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FINAL REPORT

RESEARCH AND SURVEYS

FEDERAL AID PROJECT NO. F-41-R

FACTORS INFLUENCING FISH POPULATIONS IN OKLAHOMA LAKES AND PONDS

JOB NO. 4

CHANGES IN FORAGE FISH POPULATIONS AFTER INTRODUCTION OF STRIPED BASS X WHITE BASS HYBRIDS

OCTOBER 1, 1979 THROUGH JUNE 30,1983

FINAL REPORT

State: OKLAHOMA Project Number: F-41-R-4

Project Title: Factors influencing fish populations in Oklahoma lakes and ponds

Project Section: Research and Surveys

Job Title: Changes in forage fish populations after introduction of striped bass x white bass hybrids. Job No. 4.

Contract Period: From: 1 October 1979 To: 30 June 1983

I. OBJECTIVES

Program Objective:

To determine changes in populations of forage fish and growth rates of predatory fish in a reservoir containing striped bass x white bass hybrids.

Job Objective:

Introduce hybrids and compare population structures and growth rates of forage and predatory fish before and after introduction.

II. ABSTRACT:

Striped bass x white bass hybrids were stocked in Lakes Carl Blackwell and Hams in 1981 and 1982 to evaluate their impact on populations of forage fish and growth rates of predatory fish. The relative abundances of fish species in Hams Lake did not change between any two years, but the relative importance of gizzard shad decreased dramatically in 1981 subsequent to spring flooding. Centrarchids were the dominant forage of largemouth bass in 1981 and were selected regardless of the abundance or size suitability of gizzard shad. They were also the dominant forage of hybrid bass in 1981 when no

gizzard shad of suitable sizes were available, but gizzard shad dominated the hybrid bass diet in 1982. Hybrid bass ate centrarchids randomly and stongly selected gizzard shad. Hexagenia were eaten by 13 and 22% of hybrid bass in 1981 and 1982, respectively, but may be more important forage than their dietary rank indicated. Diet overlap between hybrid bass and largemouth bass with the same buccal gape was nearly constant between 1981 and 1982. Hexagenia was the largest component of diet overlap. Diet overlap data did not indicate severe competition between largemouth bass and hybrid bass. No other species of fish appeared to be impacted by the introduction of hybrid bass in Hams Lake.

No changes occurred in relative abundances of fish species between years in Lake Carl Blackwell. Centrarchids were the dominant forage of largemouth bass in 1981 but gizzard shad was the dominant forage in 1982. Centrarchids were selected over gizzard shad by largemouth bass in 1980 and 1981 but gizzard shad were selected over centrarchids in 1982. White bass selected gizzard shad and Hexagenia was important to white bass when gizzard shad were unavailable. Hexagenia was the only food of hybrid bass in 1981 and the most important food of hybrid bass in 1982. Diet overlap between largemouth bass and white bass indicated intense competition for forage in 1981 and overlap among the three predators in 1982 affected hybrid bass more than white bass. Hybrid bass and white bass partitioned diet items between various size classes of the two predators in 1982.

White bass in Lake Carl Blackwell could be negatively affected by hybrid introductions. However, low survival of striped bass x white bass hybrids, probably as a result of insufficient Hexagenia and gizzard

shad forage, preclude a definitive statement on the effect of introduction on white bass.

III. SIGNIFICANT DEVIATIONS FROM OBJECTIVES: None

IV. BACKGROUND:

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. rservoirs are commonly dominated by clupeids such as gizzard and threadfin shad (Jenkins 1957). These fish are highly fecund (Carlander 1953, 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 (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 et al. 1979) or severe reductions in population size (King et al. 1979) and possible extermination of stocks or species (Larkin 1977). Concurrent 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 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). Discovery of a landlocked population of striped bass in Santee Cooper Reservoir initiated introductions 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 (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 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 imagined. 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 whose maximum 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).

After surveys to locate reservoirs with both gizzard shad and largemouth or white bass, Hams Lake and Lake Carl Blackwell were selected for study of the effects of introduction of striped bass x white bass hybrids on forage fish and growth rates of other predators.

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 volume 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).

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 67.8 million m^3. 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 34 million m^3, 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 et al. 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 is the east shore (Zweiacker and Brown 1971).

V. PROCEDURES:

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 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 et al. 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. 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 for 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. 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 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 et al. 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 1953). Length of fish at age was calculated with the Dahl-Lea equation (Carlander 1953):

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

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 1953) 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 et al. 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:

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

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 (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:

$$L = r_i - p_i, \text{ where}$$

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

p_i = importance of forage i in the reservoir.

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 was 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 constructed to test for differences among years in the physical characteristics of mean total length, weight and condition, median total length and weight, and logarithmic regression of weight and body depth on total length for each species. The logarithmic regression of gape on total length was also analyzed for largemouth bass, white bass and hybrid bass. Each of the parameters was compared among years. The sum of the statistics obtained was used as the test statistic. With this method, differences in individual paramters (i.e., length or weight) which appear insignificant in single analyses may show statistical differences in fish populations when viewed in an array.

Contingency tables were also used to determine whether Lee's phenomenon (Carlander 1969) occurred in centrarchids, clupeids or basses in either reservoir and to compare differences in growth rates of the species.

VI. FINDINGS AND ANALYSIS:

Hams Lake

Relative Abundances

The relative abundances of fish species in Hams Lake did not change

statistically between any two of the years studied (P_{80-81} = 0.62; P_{81-82} = 0.22; P_{80-82} = 0.48). Bluegill sunfish was the dominant species during all three years (Table 1). Redear sunfish were second in importance in 1980 and 1981, and were third in 1982. Gizzard shad were third in 1980 and 1981, and second in 1982.

Significant changes in population structure of gizzard shad and redear sunfish occurred during the study (Table 2). 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 3). Redear sunfish produced a strong year class in 1980 but few YOY redear sunfish were found in 1981 and 1982 (Figure 4).

Significant changes also occurred in 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 5). 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 6) and frequency of occurrence between 1981 and 1982. All of the physical characteristics tested for hybrid bass increased between 1981 and 1982.

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

the study indicating that the introduction of striped bass x white bass hybrids had no immediate effect on their populations.

Food Habits

Fish was the dominant food for largemouth bass during the study, comprising 64 ± 18% of the diet. Food was present in 47, 63, and 54% of the largemouth bass collected in 1980, 1981, and 1982, respectively. Centrarchids comprised 36 ± 25% of largemouth bass diets during the study and were dominant in two of the three years (Table 3). Gizzard shad and unidentified fish comprised 12 ± 2 and 16 ± 8%, 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 ($X^2 = 73.05$, $P << 0.01$) during the study. 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 3) and reduced the suitability of gizzard shad as forage for largemouth bass. Strong year-classes of largemouth bass (Figure 5) and bluegill sunfish (Figure 7) reduced the median total length of largemouth bass containing centrarchids and unidentified fish (predominantly larval forms).

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. The shift from fish to aquatic insects occurred after development of dense mats of Chara and Najas, which may have reduced the accessibility of forage fish to 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 5). No data are available for daily prey suitability in 1980. Sixty and 46% of the bluegill 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 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 6). 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 ($X^2 = 1.36$, $P > F = 0.51$). 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. The aquatic insects in the diet indicate that striped bass x white bass hybrids foraged in littoral areas in 1981, and in open water in 1982. The conclusion regarding foraging is supported by daily prey availability. In 1981, no gizzard shad of forage size were collected with hybrid bass. Less than 1% of black crappie and redear sunfish, and 8% of bluegill sunfish were available to hybrid bass. In 1982, no redear sunfish, 5% of the black crappie, and 10% of bluegill sunfish could be consumed by hybrid bass. Few gizzard shad (0.2%) were available to hybrid bass in 1982, although gizzard shad was the dominant food item.

Annual selectivity data indicated that centrarchids were inaccessible or avoided by hybrid bass in both years, but daily data

show that centrarchids were eaten randomly (Table 7). 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 8). 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. Ephemeropteans 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 due to ephemeropterans, which ranked 7 and 5, respectively, in diets of largemouth bass and hybrid bass. During both years, diet overlap 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.

Age and Growth

Scale analyses of selected fish species are shown in Table 9. 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 (P = 0.17), when a very weak year class was produced, 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 (P = 0.12). Black crappie growth was similar in 1980 and 1981. In 1980 the reservoir level rose rapidly after heavy spring rains. Spawning was interrupted for most species. In 1981, water levels declined 2-3 m, the water cleared, and dense mats of Chara and Najas covered approximately 30% of the littoral area of the reservoir. Some parameter other than water level or vegetative cover was probably responsible for increased growth of black crappie in 1979.

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 (P = 0.08). Bluegill sunfish produced a very strong year class in 1981. Growth of intermediate-size bluegills may have been accelerated by foraging on YOY fish, while age I bluegills may have been forage limited because of potential competition from the large numbers of small fish. 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 ($P < 0.0001$). In 1981, largemouth bass foraged heavily on insects (odonata and ephemeroptera; Table 3) and consumed fewer centrarchids than in 1980 or 1982. The extensive vegetative cover present in 1981 may have limited the foraging ability of largemouth bass, causing reduction in growth.

Lee's phenomenon was observed throughout the study in all of the species examined ($P < 0.05$). Table 10 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. The data suggest that growth may be limited for all but age I fish in Hams Lake.

Lake Carl Blackwell

Relative Abundance

No changes occurred in the distributions of relative abundance of fish species between years in Lake Carl Blackwell ($P_{80-81} = 0.72$; $P_{81-82} = 0.56$; $P_{80-82} = 0.56$). 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 and white crappie were numerically dominant throughout the study (Table 11). Gizzard shad (Figure 8) and white bass (Figure 9) produced strong year

classes in 1982. The strong year classes caused significant changes in the population structures of both gizzard shad and white bass (Table 12). 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 11). In 1980, most bluegill were collected by seining, but the majority of bluegill 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 12). 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. The white crappie population was 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. Lake Carl Blackwell filled to capacity the spring of 1982 and inundated shoreline vegetation. Following this filling, 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 of 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 production of benthic macroinvertebrates (Craven 1967, Norton 1968).

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 (Mann-Whitney; $P_{80/81} = 0.03$, $P_{81/82} = 0.03$, $P_{80/82} < 0.01$). Terrestrial insects occurred in 47% of stomachs with food in 1980 (Table 13). 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. 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 predators 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 11). In both 1981 and 1982, gizzard shad were eaten by largemouth bass of similar sizes (308 and 301 mm TL, respectively [Table 14]). 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 15). 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. The data from forage selectivity of largemouth bass, and the comparison of dietary to population median sizes of forage indicate that gizzard shad are preyed on less efficiently than centrarchids by largemouth bass in Lake Carl Blackwell.

Gizzard shad was the predominant food of white bass (Table 16). 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. In 1980 and 1982, the reservoir was full for most of the season, but in 1981 water level was approximately 3 m below normal. Fish reproduction was limited in 1981, and white bass relied more heavily on aquatic insects as food than in 1980 and 1982. During

periods of high water, inundated vegetation and allochthonous organic material transported by runoff decompose to increase 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 for food of predators during periods of low water, when gizzard shad production is low (Aggus and Elliot 1975, Ploskey and Jenkins 1982).

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 17). 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, when no centrarchids were collected with white bass. These data indicate random foraging on centrarchids (Table 16).

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 was found in 71% of the stomachs with food (Table 18). Hexagenia naiads and

gizzard shad were second and third in importance, respectively, and each was present in 29% of hybrid bass stomachs with food. Insects were 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 have also been reported to be numerically dominant in the diet of hybrid bass in Lake Bastrop, Texas (Day 1981). No centrarchids were eaten by hybrid bass. The absence of centrarchids in hybrid bass diets 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.

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). Since Hexagenia naiads emerge from June through August, these data suggest that striped bass x white bass hybrids less than 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).

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 $\geq$ 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 19). These

data, when compared to that of Zaret and Rand (1971) suggested intense competition for food between white bass and largemouth bass. However, in 1980 the 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 13), and only gizzard shad was of major importance to white bass (Table 16). 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 15) and strongly by white bass (L = 0.74, Table 17). 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 than 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 also different when any two of the three years were compared (Mann-Whitney; $P < 0.01$).

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 20), but decreased between largemouth bass and white bass (Table 19) and between white bass and striped bass x white bass hybrids (Table 20). 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. Both items were important food for both predators, but largemouth bass did not appear to

be adversely affected by the diet overlap. Hybrid bass may have been affected by insufficient forage, since the condition of hybrids in 1982 (1.08) was less than in 1981 (1.27).

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 15) more frequently than did white bass (Table 17) in 1982, both on annual and daily bases. However, largemouth bass may be inefficient predators on gizzard shad in Lake Carl Blackwell.

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 18) and white bass (Table 16). The predators appeared to partition overlapped diet items to some extent, since gizzard shad were eaten by larger white bass and small hybrids (median TL of 295 and 175 mm, respectively), as were ephemeroptera (median TL of 262 and 218 mm for white bass and hybrid bass, respectively). Unidentified fish was recovered from small white bass (95 mm TL) and larger hybrid bass (275 mm TL).

Age and Growth

Growth and age composition of selected fish species are presented in Table 21. Data for striped bass x white bass hybrids is not presented. All hybrid bass scales exhibited false annuli which may be attributed to forage limitations (Coble 1970). 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 ($P \leq 0.05$) for bluegill sunfish and gizzard shad (all comparisons), white crappie (1979/1980 and 1979/1981) and largemouth bass (1979/1981). White bass showed marginal differences ($P = 0.1$) in median increment at annulus in all comparisons. Differences in growth rates of the various fish species appear to have been determined by environmental factors rather than density-dependent interactions. Water levels in both reservoirs were 3-5 m below spillway level in 1979. Heavy spring rains in 1980 filled both reservoirs 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 2-4 m in both reservoirs. Fish species dependent on submerged vegetation for reproduction were less successful during 1981 than 1980, while other fish appeared to benefit from the drawdown.

Growth of bluegill sunfish was not estimated for 1979 because of small sample sizes of adult fish (Figure 11). Growth in median increment at annulus of bluegill was less in 1980 than 1981 (Mann-Whitney, $P = 0.01$). Although growth of bluegills was

statistically different between 1980 and 1981 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 by heavy spring rains and runoff, 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. Reduced growth of YOY fish in 1980 probably provided age IV bluegills with more abundant forage than was present in 1981.

Median growth increments of gizzard shad were greatest in 1980, followed by 1981 and 1979 (Mann-Whitney, P = 0.05 for all three pairwise comparisons). The data indicate the gizzard shad population in Lake Carl Blackwell is chronically forage-limited for older age classes. 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 21). 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 (Mann-Whitney, P = 0.08 for both comparisons). Mitzner (198) also observed greater growth of gizzard shad at low population densities. Gizzard shad exhibited Lee's phenomenon during all years of the study (Chi-square, $P < 0.0001$) but when the data were analyzed without age I fish Lee's phenomenon was not present in 1980 (Chi-square, P = 0.58). The results indicate that growth of age I gizzard shad was enhanced by high water levels in 1980.

Median growth increments of largemouth bass increased each year of the study but were statistically different only between 1979 and 1981 (P = 0.008). The differences in growth increments were related to steady increases in growth of age I fish during the study and to increases in 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. 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 (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 (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 (P = 0.10) or 1981 (P = 0.12) and growth of white bass in 1981 was greater than in 1980 (P = 0.10). During 1981 white bass foraged heavily on gizzard shad, which formed 77% of the diet (Table 16). In 1980 gizzard shad were less than half of the white bass diet and Hexagenia naiads were nearly as important as gizzard shad. However, the white bass switched from Hexagenia to gizzard shad forage in June, 1980 when gizzard shad of suitable size became available. The partial dependence on Hexagenia as forage, and the associated reduced growth rates of the predator indicate that white bass were more forage-limited in 1980 than in 1979 or 1981. Growth at annulus "n" vs. annulus "n+1" was less in

1980 than in 1979 (P = 0.12) and was much less in 1981 than in 1980 (P = 0.01). With the exception of age I, white bass grew more in 1979 than in 1980 (Table 21). 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 ($P < 0.001$) regardless of whether age I growth was included in the calculations. In 1980 the phenomenon was also significant (P = 0.07) but was more significant when age I data were not included (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 (P = 0.02) or 1981 (P = 0.05) but there was no difference in growth between 1980 and 1981 (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 22). Growth in 1980 at annulus "n+1" was greater than in 1979 at annulus "n" (P = 0.05) and growth at annulus "n" in 1980 was greater than at annulus "n+1" in 1981 (P = 0.04). 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.

VII. CONCLUSIONS:

Hams Lake

The relative abundance and importance of centrarchid forage in Hams Lake remained stable throughout the study, but gizzard shad fluctuated significantly (P = 0.01) 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 directly 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 nearly constant between 1981 and 1982, and during both years diet overlap was dominated by ephemeropterans. 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 density-independent environmental factors which regulated 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 was 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. White bass and hybrid bass appeared to partition 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.

VIII. RECOMMENDATIONS

Data from Hams Lake indicates 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, Summerfelt1971). 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, we make the following recommendations:

1. Since survival/recruitment of hybrid bass in Lake Carl Blackwell is low, we recommend additional introductions in 1984-1986 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.

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 the sport fisheries (Noble 1981; Ploskey and Jenkins 1982).

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Table 1. Relative abundance of selected fish species in Hams Lake. Numbers in parentheses are numbers of fish collected.

Species	Number 1980	Number 1981	Number 1982
Black crappie	0.02 (44)	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)
	Weight 1980	**Weight 1981**	**Weight 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 2. Comparisons of the relative importance, condition (K), mean and median total lengths and weights, and slopes of the regressions of the logarithms of weight, body depth, and buccal gape (for largemouth bass and striped bass x white bass hybrids) on the logarithm of total length for fish in Hams Lake.

Species	1980 vs. 1981		1981 vs. 1982		1980 vs. 1982	
	Chi-square	P	Chi-square	P	Chi-square	P
Black crappie	7.13	0.42	0.44	0.99	8.18	0.32
Bluegill sunfish	2.46	0.93	7.71	0.36	8.29	0.31
Channel catfish	2.65	0.85	5.47	0.49	2.13	0.91
Golden shiner	0.53	0.99	17.29	0.02	16.00	0.03
Green sunfish	15.46	0.03	8.61	0.28	10.70	0.15
Gizzard shad	45.67	<0.01	18.28	0.01	24.37	<0.01
Largemouth bass	90.87	<0.01	49.00	<0.01	158.25	<0.01
Redear sunfish	28.90	<0.01	4.08	0.77	38.80	<0.01
Striped bass x white bass hybrid			89.97	<0.01		
Yellow bullhead	105.46	<0.01	104.85	<0.01	1.10	0.99

Table 3. 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 4. Median total lengths (mm) of largemouth bass which consumed specific food items. Values in parentheses indicate the percentage of maximum buccal capacity of largemouth bass fir 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)

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

\+ Food items were too decomposed for accurate determinations.

Table 5. Forage selectivity of largemouth bass in Hams Lake.

	Lepomis spp.		Gizzard shad	
	Σ[1]	0[2]	Σ[1]	0[2]
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

[1] Σ - refers to all sizes of largemouth bass

[2] 0 - refers to largemouth bass with the same buccal gape as striped bass x white bass hybrids

Table 6. Relative importance and rank of food items in diets of striped bass x white bass hybrids in Hams Lake.

Food item	Importance 1981	Importance 1982	Rank 1981	Rank 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 7. 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 8. Diet overlap of largemouth bass and striped bass x white bass hybrids in Hams Lake. "Σ" refers to all sizes of largemouth bass and hybrid bass, and "0" refers to largemouth bass and hybrid bass with the same buccal gape.

	Σ	0
1981	0.56	0.42
1982	0.27	0.43

Table 9. Growth and age composition of selected fish species in Hams Lake. Data are reported as median TL (mm) at annulus and the number of fish in each sample (N).

	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)	

Table 9. Continued.

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

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

Table 10. Growth increments of selected fish species in Hams Lake. Data reported are median increment (mm) at annulus and number of fish (N) in each age class.

	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)	

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

Table 11. 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)

Table 11. 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 12. Comparisons of the relative importance, condition (K), mean and median total lengths and weights, and slopes of the regressions of the logarithms of weight, body depth, and buccal gape (of largemouth bass, striped bass x white bass hybrids and white bass) on the logarithm of total length for selected fish species in Lake Carl Blackwell.

Species	1980 vs. 1981		1981 vs. 1982		1980 vs. 1982	
	Chi-square	P	Chi-square	P	Chi-square	P
Bluegill sunfish	8.91	0.26	2.40	0.93	13.76	0.06
Carp	0.89	0.99	25.03	<0.01	27.94	<0.01
Channel catfish	11.23	0.08	11.64	0.07	11.80	0.07
Freshwater drum	27.41	<0.01	16.38	0.02	6.03	0.54
Gizzard shad	1.47	0.98	17.30	0.02	14.79	0.04
Inland silverside	0.69	0.99	3.40	0.85	4.26	0.79
Largemouth bass	95.78	<0.01	22.38	<0.01	50.14	<0.01
Red shiner	0.77	0.99	0.59	0.99	0.36	0.99
River carpsucker	4.85	0.56	3.95	0.68	0.29	0.99
Striped bass x white bass hybrid			26.02	<0.01		
White bass	13.35	0.10	60.73	<0.01	89.18	<0.01
White crappie	0.88	0.99	0.98	0.96	0.39	0.99

Table 13. Relative importance and rank of food items eaten by largemouth bass in Lake Carl Blackwell. Median total lengths of predators are shown in parentheses.

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

Table 14. Median total lengths (mm) of largemouth bass in Lake Carl Blackwell which preyed on specific food items. Numbers in parentheses give the median percentages of the maximum sizes of prey items which were eaten.

	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	-	-

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

Table 15. 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 16. Relative importance and rank of food items eaten by white bass in Lake Carl Blackwell. Median total lengths of predators are shown in parentheses.

Food item	Importance			Rank		
	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

Table 17. Annual and daily forage selectivity of white bass in Lake Carl Blackwell.

Forage	1980		1981		1982	
	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 18. Relative importance and rank of food items eaten by striped bass x white bass hybrids in Lake Carl Blackwell during 1982. Median total lengths (mm) of predators are given in parentheses.

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

Table 19. Diet overlap between largemouth bass and white bass in Lake Carl Blackwell. "All" indicates all largemouth bass and white bass, and "overlap" refers to only those largemouth bass and white bass with the same buccal gape.

	All	Overlap
1980	0.57	0.77
1981	0.54	0.81
1982	0.75	0.58

Table 20. Diet overlap of striped bass x white bass hybrids with white bass and largemouth bass in 1982. "Σ" refers to all sizes of predators and "0" refers to only those white bass and largemouth bass with the same buccal gape (29-41 mm) as striped bass x white bass hybrids.

Hybrid bass vs. White bass		Hybrid bass vs. Largemouth bass	
Σ	0	Σ	0
0.72	0.60	0.55	0.92

Table 21. Growth and age composition of selected fish species in Lake Carl Blackwell. Data are reported as median TL (mm) at annulus and number of fish (N) in each sample.

	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

Table 21. 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				

Table 22. 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.

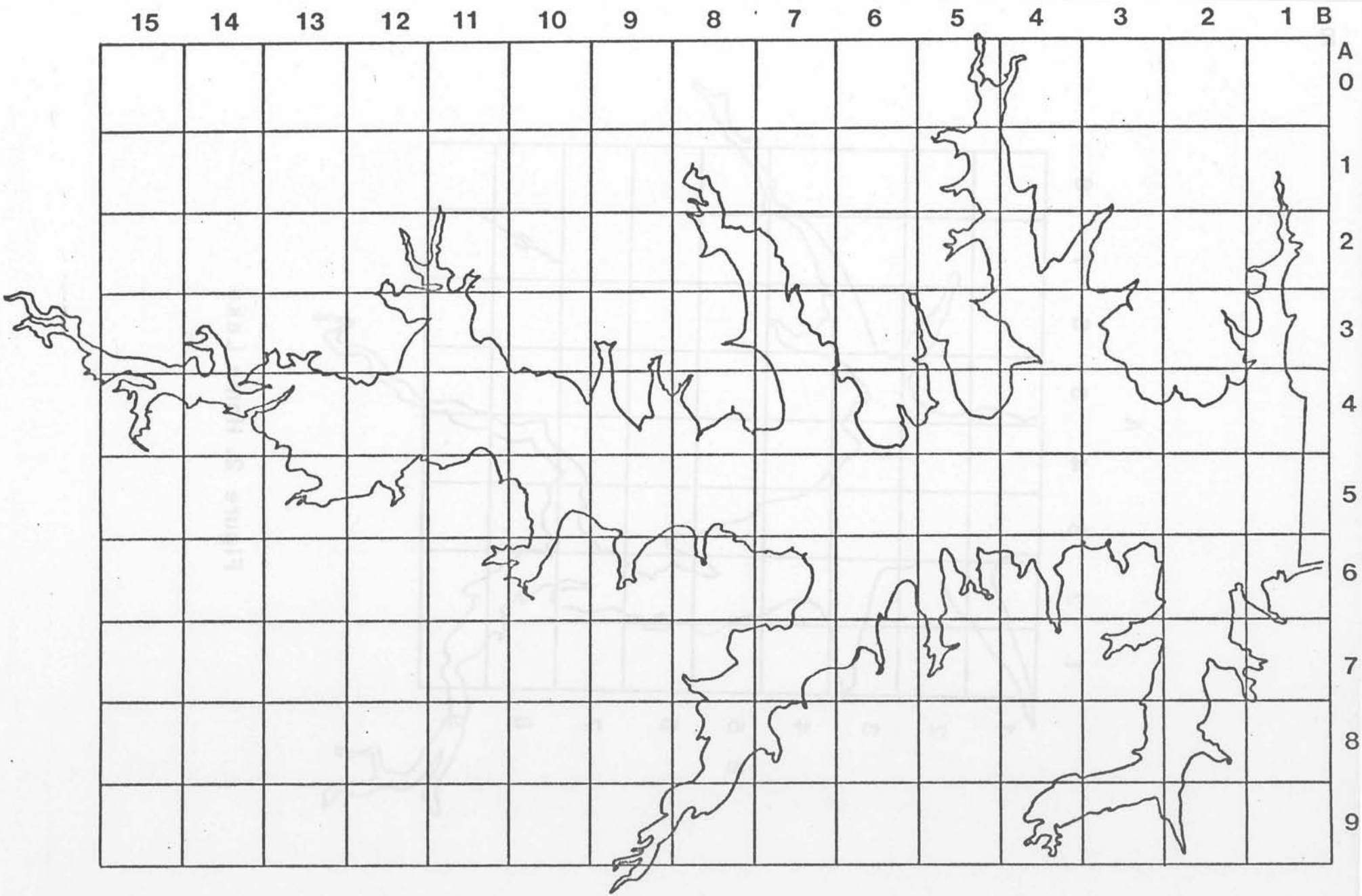

Figure 1. Lake Carl Blackwell

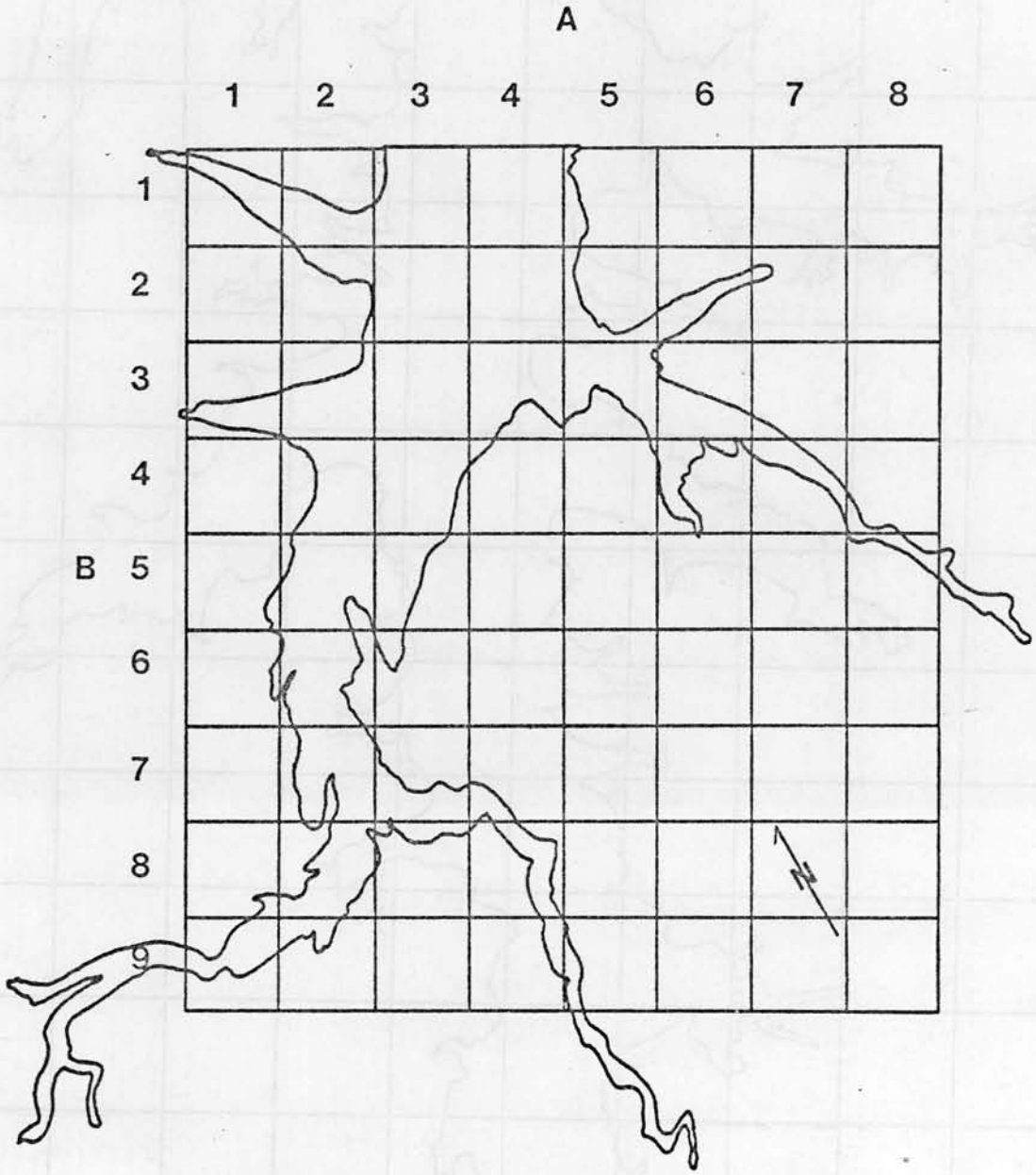

Figure 2. Hams Lake

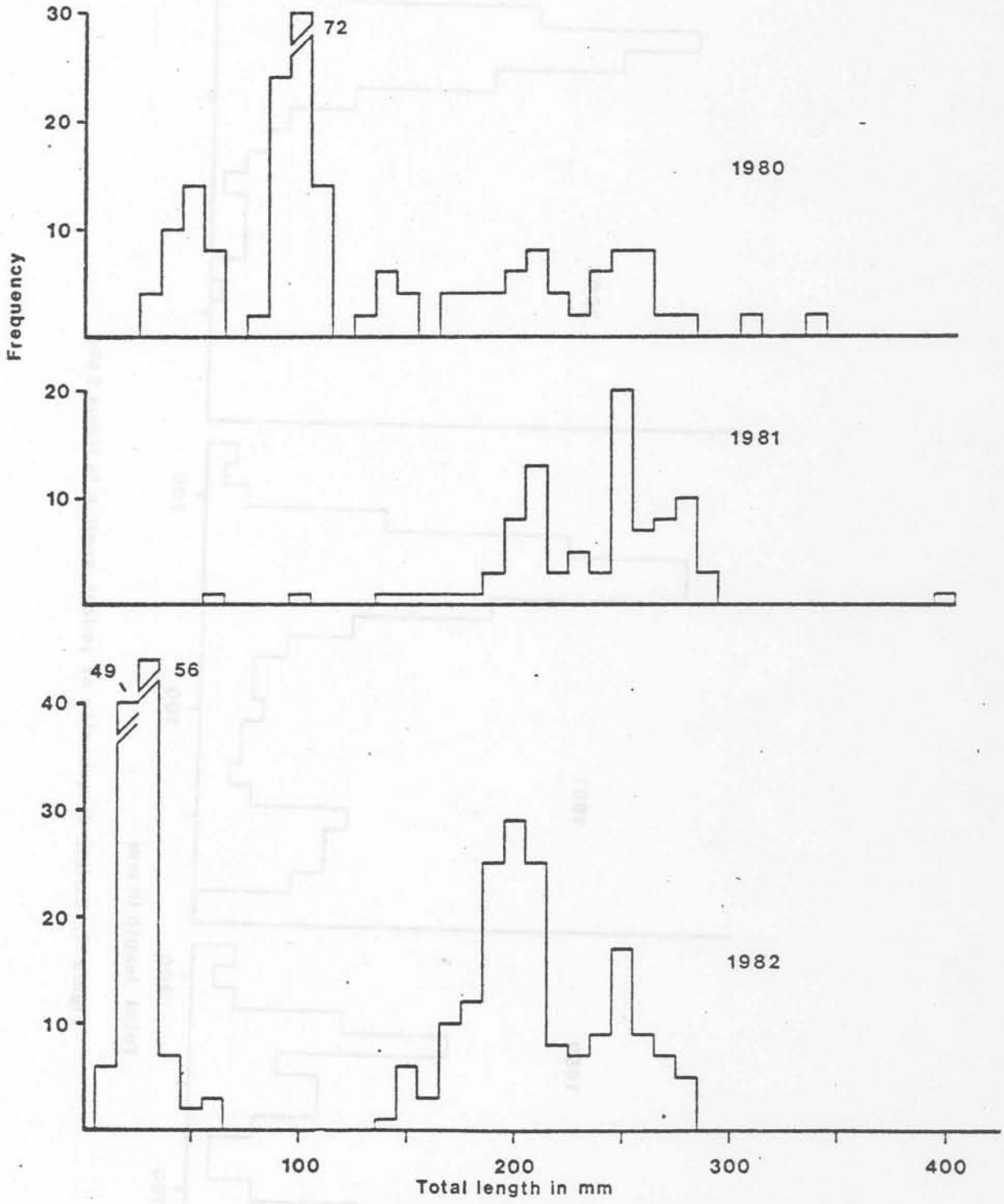

Figure 3. Length frequencies of gizzard shad in Hams Lake

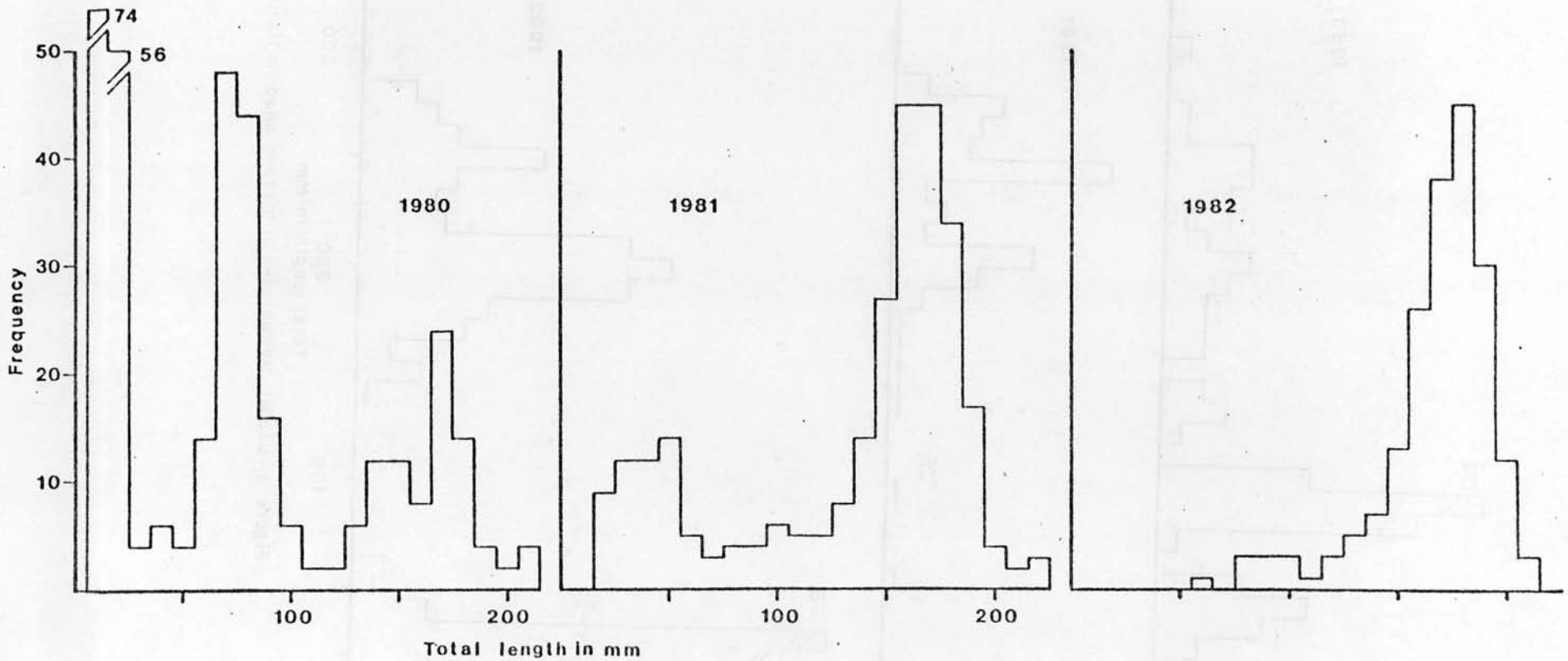

Figure 4. Length frequencies of redear sunfish in Hams Lake

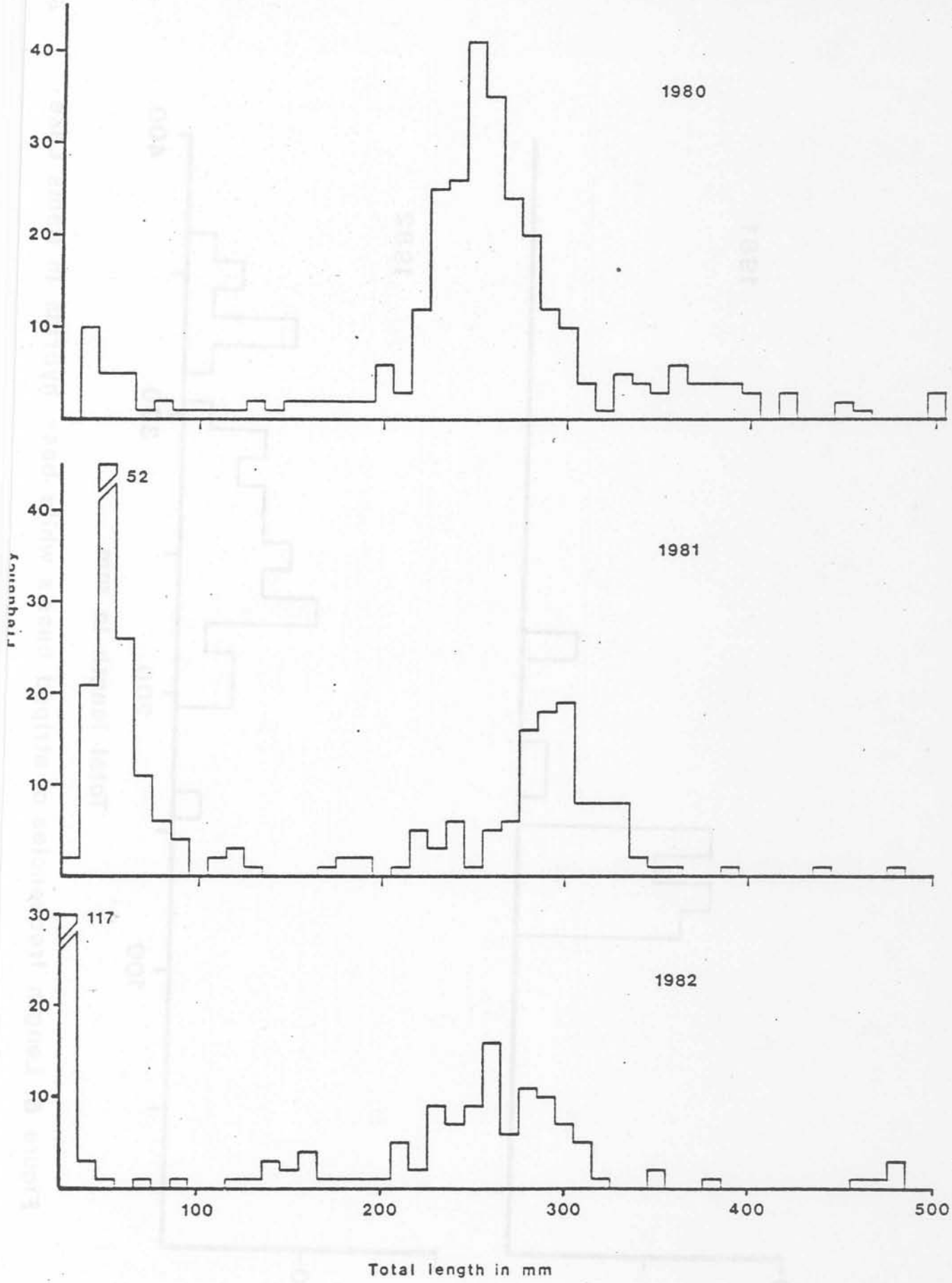

Figure 5. Length frequencies of largemouth bass in Hams Lake

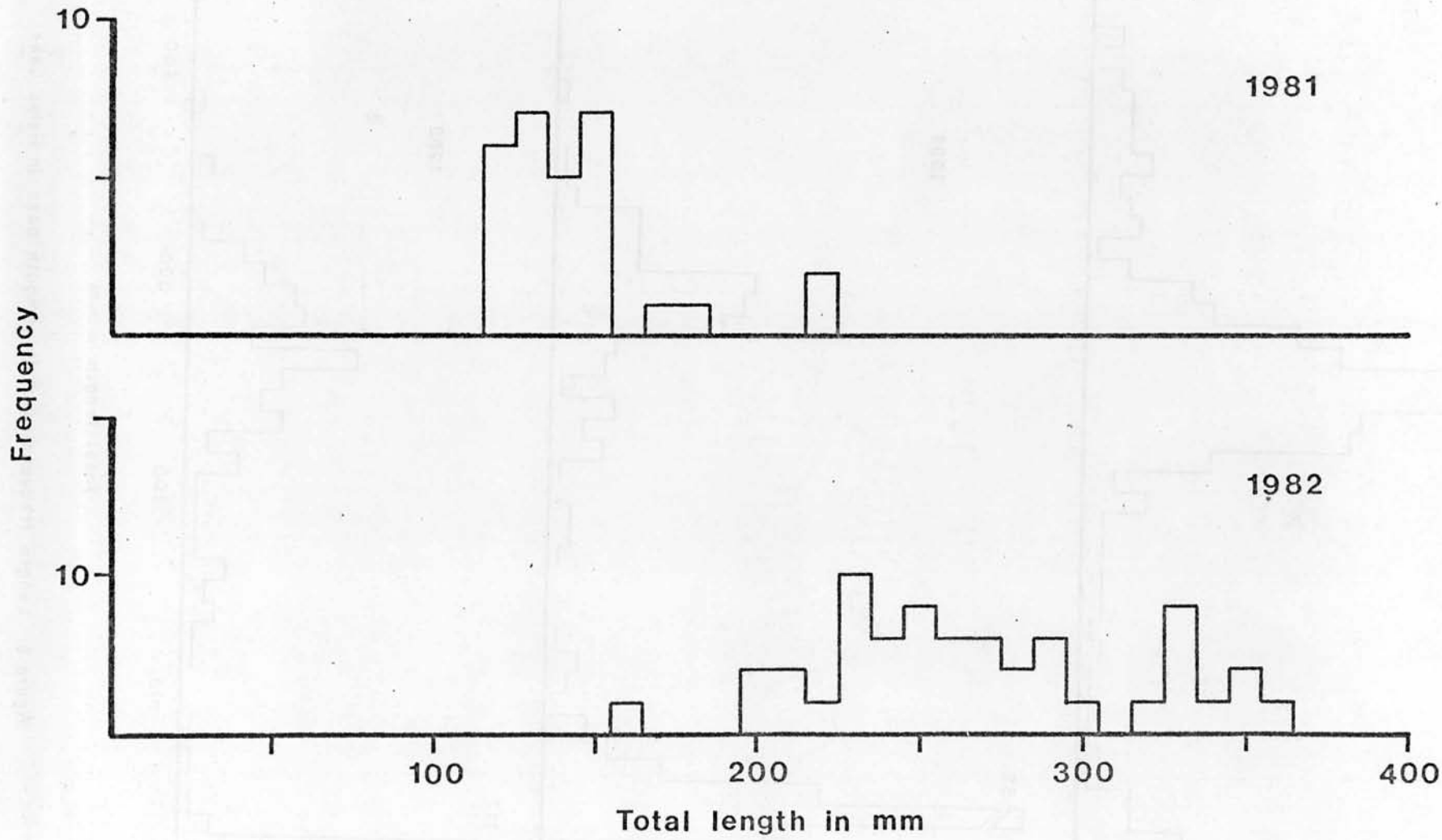

Figure 6. Length frequencies of striped bass x white bass hybrids in Hams Lake

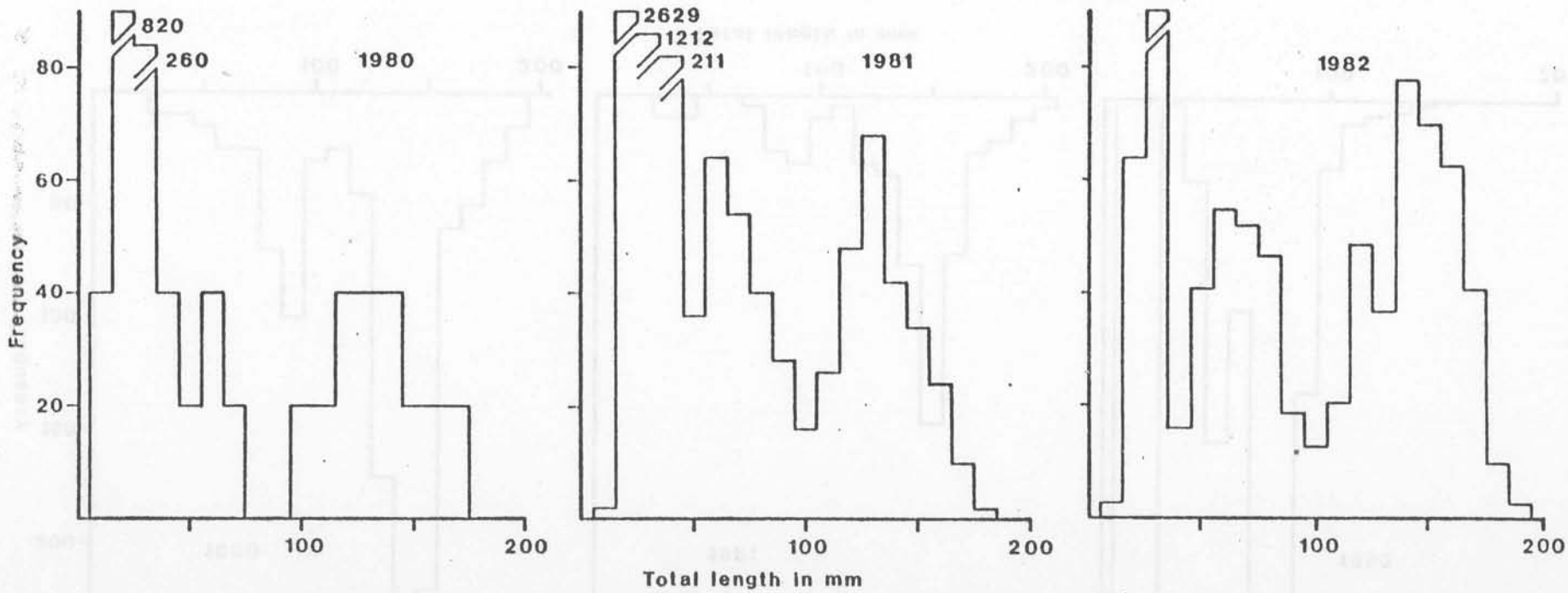

Figure 7. Length frequencies of bluegill sunfish in Hams Lake

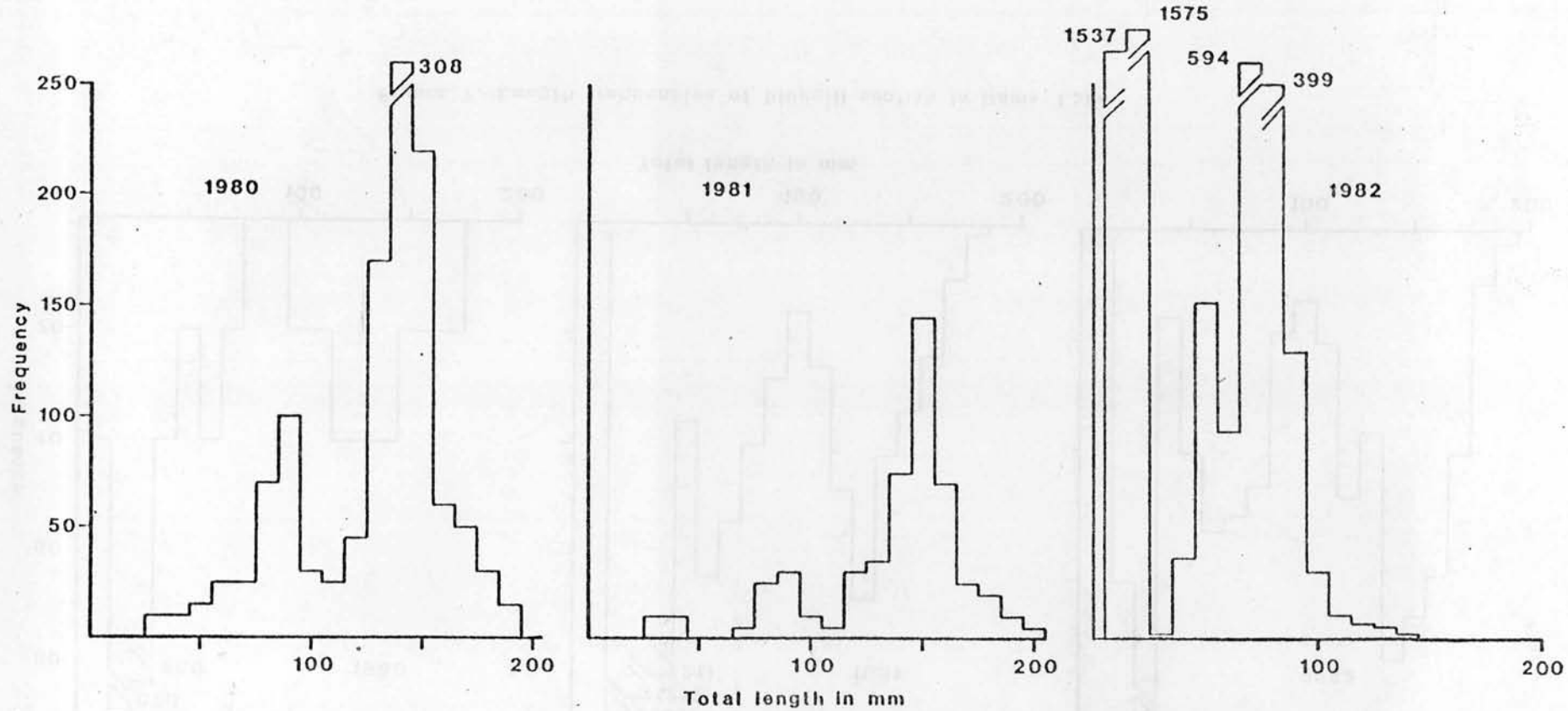

Figure 8. Length frequencies of gizzard shad in lake Carl Blackwell

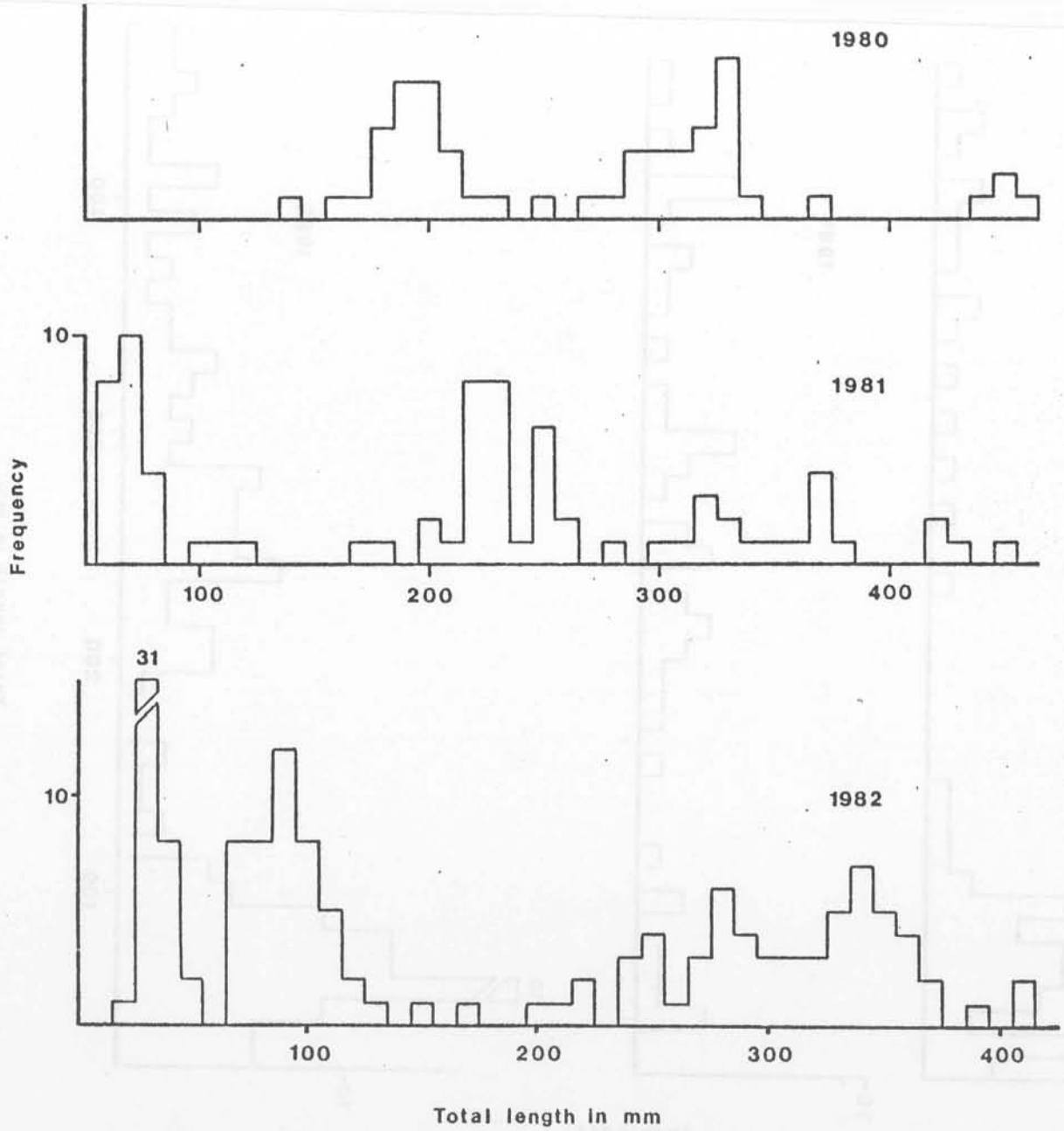

Figure 9. Length frequencies of white bass in lake Carl Blackwell

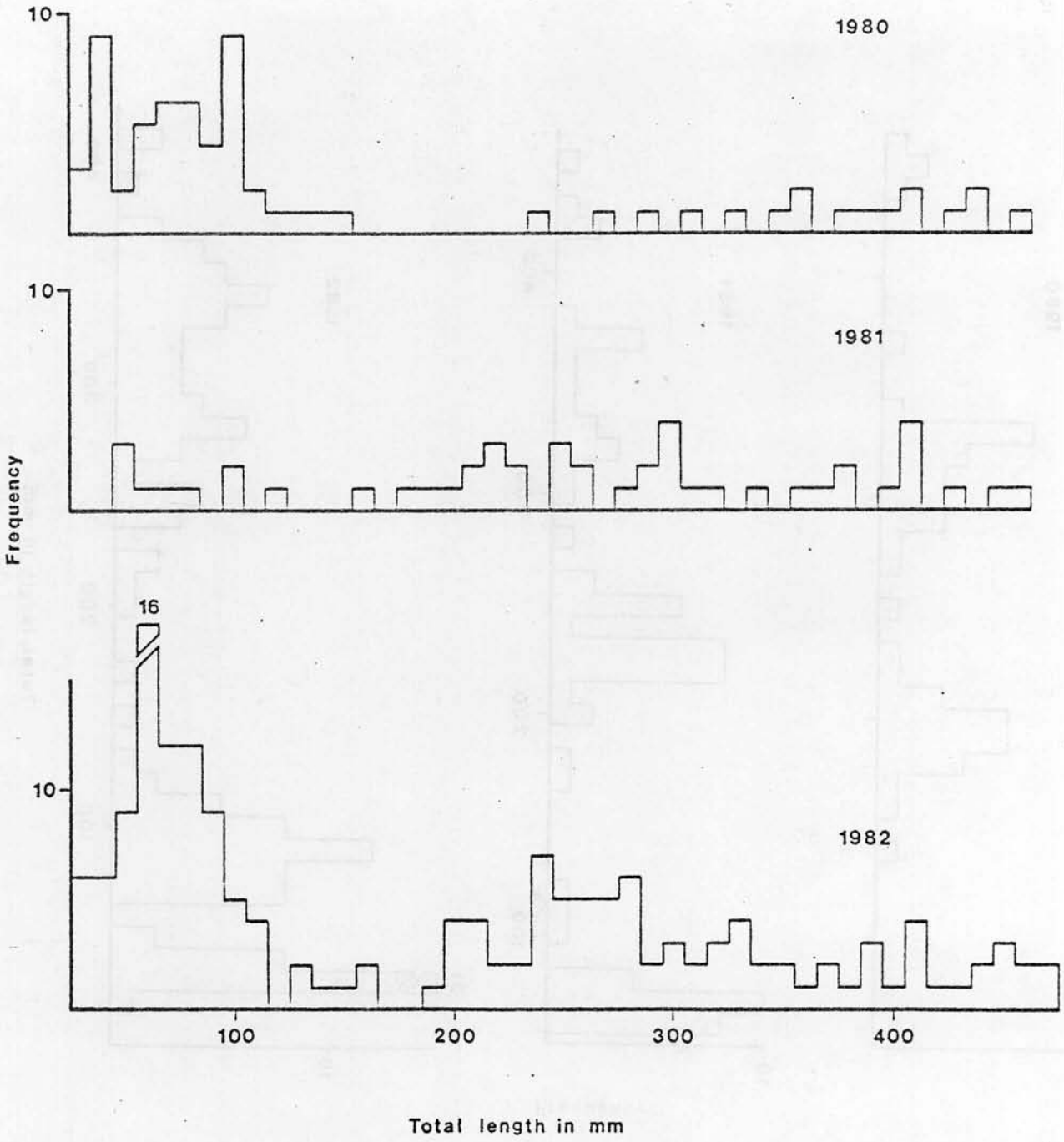

Figure 10. Length frequencies of largemouth bass in lake Carl Blackwell

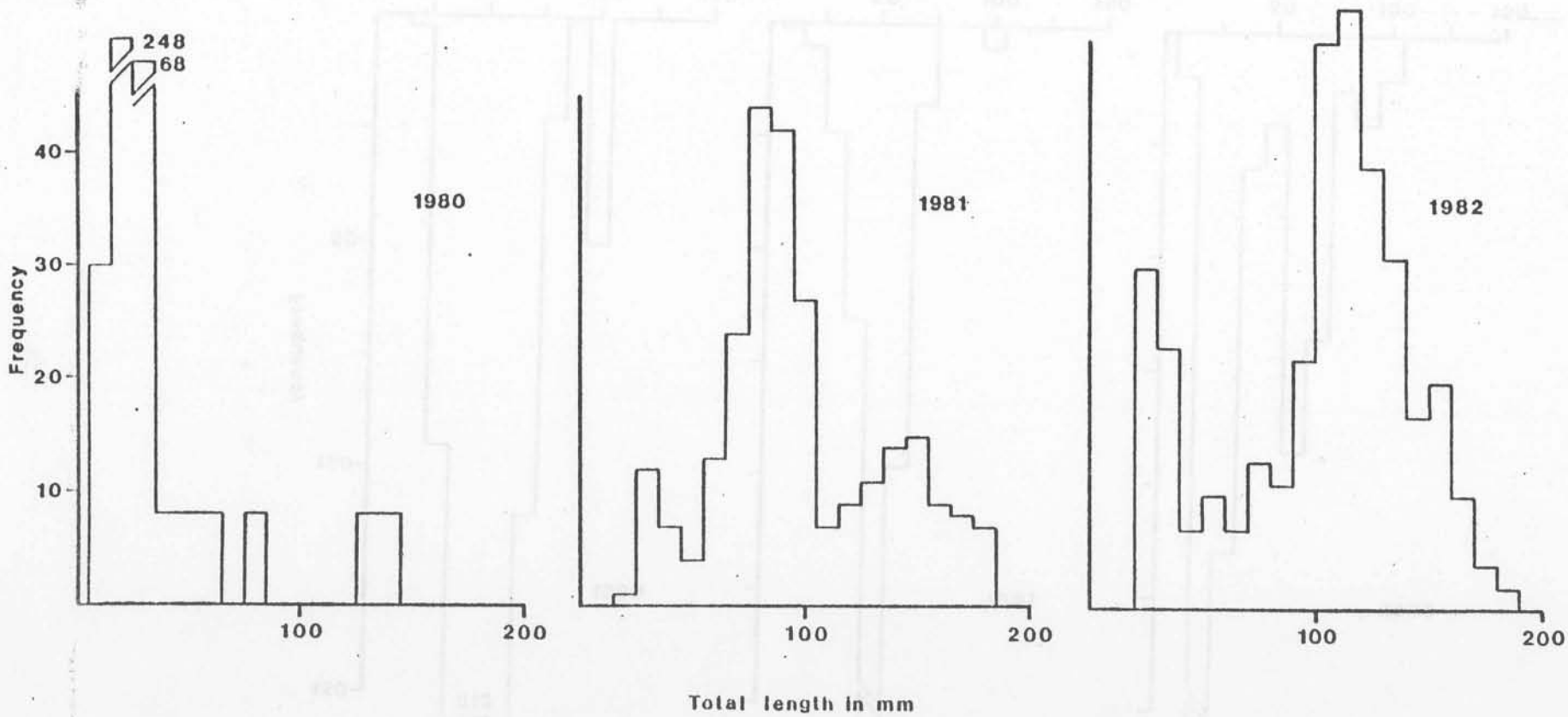

Figure 11. Length frequencies of bluegill sunfish in lake Carl Blackwell

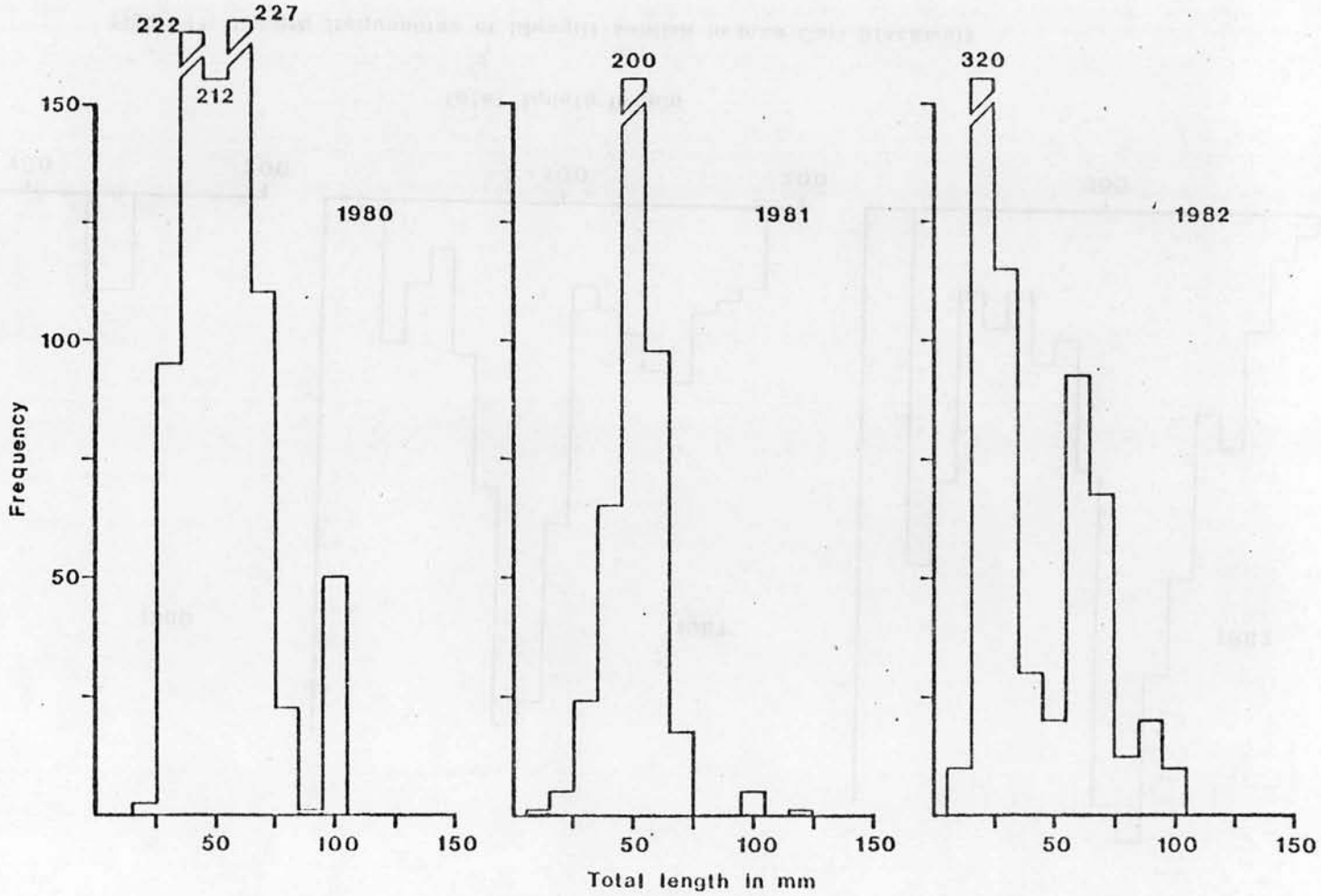

Figure 12. Length frequencies of inland silversides in Lake Carl Blackwell

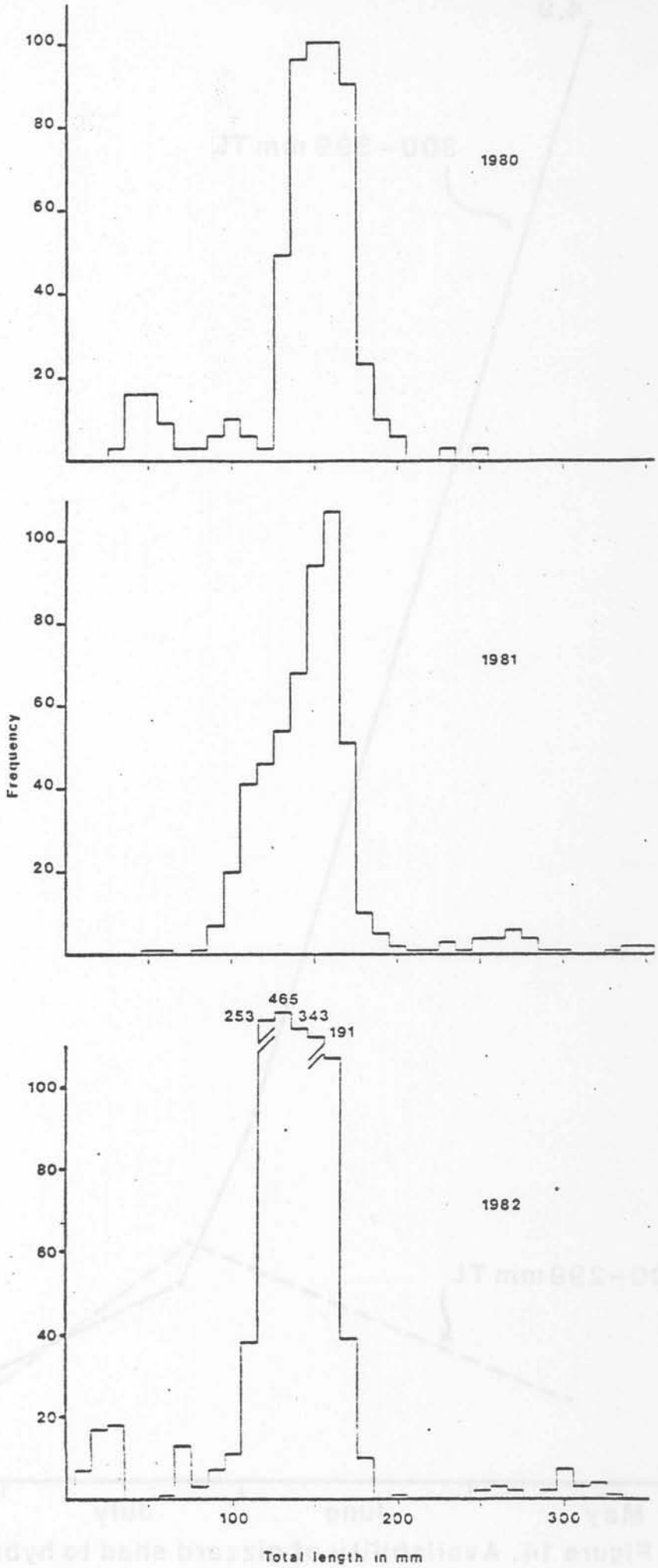

Figure 13. Length frequencies of white crappie in lake Carl Blackwell

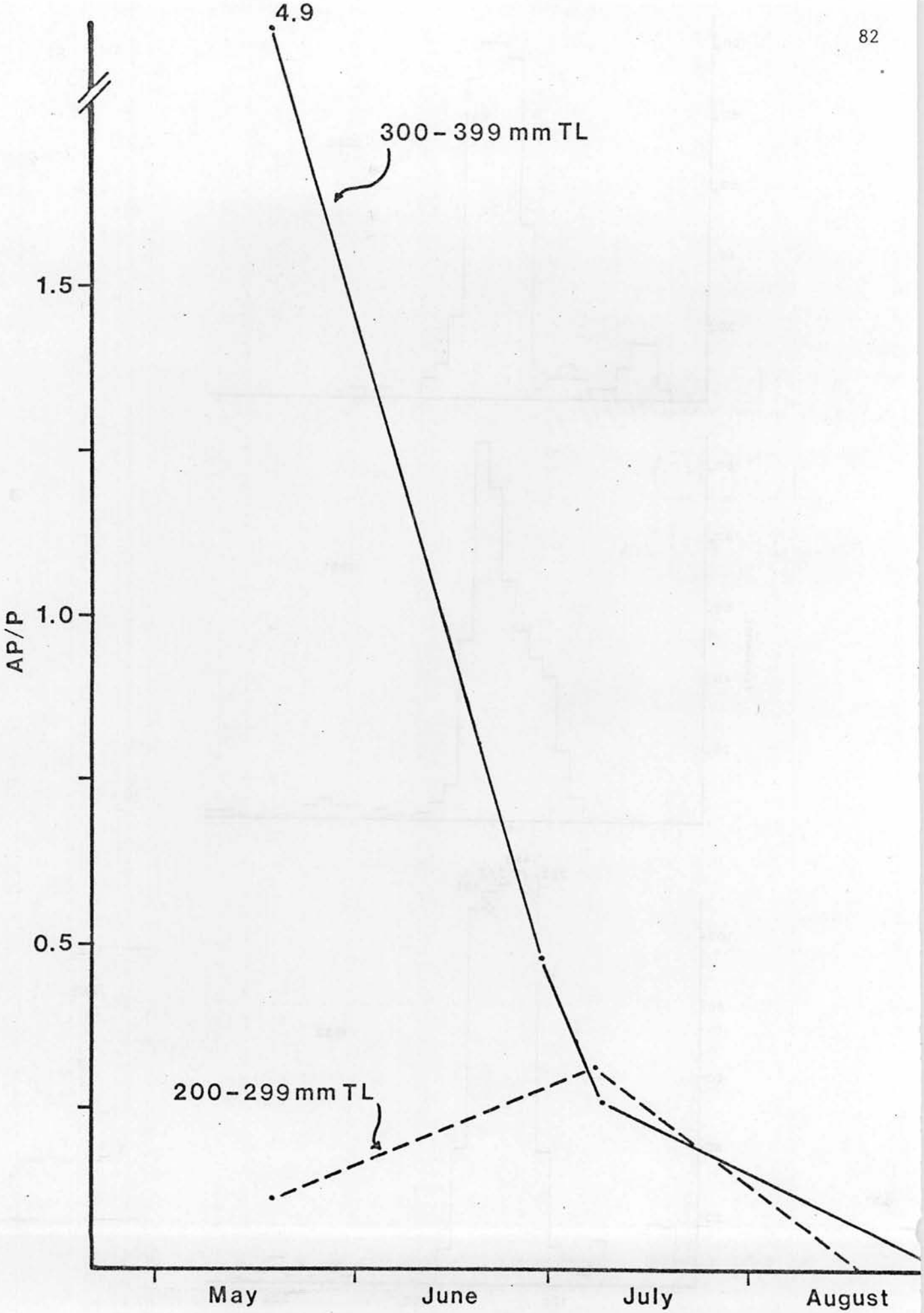

Figure 14. Availability of gizzard shad to hybrid bass

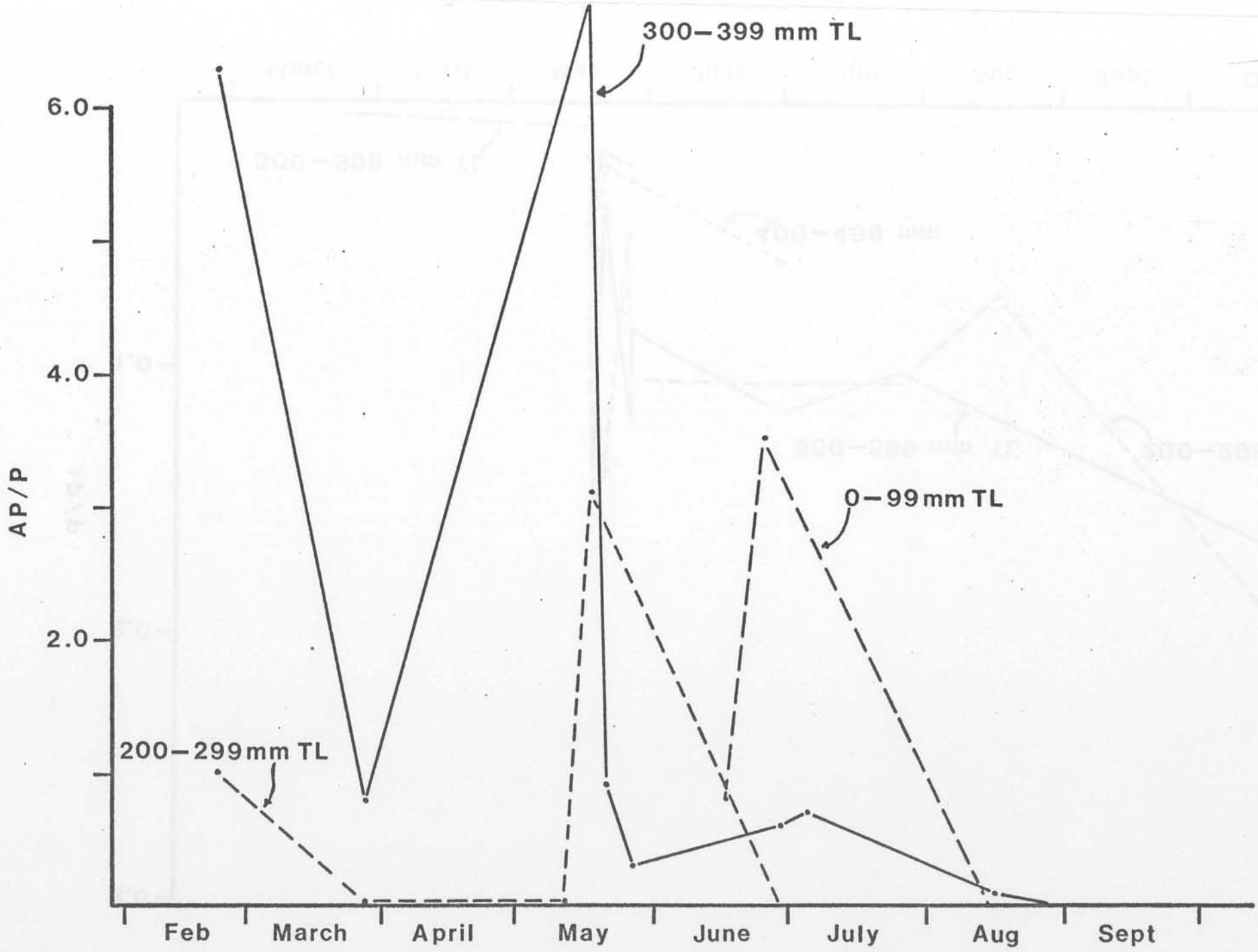

Figure 15. Availability of gizzard shad to white bass

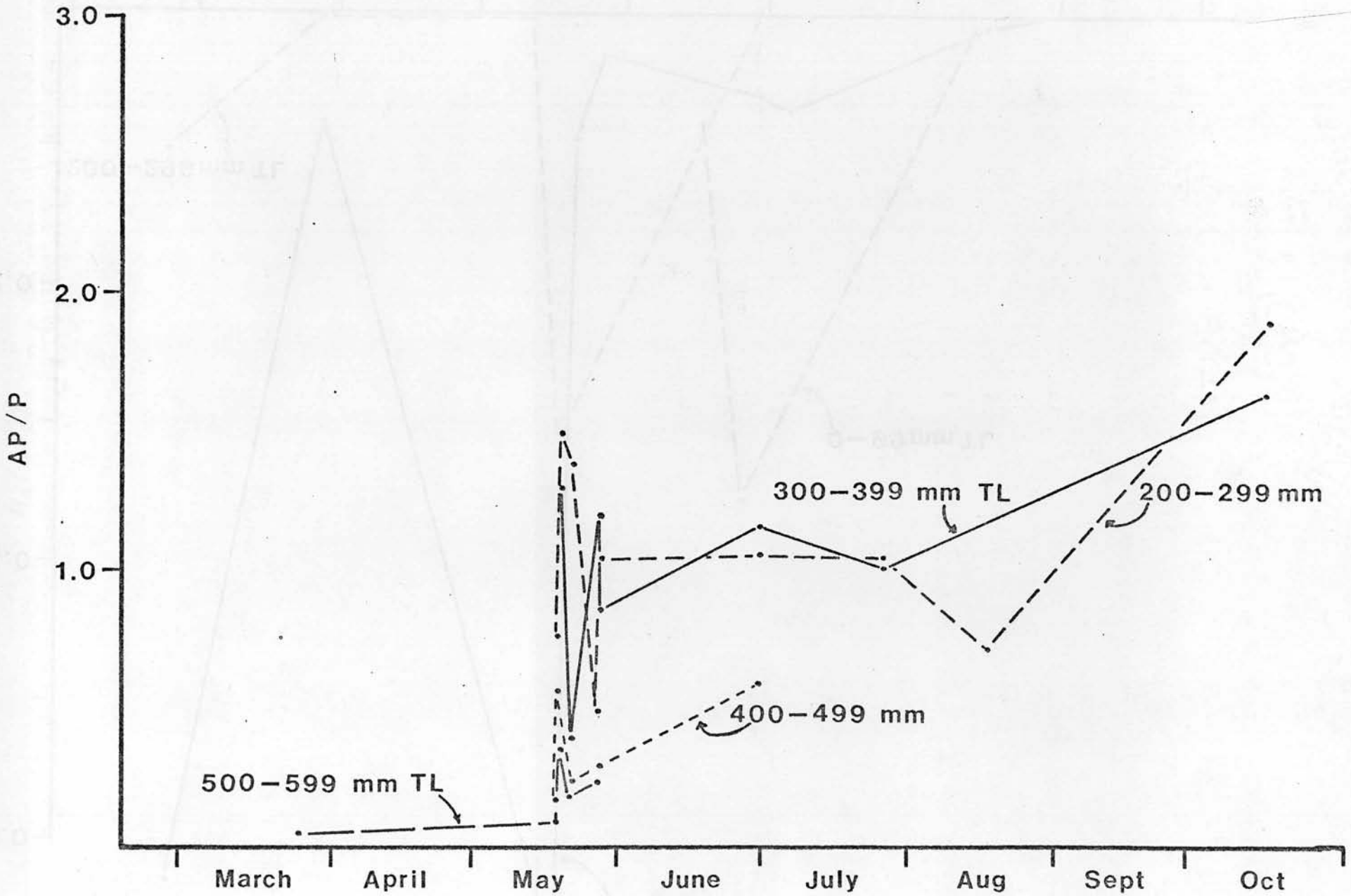

Figure 16. Availability of gizzard shad to large mouth bass