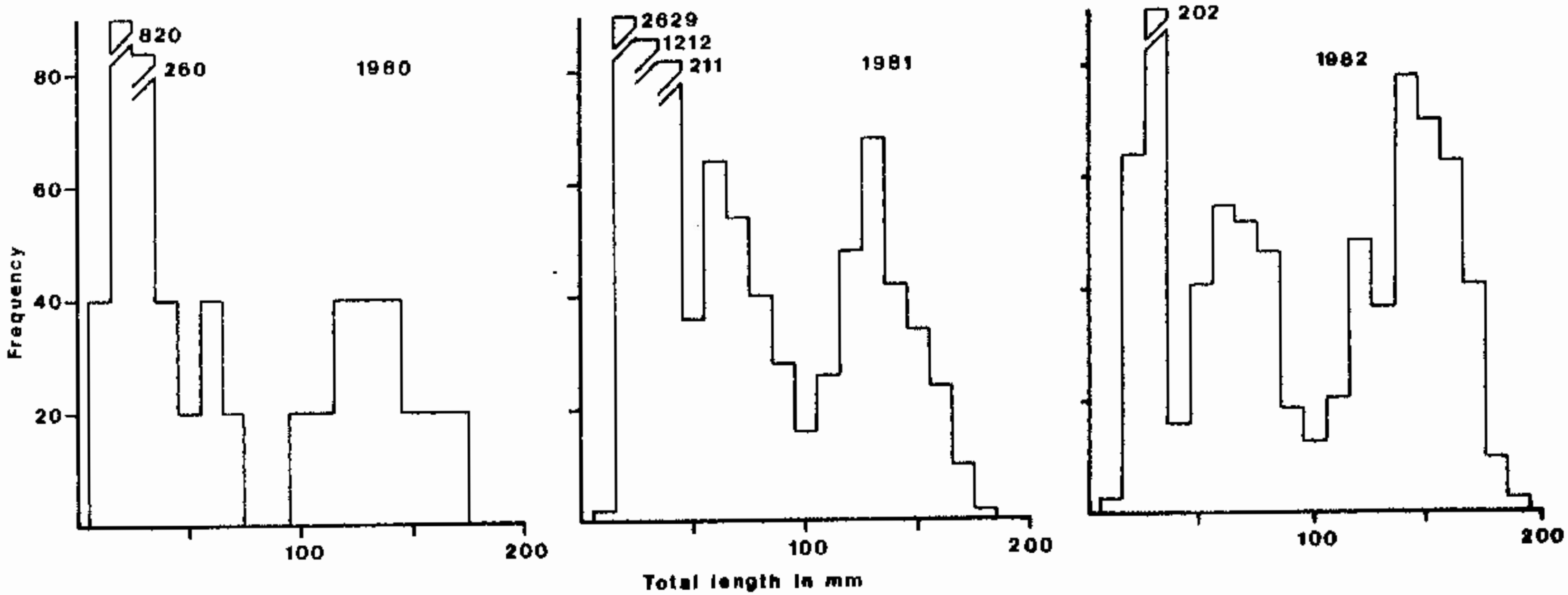

Figure 3. Length Frequencies of Bluegill Sunfish in Hams Lake

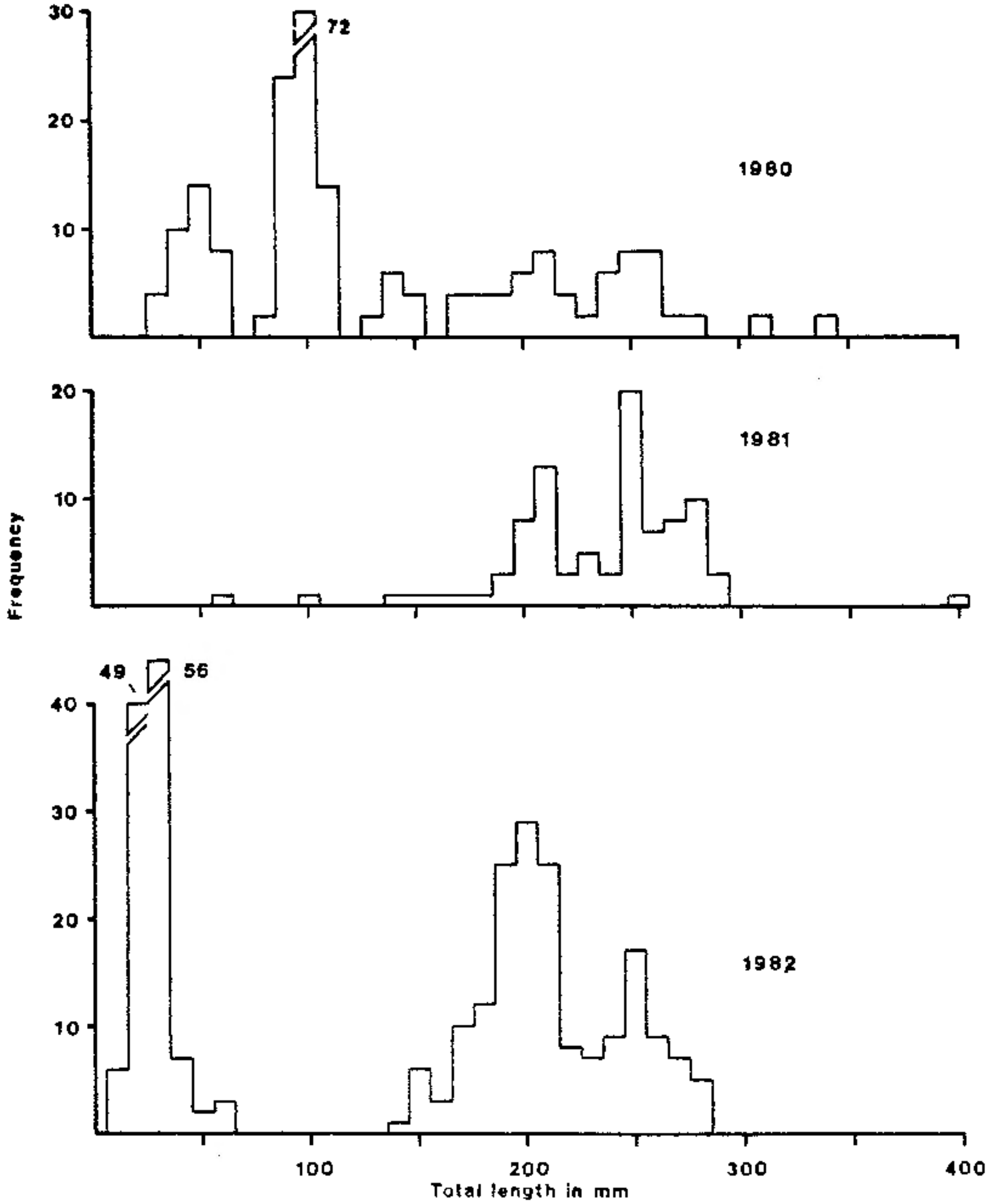

Figure 4. Length Frequencies of Gizzard Shad in Hams Lake

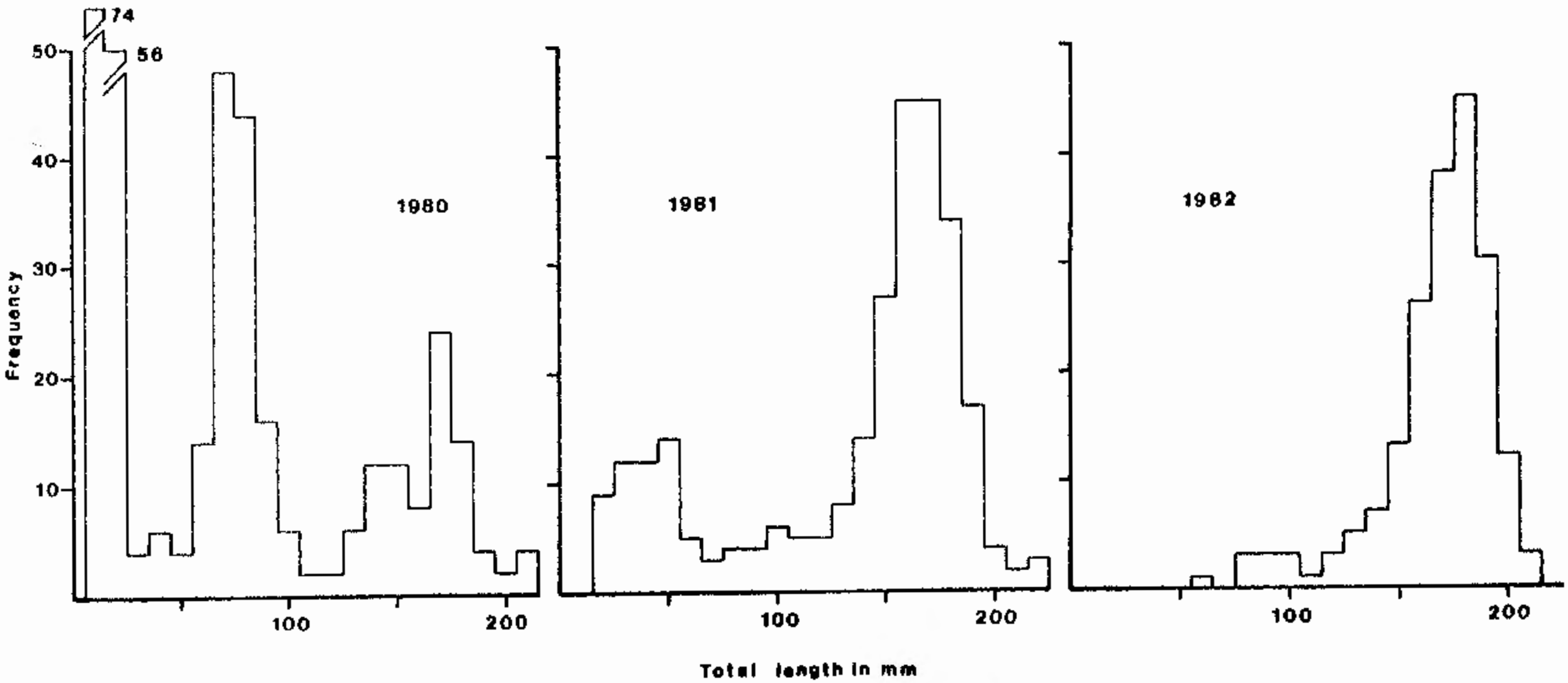

Figure 5. Length Frequencies of Redear Sunfish in Hams Lake

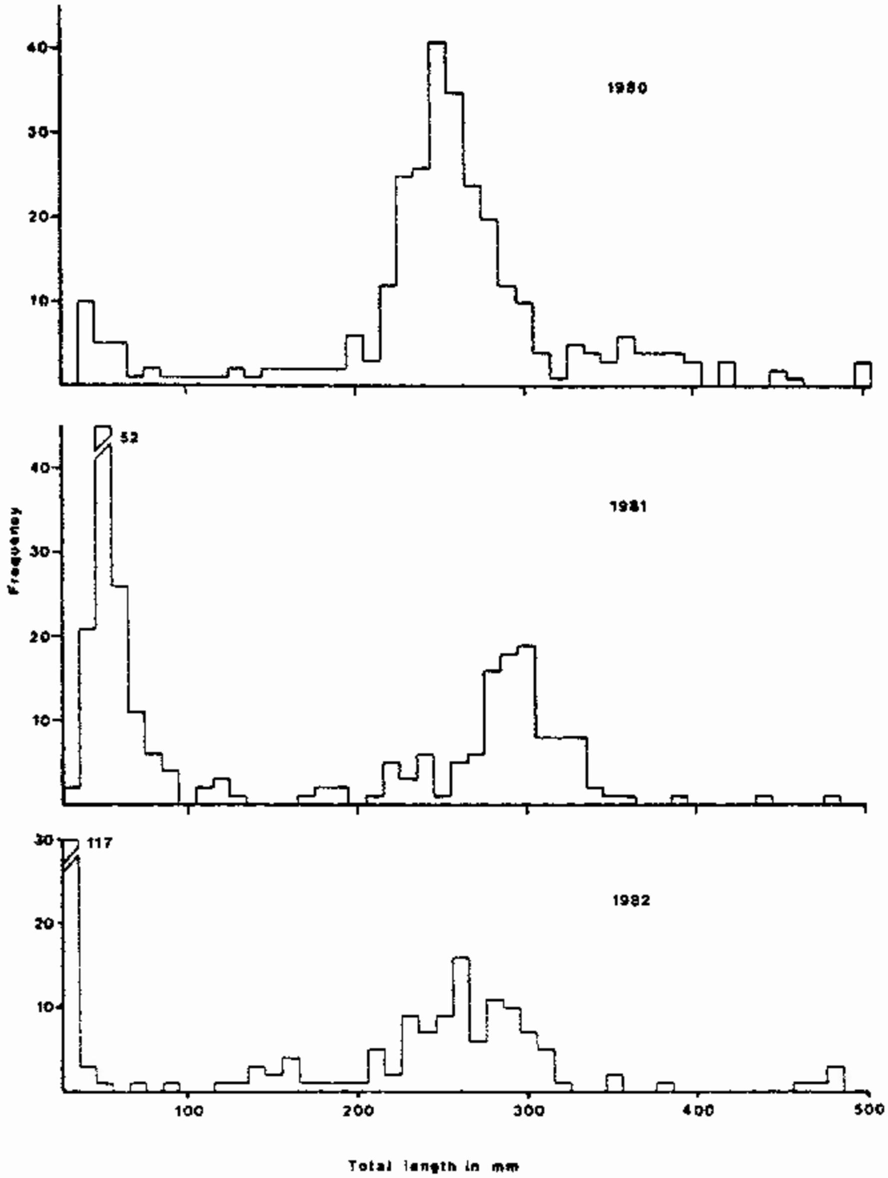

Figure 6. Length Frequencies of Largemouth Bass in Hams Lake

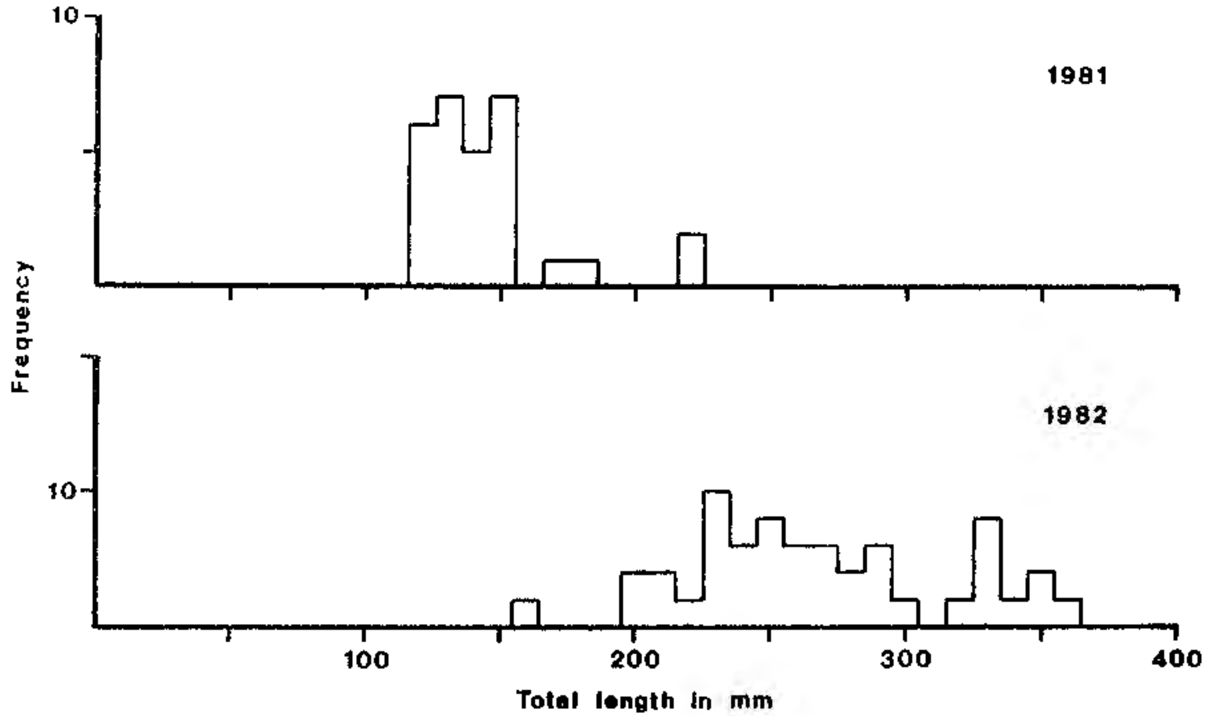

Figure 7. Length Frequencies of Striped Bass x White Bass Hybrids in Hams Lake

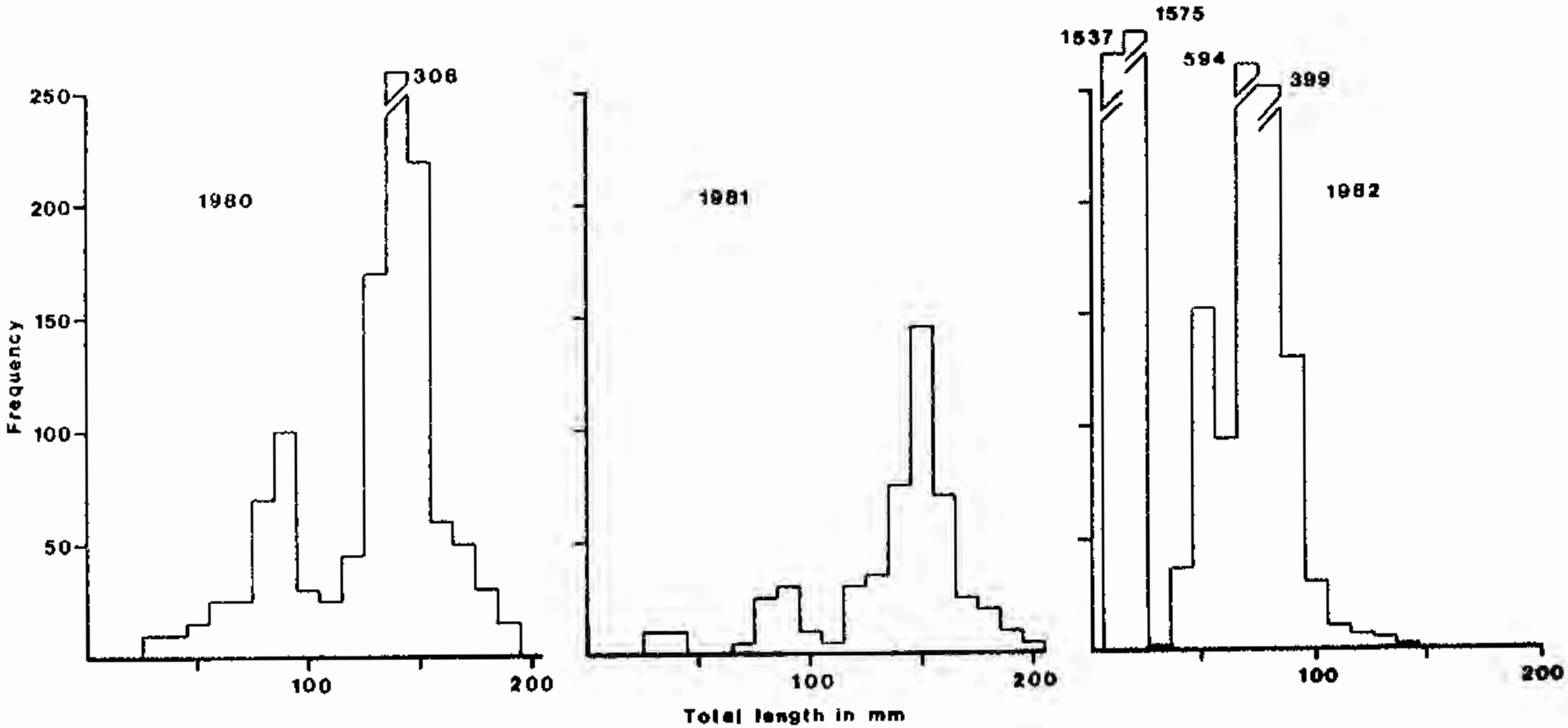

Figure 8. Length Frequencies of Gizzard Shad in Lake Carl Blackwell

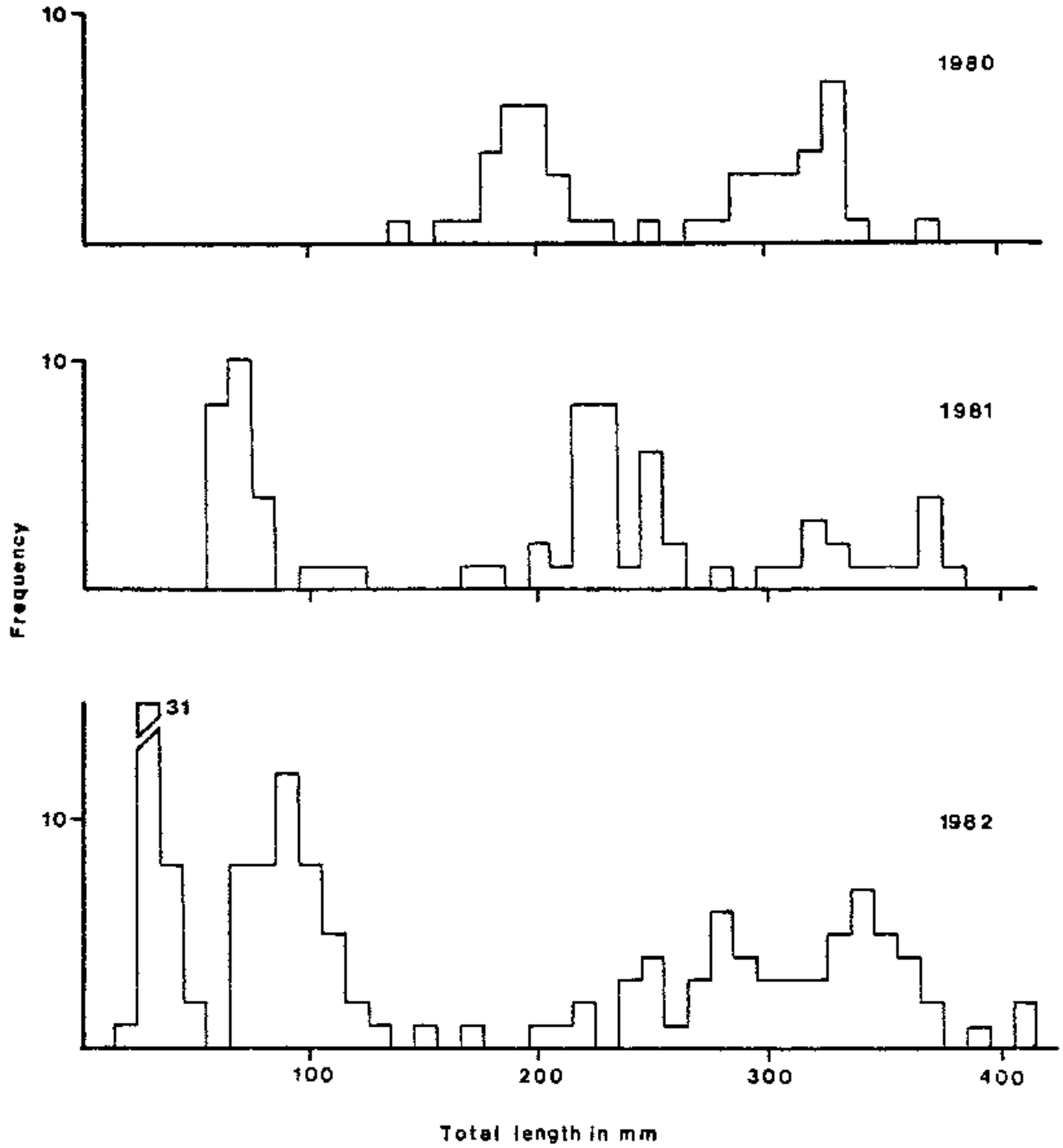

Figure 9. Length Frequencies of White Bass in Lake Carl Blackwell

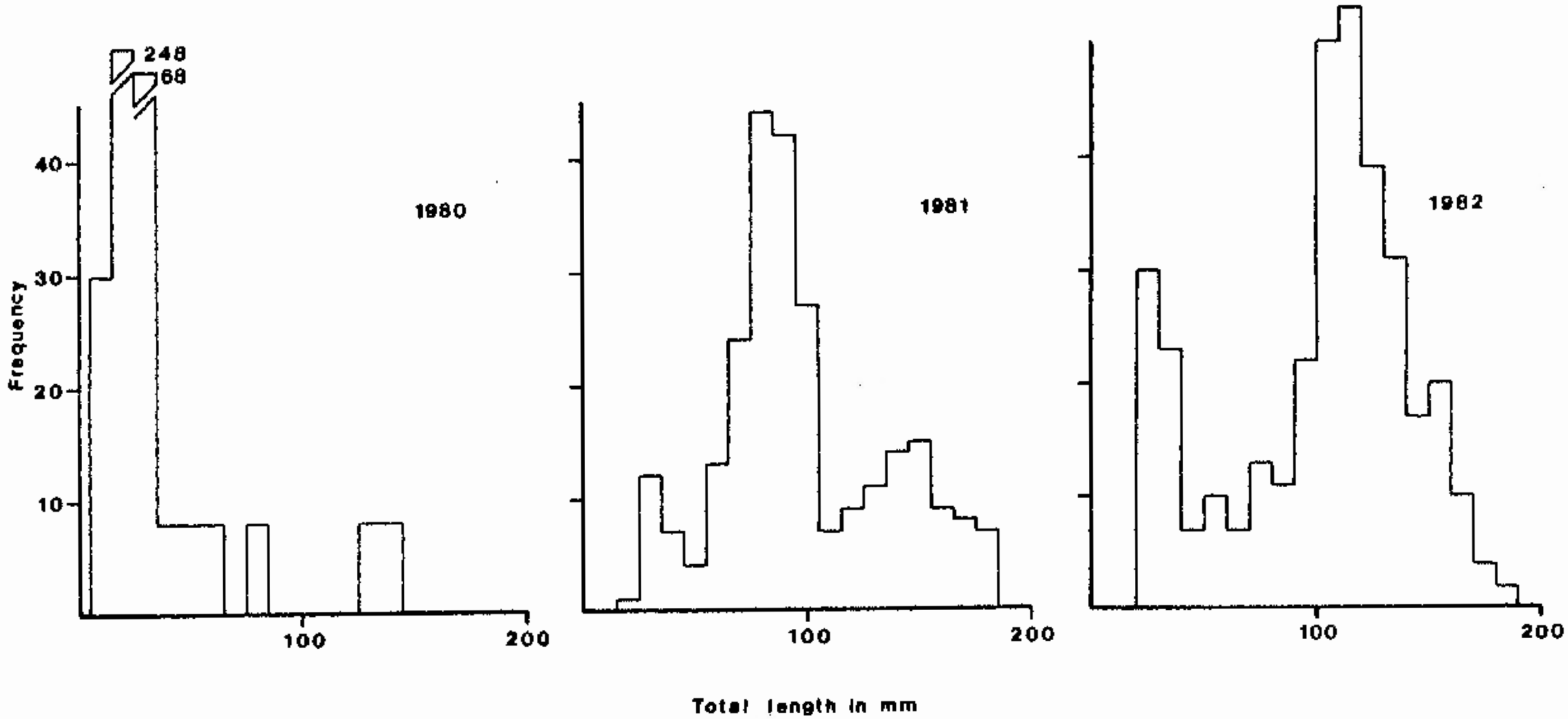

Figure 10. Length Frequencies of Bluegill Sunfish in Lake Carl Blackwell

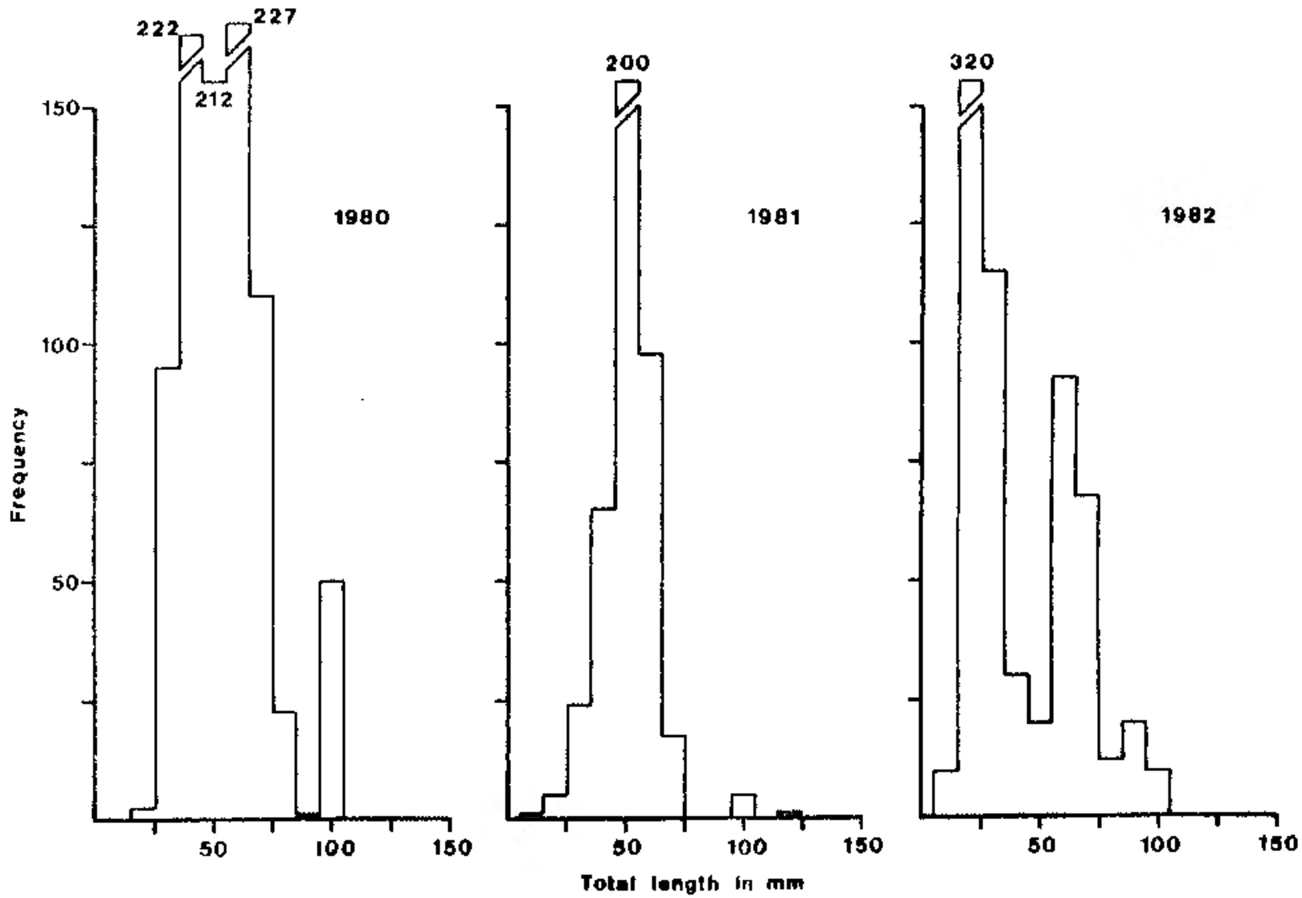

Figure 11. Length Frequencies of Inland Silversides in Lake Carl Blackwell

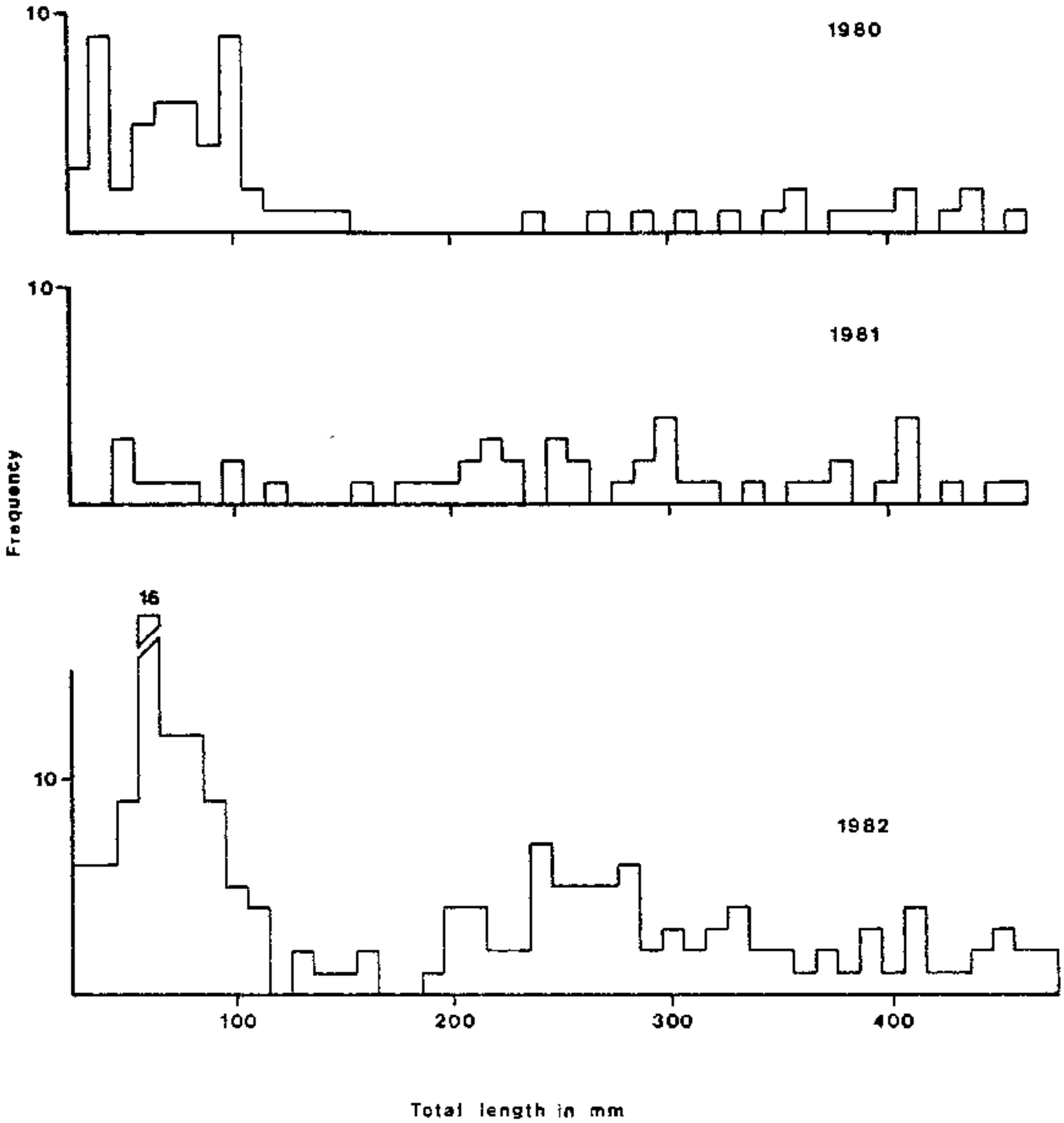

Figure 12. Length Frequencies of Largemouth Bass in Lake Carl Blackwell

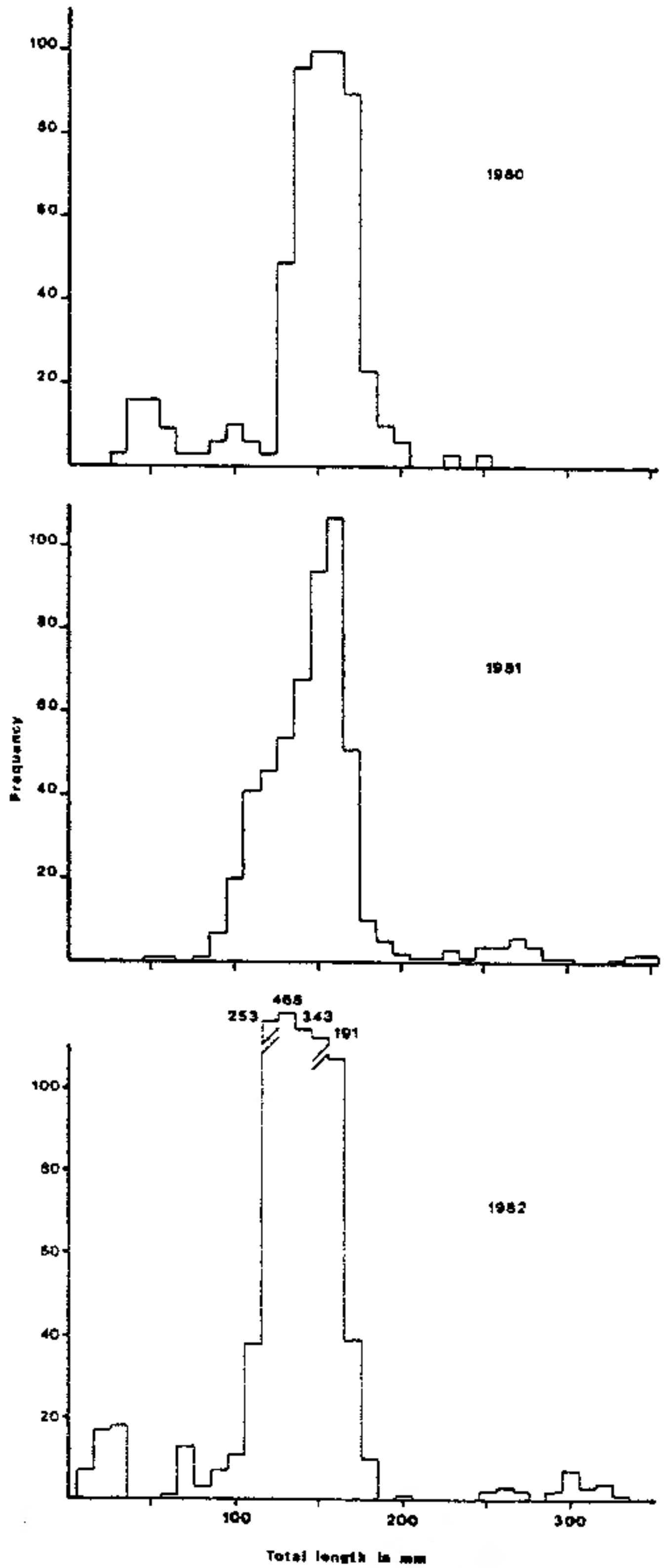

Figure 13. Length Frequencies of White Crappie in Lake Carl Blackwell

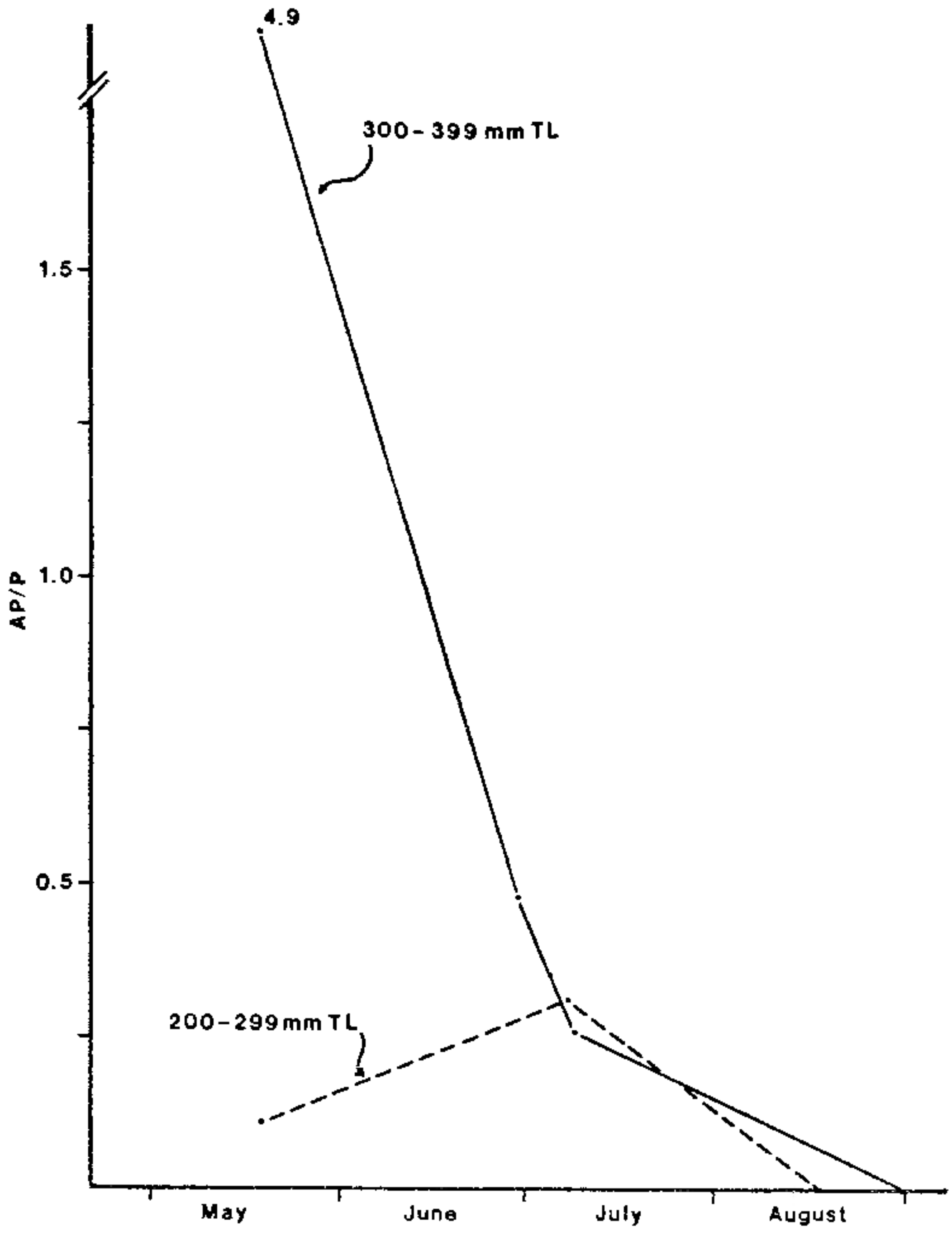

Figure 14. Availability of Gizzard Shad to Two Size Classes of Hybrid Bass

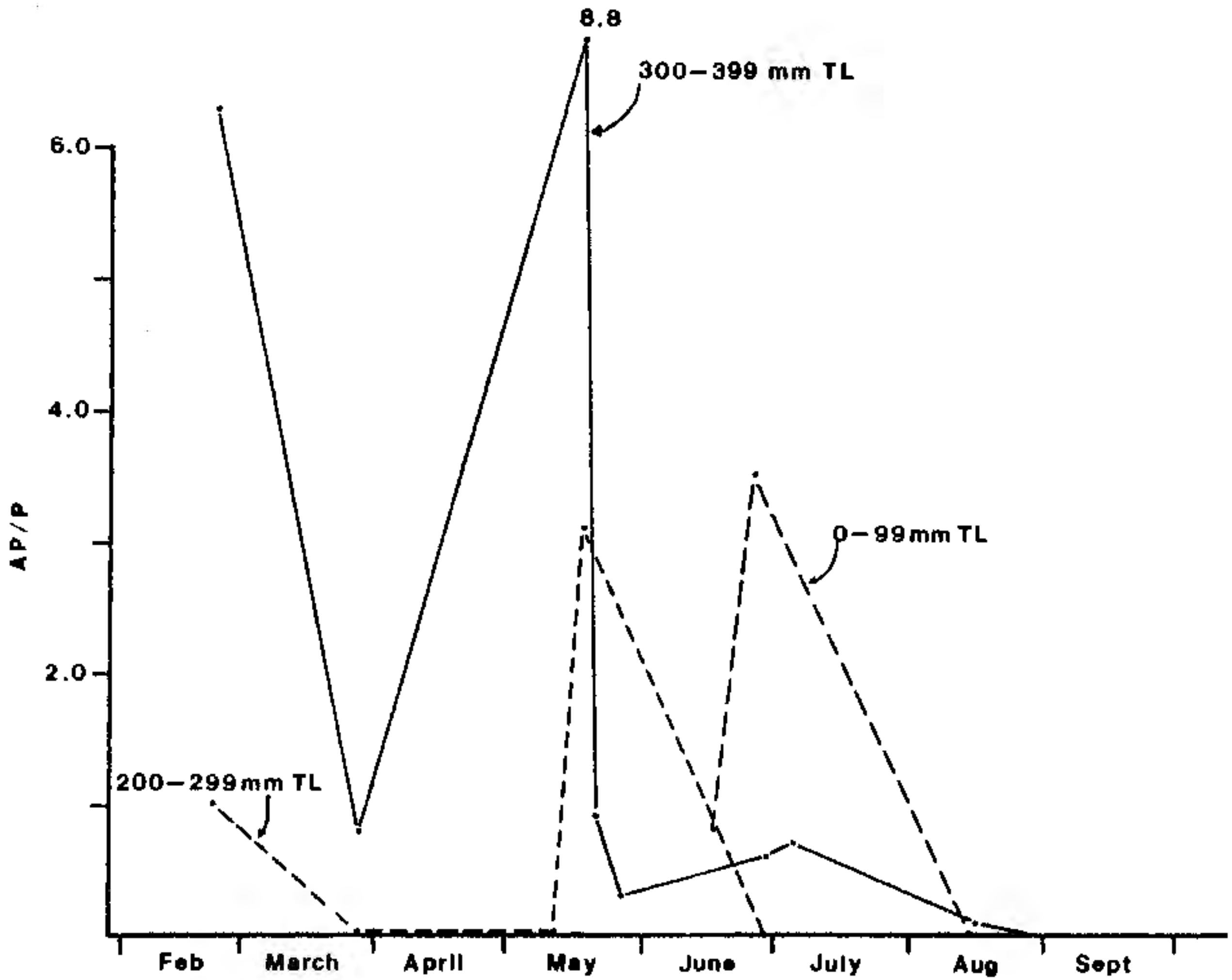

Figure 15. Availability of Gizzard Shad to Three Size Classes of White Bass

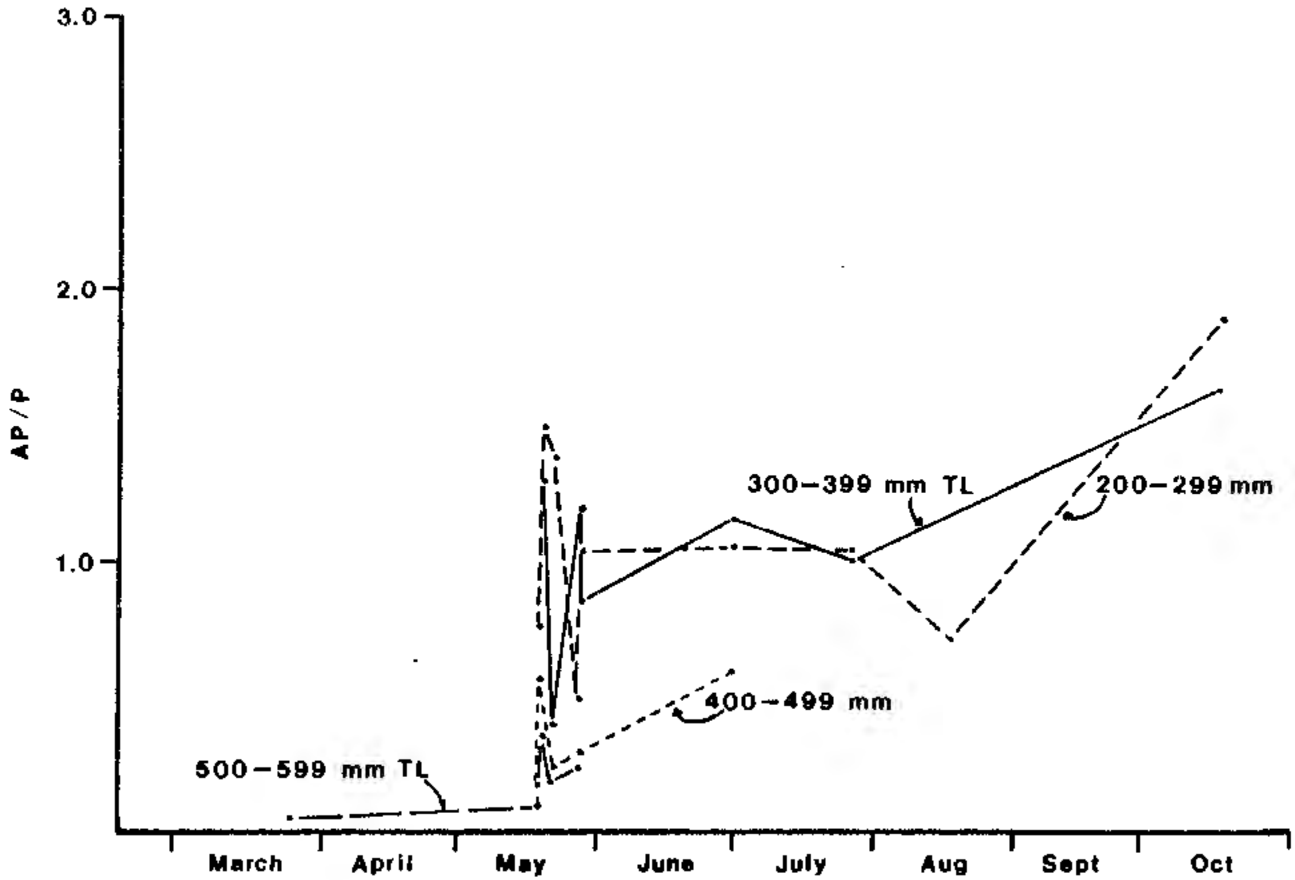

Figure 16. Availability of Gizzard Shad to Four Size Classes of Largemouth Bass

VITA

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