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FINAL REPORT

RESEARCH AND SURVEYS

FEDERAL AID GRANT NO. F-41-R

FACTORS INFLUENCING FISH POPULATIONS IN OKLAHOMA WATERS

PROJECT 20

EVALUATION OF A DIFFERENTIAL HARVEST REGULATION ON BLACK BASS POPULATIONS IN SKIATOOK LAKE, OKLAHOMA

JULY 1, 1996 through JUNE 30, 2000

FINAL REPORT

STATE: OKLAHOMA GRANT NUMBER: F-41-R

GRANT TITLE: Factors Influencing Fish Populations in Oklahoma Waters

PROJECT TITLE: Evaluation of a Differential Harvest Regulation on Black Bass Populations in Skiatook Lake, Oklahoma

PROJECT NUMBER: 20

PROJECT OBJECTIVE: To evaluate the responses of three black bass populations to increased harvest of spotted bass in Skiatook Lake, Oklahoma

ABSTRACT

We evaluated the response of largemouth bass Micropterus salmoides, smallmouth bass M. dolomieu, and spotted bass M. punctulatus to a differential harvest regulation and assessed the effects of environmental variability and resource availability on these populations in Skiatook Lake, Oklahoma. This report in divided into four chapters that address: (1) angler responses to the regulation change, (2) fish population responses to the regulation change, (3) prey and habitat resource use by the black bass populations, and (4) environmental influences on the three populations.

We used a two-stage probability roving creel survey from 1997 to1999 to evaluate anglers responses to a differential black bass harvest regulation that was implemented January 1, 1997 at Skiatook Lake, Oklahoma. This regulation allowed anglers to harvest 15 spotted bass of any size and six largemouth and smallmouth bass greater than 356 mm (in aggregate) per day. Prior to this regulation change, all black bass were managed with a 365 mm size limit and a six fish aggregate creel limit. This change was made to minimize competition among black bass by reducing the abundance of spotted bass through angler harvest. Increases were detected in: (1) anglers abilities to distinguish spotted bass from largemouth and smallmouth bass; (2) the proportion of anglers that would not change the number of spotted they harvested per fishing trip; (3) the proportion of anglers that would not increase their fishing effort toward spotted bass; (4) and the proportion of anglers did not have an opinion as to whether or not the regulation change was necessary. The majority of anglers reported that they preferred to catch a few averaged size fish; did not plan on harvesting the bass caught that day; they never or rarely harvested the bass they caught; and rated their fishing trip from fair to excellent. Relaxation was the most commonly reported motive for fishing in 1998 and 1999. Throughout the study, angler knowledge of the regulation change and harvest of spotted bass did not increase while the population structure of largemouth bass decreased in each year of the study. Although smallmouth bass RSD_{356} was significantly higher in 1999 than 1997, we did not attribute this difference to the regulation change. This regulation failed to accomplish the primary objective of decreasing the relative abundance of spotted bass; however, it did provide anglers with the opportunity to harvest more bass.

We evaluated the response of largemouth bass, smallmouth bass, and spotted bass populations to this differential-harvest regulation in Skiatook Lake during the spring and fall of 1997-1999. Standardized sampling protocol (SSP) data from the Oklahoma Department of Wildlife Conservation showed no differences in electrofishing catch rates of spotted bass between two years pre-regulation change and two years post-regulation change. Largemouth bass were equally distributed throughout the reservoir in fall and less abundant in Hominy Creek in spring during the entire study period. Largemouth bass relative abundance increased in fall, but not in spring, over the three years, while recruitment, relative weights, and survival remained unchanged. Largemouth bass growth was greatest in 1998 but proportional stock density (PSD) decreased in spring 1999. Smallmouth bass were distributed primarily in the lower-lake regardless of season. Smallmouth bass relative abundance increased over the study period in spring, but not in fall and recruitment remained constant. Relative weights of smallmouth bass were depressed in spring 1998 but constant in fall during the three years. Smallmouth bass PSDs were constant in fall but greatest in spring 1999. Growth rates of smallmouth bass were also greatest in spring 1999 while survival remained constant. Spotted bass were distributed more in the upper lake in spring and in the mid- and lower-lake areas in fall. Spotted bass relative abundance remained constant over the study period, as did recruitment, while mean relative weights were greatest in both spring and fall of 1997. Spotted bass PSDs and survival remained unchanged over the study period while growth rates were depressed in 1999. The stable survival rates for all species, coupled with the constant trend in spotted bass abundance, indicate that this regulation change failed to reduce spotted bass from Skiatook Lake.

We examined prey and habitat use by juvenile and adult largemouth bass smallmouth bass and spotted bass in Skiatook Lake during spring and fall 1997-1999. The greatest amount of niche segregation for prey was in spring 1997 when juvenile and adult largemouth bass and adult smallmouth bass consumed various fish species, juvenile smallmouth bass and spotted bass consumed insects, and adult spotted bass consumed crayfish. Prey overlap increased, although not significantly, from 1997 to 1999 and all sizes and species consumed fish while adults of all three species also consumed crayfish. We measured 22 habitat variables in spring 2000 and fall 1999 and analyzed habitat use patterns over the three years with the aid of geographic information systems (GIS) technology. The largest source of variation in habitat was associated with water quality variables (Secchi depth, surface water temperature, conductivity, and dissolved oxygen) along a longitudinal gradient in the reservoir. Density of both size classes of largemouth bass was poorly associated with any habitat variables in any season or year, although distance to the main river channel and several substrate and cover variables were significant most often. Density of both size classes of smallmouth bass was associated with those variables that exhibited a longitudinal gradient in the reservoir, and smallmouth bass were restricted to the lower-end of the reservoir. Few relationships were found between density of juvenile spotted bass and habitat in any season or year. Adult spotted bass density was related to similar variables as smallmouth bass, except that shoreline slope explained more variation in density than the other longitudinally distributed variables. These results indicate that largemouth bass is a habitat generalist, smallmouth bass is a habitat specialist, and that spotted bass use habitat most similar to smallmouth bass, but

exhibit seasonal differences in Skiatook Lake. Habitat was most likely stronger than prey in segregating the niches of these three species in Skiatook Lake, although finer scale measurements are needed to verify this hypothesis.

We analyzed trends in recruitment of largemouth bass smallmouth bass and spotted bass in relation to environmental conditions in Skiatook Lake, Oklahoma from 1997 through 1999. We correlated catch rates of young-of-year (YOY) and juvenile largemouth bass, juvenile smallmouth bass, and juvenile spotted bass with three weather variables and five reservoir hydrology variables for the period 1997 through 1999. Young-of-year largemouth bass were positively correlated with inflows into the reservoir during the spawning season (April - June) while juveniles were positively related to reservoir releases during the post-spawning period (June - November). Juvenile smallmouth bass relative abundance was positively related to days of flooding during the spawning season. Juvenile spotted bass were related only to weather variables: positively to accumulated rainfall in the spawning season and to mean wind speed in the post-spawning season. Juvenile largemouth bass relative abundance increased from 1997 through 1999 based on fall electrofishing samples while juvenile smallmouth bass and spotted bass relative abundance remained constant. We found no significant influences of over-winter mortality among all three black bass species. Swim-up dates for young-of-year largemouth bass, based on daily otolith ring counts, were later every year from 1997 to 1999. Swim-up dates for young-of-year smallmouth bass were variable with the earliest dates in 1998. No young-of-year spotted bass were collected in 1997 and swim-up dates were similar between 1998 and 1999. Growth of YOY largemouth bass was greatest in 1999 and greatest in 1998 for YOY smallmouth bass. There was no statistical test of YOY spotted bass growth between 1998 and 1999 due to low sample sizes. Growth of YOY largemouth bass was not correlated with any of the environmental variables; and growth of YOY smallmouth bass and spotted bass were not included in the correlation analysis due to low sample size. The poor associations between black bass population characteristics and environmental variables at Skiatook Lake may be influenced by low detectability, increased importance of density-dependent factors, or a combination of these factors.

RECOMMENDATIONS

1. A publicity effort in magazine and newspapers articles, at fishing club gatherings, and to bait shop owners is needed to better inform anglers about the differential harvest regulation on black bass populations in Skiatook Lake.
2. On-going monitoring of the black bass populations and angler catch and harvest will be needed to assess the effectiveness of the regulation.

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Chapter I

RESPONSE OF ANGLERS TO A DIFFERENTIAL HARVEST REGULATION ON THREE BLACK BASS SPECIES IN SKIATOOK LAKE, OKLAHOMA

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Introduction

Providing anglers with satisfying fishing trips requires that fisheries are managed to produce a variety of fish of reasonable size and number. This is often accomplished by imposing regulations that protect or enhance the fish populations. Size limits are popular among fisheries management agencies because their effects on the population structure of sport fish and forage fish are usually predictable (Fox 1975; but see Wilde 1997). Minimum-length limits are best used to prevent over-exploitation, protect fish to spawning size, decrease the abundance of prey species (Novinger 1984; Noble and Jones 1993), and increase catch rates of quality-size fish (Kornman 1990; Nobel and Jones 1993). Populations that exhibit good growth but have low natural mortality, high fishing mortality, and low recruitment are good candidates for a minimum-length limit (Novinger 1984).

Black bass Micropterus often exhibit these characteristics and are successfully managed under minimum size limits. These regulations work well when a fishery contains only one black bass species, but it is common in the southeastern U.S. to have reservoir systems with some combination of largemouth M. salmoides, smallmouth M. dolomieui and or spotted bass M. punctulatus. The same minimum size limit is often used to manage all black bass present in a particular fishery. However, biologists have noted that black bass, especially spotted bass, tend to "stockpile" under minimum-length limits (Kornman 1990; Buynak et al. 1991, 1995).

Novinger (1987) suggested the use of a differential black bass harvest regulation when he reasoned that a minimum size limit when applied to both largemouth and spotted bass would not affect both populations in the same manner. Slower growth rates and shorter life span of the spotted bass allow for higher natural mortality rates and an increase in the amount of time until harvest (Novinger 1987). Novinger (1987) also pointed out that for such a regulation to work, anglers would have to be able to correctly distinguish spotted bass from largemouth bass.

Differential black bass harvest regulations have rarely been used, presumably because anglers have difficulty correctly identifying spotted bass. However, a differential black bass harvest regulation was successfully implemented on Cave Run Lake, Kentucky (Buynak et al.1991). The regulation allowed harvest of any size spotted bass, but only largemouth bass greater than 381 mm. Buynak (1995) presumed that informing anglers of the tooth patch characteristic to distinguish spotted bass from largemouth bass was sufficient information to meet management needs, although 10% of the largemouth bass in Cave Run Lake also had a tooth patch. Buynak et al. (1991) found the number of largemouth bass that anglers misidentified and harvested constantly decreased in the years following the regulation change. Spotted bass harvest in Cave Run Lake increased in the five years following removal of the size limit, while the average size of all black bass harvested decreased. Cave Run Lake anglers harvested over 41% of the spotted bass caught that were under 30 mm and 59% of the fish in the 229 mm size range (Buynak et al. 1991). This added harvest decreased survival rates and increased fishing mortality but failed to increase body conditions or growth rates of the spotted bass (Buynak et al. 1991).

Skiatook Lake was opened for public fishing in 1986, and since then, the black bass populations have been protected from over exploitation by both size and harvest regulations. Under the regulation, all black bass caught that are less than 356 mm must

be immediately released and no more than 6 black bass, in aggregate, may be kept. Anglers as well as the spotted bass populations have benefited from this regulation. Anglers have had the opportunity to catch good numbers of quality-sized largemouth bass and smallmouth bass, while the slower-growing spotted bass have benefited from the extra protection that they receive under the regulation. However, since spotted bass grow slower than the largemouth and smallmouth bass, harvest of the spotted bass rarely takes place. This has allowed the spotted bass population to stockpile under the minimum size length (ODWC 1995).

Until recently, the differential abundance of black bass species had not been a problem at Skiatook Lake; however, beginning in 1992 fisheries biologist with the Oklahoma Department of Wildlife Conservation (ODWC) noticed a dramatic increase in the number of the spotted bass with very few of them reaching the 356-mm size limit. At the same time, they also reported a significant decline in the relative weight for all sizes of this species. By 1994, body condition of largemouth bass > 300 mm had also declined, and the condition of smallmouth bass between 200 mm and 299 mm was considered unsatisfactory (ODWC 1995).

Beginning 1 January 1997, the ODWC removed the size limit on spotted bass and increased the harvest limit to 15 fish/day. These new limits only applied to spotted bass; the previous 356-mm and 6 fish (aggregate) daily bag limit remained in effect for the largemouth and smallmouth bass. This regulation change was done to improve the population structure of all black bass species. The underlying assumption of the regulation change was that there is significant niche overlap among the three black bass species and allowing anglers to harvest more spotted bass will reduce interspecific competition. Clady and Luker (1982) reported that intraspecific competition affected both weight and survival of largemouth bass but not spotted bass stocked in small Oklahoma ponds. Increased harvest of spotted bass will presumably allow for better growth rates, survival, and possibly higher recruitment of the largemouth and smallmouth bass in Skiatook Lake

The objectives of my study were to determine the effectiveness of this new regulation by documenting the effects of angling on the black bass population structure. Quantitative data on angler catch, harvest, and effort were gathered and monitored throughout the study period to identify trends associated with the regulation change. Qualitative data for angler knowledge, attitudes, opinions, motivations, and satisfaction level were also collected.

Methods

Study Site. --Skiatook Lake is a 4,266 ha flood control reservoir located 8 km west of Skiatook in Osage County, Oklahoma (ODWC 1995). The lake was created in 1984 when the U.S. Army Corps of Engineers (USCOE) impounded Hominy Creek. The USCOE currently manages the lake for flood control and recreation, while the ODWC manages the lake's fisheries resources. Under a cooperative agreement between the USCOE and the ODWC, the lake was filled in stages from October 1984 to July 1989 to increase the naturally high productivity of the newly constructed reservoir (ODWC 1995). Although the lake was not at full pool, public fishing was allowed beginning in May 1986.

Skiatook Lake drains forest and agricultural land, has high rocky bluffs, and a

steep rocky shoreline. Fish habitat at Skiatook Lake is characterized by deep clear water, particularly in the lower end of the lake, a rock-covered substrate, and abundant standing and fallen timber. Skiatook Lake has a 257- km shoreline with a shoreline development ratio of 11.3 (ODWC 1995). The trophic state of the lake ranges from oligotrophic at lower end near the dam to eutrophic at the upper end (Jim Long unpublished data). The lake has a mean depth of 9.7m with a maximum depth of 31m (ODWC 1995).

Popular recreational activities on Skiatook Lake include boating, camping and fishing. Fishing pressure from tournament and non-tournament anglers is high. Skiatook Lake hosted the second highest number of black bass fishing tournaments for lakes over 1,000 acres in Oklahoma (ODWC 1995). Major sport fish of Skiatook Lake include largemouth bass, smallmouth bass, spotted bass, white crappie Pomoxis annularis, channel catfish Ictalurus punctatus blue catfish I. furcatus. flathead catfish Pylodictis olivaris, hybrid striped bass Morone saxatilis X M. chrysops and walleye Stizostedion canadense. A large proportion of angler effort is directed towards the black bass and crappie fisheries (Zale and Stubbs 1991).

Angler data were collected from March-October in 1997, 1998, and 1999 using a two-stage probability roving creel survey (Robson 1991) to monitor catch, harvest, and effort, and to assess anglers' knowledge of the regulation change, abilities to identify spotted bass, attitudes, opinions, effects on anglers fishing effort and harvest of spotted bass, and satisfaction levels (Appendix A). In 1998, our questionnaire was modified to collect information on angler motivations for fishing, preferred size of catch, mean distance traveled, age, sex and race of anglers (Appendix B).

A two-stage probability roving creel survey requires sampling time to be allocated in proportion to fishing effort. We allocated effort by the following strata: month, day type (weekend, weekdays), and day time (AM-PM) (Pollock et al.1994, Malvestuto and Hudgins 1996). Monthly sampling effort in 1997 was allocated based on monthly car count data at boat ramps from October 1993 through September 1996, which was provided by the U.S. Army Corps of Engineers. Creels were scheduled for one weekday and one weekend day in March and October; two weekdays and one weekend day per week in April, June, July, August, and September; and three weekdays and one weekend day per week in May. All creels were scheduled with a 0.5 probability of sampling in the AM or PM in 1997. Weekdays and weekend days were randomly selected for each week of the study (Long et al. 1997).

In 1998 and 1999, sampling time was allocated in proportion to 1997 monthly, day-type and day-time effort estimates. Monthly and day-type sampling remained the same as 1997. Sampling effort in the daytime stratum varied by month and day type. In March, creels were scheduled with an 85% probability of sampling in the AM time period during weekdays and 70% on the weekends. In April, the probability of sampling a weekday morning was 80% and 45% on the weekends. In May, sampling was conducted with a 30% probability of sampling on weekday mornings and 67% on the weekends. In June, weekday creels were selected with a 55% probability of sampling in the AM time period and a 40% probability on weekends. In July, the probability of a morning weekday creel was 80% while weekend mornings had a 53% chance of being sampled. In August, weekday creels were scheduled with a 54% probability of being sampled in the AM time period and a 33% probability on the weekends. In September and October, the chance of conducting a creel on a weekday morning was 47% and

72% respectively, while the chance of creeling on a weekend morning in both months was 50%.

The lake was divided into eight sections of equal shoreline distance that served as checkpoints as well as starting and stopping locations for the creel clerk (Figure 1). The creel clerk was required to spend an equal amount of time interviewing anglers in each section of the lake, which provided an instantaneous angler count for each section (Pollock et al. 1994). Each day, the creel clerk traveled by boat in a randomly chosen direction around the lake starting in a randomly chosen section. Anglers actively fishing were approached using a trolling motor and asked if they would participate in the survey. Those anglers that agreed to participate were asked questions regarding their knowledge of the regulation change, if they were aware that spotted bass could be distinguished from largemouth by the tooth patch on the tongue, if they were aware that smallmouth bass could be identified by their external body coloration, and whether or not they felt the regulation change was necessary. Anglers were then asked how this regulation would change their fishing habits (effort and harvest), how often they kept the bass they caught, how many bass they had caught, and if they planned on keeping the bass they caught that day. We then asked if we could measure any bass that they had kept. All bass in the angler's creel were measured to the nearest 0.1 cm and weighed to the nearest 0.1 kg. Anglers were asked about the size of fish that they would most prefer to catch and what was the most important reason that they went fishing. At the end of the survey anglers were asked for a zip code and to rate their fishing trip that day (Appendix B). Angler counts were made in conjunction with interviews to provide data on angling effort.

Monthly estimates of angler catch per unit effort (CPUE) and harvest per unit effort (HPUE) were calculated using the mean-of-ratio estimator (Malvestuto 1996). These estimates provided the number of fish caught and harvested per hour. Reported CPUE and HPUE estimates are the average of the mean daily CPUE and HPUE estimates. Due to departures from normality and homogeneity of variances we used non-parametric analysis of variance and Tukey's test to compare annual CPUEs (Zarr 1996).

Angler count data was used to estimate total fishing effort using the method described by Pollock et al. (1994). Total fishing effort in 1997, 1998, and 1999 was compared using multiple t-tests. Standard errors were calculated using pooled variances from the following day-type strata: weekdays, weekdays with tournaments, weekday holidays, weekends, weekends with tournaments, and weekend holidays. Total catch and harvest estimates were computed by multiplying the mean daily angler CPUE and HPUE by mean daily effort estimates for an average daily total catch and harvest estimate for each of the previous stratum. These estimates were then multiplied by the number of days in the study period to obtain a total catch and harvest estimate for each stratum. Total catch and harvest estimates for each stratum were summed to estimate the total catch and harvest for each black bass species (Pollock et. al. 1994). Total catch and harvest estimates from 1997, 1998, and 1999 were compared using multiple t-tests. Standard error estimates were calculated after pooling variance estimates from each of the strata used to obtain the total catch and harvest estimates.

Among-year estimates of HPUE were not compared due to a large number of daily harvest estimates that equaled zero. Instead, we compared the proportions of

each black bass species caught that were harvested using the multiple two-sample test of proportions (McGrew and Monroe 1993). Length-frequency distributions were monitored by calculating a relative stock density (RSD356) (Anderson and Neumann 1996) for each bass species. Yearly RSD_{356} values for each species were compared with multiple two sample test of proportions. Since data were collected from the angler's reported catch, all fish caught were considered stock size or greater (Anderson and Gutreuter 1983). Anglers' responses to questions concerning their knowledge of the regulation change and abilities to distinguish spotted bass from largemouth and smallmouth bass were tested with ANOVA (SAS Institute 1992). Contrasts were used to detect differences between years and linear trends throughout the study period. Yearly angler responses to the remaining survey questions were compared using Chi-square contingency tables (SAS Institute 1992). Fisher's exact test was used in cases where the cell expected values were less than 5% (SAS Institute 1992).

Mean distances traveled by anglers fishing at Skiatook Lake were found by identifying the angler's hometown from the zip codes provided during the surveys and calculating the shortest driving distance to the town of Skiatook. The mean distance traveled by anglers in 1998 and 1999 were compared using a t-test.

Results

Creel surveys were conducted on 95 days from March 1 through October 31 in 1997, 92 days in 1998, and 78 in 1999. Eight hundred sixty-eight angler surveys were completed in 1997, while 601 and 395 anglers were surveyed in 1998 and 1999, respectively. In 1997, 82% of the anglers approached participated in the surveys while 3% declined and 15% were repeat surveys. In 1998 angler participation was similar to 1997, with 84% of the anglers participating in the survey, 2% declining and 14% were repeat surveys. In 1999, the percent of repeat surveys increased significantly from 1997 (P.003) and 1998 (P=0.002) to 23% (Table 1).

Although we detected a significant differences in the proportions of anglers fishing from a boat, dock and shoreline throughout the study period (Table 1), the vast majority of anglers surveyed in each year were fishing from a boat. In 1997, boat anglers accounted for 89% of the respondents, and similar percentages were seen in 1998 (88%) and 1999 (89%). About 10% of surveys were from shoreline anglers, and around 1% were from dock anglers during the three years. Proportions of fishing methods were similar in 1997 and 1998 (P=0.967) while differences were detected between 1997 and 1999 (P=0.011) and 1998 and 1999 (P=0.04). Cell Chi-square values indicated that differences between years were caused by a decrease in the proportion of shoreline anglers surveyed in 1999.

Although proportions changed among years, the majority of angler groups surveyed in each year were fishing for either bass or crappie (Table 1). Most anglers encountered were white (83-86%) males (98-97%) in 1998 and 1999. We did not detect a difference in the proportions of male and female anglers between years, but the racial composition of anglers differed (Table 1). Anglers traveled a mean distance of 35 miles (range 5.4 mi-654 mi) to fish at Skiatook Lake in 1998, and this was similar to 1999 when anglers traveled an average of 36 miles (range 5.4 mi-589 mi; P=0.887).

In 1997, anglers spent approximately 182,599 daytime angling hours fishing at

Skiatook Lake from March 1 through October 31. This was significantly higher than 136,960 hours in 1998 (P=0.031) and 136,671 hours in 1999 (P=0.033). CPUE of largemouth (P=0.729), smallmouth (P=0.981), and spotted bass (P=0.368) did not change significantly throughout the study. Significant differences in unidentified bass CPUE were found among years (P=005). Multiple comparisons indicated unidentified bass CPUE decreased from 1997 to 1998 (P<0.005) and 1998 to 1999 (P<0.005; Table 2). Largemouth bass HPUE ranged from 0.001 fish/hr in 1999 to 0.011 fish/hr in 1997. Smallmouth bass HPUE ranged from 0.0004 fish/hr in 1999 to 0.007 fish/hr in 1998 while spotted bass HPUE were lowest in 1998 (0.062 fish/hr) and highest in 1999 (0.095 fish/hr; Table 2).

Few fish were actually observed by the creel clerk in any year. Of the 17 largemouth bass observed in 1997 three were below the size limit. Twenty-six largemouth bass were observed in 1998 and two in 1999. None of these were below the size limit. Almost all of the smallmouth bass observed were less than 356 mm in each year. In 1997, all three smallmouth in the anglers' creels were sub-legal while three of the four smallmouth measured in 1998 were below the size limit. In 1999, two of the three fished measured were sub-legal. Seventeen spotted bass were observed in 1997, 10 in 1998 and six in 1999.

The proportion of largemouth, smallmouth and spotted bass that were harvested did not change significantly among years following the regulation change (P>0.4). Anglers harvested 5%, 8% and 2% of the largemouth bass caught in 1997, 1998 and 1999 respectively. Three percent of the smallmouth bass and 8% of spotted bass were harvested in 1997 while 5% of the former and 6% of the later species were harvested in 1998, and 1999.

Few changes in catch and harvest estimates were detected throughout the study. Total catch of largemouth bass increased from 24,632 fish in 1997 to 31,991 fish in 1999 (P=0.037; Table 2). Estimates of total catch were similar between 1997 and 1998 (P=0.704), and between1998 and 1999 (P=0.329; Table 2). Total harvest decreased from 2,835 fish in 1998 to 849 fish in 1999 (P=0.032) while total harvest remained similar between 1997 and 1998 (P=0.436) and 1997 and 1999 (P=0.093; Table 2). Total catch and harvest of smallmouth bass were similar in each year of the study (P>0.05;Table 2). Total catch of spotted bass decreased from 14,478 fish in 1997 to 8,859 fish in 1998 (P<.001) but increased to 16,751 in 1999 (P<0.001). We did not detect any annual changes in spotted bass total harvest following the regulation change. Anglers harvested 1,391 spotted bass in 1997, which was similar to 686 in 1998 (P=0.432) and 510 in 1999 (P=0.144; Table 2). The total catch of 13,390 unidentified bass in 1997 was similar to 7,897 caught in 1998 (P=0.156) but less than 4,135 in 1999 (P=0.001). Total catch estimates were lower in 1999 than in 1998 (P=0.033; Table 2).

Largemouth bass relative stock density estimates for fish greater than 356-mm decreased in each of the years following the regulation change. In 1997, 34% of the largemouth bass caught were greater than 356-mm. This was significantly higher than in 1998 (33%: P<0.001) and 1999 (28%; P<0.001). Smallmouth bass RSD_{356} values indicated that the proportion of smallmouth greater than 356 mm was significantly greater in 1999 than in 1997 (P<0.001) and 1998 (P<0.001), with RSDs increasing from 12% in 1997 to 17% in 1998 and 24% in 1999 (Figure 2). Spotted bass RSD_{356} estimates never exceeded 1%.

Anglers' knowledge of the regulation change was similar during the years following the regulation change (P=0.081), whereas the proportions of anglers that knew that spotted bass could be distinguished from largemouth by feeling for a tooth patch on the tongue (of spotted bass) increased linearly. Also, there was a linear increase from 1997 to 1999 in the proportion of anglers who knew that smallmouth bass could be distinguished from largemouth and spotted bass by their external body coloration (Table 3). The percent of the anglers reporting that they could identify spotted bass by their tooth patch increased from 54% in 1997 to 64% in 1998 (P=0.004). The proportion (69%) in 1999 was significantly higher than in 1997 (P<0.0001) but not 1998 (P=0.114). Angler's ability to distinguish smallmouth bass increased from 77% in 1997 to 83% in 1998 (P=0.005). These percentages increased again in 1999 to 89% (P=0.036; Table 3).

The majority of anglers in each year reported that they did not have an opinion as to whether or not the regulation change was necessary and rated their fishing trips from fair to excellent in each year following the regulation change. A substantial decrease in the proportions of anglers who felt the regulation change was not necessary was detected (Table 4). Although a distinct pattern could not be detected, changes in the percentages of anglers who rated their fishing trip as very poor contributed the greatest amount to the overall Chi-square value (Table 4).

In 1998 and 1999, the majority of anglers reported that they would prefer to catch a few averaged-size fish and that relaxation was their most common motive for fishing. Following relaxation, other motives were, in order: spending time with family and friends, to experience the outdoors, competition, and catch related motives. Fourteen percent and 11% of the responses could not be classified into a category in 1998 and 1999, respectively (Table 4). One trophy fish was preferred by 18% of the anglers in 1998 and 17% in 1999. Thirteen percent of the anglers preferred to catch large numbers of small fish in 1998 and 11% in 1999 while 2% and 3% of the responses could not be classified in 1998 and 1999 respectively (Table 4).

Most anglers reported that the regulation would not effect the amount of time that they spent fishing for spotted bass in the years following the change. Only 7% of the anglers said that they would spend more time fishing for spotted bass in 1997. This proportion declined to 4% in 1998 and 1999 (Table 5). This trend also was evident in the proportions of angler who reported that they would increase the number of spotted bass they harvested per fishing trip. Percentages decreases from 38% in 1997 to 31% and 21% in 1998 and 1999, respectively. The proportion of anglers reporting that this regulation would not effect the numbers of spotted bass they would keep increased from 54% in 1997 to 62% in 1998 to 76% in 1999 (Table 5).

Greater than 65% of the anglers combined in each year reported they either never or rarely harvested the bass they caught (Table 5). Over 60% of the anglers responded that they did not plan to keep the bass they caught that day in each year of the study. When asked if they planned to keep the bass they caught that day, over 60% of the responses were "no" in each year (Table 5). On average, 91% of the anglers interviewed did not have bass on board to measure.

Discussion

Although, fisheries biologists have recognized the need for the differential black bass harvest regulation (Novinger 1984), they rarely have been implemented. Concerns about anglers' abilities to differentiate spotted bass from largemouth bass may have discouraged agencies from using such regulations. To the best of our knowledge, only two states besides Oklahoma currently use differential harvest regulations when largemouth and spotted bass are both present. Kentucky currently uses such a regulation statewide where anglers are allowed to harvest spotted bass of any size with an aggregate daily black bass creel limit of six fish. Missouri currently manages Bull Shoals Lake, Lake of the Ozarks and Norfolk Lake with a 381 mm minimum size limit on largemouth and smallmouth bass while spotted bass greater than 305 mm may be harvested. To date, only one study focusing on the effects of a differential black bass harvest regulation has been published in the primary literature. Understanding the impacts of such a regulation on the angling community is vital to understanding how these regulations could be used to improve fishing in areas containing more than one black bass species.

Our data indicates that the age and racial composition of Skiatook Lake anglers was similar to statewide proportions. Throughout Oklahoma 71% of anglers were male and 29% were female (U.S. Department of the Interior et al. 1991). Similarly, an average of 84% of the anglers encountered at Skiatook Lake were males and 16% were female. Statewide, 89% of the anglers were white, 4% were black and 6% were other races (U.S. Department of the Interior et al. 1991) while Skiatook Lake anglers averaged 97% white, 2% black and 1% other races. Although these proportions were similar to statewide averages, they were closer to the proportions reported Hunt and Ditton (1998) for non-guided anglers at Lake Texoma. They reported that 95% of anglers surveyed were white and 88% were male. Skiatook anglers predominately fished from a boat, and bass and crappie were the most sought after species

Following the regulation change, spotted bass catch, harvest rates, total catch and total harvest estimates were expected to increase. Likewise if population numbers were reduced by angler harvest, spotted bass CPUE, HPUE, total catch and total harvest were expected to decrease throughout the study period. Results indicate that spotted bass CPUE did not change significantly over the three year study. Although total catch in 1998 was significantly lower than 1999, total catch was similar between 1997 and 1999. Harvest rates were less than 0.001 fish/hr in each year. Total harvest of spotted bass decreased each year but these estimates were extremely small and not statistically significant. Anglers never harvested more than 8% of the spotted bass they caught during each year of this study. From 1997 to 1999, we did not observe any anglers who harvested a limit of fifteen spotted bass. Spotted bass CPUE at Skiatook Lake averaged 0.119 fish/hr compared to a statewide average of 0.003 fish/hr (Summers 1978). These results suggest that this regulation failed to accomplish its primary objective of reducing spotted bass abundance through angler harvest.

Contrary to our results, Buynak et al. (1991) found that after removing the spotted bass size limit at Cave Run Lake, Kentucky catch rates of this species greater than 229 mm decreased in the five years following the regulation change. They also reported that the actual numbers of spotted bass observed in anglers' creels increased dramatically in the five years after the regulation change, and that anglers harvested

41% of the spotted bass caught. Prior to removing the size limit on spotted bass Cave Run Lake, anglers harvested 0.1 fish/hr and 0.1 fish/acre. After removal harvest increased to 0.4 fish/hr. After the size limit was removed at Skiatook Lake spotted bass harvest rates never exceeded 0.01 fish/hr.

If reductions in spotted bass numbers had decreased to levels that would have minimized competition among the three black bass species, we would have expected largemouth and smallmouth bass catch statistics to increase. However, largemouth and smallmouth bass CPUE remained similar during each year, with largemouth bass HPUE never exceeding 0.011 fish/hr and smallmouth HPUE less than 0.007 fish/hr.

Relative stock density estimates of angler-caught largemouth bass decreased in each year following the removal of the spotted bass size limit suggesting that this regulation failed to improve the population structure of largemouth bass. Despite similar estimates of spotted bass CPUE, total catch and harvest, positive responses included increased total catch of largemouth bass from 1997 to 1999 and annual increases in smallmouth bass relative stock density estimates. However, we do not feel that the Increases in smallmouth bass RSD_{356} was related to the regulation change. The smallmouth bass population has been increasing in size from its original stocking in 1992.

Although the ODWC placed signs at each boat ramp to inform anglers of the regulation change, angler's knowledge of the change failed to increase during this study. In contrast, anglers' abilities to distinguish spotted bass from largemouth and smallmouth bass increased during each year of the study. Little opposition to the new regulation was detected in each year. The proportions of anglers who felt that this regulation was not necessary declined from 8% in 1997 to 6% in 1998 and 2% 1999. Unfortunately little support for the regulation was found during the study. Only about one-third of the anglers felt this regulation was necessary in each year while almost two-thirds had no opinion. Although, significant differences were detected in angler's satisfaction levels, no distinct patterns in change could not be detected.

Our results indicate that the opportunity to increase harvest of spotted bass was of little interest to the majority of anglers at Skiatook Lake. The majority of anglers reported that they either never or rarely kept the bass they caught; that they would not increase the amount of time they spent fishing for spotted bass; that they would not harvest more spotted bass per fishing trip; they didn't plan on keeping the bass caught the day of the survey. In fact, the proportion of anglers reporting that they the would not change the amount of time spent fishing for or change the numbers of spotted bass they would keep increased in each year following the change. This trend was also seen in the proportion of anglers who reported that they did not plan to keep the bass they caught the day of the survey. Although the majority anglers preferred to catch a few fish in the average size range, catch-related motives were rarely reported as the most important reason fishing. All of these factors help explain why the catch and harvest statistics for spotted bass did not change throughout the study period.

While angler motivations may help to explain why anglers were not interested in harvesting spotted bass, recent studies suggest caution should be used when generalizations are made from population level motivational data. In their review of seventeen angler motivation studies, Fedler and Dittion (1994) found that it was common for anglers to rate non-catch-relative motives higher than catch related motives, especially when anglers were grouped at the population level. Motivational

differences have been detected at many levels including angler age, species sought, method of fishing (Hudgins 1984) and among types of bass (Ditton 1996), crappie anglers (Allen and Miranda 1996). This suggests that subdividing anglers into sub-populations to determine the effects of the regulation on each angling group would provide further insight as to why anglers did not harvest more fish after the size limit was removed and may identify sub-populations that benefited from the regulation change.

Management Recommendations. --The differential harvest regulation in Skiatook Lake has the potential to be effective in the future. However, for this to happen anglers need to be better informed about the regulation and its purpose. During surveys, many anglers commented that a slot-limit was needed to improve bass fishing at Skiatook Lake. If the ODWC could educate anglers that the differential harvest regulation served the same biological purpose as a slot-limit, anglers might be inclined to harvest more spotted bass. Anglers need to know the biological basis of this regulation. Slot limits are commonly used to restructure bass populations by increasing harvest of small fish, which reduces competition and improves growth rates (Wilde 1997). However, slot limits are most effective in aquatic systems where reproduction is high and growth rates are not optimal. Largemouth and smallmouth bass growth is good at Skiatook Lake but relative abundances are somewhat low. Increased harvest of small-sized bass in Skiatook Lake would do more harm than good. In contrast, spotted bass abundance is high and growth rates are poor which suggests that decreasing their abundance would benefit the fishery.

The ODWC has a variety of educational resources at their disposal, which could be used, educate anglers throughout the state. These include the Outdoor Oklahoma television program, information and education personnel, local newspapers and local news stations. Although, out-of-state anglers were encountered at Skiatook Lake, the vast majority of anglers resided in Oklahoma. Our results indicate that the mean distance traveled by anglers was approximately 35 mi. This suggests that a large proportion of anglers are from the Tulsa metropolitan area and that publishing articles in the Tulsa newspaper promoting this regulation would be an effective way of reaching a large segment of the angling population. These articles could be submitted by information and education personnel. Anglers could be educated statewide using the Outdoor Oklahoma television program.

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Table 1.--Characteristics of anglers surveyed from 1997-1999 at Skiatook Lake. Chi-square cell values are in parentheses.

Characteristic	1997 (%)	1998 (%)	1999 (%)	Chi-square P
		Method		
Boat	89 (0.002)	88 (0.009)	89 (0.03)	
Dock	1 (1.38)	1 (0.52)	2 (6.78)	
Shore	10 (0.24)	11 (0.26)	8 (1.79)	0.027
		Species sought		
Bass	43 (1.98)	48 (0.41)	50 (1.68)	
Crappie	39 (1.52)	33 (2.03)	36 (0.005)	
Hybrid striped bass	3 (0.45)	5 (1.0)	4 (0.06)	
Other	4 (0.44)	6 (3.71)	3 (2.6)	
Nothing in particular	11 (2.56)	8 (0.38)	7 (2.6)	0.008
		Interview type		
Interviewed	82 (0.01)	84 (0.54)	75 (1.85)	
Declined	3 (0.80)	2 (0.77)	2 (0.06)	
Repeat	15 (1.03)	14 (1.74)	23 (9.73)	0.002
		Sex		
Male	NA	83 (0.10)	86 (0.14)	
Female	NA	17 (0.37)	14 (0.76)	0.268

Table 1.--Continued.

Characteristic	1997 (%)	1998 (%)	1999 (%)	Chi-square P
		Race		
White	NA	98 (0.02)	97 (0.05)	
Black	NA	1 (2.09)	3 (4.41)	
Hispanic	NA	<1 (0.61)	0 (1.29)	
Native American	NA	<1 (0.09)	<1 (0.09)	
Middle Eastern	NA	<1 (0.15)	0 (0.32)	0.03

Table 2.--Comparisons of catch per unit effort (CPUE), harvest per unit effort (HPUE), total catch and total harvest estimates of largemouth, smallmouth, spotted and unidentified bass at Skiatook Lake from 1997 to 1999.

Year	CPUE[1] (fish/hr)	HPUE (fish/hr)	Total catch[2]	Total harvest[2]
		Largemouth bass		
1997	0.13[a]	0.011	24,632[a]	2,343[ab]
1998	0.16[a]	0.01	27,577[ab]	2,835[a]
1999	0.17[a]	0.001	31,991[b]	849[b]
		Smallmouth Bass		
1997	0.032[a]	0.0006	7,208[a]	130[a]
1998	0.065[a]	0.007	8,124[a]	610[a]
1999	0.04[a]	0.0004	5,988[a]	73[a]
		Spotted bass		
1997	0.08[a]	0.08	14,478[ab]	1,391[a]
1998	0.062[a]	0.062	8,859[a]	686[a]
1999	0.095[a]	0.095	16,751[b]	510[a]
		Unidentified bass		
1997	0.064[a]	NA	13,390[a]	NA
1998	0.046[b]	NA	7,897[a]	NA
1999	0.031[c]	NA	4,135[b]	NA

[1] CPUE was tested using a Kruskall-Wallis

[2] Total catch and total harvest were tested using a t-test

Letters a, b and c are used to indicate significant differences among years ($P < 0.05$). Similar letters indicate non-significant differences.

Table 3.--Comparisons of angler responses to questions concerning their knowledge of the regulation change and abilities to distinguish spotted bass from largemouth and smallmouth bass at Skiatook Lake from 1997-1999.

Response	1997 (%)	1998 (%)	1999 (%)	Linear contrast P
		Knowledge of regulation change		
Yes	55[a]	55[a]	53[a]	NS
No	45[a]	45[a]	47[a]	
		Ability to distinguish spotted bass by the tooth patch		
Yes	54[a]	64[b]	69[b]	0.0001
No	46[a]	36[b]	31[b]	
		Ability to distinguish smallmouth bass		
Yes	77[a]	83[b]	89[b]	0.0001
No	23[a]	17[b]	11[b]	

Letters a, b and c are used to indicate significant differences among years ($P < 0.05$). Similar letters indicate non-significant differences.

Table 4.--Angler responses to questions regarding their opinion of the regulation and preferred size of fish, motives for fishing and satisfaction levels at Skiatook Lake from 1997-1999. Chi-square cell values are in parentheses.

Response	1997 (%)	1998 (%)	1999 (%)	Chi-square P
Was the regulation change necessary?				
Yes	32 (0.14)	34 (0.57)	32 (0.14)	
No	8 (4.49)	6 (0.14)	2 (7.45)	
No opinion	60 (0.15)	60 (0.19)	66 (1.29)	0.006
How would you rate your fishing trip				
Excellent	8 (0.01)	7 (0.22)	9 (0.49)	
Good	22 (0.57)	25 (0.54)	24 (0.04)	
Fair	31 (0.38)	30 (0.05)	26 (1.49)	
Poor	30 (0.002)	32 (0.94)	26 (1.67)	
Very poor	10 (0.01)	6 (8.17)	15 (11.98)	0.001
What size of fish would you prefer to catch?				
Large numbers of small fish	NA	13 (0.17)	11 (0.29)	
Few average size fish	NA	67 (0.08)	69 (0.14)	
One trophy fish	NA	18 (0.02)	17 (0.03)	
Other	NA	2 (0.04)	3 (0.07)	NS

Table 4.--Continued.

Response	1997 (%)	1998 (%)	1999 (%)	Chi-square P
		Motive for fishing		
Relaxation	NA	50 (0.49)	45 (0.81)	
Spend time with family/friends	NA	19 (0.47)	22 (0.78)	
Catch related	NA	3 (0.69)	5 (1.15)	
Experience the outdoors	NA	9 (0.66)	12 (1.1)	
Competition	NA	6 (0.02)	6 (0.03)	
Other	NA	14 (0.52)	11 (0.86)	NS

Table 5.--Angler responses to questions related to their fishing habits and how this regulation would change their fishing effort and harvest of spotted bass from 1997-1999 at Skiatook Lake. Chi-square cell values are in parentheses.

Response	1997 (%)	1998 (%)	1999 (%)	Chi-square P
		Effects on fishing effort		
Increase	7 (4.86)	4 (2.59)	4 (1.59)	
No change	89 (0.84)	94 (0.30)	96 (0.47)	
Decrease	1 (3.49)	0.2 (1.33)	0 (1.83)	
Unsure	3 (3.74)	1.8 (0.35)	0 (4.68)	< 0.001
		Effects on angler harvest		
Increase	38 (7.17)	31 (0.32)	21 (11.09)	
No change	54 (6.21)	62 (0.18)	76 (10.47)	
Decrease	1 (3.68)	0 (1.99)	0 (1.22)	
Unsure	7 (1.56)	7 (0.11)	3 (5.31)	< 0.001
		How often do you keep the bass you catch?		
Never	41 (0.13)	42 (.03)	43 (0.11)	
Rarely	26 (0.4)	31 (2.31)	24 (.98)	
Sometimes	3 (0.31)	10 (2.60)	14 (1.49)	
Usually	9 (1.36)	11 (0.08)	14 (1.99)	
Always	11 (6.99)	6 (2.35)	5 (4.22)	0.001

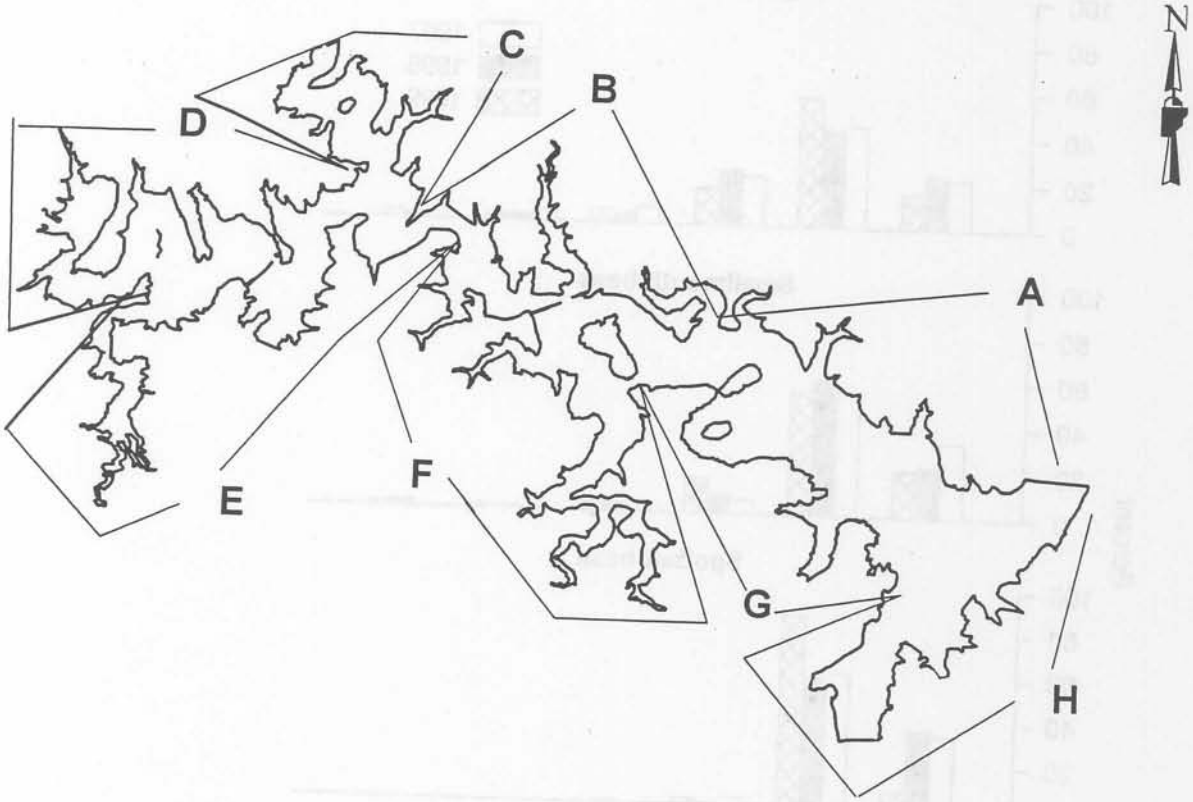
Table 5.--Continued.

Response	1997 (%)	1998 (%)	1999 (%)	Chi-square P
	Do you plan on keeping bass caught today?			
Yes	27 (0.22)	24 (1.13)	28 (0.39)	
No	62 (0.51)	65 (0.2)	66 (0.24)	
Maybe	11 (1.06)	11 (0.33)	6 (4.91)	NS
	May I measure the bass you have?			
Yes	5 (0.002)	7 (2.59)	3 (3.67)	
No	6 (1.64)	6 (0.91)	1 (9.35)	
None	89 (0.08)	87 (0.37)	96 (1.37)	0.001

FIGURE LEGENDS

Figure 1. Creel survey sections at Skiatook Lake used from 1997 to 1999.

Figure 2. Relative length frequency distribution of angler-caught largemouth, smallmouth and spotted bass from 1997 to 1999 at Skiatook Lake, Oklahoma.


N
A
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D
E
F
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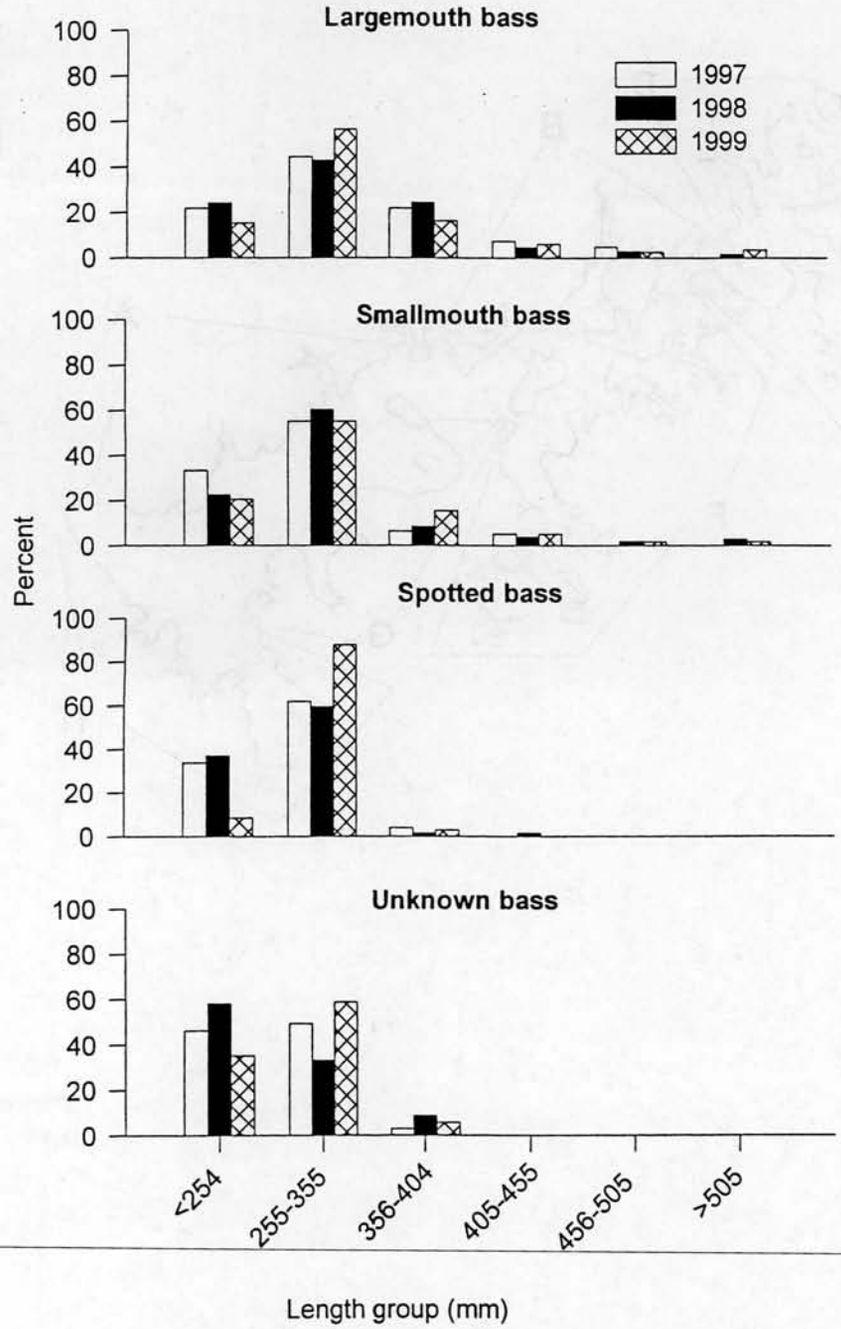
1 km


Largemouth bass
Smallmouth bass
Spotted bass
Unknown bass
1997
1998
1999
Percent
100
80
60
40
20
0
<254
255-355
356-404
405-455
456-505
>505
Length group (mm)

Appendix A. Survey questionnaire used in 1997 at Skiatook Lake, Oklahoma.

Survey #_____ Survey Section_____ Date_____ Day Type **WD WE**

Time of Interview_____**(mil)** Method **BOAT DOCK SHORE** # in Party_____ Special Type **Tourn Hol**

INTERVIEWED DECLINED REPEAT

Times Fish/Mth_____ Start Time_____ **(mil)** Finish Time (est.)_____**(mil)**

Species Sought: **LMB SMB SPB Bass Crappie Hybrid Striped Other**
Nothing in Particular

Q. The Oklahoma Department of Wildlife Conservation is interested in knowing how well it informs anglers of new regulations. Did you know that beginning Jan. 1, 1997, there is a creel limit on spotted bass of 15 fish per day with no size limit on Skiatook Lake?

YES NO

Q. The Oklahoma Department of Wildlife Conservation is also interested in knowing how well it informs anglers on how to distinguish "hard-to-identify" species from one another.

1. Did you know that spotted bass can be distinguished from largemouth bass in that spotted bass have a rough tooth patch on the tongue? (If no, offer to demonstrate)

YES NO

2. Did you know that largemouth and spotted bass can be distinguished from smallmouth bass in that smallmouth bass have vertical bars along their sides? (If no, offer to demonstrate)

YES NO

Q. Do you feel that this regulation change is necessary?

YES NO NO OPINION

Why?_____

Q. How will this new regulation change the amount of time spent fishing by you for spotted bass?

Q. How will this new regulation change the amount of spotted bass that you keep per trip?

	Spotted Bass
Effort	
Harvest	

Appendix A cont.

+ = Increase **0 = No Change** **- = Decrease** **N = No Opinion**
U = Unsure

Q. How often do you keep the bass that you catch?

NEVER **RARELY** **SOMETIMES** **USUALLY** **ALWAYS**

Q. Do you plan on keeping the bass that you catch today?

YES **NO** **MAYBE** **CULL**

Q. May I measure them?

YES **NO** **NONE**

Q. Would you please pick one of the following that is the most important reason why you go fishing?

Q. Would you please describe for me the species, numbers, and approximate sizes of all bass caught today?

Q. How would you rate today's fishing?

EXCELLENT **GOOD** **FAIR** **POOR** **VERY POOR**

Q. Would you please fill out this "Catch Card" describing your total catch (species, number, and length), length of your fishing trip, and return address upon completion of your trip and mail back? **(All Returned Cards will be entered in a $100 drawing to be awarded at the end of the year).**
YES **NO**

ALL ANSWERS WILL BE KEPT CONFIDENTIAL

Appendix A cont.

Survey #_____ **Date_____**

HARVEST DATA

LMB=largemouth bass **SMB=smallmouth bass** **SPB=spotted bass**

Species	Length (cm)	Weight (kg)	Scale Sample (y,n)	Kept/ Released (K/R)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Appendix A cont.

CATCH DATA

Bass Species	Under 10.0 in.	10.0-13.9 in.	14.0-15.9 in.	16.0-17.9 in.	18.0-19.9 in.	Over 20.0 in.	Total
Largemouth Bass							
Smallmouth Bass							
Spotted Bass							
Unknown Bass							
Total							

Appendix B. Survey questionnaire used in 1998 and 1999 at Skiatook Lake, Oklahoma.

Survey #_____ Survey Section_____ Date_____ Day Type **WD WE**

Time of Interview_____(mil) Method **BOAT DOCK SHORE** # in Party_____ Special Type **Tourn Hol**

INTERVIEWED DECLINED REPEAT

Times Fish/Mth_____ Start Time_____ (mil) Finish Time (est.)_____(mil)

Species Sought: **LMB SMB SPB Bass Crappie Hybrid Striped Other Nothing in Particular**

Q. The Oklahoma Department of Wildlife Conservation is interested in knowing how well it informs anglers of new regulations. Did you know that beginning Jan. 1, 1997, there is a creel limit on spotted bass of 15 fish per day with no size limit on Skiatook Lake?

YES NO

Q. The Oklahoma Department of Wildlife Conservation is also interested in knowing how well it informs anglers on how to distinguish "hard-to-identify" species from one another.

1. Did you know that spotted bass can be distinguished from largemouth bass in that spotted bass have a rough tooth - patch on the tongue? (If no, offer to demonstrate)

YES NO

2. Did you know that largemouth and spotted bass can be distinguished from smallmouth bass in that smallmouth bass have vertical bars along their sides? (If no, offer to demonstrate)

YES NO

Q. Do you feel that this regulation change is necessary?

YES NO NO OPINION

Why?_____

Q. How will this new regulation change the amount of time spent fishing by you for spotted bass?

Q. How will this new regulation change the amount of spotted bass that you keep per trip?

	Spotted Bass
Effort	
Harvest	

Appendix B cont.

+ = Increase **0 = No Change** **- = Decrease** **N = No Opinion**
U = Unsure

Q. How often do you keep the bass that you catch?

NEVER **RARELY** **SOMETIMES** **USUALLY** **ALWAYS**

Q. Do you plan on keeping the bass that you catch today?

YES **NO** **MAYBE** **CULL**

Q. May I measure them?

YES **NO** **NONE**

Q. Would you please chose one of the following size groups of fish that you would most prefer to catch?

LARGE #S OF SMALL FISH **FEW AVERAGE SIZED FISH** **TROPHY FISH** **OTHER**

Q. What would you consider the single most important reason why you go fishing?

RELAXATION **TIME WITH FRIENDS/FAMILY** **TO CATCH FISH TO CONSUME**
TO GET AWAY FROM PEOPLE **THE CHALLENGE OF FISHING** **TO EXPERIENCE THE OUTDOORS** **COMPETITION** **CATCH FISH** **OTHER**

Q. Would you please describe for me the species, numbers, and approximate sizes of all bass caught today?

Q. How would you rate today's fishing?

EXCELLENT **GOOD** **FAIR** **POOR** **VERY POOR**

Would you please fill out this "Catch Card" describing your total catch (species, number, and length), length of your fishing trip, and return address upon completion of your trip and mail back? **(All Returned Cards will be entered in a $100 drawing to be awarded at the end of the year).**
YES **NO**

ALL ANSWERS WILL BE KEPT CONFIDENTIAL

Appendix B cont.

Survey #_____ **Date**_____

	< 10	10-20	20-30	30-40	40-50	50-65	> 65
AGE							
SEX							
RACE							
ZIP							

HARVEST DATA

LMB=largemouth bass **SMB=smallmouth bass** **SPB=spotted bass**

Species	Length (cm)	Weight (kg)	Scale Sample (y,n)	Kept/ Released (K/R)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Appendix B cont.

CATCH DATA

Bass Species	Under 10.0 in.	10.0-13.9 in.	14.0-15.9 in.	16.0-17.9 in.	18.0-19.9 in.	Over 20.0 in.	Total
Largemouth Bass							
Smallmouth Bass							
Spotted Bass							
Unknown Bass							
Total							

CHAPTER II

POPULATION CHARACTERISTICS OF THREE BLACK BASS SPECIES AS AFFECTED BY A DIFFERENTIAL-HARVEST REGULATION IN SKIATOOK LAKE, OKLAHOMA

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INTRODUCTION

Reservoir fisheries in Oklahoma have historically been managed for largemouth bass Micropterus salmoides and, where they have been introduced, smallmouth bass M. dolomieu. Spotted bass M. punctulatus are native to Oklahoma waters and are often found in sympatry with these other two black bass species. However, spotted bass do not regularly attain the statewide minimum harvest length of 356 mm and, therefore, have not received much attention from anglers and fisheries managers. In 1994, Oklahoma Department of Wildlife Conservation (ODWC) biologists observed an approximate five-fold increase in the relative abundance of spotted bass in Skiatook Lake, Oklahoma compared with prior years (Hicks 1994; Figure 1). Concerned that the increased abundance of spotted bass might negatively affect largemouth bass and smallmouth bass fisheries, the ODWC enacted a differential harvest regulation on January 1, 1997 aimed at reducing the abundance of spotted bass. Previously, all three species were managed with a minimum size limit of 356-mm and a daily harvest of 6 fish in aggregate. The new regulation removed the length-limit and allowed for the harvest of 15 spotted bass per day, while maintaining the previous regulation for largemouth bass and smallmouth bass. The expected outcome of this regulation change was alteration of the population structure (i.e., relative abundance, mortality, and/or growth) of not only the target species spotted bass, but also of the non-target largemouth bass and smallmouth bass populations.

Fisheries regulations have often been used to modify or enhance the population characteristics of a target species (Noble and Jones 1993). Redmond (1986) reported alterations such as altered size structure, proportional stock density (PSD), growth, and reproduction of largemouth bass populations in response to a variety of management regulations. Zagar and Orth (1986) demonstrated with computer simulations the relationship between various fisheries management regulations and the population characteristics of largemouth bass. For example, they found that a trophy fishery was best achieved with a high minimum-length limit, whereas maximum harvest was best obtained with a low minimum-length limit. Novinger (1987) reported increased catch rates of black bass (largemouth bass and spotted bass combined) after implementation of a 381-mm minimum-length limit on Table Rock Lake, Missouri; however, growth rates for both species declined during the study, possibly due to decreased forage or density-dependent growth depression. Wilde (1997) analyzed data from 91 fisheries regulation evaluations around the U.S. and found that the size structure of largemouth bass populations was improved with minimum-length limits as a whole, but not when 305-mm minimum-length limits were excluded from the analysis. Additionally, he found that minimum-length limits failed to increase PSD and the number and weight of fish harvested by anglers. These studies demonstrate the varying ability of fisheries regulations to alter the population characteristics of their target species, however, they say nothing about how they might impact not-target, ecologically similar species.

Buynak et al. (1991a) provide the only published study of a fisheries regulation that was implemented to alter the population characteristics of a target and non-target species. A differential harvest regulation was enacted on Cave Run Lake, Kentucky in 1985 that removed the size limit from spotted bass in an attempt to reduce the potential for overharvest of largemouth bass (Buynak et al. 1991). Additionally, the largemouth bass minimum-length limit was changed from 305-mm to 381-mm. As a result of this

regulation change, largemouth bass exploitation declined while spotted bass exploitation increased. Electrofishing catch rates increased for all sizes of largemouth bass, but declined for 229-mm and longer spotted bass. Total weight of harvested largemouth bass remained unchanged but angler catch of quality-size fish increased.

The objective of this study was to monitor relative abundance, condition, growth, survival, and size structure of largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake for three years following implementation of the differential-harvest regulation.

METHODS

Study site.--Skiatook Lake is a 4,266-ha flood control impoundment of Hominy Creek in north-central Oklahoma that was formed in 1984 by the U.S. Army Corps of Engineers by filling the reservoir in stages until it reached conservation pool level in August 1989. The lake has a mean depth of 9.7 m and a shoreline development index of 11.3. The upper end of the reservoir is more turbid than the lower end, with average spring Secchi depths of 0.1 m and 1.2 m, respectively and was classified as mesotrophic in 1997 with a mean chlorophyll-a concentration of 5.10 mg/m^3 (Long et al. 1999). The top of the conservation pool is 217.6 meters above mean sea level. Sportfish species in the lake consist mainly of largemouth bass, smallmouth bass, spotted bass, sunfish Lepomis spp., hybrid striped bass Morone saxatilis X M. chrysops, walleye Stizostideon vitreum, channel catfish Ictalurus punctatus, and flathead catfish Pylodictis olivaris.

We obtained standardized electrofishing data from the ODWC collected at Skiatook Lake from 1987 through 1998. Since the objective of the regulation was to reduce spotted bass abundance because of their marked increase in 1994, We classified the years 1994 and 1996 as the pre-regulation period (1995 was not sampled) and 1997 and 1998 as the post-regulation period. We did not include the years prior to 1994 as spotted bass abundance was consistently low until that year (Figure 1). We then tested differences in mean catch rates (number of fish per electrofishing hour) of each species between the two periods with a t-test (SAS Institute 1992) to determine if their relative abundance had changed.

We sampled black bass with nighttime, boat-mounted electrofishing during spring and fall in 1997-1999 using a stratified-random design (Wilde and Fisher 1996). We stratified Skiatook Lake into four areas (lower-lake, mid-lake, Hominy Creek, and Bull Creek) based on morphometry and Secchi depth measurements (Figure 2). Sampling sites were identified by delineating shoreline habitat types in a Geographic Information Systems (GIS) database and randomly selected within strata for each season and year. At least 10% of the shoreline was sampled. Habitat types consisted of substrate and cover type combinations which were classified by surveying the entire perimeter of Skiatook Lake by boat in winter 1996. Sites selected for sampling were electrofished with varying amounts of effort, depending on site length and habitat complexity. All black bass captured were identified, measured to the nearest 1 mm, and weighed to the nearest 0.01 kg. Scale samples were taken from the left side posterior to the opercle from all fish in spring 1997 and 1999; sagittal otoliths were removed from a representative sub-sample in spring 1997, and from all fish in spring 1998 and 1999.

We tracked trends in mean relative abundance, distribution, and mean relative

weight (Wr) of each species over the three years for spring and fall using ANOVA and trend analysis with orthogonal polynomials (Kuehl 1994). Distribution was assessed by comparing the mean relative abundance of each species among the four strata of the lake and among the three sample years with a 4x3 factorial ANOVA. Relative weight (Wr) is a measure of condition (Anderson and Neumann 1996) and was assessed using the standard weight (Ws) equations developed by Henson (1991; cited in Anderson and Neumann 1996) for largemouth bass, Kolander et al. (1993) for smallmouth bass, and Wiens et al. (1996) for spotted bass and was calculated with the equation

$$Wr = 100(W/Ws),$$

where W is the measured weight of the fish and Ws is the standard weight of the fish.

We tracked recruitment by analyzing the relative abundance of yearling fish in the spring, which were produced from the previous year's spawn, for each species using ANOVA and trend analysis with orthogonal polynomials (Kuehl 1994). We classified juveniles according to the respective upper central 50% length range of age-one fish in Oklahoma waters, as reported by Carlander (1977). Thus, largemouth bass less than 226-mm, smallmouth bass less than 185-mm, and spotted bass less than 178-mm were considered juveniles. Multiple comparisons for all ANOVA tests were made using the LSMEANS procedure in SAS (SAS Institute 1992).

We estimated the age of all fish collected during spring electrofishing for all three sample years. Ages were estimated with scales in 1997 and 1999 and with whole otoliths in 1998 and 1999. We also estimated age using whole otoliths for a subsample of fish in 1997. Ages were determined with scales by making impressions in acetate slides and counting annuli with a microfiche reader and with otoliths by immersing the otolith in clarifying oil and counting annuli with a dissecting microscope (DeVries and Frie 1996). Each structure was read two times by separate readers and then the modal age was calculated for each fish. When a modal age could not be calculated from two readings, then a third reading was taken and the modal age recalculated. Fish whose modal age could not be calculated after three readings were considered unageable and were removed from the analyses. Annuli from scales were delineated and measured using a digitizer.

We compared growth over the three year study period by comparing the slopes of log-log transformed length-at-age data with ANCOVA (SAS Institute 1992) using whole otoliths to estimate age. Additionally, we compared growth using the Weisberg (1993) method of back-calculated length-at-age data from annuli measurements using scales. The Weisberg (1993) method allowed me to separate differences in growth due to age and year via 2-way ANOVA.

We calculated survival for each species for each year using catch curve analysis (Van Den Avyle 1993) based on ages estimated from whole otoliths and compared the slopes of the catch curve regression lines with ANCOVA (SAS Institute 1992) to determine if survival changed annually over the study period. Only those age classes represented by five or more individuals were used in the catch curve analysis (Van Den Avyle 1993). Since the ages of only a subsample of fish were estimated by whole otoliths in 1997, we constructed an age-length key with 25 mm length groups to enumerate numbers of each species for each age class in 1997 (DeVries and Frie

1996).

Finally, we calculated proportional stock density (PSD; Anderson 1976) for each species, season, and year to document changes in population size structure. Stock and quality sizes were taken from Anderson and Neumann (1996). We compared the PSD estimates using the approximation to the normal distribution for comparing two proportions (Zar 1999) between all possible pairs of years for each species and season. We used a Bonferroni correction for alpha = 0.05 with three groups to test for significance (Kuehl 1994).

RESULTS

Abundance, Distribution, Condition, and Recruitment

Largemouth bass.--There was no difference in ODWC mean catch rates of largemouth bass between pre- and post-regulation periods ($P = 0.97$; Table 1). We captured 144, 151, and 100 largemouth bass in the spring of 1997, 1998, and 1999, respectively. In the corresponding fall seasons, we captured 65, 55, and 118 largemouth bass. In spring, there was no difference in largemouth bass catch rates among years ($P = 0.20$). Fall largemouth bass catch rates differed among years ($P < 0.01$) and there was an increasing linear trend ($P = 0.03$; Table 2). Largemouth bass were equally abundant among the four strata among the three years in spring ($P = 0.60$ for year*stratum interaction and $P = 0.30$ for stratum) and less abundant in Hominy Creek in fall ($P = 0.76$ for year*stratum interaction and $P = 0.02$ for stratum; Table 3). Mean relative weights remained unchanged over the three years ($P = 0.23$ for spring and $P = 0.85$ for fall; Table 4). Relative abundance of juvenile largemouth bass remained constant over the study period ($P = 0.08$; Table 5).

Smallmouth bass.--The ODWC data showed a difference in mean catch rates of smallmouth bass between pre- and post-regulation periods ($P = 0.02$; Table 1). In the spring of 1997, 1998, and 1999, we captured 74, 137, and 116 smallmouth bass, respectively. In the corresponding fall seasons, we captured 81, 105, and 51 smallmouth bass. Catch rates of smallmouth bass increased linearly over the three year sampling period during spring ($P = 0.02$), but remained constant during fall ($P = 0.70$; Table 2). During all three years, smallmouth bass were always more abundant in the lower-lake stratum in spring ($P = 0.30$ for stratum*year interaction and $P < 0.01$ for stratum) and fall ($P = 0.98$ for stratum*year interaction and $P < 0.01$ for stratum; Table 3). In spring, mean relative weights fluctuated with the lowest in 1998 and the highest in 1997 ($P < 0.01$; Table 4). Fall mean relative weights remained unchanged over the three years ($P = 0.11$; Table 4). Recruitment, as indexed by catch rates of juvenile fish, remained constant over the three year period ($P = 0.16$; Table 5).

Spotted bass.--We found no significant decrease in ODWC's mean catch rates of spotted bass between pre- and post-regulation periods ($P = 0.84$; Table 1). We captured 305, 144, and 138 spotted bass in the spring and 125, 128, and 128 in the fall of 1997, 1998, and 1999, respectively. Mean catch rates were constant over the three years in spring ($P = 0.12$) and fall ($P = 0.46$; Table 2). Spotted bass were more abundant in Bull Creek in the spring regardless of year ($P < 0.01$ for stratum and $P = 0.30$ for the year*stratum interaction), but were more abundant in the lower-lake and mid-lake strata in the fall ($P < 0.01$ for stratum and $P = 0.99$ for the year*stratum interaction; Table 3). Mean relative weight of spotted bass fluctuated over the three

years with the highest relative weights in spring ($P < 0.01$) and fall ($P < 0.01$) 1997 (Table 4). Mean relative abundance of juvenile spotted bass in spring remained constant over the three year study period ($P = 0.12$; Table 5).

Age and Growth, Survival, and Size Structure

Largemouth bass.--We were able to determine ages from 39, 143, and 92 largemouth bass from 1997, 1998, and 1999, respectively, using whole otoliths. Analysis of covariance of the log-log transformed length-at-age data showed an increased growth rate for largemouth bass in 1998 compared to 1999 ($P = 0.01$; Figure 3A), while the Weisberg (1993) method found no differences in growth among years ($P = 0.18$ for 1997 scale age data and $P = 0.36$ for 1999 scale age data; Table 6). Survival was constant among years and averaged 66.82% (Table 7). Proportional stock density (PSD) in spring was lowest in 1999 compared to 1998 ($P = 0.05$) and 1997 (corrected $P = 0.02$), but in fall was constant among years (Table 8).

Smallmouth bass.--Using whole otoliths, we aged 22, 133, and 113, smallmouth bass from 1997, 1998, and 1999, respectively. Growth rates were greater in 1999 compared to 1998 ($P < 0.01$; Figure 3B) with the ANCOVA method, but no differences in growth were found with the Weisberg (1993) method ($P = 0.84$ for 1997 scale age data and $P = 0.80$ for 1999 scale age data; Table 6). Survival was constant among years and averaged 57.41% (Table 7). Proportional stock density (PSD) in fall was greatest in 1999 compared to 1997 ($P < 0.01$) and 1998 ($P < 0.01$), but in spring was constant among years (Table 8).

Spotted bass.--We aged 56, 139, and 136 spotted bass using whole otoliths from 1997, 1998, and 1999, respectively. Growth rates were lowest in 1999 compared to 1997 and 1998 ($P < 0.01$, respectively; Figure 3C) with the ANCOVA method, but not with the Weisberg (1993) method ($P = 0.99$ for 1997 scale age data and $P = 0.37$ for 1999 scale age data; Table 6). Survival was constant over the three years and averaged 60.54% (Table 7). Proportional stock density (PSD) was also constant among years, averaging 31.68% in spring and 49.69% in fall (Table 8).

DISCUSSION

The purpose of the differential harvest regulation on black bass in Skiatook Lake was to alter the population characteristics of not only spotted bass but also of largemouth bass and smallmouth bass. Moreover, the primary goal of this regulation was to reduce the abundance of spotted bass. The ODWC and my electrofishing data failed to show a reduction in spotted bass abundance following the regulation change. Additionally, the concomitant increase in largemouth bass abundance in fall samples and smallmouth bass abundance in spring samples suggests that factors other than those associated with the regulation change have influenced the population characteristics of these three black bass species.

If black bass abundance in Skiatook Lake was controlled by angler catch and harvest resulting from the regulation change, then there should have been changes in survival of all three species, as has been shown by Novinger (1987) and Buynak et al. (1991a). A working hypothesis is that increased abundance of largemouth bass and smallmouth bass would have been the result of decreased harvest and thus increased survival over time. We saw no changes in survival for any of the three species over the

three year study period. However, since survival is the complement of mortality and mortality has two components, natural and fishing (Van Den Avyle 1993), there conceivably could have been a change in one of the mortality components and an opposite, compensatory change in the other, which would have allowed for no net change in total mortality. However, given the additive relationship of fishing mortality and natural mortality to total mortality (Van Den Avyle 1993), it is unlikely that this occurred. For density-dependent populations, one form of mortality simply replaces the other (Wootton 1990). We did not directly measure the effects of fishing mortality; however, creel surveys of anglers on Skiatook Lake show decreasing trends in harvest and in the ratio of harvest:catch for all three species from 1997 through 1999 (Randy Hyler, Oklahoma State University, personal communication). Assuming constant natural mortality, these results indicate a decrease in fishing mortality and thus verify that the post-regulation trends in spotted bass relative abundance were not related to the regulation change. Consequently, other external factors presumably have brought about changes in the population characteristics of each species.

Environmental conditions can confound interpretations of regulation changes. Novinger (1987) was unable to conclusively demonstrate changes in largemouth bass and spotted bass survival in Table Rock Lake, Missouri because of variations in electrofishing sampling efficiency in several years. These variations were presumably due to differences in the water chemistry, as he reported lower water transparencies in the years with variable sampling conditions. Buynak et al. (1991b) found that they could not evaluate the effects of a regulation change on the largemouth bass populations in Kentucky and Barkley lakes, Kentucky due to a drought that occurred during their study. During my study, 1998 was one of the warmest years on record for this region of Oklahoma over the past 93 years (National Oceanographic and Atmospheric Administration, unpublished data), and most differences in the black bass population characteristics at Skiatook Lake are in relation to this year. For example, mean relative weight of smallmouth bass in spring was lowest in 1998 and growth rates of smallmouth bass were reduced in 1998 as compared to 1999, but the opposite was true for largemouth bass.

The reasons for the increased abundance of largemouth bass and smallmouth bass is unclear since recruitment did not change for either of these species. Smallmouth bass were initially stocked in 1990 in Skiatook Lake and their relative abundance has increased every year since (Hicks 1994). This population has probably not yet reached carrying capacity and will continue to expand. The largemouth bass population has fluctuated over the lifetime of the reservoir (Hicks 1994) and the trends observed during the study period are, more than likely, another population cycle. Assuming that spotted bass is an equilibrium species (Winemiller [1992] classified centrarchids as an equilibrium species) and are thus controlled by density-dependent factors, their constant relative abundance since 1997 suggests that they have reached steady state where reproduction equals mortality and this level of abundance will probably continue in Skiatook Lake, unless resources fluctuate (Pianka 1994).

Although certain population characteristics of each of three black bass changed during my study, it is not certain that they were directly influenced by the differential harvest regulation. In general, minimum-length limits have performed well at restructuring largemouth bass populations (Fox 1975; Novinger 1986; Redmond 1986; Wilde 1997). However, the literature on effects of fisheries management regulations on

smallmouth bass and spotted bass populations in reservoirs is sparse at best, and no clear generalizations can be made regarding these species. Buynak et al. (1991a) provide the only published results of the effects of a differential harvest regulation. Although they found that the regulation was effective at restructuring the relative abundance and size structure of the largemouth bass and spotted bass populations, these changes were attributed to a reduced minimum-length limit on spotted bass and increased minimum-length limit on largemouth bass. Therefore, it is difficult to determine which of the two changes, singularly or together, brought about the responses in the largemouth bass and smallmouth bass species.

With three years of data post-treatment data collected for this study, the minimum needed to evaluate effects of a regulation (Wilde 1997), the evidence presented herein suggests that this differential harvest regulation has not altered the population characteristics of these three black bass species. Further research is needed to examine the influences of the environment on the black bass populations in Skiatook Lake during this study period. More long-term monitoring of the black bass populations needs to be conducted to determine the effects of minimum-length limit regulations on smallmouth bass and spotted bass in reservoirs and on the effects of regulations on non-target species.

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Table 1.---Differences between pre-and post-regulation mean electrofishing catch-per-effort (CPE; number of fish per hour) estimates of largemouth bass, smallmouth bass, and spotted bass populations in Skiatook Lake, Oklahoma. N = number of sites and SE = standard error. Data courtesy of the ODWC.

		Largemouth Bass		Smallmouth Bass		Spotted Bass	
Period	N	Mean	SE	Mean	SE	Mean	SE
Pre-regulation	19	80.85	16.88	17.48	6.13	58.01	11.95
Post-regulation	24	81.53	10.57	53.58	13.54	61.48	8.73
t-test		P = 0.97		P = 0.02		P = 0.84	

Table 2.--Electrofishing catch-per-effort (CPE; number of fish per hour) statistics for largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma in spring and fall 1997, 1998, and 1999. N = number of sites and SE = standard error.

		Largemouth Bass		Smallmouth Bass		Spotted Bass	
Year	N	Mean	SE	Mean	SE	Mean	SE
				Spring			
1997	45	4.38	1.37	3.64	1.79	17.64	2.51
1998	34	7.67	1.58	7.85	2.06	9.71	2.89
1999	40	7.37	1.46	10.96	1.90	15.03	2.67
ANOVA		$P = 0.20$		$P = 0.02$		$P = 0.12$	
Linear		$P = 0.14$		$P < 0.01$		$P = 0.48$	
				Fall			
1997	21	8.49	3.05	10.77	4.67	11.63	4.37
1998	40	7.53	2.15	13.73	3.38	15.93	3.17
1999	37	16.90	2.24	9.63	3.62	18.43	3.30
ANOVA		$P < 0.01$		$P = 0.70$		$P = 0.46$	
Linear		$P = 0.03$		$P = 0.86$		$P = 0.22$	

Table 3.---Electrofishing catch-per-effort (CPE; number of fish per hour) statistics among strata for largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma in spring and fall. Since the year*stratum interaction was never significant, we grouped data for 1997, 1998, and 1999. N = number of sites and SE = standard error. P-values for ANOVA indicate probability that strata are different. Similar letters indicate no significant difference between means among strata for each species and season at $\alpha = 0.05$.

		Largemouth Bass		Smallmouth Bass		Spotted Bass	
Stratum	N	Mean	SE	Mean	SE	Mean	SE
				Spring			
Bull Creek	19	4.13zy	2.08	0.24z	2.33	25.27zw	3.55
Hominy Creek	22	2.14y	1.99	0.03z	2.22	2.44y	3.39
lower-lake	59	8.81z	1.19	14.12y	1.33	14.39xw	2.03
mid-lake	19	6.06zy	2.08	1.82z	2.33	15.34w	3.55
ANOVA		P = 0.02		P < 0.01		P < 0.01	
				Fall			
Bull Creek	18	8.78z	3.31	0.15z	4.72	9.73zy	4.73
Hominy Creek	16	5.83z	3.49	0.70z	4.97	1.55zx	4.98
lower-lake	50	12.30z	2.08	21.88y	2.93	19.44y	2.89
mid-lake	14	14.29z	3.86	2.68z	5.50	23.34y	5.51
ANOVA		P = 0.30		P < 0.01		P < 0.01	

Table 4.--Relative weight (Wr) statistics for largemouth bass, smallmouth bass, and spotted bass at Skiatook Lake, Oklahoma in spring and fall 1997, 1998, and 1999. SE = standard error, LIN indicates linear trend, and LOF ('lack of fit') indicates quadratic or higher order trend in means among years for each species and season.

	Largemouth Bass		Smallmouth Bass		Spotted Bass	
Year	Mean	SE	Mean	SE	Mean	SE
			Spring			
1997	92.88	1.51	94.99	1.85	104.57	1.36
1998	91.62	1.58	81.20	1.66	92.81	1.87
1999	95.17	1.81	86.72	1.37	96.55	1.89
ANOVA	$P = 0.33$		$P < 0.01$		$P < 0.01$	
LOF	$P = 0.33$		$P < 0.01$		$P < 0.01$	
			Fall			
1997	89.45	2.05	91.16	1.92	93.57	1.48
1998	86.93	1.82	77.96	1.20	84.19	1.46
1999	86.02	1.34	75.67	1.83	83.55	1.52
ANOVA	$P = 0.38$		$P < 0.01$		$P < 0.01$	
LOF	$P = 0.72$		$P < 0.01$		$P < 0.01$	

Table 5.--Electrofishing catch-per-effort (CPE; number of fish per hour) statistics for juvenile largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma in spring 1997, 1998, and 1999. SE = standard error and linear indicates linear trend in means among years for each species.

	Largemouth Bass		Smallmouth Bass		Spotted Bass	
Year	Mean	SE	Mean	SE	Mean	SE
1997	1.71	0.66	1.41	0.84	6.14	1.06
1998	3.91	0.75	3.76	0.89	3.42	1.16
1999	3.21	0.67	2.50	0.97	3.25	1.14
ANOVA	$P = 0.08$		$P = 0.16$		$P = 0.12$	
Linear	$P = 0.11$		$P = 0.40$		$P = 0.07$	

Table 6.--Sources of variation, F statistics, and P-values for comparing growth among age, growth-year, and age*growth-year interaction using annuli measurements from scales taken in 1997 and 1999 from largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma.

	Largemouth Bass		Smallmouth Bass		Spotted Bass	
Source	F	P	F	P	F	P
		1997				
Age	10.53	< 0.01	2.48	0.04	0.72	0.72
Growth-year	1.45	0.18	0.41	0.84	0.11	0.99
Age*Growth-year	0.37	0.98	1.47	0.20	0.25	0.99
		1999				
Age	10.70	< 0.01	16.85	< 0.01	18.06	< 0.01
Growth-year	1.13	0.36	0.47	0.80	1.08	0.37
Age*Growth-year	1.53	0.12	0.80	0.63	1.54	0.17

Table 7.--Survival estimates (S) and catch-curve statistics for largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma as aged by whole otoliths in spring 1997, 1998, and 1999. Similar letters indicate no significant differences in the slopes or y-intercepts (y-int) of the catch-curves at $\propto = 0.05$.

	Largemouth Bass			Smallmouth Bass			Spotted Bass		
Year	S	Slope	Y-int	S	Slope	Y-int	S	Slope	Y-int
1997	59.63	-0.51z	2.82z	56.89	-0.56z	2.65z	59.04	-0.53z	3.19z
1998	76.41	-0.27z	2.15z	52.78	-0.64z	2.96z	50.76	-0.68z	3.23z
1999	64.40	-0.44z	2.49z	62.56	-0.47z	2.67z	71.82	-0.33z	2.41z

Table 8.--Proportional stock density (PSD) estimates for largemouth bass, smallmouth bass, and spotted bass in spring and fall 1997, 1998, and 1999 in Skiatook Lake, Oklahoma. Similar letters indicate no significant differences between PSD estimates among years for each species and season at $\alpha = 0.017$ ($\alpha = 0.05$ corrected for 3 groups with Bonferroni correction).

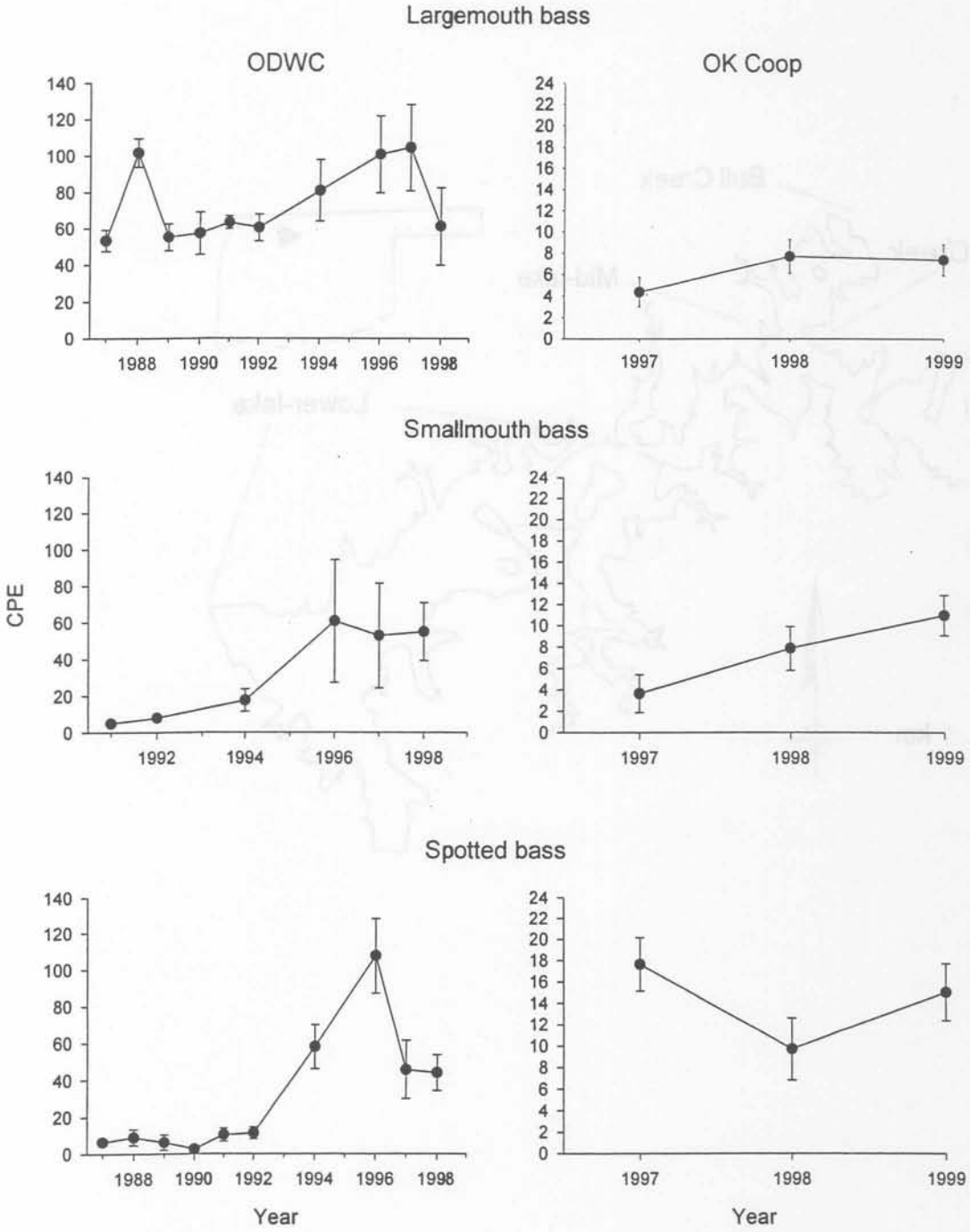
	Largemouth Bass	Smallmouth Bass	Spotted Bass
Year	PSD	PSD	PSD
	Spring		
1997	52.14z	45.45z	28.03z
1998	55.10z	42.67z	26.67z
1999	35.21y	37.86z	40.34z
	Fall		
1997	61.29z	23.68z	34.31z
1998	61.90z	33.00z	48.11z
1999	53.42z	84.85y	66.67z

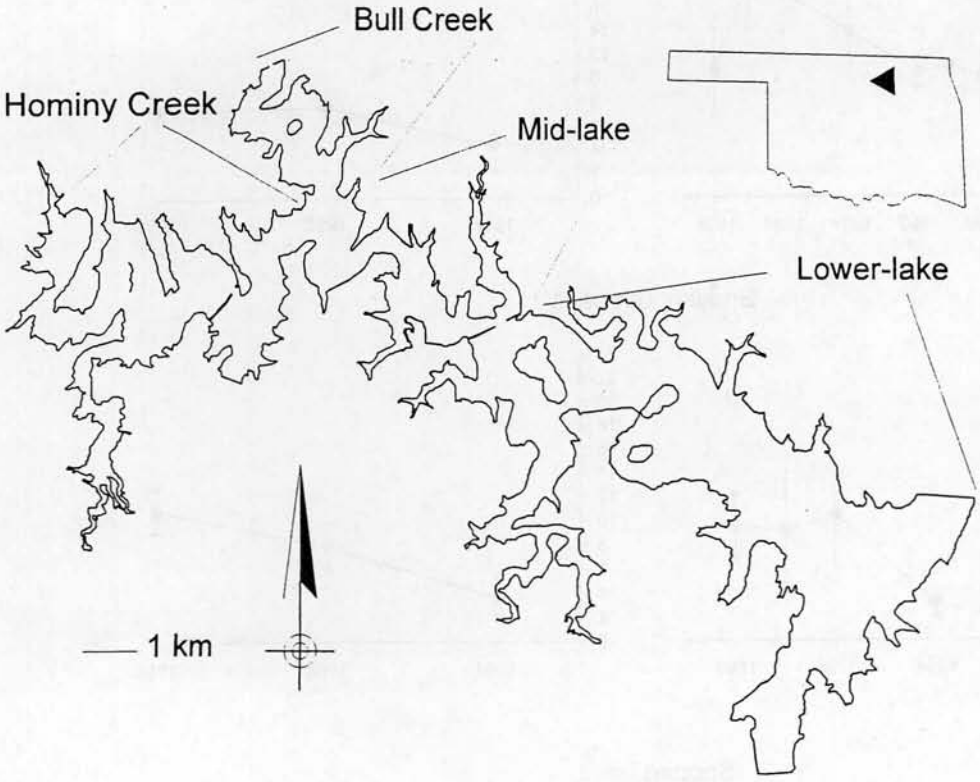
FIGURE LEGENDS

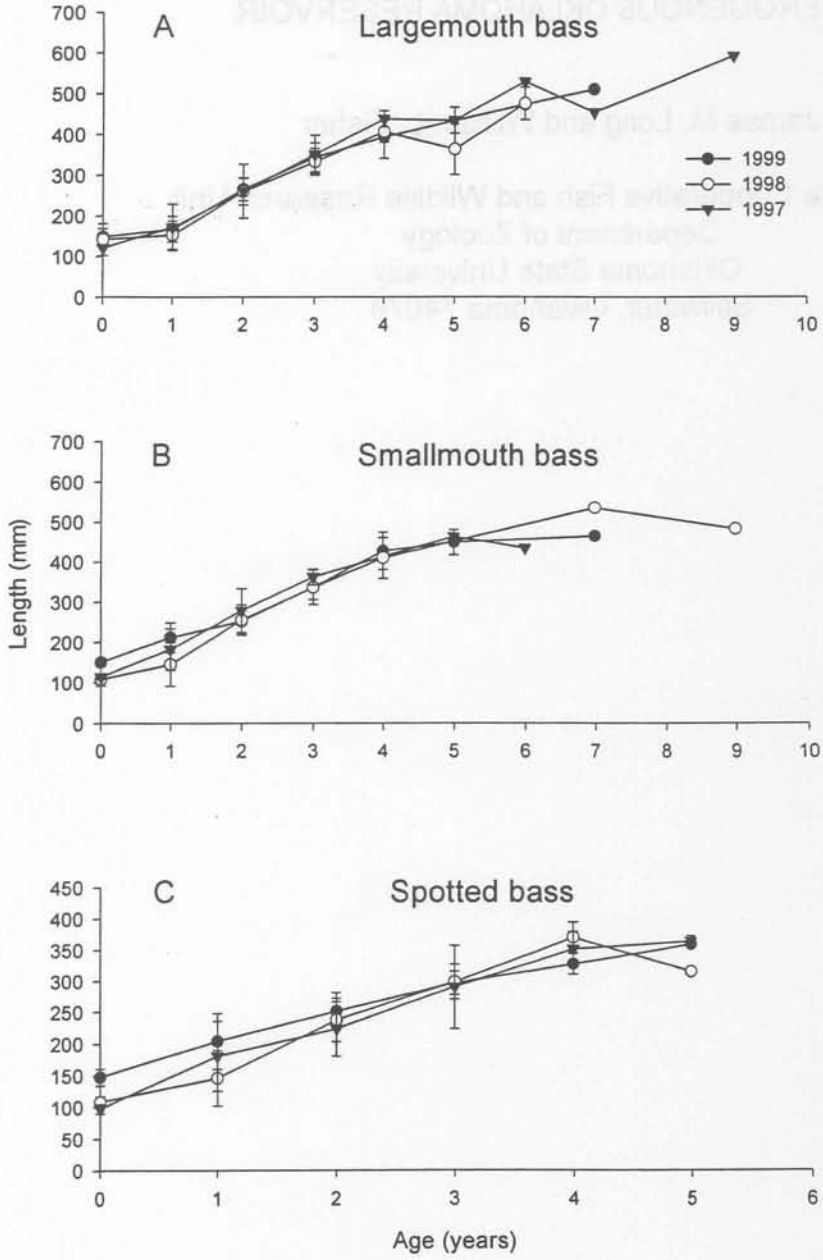
Figure 1.--Trends in mean catch-per-effort (CPE; number of fish per electrofishing hour) of largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma 1987 - 1999. The left half of the page are data collected by the Oklahoma Department of Wildlife Conservation (ODWC) before (1987 - 1996) and after (1997 - 1998) the differential harvest regulation and the right half of the page are data collected by the Oklahoma Cooperative Fish and Wildlife Research Unit (OK Coop) after (1997 - 1999) the differential harvest regulation. Error bars are 1 standard error on either side of the mean CPE (note differences of scale on y-axes).

Figure 2.--Map of Skiatook Lake, Oklahoma indicating Bull Creek, Hominy Creek, mid-lake, and lower-lake strata.

Figure 3.--Mean length-at-age graphs for largemouth bass, smallmouth bass, and spotted bass from Skiatook Lake, Oklahoma in spring 1997, 1998, and 1999. Error bars are 1 standard deviation on either side of the mean length.


Largemouth bass
ODWC
OK Coop
Smallmouth bass
Spotted bass
CPE
Year
Year


Bull Creek
Hominy Creek
Mid-lake
Lower-lake
1 km


A
Largemouth bass
1999
1998
1997
B
Smallmouth bass
Length (mm)
C
Spotted bass
Age (years)

CHAPTER III

RESOURCE USE BY THREE BLACK BASS SPECIES IN A TROPHICALLY HETEROGENOUS OKLAHOMA RESERVOIR

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INTRODUCTION

The genus Micropterus is composed of at least six black bass species, the most widespread of which are largemouth bass M. salmoides, smallmouth bass M. dolomieu, and spotted bass M. punctulatus (Robbins and MacCrimmon 1974; Coble 1975; Heidinger 1975; Vogele 1975). These three species are economically important as sportfishes, ecologically similar, and often occur sympatrically in reservoirs in the southeastern United States and have therefore been extensively studied (Aggus 1972; Lewis 1976; Farquhar and Whiteside 1995; Scott and Angermeier 1998; Ward and Newmann 1998). An interest among ecologists studying sympatrically occurring, ecologically similar species is interspecific resource partitioning (Schoener 1970; Ross 1986; Stauffer et al. 1996) because resource partitioning is one mechanism that allows for coexistence of these species (Schoener 1974).

Schoener (1974) concluded that the important resources, in descending order, were habitat, food, and time. However, his synthesis of the current literature was poorly represented by studies on fish. Ross (1986) reviewed resource partitioning studies for fish assemblages and reported that among 37 studies that incorporated all three major groups of resources, most (57%) exhibited segregation by food, followed by habitat (32%) and time (11%).

Important segregating mechanisms among black bass species seem to be primarily related to habitat. Miller (1975) reported differences in habitat preferences among largemouth bass, smallmouth bass, and spotted bass, with largemouth bass preferring lacustrine environments with abundant vegetation, smallmouth bass preferring clear, cooler areas of rivers and lakes, and spotted bass utilizing areas intermediate to those preferred by the other two species. Buynak et al. (1989) found longitudinal segregation of three black bass species in Cave Run Lake, Kentucky with largemouth bass more abundant in the eutrophic upper end, spotted bass more abundant in the lower and middle lake, and smallmouth bass more abundant in the oligotrophic lower end. Janssen (1992) concluded that largemouth bass, smallmouth bass, and spotted bass segregated habitat but not food in the upper portion of Pickwick Reservoir, Alabama, and that prey consumption was habitat specific for prey other than fish and insects. Farquhar and Whiteside (1995) examined habitat and food differences among native Guadalupe bass (M. treculi), largemouth bass, and non-native smallmouth bass in the Blanco River, Texas. They found largemouth bass to inhabit areas with wood and mud/silt substrate whereas smallmouth bass inhabited areas with rocks and Guadalupe bass inhabited areas with rocks and wood. Additionally, largemouth bass consumed more fish than either smallmouth bass or Guadalupe bass, both of which consumed more aquatic insects. Their study primarily focused on the potential negative impacts of smallmouth bass introduction in the Blanco River, and they concluded that smallmouth bass and Guadalupe bass segregated habitat more than prey, but that largemouth bass were segregated from both species by habitat and prey. Scott and Angermeier (1998) studied habitat and prey use between smallmouth bass and spotted bass in impounded and riverine sections of the New River, Virginia. They found segregation for habitat on two scales: between impounded and riverine sections and within each section. Spotted bass were predominately found in the impounded portion and smallmouth bass in the riverine portion. Within the impounded portion, spotted bass were widely distributed whereas smallmouth bass were concentrated in

steep-sloping dropoffs with rock substrate. Within the riverine portion, spotted bass were restricted near the banks away from high flow but smallmouth bass were not. Additionally, they found little segregation between these two species for prey because both ate predominately the same forage items and differed only in proportion consumed. Long and Fisher (in press) found segregation for prey among two sizes of sympatric largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma in one year but little segregation two years later. They did not assess habitat but hypothesized that it may be more important than prey in segregating the niches of these three species in that reservoir.

Intraspecific resource partitioning among black bass species can also be important in niche segregation. Wanjala et al. (1986) found that three size groups of largemouth bass in Alamo Lake, Arizona segregated habitat and prey resources. They found small fish restricted to the littoral zone, intermediate-size fish foraging in the limnetic zone, and large fish solitary using submerged structure. Lynch and Johnson (1989) experimentally showed size-related use of structure by largemouth bass, with small (<300 mm) individuals using a wider range of interstice sizes than larger fish, which were confined to only the largest interstice size structure. Janssen (1992) showed length to be an important factor when analyzing habitat use within and among largemouth bass, smallmouth bass, and spotted bass. Long (1995) found that larger largemouth bass in experimental pools preferentially used different artificial structures than smaller individuals when structure was abundant and could displace smaller ones from an area that was preferred by both.

My objective was to assess temporal resource (habitat and food) use by two size classes of three sympatric black bass species (largemouth bass, smallmouth bass, and spotted bass) in Skiatook Lake, Oklahoma.

METHODS

Black Bass Sampling

We sampled black bass with nighttime, boat-mounted electrofishing during spring and fall in 1997-1999 using a stratified-random design (Wilde and Fisher 1996). We stratified Skiatook Lake into four areas (lower-lake, mid-lake, Hominy Creek, and Bull Creek) based on morphometry and Secchi depth measurements (Figure 1). Sampling sites were identified by delineating shoreline habitat types in a Geographic Information Systems (GIS) database and randomly selected within strata for each season and year. At least 10% of the shoreline was sampled. Habitat types consisted of substrate and cover type combinations which were classified by surveying the entire perimeter of Skiatook Lake by boat in winter 1996. Sites selected for sampling were electrofished with varying amounts of effort, depending on site length and habitat complexity. All black bass captured were identified and measured to the nearest 1 mm. We classified each species into two size classes, juveniles and adults, according to the upper end of the central 50% length range for age-one fish in Oklahoma waters, as reported by Carlander (1977). Thus, largemouth bass less than 226-mm, smallmouth bass less than 185-mm, and spotted bass less than 178-mm were considered juveniles.

Electrofishing sampling sites in the GIS were converted from lines to polygons by creating 10-m buffers inside the reservoir boundary using ArcView. Ten meters was chosen because it represented the approximate maximum area that the electrofishing

boat sampled. Numbers of each size class of the three species of black bass were added as attributes to these sampling sites in the GIS database and the density of each size class/species combination was estimated for each sampling site. We tested for differences among years for each size/species/season combination with ANOVA (SAS Institute 1992).

Prey Use

During spring electrofishing in 1997-1999, black bass were sacrificed by placing them on ice immediately after capture and prey items were removed from the stomach via dissection. Dissection was used since another concurrent study of black bass in this reservoir required removing the otoliths for age analysis which also requires sacrificing the fish (DeVries and Frie 1996). During fall electrofishing in 1998-1999, we removed prey items from the stomachs of all captured black bass with acrylic tubes (Van Den Avyle and Roussel 1980; Caliteux et al. 1990) and returned the fish to the water. Prey use was not assessed in fall 1997. Except in 1998, all prey items removed were enumerated and identified to genus for fish, order for insects, and class for other invertebrates and are hereafter referred to as "expanded prey categories." Preliminary analysis of the spring 1997 data showed that prey segregation among these three species in Skiatook Lake could be accurately shown with only four categories; thus, we identified prey accordingly as fish, crayfish, insects, and miscellaneous in 1998 reducing the expanded prey use data to these four groups hereafter referred to as "reduced prey categories."

Habitat Use

We scanned the five 7.5' topographic maps (USGS 1966, photo-revised 1983) that contained the boundaries of Skiatook Lake and exported them into ArcView (Environmental Systems Research Institute, Redlands, California) GIS software. This GIS coverage was then used to produce a digital elevation model (DEM) using ARC/INFO (Environmental Systems Research Institute, Redlands, California; Figure 2). A DEM interprets the discrete values assigned to contour lines and interpolates values between them to create a smooth surface that represents the topography of the coverage. The DEM was used to compute shoreline slope in ArcView.

Substrate types (based on particle size using the modified Wentworth scale) and cover types (dominant features seen above the water surface) were classified, delineated using shoreline landmarks, and added as binary codes. The main river channel and the location of the dam was delineated from the topographic map and distances from these features to the sampling sites were calculated using the GIS. In fall 1999 and spring 2000, we conducted longitudinal sampling of four physicochemical variables (Secchi depth, surface water temperature, surface dissolved oxygen, and surface conductivity) from 30 fixed stations throughout the reservoir to quantify the spatial limnological characteristics of the reservoir (Figure 3). Four longitudinal samples each were collected during fall 1999 and spring 2000. We used the ArcView GIS to interpolate values between sampling sites to create a smooth surface of the entire reservoir for each physicochemical variable in each season. These surfaces were then used to calculate and visually display the mean and variance of each of the four physicochemical variables in spring and fall. We used inverse direct weighting (IDW) and nearest neighbor distance with 3 neighbors as the interpolation method in ArcView

(Environmental Systems Research Institute, Inc. 1998). All surfaces created with the GIS were based on a 10x10-m cell size to correspond with the 10-m polygons created for the electrofishing sampling sites.

Statistical Methods

Prey use.--For the reduced prey category data (spring 1997 - spring 1999 and fall 1998 - fall 1999) and the expanded prey category data (spring 1997, spring 1999, and fall 1999), we calculated frequency of occurrence (number of stomachs containing one or more of a particular prey type) and compared prey use among juvenile and adult size largemouth bass, smallmouth bass, and spotted bass with Chi-square for the reduced data set and Fisher's exact tests for the expanded data set (SAS Institute 1992). We compared prey overlap by calculating Pianka's (1973) index of niche overlap for each season and year and then compared the overlap values among seasons and years with ANOVA and least square means (LSMEANS) for pairwise comparisons (SAS Institute 1992). We tested the degree of niche overlap with randomization tests using EcoSim 4.0 software (Gotelli and Entsminger 1999) to ascertain whether or not mean niche overlap was greater than expected by chance for each season and year.

Using number of prey items in the gut of each size/bass species combination, we performed canonical correspondence analysis (CCA) to examine differences in prey use among juvenile and adults of the three black bass species for each season and year where we had expanded prey category data. Canonical correspondence analysis is a multivariate, direct gradient analysis that ordinates species according to measured environmental variables (ter Braak 1986). For the CCA, we used a square root transformation on the raw prey data to minimize the effects of large numbers of individuals in any one stomach and we downweighted rare prey items (ter Braak and Šmilauer 1998). We conducted Monte Carlo randomization tests for the first and all combined canonical axes, with 1000 permutations, to determine the probability that the correlations among species occurrences could occur by chance alone.

Habitat use.--We used principal component analysis (PCA; ter Braak 1995) on the physicochemical characteristics of the reservoir measured in fall 1999 and spring 2000 to determine the most important environmental gradients in the reservoir in each season. Habitat data were standardized to account for differences in measurement scales, binary variables were entered as dummy variables, and the eigenvalues and corresponding eigenvectors of the first four principal components (axes) were calculated. To examine the relationship between habitat and density of each size/bass species combination for fall and spring 1997-1999, we used CCA and Pearson correlation analysis (SAS Institute 1992) with bass density in each year and season and the habitat variables measured in fall 1999 and spring 2000 to determine the significance and magnitude of the relationships at the $\alpha = 0.05$ level. We only used the habitat variables in fall 1999 and spring 2000 as they represented the spatial variability that occurred in the reservoir over the sampling period. Only the first two axes of the CCA were interpreted for each season and year, and we used Monte Carlo randomization tests for the first and all combined canonical axes to determine if the results could have occurred by chance.

RESULTS

Black Bass Density

Adult largemouth bass and juvenile spotted bass densities were not significantly different among years in spring (P = 0.79 and 0.05, respectively; Table 1) or fall (P = 0.57 and 0.31, respectively; Table 2). Juvenile largemouth bass densities were not significantly different among years in spring (P = 0.13) but were depressed in fall 1998 (P < 0.01). Adult smallmouth bass densities were greatest in spring 1999 (P = 0.02) but constant in fall 1999 (P = 0.07). Juvenile smallmouth bass densities were similar among years in spring (P = 0.15) and greatest in fall 1997 (P < 0.01). Adult spotted bass exhibited their lowest densities in spring 1999 (P = 0.02) but remained constant among years in fall (P = 0.31).

Prey Use

Prey use among the two size classes of black bass was not equal for each season and year (Chi-square P < 0.01 for each season and year; Figure 4) using the reduced prey categories. Juvenile and adult largemouth bass were mainly piscivorous regardless of season or year and adult spotted bass mainly consumed crayfish. In fall, juvenile smallmouth bass and juvenile spotted bass consumed insects, but fish contributed more to their diet in spring. Adult smallmouth bass diets changed annually more than any other species, with insects making up the bulk of their diet in spring 1997 and fish and crayfish being the dominant items in spring 1999. In fall 1999, crayfish made up the majority of the diet of adult smallmouth bass in contrast to fall 1998 when fish made up the majority. Mean niche overlap in spring 1997-1999 was 0.70, 0.72, and 0.83, respectively, and in fall 1998 and 1999 was 0.81 and 0.84, respectively (Table 3). Overlap was not significantly different among seasons and years (P = 0.09). Niche overlap was greater than expected by chance in fall 1998 (P < 0.01) and 1999 (P < 0.01) and in spring 1999 (P < 0.01), but not in spring 1997 (P = 0.05) or 1998 (P = 0.07; Table 3).

Using the expanded prey categories, prey use among the two size classes of black bass was significantly different (Fisher's exact P < 0.01 for each season and year; Figures 5-7). Since the proximity of a particular prey item to any predator in a CCA is related to the magnitude of association between the prey and predator (ter Braak 1995), one can examine a CCA diagram and determine which prey item was used most often by a certain predator. In spring 1997, adult largemouth bass and smallmouth bass and juvenile largemouth bass clustered around various fish prey species (e.g. Dorosoma, Lepomis, and unidentified fish). Adult spotted bass clustered around molluscs and crayfish and juvenile smallmouth bass and spotted bass clustered around various insect prey. The pattern in the CCA diagram for spring 1997 was significant for the first (P = 0.04) and all combined (P = 0.01) canonical axes (Figure 5). In spring 1999, the prey items were clustered around the origin and the predators were arranged around the outside indicating a high degree of overlap. The randomization tests for the first and combined canonical axes were not significant (P = 0.16 and 0.36, respectively) indicating that these results could be found by chance and further indicating a high degree of overlap (Figure 6). The fall 1999 prey use CCA diagram was similar to spring 1999, but the randomization tests were significant for the first (P < 0.01) and all combined axes (P < 0.01). All three species and size classes of black bass consumed

Dorosoma, whereas adults of all three species ate Lepomis and other various insects and juveniles of all three species fed on various insects (Figure 7). Prey overlap was not significantly different among years and seasons ($P = 0.13$) but significantly greater than expected by chance in every year and season (Table 4).

Habitat Use

Spring.--Summary statistics and explanation of variable names for habitat variables in spring are found in Table 5. The first four principal components of the habitat variables explained 61.5% of the variation and the first axis represented longitudinal variation in water quality (Table 6; Figure 8 and 9). Mean Secchi depth and mean dissolved oxygen were higher in the lower end of the lake while mean surface water temperature and conductivity were higher in the upper ends of the reservoir (Figure 8). In general, conductivity and dissolved oxygen were more variable in the upper ends of the reservoir, water temperature in the lower end, and Secchi depth in mid-reservoir (Figure 9). Prinicipal component 2 also represented longitudinal variation in water quality (i.e., variance of Secchi depth, variance of water temperature, distance to river channel, and standing timber). The variance of Secchi depth was greatest in the mid-reach of the reservoir and in the southern-most part of the lower-end of the reservoir (Figure 9). Surface water temperature was most variable in Bull Creek and in the lower-end of the reservoir. Principal component 3 was a cover and substrate axis and principal component 4 was a shoreline slope axis.

The relationships between habitat variables and density of each size class and black bass species in each year were variable. In 1997, no significant correlations between density and habitat variables could be found for juvenile largemouth bass although they were located in the CCA diagram (Figure 10) nearest to the RIVER (distance to main river channel) variable. Adult largemouth bass were located nearest RIVER ($r = 0.46$) and farthest from SLOPE ($r = -0.32$) in the CCA diagram. Juvenile and adult smallmouth bass were significantly and positively correlated with mean Secchi depth ($r = 0.45$ and 43, respectively) and mean dissolved oxygen ($r = 0.50$ and 0.43, respectively), but negatively correlated with variance of dissolved oxygen ($r = -0.50$ and -0.42, respectively), mean temperature ($r = -0.49$ and -0.51, respectively), mean conductivity ($r = -0.49$ and 0.46, respectively), variance of conductivity ($r = -0.34$ and -0.36, respectively), and distance from the dam ($r = -0.46$ and -0.55, respectively), all of which exhibited a high degree of longitudinal zonation in Skiatook Lake (Figures 8 and 9). Additionally, juvenile smallmouth bass were positively correlated with rip-rap ($r = 0.37$) and vegetation ($r = 0.71$) although these variables did not cluster very close to this size and species in the CCA diagram (Figure 10). Juvenile spotted bass were positively correlated with silt substrates ($r = 0.63$) while adult spotted bass were positively correlated with slope ($r = 0.31$), rip-rap ($r = 0.45$) and vegetation ($r = 0.49$). The first two axes of the CCA explained 68.9% of the variation in the density-habitat relation and the results of the randomization tests were significant for the first ($P < 0.01$) and all combined axes ($P < 0.01$).

In 1998, no significant correlations could be found for either size of largemouth bass or either size of spotted bass although the two sizes of largemouth bass were located nearest RIVER, juvenile spotted bass were located nearest standing timber (STANDTIM), and adult spotted bass were located nearest bedrock and variance of dissolved oxygen (DOV) in the CCA diagram (Figure 11). The two sizes of smallmouth

bass were correlated in a fashion similar to that seen in 1997. Mean Secchi depth (r = 0.55 for juveniles and r = 0.59 for adults) and mean dissolved oxygen (r = 0.56 for juveniles and r = 0.64 for adults) were significant, positive correlates, while mean temperature (r = -0.62 for juveniles and r = -0.65 for adults), mean conductivity (r = -0.63 for juveniles and r = -0.69 for adults), variance of conductivity (r = -0.45 for juveniles and r = -0.49 for adults), variance of dissolved oxygen (r = -0.51 for juveniles and r = -0.60 for adults), and distance from dam (r = -0.64 for juveniles and r = -0.67 for adults) were negative correlates, and these results were reflected in the CCA diagram. Additionally, slope was positively correlated (r = 0.39) with juvenile smallmouth bass density. Areas that contained vegetation and/or silt, which were significant correlates in 1997, were not sampled in 1998. The first two axes of the CCA explained 78.7% of the variation in the density-habitat relation and the results of the randomization tests were significant for the first (P < 0.01) and all combined axes (P < 0.01).

In 1999, juvenile and adult largemouth bass were positively correlated with distance from the river channel (r = 0.50 and 0.35, respectively) and standing timber (r = 0.62 and 0.49, respectively) and juvenile largemouth bass were negatively correlated with shrubs (r = -0.45), although both appearred closer to variance in Secchi depth (SECCHV) in the CCA diagram (Figure 12). Juvenile and adult smallmouth bass were correlated in a similar fashion to 1997 and 1998: positively with mean Secchi depth (r = 0.36 and 0.51, respectively) and mean dissolved oxygen (r = 0.43 and 0.53, respectively) but also with fallen timber (r = 0.47 and 0.44, respectively) and negatively with mean water temperature (r = -0.44 and -0.65, respectively), mean conductivity (r = -0.46 and -0.61, respectively), mean dissolved oxygen (r = -0.43 and -0.53, respectively), variance of dissolved oxygen (r = -0.46 and -0.51, respectively), and distance from the dam (r = -0.44 and -0.65, respectively). Adult smallmouth bass were also negatively correlated with variance of conductivity (r = -0.43) and positively with boulder substrate (r = 0.35). The results for both size classes of smallmouth bass correspond well with the CCA diagram (Figure 12). Juvenile spotted bass were positively correlated with variance of water temperature (r = 0.45) and rip-rap (r = 0.34) and negatively with shrubs (r = -0.31). Adult spotted bass were positively correlated with mean dissolved oxygen (r = 0.32) and distance from the river channel (r = 0.31) but negatively with variance of conductivity (r = -0.33). The CCA diagram for both sizes of this species corresponded moderately with the results of the correlation analyses. The first two axes of the CCA explained 81.6% of the variation in the density-habitat relation and the results of the randomization tests were significant for the first (P < 0.01) and all combined axes (P < 0.01).

Fall.--Summary statistics and explanation of variable names for habitat variables in fall are found in Table 7. The first four principal components of the habitat variables explained 61.2% of the variation with the first axis represented by the longitudinal variation in water quality parameters (Table 8; Figure 8 and 9). Mean Secchi depth and mean surface water temperature were higher in the lower end of the reservoir, while mean conductivity and dissolved oxygen were highest in the upper-end (Figure 8). Mean variation in Secchi depth and dissolved oxygen were highest in the lower-end while mean variation in surface water temperature and conductivity were highest in the upper-end (Figure 9). The spatial distribution of mean dissolved oxygen, variance of surface water temperature, and variance of dissolved oxygen in fall 1999 was the opposite of the trend in spring 2000 (Figure 8 and 9). Prinicipal component 2 was also

a longitudinal axis representing distance to main river channel and substrate and cover types. Principal component 3 was a shoreline slope, substrate, and cover axis and prinicpal component 4 was a fallen timber cover and distance to main river channel axis.

In 1997, we found no significant correlations between juvenile largemouth bass density and any of the environmental variables, although the CCA diagram clustered this size and species with rip-rap and no cover (Figure 13), and only distance to the main river channel was significant (r = 0.67) for adult largemouth bass (Figure 13). Juvenile and adult smallmouth bass densities were similarly correlated with water quality variables; negatively with variance of water temperature (r = -0.57 and -0.58, respectively), variance of conductivity (r = -0.49 and -0.50, respectively), mean dissolved oxygen (r = -0.48 and -0.46, respectively), and distance from the dam (r = -0.53 and -0.58, respectively). Juvenile smallmouth bass were also negatively correlated with mean conductivity (r = -0.43) and adult smallmouth bass were positively correlated with mean Secchi depth (r = 0.44), variance of Secchi depth (r = 0.47) and fallen timber (r = 0.51) and these correlations correspond well with the CCA diagram (Figure 13). We found no significant correlations between juvenile spotted bass and the environmental variables but the CCA placed them near vegetation and distance from the river channel (Figure 13). Adult spotted bass were correlated with several longitudinally distributed variables: positively with mean Secchi depth (r = 0.58), variance of Secchi depth (r = 0.58), and mean water temperature (r = 0.58) and negatively with variance of water temperature (r = -0.57), mean conductivity (r = -0.49), variance of conductivity (r = -0.51), mean dissolved oxygen (r = -0.57), and distance from the dam (r = -0.57). Additionally, adult spotted bass was positively correlated with shoreline slope (r = 0.59) and fallen timber (r = 0.47; Figure 13). The first two axes of the CCA explained 68.2% of the variation in the density-habitat relation and the results of the randomization tests were significant for the first (P < 0.01) and all combined axes (P < 0.01).

In 1998, no significant correlations between juvenile largemouth bass and their environment were evident and they clustered near the origin of the CCA diagram (Figure 14). Adult largemouth bass were positively correlated with cobble substrate (r = 0.44) and standing timber (r = 0.32). Juvenile and adult smallmouth bass were negatively correlated with mean dissolved oxygen (r = -0.36 and -0.37, respectively) and distance from the dam (r = -0.42 and -0.36, respectively) and corresponded well with the CCA results (Figure 14). Juvenile smallmouth bass were also positively correlated with mean Secchi depth (r = 0.33), variance of Secchi depth (r = 0.41), shoreline slope (r = 0.32), and fallen timber (r = 0.51), but negatively with variance of water temperature (r = -0.39). Adult smallmouth bass were positively correlated with mean water temperature (r = 0.39) and variance of dissolved oxygen (r = 0.44). No significant correlations were found for juvenile spotted bass, but adult spotted bass were positively correlated with mean water temperature (r = 0.44), variance of dissolved oxygen (r = 0.39), shoreline slope (r = 0.51), bedrock (r = 0.37), and standing timber (r = 0.37), but negatively with shrubs (r = -0.34). The first two axes of the CCA explained 74.4% of the variation in the density-habitat relation and the results of the randomization tests were significant for the first (P < 0.01) and all combined axes (P < 0.01).

In fall 1999, no significant correlations were found for juvenile largemouth bass, juvenile spotted bass, or adult spotted bass and is consistent with the clustering of these sizes and species around the origin of the CCA diagram (Figure 15). Adult largemouth bass were positively correlated with standing timber (r = 0.42) and

negatively correlated with shrubs (r = -0.36). Juvenile smallmouth bass were positively correlated with distance to the main river channel (r = 0.33) and rip-rap (r = 0.50). Adult smallmouth bass were correlated with the longitudinal water quality variables: positively with mean Secchi depth (r = 0.36), variance of Secchi depth (r = 0.37), mean water temperature (r = 0.34) and negatively with mean dissolved oxygen (r = -0.35) and distance from the dam (r = -0.34; Figure 15). The first two axes of the CCA explained 65.2% of the variation in the density-habitat relation and the results of the randomization tests were significant for the first (P < 0.01) and all combined axes (P < 0.01).

DISCUSSION

Prey Use

We found evidence for niche segregation among the two size classes of the three black bass species in Skiatook Lake by prey type, although the magnitude of the differences was reduced by the end of the study. Both size classes of largemouth bass were mainly piscivorous, although juveniles in spring often consumed insects (mostly dipterans) and adults consumed more crayfish from 1997 to 1999. Smallmouth bass diets varied the most, changing from insects to fish and crayfish over time. Spotted bass mainly consumed crayfish during the three-year study. The reason for the diet changes in adult largemouth bass and both sizes of smallmouth bass are unclear. One speculation is that since smallmouth bass densities have increased, a competitive "crunch" for prey may have occurred, allowing for a concomitant increase in prey overlap. Although we found no evidence for a significant increase in prey overlap, there is evidence that a competitive "crunch" has occurred. Long and Fisher (in press) found an increase in prey overlap for the size classes and species of black bass in Skiatook Lake as well as evidence of an apparent declining abundance of the major forage fish species. Additionally, relative weights for smallmouth bass and spotted bass declined over the study period, which supports this hypothesis (Chapter II of this report). Regardless, the proportion of fish and crayfish in the diets of all three species seems to be increasing. However, smallmouth bass, whose diet changed the most over the study period, has been reported to be very plastic in regards to prey use, changing diets in response to a changing prey base (Coble 1975; Scott and Angermeier 1998). Therefore, changes in diet overlap may be due to changes in the composition of the prey base rather than an indicator of increasing competition.

The use of reduced (i.e., four) prey categories versus expanded (i.e., 13 and 14) prey categories did not alter the basic results of the prey overlap analyses. However, Long and Fisher (in press) found that prey overlap did increase between spring 1997 and spring 1999 with nearly identical size categories of black bass in this lake. In the present study, we also included fall 1999 in the analysis which obviously affected the results. However, the pairwise comparisons for the ANOVA still indicated a difference between spring 1997 and 1999 (P = 0.04) although the overall ANOVA did not. These results were exactly the same for the analysis using the reduced prey categories: the pairwise comparisons showed a difference between spring 1997 and spring 1999 (P = 0.05) even though the overall ANOVA did not. Therefore, it seems that reducing the number of prey categories for these sizes and species of black bass did not affect the results of this study. Additionally, reducing the number of prey categories, which is often done by others (Aggus 1972; Lewis 1976; Farquhar and Whiteside 1995),

facilitated interpretation of results. Also, the reduced prey categories allowed for a more conservative analysis, making it harder to find significance, although it did inflate the overlap values. For example, with the randomization tests for the spring 1997 comparisons, we found that mean prey overlap among all sizes and species was not significant with the reduced prey categories, but was significantly greater than random with the expanded prey categories. The use of the randomization tests put these values in context and made the absolute values less meaningful. Although the Chi-square and the Fisher's exact tests always showed prey segregation, the CCA analysis showed spring 1997 to be the year and season with greatest segregation of prey use using expanded prey categories. Furthermore, the overlap results with reduced prey categories actually agreed better with the increased prey segregation observed in spring 1997 with the CCA than did the overlap results with expanded prey categories.

Habitat Use

There could be biases in relationships between black bass density and habitat because we used habitat variables measured in fall 1999 and spring 2000 to evaluate relationships in all years of the study. The rationale for this approach was that it represented the spatial properties of those variables better than measurements made concurrently with the fish sampling. For example, since black bass sampling was conducted over 2 months, one measurement of dissolved oxygen might be 8 mg/L and another measurement 50 meters away taken 2 months later might be 5 mg/L. Measurements taken in such a manner are confounding because they incorporate a temporal component that increases variability. Therefore, we measured water quality after the black bass sampling period to more accurately describe the spatial variation in the reservoir. My assumption was that the spatial arrangement of the water quality did not vary over the three year study period. The physical features (e.g., substrate types, structure types, distance from the dam, distance to the river channel, and slope) do not change appreciably over time, but the water quality characteristics (e.g., Secchi depth, temperature, dissolved oxygen, and conductivity) do. To verify this assumption, we used a two-way ANOVA to test for differences in water quality variables measured concurrently with fish sampling (e.g., surface water temperature, conductivity, and dissolved oxygen) among years and strata for each season. A non-significant interaction would show that the spatial arrangement of that variable was constant over the three year study period. There was not a significant interaction for water temperature in spring ($P = 0.91$) or for dissolved oxygen in fall ($P = 0.08$) and spring ($P > 0.05$). However, there was a significant interaction for conductivity in both seasons ($P < 0.01$ in spring and fall) and for water temperature in fall ($P < 0.01$). Therefore, the assumption of similar spatial arrangement of water quality variables is verified for dissolved oxygen and for water temperature in spring, but not for conductivity or for water temperature in fall and will affect the results of relationships with black bass density. However, many water quality variables that were measured concurrently with fish sampling were done so on only one or two days out of an entire month or two and do not represent a true mean for that season, and therefore do not adequately characterize the spatial arrangement within the reservoir.

We found no consistent pattern between largemouth bass density, as juveniles or adults, and habitat. Only in spring 1999 were any significant correlations found for juveniles, which was for distance to the main river channel and two cover types

(standing timber and shrub). Adult largemouth bass tended to be related to distance to main river channel in 1997 and in spring 1999. In fall 1998 and after, adult largemouth bass was often associated with cover and substrate variables. The variables that both size classes were related to were most closely associated with principal components 2 and 3, mainly indicators of substrate and cover, in both fall and spring samples. The lack of good correspondence between this species and the available habitat suggests that it is a habitat generalist in Skiatook Lake.

Smallmouth bass was the most specialized species in terms of habitat. Juveniles and adults were consistently and positively associated with mean Secchi depth and negatively with distance from the dam regardless of season, indicating that they were always more abundant in the lower-end (Chapter II of this report). These two size classes were also consistently associated with mean dissolved oxygen, but in opposite directions depending on season. In fall, they were negatively associated with mean dissolved oxygen, whereas in spring they were positively associated. These results only make logical sense when the spatial arrangement of this variable is taken into account. In fall, the highest mean dissolved oxygen levels are found in the upper-end of the reservoir and in spring the lower-end. These results also confirm that the distribution of this species is limited to the lower-end, indicating that it is a habitat-specialist in Skiatook Lake. Additionally, the variables that this species distribution is most often associated with are those variables that have the highest loadings on the first principal component axis in fall and spring. Thus, the distribution of this species is highly associated with these water quality characteristics that were most variable, which suggests that the distribution of this species in Skiatook Lake is influenced more by macro- or mesohabitat than by microhabitat. Although no studies have examined habitat use on a large scale with smallmouth bass, Noble et al. (1994) discussed their studies with largemouth bass in B.E. Jordan Lake, North Carolina and Lago Lucchetti, Puerto Rico and have shown that they respond to the spatial heterogeneity inherent in reservoirs on several spatial scales from small scale (i.e., microhabitat) to large scale (i.e., whole reservoir).

Associations between spotted bass density and habitat were variable among years and seasons. Juvenile spotted bass typically exhibited low correlations with habitat variables, and no clear relations were evident in fall 1997 and 1998 and spring 1999. Significant correlations were usually with a substrate or cover variable. Adults were usually correlated with those large scale variables (e.g., principal component 1 variables) that smallmouth bass were correlated with, and usually in similar fashion. However, shoreline slope often accounted for the greatest amount of variation in adult spotted bass density in fall samples. In contrast, few habitat variables were significant with spring fish density and those variables that were significant were often different from those variables associated with smallmouth bass density. The variables that this species associated with in fall were those variables associated with principal component 1 and 2. In Chapter II of this report, we found that spotted bass in Skiatook Lake alternated its distribution depending on season. In spring, it was more abundant in the upper-end of the reservoir, but in fall it was more abundant in the mid- and lower-end. In fall, spotted bass and smallmouth bass were associated with similar variables, but slope tended to account for more variation in the density of spotted bass than the water quality variables. Thus, slope may be a segregating factor operating at the meso- or microhabitat scale in areas where the two species are sympatric.

These results are similar to other studies that have examined habitat use among all three species in reservoirs. Jenkins (1975) reported on correlations on standing crop among fish communities in reservoirs and noted that largemouth bass were positively associated with spotted bass, but negatively associated with smallmouth bass. Additionally, smallmouth bass were negatively associated with spotted bass and he suggested that these correlations could be an indicator of similarities in habitat preferences. Buynak et al. (1989) showed that these three black bass responded to a longitudinal gradient in Cave Run Lake, Kentucky with largemouth bass more abundant in the upper lake area, smallmouth bass more abundant in the lower lake area, and spotted bass more abundant in the middle and lower lake areas.

Conclusions

Other researchers have found that black bass segregate habitat over prey resources (Janssen 1992; Scott and Angermeier 1998). In Skiatook Lake, prey overlap increased from 1997 to 1999 as did total black bass density. We were unable to directly calculate habitat overlap since the sampling design was based on sampling sites as the experimental unit rather than on individual fish as the experimental unit. Thus, conventional methods for calculating habitat overlap were unusable and more indirect approaches (i.e., correlation and multivariate analyses) were warranted. Except for juvenile largemouth bass in spring and juvenile smallmouth bass and adult spotted bass in fall, the number of significant correlations between habitat and density were relatively constant, indicating a fixed level of habitat segregation throughout the study period.

The number of significant correlations between habitat and density of juvenile largemouth bass increased from 0 in spring 1997 and 1998 to 3 in spring 1999, indicating an increase in habitat preference. This could possibly be due to an increase in total black bass abundance, resulting in an increase in potential competition, and a concomitant increase in the use of more suitable habitat (Werner 1977; Werner and Hall 1977). Increased overlap in prey use, coupled with an increase in habitat preference, is predicted by the niche compression hypothesis (MacArthur and Wilson 1967; cited in Pianka 1994) and corresponds with the data for juvenile largemouth bass in Skiatook Lake during this study period.

The decrease in the number of significant correlations between habitat and density of juvenile smallmouth bass and adult spotted bass in fall over the study period indicates a decrease in habitat preference for both these sizes and species. Since fall was when spotted bass density was greatest in the lower-lake and that area is where smallmouth bass were restricted, and since total black bass density had increased from 1997 to 1999, we hypothesize that the decrease in habitat preference was in accordance to the expanding population hypothesis (Pianka 1994). This hypothesis predicts that a population whose abundance is increasing would utilize a larger variety of resources and thus decrease specialization. Although this hypothesis is usually applied intraspecifically, we believe that it is still applicable for this interspecific example given the inter-relatedness of these two species and the similarity in habitat use by these two sizes and species in Skiatook Lake during this study period.

With the two exceptions noted above, habitat use by these two sizes of black bass species in Skiatook Lake over the three year study period remained relatively constant despite an increasing similarity in prey use. This would indicate that prey use by these species is very plastic and that habitat was the greater niche segregating

factor for these populations in Skiatook Lake. Additionally, spotted bass in this reservoir seem to use time (seasons) as a segregating factor. Furthermore, relative weights have declined over the study period and could indicate that the increase in prey overlap had a negative, competitive, impact on these species. We are unaware of any studies on these species that have examined resource use on a temporal scale and we recommend that these issues be considered whenever changes in abundances occur.

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Table 1.--Summary statistics of density (number of fish per hectare) of juvenile and adult largemouth bass, smallmouth bass, and spotted bass in spring samples in Skiatook Lake, Oklahoma. N = number of sampling sites.

		Largemouth Bass		Smallmouth Bass		Spotted Bass	
Year	N	Mean	SD	Mean	SD	Mean	SD
			Juvenile				
1997	45	1.23	2.51	1.12	2.82	3.96	7.55
1998	35	2.60	3.62	2.42	3.90	2.19	3.71
1999	40	1.90	2.96	1.15	3.11	1.21	2.11
			Adult				
1997	45	2.67	5.38	2.29	4.89	14.92	21.92
1998	35	3.52	5.24	3.00	4.44	5.80	6.99
1999	40	3.09	6.05	6.59	10.47	8.15	8.87

Table 2.--Summary statistics of density (number of fish per hectare) of juvenile and adult largemouth bass, smallmouth bass, and spotted bass in fall samples in Skiatook Lake, Oklahoma. N = number of sampling sites.

		Largemouth Bass		Smallmouth Bass		Spotted Bass	
Year	N	Mean	SD	Mean	SD	Mean	SD
				Juvenile			
1997	22	3.89	3.78	6.79	12.68	3.09	6.85
1998	40	0.68	1.61	1.13	2.58	1.42	3.40
1999	37	2.79	3.65	0.85	3.15	3.41	7.36
				Adult			
1997	22	3.43	6.27	5.37	10.67	7.58	7.65
1998	40	2.19	3.36	5.40	11.56	6.27	8.70
1999	37	2.91	4.60	1.03	2.28	3.87	6.26

Table 3.--Pianka's (1973) niche overlap values of prey use among juvenile (J) and adult (A) largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in spring 1997 - 1999 and fall 1998 - 1999 in Skiatook Lake, Oklahoma using reduced (4) prey categories. P-values are the probability that the mean niche overlap values could have occurred by chance.

	Spring			Fall	
Species Pairs	1997	1998	1999	1998	1999
ALMB-ASMB	0.75	0.86	0.90	0.93	0.88
ALMB-ASPB	0.43	0.66	0.78	0.51	0.91
ALMB-JLMB	0.84	0.94	0.98	0.99	0.90
ALMB-JSMB	0.81	0.45	0.63	0.94	0.90
ALMB-JSPB	0.38	0.68	0.93	0.99	0.94
ASMB-ASPB	0.60	0.77	0.95	0.78	0.99
ASMB-JLMB	0.96	0.86	0.90	0.92	0.66
ASMB-JSMB	0.91	0.73	0.73	0.91	0.63
ASMB-JSPB	0.89	0.88	0.93	0.91	0.74
ASPB-JLMB	0.43	0.50	0.74	0.48	0.69
ASPB-JSMB	0.75	0.43	0.55	0.48	0.67
ASPB-JSPB	0.47	0.72	0.78	0.47	0.77
JLMB-JSMB	0.83	0.67	0.76	0.98	0.99
JLMB-JSPB	0.79	0.78	0.97	0.98	0.99
JSMB-JSPB	0.68	0.93	0.86	0.93	0.98
Mean	0.70	0.72	0.83	0.81	0.84
P-value	0.05	0.07	< 0.01	< 0.01	< 0.01

Table 4.--Pianka's (1973) niche overlap values of prey use among juvenile (J) and adult (A) largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in spring 1997 - 1999 and fall 1998 - 1999 in Skiatook Lake, Oklahoma using expanded (13 in spring 1997 and fall 1999 and 14 in spring 1999) prey categories. P-values are the probability that the mean niche overlap values could have occurred by chance.

	Spring		Fall
Species Pairs	1997	1999	1999
ALMB-ASMB	0.68	0.84	0.75
ALMB-ASPB	0.40	0.72	0.91
ALMB-JLMB	0.69	0.95	0.73
ALMB-JSMB	0.70	0.62	0.40
ALMB-JSPB	0.46	0.80	0.71
ASMB-ASPB	0.53	0.95	0.93
ASMB-JLMB	0.61	0.77	0.44
ASMB-JSMB	0.71	0.59	0.30
ASMB-JSPB	0.67	0.79	0.56
ASPB-JLMB	0.24	0.62	0.52
ASPB-JSMB	0.64	0.42	0.29
ASPB-JSPB	0.39	0.65	0.58
JLMB-JSMB	0.69	0.70	0.81
JLMB-JSPB	0.69	0.88	0.96
JSMB-JSPB	0.80	0.63	0.84
Mean	0.59	0.73	0.65
P-value	< 0.01	< 0.01	< 0.01

Table 5.--Summary statistics of habitat variables used to correlate with density of juvenile and adult largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma in Spring.

Variable Name	Variable	Mean	SD	Min	Max
SECCHM	Mean Secchi depth (m)	0.61	0.25	0.18	0.92
SECCHV	Variance of Secchi depth (m)	0.03	0.03	0.01	0.10
TEMPM	Mean water temperature (°C)	18.27	0.67	17.27	19.45
TEMPV	Variance of water temperature (°C)	12.66	1.45	10.52	16.06
CONDM	Mean conductivity (mS/cm)	230.60	19.28	202.90	259.70
CONDV	Variance of conductivity (mS/cm)	3839.60	4172.50	316.30	12550.6
DOM	Mean dissolved oxygen (mg/L)	8.82	0.96	7.11	10.40
DOV	Variance of dissolved oxygen (mg/L)	3.84	1.93	0.89	7.24
SLOPE	Shoreline slope	21.19	11.30	2.42	43.69
RIVER	Distance to main river channel (m)	297.30	283.60	33.72	1123.30
DAM	Distance to dam	8045.90	4428.00	0.00	14928.10

Table 6.--Eigenvectors of the first four prinicpal components (PRIN 1-4) of habitat variables [1] in Spring 2000 in Skiatook Lake, Oklahoma. Explanation of continuous variable names are given in Table 5 .

Variable Name[2]	PRIN 1	PRIN 2	PRIN 3	PRIN 4
Eigenvalue	6.58	2.27	1.77	1.68
(percent of variation explained)	(32.9)	(11.3)	(8.9)	(8.4)
Water Quality				
SECCHM	-0.37	-0.01	0.01	-0.05
SECCHV	-0.05	0.39	0.05	-0.07
TEMPM	0.34	0.04	0.05	0.01
TEMPV	-0.17	-0.28	0.14	0.04
CONDM	0.34	0.06	-0.05	0.12
CONDV	0.34	-0.05	0.04	0.05
DOM	-0.38	-0.04	0.02	-0.07
DOV	0.33	0.22	-0.10	0.15
Physical				
SLOPE	-0.09	0.01	-0.03	0.55
RIVER	-0.11	0.41	0.11	-0.32
DAM	0.37	0.01	0.05	0.01
Substrate				
RIP-RAP	0.06	-0.17	0.63	0.14
BOULDER	-0.16	0.22	-0.41	0.27

Table 6.–Continued.

Variable Name[2]	PRIN 1	PRIN 2	PRIN 3	PRIN 4
Substrate				
COBBLE	0.08	-0.19	-0.07	-0.46
BEDROCK	0.07	0.03	-0.02	-0.09
Cover				
SHRUB	0.07	-0.30	-0.48	-0.26
STANDTIM	-0.05	0.56	0.04	0.01
VEG	-0.05	0.03	0.37	-0.13
FALLTIM	-0.14	-0.18	-0.04	0.38
GRAVEL	0.06	-0.01	0.06	-0.01

[1] NOCOVER = no cover present and SILT were left out of the analysis to allow for inclusion of the other cover and substrate variables as dummy variables.
[2] STANDTIM = standing timber, VEG = vegetation, and FALLTIM = fallen timber.

Table 7.--Summary statistics of habitat variables used to correlate with density of juvenile and adult largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma in Fall.

Variable Name	Variable	Mean	SD	Min	Max
SECCHM	Mean Secchi depth (m)	0.99	0.22	0.45	1.27
SECCHV	Variance of Secchi depth (m)	0.30	0.16	0.06	0.68
TEMPM	Mean water temperature (°C)	18.65	0.40	17.97	19.24
TEMPV	Variance of water temperature (°C)	11.78	1.72	9.46	14.60
CONDM	Mean conductivity (mS/cm)	212.00	9.10	200.60	236.80
CONDV	Variance of conductivity (mS/cm)	16.42	12.07	2.72	56.94
DOM	Mean dissolved oxygen (mg/L)	8.66	0.69	7.88	9.77
DOV	Variance of dissolved oxygen (mg/L)	0.85	0.33	0.32	1.58
SLOPE	Shoreline slope	20.40	10.12	2.36	41.23
RIVER	Distance to main river channel (m)	337.80	274.00	30.25	1179.20
DAM	Distance to dam	8447.80	4171.70	944.90	14531.90

Table 8.--Eigenvectors of the first four prinicpal components (PRIN 1-4) of habitat variables [1] in Fall 1999 in Skiatook Lake, Oklahoma. Explanation of continuous variable names are given in Table 7 .

Variable Name[2]	PRIN 1	PRIN 2	PRIN 3	PRIN 4
Eigenvalue	8.22	1.98	1.74	1.49
(percent of variation explained)	(41.1)	(9.9)	(8.7)	(7.5)
	Water Quality			
SECCHM	-0.33	0.12	0.01	-0.02
SECCHV	-0.31	-0.02	0.05	-0.08
TEMPM	-0.30	0.16	-0.01	0.05
TEMPV	0.32	0.03	0.02	-0.01
CONDM	0.31	-0.15	0.01	-0.03
CONDV	0.30	-0.16	-0.01	-0.03
DOM	0.34	-0.02	0.03	0.03
DOV	-0.26	0.13	-0.04	0.12
	Physical			
SLOPE	-0.14	0.10	0.46	-0.26
RIVER	-0.16	-0.33	-0.23	0.33
DAM	0.33	0.02	0.02	0.04
	Substrate			
RIP-RAP	0.12	-0.10	0.51	-0.01
BOULDER	0.08	0.17	-0.22	0.17

Table 8.–Continued.

Variable Name[2]	PRIN 1	PRIN 2	PRIN 3	PRIN 4
Substrate				
COBBLE	0.08	0.17	-0.22	0.17
BEDROCK	0.02	0.41	0.23	0.37
Cover				
SHRUB	0.10	0.46	-0.45	-0.17
STANDTIM	-0.15	-0.46	0.12	0.29
VEG	0.01	0.02	-0.01	0.23
FALLTIM	-0.08	0.05	0.18	-0.51
GRAVEL	-0.03	0.01	-0.04	0.18

[1] NOCOVER = no cover present and SILT were left out of the analysis to allow for inclusion of the other cover and substrate variables as dummy variables.
[2] STANDTIM = standing timber, VEG = vegetation, and FALLTIM = fallen timber.

FIGURE LEGENDS

Figure 1.--Map of Skiatook Lake, Oklahoma indicating Bull Creek, Hominy Creek, mid-lake, lower-lake strata, and the location of the dam.

Figure 2.--Digital elevation model (DEM) of Skiatook Lake used to estimate shoreline slope.

Figure 3.--Map of the 30 sites where Secchi depth, surface water temperature, conductivity, and dissolved oxygen were measured in Skiatook Lake in Fall 1999 and Spring 2000.

Figure 4.--Percent number of prey items found in the guts of juvenile (J) and adult (A) largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in Fall 1998 and 1999 and Spring 1997 - 1999 using reduced prey categories in Skiatook Lake.

Figure 5.--Canonical correspondence analysis (CCA) diagram of prey items found in the guts of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in Spring 1997 using expanded prey categories in Skiatook Lake. Open circles denote a size and species of black bass and closed circles denote a prey type.

Figure 6.--Canonical correspondence analysis (CCA) diagram of prey items found in the guts of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in Spring 1999 using expanded prey categories in Skiatook Lake. Open circles denote a size and species of black bass and closed circles denote a prey type.

Figure 7.--Canonical correspondence analysis (CCA) diagram of prey items found in the guts of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in Fall 1999 using expanded prey categories in Skiatook Lake. Open circles denote a size and species of black bass and closed circles denote a prey type.

Figure 8.--Maps of the surfaces produced for the means of Secchi depth, surface water temperature, conductivity, and dissolved oxygen in Skiatook Lake in Fall 1999 and Spring 2000. All maps are presented at the same scale. Darker areas represent higher values for the respective variables (See Table 5 and 7 for summary statistics).

Figure 9.--Maps of the surfaces produced for the variances of Secchi depth, surface water temperature, conductivity, and dissolved oxygen in Skiatook Lake in Fall 1999 and Spring 2000. All maps are presented at the same scale. Darker areas represent higher values for the respective variables (See Table 5 and 7 for summary statistics).

Figure 10.--Canonical correspondence analysis (CCA) diagram of density of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in relation to environmental variables in Spring 1997 in Skiatook Lake. Arrows represent continuous habitat variables, closed circles represent categorical habitat variables, and open circles represent a size and species of black bass.

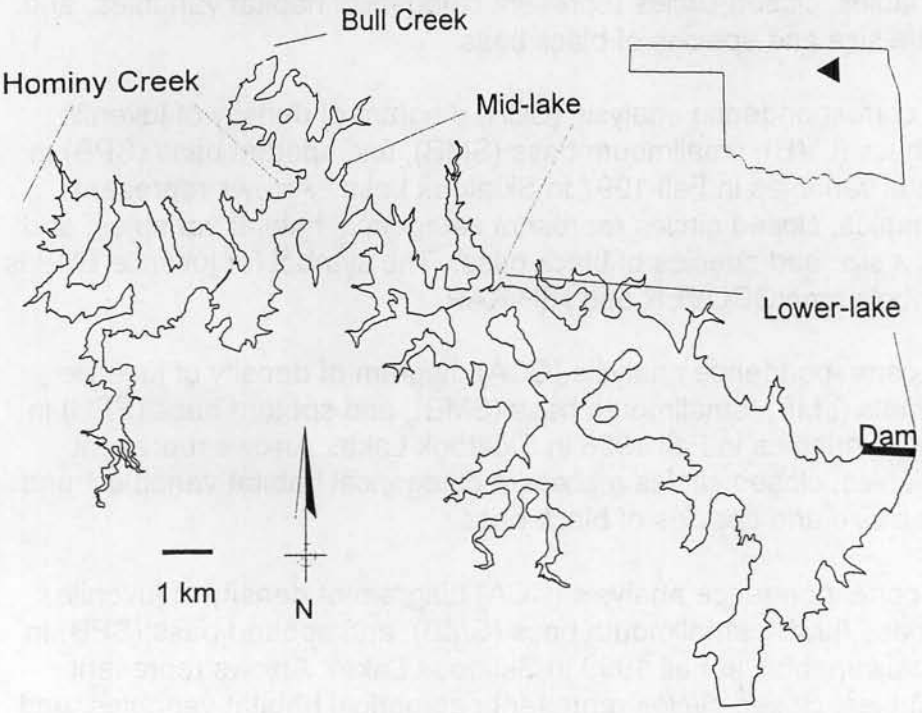
Figure 11.--Canonical correspondence analysis (CCA) diagram of density of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in relation to environmental variables in Spring 1998 in Skiatook Lake. Arrows represent continuous habitat variables, closed circles represent categorical habitat variables, and open circles represent a size and species of black bass.

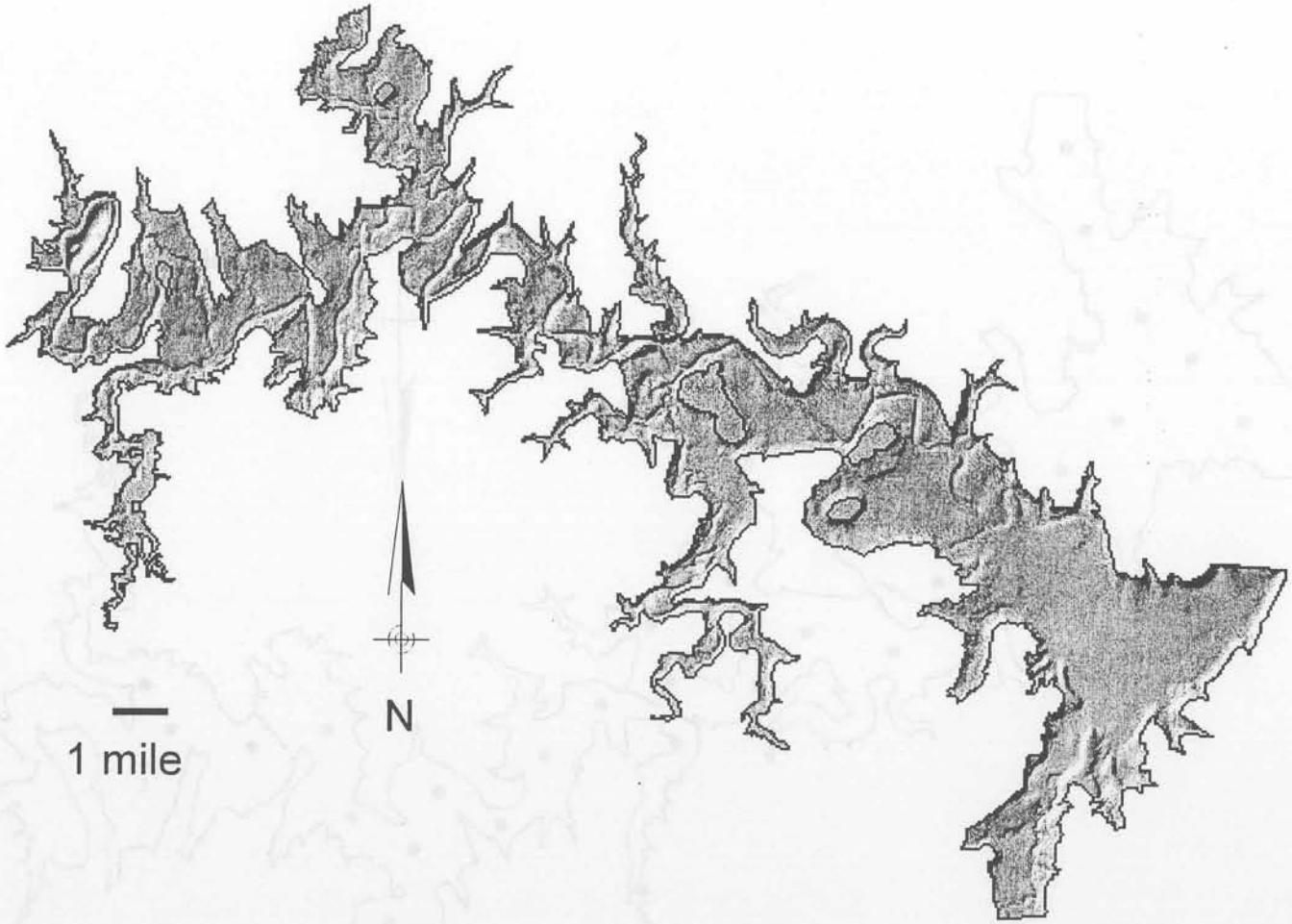
Figure 12.--Canonical correspondence analysis (CCA) diagram of density of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in relation to environmental variables in Spring 1999 in Skiatook Lake. Arrows represent continuous habitat variables, closed circles represent categorical habitat variables, and open circles represent a size and species of black bass.

Figure 13.--Canonical correspondence analysis (CCA) diagram of density of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in relation to environmental variables in Fall 1997 in Skiatook Lake. Arrows represent continuous habitat variables, closed circles represent categorical habitat variables, and open circles represent a size and species of black bass. The symbol for juvenile LMB is hidden behind the symbols for NOCOVER and RIP-RAP.

Figure 14.--Canonical correspondence analysis (CCA) diagram of density of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in relation to environmental variables in Fall 1998 in Skiatook Lake. Arrows represent continuous habitat variables, closed circles represent categorical habitat variables, and open circles represent a size and species of black bass.

Figure 15.--Canonical correspondence analysis (CCA) diagram of density of juvenile and adult largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPB) in relation to environmental variables in Fall 1999 in Skiatook Lake. Arrows represent continuous habitat variables, closed circles represent categorical habitat variables, and open circles represent a size and species of black bass.


Bull Creek
Hominy Creek
Mid-lake
Lower-lake
Dam
1 km
N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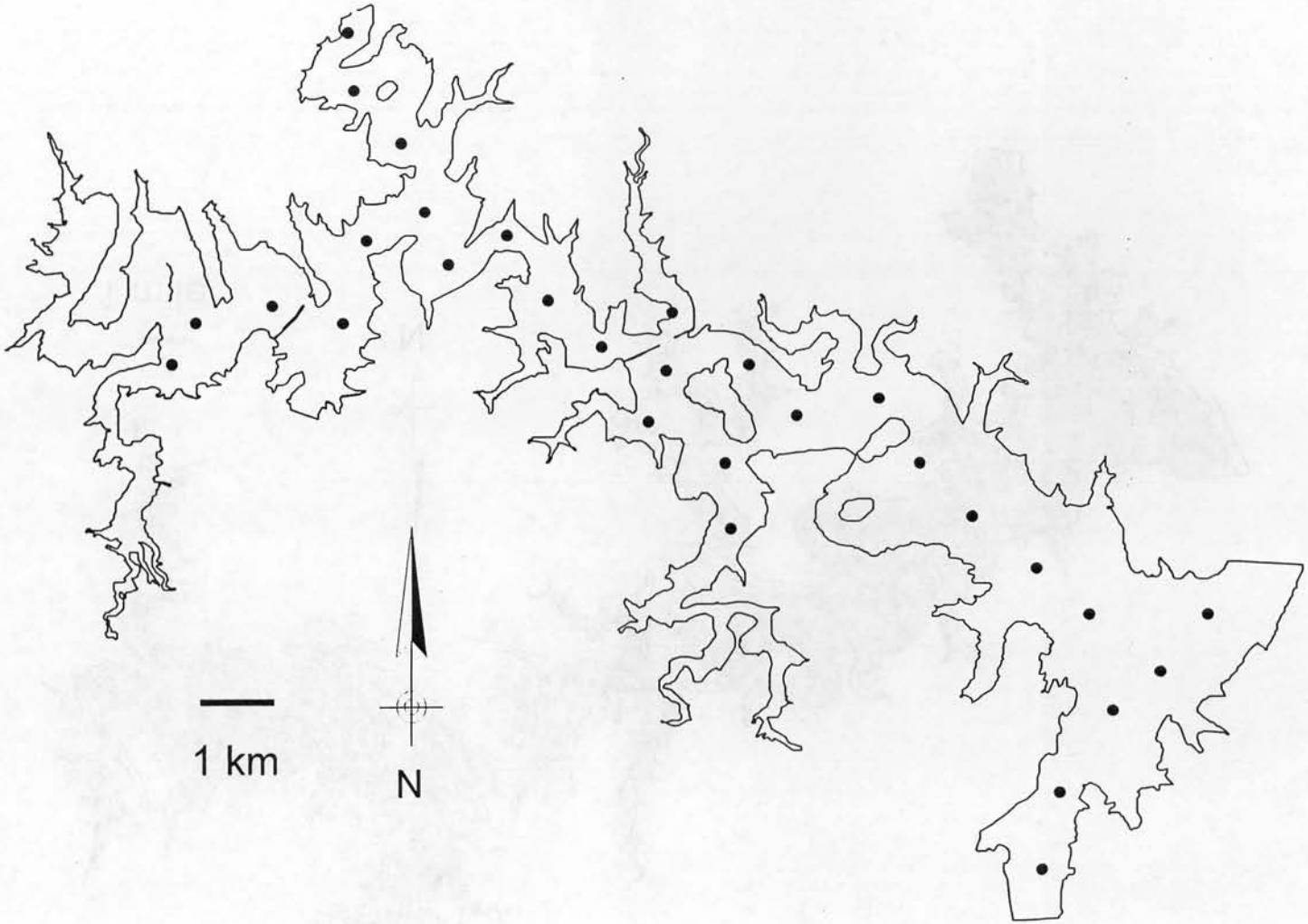
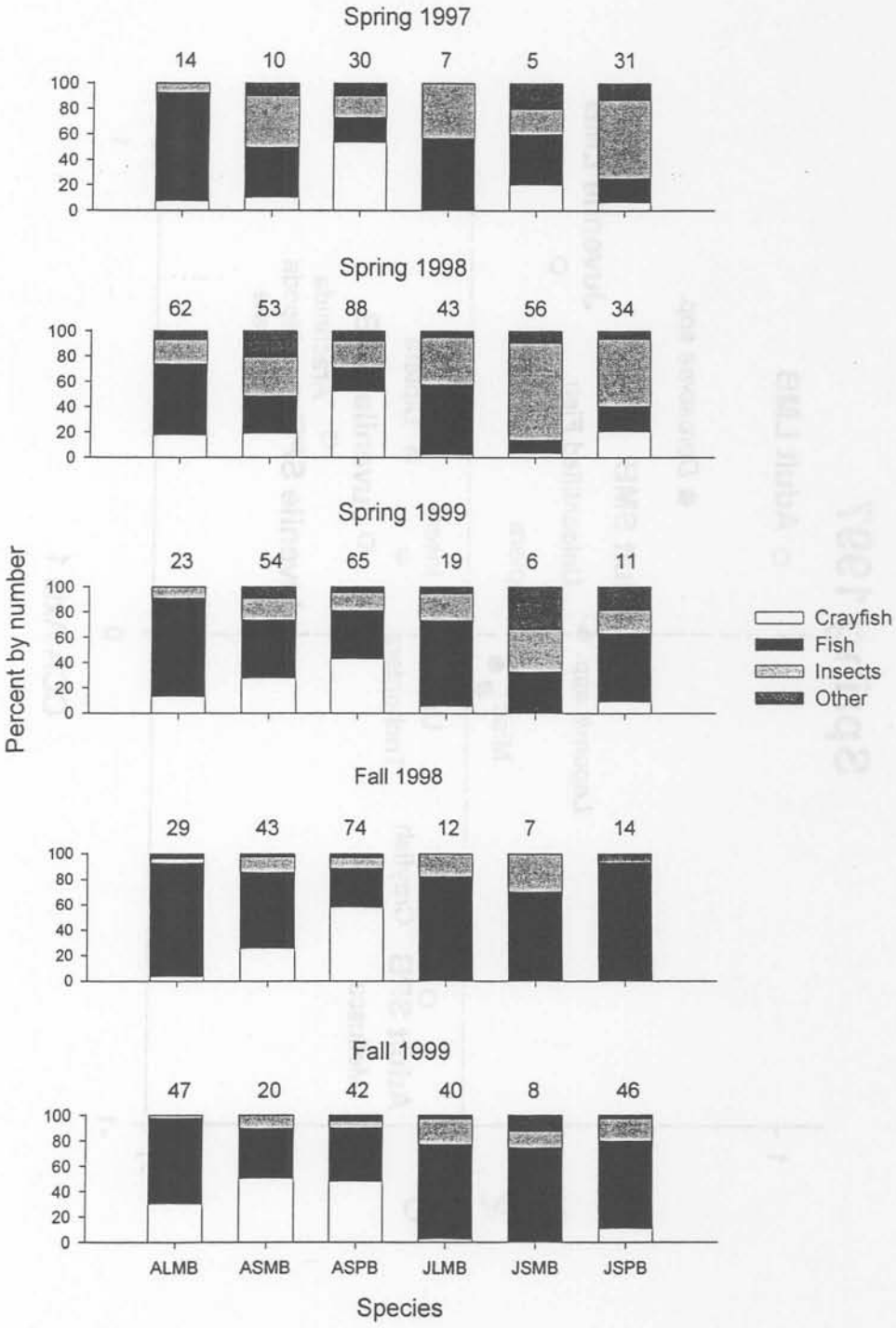
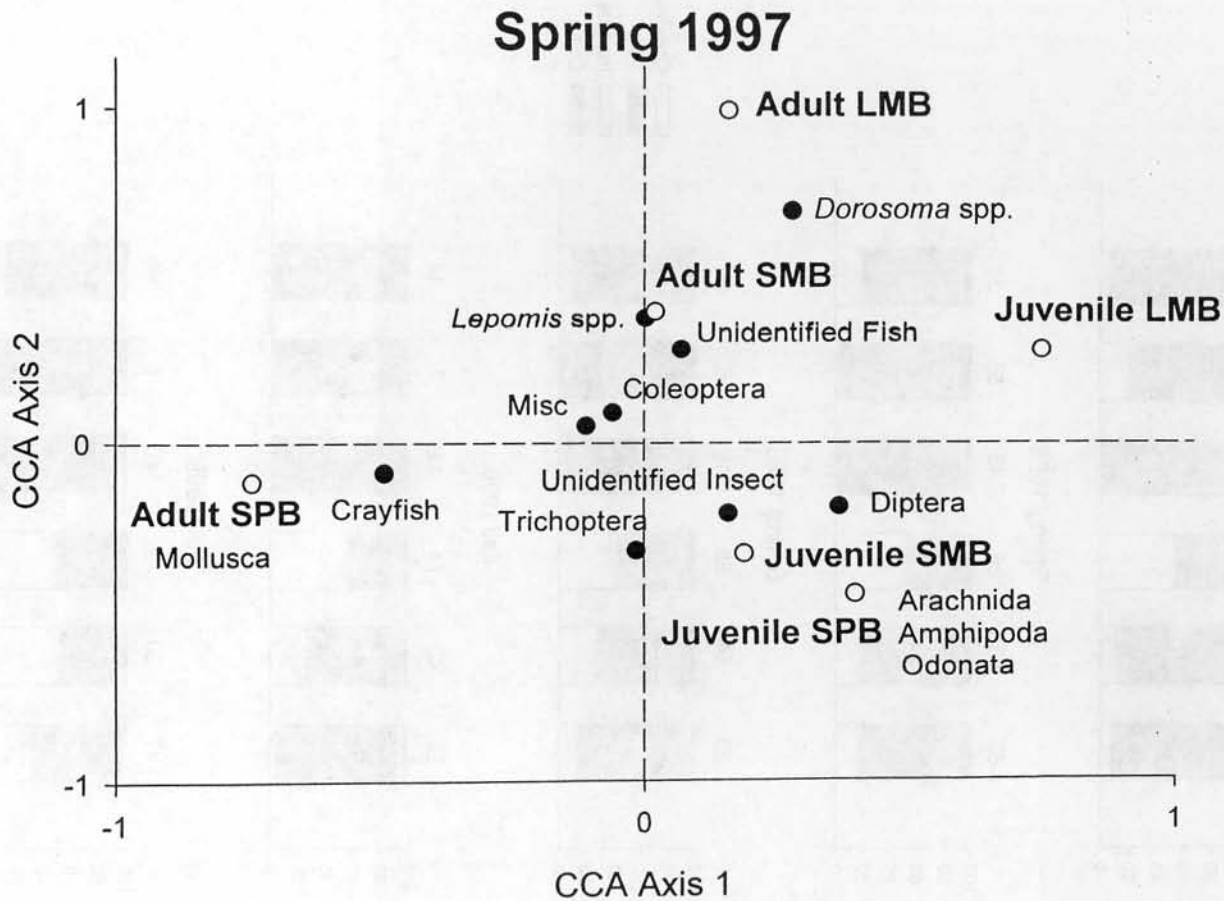
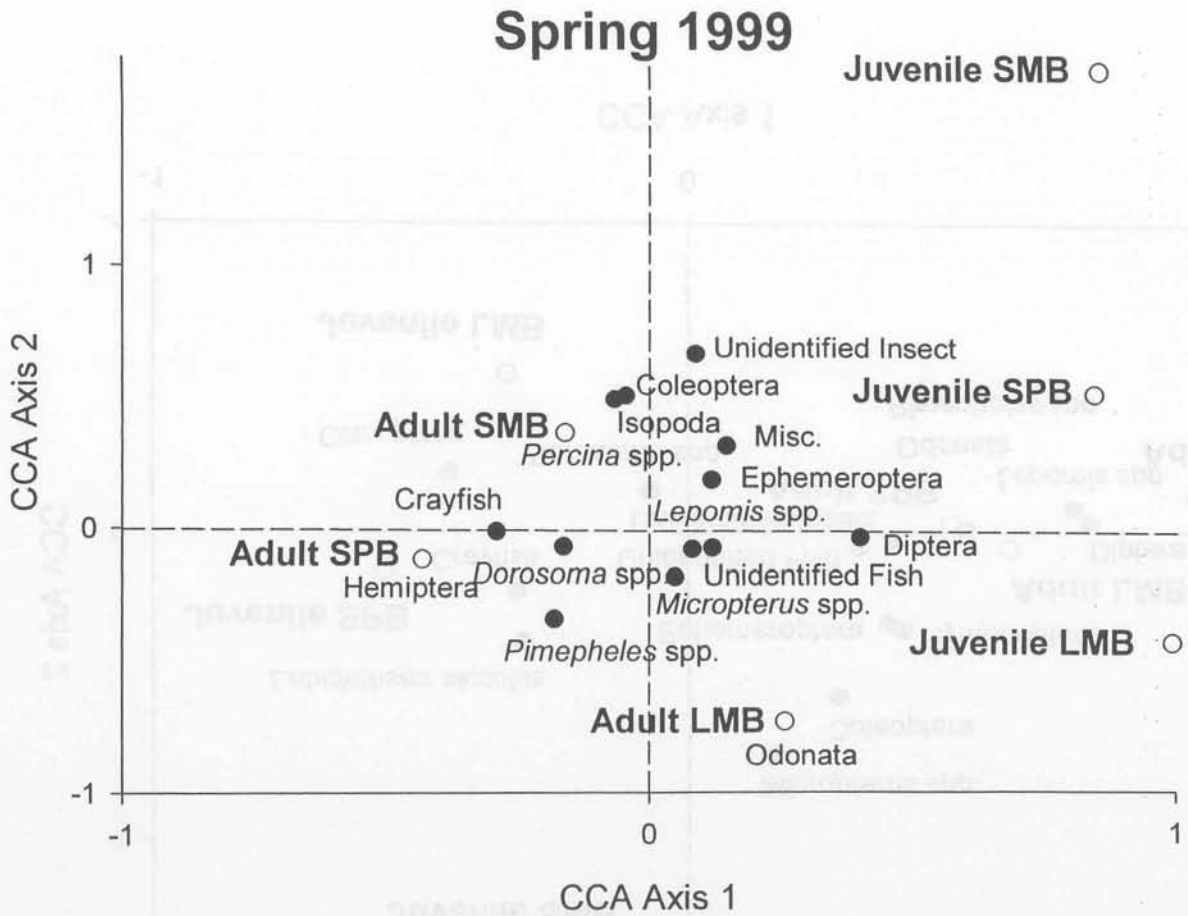
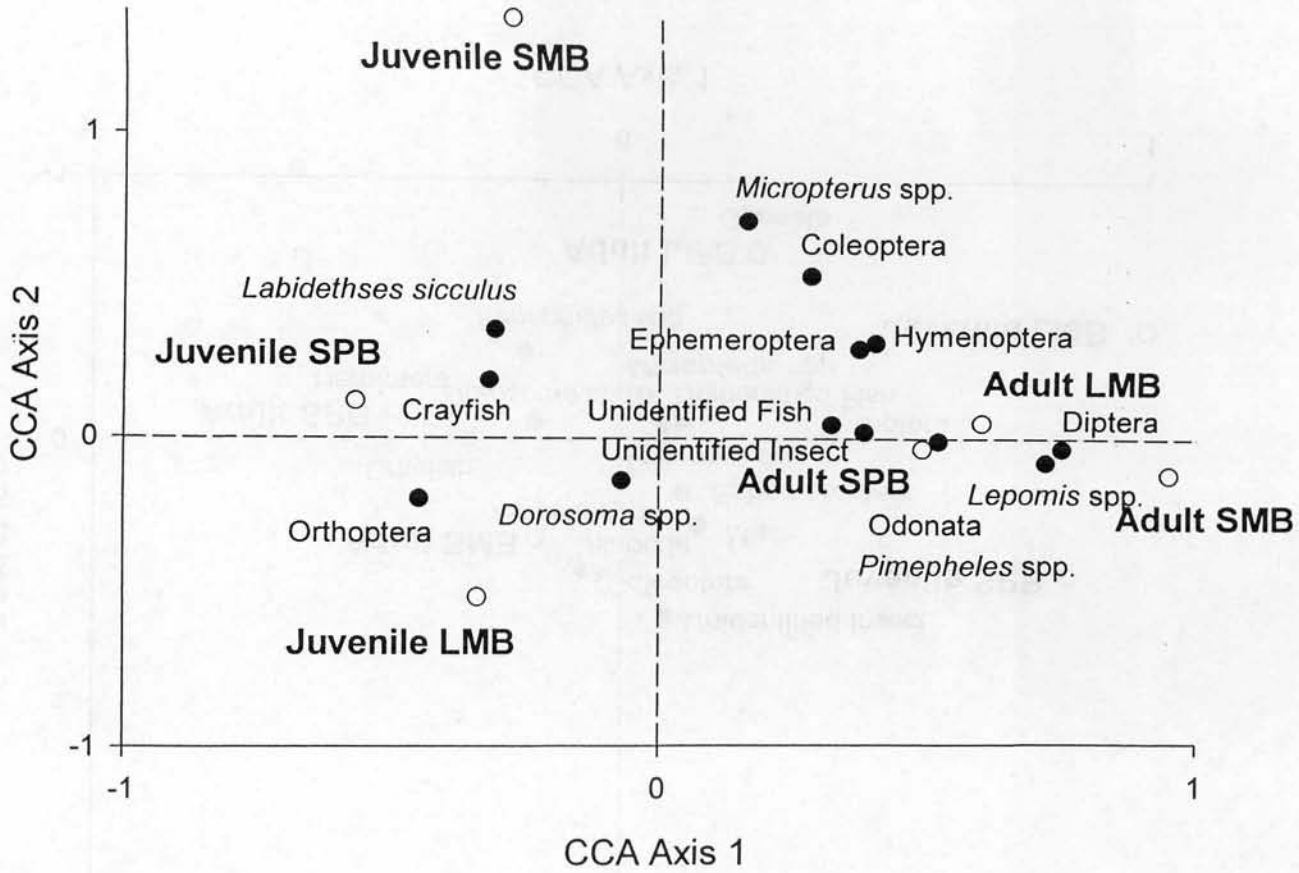

1 km
N


Spring 1997
14
10
30
7
5
31
Spring 1998
62
53
88
43
56
34
Spring 1999
23
54
65
19
6
11
Fall 1998
29
43
74
12
7
14
Fall 1999
47
20
42
40
8
46
100
80
60
40
20
0
Percent by number
Crayfish
Fish
Insects
Other
ALMB
ASMB
ASPB
JLMB
JSMB
JSPB
Species


Spring 1997
Adult LMB
Dorosoma spp.
Adult SMB
Lepomis spp.
Unidentified Fish
Juvenile LMB
Coleoptera
Misc
Unidentified Insect
Adult SPB
Crayfish
Trichoptera
Diptera
Mollusca
Juvenile SMB
Arachnida
Juvenile SPB
Amphipoda
Odonata
CCA Axis 2
CCA Axis 1
1
0
-1
-1
0
1

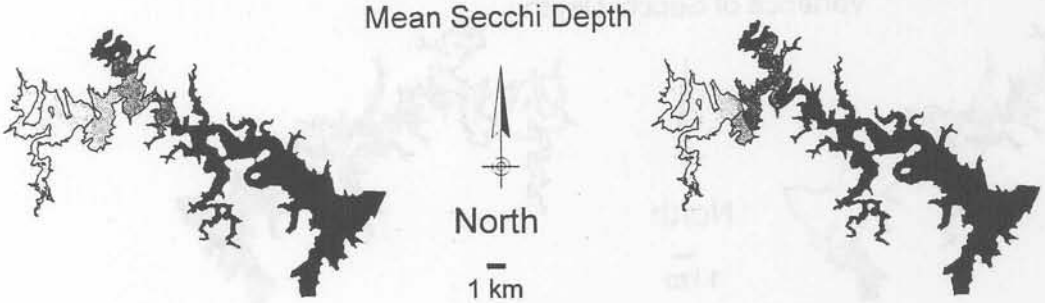

Spring 1999
Juvenile SMB
Unidentified Insect
Coleoptera
Juvenile SPB
Adult SMB
Isopoda
Misc.
Percina spp.
Ephemeroptera
Crayfish
Lepomis spp.
Adult SPB
Diptera
Dorosoma spp.
Unidentified Fish
Hemiptera
Micropterus spp.
Juvenile LMB
Pimepheles spp.
Adult LMB
Odonata
CCA Axis 2
CCA Axis 1
1
0
-1
-1
0
1

Fall 1999

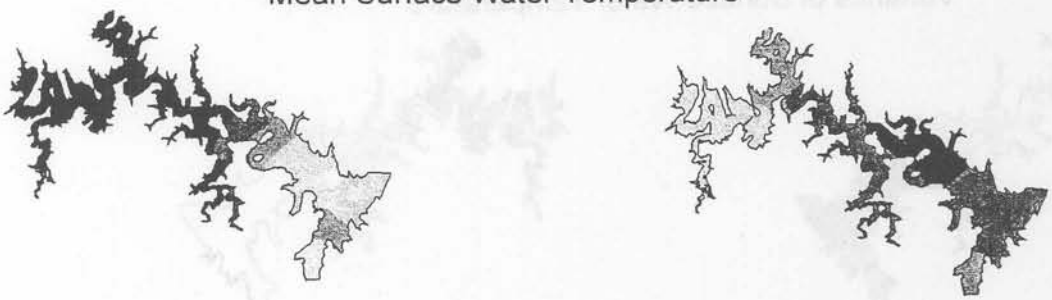

Juvenile SMB
Micropterus spp.
Coleoptera
Labidethses sicculus
Juvenile SPB
Ephemeroptera
Hymenoptera
Adult LMB
Crayfish
Unidentified Fish
Diptera
Unidentified Insect
Adult SPB
Lepomis spp.
Adult SMB
Orthoptera
Dorosoma spp.
Odonata
Pimepheles spp.
Juvenile LMB
CCA Axis 2
CCA Axis 1
1
0
-1
-1
0
1

Spring 2000 Fall 1999

Mean Secchi Depth

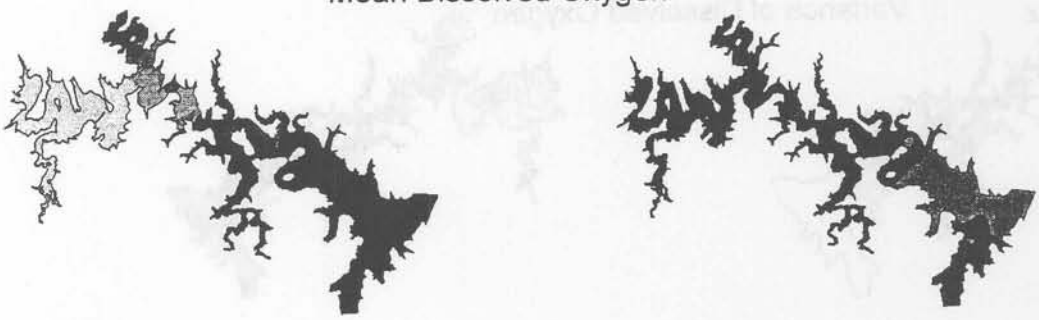


Mean Surface Water Temperature



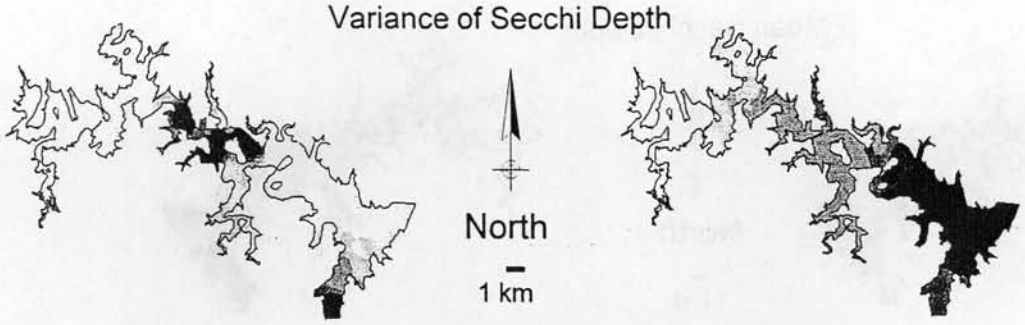
Mean Conductivity

Mean Dissolved Oxygen



Spring 2000 Fall 1999

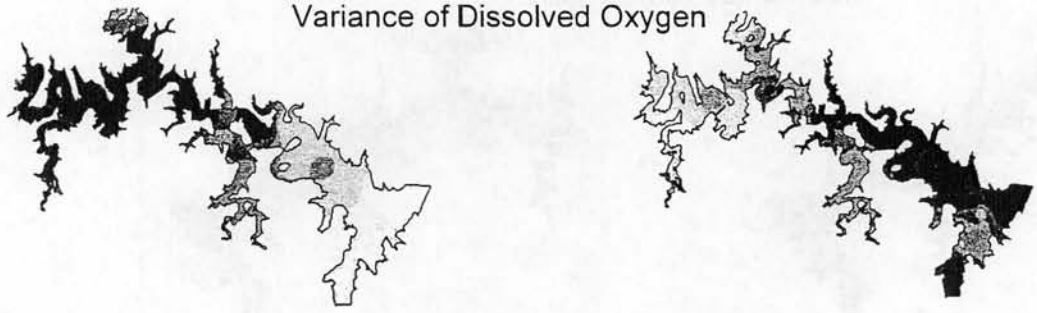
Variance of Secchi Depth



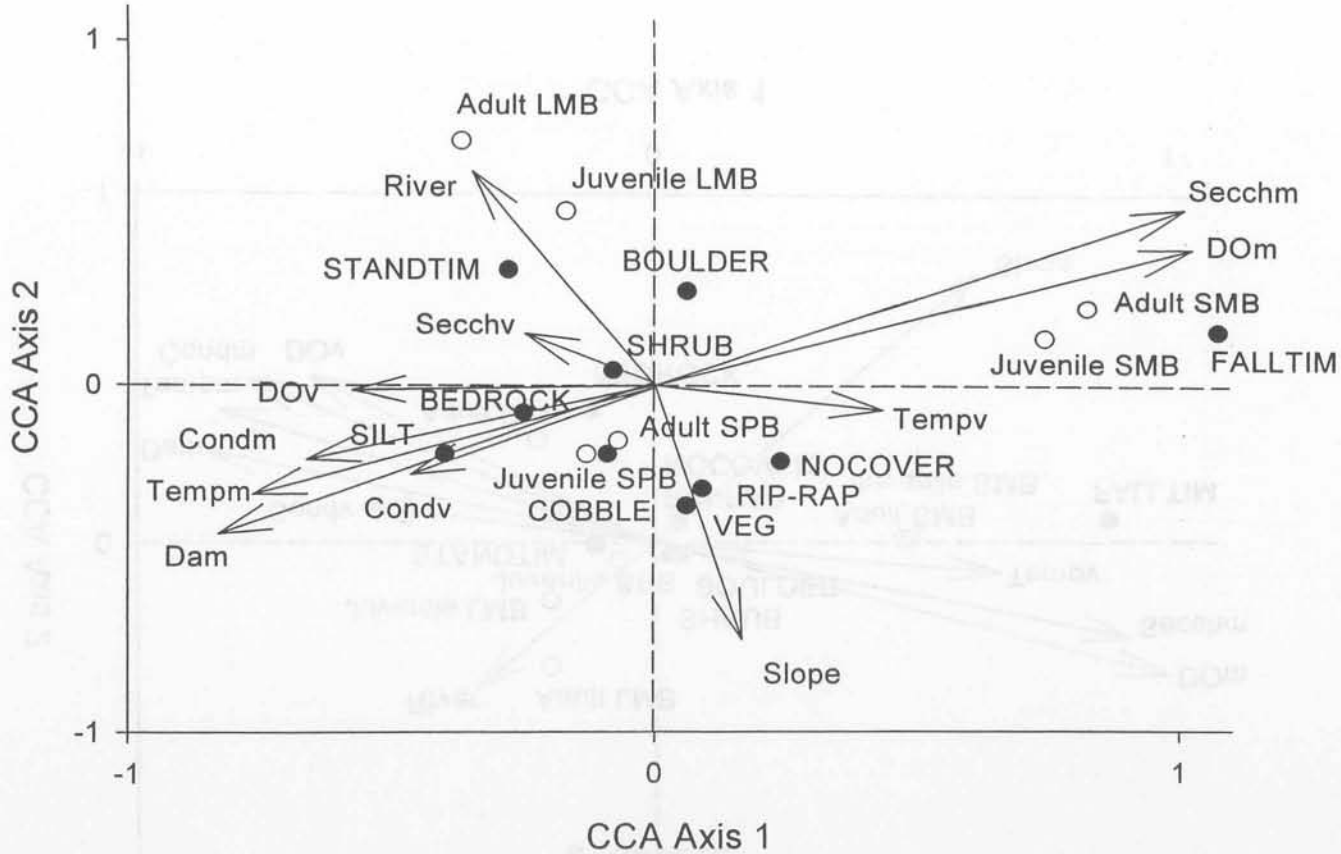
Variance of Surface Water Temperature

Variance of Conductivity

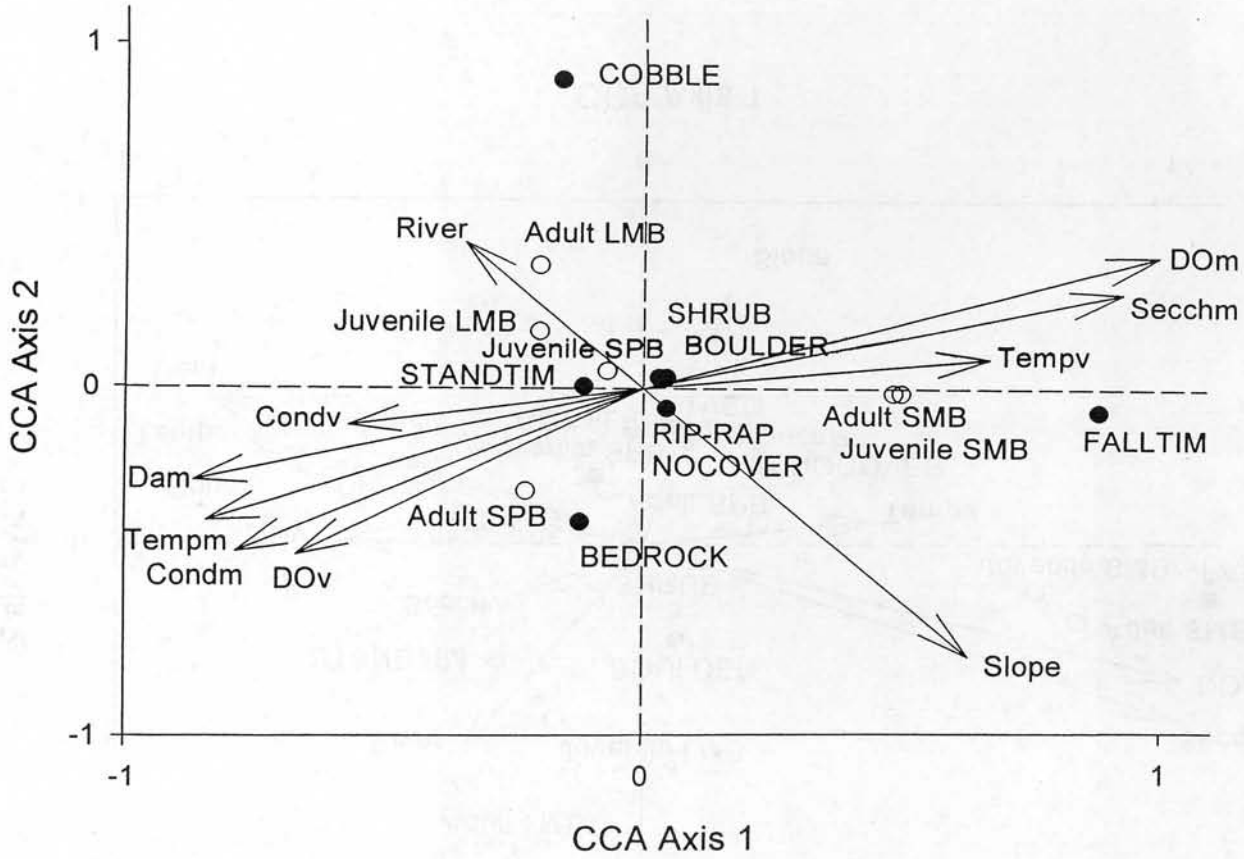
Variance of Dissolved Oxygen



Spring 1997


Adult LMB
River
Juvenile LMB
Secchm
DOm
STANDTIM
BOULDER
Adult SMB
Secchv
SHRUB
Juvenile SMB
FALLTIM
DOV
BEDROCK
Tempv
Condm
SILT
Adult SPB
NOCOVER
Juvenile SPB
Tempm
RIP-RAP
Condv
COBBLE
VEG
Dam
Slope
CCA Axis 2
CCA Axis 1
1
0
-1
-1
0
1

Spring 1998


COBBLE
River
Adult LMB
DOm
Secchm
Juvenile LMB
SHRUB
Juvenile SPB
BOULDER
Tempv
STANDTIM
Condv
Adult SMB
Juvenile SMB
FALLTIM
RIP-RAP
NOCOVER
Dam
Adult SPB
Tempm
Condm
DOv
BEDROCK
Slope
CCA Axis 2
CCA Axis 1
1
0
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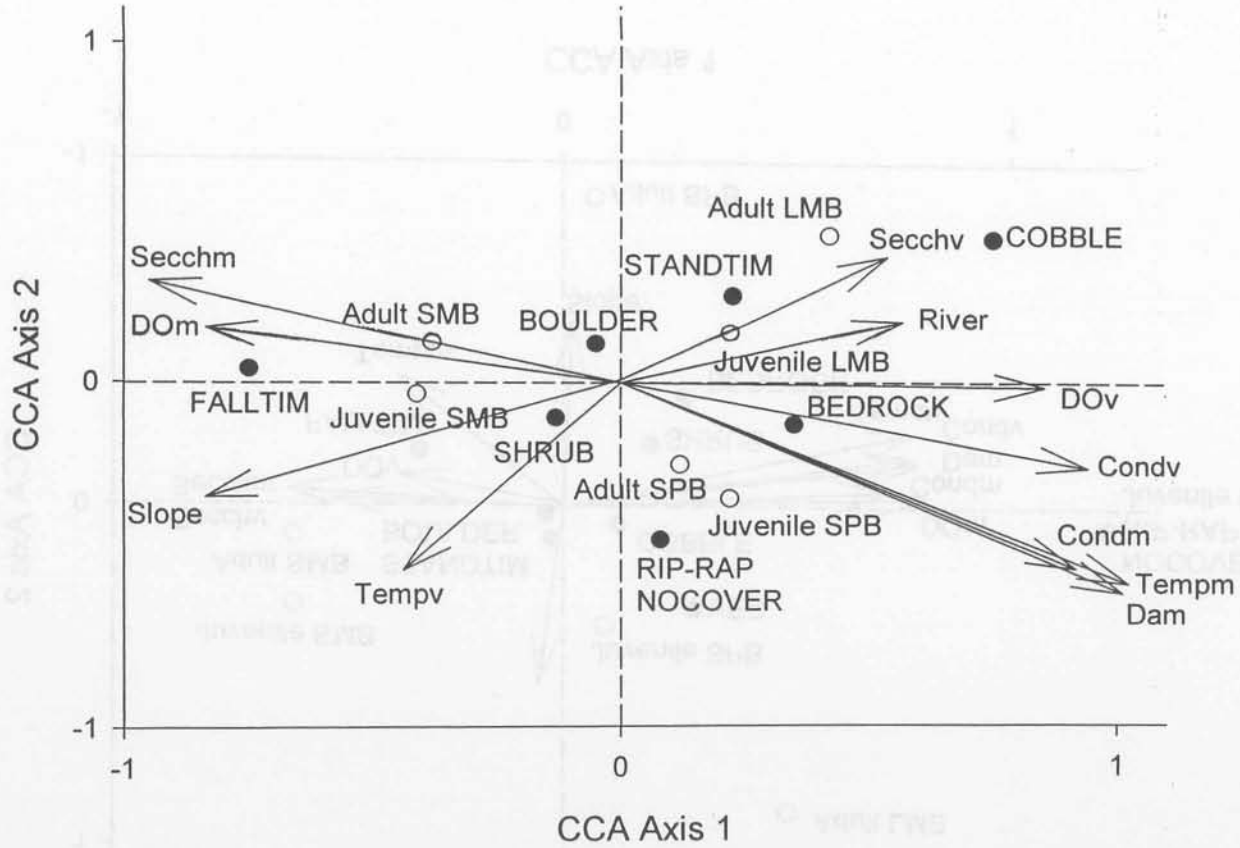
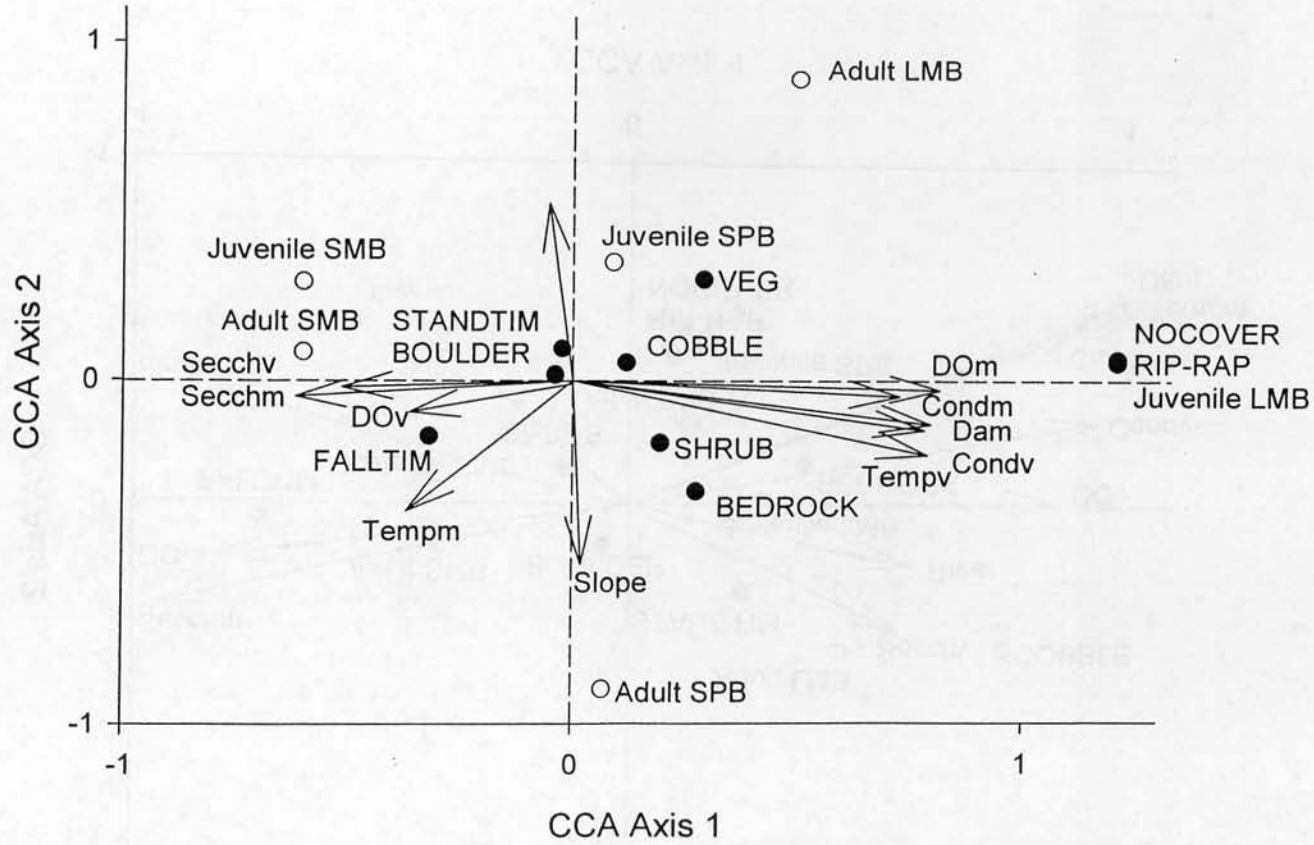
0
1

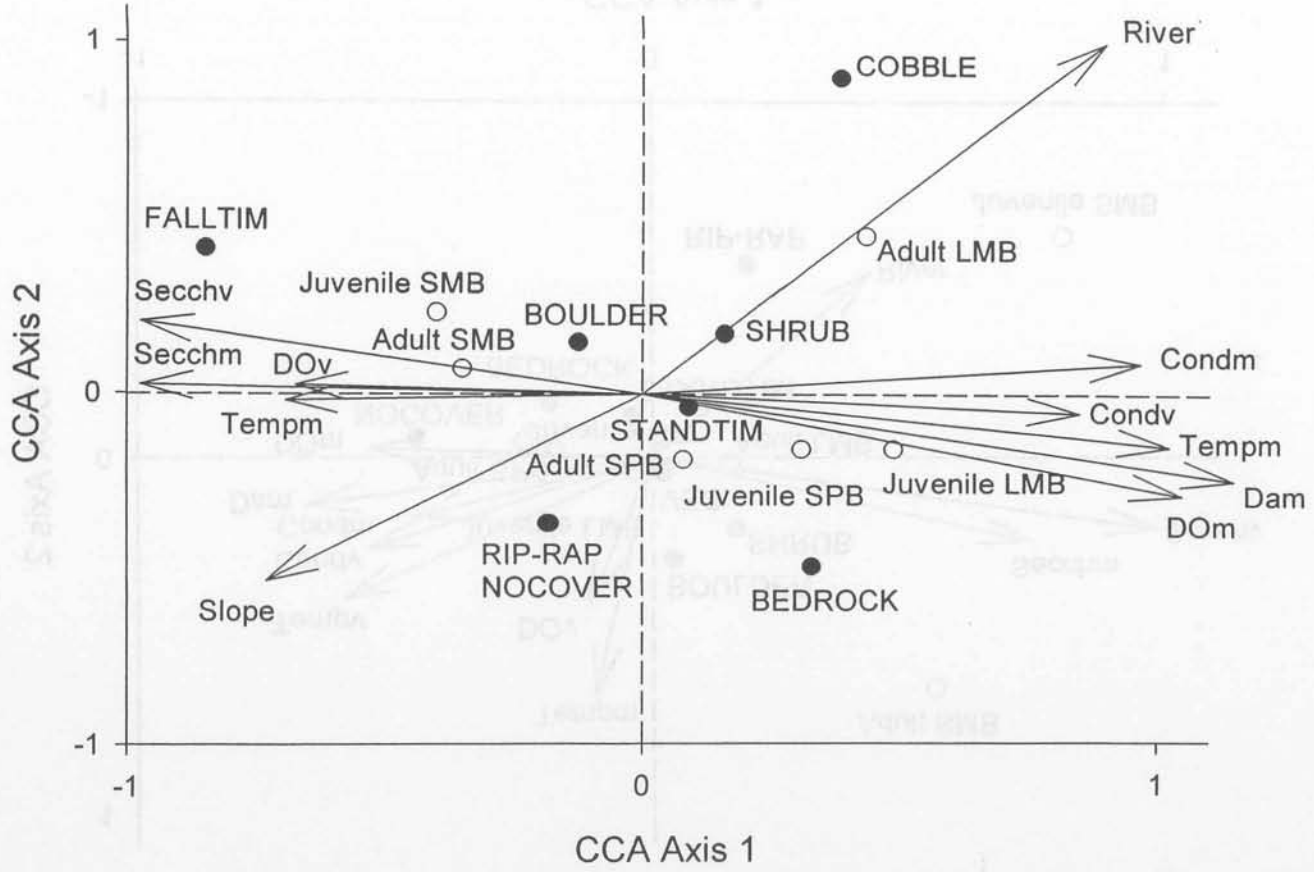
Spring 1999


Adult LMB
Secchv
COBBLE
Secchm
STANDTIM
DOm
Adult SMB
BOULDER
River
Juvenile LMB
FALLTIM
Juvenile SMB
BEDROCK
DOv
SHRUB
Condv
Adult SPB
Slope
Juvenile SPB
Condm
RIP-RAP
NOCOVER
Tempv
Tempm
Dam
1
0
-1
-1
0
1
CCA Axis 2
CCA Axis 1

Fall 1997


Adult LMB
Juvenile SMB
Juvenile SPB
VEG
Adult SMB
STANDTIM
BOULDER
COBBLE
NOCOVER
RIP-RAP
Juvenile LMB
Secchv
Secchm
DOm
Condm
Dam
Condv
Tempv
DOv
FALLTIM
SHRUB
BEDROCK
Tempm
Slope
Adult SPB
CCA Axis 2
CCA Axis 1
1
0
-1
-1
0
1

Fall 1998


River
COBBLE
FALLTIM
Adult LMB
Juvenile SMB
Secchv
BOULDER
SHRUB
Adult SMB
Secchm
DOv
Condm
Tempm
STANDTIM
Condv
Tempm
Adult SPB
Juvenile SPB
Juvenile LMB
Dam
DOm
RIP-RAP
NOCOVER
BEDROCK
Slope
CCA Axis 2
CCA Axis 1
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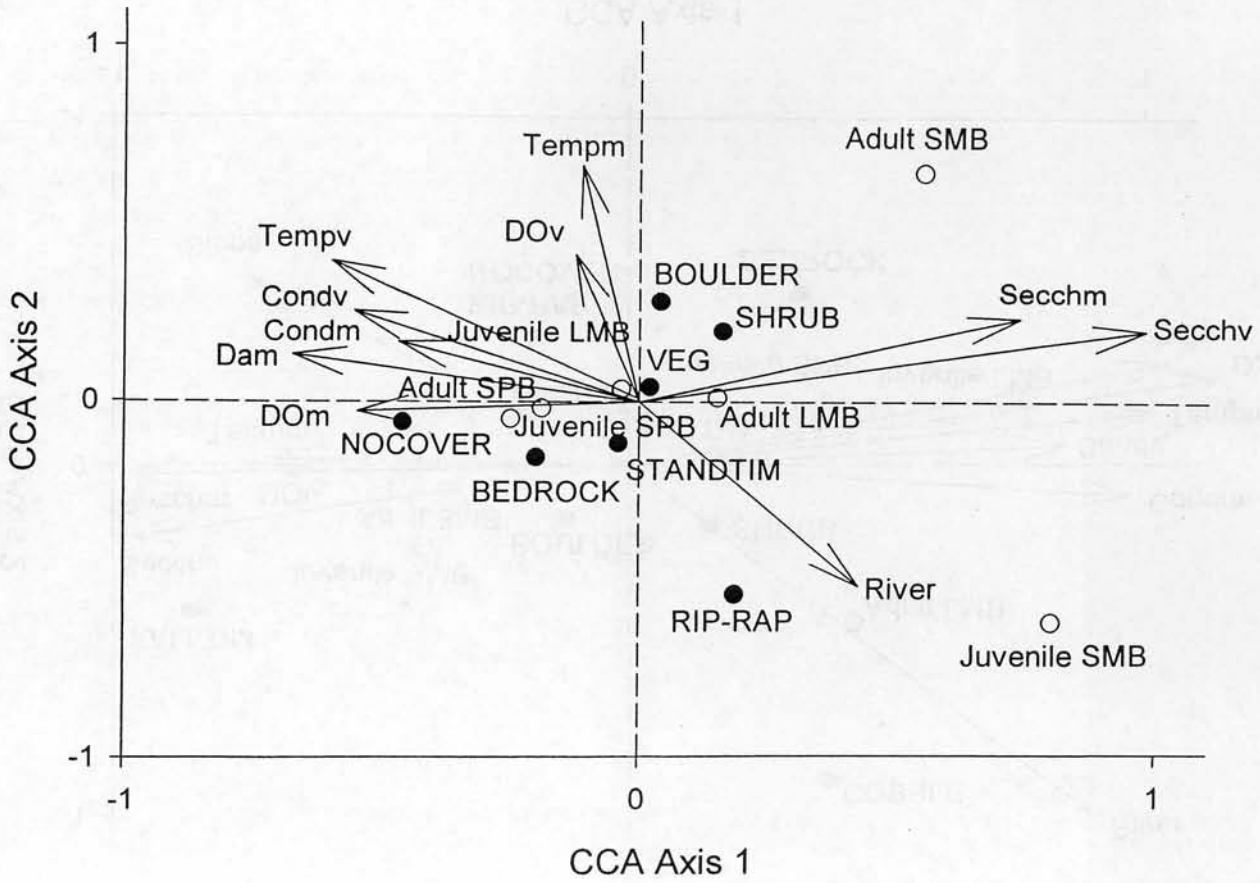
Fall 1999


Tempm
Adult SMB
Tempv
DOv
BOULDER
Condv
Secchm
SHRUB
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Secchv
Dam
VEG
Adult SPB
DOm
Juvenile SPB
Adult LMB
NOCOVER
STANDTIM
BEDROCK
River
RIP-RAP
Juvenile SMB
CCA Axis 2
CCA Axis 1
1
0
-1
-1
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1

CHAPTER IV

ENVIRONMENTAL INFLUENCES ON THE POPULATION DYNAMICS OF THREE BLACK BASS SPECIES IN SKIATOOK LAKE, OKLAHOMA

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Oklahoma Cooperative Fish and Wildlife Research Unit
Department of Zoology
Oklahoma State University
Stillwater, Oklahoma 74078

INTRODUCTION

Environmental variability has long been known to affect population dynamics of fish. Recruitment, or year-class strength, is particularly susceptible to environmental variability and has been quantified directly by measuring production of offspring at or after spawning and indirectly by measuring juvenile growth and timing of spawn. Most fish are constrained to reproduce at certain times of the year when conditions are optimal for larval fish survival. Consequently, recruitment varies as conditions change from year to year.

Environmental factors that have been shown to affect recruitment of reservoir fishes and can be lumped into two distinct categories: reservoir hydrology and weather. Variations in water levels or water temperature during spawning often correlate with reproductive success of reservoir fishes (Matthews 1998). In a review of the effects of water-level manipulations on reservoir ecosystems, Ploskey (1986) found that rapidly rising water-levels inundate terrestrial vegetation and provide for an enhanced food source for fish. Additionally, water-level drawdowns may concentrate prey near predators and thus provide for enhanced predator growth. Predator-prey dynamics may also be influenced by water-level manipulations. As habitat complexity changes with water-level changes, foraging efficiency of the predator, or predator avoidance by the prey may result. Summerfelt and Shirley (1978) described the effects of weather (wind and air temperature) and reservoir hydrology (turbidity, pH, hardness, alkalinity; and water level fluctuations) on largemouth bass Micropterus salmoides year-class strength in Lake Carl Blackwell, Oklahoma, and concluded that water level fluctuations were most responsible for producing variable year-classes. They speculated that rising water levels during and immediately after spawning improved the environment for bass production and, thus, produced five of the six largest year classes over the study period. Falling water levels during spawning produced some of the poorest year-classes. Willis (1986) found that a four-stage water-level management plan in Kansas reservoirs provided for an increased production of walleye Stizostedion vitreum, white crappie Pomoxis annularis, and white bass Morone chrysops, but decreased production of largemouth bass. He suggested that the area exposed during drawdown was a major factor affecting recruitment and that a drawdown during the entire year, rather than separate ones in spring and fall, would provide benefits to the largemouth bass population.

Most of the research on the effects of reservoir hydrology on black bass recruitment has focused on largemouth bass. Miranda et al. (1984) reported positive relationships between young-of-year (YOY) largemouth bass survival and water level during the spawning and post-spawning seasons in West Point Reservoir, Alabama-Georgia. However, they found an inverse relationship between YOY largemouth bass growth and water level during the post-spawning period. Fisher and Zale (1991) found positive correlations between largemouth bass abundance and days of littoral flooding during the spawning and post-spawning periods in Grand Lake, Oklahoma. Kohler et al. (1993) showed peak spawning success during periods of stable water levels but found no relationship between timing of peak hatch and abundance in the first year of life in two Illinois reservoirs.

Fewer studies exist that have examined the effects of environmental variables on reproduction of other black bass species. Rainwater and Houser (1975) found positive

correlations between water level and inflow with total black bass (largemouth bass, smallmouth bass Micropterus dolomieu, and spotted bass) numbers and standing crop in Bull Shoals Reservoir, Missouri-Arkansas. Reinert et al. (1995) developed predictive models that related largemouth bass and spotted bass Micropterus punctulatus reproductive success to reservoir hydrology in four southeastern U.S. reservoirs. In West Point Reservoir, Georgia-Alabama, YOY spotted bass abundance was positively related to change in reservoir volume in spring whereas largemouth bass YOY was positively related to the ratio of inflow to release in summer. Ploskey et al. (1996) found positive relationships between several measures of reservoir hydrology and abundance of small and intermediate largemouth bass, spotted bass, and smallmouth bass in Bull Shoals Reservoir, Missouri-Arkansas. However, they also found lower percent contribution to total black bass biomass by smallmouth bass and spotted bass with increased hectares days of flooding.

Another important factor affecting fish recruitment that is influenced by the environment is over-winter survival. Winter starvation has been shown to be a major factor affecting over-winter survival of smallmouth bass Micropterus dolomieu in the northern limits of their range (Shuter et al. 1989). Serns (1982) found that recruitment of smallmouth bass in Nebish Lake, Wisconsin was positively correlated with water temperatures in June-August which allowed for the accumulation of energy reserves and, thus, increased over-winter survival. Over-winter survival of largemouth bass has been shown in many cases to be length-dependent (Miranda and Hubbard 1994a; Miranda and Hubbard 1994b). However, Kohler et al. (1993) found that over-winter survival of largemouth bass in an Illinois reservoir was length-dependent in only one out of three years. Goodgame and Miranda (1993) showed that earlier swim-up dates of larval largemouth bass, which could be influenced by weather and/or reservoir hydrology, resulted in lower over-winter mortality.

My objective for this study was to examine the effects of environmental conditions, weather and reservoir hydrology, on recruitment and growth of largemouth bass, smallmouth bass, and spotted bass in Skiatook Lake, Oklahoma, a southern Great Plains reservoir.

METHODS

Fisheries Data

We electrofished at night for black bass in spring and fall of 1997 through 1999 using a randomized sampling design with a boat mounted electrofishing unit. We identified, measured to the nearest 1 mm, and removed scale samples from the left side posterior to the opercle in spring 1997 and 1999. We made impressions of the scales on acetate slides, then identified and measured distances between annuli using a microfiche reader. We classified juvenile fish of each species using the central 50% range of lengths from Carlander (1977) for age-1 fish in fall and spring samples. When Carlander (1977) compiled more than one data source to summarize length at age for a species in a particular region or type of water body, he reported the range of the central 50% of those lengths; we used the upper end of this range for each species to assign an age to each individual of measured length. This classification is based on size criteria; ages were not actually estimated for these fish. Therefore, largemouth bass less than 226-mm, smallmouth bass less than 185-mm, and spotted bass less than 178-

mm were considered juvenile in spring and fall samples.

In summer (June - August) 1997 through 1999, we collected YOY black bass by backpack electrofishing. Sites for collection of YOY fish were arbitrarily selected from probable spawning sites of each species. We identified and measured fish to the nearest 1-mm, and removed their sagittae otoliths to estimate daily age. Ages were estimated by mounting, sanding, and polishing the otolith in the sagittal plane and then counting rings with a compound microscope. We counted the rings in each otolith until the counts differed by no more than 2 and then assigned the highest count as the age in days since larval swim-up. Daily ring formation has been validated for largemouth bass (Miller and Storck 1982), smallmouth bass (Graham and Orth 1987) and spotted bass (DiCenzo and Bettoli 1995).

Environmental Data

We obtained daily weather data (average air temperature, average wind speed, and accumulated rainfall) from the Oklahoma Mesonet station at Skiatook for the period 1997 through 1999 and provided site specific data. We obtained daily reservoir hydrology data (elevation, storage, inflows, and releases) for Skiatook Lake from the U.S. Army Corps of Engineers for period 1997 through 1999.

We grouped the daily environmental data into two seasons: spawning (April - May) and post-spawning (June - November). For the Mesonet data, we calculated average air temperature, average wind speed, and accumulated rainfall for each year and season from 1997 through 1999. For the reservoir hydrology data, we calculated average water elevation, average storage, total releases, and total inflows for each year and season from 1997 through 1999. Additionally, we calculated accumulated days above conservation pool elevation (217.6 m above mean sea level).

Statistical Analyses

We used correlation analysis (SAS Institute 1992) to examine the relationship between environmental variables during the spawning season and the mean catch rates of YOY black bass species captured in June and July (August was omitted from this analysis to avoid lowering the mean catch rates due to mortality and decreased susceptibility to backpack electrofishing) and between environmental variables during the spawning and post-spawning seasons and the mean catch rates of juvenile bass. We used ANOVA and orthogonal polynomial contrasts (Kuehl 1994) to compare catch rates of juvenile bass among years to determine recruitment trends for spring and fall 1997 through 1999. Additionally, we used ANOVA (SAS Institute 1992) to compare catch rates of juvenile fish in fall 1997 and 1998 with catch rates of juvenile fish the following spring (1998 and 1999, respectively) to detect a decrease in relative abundance due to over-winter mortality.

Using the summer (June - August) electrofishing data, we compared swim-up dates (Julian days), among years (1997-1999) for each three black bass species with ANOVA. We also calculated and compared average daily growth rates (mm/day) among years for each species with ANOVA. Finally, we correlated mean growth rates of YOY bass species with the environmental variables during the spawning season. Since the correlation analyses were based on small sample sizes and we were interested in finding relationships, we used $\propto = 0.10$ to detect differences with these analyses, but used $\propto = 0.05$ for all other analyses.

RESULTS

Summary statistics for environmental variables from 1997 - 1999 are in Table 1. We collected 41, 87, and 61 YOY largemouth bass, 18, 9, and 2 YOY smallmouth bass, and 0, 1, and 6 YOY spotted bass in June and July 1997, 1998, and 1999 respectively (Table 2). Given the low catches of YOY smallmouth bass and YOY spotted bass, we only analyzed the relation between environmental variables and YOY largemouth bass relative abundance which was positively correlated to accumulated inflow during the spawning season ($P = 0.02$, $r = 0.99$; Figure 2a). Juvenile largemouth bass relative abundance was positively correlated with accumulated releases during the post-spawning season ($P = 0.02$, $r = 0.99$; Figure 2b). Juvenile smallmouth bass catch rates were positively correlated with accumulated days of flooding during the spawning season ($P = 0.09$, $r = 0.99$; Figure 2c). Juvenile spotted bass catch rates were positively correlated with accumulated rainfall during the spawning season ($P = 0.02$, $r = 0.99$; Figure 2d) and mean wind speed during the post-spawning season ($P = 0.05$, $r = 0.99$; Figure 2e).

Catch rates of juvenile largemouth bass increased from 1997 through 1999 in fall ($P < 0.01$; Table 3) but not in spring ($P = 0.08$; Table 3). Juvenile smallmouth bass catch rates remained constant in fall ($P = 0.58$) and spring ($P = 0.16$) over the three years (Table 3). Juvenile spotted bass catch rates remained constant all three years in fall ($P = 0.10$) and spring ($P = 0.12$; Table 3).

We did not detect any significant effects of over-winter mortality among the three black bass species based on differences in juvenile catch rates between fall and corresponding spring samples (Table 3). The mean catch rates (number of fish per electrofishing hour) of juvenile largemouth bass were 5.60 in fall 1997 and 3.91 in spring 1998 and were not significantly different ($P = 0.19$). Mean catch rates of juvenile largemouth bass in fall 1998 were 2.23 and 3.21 in spring 1999 and also were not significantly different ($P = 0.37$). Smallmouth bass catch rates were 6.23 in fall 1997 and 3.76 in spring 1998 ($P = 0.27$) and 3.14 in fall 1998 and 2.50 in spring 1999 ($P = 0.65$). Spotted bass catch rates were 5.17 in fall 1997 and 3.42 in spring 1998 ($P = 0.32$) and 4.56 in fall 1998 and 3.25 in spring 1999 ($P = 0.40$).

We collected and aged 31, 79, and 69 YOY largemouth bass in summer 1997, 1998, and 1999, respectively. Mean Julian dates for largemouth bass swim-up were 133.39 in 1997, 132.14 in 1998, and 140.48 in 1999 and differed among years ($P < 0.01$; Figure 3). Growth of YOY largemouth bass increased significantly from 1997 through 1999 ($P < 0.01$; Table 4) and was not correlated with any of the environmental variables at the $\propto = 0.10$ level. From 17, 6, and 2 YOY smallmouth bass captured and aged in 1997, 1998, and 1999, respectively, we calculated mean Julian swim-up dates of 140.41, 125.67, and 144. We omitted 1999 from the swim-up date and growth comparison for smallmouth bass due to low sample size and found a significant different in swim-up dates between 1997 and 1998 ($P < 0.01$; Figure 4). Additionally, smallmouth bass growth increased significantly between 1997 and 1998 ($P = 0.50$; Table 4) and no correlations were computed with growth due to low sample sizes. No YOY spotted bass were collected in 1997 and only 1 and 6 were collected in 1998 and 1999, respectively. The Julian day of swim-up for spotted bass was 138 in 1998 and the mean Julian day of swim-up was 143 in 1999 (Figure 5) and growth appeared constant (Table 4), however, no statistical tests were performed due to low sample size

in every year.

DISCUSSION

We found increased catch rates of YOY largemouth bass in years with increased inflows during the spawning period (April - May) and increased catch rates of juvenile largemouth bass in years with increased releases during the post-spawning period (June - November) which is consistent with the hypothesis that increased spring water levels and inflows result in enhanced nutrient loading and thus enhanced fish production (Ploskey et al. 1996). At Skiatook Lake, water releases seem to be inportant in drawing the productive waters from the eutrophic upper-end of the reservoir to the rest of the reservoir (Kennedy and Walker 1990; Long et al. 1999) and increasing mixing (Ford 1990), which would explain the correlation between juvenile largemouth bass catch rates and releases. Juvenile smallmouth bass catch rates were positively associated with accumulated days of flooding (water level above 217 msl) during the spawning season. In the lower, lacustrine end of Skiatook Lake where smallmouth bass are constrained to live, the input of nutrients may be more dependent on lateral transport from the surrounding shore than from the longitudinal transport from Hominy Creek in the upper-end (Ford 1990; Kennedy and Walker 1990; Long et al. 1999), which conforms to a river-floodplain model (Junk et al. 1989). This is also consistent with spring nutrient loadings increasing fish production for smallmouth bass. Increased rainfall and mean windspeed during the post-spawning season may be also be responsible for increased lateral transport of nutrients to enhance spotted bass production. However, these data are the first of their kind, linking weather variables to spotted bass recruitment, and previous studies for comparison do not exist to my knowledge.

The trends in YOY and juvenile largemouth bass and juvenile smallmouth bass catch rates in fall corresponded well with trends in the environmental data. However, the constant recruitment patterns of spotted bass did not correspond well with the trends in the environmental data. Although juvenile spotted bass catch rates were positively correlated with spawning season accumulated rainfall and post-spawning mean wind speed, catch rates did not parallel these changes along the temporal gradient. Spawning season accumulated rainfall almost doubled between 1997 and 1999. However, the lack of a relationship between these two variables may be due to low detectability because spotted bass catch rates in fall did not show a significant increasing trend. Additionally, the patterns in average date of swim-up are not synchronous with the increases in electrofishing catch rates of juvenile fish. For example, swim-up dates for largemouth bass were later, not earlier, in the latter years followed by increased catch-rates of juvenile largemouth bass that fall indicating increased recruitment. We would have predicted the opposite effect based on conclusions from Goodgame and Miranda (1993) and Miranda and Hubbard (1994a and 1994b) which showed that larger individuals were more likely to have been spawned earlier, grow faster, converted to a fish diet sooner, allowed to increase their lipid levels, and thus be more likely to survive the over-winter period. However, the negative effects of later spawning dates may have been mitigated by the positive effects of increased inflows during the spawning period and the positive effects of increased growth over the three year study period.

Rose (2000) stated that quantifying environmental quality effects on fish populations has been difficult and lists detectability as a primary issue in relating environmental variables to fish population dynamics. We were able to derive relations between all three species of black bass with environmental variables with only three years of data and these relationships are consistent with other studies on the effects of environmental conditions on black bass recruitment. However, most of the relationships were only moderately significant ($0.05 \leq \underline{P} \leq 0.10$) and there are some inconsistencies (e.g., spotted bass recruitment trends not corresponding with environmental trends) that raise the issue of detectability.

The ability to derive models of recruitment for largemouth bass, smallmouth bass, and spotted bass against environmental variables have met with varying degrees of success, depending on the species. Reinert et al. (1995) were able to produce more significant models for largemouth bass than for spotted bass based on reservoir hydrology in southeastern reservoirs, and they could not produce any models for smallmouth bass. Ploskey et al. (1996) could produce only one significant model for smallmouth bass recruitment based on reservoir hydrology but produced nine models for largemouth bass and six models for spotted bass in Bull Shoals Reservoir, Arkansas-Missouri. Summerfelt and Shirley (1978) were unable to find any correlation between year-class strength of largemouth bass and weather variables in Lake Carl Blackwell, Oklahoma, but were able to find significant correlations with reservoir hydrology.

Given that we were only able to capture a sufficient number of YOY largemouth bass, but an insufficient number of YOY smallmouth bass and spotted bass to analyze trends, suggests a lack of detectability between recruitment and environmental variables, but also raises an issue of sampling methodology. Studies by Reinert et al. (1995) and Ploskey et al. (1996) who collected data on these three black bass species but failed to produce models for smallmouth bass and spotted bass as good as those for largemouth bass suggest that these former two species are harder to collect in sufficient quantities to detect relationships with environmental variables. Rainwater and Houser (1975) found that annual fluctuations in standing crop in Bull Shoals and Beaver reservoirs were greatest for largemouth bass than for smallmouth bass or spotted bass. Ploskey et al. (1996) found that both largemouth bass and spotted bass responded positively to increased water levels, but that spotted bass contribution to overall black bass biomass declined because the largemouth bass contribution was overwhelming. Apparently, largemouth bass respond much more to changes in the reservoir environment than do spotted bass or smallmouth bass. Additionally, Ploskey et al. (1996) found that smallmouth bass responses to water level fluctuations in Bull Shoal Reservoir were different from the other two black bass species. Moreover, the coefficient of variation in smallmouth bass biomass estimates from their 22 years of standardized sampling were much higher for smallmouth bass than for spotted bass or largemouth bass indicating that catches of this species were much more difficult and sporadic, which would result in decreased detectability of environmental influences. Alternatively, smallmouth bass and spotted bass populations may be less susceptible to environmental change than largemouth bass, especially in Skiatook Lake.

In a reservoir gradient, the greatest environmental changes occur in the upper-end, where the largest input of water and nutrients occur (Kennedy and Walker 1990). Smallmouth bass do not reside in these areas in Skiatook Lake (Long et al. 1999) or in

some other reservoirs (such as Bull Shoals and Beaver reservoirs; Rainwater and Houser 1975). Therefore, the environment in areas of reservoirs that smallmouth bass do occupy tend to be less variable, and populations of this species may be controlled by density-dependent processes (e.g., prey availability and competition; Winemiller 1992; Matthews 1998). Additionally, smallmouth bass are relatively new to Skiatook Lake, having been stocked in 1990 (Hicks 1994), and their population has been increasing ever since (Long et al. 1999). The spotted bass populations in Skiatook Lake may also be regulated by density-dependent factors. Using standardized electrofishing data supplied by the Oklahoma Department of Wildlife Conservation, we were able to produce a stock-recruitment model for spotted bass (Ricker 1975; cited in Wootton 1990). Spotted bass was the only black bass species not supplementally stocked by the ODWC (Hicks 1994) and, therefore, the only species whose population fluctuations are the result of natural processes. Additionally, the spotted bass was the only species that the ODWC had enough year-to-year data on to produce this model. We regressed catch rates of juvenile spotted bass onto the previous year's catch rates of adult spotted bass using the equation from Ricker (1975) and also with linear least-squares (SAS Institute 1992). A significant, and better fit with the Ricker model over the linear least-squares model would suggest density-dependent control whereas the latter would suggest density-independent control (Wootton 1990). Figure 6 shows the relationship between juvenile catch-per-unit-effort (CPE) and adult CPE. The Ricker curve was significant ($P = 0.02$) but had a moderately better fit ($R^2 = 0.61$) than the linear model ($P = 0.03$; $R^2 = 0.56$), suggesting that the spotted bass population in Skiatook Lake may be under density-dependent rather than density-independent control. This would explain the lack of good correspondence between recruitment and environmental variables.

In contrast, the dynamics of the environment at Skiatook Lake may be such that makes quantifying environmental effects on black bass populations difficult, and perhaps these effects are minimal when they do occur. Rose (2000) listed detectability as the first reason why correspondence between environmental variation and fish population dynamics is so low. The hydrology of Skiatook Lake is much less variable than many other reservoir systems in the southeastern U.S. (e.g., Bull Shoals Reservoir) that have been studied more extensively and tend to have better correspondence between environmental variability and black bass recruitment. For example, Aggus and Elliot (1975) found that the average water level fluctuation in Bull Shoal Reservoir from 1968 - 1973 was 6.9 meters. The mean water level fluctuation from 10 years of record at Skiatook Lake was 2.9 meters and the greatest was 4.2 meters. Therefore, the "normal" environmental conditions at Skiatook Lake may not act in such a way to be the most important variable that impacts these black bass populations, or at least not in a way to be very detectable.

More research is needed to identify the regulatory mechanisms, density-independent vs density-dependent, of reservoir fish populations and the relative importance of each. For sportfish, this information is needed so that fisheries managers and researchers can recognize when these factors play the pivotal role in regulating populations in reservoirs as an aid to maintain healthy stocks.

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Table 1.-Summary statistics for the environmental variables used in correlations with catch rates of young-of-year largemouth bass and juvenile largemouth bass, smallmouth bass, and spotted bass at Skiatook Lake, Oklahoma from 1997 - 1999.

Year	XELE	XSTO	SREL	SINF	TFLOOD	XTEM	XWND	SRAIN
			Spawning Season					
1997	217.80	405,458,551	641.97	714.86	56	18.15	11.84	32.41
1998	217.90	410,046,057	1,131.74	1,203.61	47	20.58	13.15	28.45
1999	218.90	455,502,915	1,444.02	2,425.48	61	19.35	12.37	61.01
			Post-spawning Season					
1997	217.67	400,037,108	507.75	660.35	29	25.27	9.35	36.88
1998	217.46	391,290,725	201.96	151.21	19	27.69	9.12	15.34
1999	217.66	399,201,850	785.91	312.62	23	27.85	10.45	6.30

XELE = mean water elevation (msl), XSTO = mean water storage in reservoir (m^3), SREL = sum of reservoir releases (m^3/sec/day), SINF = sum of inflow to reservoir (m^3/sec/day), TFLOOD = total number of days above conservation pool elevation, XTEM = mean air temperature (°C), XWND = mean wind speed (km/hour), SRAIN = sum of rainfall (cm).

Table 2.--Summary statistics of young-of-year (YOY) largemouth bass catch rates (number of fish per electrofishing hour) during summer 1997 - 1999 in Skiatook Lake. N = number, SE = standard error.

Year	N	Mean	SE
1997	6	15.74	2.87
1998	11	22.14	8.80
1999	10	39.27	10.35

Table 3.--Mean electrofishing catch rate (number of fish per hour) statistics for juvenile black bass in Skiatook Lake, Oklahoma in fall and spring 1997, 1998, and 1999. SE = standard error. P-values for recruitment indicate significant differences among years for spring electrofishing only for each species. P-values for LOF indicates quadratic or higher trend in means among years for each species.

	Largemouth Bass		Smallmouth Bass		Spotted Bass	
Year	Mean	SE	Mean	SE	Mean	SE
			Fall			
1997	5.60	1.47	6.23	3.30	5.17	3.39
1998	2.23	1.13	3.14	2.79	4.56	2.30
1999	8.98	1.02	7.14	2.79	10.97	2.09
Recruitment	P < 0.01		P = 0.58		P = 0.10	
LOF	P < 0.01		P = 0.32		P = 0.25	
			Spring			
1997	1.71	0.66	1.41	0.84	6.14	1.06
1998	3.91	0.75	3.76	0.89	3.42	1.16
1999	3.21	0.67	2.50	0.97	3.25	1.14
Recruitment	P = 0.08		P = 0.16		P = 0.12	
LOF	P = 0.10		P = 0.10		P = 0.37	

Table 4.--Mean growth rates (mm/day) of young-of-year black bass in Skiatook Lake in 1997, 1998, and 1999. N = number of fish used to calculate mean growth, SE = standard error, NA = not applicable, and LOF indicates quadratic or higher trend in means among years.

	Largemouth bass			Smallmouth bass			Spotted bass		
Year	N	Mean	SE	N	Mean	SE	N	Mean	SE
1997	31	0.80	0.03	17	0.99	0.03	0	NA	NA
1998	79	1.07	0.02	6	0.95	0.05	1	1.07	NA
1999	69	1.14	0.02	2	1.32	0.09	6	1.14	0.07
ANOVA		$P < 0.01$			$P = 0.50$			NA	
LOF		$P < 0.01$			NA			NA	

FIGURE LEGENDS

Figure 1.--Graph of water level elevation (meters above sea level; msl) and air temperature from the period 1997 through 1999 at Skiatook Lake, Oklahoma.

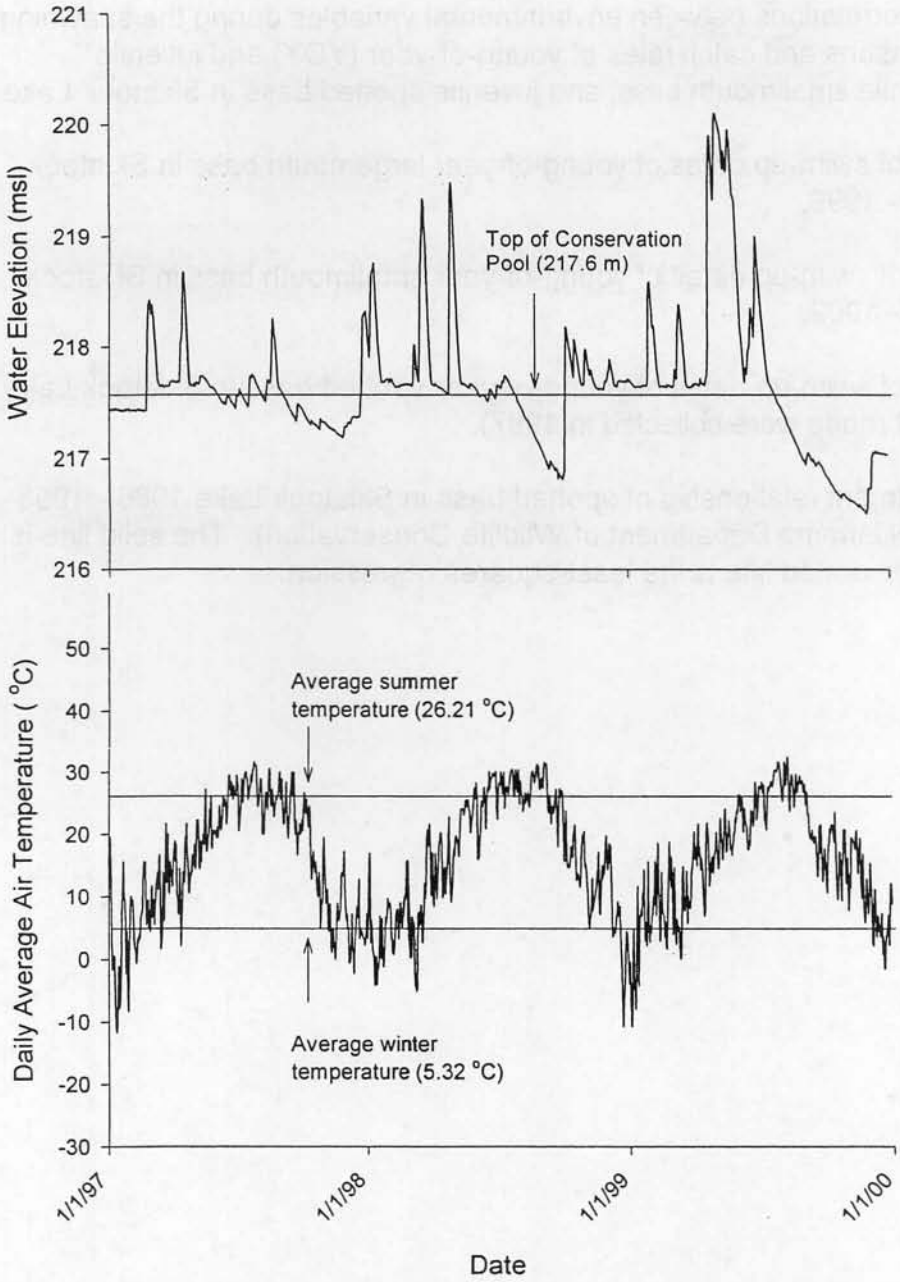
Figure 2.--Significant correlations between environmental variables during the spawning and post-spawning seasons and catch rates of young-of-year (YOY) and juvenile largemouth bass, juvenile smallmouth bass, and juvenile spotted bass in Skiatook Lake.

Figure 3.--Distribution of swim-up dates of young-of-year largemouth bass in Skiatook Lake, Oklahoma 1997 - 1999.

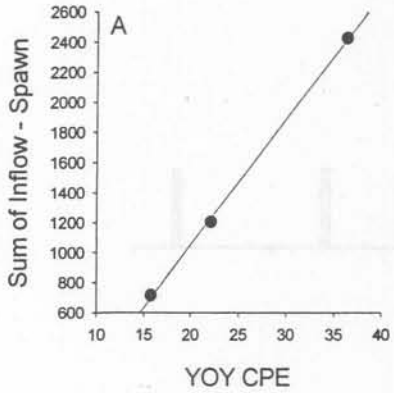
Figure 4.--Distribution of swim-up dates of young-of-year smallmouth bass in Skiatook Lake, Oklahoma 1997 - 1999.

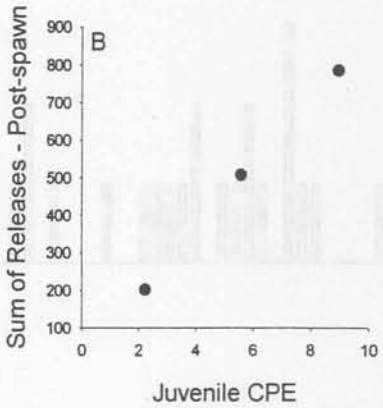
Figure 5.--Distribution of swim-up dates of young-of-year spotted bass in Skiatook Lake, Oklahoma 1998 - 1999 (none were collected in 1997).

Figure 6.--Stock-recruitment relationship of spotted bass in Skiatook Lake 1986 - 1998 (data courtesy of the Oklahoma Department of Wildlife Conservation). The solid line is the Ricker curve and the dotted line is the least-squares regression.

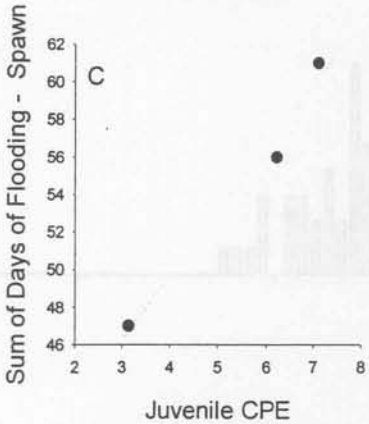

Water Elevation (msl)
221
220
219
218
217
216
Top of Conservation Pool (217.6 m)
Daily Average Air Temperature (°C)
50
40
30
20
10
0
-10
-20
-30
Average summer temperature (26.21 °C)
Average winter temperature (5.32 °C)
1/1/97
1/1/98
1/1/99
1/1/00
Date

Largemouth bass

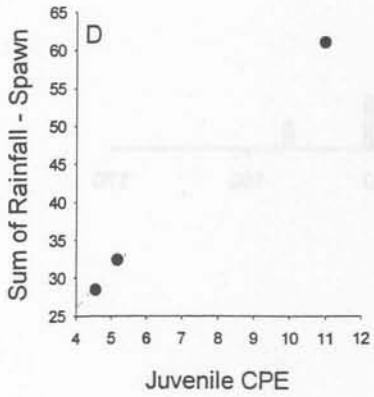


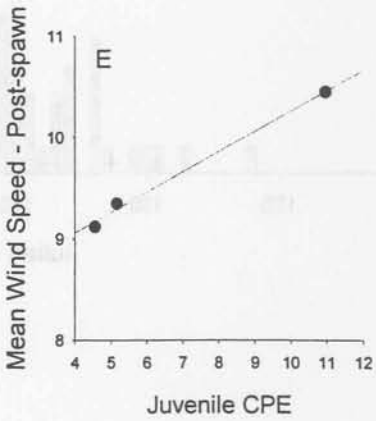


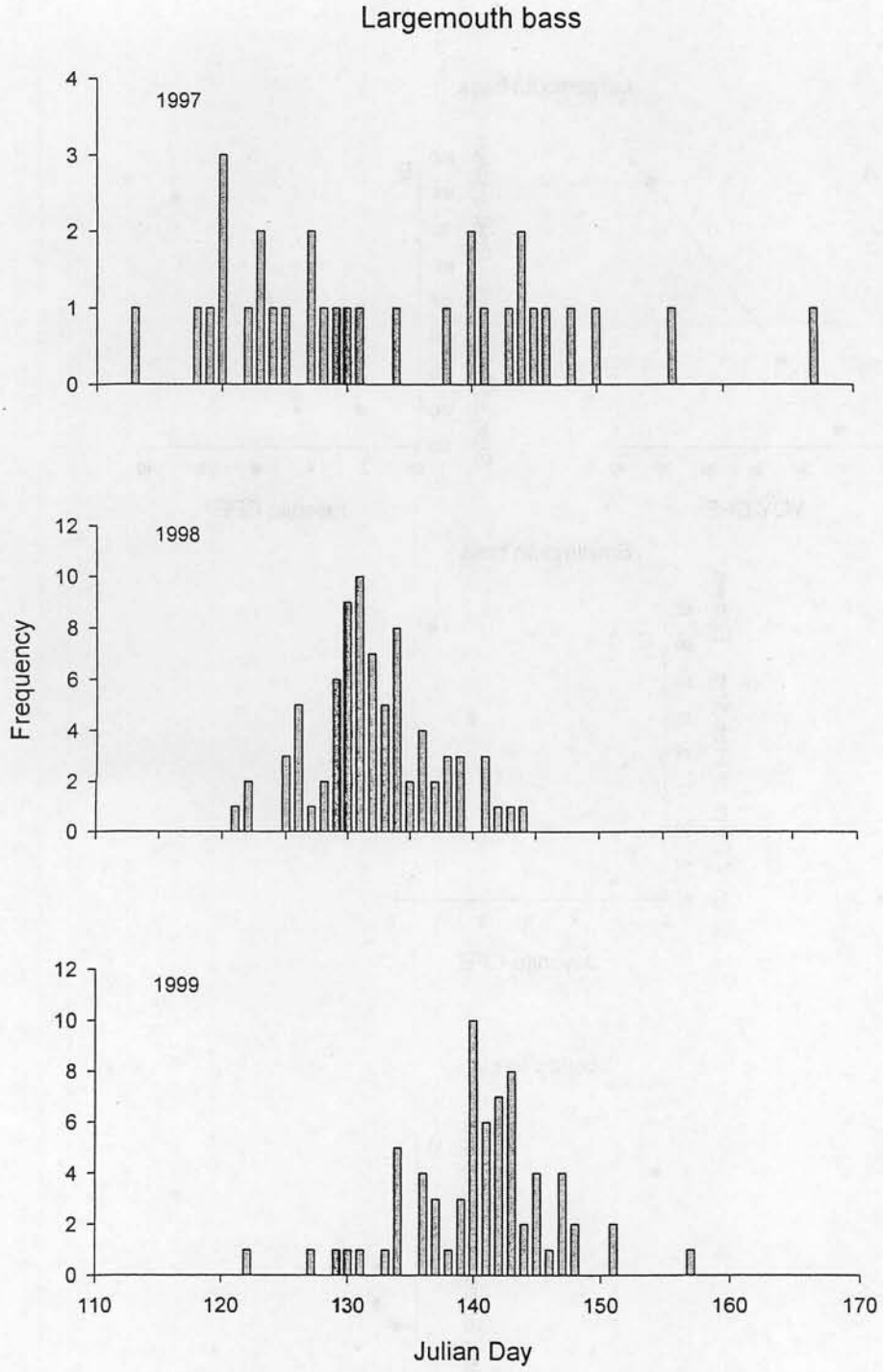
Smallmouth bass

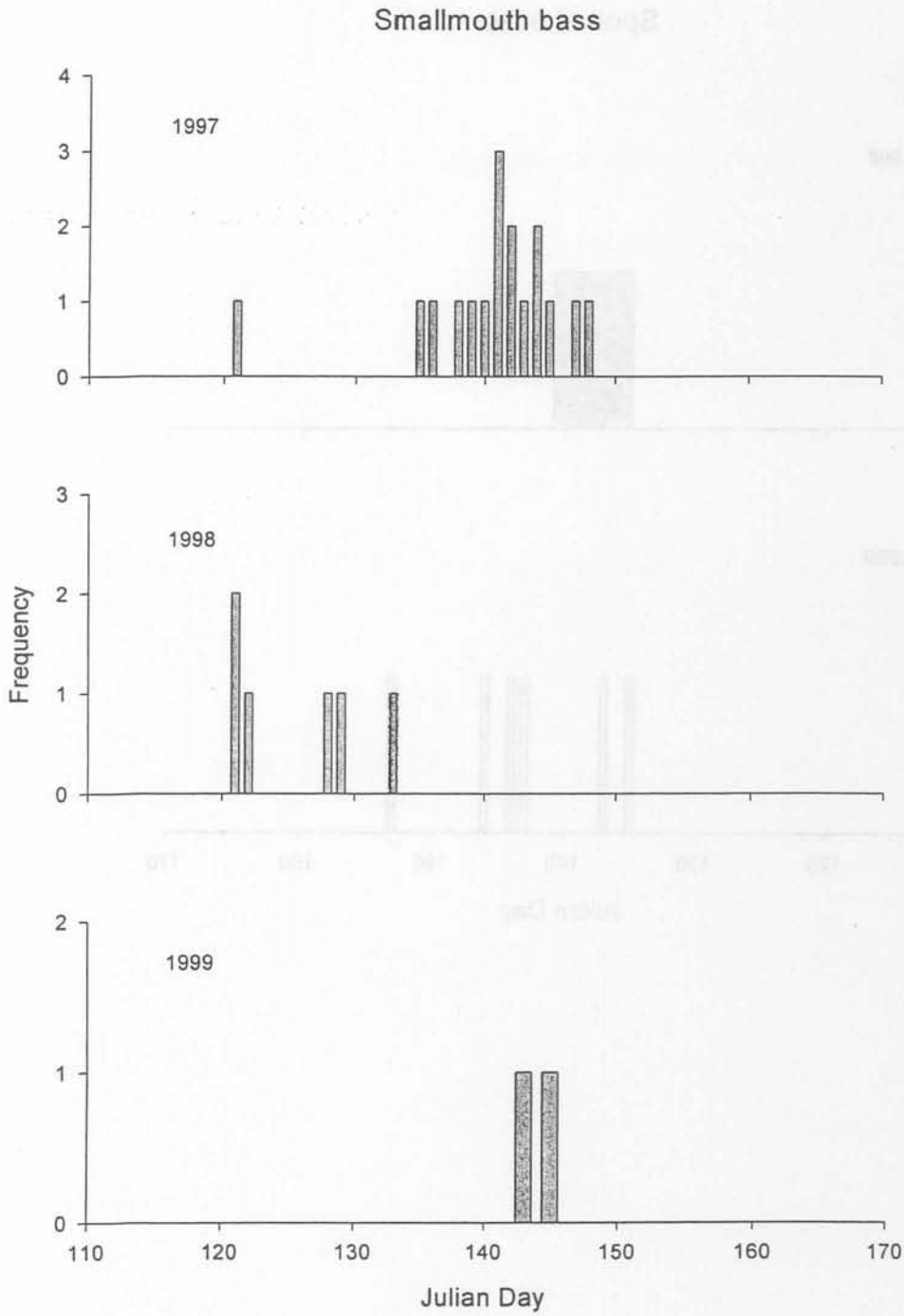


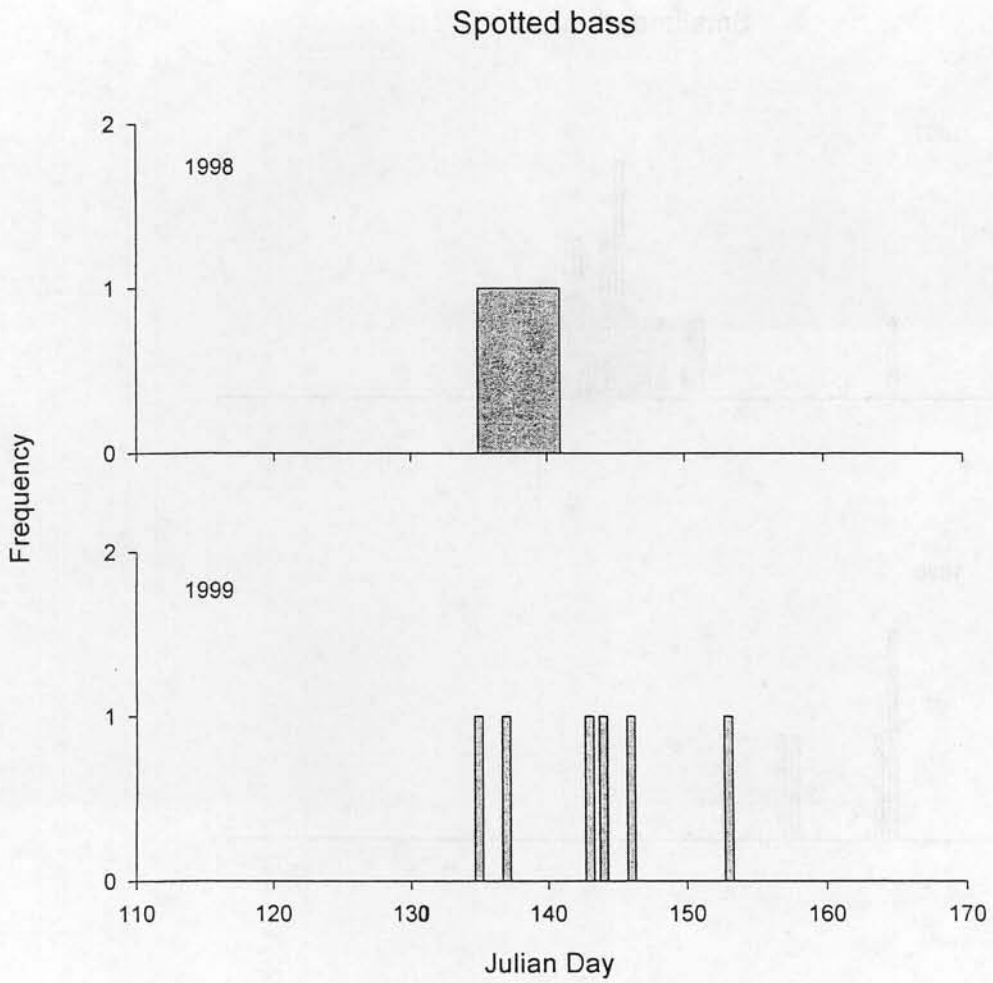
Spotted bass

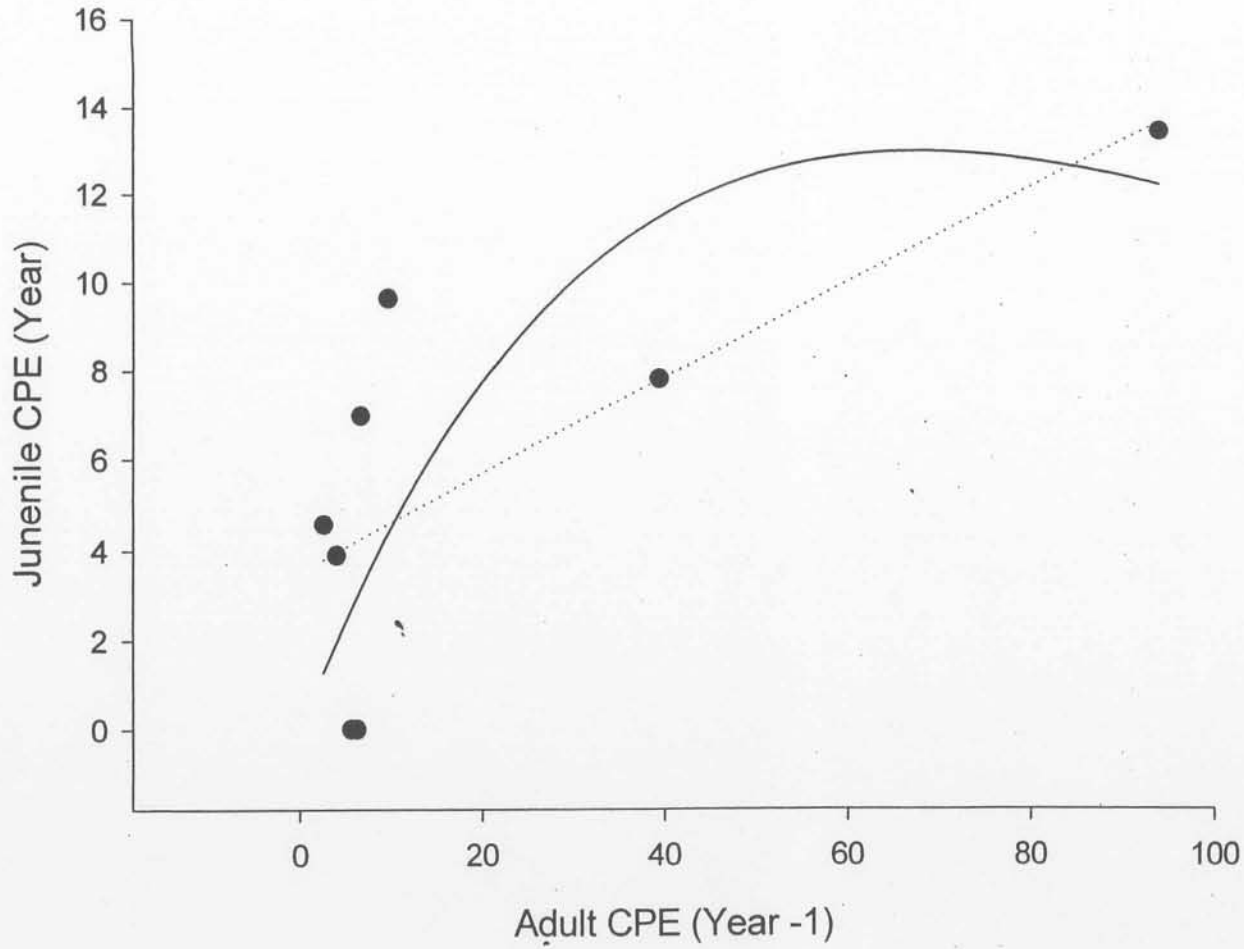





Largemouth bass
1997
1998
1999
Frequency
Julian Day
0
1
2
3
4
0
2
4
6
8
10
12
0
2
4
6
8
10
12
110
120
130
140
150
160
170


Smallmouth bass
1997
1998
1999
Frequency
Julian Day
0
1
2
3
4
110
120
130
140
150
160
170


Spotted bass
1998
1999
Frequency
2
1
0
110
120
130
140
150
160
170
Julian Day


16
14
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Junenile CPE (Year)
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20
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Adult CPE (Year -1)

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