FOOD HABITS OF STRIPED BASS X WHITE BASS HYBRIDS AND LARGEMOUTH BASS IN SOONER LAKE, OKLAHOMA

By

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AND LARGEMOUTH BASS IN SOONER LAKE, OKLAHOMA

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PREFACE

This researech was funded by the Oklahoma Department of Wildlife Conservation. Our objective was to evaluate the feeding interactions between striped bass (*Morone saxatilis*) x white bass (*M. chyrsops*) hybrids and largemouth bass (*Micropterus salmoides*) in Sooner Lake, Oklahoma. The literature was reviewed and findings applicable to this research were evaluated.

The research was conducted on Sooner Lake with the permission of Oklahoma Gas and Electric Company whose cooperation and assistance with the project are greatly appreciated.

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INTRODUCTION

This thesis is submitted to the faculty of the Graduate College of Oklahoma State University in partial fulfillment of the requirements for the degree of Master of Science in Zoology. The research project was funded through the Oklahoma Cooperative Fishery Research Unit by the Oklahoma Department of Wildlife Conservation. Funds were made available as part of D-J Federal Aid to Fish Restoration Project F-41-R, Job 3. The thesis is written in the format required for the D-J Final Report.

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ABSTRACT

The feeding interactions between striped bass x white bass hybrids (*Morone saxatilis* x *M. chrysops*) and largemouth bass (*Microptrerus salmoides*) are an important management consideration because of the widespread introduction of these fish. A literature review indicated that hybrids preyed almost exclusively on clupeids, but little work has been done on possible competition for food between the hybrid and bass.

We investigated the food habits, food selectivity, and diet overlap of hybrids and largmeouth bass in Sooner Lake. Both species ate similar foods in 1980, selecting gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*D. pentenense*),eating sunfishes (*Lepomis* spp.) in proportion to their abundance in the environment, and generally avoiding inland silversides (*Menidia beryllina*). The diet of hybrids showed increased utilization of threadfin shad in 1981, but the diet of largemouth bass remained essentially the same. Significant diet overlaps were found between various length groups of hybrids and bass during several seasons. The number and degree of overlaps decreased in most cases following threadfin shad introduction, and therefore were not considered to be detrimental to the predator populations as long as forage was abundant.

Objective: To evaluate the food habits of striped bass x white bass hybrids and largemouth bass in Sooner Lake.

Background:

In the reservoirs of the southeastern and southcentral United States, large populations of pelagic, fast growing gizzard shad (Dorosoma cepedianum) and threadfin shad (D. pentenense) are under-utilized as forage (Bishop 1967 and Ware 1977). In an attempt to utilize more of this resource, pelagic game fish such as the striped bass (Morone saxatilis) which are capable of feeding on larger clupeid fishes, have been widely introduced. However, the success of these introductions has been mixed. In Santee-Cooper Reservoir in South Carolina, and Lakes Keystone and Texoma in Oklahoma, natural reproduction has produced large populations of striped bass. In other cases, introductions failed to establish significant populations unless fish were repeatedly stocked (Bishop 1967). The unpredictable nature of these introductions and the concern over possible interactions with native gamefish led to experiments with Morone hybrids. Striped bass x white bass (M. chrysops) hybrids, first produced by Stevens in South Carolina in 1965 (Logan 1968), had a greater hatching success than striped bass (Bonn et al. 1976), were easier to rear to stockable size (Williams 1971), and grew faster and survived better than either parent (Bishop 1967). Simplified and inexpensive hatching and rearing procedures were soon developed and a number of states began stocking hybrids (Bonn et al. 1976). Introductions in South Carolina, Tennessee, Florida, and Texas provided good fishing and resulted in widespread public support for stocking programs (Moczygemba and Morris 1977).

Several studies were set up to determine if the hybrid might serve as a biological control on shad (Bishop 1967). Again, results were mixed. Following introductions of hybrids, Ware (1977) reported a marked reduction in shad biomass in Florida lakes and Crandall (1979) noted a decrease in relative abundance of shad in a heated Texas reservoir. Bishop (1967) and Bailey (1975), however, doubted if the hybrid could control shad and Ott and Malvestuto (in press) found hybrids did not utilize highly abundant gizzard shad.

Introductions of striped bass and hybrids have generally been assumed to have little or no effect on native game fish (Bailey 1975 and Hanson and Dillard 1976), even though possible feeding interactions between hybrids and largemouth bass (*Micropterus salmoides*) have not been thoroughly investigated. Preliminary results showed the hybrid strongly preferred shad (Bishop 1967, Williams 1971, Ware 1977, Crandall 1979, and Hicks 1979) although Ware (1977) noted that the hybrids opportunistically fed on sunfishes (*Lepomis* spp.), silversides (*Menidia* spp.), and other forage fishes. Overlap in food habits of hybrids and largemouth bass is likely because threadfin shad and gizzard shad are also commonly eaten by largemouth bass (Lewis and Helms 1964 and Mullen and Applegate 1967) and insects and invertebrates are important in the diets of both young hybrids and largemouth bass (Bayless 1972, Day 1981, and Ott and Malvestuto in press).

Overlapping resource requirements of coexisting species may result in competitive interactions which change the behavior of one or both species, or reduce and possibly eliminate one species. Theory states for two species to be in competition for a resource, that resource must be in limited supply (Pianka 1976) and if overlap is great enough, changes in population structure, diet, foraging patterns, or habitat utilization may occur (Werner and Hall 1978).

In the late 1970's the Oklahoma Department of Wildlife Conservation began stocking striped bass x white bass hybrids as supplemental game fish in reservoirs with abundant forage. Sooner Lake was stocked in 1977, 1978, and 1980 (Hicks 1978 and 1979). In our study at Sooner Lake we attempted to determine if competitive interactions for food existed between the hybrid and largemouth bass. Proof of competition requires a prior knowledge of the system before the introduction of the second species. We did not have this type of information for Sooner Lake so information on changes in food habits including preferences (selectivity) and diet overlap can only be suggestive of competition. However, this information along with relative abundances of predator and prey is needed for proper management of the fishery. The objectives of this study were: 1) estimate relative abundances of predator species, specifically striped bass x white bass hyrbids and largemouth bass, 2) estimate relative abundances of forage fishes, 3) evaluate food habits of the hybrids and largemouth bass as well as estimate food selectivity and diet overlap, and 4) determine seasonal changes in these relationships.

Procedures:

Description of Study Area

This study was conducted on Sooner Lake (Figure 1), a 2185 ha impoundment on Greasy Creek approximately 35 kilometers north of Stillwater, Oklahoma in Pawnee and Noble counties. The lake was constructed by Oklahoma Gas and Electric Company in 1976 as a cooling water reservoir for a coal fired steam electric generating station. Due to the limited size of the lake's watershed, the impoundment was filled and is maintained with water pumped from the nearby Arkansas River. A series of rock rip-rapped dikes direct the water to and from the plant. Electrical generation and associated hot water discharge began on an irregular basis in November 1979. At peak capacity, the heated effluent discharges 126,000 m^3/min with a maximum rise in water temperature of 11°C from ambient (OG&E 1980).

Sooner Lake is a relatively deep, clear impoundment with a maximum depth of 27 m, a mean depth of 8.5 m, and Secchi disc transparencies of 1.0 to over 2.5 m (OG&E 1980). The lake is thermally stratified in summer with a thermocline at 16 to 18 m (Hicks 1979). Mean surface water temperatures during 1980 and 1981 ranged from 7.2°C in winter to 23.8°C in summer (Table 1). Due to the length of the discharge canal, the heated effluent is cooled to within 1°C of ambient by the time this water reaches the main body of the lake. Other physical conditions of the reservoir also appear to be conducive to a high quality fishery. Oxygen concentrations were sufficient for aquatic life during all seasons at depths less than 18 m, with pH vlaues of 7.4 to 8.5 and conductivities of 1370 to 1550 micromhos/cm (Hicks 1978 and 1979). High conductivities resulted from pumping highly saline Arkansas River water into the lake.

The Oklahoma Department of Wildlife Conservation stocked Sooner Lake in 1977, 1978, and 1980 with a total of 831,000 striped bass x white bass hybrid fry. In 1977, 300,000 native largemouth bass fingerlings, 125,000 Florida largemouth bass (*M. s. floridanus*) fingerlings, 110,000 channel catfish (*Ictalurus punctatus*) fingerlings, 9,300 adult threadfin shad, and an unknown number of inland silversides (*Menidia beryllina*) were also stocked into the reservoir.

Data Collection and Analysis

Predator and Forage Abundance: Relative abundances of predator and forage fishes were estimated from catch-per-unit-effort (c/f) from several gears, assuming that c/f was proportional to the population size at the time of sampling (Ricker 1975). Experimental multifilament nylon gill nets, 61 x 2 m with bar mesh of 19 to 102 mm, were set overnight in open water to catch mobile, pelagic species (Mensinger 1971, Ware 1977, and James 1979). Trap nets (Crowe 1950) and barrel nets (Houser 1960) were also set overnight to catch species that inhabited shallower brushy areas. In addition, a 9.1 m, 6 mm mesh nylon minnow seine was pulled along 35 m transects of shoreline and night electrofishing with a 3750 W, boat mounted pulsed-DC unit was conducted along shoreline areas. Sampling locations were selected using a random number table (Snedecor and Cochran 1980) and a gridded map of Sooner Lake.

Total length in mm and weight in g were recorded for all fish collected. Scale samples were also taken from hybrids and largemouth bass in the manner described by Lagler (1956) and ages determined from scale impressions in cellulose acetate (Tesch 1971) enlarged on an Eberbach Projector.

Predator Food Habits: Stomach samples were removed from all hybrids and largemouth bass with glass tubes using the technique described by Gilliland et al. (in press) and Van Den Avyle and Roussell (1980) and preserved in 70% ethanol. Stomach contents were analyzed in the following manner:

1. Contents were placed on coarse filter and dried using suction.

2. Items were separated into groups using a dissecting microscope and identified to the lowest practical taxon using species keys for fish (Miller and Robison 1973 and Eddy 1969), insects (Usinger 1956 and Borror et al. 1964), and zooplankton (Pennack 1978).
3. Number of individuals in each group were counted, or estimated from disarticulated parts, weighed to the nearest 0.1 g, and volumes determined to the nearest 0.1 ml in graduated cylinders.
4. Percent frequency of occurrence (F), percent total number (N), percent total volume (V), and mean percent volume per stomach were calculated from the fish which contained food.
5. The Index of Relative Importance (IRI) of Pinkas et al. (1971) was used to assess the overall importance of food items and compare seasonal variations. This index gives a rankable value that includes the important features of frequency of occurrence, total number, and total volume in the equation:

$$IRI = F\ (N + V)$$

For purposes of analysis, four seasons were defined on the basis of significant weather and water temperature changes as: spring - March, April, and May; summer - June, July, August, and September; fall - October and November; and winter - December, January, and February.

In addition to the traditional measurements of food habits, food selectivity and overlap indices were used to evaluate the interactions. Selectivity indices (L) were calculated using the linear index of Strauss (1979):

$$L = r_i - p_i$$

where r_i is the relative abundance of food item i in the stomach contents and p_i is the relative abundance of food item i in the environment. Catches of forage species in several gears were combined to determine values of p_i that were most meaningful in view of the habits and habitat of the predator. We calculated p_i for hybrids by combining percent total weight from catches in gill nets and seines. However, for largemouth bass, catches from seines and electrofishing were used.

Overlap indices measure the degree of interaction between two species along a given resource axis. The Schoener (1970) overlap index (α) was used to compare food habits among length groups, between species:

$$\alpha = 1 - 0.5 \ (\Sigma|p_{xi} - p_{yi}|)$$

where p_{xi} is the relative abundance of food item i in the stomach contents of species x and p_{yi} is the relative abundnce of food item i in the stomach contents of species y. Mean percent volume per stomach data were used in this equation based on Wallace's (1981) findings.

Findings:

Predator Abundance

Relative abundances of pelagic predators were estimated by c/f in gill nets and seines. Striped bass x white bass hybrids were most abundant in Spring 1981 (Table 2). Otherwise, white bass were usually most abundant. In general, hybrid catches were highest in the spring and fall of each year. Biomass of hybrids was highest in all seasons except Winter 1980-81 when biomass of both white bass and white crappie (*Pomoxis annularis*) were higher. Largemouth bass were collected in gill nets only during Winter 1980-81 and Spring 1981. During this period these species ranked fourth and second by weight, respectively, but made up only small numerical portions of the catch.

Relative abundances of largemouth bass were estimated from c/f by electrofishing and seining (Loeb 1957 and Witt and Cambell 1959). Largemouth bass were most abundant and had the greatest biomass each season except Spring 1981 when white crappie were most abundant (Table 3). Hybrids were collected by electrofishing only in Spring 1981. Abundance of largemouth bass was highest from Winter 1980-81 through Summer 1981, followed by a sharp decline in fall.

Over the study period, biomass of hybrids in our catches was greatest followed by that of largemouth bass, white bass, and white crappie, respectively. Numerically, however white bass were most abundant, followed by white crappie, hybrids, largemouth bass, respectively.

Forage Abundance

Four groups of forage fishes predominated in Sooner Lake; sunfishes, gizzard shad, threadfin shad, and inland silversides. Sunfishes included bluegill (*Lepomis macrochirus*), longear (*L. megalotis*), green (*L. cyanellus*), orangespotted (*L. humilis*), and white crappie. Percent total weight combined from pairs of gear was used as a measure of forage abundance. Forage abundance was not estimated for Spring 1980 because of failure to collect gizzard shad, sunfishes, and silversides. Gill nets and seines were used to estimate relative abundances of pelagic forage fishes (Table 4). Biomass of gizzard shad increased from Summer to Fall 1980, declined in Winter 1980-81, then rose sharply in Spring 1981. Biomass remained high throughout 1981. Threadfin shad were not stocked in Sooner Lake until Summer 1980 and were first commonly collected during Fall and Winter 1980-81. Low relative abundance of threadfin shad during Spring 1981 was probably due to winterkill. Sunfishes were seldom abundant in gill net catches and were only occasionally abundant (particularly in Summer 1980), in seine hauls. Inland silversides were the most abundant forage fish in Summer and Fall 1980, but virtually disappeared from the catch until Summer 1981.

Sunfishes were always the dominant forage collected by electrofishing except in Winter 1980-81 and Fall 1981 when biomass of gizzard shad was higher. Abundance of gizzard shad was otherwise lower than that of other forage groups. Threadfin shad were seldom collected by electrofishing in littoral areas except in Summer 1981 when their biomass was approximately equal to sunfishes and silversides. Inland silversides were consistently second or third most abundant. In general, biomass of shad peaked in spring and fall; sunfishes peaked in spring and summer; and silversides from summer through fall.

Predator Food Habits

One hundred fifty eight of 291 (54%) striped bass x white bass hybrids contained food when captured (Table 6). Fish contained food more often in summer and fall and as fish size increased, there was a decrease in the percentage of fish containing food. We collected 234 largemouth bass of which 160 (68%) contained food. Again, a greater percentage of fish contained food during summer and fall. The frequency of occurrence of food was greatest in the largest bass, 451-600 mm long, followed by ≤150 mm, 151-300 mm, and 301-450 mm groups, respectively. Glass tubes efficiently removed food from live fish and generally did not require sacrificing the catch. Eighty-two of 224 hybrids were examined with glass tubes and later dissected. The technique removed all food from 95% of these hybrids, and removed 95% of the total volume of food (Table 7). We also examined five largemouth bass from which 100% of the food was removed (Gilliland et al. in press). Fewer largemouth bass were dissected because the method was successfully used on this species by Van Den Avyle and Roussell (1980).

Foods of striped bass x white bass hybrids and largemouth bass were ranked by IRI for each length group for 1980 and 1981. During 1980, insects were the most important food of hybrids 151-300 mm long (Table 8). Fish made up only a small portion of the stomach contents of hybrids in this group, mostly in the form of unidentified fish remains (UFR). A marked shift in food occurred in 1981 when shad made up 90.3% of the food volume. Relative volume of insects dropped and overall diet was more diverse than that of the previous year because sunfishes and silversides were also eaten. Hybrids 301-450 mm long ate shad in 1980 as well as UFR. In 1981, shad were even more important, making up 98.5% of the volume of stomach contents. The largest hybrids, 451-600 mm long, ate shad and sunfishes in 1980, but utilized shad almost exclusively in 1981.

The diets of largemouth bass also changed from 1980 to 1981 (Table 9). During 1980, inland silversides were the most important food of bass $\leq$150 mm long. Insects and shad ranked second and third, respectively. Insects were most important in 1981 with UFR second. Insects were also the most important food of bass 151-300 mm long in 1980 because they occurred most frequently and were most numerous. Although shad made up the greatest volume, they ranked third in importance. Shad became the most important food for these bass in 1981. Sunfishes were the most important food of bass 301-450 mm long in 1980, followed by shad. As was the case with the smaller bass, shad became the most important food during 1981. Crayfish made up the remaining portion of the diet that year. In bass 451-600 mm long, shad were the most important food both in 1980 and 1981.

IRI rankings by season revealed hybrids 151-300 mm long caught in Summer 1980 ate mostly insects (Table 10). Hybrids in this length group were not collected again until Summer 1981 when threadfin shad were the most important food. In Fall 1981, shad remains were the most important food although threadfin shad made up 70.0% by volume. Hybrids 301-450 mm long ate gizzard shad almost exclusively in Spring 1980. In Summer 1980, UFR composed the greatest volume of food, followed by sunfishes, and gizzard shad, respectively. Gizzard shad were the only food in stomachs of hybrids of this size during Spring 1981 and shad remains the only food in Summer 1981. Threadfin shad made up 90.5% of the food volume in Fall 1981. Hybrids 451-600 mm long were the most abundant so their food habits perhaps best represent the diet of adults. In Spring 1980, insects were the most important food with gizzard shad ranked second by IRI despite making up a greater portion of the volume. In Summer 1980, gizzard shad and UFR were the most important foods in hybrid stomachs. Gizzard shad also ranked first in importance in Fall 1980, but sunfishes accounted for slightly more of the food volume. During Spring 1981, gizzard shad made up over 80.0% of the food volume. Insects again ranked highly because numerically they made up 41.0% of the food. Gizzard shad and threadfin shad were equally abundant in stomachs in Summer 1981, but gizzard shad made up 97.2% by volume. During Fall 1981, gizzard shad were most abundant, followed by threadfin shad.

Insects were the most important food of largemouth bass $\leq$150 mm long in Summer 1980. Inland silversides, gizzard shad, and other fish each accounted for 20% of the food volume. Food during Winter 1980-81 consisted of UFR and silversides. In Spring 1981, insects were again most important but second ranked UFR made up 50% of the food volume. Unidentified fish remains was dominant in Summer 1981. Threadfin shad first appeared in the diet this season and were second in importance. Food in Fall 1981 consisted of UFR and insects. As with the smaller bass, largemouth bass 151-300 mm long ate mostly insects, although this catagory made up only 1.5% of the food volume. Gizzard shad made up 57.6% of the volume but were ranked second in importance because of low numbers. In Winter 1980-81, silversides were the most important food, followed by UFR. Following the trend of smaller bass, insects were the most important food of this group in Spring 1981 even though they made up only 3.1% of the volume. Crayfish made up the largest volume of food (44.0%), followed by threadfin shad. In Summer 1981, UFR were ranked first in importance with threadfin shad ranked second. During Fall 1981 UFR ranked first and occurred most frequently, followed by insects which were most numerous, and sunfishes which made up the most volume. Unlike the two smaller groups, largemouth bass 301-450 mm long relied mostly on gizzard shad in Spring 1980. During Summer 1980, however, these bass utilized a wider variety of foods. Sunfishes were most important, insects were second, and gizzard shad, which made up the greatest volume of food, was ranked third. Gizzard shad were the dominant food in stomachs during Winter 1980-81. Threadfin shad were the most important in Spring 1981, with gizzard shad second. During Summer 1981, sunfishes and shad remains were most common. In Fall 1981, crayfish and sunfishes both had equal IRI values, however, crayfish accounted for only 1.0% of the volume whereas sunfishes made up 99.0%. Few largemouth bass, 451-

600 mm long were collected and then only in three seasons. In Summer 1980, a single white bass was the only food. Gizzard shad was the only food in Winter 1980-81 and in Spring 1981 made up 88.2% of the food volume.

Selectivity

Selectivity values (L) for hybrids and largemouth bass of various lengths were computed for each season for the four major components of the diet - gizzard shad, threadfin shad, sunfishes, and silversides. Values of -1 indicate a complete avoidance or inaccessibility of abundant prey and of +1 a selection or preference for a relatively rare prey. Values near zero indicate that prey items were consumed in proportion to their abundance in the environment.

Hybrids 151-300 mm long were not found to contain fish until Summer and Fall 1981 at which time they preferred threadfin shad (L's of 0.70 and 0.90, respectively; Table 12), ate gizzard shad and sunfishes in proportion to their abundance in the environment, and avoided silversides. Hybrids 301-450 mm long preferred gizzard shad in Summer 1981 (L of 0.33) and threadfin shad in Fall 1981 (L of 0.88). Silversides were avoided in Summer 1980, and Summer and Fall 1981. Otherwise, gizzard shad, threadfin shad, and sunfishes were eaten in proportion to their abundance in the environment. Food preferences of the largest hybrids changed by season. They selected gizzard shad in Summer 1980 (L of 0.63) and Summer and Fall 1981 (L's of 0.50 and 0.32, respectively) but avoided them in Fall 1980 and Spring 1981. Threadfin shad were selected in Summer and Fall 1981 and eaten in proportion to their abundance in the environment in all other seasons. Sunfishes were consistemtly eaten in proportion to their abundance in the reservoir.

The smallest largemouth bass, with few exceptions, did not appear to have preferred foods (Table 13). Silversides were generally avoided except during Spring 1980. Sunfishes and threadfin shad were eaten proportionally to their abundance in the lake each season except Spring 1981 when sunfishes were avoided (L of -0.78). Selectivity values for gizzard shad were negative or close to zero in all seasons. L values for bass 301-450 mm long were negative for gizzard shad and ranged from -0.07 to -0.86. Sunfishes were avoided in Spring 1981 (L of -0.72) but were otherwise eaten in proportion to their abundance in the environment. Selection for threadfin shad was positive in Summer 1981 but all other values were close to zero. Gizzard shad were eaten proportionally each season. Largemouth bass 301-450 mm long preferred gizzard shad in Winter 1980-81 (L of 0.65) but less so in Summer 1980, and Spring, Summer, and Fall 1981. Threadfin shad were preferred in Spring 1981 and eaten in proportion to abundance in other seasons. Sunfishes were preferred in Summer 1980, and Summer and Fall 1981, but avoided in Spring 1981 (-0.65). The largest bass preferred gizzard shad in Winter 1980-81 (L of 0.98), but less so in Spring 1981. Sunfishes were avoided in Spring 1981 as were silversides in Summer 1980, Winter 1980-81, and Spring 1981.

Overlap

The degree to which hybrids and largemouth bass were utilizing the same food resources was determined from a matrix of overlap values (α) for the paired size groups, assuming that values equal to or greater than 0.6 indicate significant interaction (Zaret and Rand 1971). During 1980, diet of hybrids 151-300 mm long overlapped significantly with that largemouth bass 451-600 mm long (α of 0.6; Table 14). The foods of

301-450 mm long hybrids, however, overlapped significantly with those of all largemouth bass except the largest. Significant diet overlap was also calculated between the largest hybrids and all bass except the 151-300 mm long fish. In 1981 there were fewer significant overlaps in food habits. The diet of the smallest hybrids overlapped significantly with both 301-450 mm and 451-600 mm long largemouth bass (α's of 0.6 and 0.7, respectively).

Diet overlap values calculated on a seasonal basis were less significant than annual values. In Spring 1980, the diets of the 301-450 mm long hybrids and bass overlapped significantly (Table 15). In Summer 1980 the largemouth bass $\leq$150 mm long and the 151-300 mm long hybrids had a diet overlap of 0.6. Also that season, food habits of hybrids 301-450 mm long overlapped significantly with those of largemouth bass 151-300 mm and 301-450 mm long. No significant overlaps occurred in Winter 1980-81, but significant values were calculated for Spring 1981 when food habits of 301-450 mm long hybrids overlapped with those of 451-600 mm long bass (α of 0.6), and those of 451-600 mm long hybrids overlapped with those of largemouth bass 151-300 mm and 451-600 mm long (α of 0.6 and 0.8, respectively). The final significant diet overlap value in 1981 occurred in summer between 151-300 mm long hybrids and 151-300 mm long largemouth bass.

Analysis:

Relative Abundances

Higher catches by number of striped bass x white bass hybrids in spring and fall than in winter and summer were probably related to moderate water temperatures that stimulated movement of hybrids. Biomass followed similar trends because mean weight was greatest in spring, declined in summer, then gradually increased in fall. Changes in mean weights were a result of the presence of gravid females in spring and subsequent growth of all fish through fall. Higher seasonal catches of hybrids in 1981 were probably due to our better knowledge of the hybrid's habits and habitat as well as an increased vulnerability of the fast growing 1980 year class to gill netting. From 1978 through 1981 there was an overall decrease in the number of large hybrids but a progressive increase in mean weight (Hicks and Russel 1980). Overall, abundance of hybrids appeared to be closely related to stocking by O.D.W.C., with larger fish removed by natural and fishing mortality being replaced by rapidly growing younger fish.

Relative abundances of largemouth bass were estimated for fewer seasons than hybrids. Number and weight caught per-unit-effort were approximately equal in Summer and Winter 1980, reached their peak in Spring 1981, and declined in Summer and Fall 1981. Although abundance declined, mean weight increased through the year. Populations of largemouth bass were apparently dependent on the number of fish of reproductive age, angler harvest rates, and physical factors such as low lake levels experienced in 1980 (Hicks and Russel 1980).

We were unable to estimate relative abundance for any major forage group in Spring 1980 because of our failure to collect gizzard shad and sunfishes in gill nets. Hicks (1979) had similar problems trying to estimate forage abundance in Sooner Lake in 1979. Nevertheless, forage fishes were eaten by hybrids and largemouth bass during Spring 1980. Capture of a wide range of sizes of gizzard shad and sunfishes throughout the rest of 1980 and 1981 suggested that these low catches in spring were not representative of real forage abundances. Sunfish abundance, while relatively low in open waters, was high inshore. With the expanding populations typical in new reservoirs, catches of sunfishes would be expected to increase as they did in Sooner Lake (Hicks 1978, 1979, and Hicks and Russel 1980). Inland silversides were rarely collected in winter and spring but were dominant by number and weight in summer and fall each year. Seine samples probably best represented the true abundance of this species (Mense 1967). Threadfin shad, stocked in Summer 1980, were first abundant in Winter 1980-81. Winterkill may have reduced abundance of adult threadfin shad in Spring 1981, but a mild winter apparently contributed to some survival in several portions of the lake and by Summer 1981, they were common. Large schools of young threadfin shad and silversides produced that summer could not be sampled effectively in open areas of the lake. Thus, Summer 1981 estimates of abundance were probably low for these species. Overall, forage abundance in Sooner Lake, while showing seasonal fluctuations, appeared to be high and adequate for sustaining predator populations. Due to the diversity of the forage base, seasonal declines in abundance by one or more species are compensated for by the remaining forage.

Predator Food Habits

Hybrids in Sooner Lake could be caught consistently only by gill net although a number of fish were caught angling. Fifty-four percent of the hybrids collected in gill nets contained food. High water temperatures during summer and early fall which resulted in death of many fish in gill nets and increased food decomposition and digestion (Molnar and Tolg 1962) probably increased the proportions of UFR in stomach contents. Removal of food from live fish generally avoided this problem. The glass tubing method of removing food was fast, efficient, and allowed fish to be released uninjured (Gilliland et al. in press). This technique used in conjunction with gill netting in cooler seasons and electrofishing in all seasons allowed us to obtain representative food habits data based on the assumption that our predator sampling accurately represented the population structure.

Food habits of hybrids and largemouth bass were diverse in Sooner Lake and shifted between 1980 and 1981. For example, in hybrids 151-300 mm long (Figure 2) insects were replaced by threadfin shad in 1981. Hybrids in this size group caught in 1980 had just recently been released as fry and were relatively small, whereas fish collected in 1981 had grown and varied more in size. Increased consumption of fish by larger hybrids was also noted by Ott and Malvestuto (in press). They found hybrids <150 mm long ate primarily insects, but switched to threadfin shad as they grew larger. The apparent increased utilization of shad between years by Sooner hybrids in this size group may be an artifact of sampling, or more likely, the result of an increased abundance and availability of preferred forage fish. Food habits for 301-450 mm long hybrids also shifted between years (Figure 3). In 1980, shad, sunfishes, and silversides were all important foods. In 1981, however, shad and small amounts of UFR (probably shad) were the dominant foods consumed. Most other authors have reported that hybrids this size eat predominantly shad. However, our data for 1980 compares with Day (1980) who reported hybrids this size ate shad, insects, and sunfishes. Hybrids 451-600 mm long also ate sunfishes, silversides, and shad in 1980. These data are in agreement with the findings of Crandall (1979) and Day (1980) who reported increased consumption of sunfishes and silversides with increasing hybrid size. During 1981, however, our data showed hybrids in this size group ate predominantly gizzard threadfin shad. In general there was a trend towards greater utilization of shad from 1980 to 1981 by each size group of hybrids. This shift was primarily in the form of threadfin shad consumption.

Largemouth bass $\leq$150 mm long ate more insects in 1981 and more UFR in 1980 (Figure 5). The high volume of UFR in 1980 was probably shad since this was the only species identified in stomachs. Silversides, which were the most abundant food in stomachs during 1980, completely disappeared from the diet in 1981. Largemouth bass 151-300 mm long ate more insects and crayfish in 1981 than in 1980 whereas volume of shad eaten decreased markedly between the two years (Figure 6). It is possible that increased utilization of insects and crayfish were a result of increased abundances and availability of preferred items. However, Applegate and Mullen (1970) and Vogele (1975) found that largemouth bass did not select insects when suitable forage fish such as threadfin shad, (highly abundant in Sooner in 1981) are available. Like hybrids, 301-450 mm long largemouth bass ate more shad in 1981 than in 1980 (Figure 7). The importance of sunfish decreased between 1980 and 1981 while that of insects and crayfish increased. The small number of bass 451-600 mm long collected in 1980 and 1981 also showed increased shad utilization but had a more diverse overall diet in 1981 than 1980 (Figure 8). In summary, the diets of largemouth bass were, in general, more varied than the diets of hybrids. Insects and crayfish were most important to smaller bass whereas sunfishes and gizzard shad were most important to older, larger bass. Progressively greater utilization of expanding threadfin shad population did not occur as it had with the hybrids.

We ranked the foods of the various length groups of hybrids and largemouth bass by season according to the Index of Relative Importance. During Spring 1980, only largemouth bass bass 301-450 mm long and the two larger groups of hybrids were collected. Fish of both species in the 301-450 mm groups ate mostly gizzard shad (Figures 9 and 10). However, insects were also important to the largest hybrids. Insects were also eaten by these largest hybrids in Spring 1981. These observations may suggest that suitable forage fishes were unavailable or that acceptable insects were highly abundant. In support of the former hypothesis, Day (1980) found that hybrids ate more insects in months when shad abundance was low. Summer diets of hybrids consisted primarily of gizzard shad and threadfin shad except in 1981 when 151-300 mm long hybrids ate insects and 301-450 mm long fish ate silversides. Summer foods of largemouth bass appeared to be related to fish size. Smaller bass ate insects; bass 301-450 mm long ate sunfishes; and the largest bass relied on gizzard shad. These data are only in partial agreement with Aggus (1972) and Day (1980) who found largemouth bass of various size groups fed heavily on shad in summer months. The conclusions of these authors are further challenged by the fact that Sooner Lake largemouth bass did not feed on the numbers of threadfin shad available in Summer 1981. However, during the fall of each year, gizzard shad, and in 1981, threadfin shad, were the most important food of hybrids in each size group. Largemouth bass diets in fall and winter were more varied than during other seasons. Invertebrates including insects and crayfish were the most important food of all three smaller size groups of bass in fall and silversides were most important for the smaller two bass groups in winter. Sunfishes which were commonly eaten by largemouth bass 301-

450 mm long, were not eaten by hybrids to any great extent. Silversides were consumed by 301-450 mm hybrids only in Summer 1980 and by the smaller bass in winter. This pattern is contrary to Crandall's (1979) findings that silversides accounted for one-half of the food of Lake Bastrop hybrids for three years following hybrid introduction. Silversides which were extremely abundant in Sooner Lake from summer through winter were only occasionally eaten by either predator. Crayfish was the only food that was eaten exclusively by the largemouth bass and made up much of the invertebrate portion of the diet in several seasons.

Selectivity

Hybrids and largemouth bass clearly preferred gizzard shad in most seasons and threadfin shad in late 1981 (Figures 10 and 11). However, hybrids developed a much greater preference for threadfin shad than did largemouth bass. Ott and Malvestuto (in press) found a direct relationship between forage population levels and predation on threadfin shad by hybrids. They concluded that hybrids were more likely to prey on the schooling, pelagic shad when prey density increased enough to make predation energy efficient. Selectivity values for threadfin shad by Sooner hybrids are probably inflated due to low estimates of prey abundance when shad were too small to collect in gill nets and remained in open areas. Nevertheless, the trends are good evidence that hybrids shifted diet to a greater extent than did the largemouth bass. Hybrids selected sunfishes in proportion to their abundance in the environment, whereas selection of sunfishes by largemouth bass fluctuated from positive to negative. Largemouth bass selected less for sunfishes during 1981 than in 1980. In contrast to our data, Day (1980), using Ivlev's (1961) electivity index found that both hybrids and largemouth bass avoided sunfishes. In Sooner lake, both species of predator also appreared to generally avoid silversides. Again, our selectivity values are probably somewhat off because of our sampling methods, but the consistently low values suggest they are representative of predator selection. It is not clear, however, if strong negative values represent true avoidance of prey, inaccessibility because of differences in habitat between predator and prey, or invulnerability of prey to capture by the predator. Although concurrent availability of strongly preferred forage could also have contributed to the low degree of utilization of silversides in Sooner Lake, Crandall (1979) found that hybrids strongly preferred this species despite high abundance of gizzard and threadfin shad.

Overlap

Zaret and Rand (1971) concluded that any overlap value greater than or equal to 0.6 was biologically significant and indicated possible detrimental interactions between species. In this study, we found overlap values at or above this level on several occassions but never for more than one season in succession.

On an annual basis, 75% of the significant overlaps were between the two larger groups of largemouth bass and the three groups of hybrids. The mean percent volume per stomach for each paired group indicated that largemouth bass ate similar foods in 1980 and 1981, selecting first gizzard shad, insects, sunfishes, then silversides. Hybrids however, ate progressively more shad, especially threadfin, with fewer insects, sunfishes, and silversides.

Our plots of seasonal overlaps, which compared each hybrid length group with the four largemouth bass groups, suggested size related differences. Diets of hybrids 151-300 mm long overlapped highly with the diets of each bass group in summer. During this season, invertebrates and shad were the most important foods of each species, and selectivities indicated the predators preferred shad (Figure 11). Overlaps dropped sharply following Summer 1981 when threadfin shad became the most important food in the diet of hybrids. At this same time, threadfin shad were relatively unimportant to largemouth bass. The patterns of overlap for hybrids 301-450 mm long varied more than overlap for other size groups, but in general, highest values were found in Spring and Summer 1980 with overall decreases through 1981 (Figure 12). Food habits data again revealed that gizzard shad were the most important food of this group of hybrids and their consumption accounted for most of the overlap. Overlap values in 1981 were very low and never increased to significant levels. The largest hybrids' diet overlapped most strongly with each size group of largemouth bass during Fall and Winter 1980-81 and Spring 1981 (Figure 13). These values were the result of gizzard shad and silversides being found in the diets during fall and winter, and insects being found in the diets during spring for both species. As was seen with the other hybrid groups, an overall decrease in the diet overlap was seen after threadfin shad became important in the hybrids' diet. The decreased overlap between hybrids and bass correspond well with the seasons when threadfin shad abundances increased, as well as when hybrid selectivities for threadfin shad rose.

A number of factors may have influenced the overlap values in addition to prey preference and habitat differences between predators. For example, prey availability as a function of predator mouth size (gape) may have been important. The relatively large gape measurements of much smaller bass would allow them to eat food of similar size to that eaten by larger hybrids (Kleinholz 1981). This difference in gape size could account for the higher diet overlap seen between smaller bass and larger hybrids. Ott and Malvestuto (in press) found that hybrids usually chose prey of less than maximum ingestible size and this behavior should increase the likelihood of diet overlap between hybrids and smaller bass. This size preference suggests that hybrids might not heavily utilize populations of gizzard shad if threadfin shad were abundant and may explain why threadfin shad are preferred.

It was apparent from comparing our results and those of Day (1981) to the findings of other authors that the hybrid is not a strict clupeid feeding predator. Conversely, both of these studies have shown a wide diversity on the diets of hybrids, but with strong preferences for shad when available. Introduction of hybrids into reservoirs with largemouth bass populations that depend on clupeid forage may set the stage for competition and possible harm to one or both predators. However, in situations where bass feed primarily on sunfishes, silversides, etc., the potential for feeding interactions appears to be lower than in those where they depend on shad. In Sooner Lake, the initial forage population structure was such that competitive interactions were probably and given continued predation on gizzard shad by both species, diet shifts which would have affected the growth and fitness of the populations might have been predicted. However, the introduction of threadfin shad, and the shift of hybrids to this forage, appeared to have decreased the likelihood of competition for food between the hybrid and largemouth bass populations.

The utilization of threadfin shad by hybrids may have several other impacts on the fish populations. The consumption of gizzard shad dropped after threadfin shad introduction for all but the largest hybrids. Any hoped for control or harvest of underutilized crops of gizzard shad appeared to be reduced. This, however, may also have made this forage more available for use by largemouth bass by reducing possible competition during periods of low gizzard shad abundance. However, this simple predator-prey system may be highly unstable because threadfin shad are subject to winterkill. This problem may be especially important in reservoirs such as Sooner Lake where heated effluent concentrates the forage in the discharge area during winter and early spring. A power plant shut-down during this period could be critical and focus additional pressure on the remaining forage from both predator populations. Careful monitoring of shad populations and over-winter survival of threadfin fin shad would be essential in the management of the hybrid/largemouth bass system in Sooner Lake so that future stocking rates can be adjusted to insure minimal impact in the event of forage failure.

Conclusions

Relative abundance of striped bass x white bass hybrids was dependent on natural and fishing mortality and the stocking scheme of O.D.W.C., whereas largemouth bass abundance appeared to be related to both natural and fishing mortality plus spawning and recruitment. Forage populations appeared to be abundant and diverse enough to sustain healthy predator populations despite seasonal fluctuations and periodic limited availability. The food of hyrbids consisted primarily of gizzard shad and after 1981, increasingly more threadfin shad. However, sunfishes and insects were also eaten. Diets of largemouth bass included gizzard shad, sunfishes, and insects. Threadfin shad were utilized to a much lesser extent by bass than by hybrids. Inland silversides were eaten by both groups at times but were generally not a significant forage item despite seasonally high abundance. The diets of the predators overlapped significantly during several seasons but never for two or more consecutive seasons. These data appear to indicate that any detrimental interactions were temporary. Following the introduction of threadfin shad, the diet overlap values decreased for all but the largest of bass and hybrids. The largest hybrids continued to feed primarily on gizzard shad. This interaction was not seen as detrimental because of low abundance of large hybrids due to fishing and natural mortality.

Recommendations:

Future research should be conducted to assess the predator and prey populations in Sooner Lake well in advance of future stockings. Additional long term data should be collected on largemouth bass to determine if the diet overlaps we calculated were significant enough to affect growth rates. It should also be determined if the hybrids' shifts in diet are sustained and if largemouth bass begin to utilize the threadfin shad to a greater extent. Further study of the interactions between hybrids and white bass may be necessary in Sooner Lake because of recent successful white bass reproduction. Our limited data suggests that the hybrids and white bass utilize almost identical foods and strong year classes of white bass would potentially affect the success of stocked hybrids.

In regard to further introduction of the hybrid in Oklahoma; we recommend a case by case study of the forage populations and food habits of resident predators prior to introduction.

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Table 1. Seasonal mean and ranges of surface water temperatures from Sooner Lake during 1980 and 1981.

Season	Mean (°C)	Range (°C)
Spring 1980	13	12-17
Summer 1980	23	21-27
Fall 1980	17	7-21
Winter 1980-81	7	4-10
Spring 1981	15	10-18
Summer 1981	24	16-29
Fall 1981	21	16-27

Table 2. Seasonal relative abundances for species collected by gill nets and seines from Sooner Lake during 1980 and 1981

Species	No.	% No.	c_N/f	Wt. (g)	% Wt.	c_W/f
		Spring 1980				
Striped bass x white bass hybrid	31	12.7	5.1	46002	58.3	7510
White bass	57	23.3	9.3	5697	7.2	930
White crappie	11	4.8	1.8	1892	2.4	309
Channel catfish	17	6.9	2.8	1334	1.7	218
Other[a]	128	52.3	20.9	23147	29.4	3779
		Summer 1980				
Striped bass x white bass hybrid	40	0.4	1.2	37249	12.1	1115
White bass	110	1.0	3.3	8835	2.9	264
White crappie	39	0.4	1.2	6449	2.1	193
Sunfishes	158	1.5	4.7	3031	1.0	91
Shad	42	0.4	1.3	1324	0.4	40
Inland silversides	9543	89.2	285.7	9805	3.2	294
Channel catfish	282	2.6	8.4	114712	37.4	3434
Other[a]	479	4.5	14.3	122558	39.9	3669

Table 2. Continued.

Species	No.	% No.	c_N/f	Wt. (g)	% Wt.	c_W/f
			Fall 1980			
Striped bass x white bass hybrid	35	0.4	1.6	68268	32.9	3131
White bass	41	0.5	1.9	16623	8.0	763
White crappie	13	0.2	0.6	1607	0.8	73
Sunfishes	14	0.2	0.6	767	0.4	35
Shad	37	0.5	1.7	2337	1.1	107
Inland silversides	7633	95.7	350.1	5023	2.4	230
Channel catfish	70	0.9	11.7	24320	11.7	1115
Other[a]	134	1.7	42.8	88817	42.8	4074
			Winter 1980-81			
Striped bass x white bass hybrid	10	4.7	1.3	1161	4.0	151
White bass	36	17.1	4.7	4862	16.7	631
White crappie	17	8.1	2.2	2824	9.7	367
Largemouth bass	2	1.0	0.3	1535	5.3	199
Sunfishes	6	2.8	0.8	288	1.0	37
Shad	45	21.3	5.8	4040	13.9	524
Channel catfish	28	13.2	3.6	10891	37.5	1414
Other[a]	67	31.7	8.7	12646	43.5	1642

Table 2. Continued.

Species	No.	% No.	c_N/f	Wt. (g)	% Wt.	c_W/f
			Spring 1981			
Striped bass x white bass hybrid	83	21.1	7.2	205093	63.5	17680
White bass	37	9.4	3.2	7716	2.4	665
Largemouth bass	10	2.5	0.9	15372	4.8	1325
White crappie	19	4.8	1.6	3271	1.0	281
Sunfishes	3	0.8	7.4	195	0.1	17
Shad	86	21.9	0.3	7019	2.2	605
Channel catfish	88	22.5	7.6	64312	19.9	5544
Other[a]	67	17.0	5.8	19709	6.1	1699
			Summer 1981			
Striped bass x white bass hybrid	37	0.2	1.1	53413	35.1	1638
White bass	44	0.2	1.3	3891	2.6	119
White crappie	37	0.2	1.2	4988	3.3	153
Sunfishes	70	0.4	2.1	2599	1.7	79
Shad	2459	13.9	75.4	13934	9.1	427
Inland silversides	14882	84.1	456.5	4846	3.2	15
Channel catfish	124	0.7	3.8	48651	32.0	1492
Other[a]	38	0.2	1.2	19657	12.9	603

Table 2. Continued.

Species	No.	% No.	c_N/f	Wt. (g)	% Wt.	c_W/f
			Fall 1981			
Striped bass x white bass hybrid	52	2.7	7.0	110848	70.1	14979
White bass	32	1.7	4.3	8017	5.1	1083
White crappie	53	2.7	7.2	9059	5.7	1224
Sunfishes	6	0.3	0.8	43	0.1	6
Shad	47	2.4	6.3	2958	1.9	399
Inland silversides	1667	86.4	225.3	1525	0.9	206
Channel catfish	76	3.9	10.3	25722	16.3	3476

[a]Includes carp, buffalo, drum, gar, carpsuckers, and bullheads.

Table 3. Seasonal relative abundances for species collected by electrofishing gear and seines from Sooner Lake during 1980 and 1981.

Species	No.	% No.	c_N/f	Wt. (g)	% Wt.	c_W/f
		Summer 1980				
Largemouth bass	50	0.5	2.0	13280	24.8	531
Striped bass x white bass hybrid	23	0.2	0.9	1366	2.5	54
White bass	22	0.2	0.9	966	1.8	39
White crappie	5	0.1	0.2	382	0.7	15
Sunfishes	957	8.9	38.3	26686	49.9	1067
Shad	146	1.4	5.9	1115	2.1	44
Inland silversides	9543	88.8	381.7	9805	18.3	392
		Winter 1980-81				
Largemouth bass	23	0.3	1.8	10841	33.9	867
White bass	9	0.1	0.9	1215	3.8	97
White crappie	3	0.1	0.2	382	3.8	97
Sunfishes	107	1.3	8.6	3211	10.0	257
Shad	160	2.0	12.8	11307	35.3	904
Inland silversides	7633	96.2	610.6	5023	15.7	402

Table 3. Continued.

Species	No.	% No.	c_N/f	Wt. (g)	% Wt.	c_W/f
			Spring 1981			
Largemouth bass	64	6.4	5.1	14244	20.4	1220
Striped bass x white bass hybrid	3	0.3	0.2	5852	7.8	468
White bass	27	2.7	2.2	5070	6.8	405
White crappie	73	7.3	5.8	12292	16.5	983
Sunfishes	658	66.1	52.6	27252	36.5	2180
Shad	115	11.6	9.2	8603	11.5	7
Inland silversides	55	5.5	4.4	330	0.4	26
			Summer 1981			
Largemouth bass	53	0.3	2.1	39593	70.4	1553
Sunfishes	133	0.8	5.2	4812	8.6	189
Shad	2024	11.8	79.3	6983	13.4	273
Inland silversides	14882	87.1	583.6	4848	8.6	190
			Fall 1981			
Largemouth bass	30	1.6	3.3	6772	41.1	752
Sunfishes	63	3.5	7.0	2569	15.6	285
Shad	62	3.4	6.9	5591	33.9	621
Inland silversides	1667	91.4	185.2	1552	10.1	172

Table 4. Seasonal relative abundances (percent total weight) for forage species collected by gill nets and seines from Sooner Lake during 1980 and 1981.

Species	Total Weight (g)	% Wt.
	Summer 1980	
Sunfishes	3031	21.4
Threadfin shad	3	0.1
Gizzard shad	1321	9.3
Inland silversides	9805	69.2
	Fall 1980	
Sunfishes	767	9.4
Threadfin shad	83	1.0
Gizzard shad	2254	27.7
Inland silversides	5023	61.8
	Winter 1980-81	
Sunfishes	195	2.7
Threadfin shad	4040	93.3
	Spring 1981	
Sunfishes	195	2.7
Threadfin shad	7019	97.3
	Summer 1981	
Sunfishes	2599	12.2
Threadfin shad	4326	20.2
Gizzard shad	9608	44.9
Inland silversides	4846	22.7
	Fall 1981	
Sunfishes	43	1.0
Threadfin shad	70	1.5
Gizzard shad	2888	63.8
Inland silversides	1525	33.7

Table 5. Seasonal relative abundance (percent total weight) for forage species collected by electrofishing gear and seines from Sooner Lake during 1980 and 1981.

Species	Total Weight (g)	% Wt.
	Summer 1980	
Sunfishes	26686	71.0
Threadfin shad	3	0.1
Gizzard shad	1112	3.0
Inland silversides	9805	26.1
	Winter 1980-81	
Sunfishes	3211	16.4
Gizzard shad	12	0.1
Inland silversides	11295	57.8
	5023	25.7
	Spring 1981	
Sunfishes	27252	75.3
Threadfin shad	8603	23.8
Gizzard shad	330	0.9
Inland silversides	0	0.0
	Summer 1981	
Sunfishes	4812	28.9
Threadfin shad	4171	25.1
Gizzard shad	2812	16.9
Inland silversides	4848	29.1
	Fall 1981	
Sunfishes	2568	26.4
Threadfin shad	50	0.5
Gizzard shad	5541	57.1
Inland silversides	1552	16.0

Table 6. Number of fish examined, (percent with food), and total number of striped bass x white bass hybrids and largemouth bass collected from Sooner Lake each season during 1980 and 1981.

Length group	SP80	SU80	FA80	WN80	SP81	SU81	FA81
			Hybrids				
151-300 mm		8(100)				28(82)	13(46)
301-450 mm	16(38)	20(50)			2(50)	1(100)	5(80)
451-600 mm	15(47)	12(75)	35(60)		84(29)	22(18)	34(100)
			Largemouth bass				
≤150 mm		4(50)		5(40)	14(50)	6(100)	5(60)
151-300 mm		25(56)		11(36)	40(73)	42(100)	18(67)
301-450 mm	2(100)	20(65)		6(50)	13(46)	4(50)	7(43)
451-600 mm		1(100)		3(100)	7(86)	1(0)	

Totals:	Number	Stomachs	Mean percent w/food
Hybrids	291	158	54
Largemouth bass	234	160	68

Table 7. Species of fish collected from Sooner Lake, Oklahoma April 1980 through April 1981, number examined with glass tubes, number dissected, number and percent from which tubes removed all food, and the range and mean percent (by weight or volume) of food removed.

			All food removed		% Food removed	
Species	Examined	Dissected	No.	%	Range	Mean
Striped bass x white bass hybrid	224	82	78	95	0-100	95
Striped bass	7	4	4	100	100	100
Largemouth bass	122	5	5	100	100	100
White bass	317	48	43	90	20-100	90
White crappie	128	16	12	75	0-100	75
All species	798	155	141	91	0-100	92

From Gilliland et al. (in press).

Table 8. Yearly summaries of striped bass x white bass hybrid stomach contents from Sooner Lake during 1980 and 1981, by length group.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		151-300 mm, N=37			
1980					
Insects	100.0	98.2	75.0	89	17320
Unidentified fish remains	25.0	0.3[b]	16.7	7	425
Other fish	12.5	1.4	8.3	4	121
1981					
Shad	79.3	89.3	90.3	73	14242
Unidentified fish remains	13.7	2.6	6.3	13	122
Insects	6.9	7.3	1.4	2	60
Sunfishes	3.4	0.7	1.4	3	7
Inland silversides	3.4	1.3	0.7	1	7
		301-450 mm, N=22			
1980					
Shad	37.5	26.1	67.9	34	3525
Unidentified fish remains	43.8	30.4	16.5	41	2050
Insects	25.0	26.1	1.8	13	698
Sunfishes	12.5	17.4	13.8	13	390
1981					
Shad	83.3	90.9	98.5	83	15777
Unidentified fish remains	16.7	9.1	1.5	17	1797

Table 8. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\text{\% Vol.}}$ [a]	IRI
		451-600 mm, N=99			
1980					
Shad	45.9	15.3	48.4	41	2924
Sunfishes	18.9	5.3	38.9	15	835
Unidentified fish remains	40.5	11.5[b]	7.9	31	786
Insects	10.8	48.1	0.3	4	523
Inland silversides	8.1	17.6	4.3	4	177
Other fish	5.4	2.3	0.3	5	14
1981					
Shad	74.2	65.6	85.0	82	11174
Unidentified fish remains	21.0	10.7	5.7	20	344
Insects	6.5	20.5	0.2	4	135
Sunfishes	4.8	2.5	8.7	3	54
Inland silversides	1.6	0.8	0.4	1	2

[a]Denotes mean percent volume per stomach.

[b]denotes estimated numbers.

Table 9. Yearly summaries of largemouth bass stomach contents from Sooner Lake during 1980 and 1981, by length group.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\text{ Vol.}}$[a]	IRI
		<150 mm, N=20			
1980					
Inland silversides	50.0	27.3	64.7	31	4600
Insects	50.0	45.5	11.8	31	2865
Shad	25.0	18.2	25.0	25	1080
Unidentified fish remains	25.0	9.1[b]	11.8	25	523
1981					
Insects	43.8	77.4	38.9	36	4656
Unidentified fish remains	62.5	18.9	55.6	58	1185
shad	6.0	3.8	5.6	6	56
		151-300 mm, N=101			
1980					
Insects	35.5	29.7	1.4	21	1098
Shad	11.8	5.4	54.7	8	709
Other fish	17.6	37.8	1.4	13	690
Unidentified fish remains	29.4	10.8	2.1	22	379
Inland silversides	23.7	13.5	18.5	24	320
Sunfishes	23.7	13.5	18.5	24	320
Crayfish	5.9	2.7	21.3	6	142
	5.9	2.7	0.2	6	17
1981					
Shad	28.6	28.8	38.0	27	1910
Unidentified fish remains	39.3	20.7	13.4	37	1340
Insects	22.6	44.6	3.1	15	1078
Crayfish	4.8	2.2	32.1	4	165
sunfishes	9.5	4.3	10.9	9	144
Inland silversides	5.9	4.3	1.8	9	36

Table 9. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		301-450 mm, N=29			
1980					
Sunfishes	33.3	27.3	41.7	37	2298
Shad	26.7	18.2	47.1	26	1744
Insects	40.0	36.4	3.3	17	1588
Unidentified fish remains	20.0	13.6[b]	5.0	8	372
Crayfish	13.3	9.1	2.2	18	150
1981					
Shad	50.0	46.7	70.3	50	5850
Crayfish	21.4	20.0	21.3	21	884
Sunfishes	21.4	20.0	7.7	28	593
Inland silversides	7.1	6.7	0.4	5	50
Unidentified fish remains	7.1	6.7	0.2	2	49
Insects	7.1	6.7	0.1	1	48
		451-600 mm, N=9			
1980					
Shad	75.0	80.0	69.3	75	11198
Other fish	25.0	20.0	30.7	25	1268
1981					
Shad	50.0	50.0	88.2	48	6910
Sunfishes	16.7	12.5	4.3	2	281
Other fish	16.7	12.5	2.7	17	181
Inland silversides	16.7	12.5	4.3	17	255
Unidentified fish remains	16.7	12.5	0.4	17	215

[a]Denotes mean percent volume per stomach.

[b]Denotes estimated numbers.

Table 10. Seasonal summaries of striped bass x white bass stomach contents from Sooner Lake during 1980 and 1981, by length group.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		151-300 mm, N=36			
Summer 1980					
Insects	100	98.2	75.0	89	17320
Unidentified fish remains	25.0	0.1[b]	16.7	7	425
Other	12.5	1.4	8.3	4	121
Summer 1981					
Threadfin shad	43.3	78.4	32.3	39	4793
Shad remains	26.1	5.6	19.4	26	653
Gizzard shad	8.7	4.9	37.1	6	365
Unidentified fish remains	17.4	2.5	7.3	16	171
Insects	8.7	6.8	1.6	3	73
Fall 1981					
Shad remains	67.0	57.1	30.0	52	5836
Threadfin shad	50.0	42.9	70.0	48	5645
		301-450 mm, N=22			
Spring 1980					
Gizzard shad	67.0	57.1	98.5	67	10425
Insects	16.7	28.6	0.8	17	491
Unidentified fish remains	16.7	28.6	0.8	17	252
Summer 1980					
Unidentified fish remains	60.0	37.5	38.7	55	4572
Sunfishes	20.0	25.0	33.3	20	1166
Insects	30.0	25.0	3.2	10	846
Gizzard shad	20.0	12.5	24.7	15	744

Table 10. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		301-450 mm, N=22			
Spring 1981					
Gizzard shad	100.0	100.0	100.0	100	20000
Summer 1981					
Shad remains	100.0	100.0	100.0	100	20000
Fall 1981					
Threadfin shad	50.0	75.0	90.5	50	8275
Shad remains	25.0	13.0	7.4	25	510
Unidentified fish remains	25.0	13.0[b]	2.4	25	385
		451-600 mm, N=99			
Spring 1980					
Insects	57.1	90.0	28.3	22	6755
Gizzard shad	28.5	2.9	47.8	25	1445
Sunfishes	42.9	4.3	8.7	32	588
Unidentified fish remains	28.5	2.9	15.2	19	516
Summer 1980					
Gizzard shad	55.6	63.4	78.8	56	7906
Unidentified fish remains	44.4	36.6	21.2	44	2566
1980					
Gizzard shad	47.6	22.0	42.2	45	3056
Sunfishes	19.0	8.0	47.3	15	1051
Unidentified fish remains	42.9	18.0	5.1	24	991
Inland silversides	14.3	46.0	5.2	7	700
Other fish	9.5	6.0	0.3	8	60

Table 10. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		451-600 mm, N=99			
Spring 1981					
Gizzard shad	58.3	41.0	81.3	54	7460
Insects	16.7	41.0	3.3	10	740
Unidentified fish remains	29.2	11.5[b]	5.1	26	485
Sunfishes	12.5	4.9	12.7	9	220
Inland silversides	4.2	1.6	0.6	2	9
		151-300 mm, N=36			
Summer 1980					
Insects	100.0	98.2	75.0	89	17320
Unidentified fish remains	25.0	0.3	16.7	7	425
Other	12.5	1.4	8.3	4	121
Summer 1981					
Threadfin shad	43.3	78.4	32.3	39	4793
Shad remains	26.1	5.6	19.4	26	653
Gizzard shad	8.7	4.9	37.1	6	365
Unidentified fish remains	17.4	2.5	7.3	16	171
Insects	8.7	6.8	1.6	3	73
Fall 1981					
Shad remains	67.0	57.1	30.0	52	5836
Threadfin shad	50.0	42.9	70.0	48	5645
		301-450 mm, N=22			
Spring 1980					
Gizzard shad	67.0	57.1	98.5	67	10425
Insects	16.7	28.6	0.8	17	491
Unidentified fish remains	16.7	28.6	0.8	17	252

Table 10. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}^{a}$	IRI
		301-450 mm, N=22			
Summer 1980					
Unidentified fish remains	60.0	37.5[b]	38.7	55	4572
sunfishes	20.0	25.0	33.3	20	1166
Insects	30.0	25.0	3.2	10	846
Gizzard shad	20.0	12.5	24.7	15	744
Spring 1981					
Gizzard shad	100.0	100.0	100.0	100	20000
		451-600 mm, N=99			
Summer 1981					
Gizzard shad	50.0	50.0	97.2	50	7360
Threadfin shad	50.0	50.0	2.8	50	2640
Fall 1981					
Gizzard shad	36.4	28.8	66.4	38	3465
Threadfin shad	24.2	32.7	13.8	27	1125
Unidentified fish remains	18.2	26.9	8.6	18	646
Shad remains	24.2	11.5	11.2	23	549

[a]Denotes mean percent volume per stomach.

[b]Denotes estimated numbers.

Table 11. Seasonal summaries of largemouth bass stomach contents from Sooner Lake during 1980 and 1981, by length group.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\% Vol.}$[a]	IRI
		≤150 mm, N=20			
Summer 1980					
Insects	100.0	55.6	40.0	63	9560
Inland silversides	50.0	22.2	20.0	13	2110
Gizzard shad	50.0	11.1	20.0	13	1555
Other fish	50.0	11.1	20.0	13	1555
Winter 1980-81					
Unidentified fish remains	50.0	50.0[b]	66.7	50	5850
Inland silversides	50.0	50.0	33.3	50	4400
Spring 1981					
Insects	71.4	90.9	50.0	60	10060
Unidentified fish remains	42.9	9.1	50.0	39	2535
Fall 1981					
Unidentified fish remains	83.3	62.5	62.5	75	10413
Threadfin shad	16.7	25.0	25.0	17	835
Insects	16.7	12.5	12.5	8	417
		151-300 mm, N=101			
Summer 1980					
Insects	42.9	31.5	1.5	25	1411
Gizzard shad	14.3	5.7	57.6	10	905
Other fish	21.4	40.0	1.5	16	520
Unidentified fish remains	28.6	8.6	1.0	20	275
Sunfishes	7.1	2.9	22.4	7	180
Inland silversides	14.3	8.6	15.7	14	147

Table 11. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$ [a]	IRI
		151-300 mm, N=101			
Winter 1980-81					
Inland silversides	50.0	40.0	68.2	50	5410
Unidentified fish remains	50.0	40.0[b]	27.3	38	3365
Insects	25.0	20.0	4.5	13	613
Spring 1981					
Insects	31.0	62.3	33.1	28	2024
Threadfin shad	13.8	7.5	29.9	14	516
Unidentified fish remains	24.1	13.2	3.0	23	390
Crayfish	6.9	3.8	44.0	6	330
Gizzard shad	10.3	5.7	14.8	10	211
Sunfishes	13.8	7.5	5.2	14	175
Summer 1981					
Unidentified fish remains	45.3	25.9	41.3	44	3044
Threadfin shad	33.3	49.4	21.0	30	2344
Inland silversides	7.1	5.9	5.5	2	458
Sunfishes	7.1	3.5	23.3	7	190
Insects	14.3	9.4	1.6	5	157
Gizzard shad	9.5	5.9	4.9	9	103
Fall 1981					
Unidentified fish remains	50.0	18.2	18.8	40	1850
Insects	25.0	68.2	9.0	14	1930
Sunfishes	8.0	2.3	51.6	8	431
Inland silversides	20.0	6.8	12.5	17	386
Crayfish	20.0	4.5	9.0	13	270

Table 11. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		301-450 mm, N=29			
Spring 1980					
Gizzard shad	100.0	50.0	96.7	99	14700
Insects	50.0	50.0	3.3	1	2700
		301-450 mm, N=29			
Summer 1980					
Sunfishes	46.2	31.6	44.2	43	3501
Insects	38.5	31.6	3.4	20	1348
Gizzard shad	15.4	10.5	44.8	15	851
Unidentified fish remains	23.1	15.8[b]	5.3	9	487
Crayfish	15.4	10.5	2.3	13	197
Winter 1980-81					
Gizzard shad	66.7	66.7	96.8	67	10905
Crayfish	33.3	33.3	3.2	33	1215
Spring 1981					
Threadfin shad	33.3	28.6	65.3	33	3127
Gizzard shad	33.3	28.6	5.0	33	1119
Sunfishes	16.7	14.3	27.0	17	689
Inland silversides	16.7	14.3	1.8	11	269
Unidentified fish remains	16.7	14.3	0.9	6	254
Summer 1981					
Sunfishes	50.0	33.3	78.6	46	5596
Shad remains	50.0	33.3	14.3	50	2380
Insects	50.0	33.3	7.1	4	2020
Fall 1981					
Crayfish	67.0	67.0	1.0	67	4356
Sunfishes	33.0	33.0	99.0	33	4356

Table 11. Continued.

Season and food item	% Freq.	% No.	% Vol.	$\overline{\%\ Vol.}$[a]	IRI
		451-600 mm, N=10			
Summer 1980					
Other fish	100.0	100.0	100.0	100	20000
Winter 1980-81					
Gizzard shad	100.0	100.0	100.0	100	20000
Spring 1981					
Gizzard shad	50.0	50.0	88.2	47	6910
Sunfishes	16.7	12.5	4.3	2	281
Other fish	16.7	12.5	4.3	16	281
Inland silversides	16.7	12.5	2.7	16	254
Unidentified fish remains	16.7	12.5[b]	0.4	16	215

[a]Denotes mean percent volume per stomach.

[b]Denotes estimated numbers.

Table 12. Seasonal selectivity values (L)[a] for striped bass x white bass hybrids taken from Sooner Lake during 1980 and 1981.

Season and food item	Hybrid length group 151-300 mm	301-450 mm	451-600 mm
Summer 1980			
Gizzard shad	n/a[b]	0.12	0.63
Threadfin shad		-0.01	-0.01
Sunfishes		0.22	0.02
Inland silversides		-0.98	-0.98
Fall 1980			
Gizzard shad	n/a	n/a	-0.22
Threadfin shad			0.0
Sunfishes			0.08
Inland silversides			-0.53
Winter 1980-81			
Gizzard shad	n/a	n/a	n/a
Threadfin shad			
Sunfishes			
Inland silversides			
Spring 1981			
Gizzard shad	n/a	0.03	-0.56
Threadfin shad		0.0	0.0
Sunfishes		-0.03	0.02
Inland silversides		0.0	0.0
Summer 1981			
Gizzard shad	0.05	0.33	0.50
Threadfin shad	0.70	0.16	0.37
Sunfishes	0.01	-0.01	0.01
Inland silversides	-0.84	-0.86	-0.86

Table 12. Continued.

Season and food item	Hybrid length group		
	151-300 mm	301-450 mm	451-600 mm
Fall 1981			
Gizzard shad	0.07	-0.03	0.32
Threadfin shad	0.90	0.88	0.39
Sunfishes	0.01	-0.01	0.01
Inland silversides	-0.97	-0.97	-0.97

[a]Denotes electivity index L of Strauss (1979).

[b]Denotes no fish in the length group collected that season.

Table 13. Seasonal selectivity values (L)[a] for largemouth bass taken from Sooner Lake during 1980 and 1981.

Season and food item	Largemouth bass length group			
	≤150 mm	151-300 mm	301-450 mm	451-600 mm
Summer 1980				
Gizzard shad	0.10	0.05	0.09	-0.01
Threadfin shad	-0.01	-0.01	-0.01	-0.0
Sunfishes	-0.09	-0.06	0.23	-0.09
Inland silversides	-0.67	-0.81	-0.90	-0.90
Winter 1980-81				
Gizzard shad	-0.02	-0.02	0.64	0.98
Threadfin shad	-0.01	-0.01	-0.01	-0.01
Sunfishes	-0.01	-0.01	-0.01	-0.01
Inland silversides	-0.47	-0.57	-0.97	-0.97
Spring 1981				
Gizzard shad	-0.14	-0.08	0.15	0.36
Threadfin shad	0.0	0.08	0.29	0.0
Sunfishes	-0.78	-0.72	-0.65	-0.67
Inland silversides	-0.07	-0.07	0.08	-0.12
Summer 1981				
Gizzard shad	-0.01	0.06	0.15	n/a
Threadfin shad	0.13	0.38	0.03	
Sunfishes	-0.01	0.03	0.33	
Inland silversides	-0.87	-0.81	-0.87	
Fall 1981				
Gizzard shad	-0.03	-0.03	0.03	n/a
Threadfin shad	-0.01	-0.01	0.01	
Sunfishes	-0.04	-0.01	0.30	
Inland silversides	-0.93	-0.86	-0.93	

[a]Denotes electivity index of Strauss (1979).

Table 14. Annual overlap (α)[a] in food of striped bass x white bass hybrids and largemouth bass taken from Sooner Lake during 1980 and 1981, by length group.

		Largemouth bass length group (mm)			
Year	Hybrid length group	$\leq$150	151-300	301-450	451-600
1980	151-300 mm	0.3	0.4	0.3	0.6
	301-450 mm	0.6*	0.6*	0.7*	0.5
	451-600 mm	0.6*	0.5	0.6*	0.6*
1981	151-300 mm	0.5	0.5	0.7*	0.8*
	301-450 mm	0.2	0.5	0.6*	0.5
	451-600 mm	0.2	0.5	0.6*	0.7*

[a]Denotes Schoener (1971).

*Denotes significant overlap (as defined by Zaret and Rand 1971).

Table 15. Seasonal overlap (α)[a] in food of striped bass x white bass hybrids and largemouth bass taken from Sooner Lake during 1980 and 1981, by length group.

		Largemouth bass length group (mm)			
Season	Hybrid length group	≤150	151-300	301-450	451-600
Spring 1980	301-450 mm	n/a[b]	n/a	0.7*	n/a
	451-600 mm	n/a	n/a	0.3	n/a
Summer 1980	151-300 mm	0.6*	0.5	0.3	0.0
	301-450 mm	0.2	0.6*	0.6*	0.0
	451-600 mm	0.2	0.4	0.3	0.0
Fall/Winter 1980-81	451-600 mm	0.4	0.4	0.5	0.5
Spring 1981	301-450 mm	0.0	0.1	0.3	0.6*
	451-600 mm	0.4	0.6*	0.5	0.8*
Summer 1981	151-300 mm	0.3	0.6*	0.4	n/a
	301-450 mm	0.0	0.0	0.5	n/a
	451-600 mm	0.2	0.4	0.0	n/a
Fall 1981	151-300 mm	0.0	0.1	0.3	n/a
	301-450 mm	0.3	0.4	0.3	n/a
	451-600 mm	0.2	0.3	0.3	n/a

[a]Denotes overlap index alpha (Schoener 1971).

[b]Both predators in the given length group were not collected.

*Denotes significant overlap (as defined by Zaret and Rand 1971).

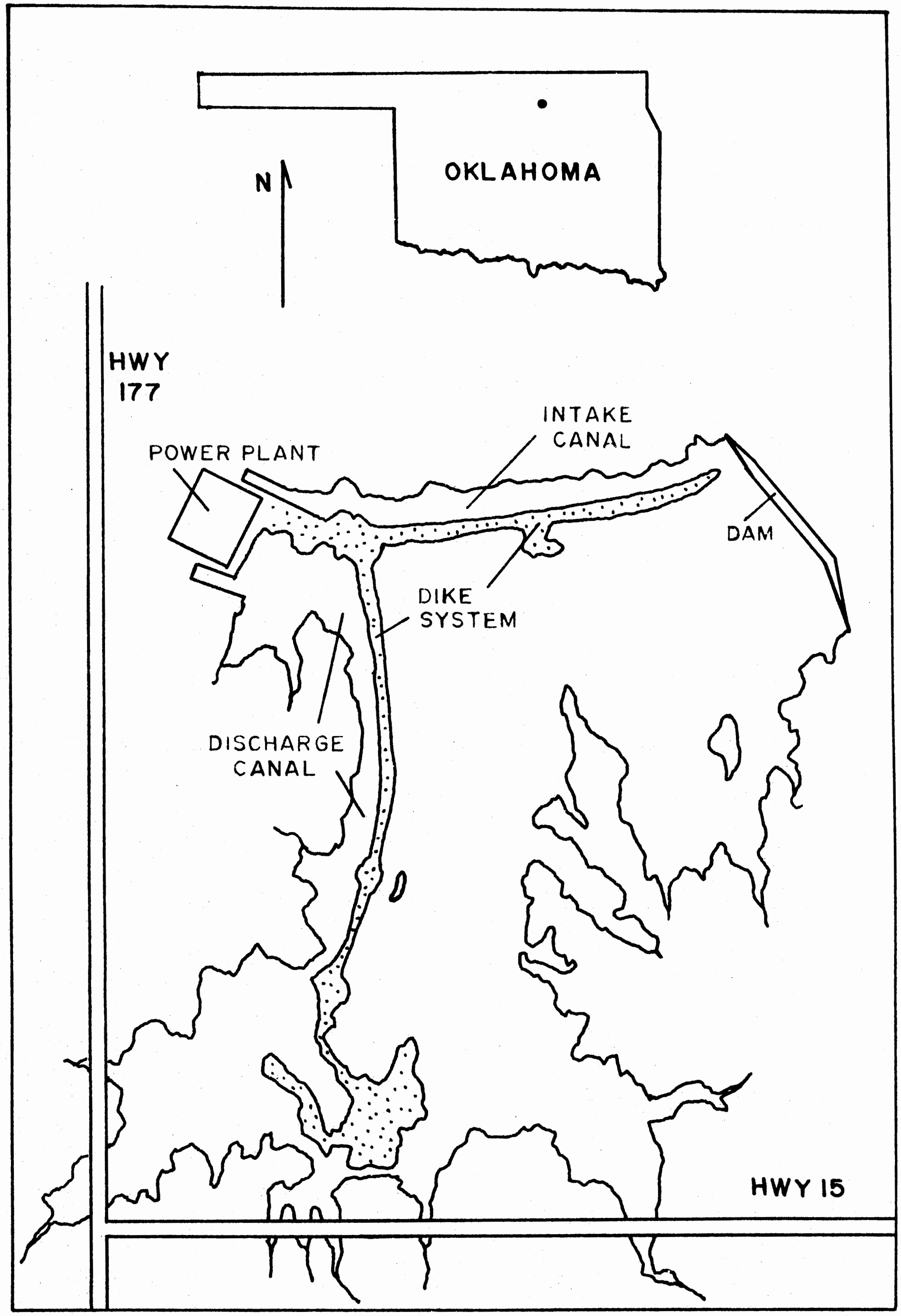

Figure 1. Map of Sooner Lake, Pawnee and Noble Counties, Oklahoma.

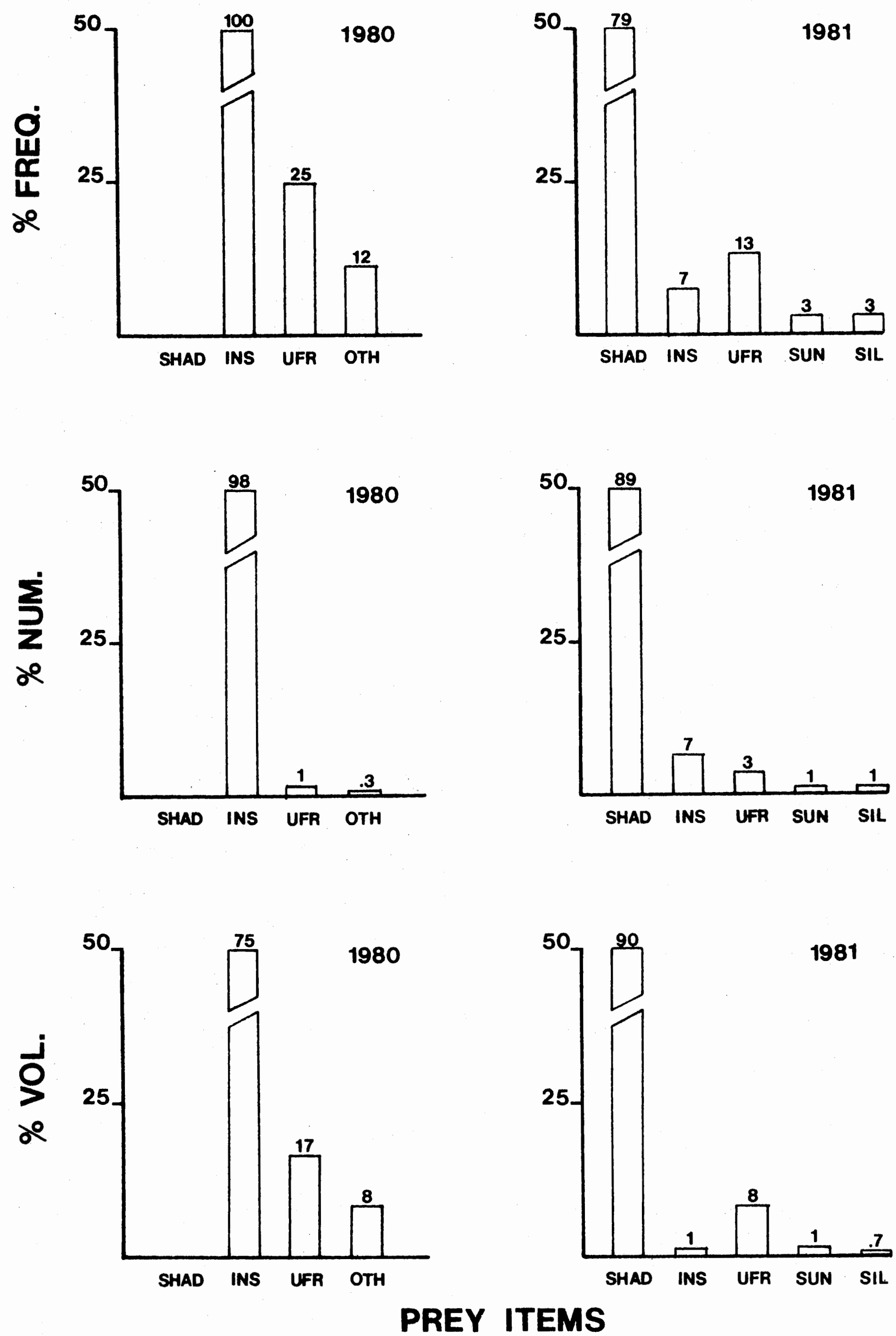

Figure 2. Annual summaries of food habits of 151-300 mm long striped bass x white bass hybrids from Sooner Lake during 1980 and 1981.

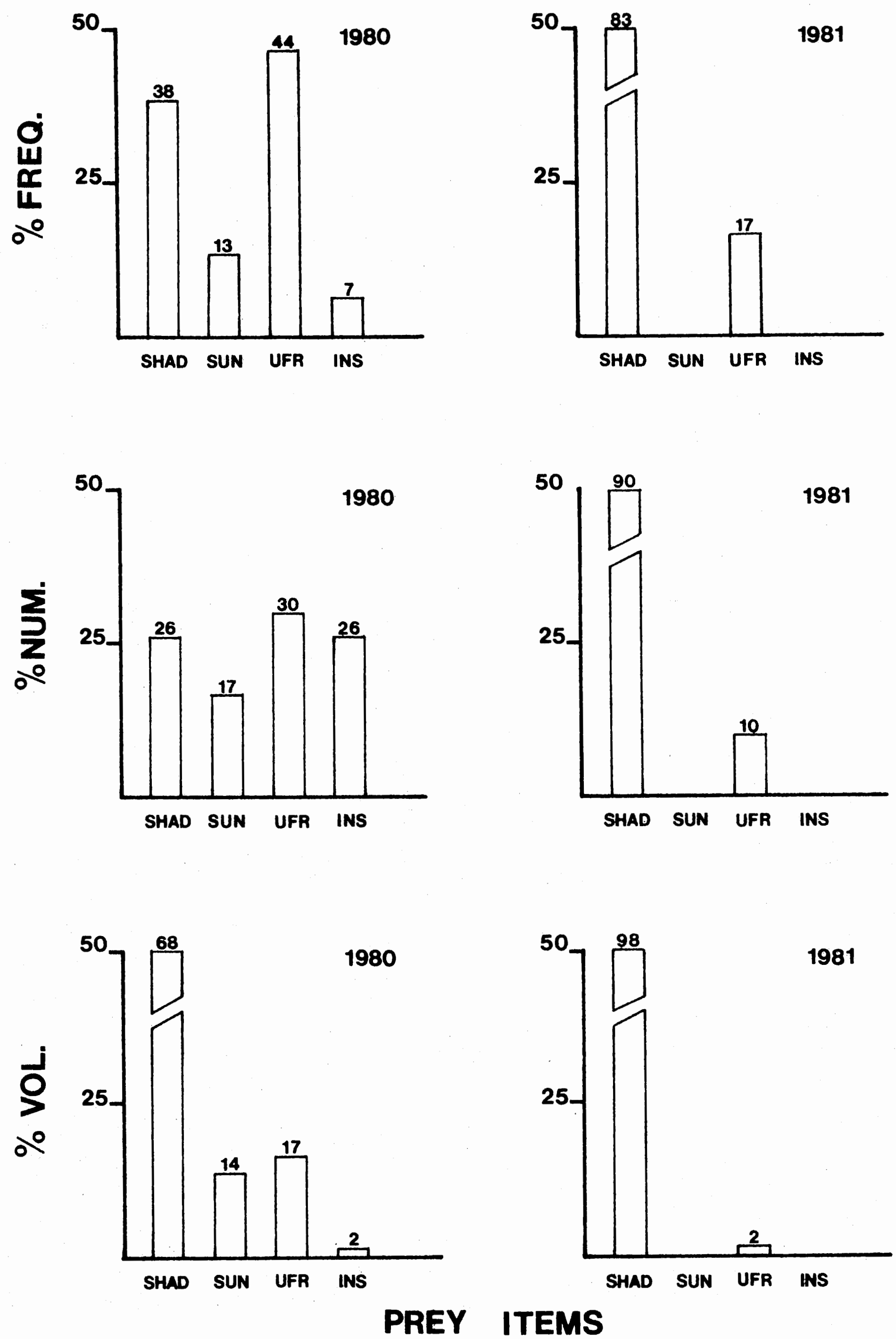

Figure 3. Annual summaries of food habits of 301-450 mm long striped bass x white bass hybrids from Sooner Lake during 1980 and 1981.

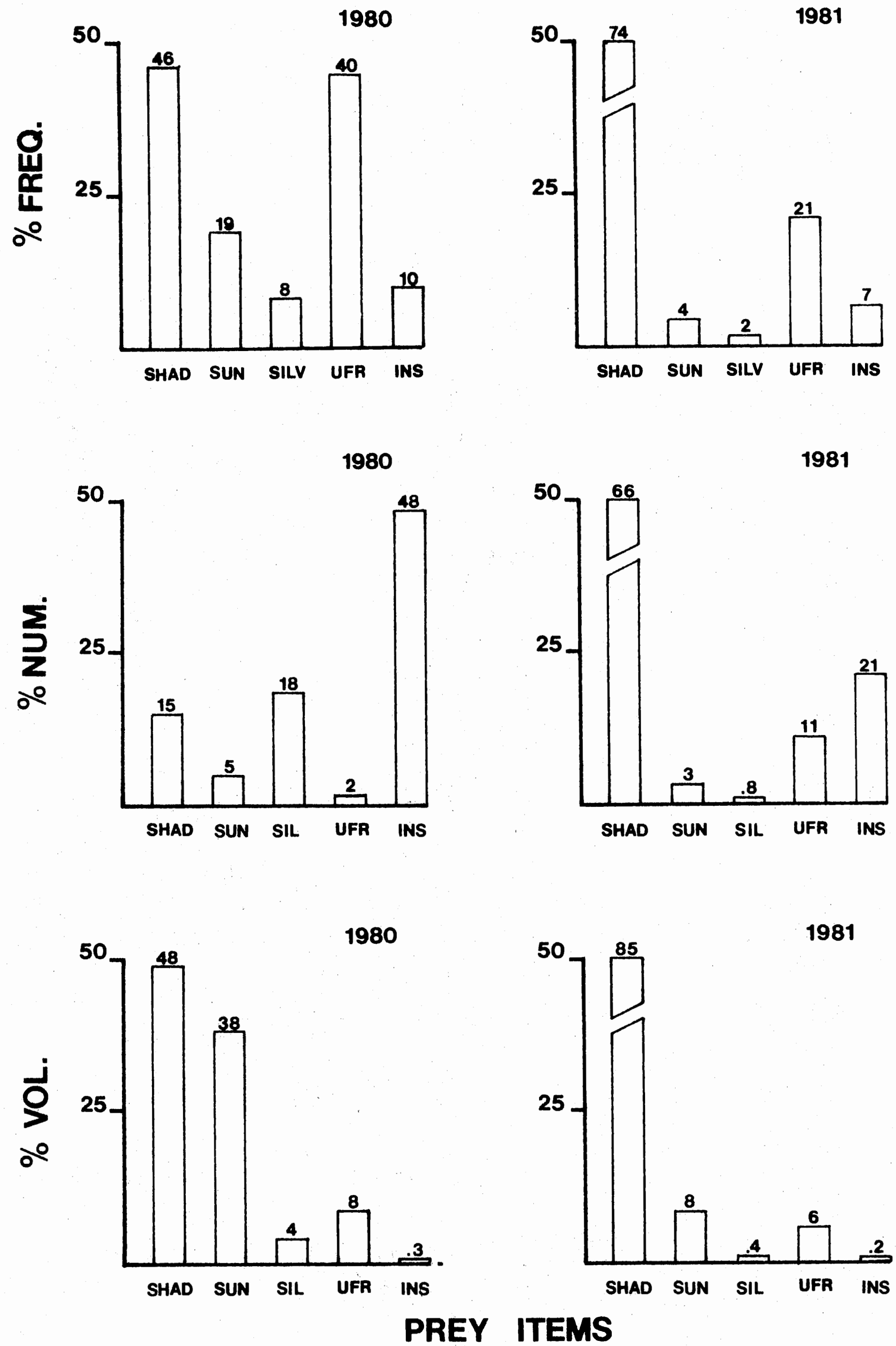

Figure 4. Annual summaries of food habits of 451-600 mm long striped bass x white bass from Sooner Lake during 1980 and 1981.

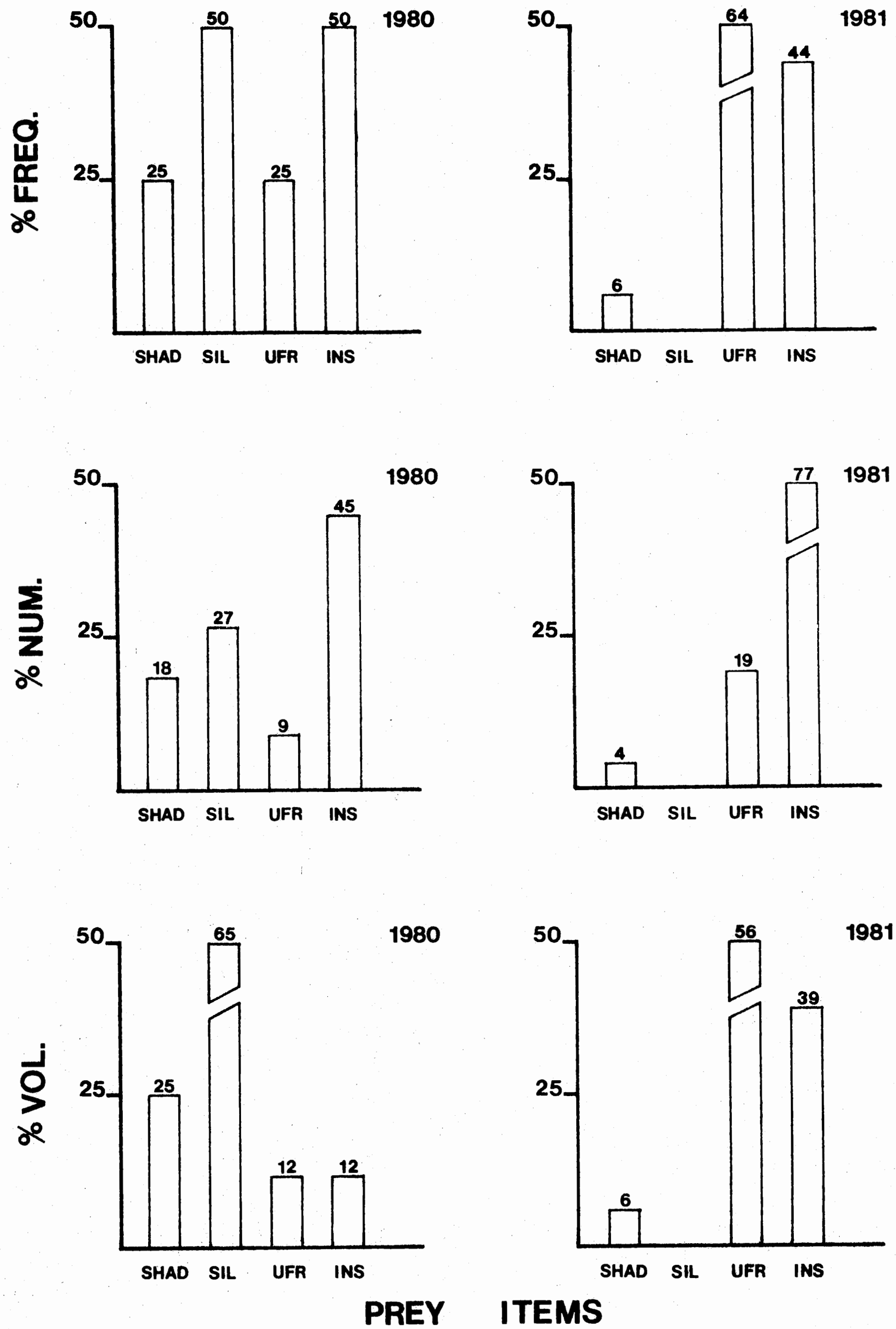

Figure 5. Annual summaries of food habits of largemouth bass 150 mm long taken from Sooner Lake during 1980 and 1981.

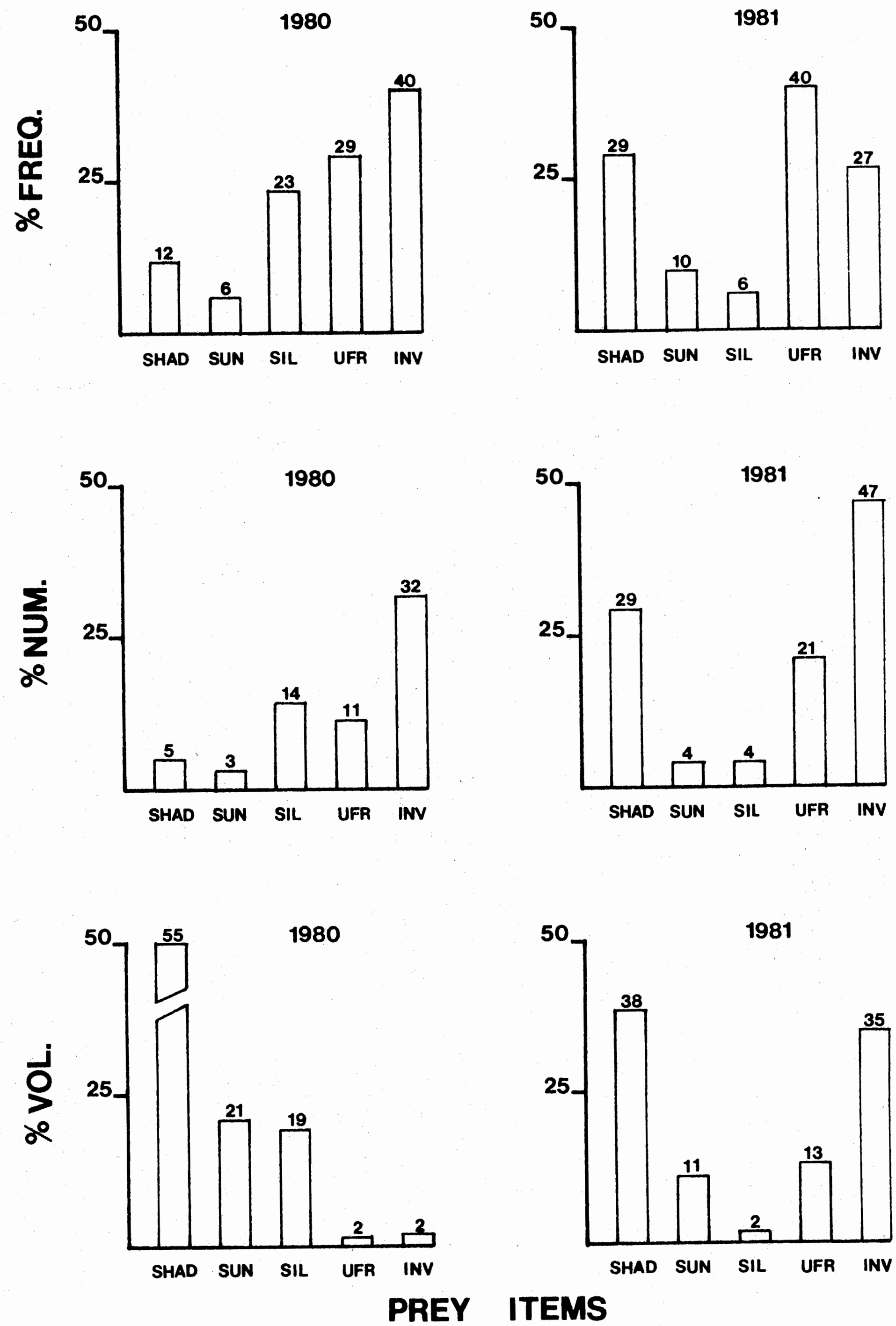

Figure 6. Annual summaries of food habits of largemouth bass 151-300 mm long taken from Sooner Lake during 1980 and 1981.

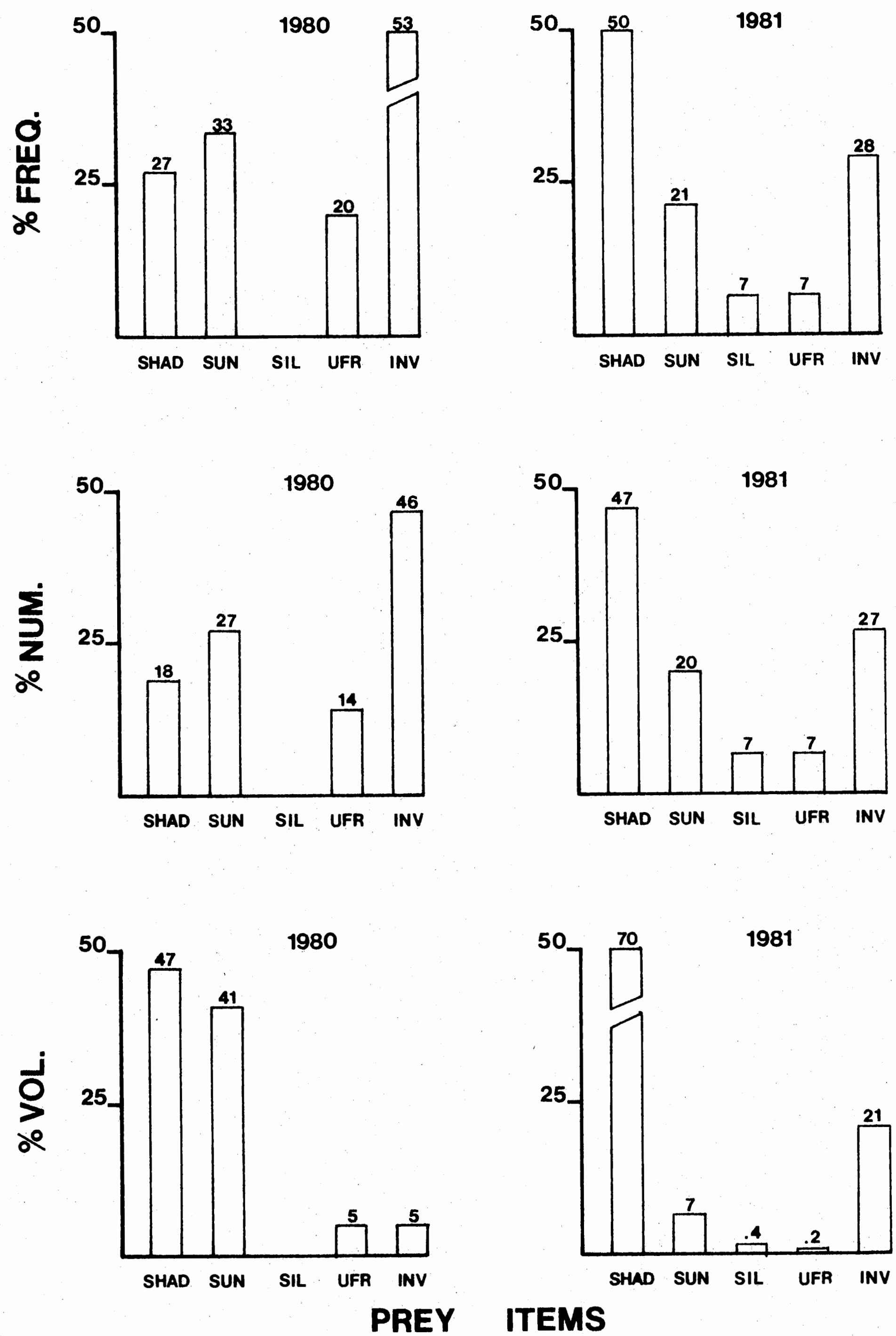

Figure 7. Annual summaries of food habits of largemouth bass 301-450 mm long taken from Sooner Lake during 1980 and 1981.

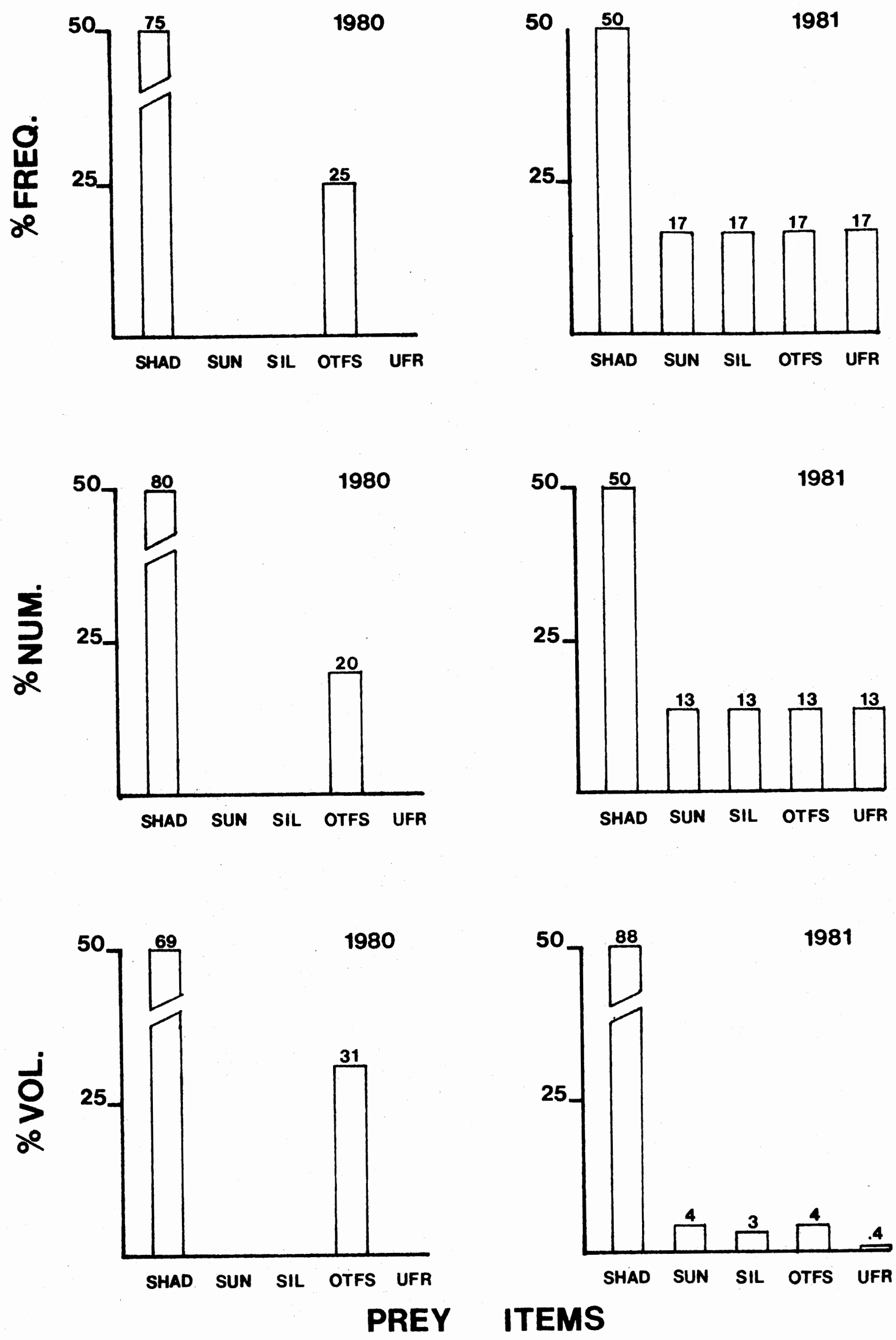

Figure 8. Annual summaries of food habits of largemouth bass 451-600 mm long taken from Sooner Lake during 1980 and 1981.

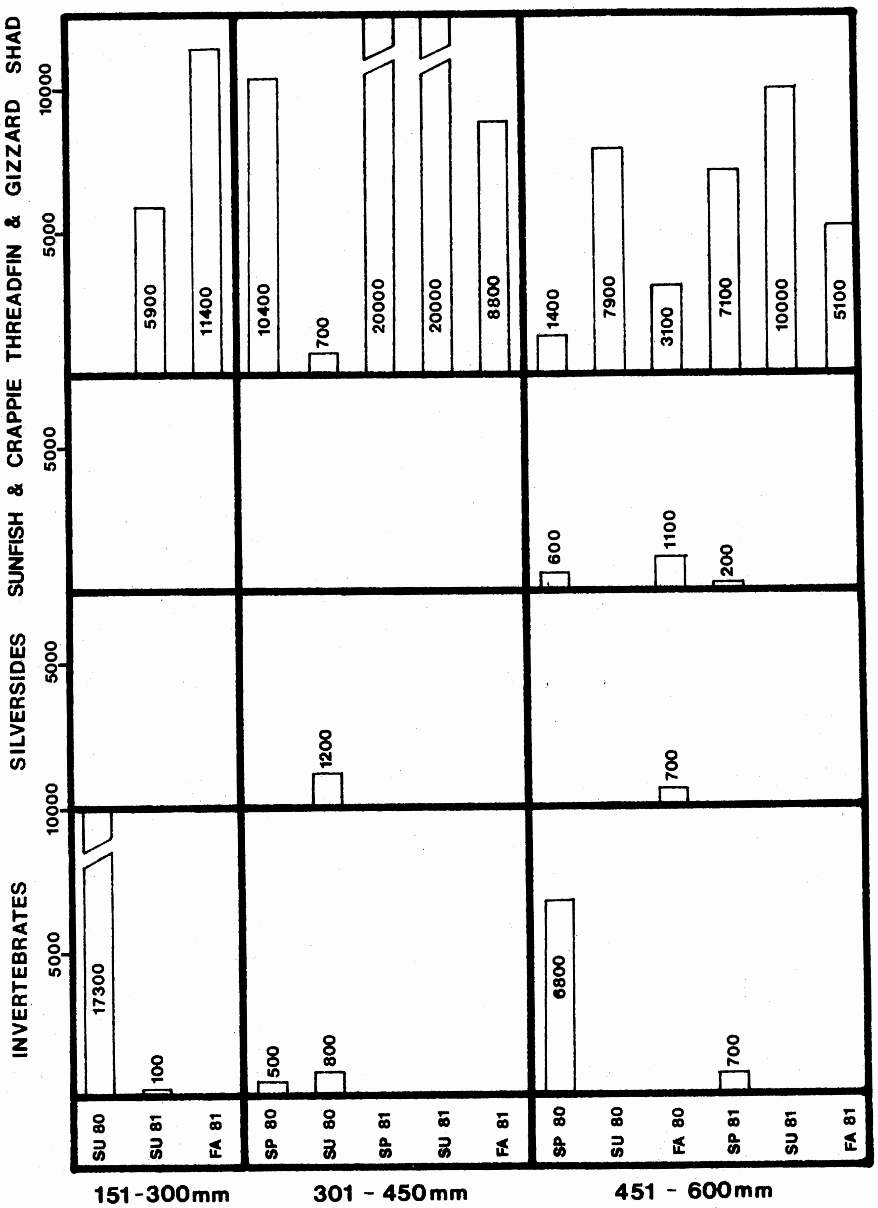

Figure 9. Seasonal IRI values for striped bass x white bass hybrids from Sooner Lake during 1980 and 1981, by length group.

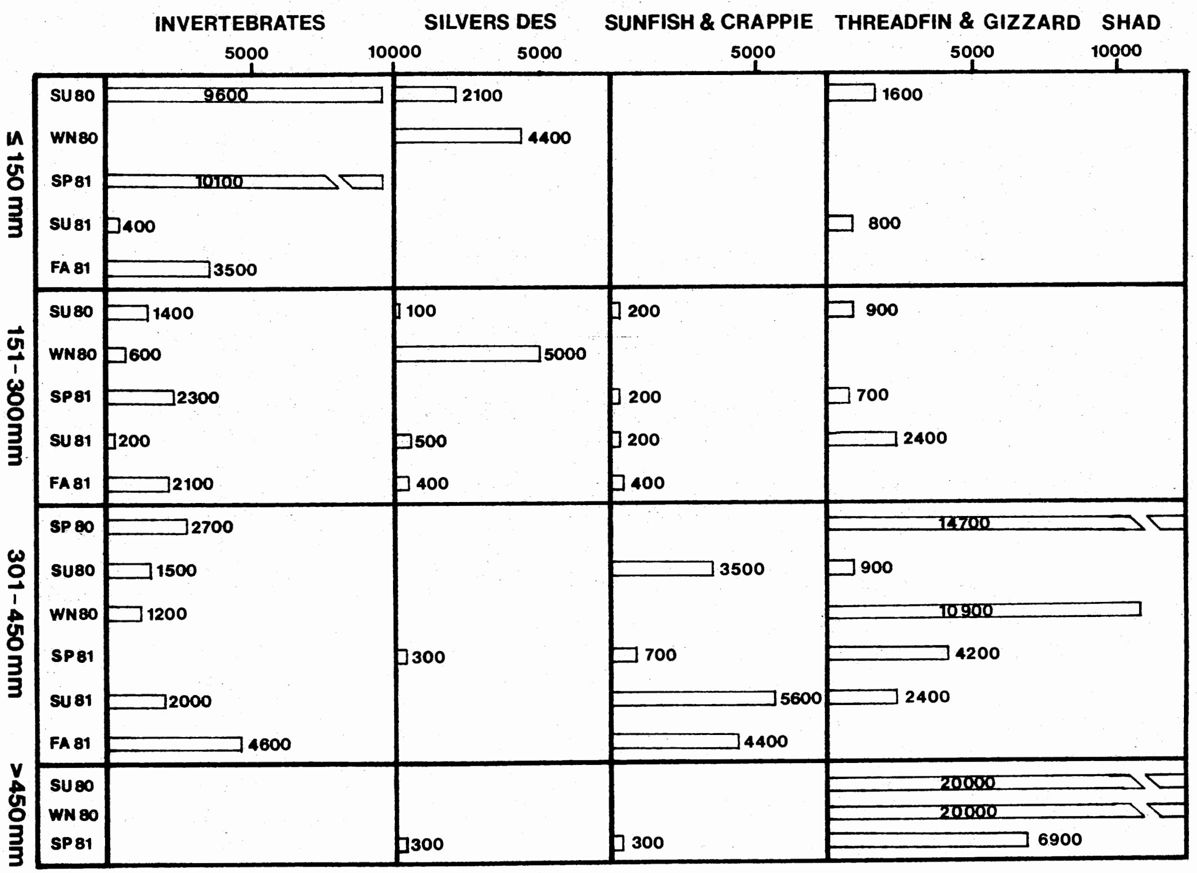

Figure 10. Seasonal IRI values for largemouth bass from Sooner Lake during 1980 and 1981, by length group.

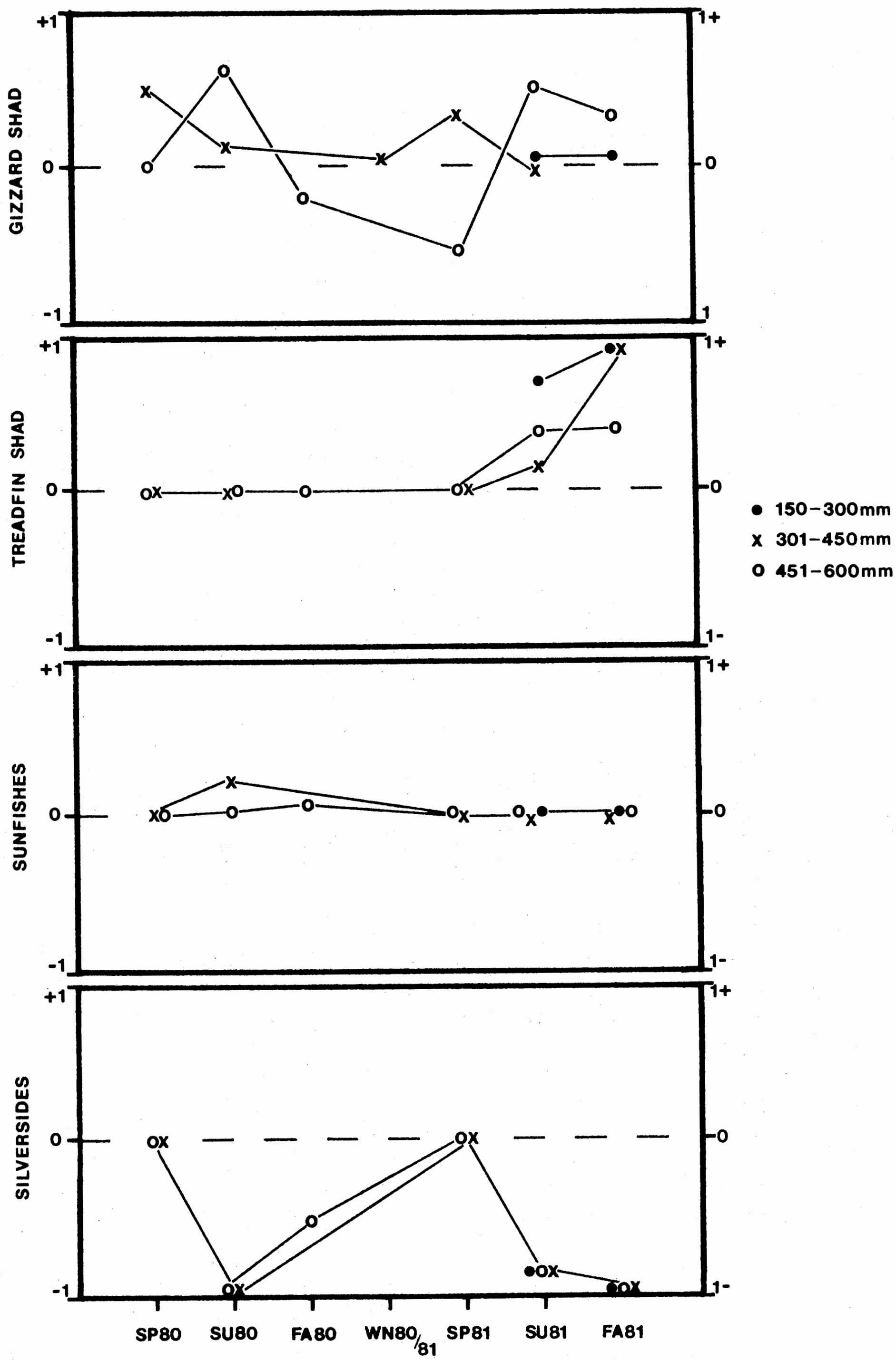

Figure 11. Seasonal selectivity values (L) for four major forage fish groups for striped bass x white bass hybrids taken from Sooner Lake during 1980 and 1981.

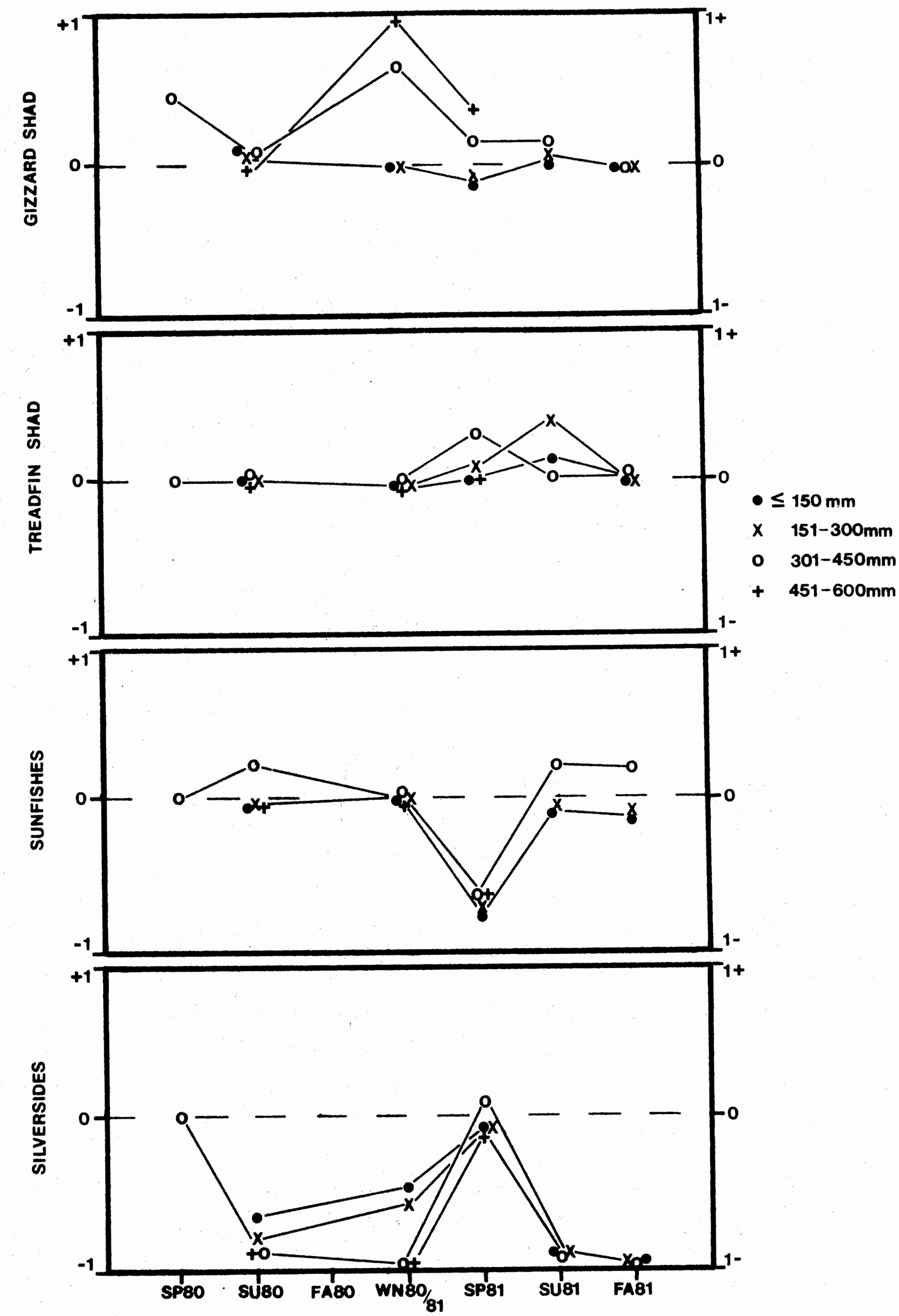

Figure 12. Seasonal selectivity values (L) for four major forage fish groups for largemouth bass taken from Sooner Lake during 1980 and 1981.

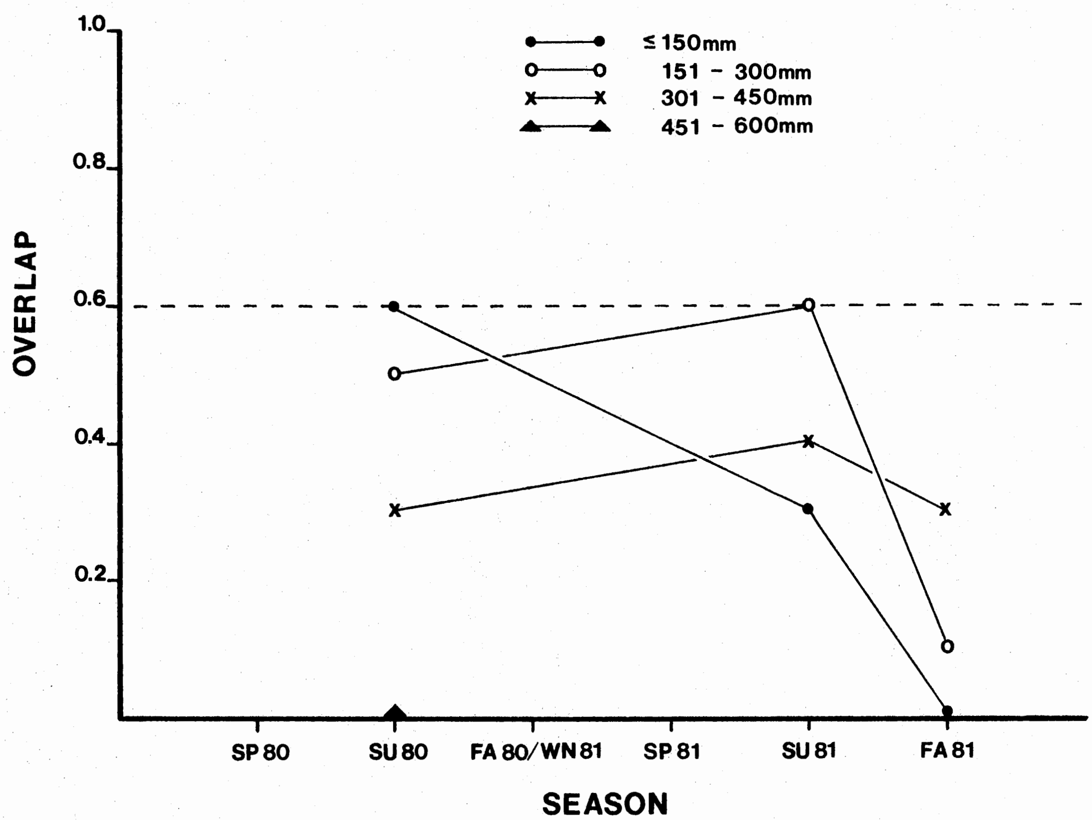

Figure 13. Seasonal diet overlap (α) between 151-300 mm long striped bass x white bass hybrids and each length group of largemouth bass from Sooner Lake during 1980 and 1981.

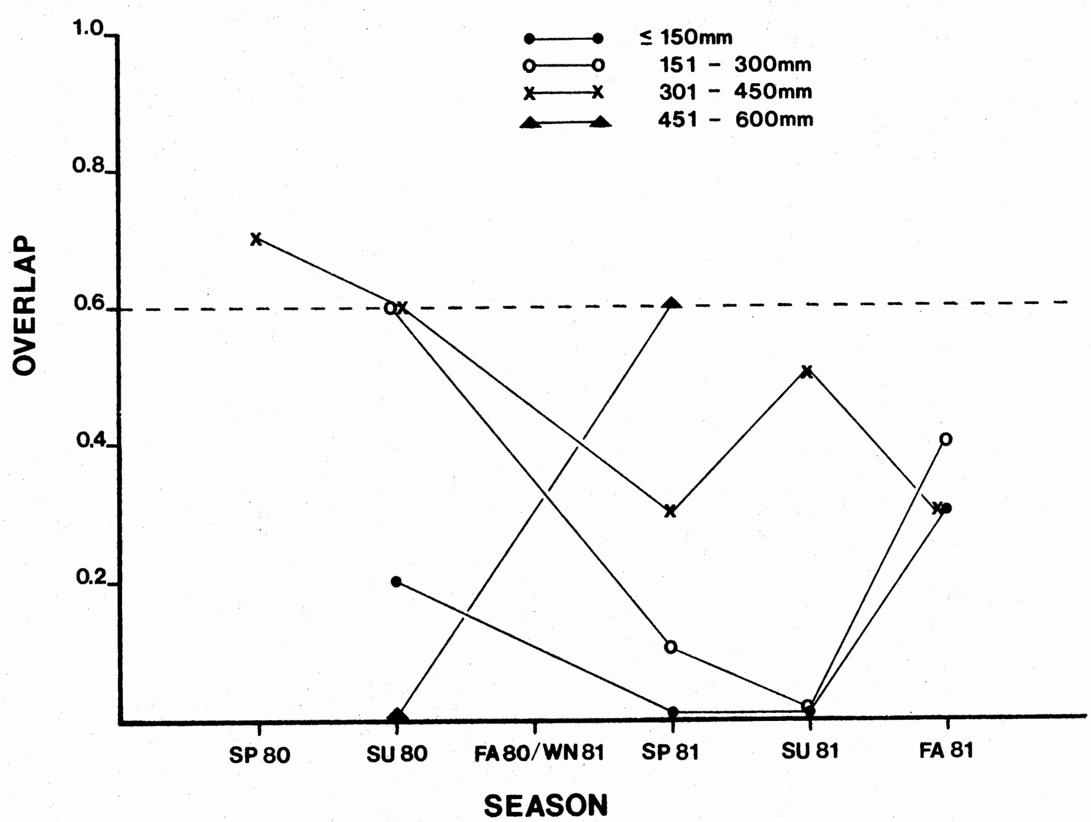

Figure 14. Seasonal diet overlap (α) between 301-450 mm long striped bass x white bass hybrids and each length group of largemouth bass from Sooner Lake during 1980 and 1981.

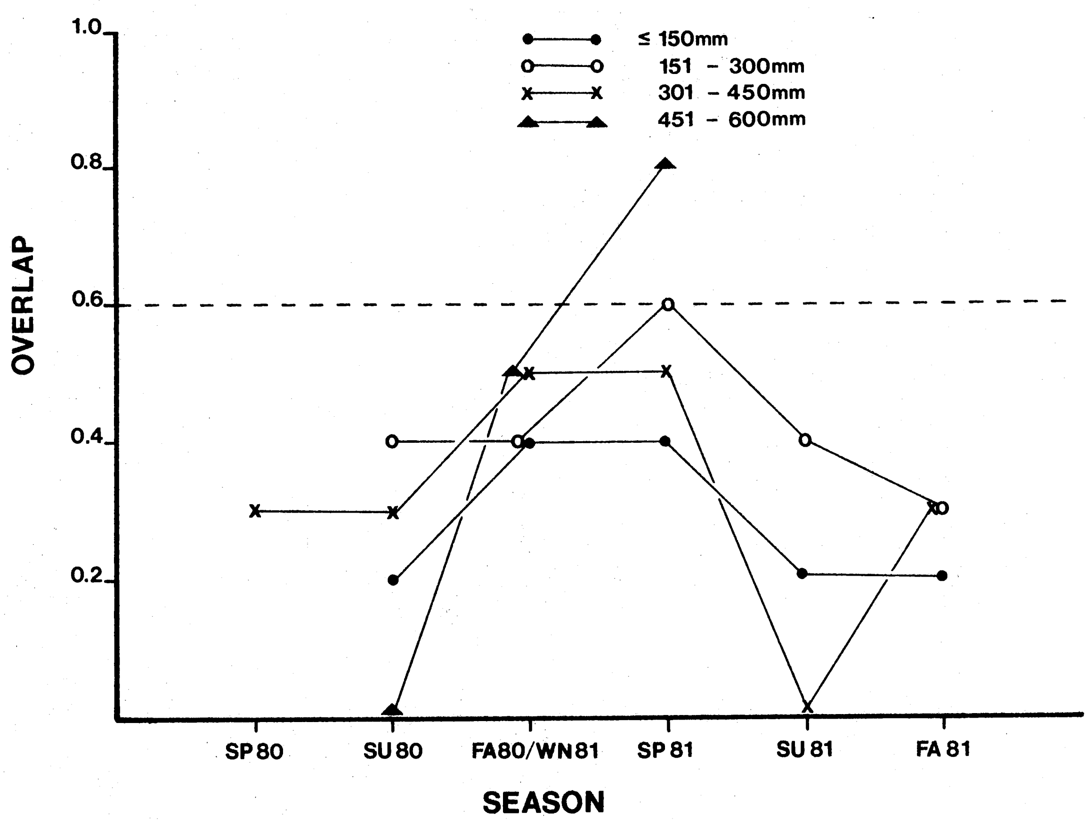

Figure 15. Seasonal diet overlap (α) between 451-600 mm long striped bass x white bass hybrids and each length group of largemouth bass from Sooner Lake during 1980 and 1981.

VITA[2]

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Master of Science

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