POPULATION BIOLOGY, MANAGEMENT, AND SAMPLING CONSIDERATIONS FOR BLACK BASS AND SUNFISH IN TWO EASTERN OKLAHOMA STREAMS

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PAUL EUGENE BALKENBUSH

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Thesis Approved:

William L. Fisher

Thesis Advisor

Anthony A. Echelle

Dale [illegible]

Thomas C. Collins

Dean of the Graduate College

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CHAPTER I.

INTRODUCTION

This thesis is composed of two manuscripts written in the format suitable for submission to the North American Journal of Fisheries Management. Chapter I is an introduction to the rest of the thesis. The manuscripts are as follows; Chapter II, "Population biology of black bass and sunfish in Baron Fork Creek and Glover River, Oklahoma, with emphasis on smallmouth bass management," and Chapter III, "Sampling considerations for sport fish in eastern Oklahoma streams."

CHAPTER II.

POPULATION BIOLOGY OF BLACK BASS AND SUNFISH IN BARON FORK CREEK AND GLOVER RIVER, OKLAHOMA, WITH EMPHASIS ON SMALLMOUTH BASS MANAGEMENT

Paul E. Balkenbush

Oklahoma Cooperative Fish and Wildlife Research Unit

Department of Zoology, Oklahoma State University

Stillwater, OK 74078

Abstract.--We sampled black bass and sunfish in Baron Fork Creek (northeast) and Glover River (southeast) Oklahoma during 1994 and 1995 to assess regional differences in populations and the fishery potential of and management options for smallmouth bass in eastern Oklahoma streams. Based on abundance of black bass and sunfish, we found that both streams sustain populations of these species. However, population characteristics (e.g., abundance, age and size structure, growth rates, mortality rates, and condition) showed distinct differences between the two regions. The fishery potential for smallmouth bass in Glover River was limited, in part, by poor year class success and a high annual mortality resulting in low recruitment to older ages. Whereas the population of smallmouth bass in Baron Fork Creek had reduced growth rates of young fish, indicating overcrowding, and increased growth in large individuals, but their biomass had declined from earlier reports. These population differences may, in part, be attributable to the relatively conservative land use within the Baron Fork Creek watershed and stable stream flows which are markedly different from those in Glover River where silviculture activities in the watershed are intensive and flow regime is flashy. Assuming the fisheries of these streams are similar to others in their region, we recommend combining best watershed management practices with slot-length limits in northeastern and high minimum length limits (320mm) in southeastern Oklahoma streams to improve their fisheries.

Stream fisheries in Oklahoma have received little management compared to reservoir fisheries, partly because of a paucity of information on stream fish populations. Previous surveys of fish populations in eastern Oklahoma streams by Jenkins et al. (1952), Finnell et al. (1956), Orth and Maughan (1984), and Smith (1982) have provided important baseline information. More intensive studies by Orth et al. (1983) and Stark and Zale (1991) of black bass populations including growth rates, recruitment, and age and size structures have revealed significant geographic variation between populations in northeastern and southeastern Oklahoma streams. These studies, however, were short term (e.g., many streams or study sites with limited sampling; Stark and Zale 1991) and geographically limited (e.g., Glover River in southeastern Oklahoma; Orth et al. 1983) and, therefore, did not assess annual differences in populations between regions. Forbes (1989) noted that populations of smallmouth bass should be investigated for several years if an accurate evaluation of fishery potential and population status is to be obtained. Additionally, Stark and Zale (1991) concluded that stream fisheries in northeastern and southeastern Oklahoma may require different management strategies that account for differences in black bass populations between these regions.

Although smallmouth bass and other black bass are preferred by stream anglers (Fajen 1975a; Fleener 1975; Forbes 1989; Martin 1995), sunfish (e.g., Lepomis spp. and rock bass Ambloplites rupestris) are also principal components of many stream fisheries (Covington et al. 1983; Martin 1995). Martin (1995) noted that sunfish composed 39% of the total sport fish harvest on Baron Fork Creek and 89% of the harvest on Glover River, indicating the importance of species other than black bass to the local fisheries. Similarly, Summers (1990) found that 57% of Oklahoma licenced anglers fished for sunfish in 1989, with 12.5% of the statewide angling pressure occurring in streams. Even so, little is known about the population biology of these species in eastern Oklahoma streams.

We sampled black bass and sunfish in two eastern Oklahoma streams for two years to assess regional differences in population dynamics. Our specific objectives were to (1) compare abundance, age and size structure, growth rates, mortality rates and condition of smallmouth bass in Baron Fork Creek (northeast) and Glover River (southeast) Oklahoma over consecutive years and to (2) use this information to assess the fishery potential and management options for this species in eastern Oklahoma streams.

Methods

Study Area.--Baron Fork Creek and Glover River are scenic and unregulated waterways in eastern Oklahoma with viable fisheries. Baron Fork Creek is located in the Ozark Plateau region of east central Oklahoma (Figure 1) and is characteristic of streams in this region with clear and cool water, stable base flow maintained by springs, and a gravel dominated substrate. Baron Fork

Creek originates in Arkansas, then flows westward for 56.9 km (OKWRB 1990) through Adair and Cherokee counties, Oklahoma draining 936 km^2 (Storm et al. 1996) before it joins the Illinois River above Lake Tenkiller. Major land use in the basin includes pasture or rangeland, native forests (OSEI 1996), and numerous confined poultry operations (Nolan et al. 1989). Glover River is located in the rugged and remote Ouachita Mountains of southeastern Oklahoma (Figure 2) and is typical of streams in this region with substrate dominated by emergent bedrock, and flow fed primarily by runoff. Glover River begins in Pushmataha and Leflore counties, Oklahoma and flows southerly for 54.2 km (OKWRB 1990) through McCurtain county, Oklahoma draining 876 km^2 (Orth and Maughan 1984) before joining the Little River. The basin is heavily forested and supports intensive silviculture activities (Rutherford et al. 1987).

Fish sampling.--Study reaches were defined and sampling sites were chosen along a 16.7-km section of Baron Fork Creek (Figure 1), and a 38.6-km section of Glover River (Figure 2). Sampling sites were randomly selected on each stream from a pool of potential sites including both easily accessible and remote areas. Our sampling sites included two remote areas (Eddings hole and poultry farm cut-bank) and two easily accessible areas (Eldon bridge and Welling bridge) on Baron Fork Creek, and two remote areas (Arkansas crossing and boy scout hole) and two easily accessible areas (forks of Glover and golden gate bridge) on Glover River. Legal descriptions and vernacular references of sampling sites are in Appendix A. Fish populations were sampled at these sites from August through October 1994 and 1995 when the streams were at or near base flow.

Fish were sampled by electrofishing with pulsed direct current using a boat equipped with a Smith-Root 2.5 GPP electrofisher. Prior to sampling, each site was block-netted at the upstream and downstream end with 55 m × 1.8 m × 12.7-mm^2 mesh block nets to prevent emigration or immigration. The area of each site was calculated by multiplying the mean stream width between the block nets by the site length. The enclosed areas were thoroughly sampled two times to mark and recapture marked fish. After each sampling run, captured fish were held in an instream pen for subsequent processing. Following the first electrofishing (marking) run, captured fish were marked (partial caudal fin clip), and lengths (mm), weights (gm), and scale samples were taken for age and growth, mortality, and condition analysis. Scale samples were not collected from fish visually determined to be young-of-year (age 0). When large numbers of fish were captured, scale samples were taken from a subsample of fish (at least 2 fish from each 20 mm length group) to reduce logistical demands (Forbes 1989). However, all captured fish were marked. Fish were released back into the enclosed area after processing and left undisturbed for about two hours to allow them to disperse. After the second electrofishing (recapture) run, collected fish were examined for marks, and lengths (mm), weights (gm), and scale samples were collected from unmarked individuals. Total number of fish captured and number of marked fish were recorded for population size estimates

(Ricker 1975).

Data analysis.--Fish captured from individual sample sites were pooled by stream and year for analysis. Population metrics were calculated for individual species within each stream by year when sample sizes were sufficient. Additionally, scale samples from both years were pooled by species for back calculations of length, and all species were combined into two groups, either black bass or sunfish, for aggregate density and biomass estimates.

Total population estimates by species and by aggregates of black bass and sunfish were calculated using the Chapman modification of the Petersen estimate (Chapman 1951). Approximate confidence limits, using either the Poisson, binomial, or normal distributions, were calculated by the methods of Seber (1973). Age-specific population estimates by species were calculated by multiplying the percentage of the sample each age group represented (determined from the length frequency histograms) by the total population estimate (Bovee et al. 1994). Density (number/ha) was then approximated by dividing the area sampled in each stream into the population estimate. We estimated biomass (kg/ha) for each age group by multiplying density by the mean weight. Mean density and biomass estimates for smallmouth bass, and aggregates of black bass and sunfish, were calculated by averaging these values for each stream over both years.

Scale samples for age and growth analysis were collected posterior to the tip of the pectoral fin, below the lateral line (Ambrose 1983). Scales were impressed onto cellulose acetate slides (Smith 1954) and viewed with a scale reader at 40 X magnification. The focus, annuli, and anterior edge of each scale were traced onto a paper strip and these tracings were measured on a digitizing pad; length histories and annual growth increments were back-calculated with the DisBCal89 1.0 software program (Frie 1982). This program uses the Frazer-Lee method for back-calculating lengths (Frie 1982).

Wilcoxon tests for two random samples (normal approximation; $P \leq 0.05$; Zar 1984) were used to test for significant differences between growth histories of fish in Baron Fork Creek and Glover River when sample sizes were five or more fish in each age class. Small sample sizes and regenerated scales precluded statistical testing of several ages. Within streams, growth histories were pooled between years, precluding statistical analysis for annual variations in growth. Therefore, we plotted frequency histograms of fish species by stream and year, using lengths at time of capture, and assigned ages to fish within a frequency group with the aid of the back-calculated length at age results. Older fish were combined with the last group of known age. As with growth histories, we used the Wilcoxon test to assess significance of length at capture for each age group.

Total annual survival and mortality rates were calculated using linear least-squares regression (Van Den Avyle 1993). We used catch curves to evaluate gear selectivity (Ricker 1975; and Van Den Avyle 1993), and survival and mortality rates were estimated from a descending line starting with the youngest age group at the origin, and ending with the oldest age group at the end. Age groups falling below an extension of this line were not sampled adequately (Van Den Avyle 1993) and, therefore, were excluded. At least three age groups not biased by gear selectivity (i.e., located on the descending portion of the catch curve) are required for the regression analysis (Van Den Avyle 1993); therefore, survival and mortality could not be computed in some cases.

Differences in body condition were assessed by comparing the slopes of length-weight regression lines with analysis of co-variance (ANCOVA; Zar 1984). We used predicted weight instead of original weight because the former represents an average response weight for any total length. A regression of $\log_{10}$-transformed total length (mm) versus $\log_{10}$-transformed weight (gm) was calculated for each stream and year and was used to predict weight from the original length measurements. Pairwise linear contrasts were used to compare the slopes of the regression equations. The first contrast tested for parallel slopes. If the slopes were parallel (i.e., both samples had similar weight increases at any value of length), a parallel lines model was used to test if the regression lines were significantly different (i.e., at any length, fish from one sample were heavier than the other). If the slopes were parallel and the lines not significantly different, then the respective length-weight relationships were considered equal (i.e., at any length, fish from the two samples have statistically equal weights). If the slopes were not parallel, a non-parallel lines model was used to compare the weights at stock, quality, and preferred length values recommended by Gabelhouse (1984). The non-parallel lines model assesses the response of fish weight among the two samples at different values of total length.

Results

A total of 3,615 fish representing nine species including largemouth bass, smallmouth bass, spotted bass, four Lepomis spp., rock bass, and warmouth Chaenobryttus gulosus were captured in the 16 samples from the two streams. The majority of fish collected (67%) were from Glover River, with 2,419 fish representing eight species, whereas Baron Fork Creek samples composed 33% of the total with 1,196 fish representing nine species. Smallmouth bass dominated the black bass catch in each stream during both years, followed in order by largemouth bass and spotted bass in Baron Fork Creek, and spotted bass and largemouth bass in Glover River. Longear sunfish Lepomis megalotis was the dominant sunfish species in both streams and years, followed by appreciable numbers of bluegill Lepomis macrochirus and rock bass in Baron Fork Creek and green sunfish Lepomis cyanellus in Glover River. Species infrequently captured were spotted bass, green sunfish, redear sunfish Lepomis microlophus and warmouth in Baron Fork Creek, and largemouth bass, spotted bass, bluegill sunfish, redear sunfish, and warmouth in Glover River. Three catfish species (channel catfish Ictalurus punctatus, yellow bullhead Ictalurus natalis, and flathead catfish Pylodictis olivaris) were collected but were excluded from the samples because of gear inefficiency (Reynolds 1983).

Density.--Total density (number/ha) of smallmouth bass in Baron Fork Creek was similar between 1994 and 1995; however, total biomass (kg/ha) was higher in 1994 due to the prevalence of age 3 and older fish (Table 1). Conversely, high catch rates of age 0 and age 2 and older fish caused 1995 smallmouth bass densities in Glover River to be three times higher than in the previous year. Total biomass in Glover River was similar between the two years because the large age 0 year class in 1995 did not contribute substantially to the biomass of smallmouth bass.

Smallmouth bass density in Baron Fork Creek was about twice that of the Glover River in 1994 but only one-third that in 1995 (Table 1). Baron Fork Creek populations had consistently more older age fish, resulting in total biomass estimates that were four times greater than those from Glover River in 1994 and 1.5 times higher in 1995 (Table 1). Total and age-specific density estimates for other black bass and sunfish species are in Appendixes B through E.

Total density of black bass was consistently higher in Baron Fork Creek and Glover River in 1995 than in 1994 (Table 2). Although black bass in Baron Fork Creek were 32% more abundant in 1995 than in 1994, total biomass was lower due to a disproportionate number of older smallmouth bass in the 1994 samples. A similar trend was evident in Glover River in 1995 when density estimates were about one-third more than that of the previous year, but total biomass values were nearly equal. Between streams and for both years, black bass in Baron Fork Creek were more dense, resulting in a greater biomass, than those in Glover River (Table 2).

Density and biomass of sunfish in the two streams also differed within and between years. In Baron Fork Creek, density of sunfish was 14% higher in 1994 than in 1995, resulting in 53% more biomass (Table 2). This was attributable to an appreciable number of age 2 and older longear sunfish (Appendix C), bluegill, and rock bass (Appendix D). Conversely, 1994 sunfish density in Glover River was nearly two times less than in 1995, but biomass was similar. This disparity is partly due to the high density of young longear sunfish found in 1995 (Appendix C). Between streams, sunfish were more abundant in Glover River than in Baron Fork Creek during both years, but biomass differed much less between streams, indicating that sunfish collected in Baron Fork Creek were older and larger than those collected in Glover River (Table 2).

Growth.–We examined 119 scale samples from smallmouth bass, including 90 (76%) from Baron Fork Creek and 29 (24%) from Glover River. Of these, six samples (5%) were regenerated and could not be aged. The maximum age of smallmouth bass in our samples was six years in Baron Fork Creek and five years in Glover River. Most of the fish we aged in Baron Fork Creek were less than age 5 (93%), and only 3 fish were age 3 or older in Glover River.

Mean back-calculated lengths at age 1 and 2 for smallmouth bass were not significantly different between the two streams (Table 3). Fish of ages 3 through 5 were similar, but low sample sizes in Glover River precluded statistical testing. Smallmouth bass in both streams reached stock size (180 mm) between age 2 and 3, and were quality length (280 mm; Gablehouse 1984) near the end of their fourth growing season. Fish of preferred lengths (350 mm; Gablehouse 1984) were rare in our samples and consisted of age 5 and older individuals. Growth histories for other black bass and sunfish species are in Appendixes F through J.

Smallmouth bass length at capture showed no consistent trends within age groups among years in either stream (Table 4). For example, age 0 and 1 smallmouth bass in Baron Fork Creek were longer in 1994 than in 1995. However, size of age 2 fish was similar between years, and age 3 and older fish were longer in 1995 than in the previous year. In Glover River, age 0 smallmouth bass were not significantly different between years, but age 1 fish were longer in 1995, and age 2 fish were longer in 1994. Smallmouth bass length at capture was generally greater for age 1 and 2 fish in Glover River than those in Baron Fork Creek. In 1994, size of young-of-year fish was not significantly different between streams, but age 1 and 2 fish appeared longer in Glover River, but could not be statistically compared. In 1995, age 0 fish appeared longer, and age 1 and 2 fish were significantly longer in Glover River than those in Baron Fork Creek. Length at capture for other black bass and sunfish species are in Appendixes K through N.

Mortality.--The estimated total annual mortality for smallmouth bass (Table 5) in Baron Fork Creek increased 39% from 28% in 1994 to 46% in 1995 (Table 5), indicating substantial annual variability. This trend in mortality rates could not be established for smallmouth bass in Glover River, because our 1994 samples contained only two year classes unbiased by gear selectivity (i.e., fish decreased in abundance with each increase in age; Table 1). Overall, Glover River smallmouth bass suffered higher mortality rates than those in Baron Fork Creek (Table 5). Estimated total annual mortality and survival for other black bass and sunfish species are in Appendix O.

Condition.--We found no significant change in condition of smallmouth bass between 1994 and 1995 in either Baron Fork Creek or Glover River (Figure 3). Conversely, smallmouth bass condition varied annually between streams. In Baron Fork Creek, smallmouth bass were significantly heavier at stock length than those in Glover River in 1994 (Figure 4). As length increased to quality and preferred categories, the response of weight was essentially the same between streams. In 1995, the length-weight regressions for each stream were remarkably similar, indicating the two populations were similar in condition. Results of the condition analysis for other black bass and sunfish species are in Appendix P through U.

Discussion

Smallmouth bass dominated the black bass catch in Baron Fork Creek and Glover River in 1994 and 1995. However, previous studies of black bass in eastern Oklahoma streams indicate that the dominant species changes over time. For example, northeastern Oklahoma streams were dominated by smallmouth bass in 1952 (Jenkins et al. 1952), changing to spotted bass in 1982 (Smith 1982) and back to smallmouth bass from 1988 - 1990 (Stark and Zale 1991). Similarly, southeastern Oklahoma streams were dominated by smallmouth bass and largemouth bass in 1955 (Finnell et al. 1956), and spotted bass from 1988 - 1990 (Stark and Zale 1991). It is likely that these apparent changes in dominance among black bass species are a function of limited sampling in the previous studies and not a true shift in abundance.

Our density and biomass estimates for smallmouth bass differed between years, especially in Glover River (Table 1), indicating variation in year class success that is typical of smallmouth bass populations (Cleary 1956; Pflieger 1975). Similarly, Stark and Zale (1991) found few large adults in Glover River, and they speculated that harsh conditions in southeastern Oklahoma contributed to low recruitment and a marginal fishery for this species. In northeast Oklahoma streams, Stark and Zale (1991) reported large numbers of younger-age fish and an uneven age distribution. However, we found smallmouth bass to have a steadily declining but relatively even age distribution in Baron Fork Creek.

We found substantial differences in mean density and biomass of smallmouth bass and black bass compared to results reported by Stark and Zale (1991) for Baron Fork Creek and Glover River (Table 6). In Baron Fork Creek, our estimates of smallmouth bass numbers and mass were six times lower and black bass were nearly four times lower than those given by Stark and Zale (1991). Part of this discrepancy may reflect an extreme estimate they reported, which was 90% higher in density and 79% higher in biomass than their next lower estimate. Ignoring this outlying value, our estimates of mean smallmouth bass and black bass densities in Baron Fork Creek were similar to previous reports (Table 6; smallmouth bass = 103 ± 100 (SD); black bass = 138 ± 131 (SD); N = 3),showing that, as Stark and Zale (1991) suggested, Baron Fork Creek still supports a high quality fishery. However, their samples had more biomass than ours (Table 6; smallmouth bass = 27.5 ± 32 (SD); black bass = 35.7 ± 33.9 (SD); N = 3), indicating a greater proportion of large individuals. In Glover River, we found smallmouth bass to be nine times more abundant with 75% more biomass than Stark and Zale (1991) reported. Similarly, our estimates of black bass abundance were two times greater than Stark and Zale's (1991) estimates, but our lower biomass estimates indicate they found a greater proportion of large individuals. The disparity between the two studies in density estimates for smallmouth bass and black bass in Glover River indicates that either production has improved since Stark and Zale's (1991) study or that they underestimated density. Three of five samples made by Stark and Zale (1991) were from areas easily accessible by anglers; thus, harvesting might explain their lower estimates of density and biomass.

Comparisons of our mean density and biomass estimates of smallmouth bass to other regional values (Table 6) indicate that abundances in Baron Fork

Creek and Glover River are intermediate to those reported for Missouri streams and slightly below those found in Wisconsin streams. Biomass estimates for Baron Fork Creek are similar to those for Wisconsin streams and the Current River, Missouri, but are well below those reported for Jacks Fork River, Missouri. In Glover River, biomass was generally two to four times less than that reported for streams in Missouri and Wisconsin, supporting our conclusion that this population consists of mostly young fish, with poor recruitment to older ages.

Sunfish were abundant in our samples from both streams. Mean sunfish density (Table 6) was well above that reported for Baron Fork Creek and Glover River by Stark and Zale (1991), but mean biomass values were generally similar. As with smallmouth bass and black bass, Stark and Zale (1991) found a higher percentage of large-sized sunfish than we collected in our samples in both streams.

Growth for age 1 through 3 smallmouth bass in Baron Fork Creek was slightly less than previous reports for this stream and the Illinois River (Stark and Zale 1991; Carlander 1977), but exceeded those for age 4 and 5 fish (Table 3). This differs from Stark and Zale's (1991) hypothesis that, based on poor growth rates in older ages, smallmouth bass in northeast Oklahoma may have reached carrying capacity. Our findings indicate that young smallmouth bass may be competing for food, whereas older fish may be exploiting a more abundant food base than was previously available. The Illinois River Basin is one of the nation's leading poultry producing areas (Nolan et al. 1989). In addition to municipal effluents, nonpoint source nutrient loading from the enormous poultry industry has drastically increased nutrients in the watershed. From 1975 to 1986, phosphorus loads increased 135% and nitrogen loads increased 6% to the basin (Nolan et al. 1989), and increased algal blooms in Lake Tenkiller are resulting from these changes. It is plausible that this sustained increase in nutrients has also boosted primary production in Baron Fork Creek, which in turn has increased production of forage fish, thereby benefiting growth of older age smallmouth bass. However, further study is needed to investigate whether land use changes are affecting smallmouth bass production. Regionally, smallmouth bass of all ages in Baron Fork Creek grew faster than their counterparts in Big Buffalo Creek, Missouri, but much slower than those in the Tennessee River, Alabama (Table 3).

Our estimates of smallmouth bass growth in Glover River can only be reasonably compared to values in the literature for ages 1 through 3, because of low sample sizes in older ages (Table 3). Within these groups, growth of smallmouth bass was similar to reports for age 1 and 2 fish, but age 3 fish had faster growth than previously reported (Orth et al. 1983). Conversely, Stark and Zale (1991) found faster growing fish at all three ages in Mountain Fork River, Oklahoma, but they made one of their estimates below the impounded portion of this stream, where regulated flows have been shown to positively influence growth (King et al. 1991). As with Baron Fork Creek, our growth estimates for Glover River were higher than those in Big Buffalo Creek, Missouri, and lower than those of the Tennessee River, Alabama (Table 3).

Smallmouth bass in eastern Oklahoma streams are not long lived. The maximum ages detected in our study were 6 years in Baron Fork Creek and 5 years in Glover River. Similarly, Orth et al. (1983) and Finnell et al. (1956) found no individuals over age 6; however, Stark and Zale (1991) collected one 7-year-old fish from Mountain Fork River, Oklahoma. Jenkins et al. (1952) suggested that large adults may be sparse in northeastern Oklahoma because of over-harvest from illegal gigging. We are unaware of this activity occurring in either stream, but angling is common in both systems (Martin 1995). Smallmouth bass are often preferred by anglers (Fajen 1975a; Fleener 1975; and Forbes 1989; Martin 1995), but mean fishing mortality for black bass is low in both streams (Baron Fork Creek = 12% ± 4% (SD); Glover River = 12% ± 6% (SD); N = 2), indicating a high natural mortality rate for adult fish (Martin 1995). Even so, angler exploitation is an apparent and controllable cause of mortality; therefore, the black bass fishery in these streams could benefit from management of angler harvest.

Total annual mortality for smallmouth bass in Baron Fork Creek in 1994 was among the lowest reported in the literature (Table 5), but exceeded values reported for Missouri and Iowa streams in 1995. Although this disparity may be attributable to variability in our data, smallmouth bass in Baron Fork Creek never had mortality rates in excess of 50%, a common characteristic of exploited streams (Paragamian and Coble 1975). Total annual mortality in Glover River could be assessed only for 1995, but out estimate of 67% (Table 5) exceeded most values reported in recent literature (e.g., 65% in Plover River, Wisconsin; Table 5).

Our results indicate that both Baron Fork Creek and Glover River sustain viable fisheries for smallmouth bass, other black bass, and sunfish, but population characteristics indicate distinct differences between the two streams. Most importantly, the fishery potential for smallmouth bass in Glover River seems limited by poor year-class success and high annual mortality, resulting in low recruitment to older ages. Alternatively, the characteristics of the smallmouth bass population in Baron Fork Creek are generally similar to other regional populations and earlier reports for this stream, except for a slight decline in the abundance of large individuals caused by natural and fishing mortality in older ages. However, the differences between these two smallmouth bass populations may be, in part, a function of differences in physical characteristics of the streams and land use practices within the two watersheds.

The Baron Fork Creek drainage basin has relatively undisturbed lands (OSEI 1996), a result of conservative land use practices compared to that of the Glover River (Stark and Zale 1991). Land use within the Little River drainage basin which includes the Glover River, has changed considerably over the last 40 years, noted by a steady drop in the amount of farmland and a significant increase in silviculture activities (Rutherford et al. 1987). Associated with this change is extensive clear-cutting of forests and associated road building.

Rutherford et al. (1987) reported that over 16,200 ha of land are clear-cut annually, and more than 6,400 km of logging roads have been built in southeastern Oklahoma since 1970, much of which occurs in the Little River drainage basin. The human population has always been low in this region, and silviculture practices seem to be the primary anthropogenic impact that affects the fish fauna in the drainage (Rutherford et al. 1987). Even so, Rutherford et al. (1992) found that streams in the Little River drainage are resilient to short-term watershed perturbances, but warned that the cumulative effects of silviculture activities over time may have significant influences on the faunal structure in the region.

Major silvicultural impacts to the Glover River likely include increased siltation (Burns 1972) and flow (Likens et al. 1970), both of which can negatively influence smallmouth bass populations. For example, smallmouth bass abundance is negatively correlated with siltation and turbidity (Trautman 1957; and Paragamian 1991), and Rabeni and Jacobson (1993) found that increased siltation homogenizes stream habitats, with less productive habitats replacing more productive ones, thereby reducing fish community diversity. Decreases in fish community diversity may result in the loss of critical prey species, thereby limiting black bass populations (Aadland 1993).

Loss of vegetation from clear-cutting in the Glover River drainage basin may augment runoff to an already flashy stream. The steep and rocky nature of the Glover River watershed is more conducive to catastrophic flood events than is Baron Fork Creek. For example, the 1994 instantaneous peak flow in Glover River was 1049 m^3/s, with a highest daily mean of 555 m^3/s (Blazs 1994), whereas Baron Fork Creek had an instantaneous peak flow of 262 m^3/s with a highest daily mean value of 184 m^3/s (Blazs 1994). Higher flows in the Glover River could negatively impact smallmouth bass populations by increasing mortality in young fish (Fajen 1975b), reducing reproductive success (Pflieger 1975), and indirectly reducing growth by increasing turbidity (Paragamian and Wiley 1987).

Flows in Baron Fork Creek are maintained by springs and are more stable than those in Glover River which are runoff dependent, and extremely low during periods of low moisture. For example, in 1994, the lowest daily mean flow in Baron Fork Creek was 1.4 m^3/s compared to 0.2 m^3/s in Glover River (Blazs et al. 1994). These low-flow periods in Glover River may reduce production and transportation of invertebrates, and increase stress to smallmouth bass (King et al. 1991).

Management Implications

Efforts to manage the fishery for smallmouth bass in eastern Oklahoma streams will need to reflect the regional differences in drainage basin characteristics and population attributes found in Baron Fork Creek and Glover River. It may also be necessary to manage land use in conjunction with fish populations to achieve the desired results. More specifically, smallmouth bass populations in eastern Oklahoma could be enhanced by maintaining conservative land use practices in the Illinois River drainage, and minimizing the impact of silviculture activities on the Little River watershed. For example, maintaining a well-vegetated riparian corridor and minimizing runoff from logging roads directly into the stream will be necessary to reduce sedimentation. The use of alternative timber harvest strategies (e.g., selective harvest) could also serve to increase vegetation structure in the drainage, thereby stabilizing flows and reducing turbidity. Possible benefits to the smallmouth bass fishery in Glover River and other streams within the basin include increased production, lower natural mortality, and higher recruitment to older ages. However, these are long-term management strategies that are logistically demanding, costly, and will require cooperation of landowners (e.g., the Weyerhauser Company).

In conjunction with proper watershed management, harvest regulations could be used to achieve management goals. Funk (1975) noted that appropriate regulations can benefit smallmouth bass fisheries by increasing biomass and improving the overall quality of fishing. Restrictive harvest regulations can maintain smallmouth bass densities at levels found in unexploited streams if growth is maintained and the resulting higher densities do not increase natural mortality (Reed and Rabeni 1989). Benefits to the smallmouth bass fishery in eastern Oklahoma could be realized more quickly, and with less expense, with the use of proper exploitation regulations, especially if there is angler cooperation and adequate enforcement.

Stark and Zale (1991) recommended a 229-mm to 305-mm slot-length limit for streams in northeastern Oklahoma to reduce competition in young smallmouth bass, and allow the harvest of some large individuals. Additionally, they recommended a low bag limit for fish over the slot to promote the harvest of smaller fish. Our results in Baron Fork Creek support these recommendations. We found reduced growth rates of young fish, indicating overcrowding, and increased growth in large individuals, but their biomass was slightly lower than earlier reports. Slot-length limits have been used to enhance populations with these characteristics. Smith and Kauffman (1991) found increases in smallmouth bass catch and harvest and increased growth in older ages under a slot-length limit in the Shenandoah River, Virginia. Similar regulations in Baron Fork Creek could reduce the numbers of young fish, potentially enhancing growth, and protect many older individuals from harvest. In southeastern Oklahoma, Stark and Zale (1991) suggested a 380-mm minimum length limit and a one fish per day creel limit for smallmouth bass. Under these guidelines, they expected the most productive part of these populations to be protected from harvest, while allowing anglers to keep an occasional trophy. The smallmouth bass fishery in Glover River could benefit from these recommendations, but 380-mm may be somewhat high. We found adequate growth rates in our samples, but high annual mortality and poor recruitment was limiting the potential of this fishery. However, few individuals near 380-mm were collected (Table 4). Hence, anglers fishing under the 380-mm minimum length restriction may never catch a harvestable fish. A lower minimum length limit (e.g. 360 mm) would still reduce angler mortality in the critical age classes and increase recruitment to older ages. Additionally, anglers could keep larger fish that are near their maximum attainable age in Oklahoma.

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Table 1.– Age specific and total density (individuals/ha) and biomass (kg/ha) of smallmouth bass in Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995.

Age	Density (no./ha)	Biomass (kg/ha)
	Baron Fork Creek - 1994	
0	26	0.23
1	32	1.25
2	25	3.18
3	20	6.64
4 plus	12	7.69
Total	115	18.99
	Baron Fork Creek - 1995	
0	3	0.01
1	48	1.49
2	29	3.39
3	10	4.06
4 plus	8	4.34
Total	98	13.29
	Glover River - 1994	
0	15	0.09
1	32	1.41
2 plus	5	2.98
Total	52	4.48
	Glover River - 1995	
0	113	0.79
1	34	2.79
2	21	4.31
3 Plus	3	1.01
Total	171	8.9

Table 2.--Total density (individuals/ha), and biomass (kg/ha) of black bass (smallmouth bass, largemouth bass, and spotted bass combined) and sunfish (bluegill sunfish, green sunfish, longear sunfish, redear sunfish, rock bass, and warmouth combined) in Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995.

Species	Density (no./ha)	Biomass (kg/ha)
	Baron Fork Creek - 1994	
Black Bass	146	30.95
Sunfish	885	50.45
	Baron Fork Creek - 1995	
Black Bass	215	26.45
Sunfish	758	23.5
	Glover River - 1994	
Black Bass	118	10.97
Sunfish	1631	37.51
	Glover River - 1995	
Black Bass	171	11.29
Sunfish	2998	38.97

Table 3.–Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for smallmouth bass from Baron Fork Creek and Glover River in eastern Oklahoma. Lengths with one letter in common within a colomn are not significantly different (Wilcoxon two-sample test; P = 0.05). Tests were not performed on age classes with samples sizes less than five.

	Mean back-calculated total length ± SE						
	Annulus						
Stream and state	1	2	3	4	5	6	Source
Baron Fork Creek, OK	a 89 ± 18 (85)	a 161 ± 28 (51)	228 ± 36 (32)	282 ± 41 (22)	357 ± 34 (4)	388 (1)	This study
Glover River, OK	a 91 ± 12 (26)	a 168 ± 25 (12)	239 ± 14 (4)	299 (1)	360 (1)		This study
			Other Oklahoma values				
Baron Fork Creek, OK	95	187	242	273	296		Stark and Zale 1991
Illinois River, OK	90	177	242	310			Carlander 1977
Glover River, OK	92	161	216	247	300	342	Orth et al. 1983
Mountain Fork River, OK	120	203	258	297	341	411	Stark and Zale 1991
			Regional values				
Tennessee River, AL	98	179	273	367	437	489	Weathers and Bain 1992
Big Buffalo Creek, MO	78	134	183	233	278	321	Reed and Rabeni 1989

Table 4.–Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for smallmouth bass in Baron Fork Creek (BFC) and Glover River (GR), Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

	Mean total length ± SD, (range), sample size				Comparison			
	Stream and year				Within streams between years		Between streams within years	
Age	BFC 94	BFC 95	GR 94	GR 95	BFC	GR	94	95
0	83 ± 12 (16)	47 ± 11 (2)	87 ± 12 (9)	82 ± 15 (27)	-	NS	NS	-
1	150 ± 11 (19)	133 ± 20 (39)	164 ± 14 (19)	190 ± 13 (8)	0.002	0.001	0.003	0.001
2	215 ± 37 (15)	212 ± 23 (24)	348 ± 68 (3)	257 ± 14 (5)	NS	-	-	0.001
3	296 ± 17 (13)	313 ± 15 (8)	-	302 (1)	0.03	-	-	-
4	385 ± 26 (7)	347 ± 11 (6)	-	-	0.02	-	-	-

Table 5.--Estimated total annual mortality (%) and survival (%) for smallmouth bass in Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995.

Stream and state	Annual mortaltiy	Survival	Source
	1994		
Baron Fork Creek, OK [a]	28	72	This study
	1995		
Baron Fork Creek, OK [a]	46	54	This study
Glover River, OK	67	33	This study
	Other Oklahoma values		
Glover River, OK [a]	61	39	Orth et al. 1983
	Other regional values		
Current River, MO	40	60	Covington et al. 1983
Jacks Fork River, MO	36	64	Covington et al. 1983
Upper Iowa River, IA	42	58	Paragamian 1984
Red Cedar River, WI	55	45	Paragamian and Coble 1975
Plover River, WI	65	35	Paragamian and Coble 1975

[a] Estimates based on fish $\geq$ age 1 due to an inadequate sample of age 0 fish.

Table 6.–Total density (individuals/ha) ± standard deviation and biomass (kg/ha) ± standard deviation of smallmouth bass, black bass (smallmouth bass, largemouth bass, and spotted bass combined), and sunfish (bluegill sunfish, green sunfish, longear sunfish, redear sunfish, rock bass, and warmouth combined) compared to values reported from other streams.

Stream and state	Density (no./ha)	Biomass (kg/ha)	Source
	Smallmouth Bass		
Baron Fork Creek, OK [a]	107 ± 12	16.1 ± 4	This study
Glover River, OK [a]	112 ± 84	6.7 ± 3.1	This study
Baron Fork Creek, OK [b]	656 ± 1109	95.8 ± 139	Stark and Zale 1991
Glover River, OK [c]	12 ± 12	1.7 ± 2.1	Stark and Zale 1991
Jacks Fork River, MO	142	28.5	Covington et al. 1983
Current River, MO	44	10.5	Covington et al. 1983
Plover River, WI	118	17.5	Paragamian and Coble 1975
Red Cedar River, WI	132	15.1	Paragamian and Coble 1975
	Black Bass		
Baron Fork Creek, OK [a]	181 ± 49	28.7 ± 3.2	This study
Glover River, OK [a]	145 ± 37.5	11.1 ± 0.2	This study
Baron Fork Creek, OK [b]	683 ± 1094	102 ± 135.3	Stark and Zale 1991
Glover River, OK [c]	63 ± 41	9.7 ± 7.2	Stark and Zale 1991
	Sunfish		
Baron Fork Creek, OK [a]	822 ± 90	37 ± 19.01	This study
Glover River, OK [a]	2315 ± 967	38.2 ± 1	This study
Baron Fork Creek, OK [b]	537 ± 228	34.6 ± 8.2	Stark and Zale 1991
Glover River, OK [c]	227 ± 174	16.2 ± 14.4	Stark and Zale 1991

[a] Values represent a mean of two estimates (one in 1994 and one in 1995) ± standard deviation.
[b] Values represent a mean of four estimates ± standard deviation.
[c] Values represent a mean of five estimates ± standard deviation.

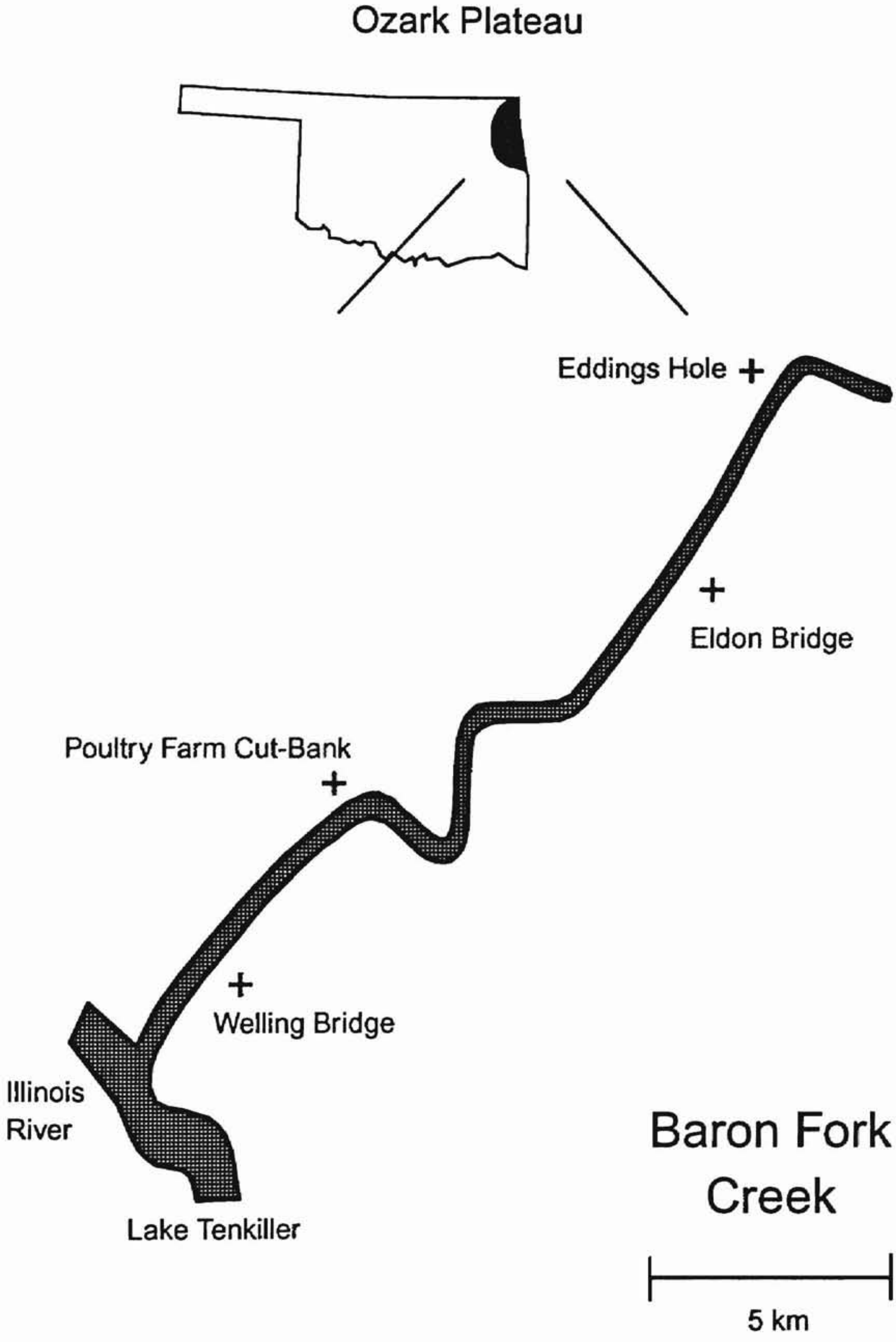
Figure Captions

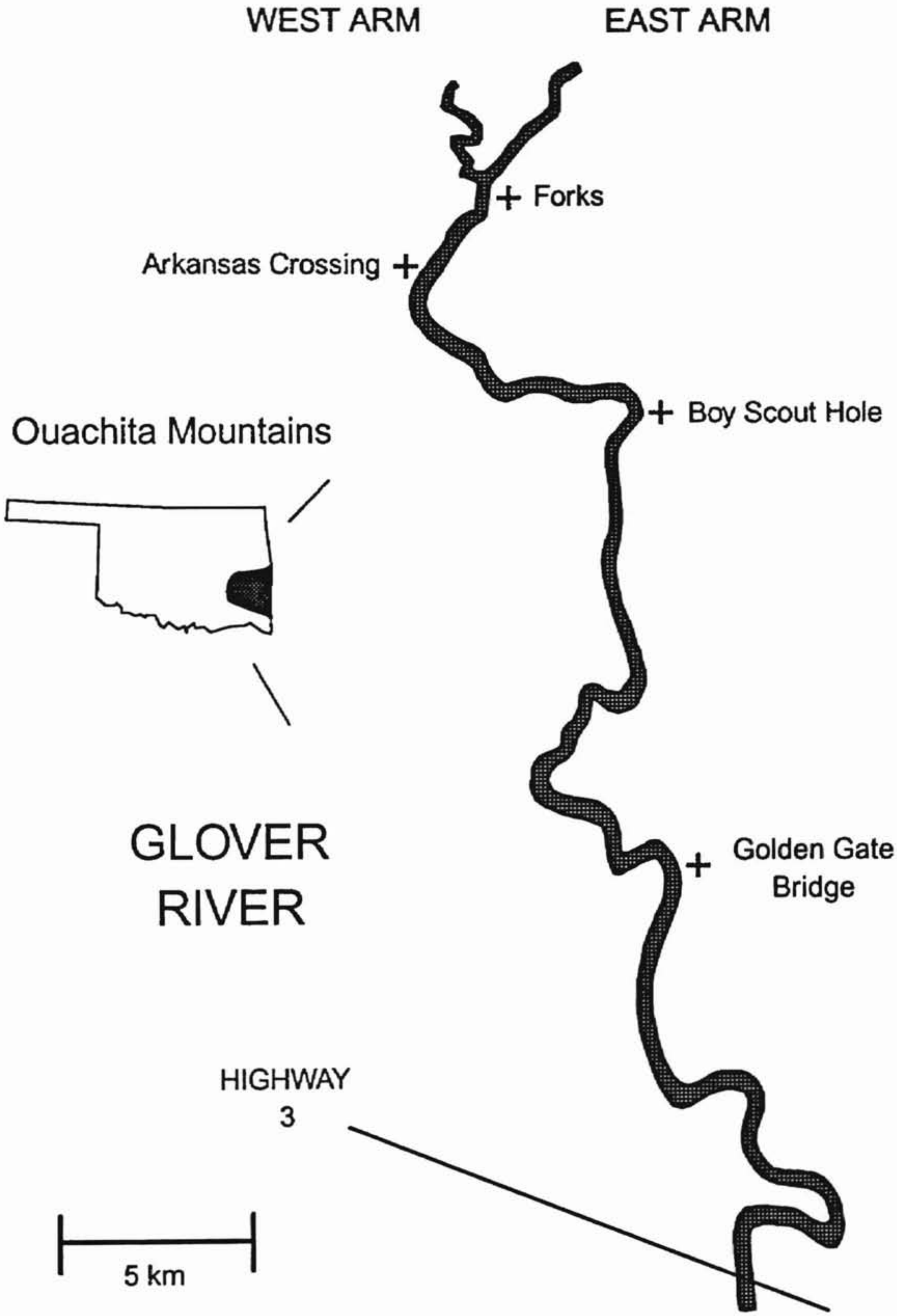
1. Study area on Baron Fork Creek in the Ozark Plateau in eastern Oklahoma. Plus signs denote fish sampling sites.

2. Study area on Glover River in the Ouachita Mountains in southeastern Oklahoma. Plus signs denote fish sampling sites.

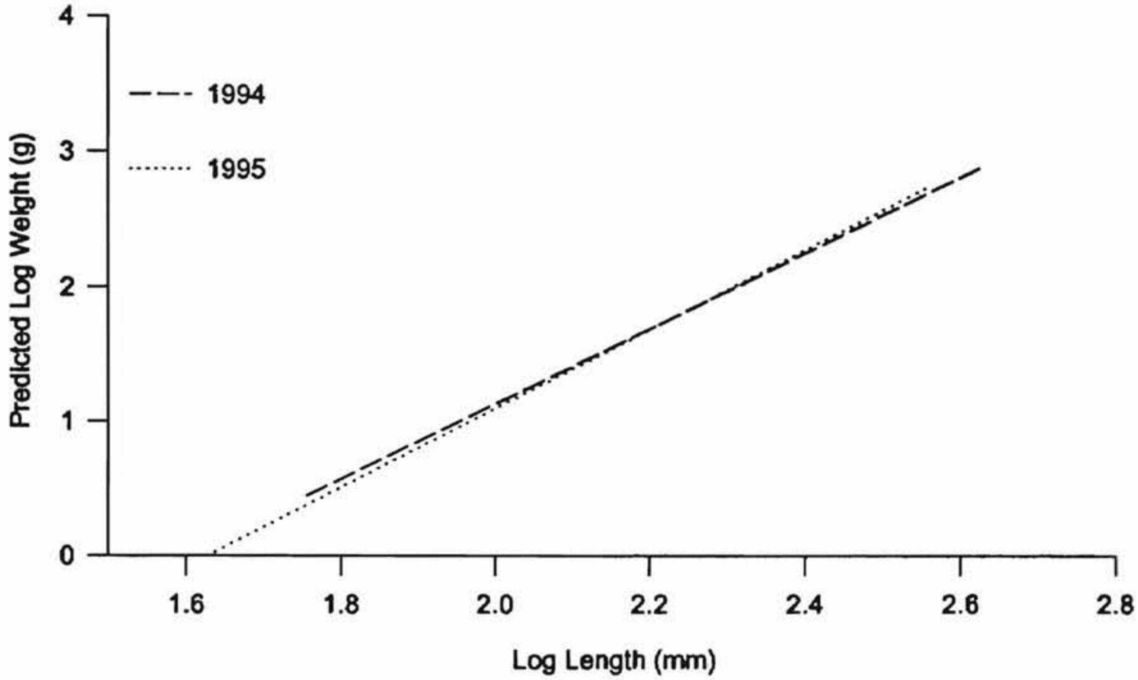
3. Between-year comparisons of the relation between log length (mm) and predicted log weight (g) for smallmouth bass collected during 1994 and 1995 from Baron Fork Creek and Glover River, Oklahoma.

4. Between-stream comparisons of the relation between log length (mm) and predicted log weight (g) for smallmouth bass collected from Baron Fork Creek and Glover River, Oklahoma during 1994 and 1995. Asterisks denote significant differences between the two lines at a specific value of log length (Analysis of Covariance test; $\underline{P} = 0.05$).

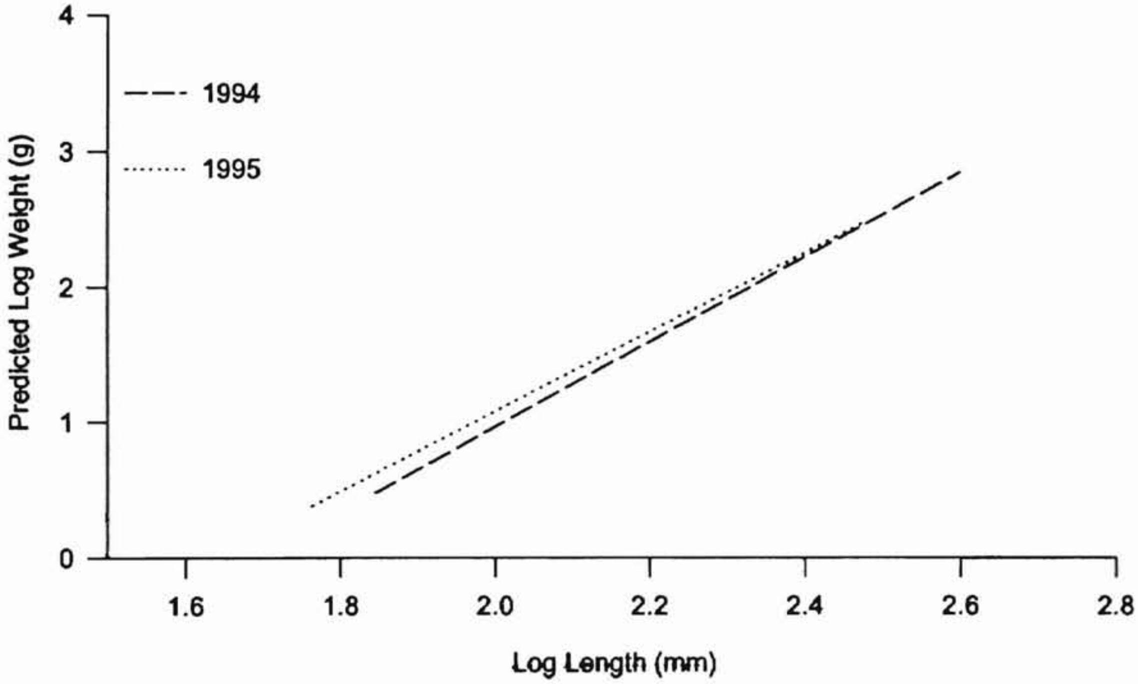

Ozark Plateau
Eddings Hole
Eldon Bridge
Poultry Farm Cut-Bank
Welling Bridge
Illinois
River
Lake Tenkiller
Baron Fork
Creek
5 km


WEST ARM
EAST ARM
Forks
Arkansas Crossing
Boy Scout Hole
Ouachita Mountains
GLOVER
RIVER
Golden Gate
Bridge
HIGHWAY
3
5 km

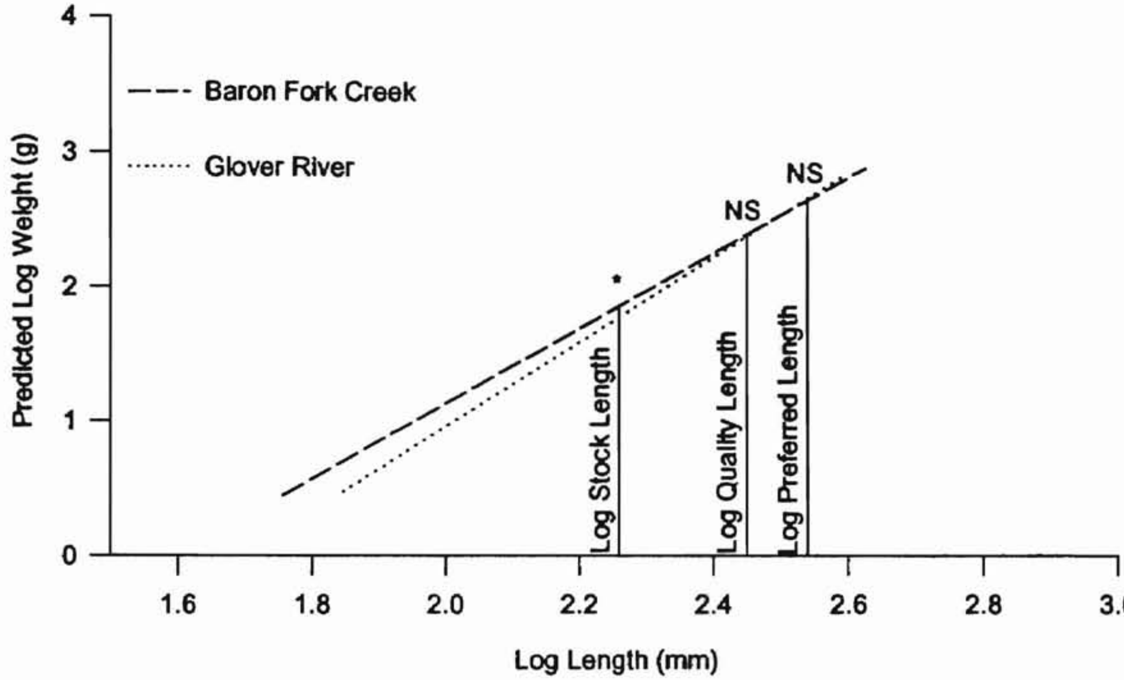
Baron Fork Creek



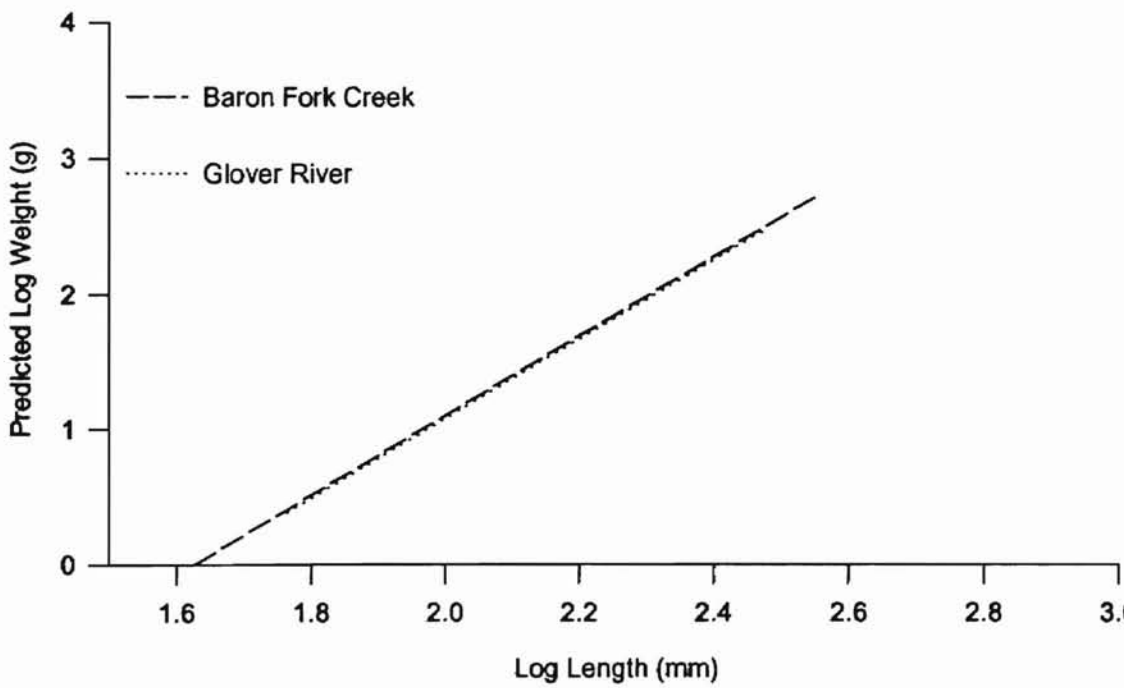
Glover River



1994


Baron Fork Creek
Glover River
Predicted Log Weight (g)
Log Length (mm)
NS
NS
*
Log Stock Length
Log Quality Length
Log Preferred Length
0
1
2
3
4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0

1995


Baron Fork Creek
Glover River
Predicted Log Weight (g)
Log Length (mm)
0
1
2
3
4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0

Appendixes

Appendix A.--Legal descriptions and vernacular references of sample localities in Baron Fork Creek and Glover River, Oklahoma. Abbreviated site names correspond to those in Figures 1 and 2.

Appendix A.--Legal descriptions and vernacular references of sample localities in Baron Fork Creek and Glover River, Oklahoma. Abbreviated site names correspond to those in Figures 1 and 2.

SITE	DESCRIPTION
EB	Baron Fork Creek: Illinois River; Cherokee Co., OK; T17N, R23E, SE 1/4 Section 27. From 200 m upstream of the Eldon bridge up to the eastward bend in the stream.
WB	Baron Fork Creek: Illinois River; Cherokee Co., OK; T16N, R23E, NE 1/4 Section 18. Pool above, underneath, and below the Welling bridge down to the riffle head.
EH	Baron Fork Creek: Illinois River; Cherokee Co., OK; T17N, R23E, SE 1/4 Section 14. Private property of Elmo Eddings.
PF	Baron Fork Creek: Illinois River; Cherokee Co., OK; T16N, R23E, NW 1/4 Section 9. Private property, cut bank near the poultry farm 1/2 mile upstream of Camp Heart O' Hills.
AC	Glover River: McCurtain Co., OK; T3S, R22E, NW 1/4 Section 13. 1/4 mile upstream from "Arkansas" low-water crossing near campsite on west side of stream.
FK	Glover River: McCurtain Co., OK; T3S, R23E, NW 1/4 Section 7. From low-water bridge upstream to the forks.
BS	Glover River: McCurtain Co., OK; T4S, R23E, SW 1/4 Section 8. Dierks boy scout camp access, private property.
GG	Glover River: McCurtain Co., OK; T4S, R23E, NE 1/4 Section 32. From "Golden Gate" low-water bridge downstream to bend in stream.

Appendix B.–Age-specific and total density (individuals/ha), and biomass (kg/ha) of largemouth bass in Baron Fork Creek, Oklahoma, 1994 and 1995.

Appendix B.--Age-specific and total density (individuals/ha), and biomass (kg/ha) of largemouth bass in Baron Fork Creek, Oklahoma, 1994 and 1995.

Age	Density (no./ha)	Biomass (kg/ha)
	1994	
1	13	1.18
2	10	1.83
3	7	1.95
4	3	1.84
5	3	2.88
6 plus	1	1.04
Total	37	10.72
	1995	
0	57	0.71
1	13	1.3
2	13	4.07
3 plus	4	3.63
Total	87	9.71

Appendix C.–Age-specific and total density (individuals/ha) and biomass (kg/ha) of longear sunfish in Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995.

Appendix C. Age-specific and total density (individuals/ha) and biomass (kg/ha) of longear sunfish in Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995.

Age	Density (no./ha)	Biomass (kg/ha)
	Baron Fork Creek - 1994	
0	16	0.08
1	28	0.28
2	164	2.95
3	80	2.16
4	64	2.37
5	52	2.34
6 plus	8	0.46
Total	396	10.56
	Baron Fork Creek - 1995	
0	7	0.04
1	148	1.48
2	84	1.6
3	63	1.95
4	46	2.3
5 plus	4	0.63
Total	352	8
	Glover River - 1994	
0	53	0.21
1	543	4.34
2	320	5.12
3	107	3
4 plus	43	1.81
Total	1066	14.48
	Glover River - 1995	
0	482	1.93
1	1239	7.43
2	413	7.02
3	92	2.67
4	46	1.98
5 Plus	6	0.31
Total	2278	21.34

Appendix D.–Age-specific and total density (individuals/ha) and biomass (kg/ha) of bluegill sunfish and rock bass in Baron Fork Creek, Oklahoma, 1994 and 1995.

Appendix D. Age-specific and total density (individuals/ha) and biomass (kg/ha) of bluegill sunfish and rock bass in Baron Fork Creek, Oklahoma, 1994 and 1995.

Age	Density (no./ha)	Biomass (kg/ha)
	Bluegill Sunfish - 1994	
0	4	0.01
1	72	1.44
2	79	2.92
3	34	2.14
4	17	1.36
5 plus	11	0.97
Total	213	8.83
	Bluegill Sunfish - 1995	
0	77	0.31
1	61	0.98
2	30	0.81
3	25	0.88
4	18	0.88
5 plus	14	1.12
Total	225	4.98
	Rock Bass - 1994	
1	12	0.53
2	10	0.67
3	42	4.33
4 plus	10	1.34
Total	74	6.87
	Rock Bass - 1995	
0	2	0.02
1	3	0.07
2	6	0.31
3	19	1.73
4	13	1.37
5 plus	7	1.08
Total	50	4.58

Appendix E.--Age-specific and total density (individuals/ha), and biomass (kg/ha) of green sunfish in Glover River, Oklahoma, 1994 and 1995.

Appendix E.–Age-specific and total density (individuals/ha), and biomass (kg/ha) of green sunfish in Glover River, Oklahoma, 1994 and 1995.

Age	Density (no./ha)	Biomass (kg/ha)
	1994	
0	30	0.12
1	209	2.3
2	115	4.37
3	75	4.5
4	30	2.91
5	20	2.62
6 plus	20	4.14
Total	499	20.96
	1995	
0	27	0.11
1	404	4.04
2	189	6.43
3	34	3.09
4 plus	20	3.66
Total	674	17.33

Appendix F.--Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for largemouth bass from Baron Fork Creek in eastern Oklahoma.

Appendix F.–Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for largemouth bass from Baron Fork Creek in eastern Oklahoma.

Stream and state	Mean back-calculated total length ± SE, Annulus 1	2	3	4	5	6	7	Source
Baron Fork Creek, OK	93 ± 24 (47)	193 ± 49 (38)	264 ± 78 (19)	278 ± 62 (6)	323 (1)	365 (1)	419 (1)	This study
Other Oklahoma values								
Illinois River, OK	117	198	264	333	401	503		Carlander 1977
Little River, OK	107	216	287	361	424	470	498	Carlander 1977
Other regional values								
North Fork and Floyds River, KY	104	188	259	320	394	404		Carlander 1977
Missouri streams (mean)	109	218	292	335	353			Carlander 1977

Appendix G.--Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for longear sunfish from Baron Fork Creek and Glover River in eastern Oklahoma. Lengths with one letter in common within a colomn are not significantly different (Wilcoxon two-sample test; P = 0.05). Tests were not performed on age classes with samples sizes less than five.

Appendix G.–Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for longear sunfish from Baron Fork Creek and Glover River in eastern Oklahoma. Lengths with one letter in common within a colomn are not significantly different (Wilcoxon two-sample test; P = 0.05). Tests were not performed on age classes with samples sizes less than five.

Stream and state	Mean back-calculated total length ± SE, Annulus 1	2	3	4	5	Source
Baron Fork Creek, OK	a 47 ± 8 (52)	a 75 ± 10 (50)	a 96 ± 12 (34)	a 108 ± 11 (14)	112 ± 12 (3)	This study
Glover River, OK	b 54 ± 10 (60)	b 82 ± 9 (49)	b 104 ± 10 (31)	b 125 ± 10 (19)	134 ± 2 (2)	This study
Other Oklahoma values						
Illinois River, OK	58	89	112	127	135	Carlander 1977
Little River, OK	51	97	130	152		Carlander 1977
Other regional values						
Missouri streams (mean)	33	64	91	109	122	Carlander 1977
Kentucky streams (mean)	66	107	135	150		Carlander 1977

Appendix H.--Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for bluegill sunfish from Baron Fork Creek in eastern Oklahoma.

Appendix H.–Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for bluegill sunfish from Baron Fork Creek in eastern Oklahoma.

Stream and state	Mean back-calculated total length ± SE Annulus 1	2	3	4	5	6	Source
Baron Fork Creek, OK	45 ± 13 (46)	76 ± 17 (37)	105 ± 32 (26)	127 ± 17 (14)	144 ± 17 (5)	153 (1)	This study
			Other Oklahoma values				
Illinois River, OK	66	135	157	188	201		Carlander 1977
Little River, OK	51	102	145	170	198		Carlander 1977
			Other regional values				
Missouri streams (mean)	38	79	112	137	157		Carlander 1977

Appendix I.--Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for rock bass from Baron Fork Creek in eastern Oklahoma.

Appendix I.—Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for rock bass from Baron Fork Creek in eastern Oklahoma.

	Mean back-calculated total length ± SE					
	Annulus					
Stream and state	1	2	3	4	5	Source
Baron Fork Creek, OK	40 ± 12 (54)	96 ± 22 (52)	145 ± 28 (48)	171 ± 16 (27)	191 ± 12 (9)	This study
			Other Oklahoma values			
Illinois River, OK	43	107	147	188	206	Carlander 1977
			Other regional values			
Missouri streams (mean)	41	86	140	178	203	Carlander 1977
Kentucky streams (mean)	84	140	178	203		Carlander 1977

Appendix J.–Mean back-calculated total lengths (mm) at age ± standard deviation and sample size (N) for green sunfish from Glover River in eastern Oklahoma.

Stream and state	Mean back-calculated total length ± SE						Source
	Annulus						
	1	2	3	4	5	6	
Glover River, OK	48 ± 13 (91)	91 ± 20 (71)	127 ± 28 (41)	161 ± 32 (20)	167 ± 25 (3)	180 (1)	This study
			Other Oklahoma values				
Little River, OK	69	132	185	229	249		Carlander 1977
Oklahoma streams (mean)	81	132	168	185	213		Carlander 1977
			Regional values				
Missouri streams (mean)	41	81	114	140	157		Carlander 1977

Appendix K.--Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for largemouth bass in Baron Fork Creek , Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; $P = 0.05$. Tests were not performed on age classes with sample sizes less than five.

Appendix K.—Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for largemouth bass in Baron Fork Creek , Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

	Mean total length ± SD, (range), and sample size		
	Year		
Age	1994	1995	P
0	-	102 ± 12 (37)	-
1	198 ± 14 13	197 ± 30 8	NS
2	246 ± 17 10	283 ± 17 8	0.03
3	286 ± 9 (7)	386 ± 85 (3)	-
4	331 ± 8 (3)	-	-
5	408 ± 4 (3)	-	-
6	435 (1)	-	-

Appendix L.--Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for longear sunfish in Baron Fork Creek (BFC) and Glover River (GR), Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

Appendix L.–Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for longear sunfish in Baron Fork Creek (BFC) and Glover River (GR), Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

	Mean total length ± SD, (range), sample size				Comparison			
	Stream and year				Within streams between years		Between streams within years	
Age	BFC 94	BFC 95	GR 94	GR 95	BFC	GR	94	95
0	65 ± 2 (9)	56 ± 8 (5)	55 ± 10 (24)	51 ± 7 (255)	0.02	0.02	0.002	NS
1	78 ± 6 (14)	82 ± 5 (115)	78 ± 5 (272)	72 ± 7 (647)	0.01	0.001	NS	0.001
2	97 ± 5 (85)	99 ± 5 (67)	98 ± 6 (159)	99 ± 218 (218)	0.02	0.01	NS	NS
3	110 ± 3 (41)	115 ± 5 (51)	119 ± 4 (54)	117 ± 5 (44)	0.001	0.008	0.001	NS
4	121 ± 2 (33)	131 ± 4 (37)	135 ± 6 (21)	135 ± 4 (27)	0.001	NS	0.001	0.001
5	128 ± 2 (27)	212 ± 101 (2)	-	146 ± 3 (3)	-	-	-	-
6	140 ± 5 (5)	-	-	-	-	-	-	-

Appendix M.--Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for bluegill sunfish and rock bass in Baron Fork Creek , Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

Appendix M.--Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for bluegill sunfish and rock bass in Baron Fork Creek , Oklahoma, 1994 and 1995. Values within a comparison colomn are results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

Age	Mean total length ± SD, (range), and sample size		P
	Year		
	1994	1995	
	Bluegill Sunfish		
0	54 ± 15 (2)	59 ± 10 (51)	-
1	102 ± 8 (28)	97 ± 7 (40)	0.005
2	125 ± 7 (31)	116 ± 20 (20)	0.001
3	149 ± 6 (13)	126 ± 3 (17)	0.001
4	161 ± 2 (7)	139 ± 4 (12)	0.004
5	176 ± 5 (4)	159 ± 8 (9)	-
	Rock Bass		
0	-	82 ± 0 (2)	-
1	112 ± 7 (8)	103 ± 13 (3)	-
2	148 ± 13 7	136 ± 6 6	NS
3	179 ± 7 29	165 ± 8 19	0.001
4	208 ± 38 7	189 ± 6 13	NS
5	205 ± 4 (7)	-	-

Appendix N.–Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for green sunfish in Glover River, Oklahoma, 1994 and 1995. Between year comparison values are the results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

Appendix N.—Mean total lengths (mm) at capture ± standard deviation, and sample size (N) for green sunfish in Glover River, Oklahoma, 1994 and 1995. Between year comparison values are the results of a Wilcoxon two-sample test; P = 0.05. Tests were not performed on age classes with sample sizes less than five.

	Total length ± SD (range), and sample size		
	Year		
Age	1994	1995	P
0	64 ± 4 (11)	43 ± 5 (13)	0.001
1	88 ± 11 (81)	83 ± 12 (214)	0.001
2	135 ± 8 (44)	128 ± 12 (100)	0.002
3	156 ± 6 (29)	173 ± 19 (19)	0.001
4	178 ± 6 (12)	211 ± 20 (9)	0.001
5	195 ± 4 (7)	-	-
6	225 ± 12 (7)	-	-

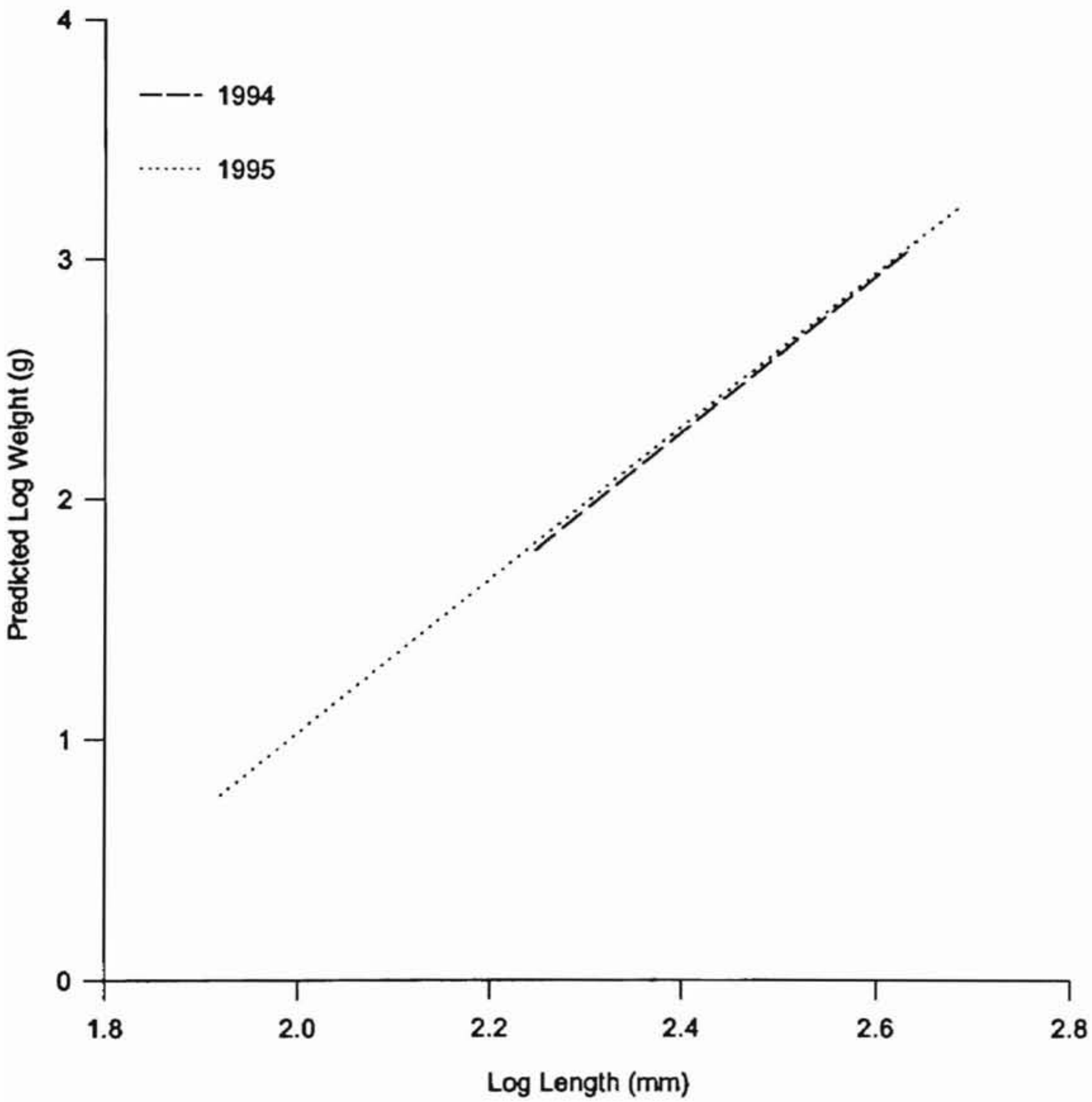
Appendix O.–Estimated total annual mortality (%) and survival (%) for largemouth bass, longear sunfish, bluegill sunfish, and rock bass in Baron Fork Creek, Oklahoma and longear sunfish and green sunfish in Glover River, Oklahoma, 1994 and 1995.

Appendix O.--Estimated total annual mortality (%) and survival (%) for largemouth bass, longear sunfish, bluegill sunfish, and rock bass in Baron Fork Creek, Oklahoma and longear sunfish and green sunfish in Glover River, Oklahoma, 1994 and 1995.

Species	Total annual mortality	Survival
	Baron Fork Creek - 1994	
Largemouth Bass [b]	40	60
Longear Sunfish [a]	51	49
Bluegill Sunfish [a]	49	51
Rock Bass [c]	76	24
	Baron Fork Creek - 1995	
Largemouth Bass	56	44
Longear Sunfish [b]	64	36
Bluegill Sunfish	29	71
Rock Bass [c]	39	61
	Glover River - 1994	
Longear Sunfish [b]	57	43
Green Sunfish [b]	39	61
	Glover River - 1995	
Longear Sunfish [b]	74	26
Green Sunfish [b]	65	35

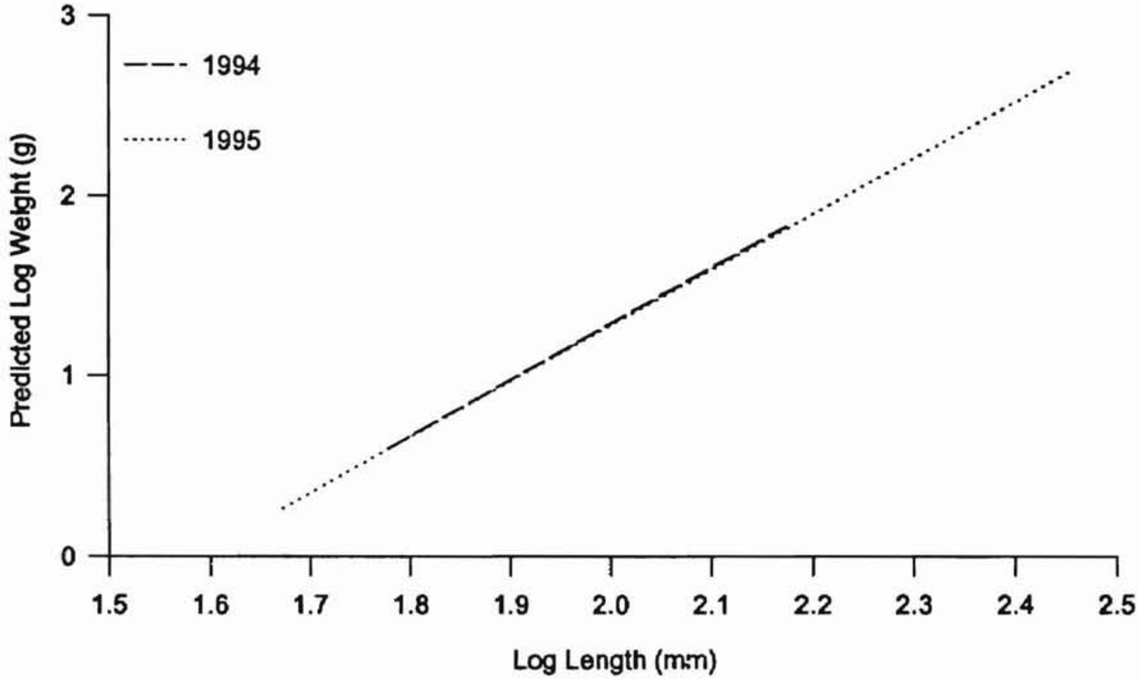
[a] Estimates based on fish ≥age 2 due to and inadequate sample of age 0 and 1 fish.
[b] Estimates based on fish ≥ age 1 due to an inadequate sample of age 0 fish.
[c] Estimate based on fish ≥ age 3 due to an inadequate sample of age 0, 1, and 2 fish.

Appendix P.--Between-year comparison of the relation between log length (mm) and predicted log weight (g) for largemouth bass collected from Baron Fork Creek, Oklahoma, 1994 and 1995.

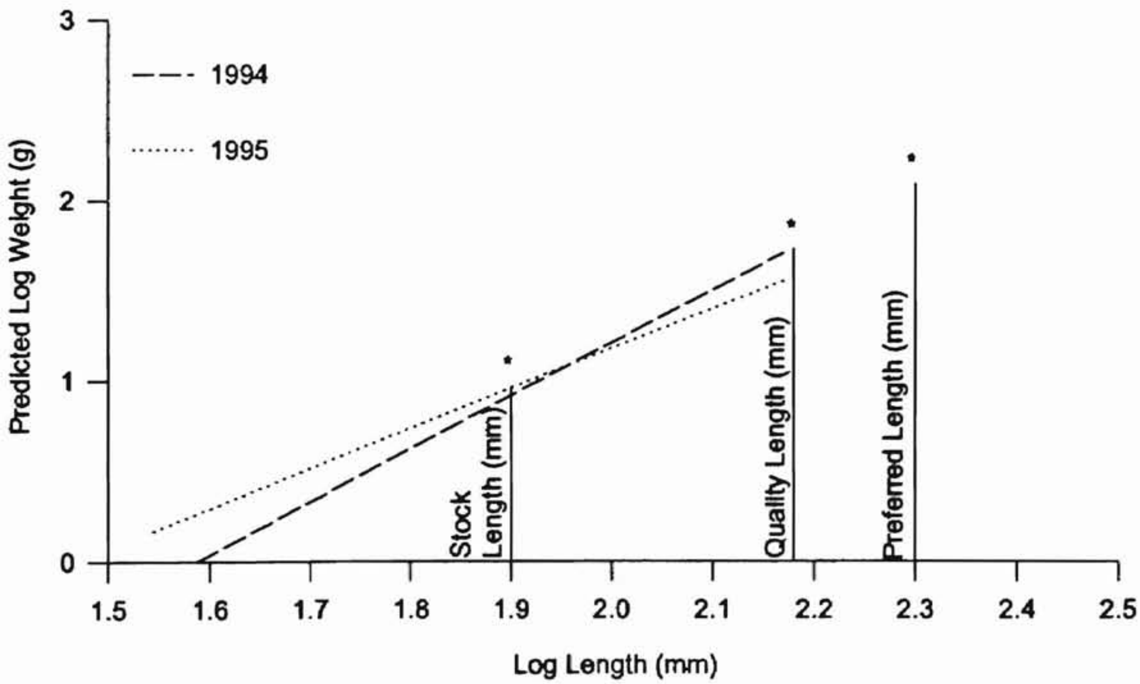

1994
1995
Predicted Log Weight (g)
Log Length (mm)
0
1
2
3
4
1.8
2.0
2.2
2.4
2.6
2.8

Appendix Q.–Between-year comparisons of the relation between log length (mm) and predicted log weight (g) for longear sunfish collected from Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995. Asterisks denote significant differences between the two lines at a specific value of log length (Analysis of Covariance test; P = 0.05).

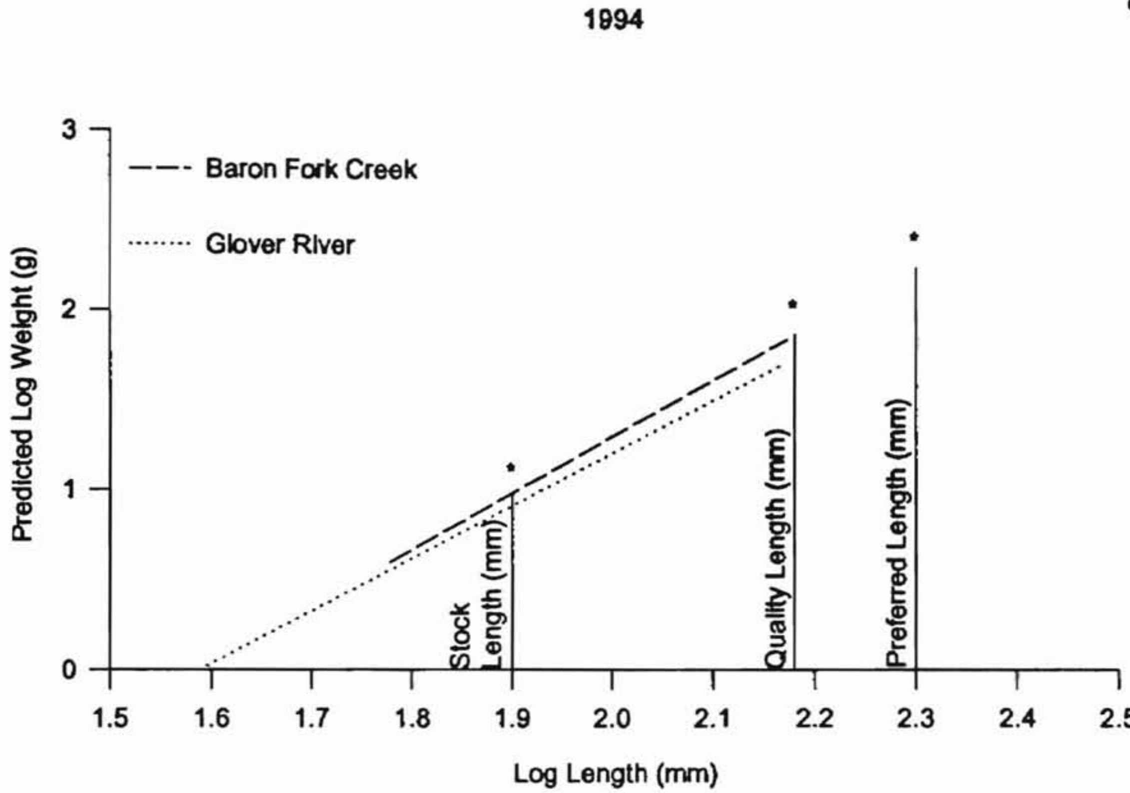
Baron Fork Creek

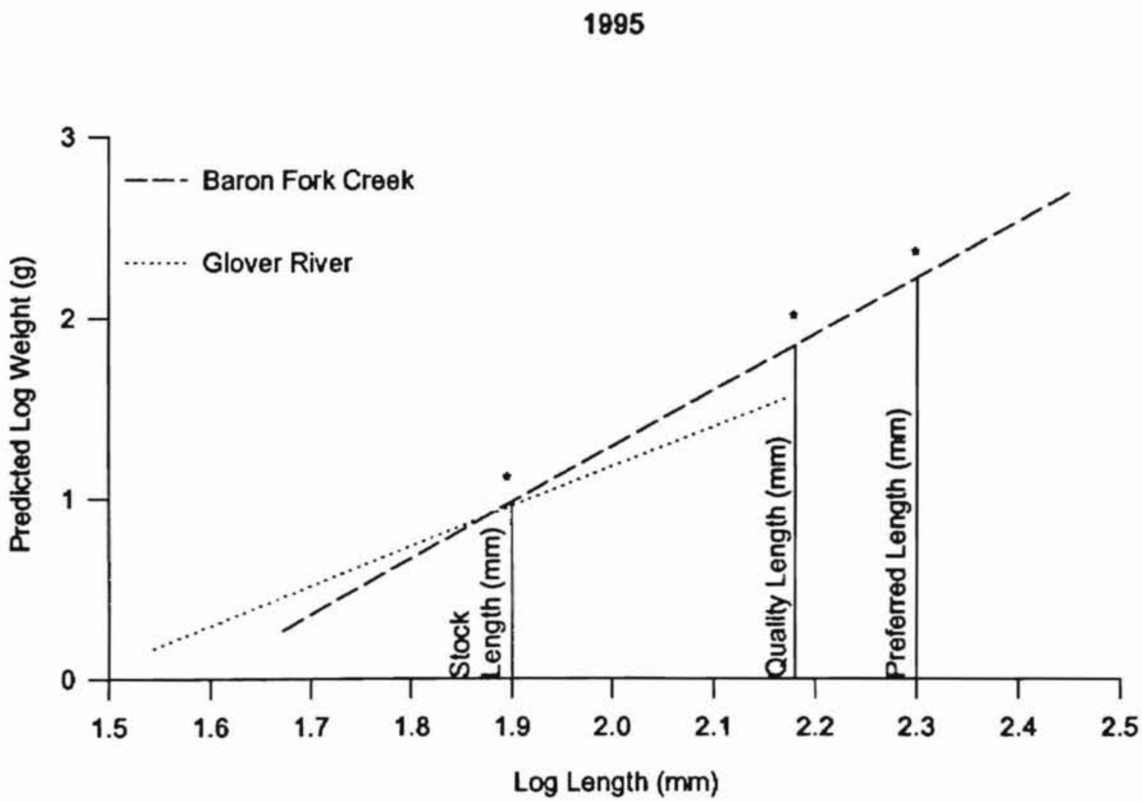


Glover River

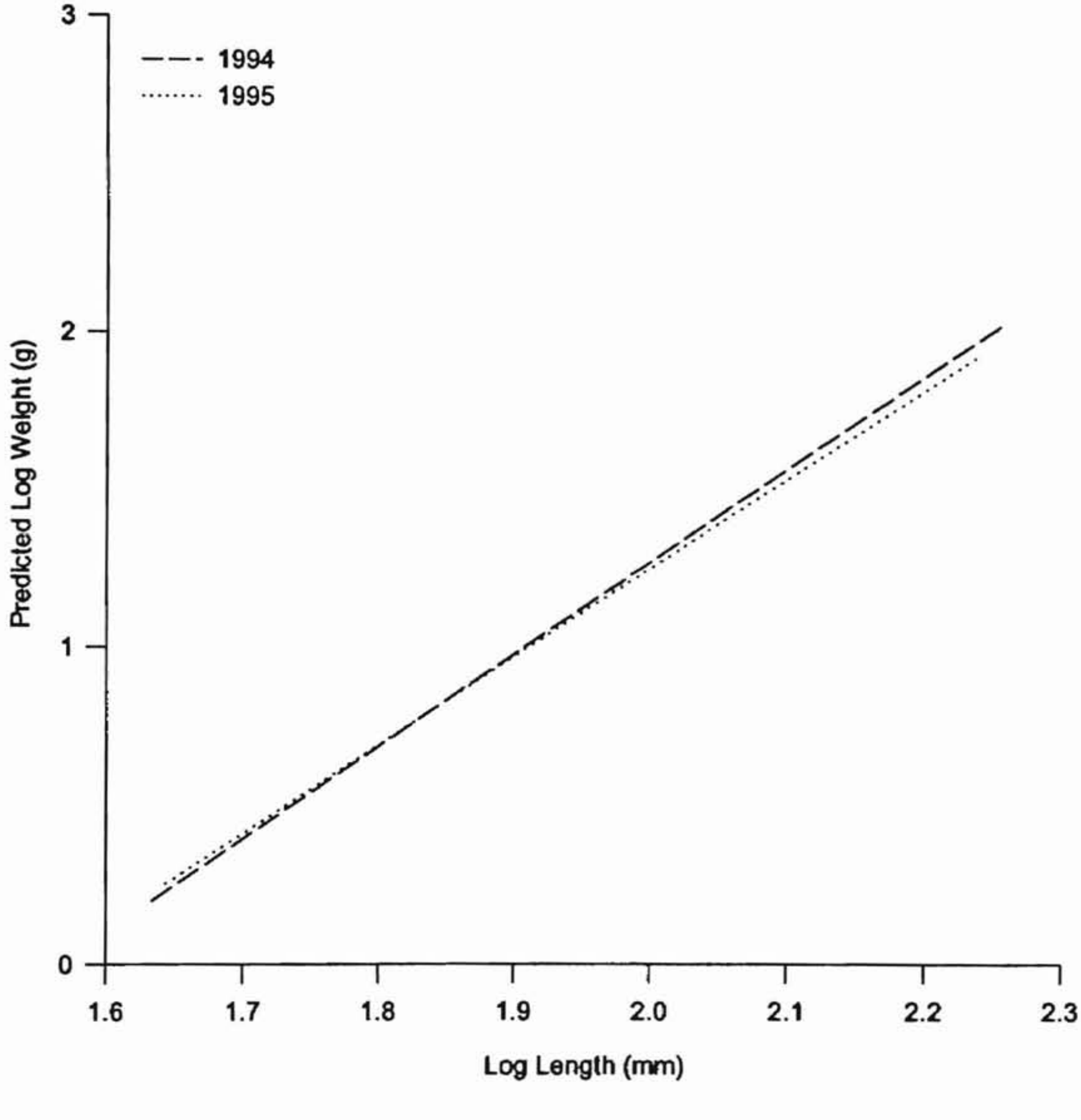


Appendix R.--Between-stream comparisons of the relation between log length (mm) and predicted log weight (g) for longear sunfish collected from Baron Fork Creek and Glover River, Oklahoma, 1994 and 1995. Asterisks denote significant differences between the two lines at a specific value of log length (Analysis of Covariance test; P = 0.05).


1994
Baron Fork Creek
Glover River
Predicted Log Weight (g)
Log Length (mm)
Stock Length (mm)
Quality Length (mm)
Preferred Length (mm)
0
1
2
3
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5

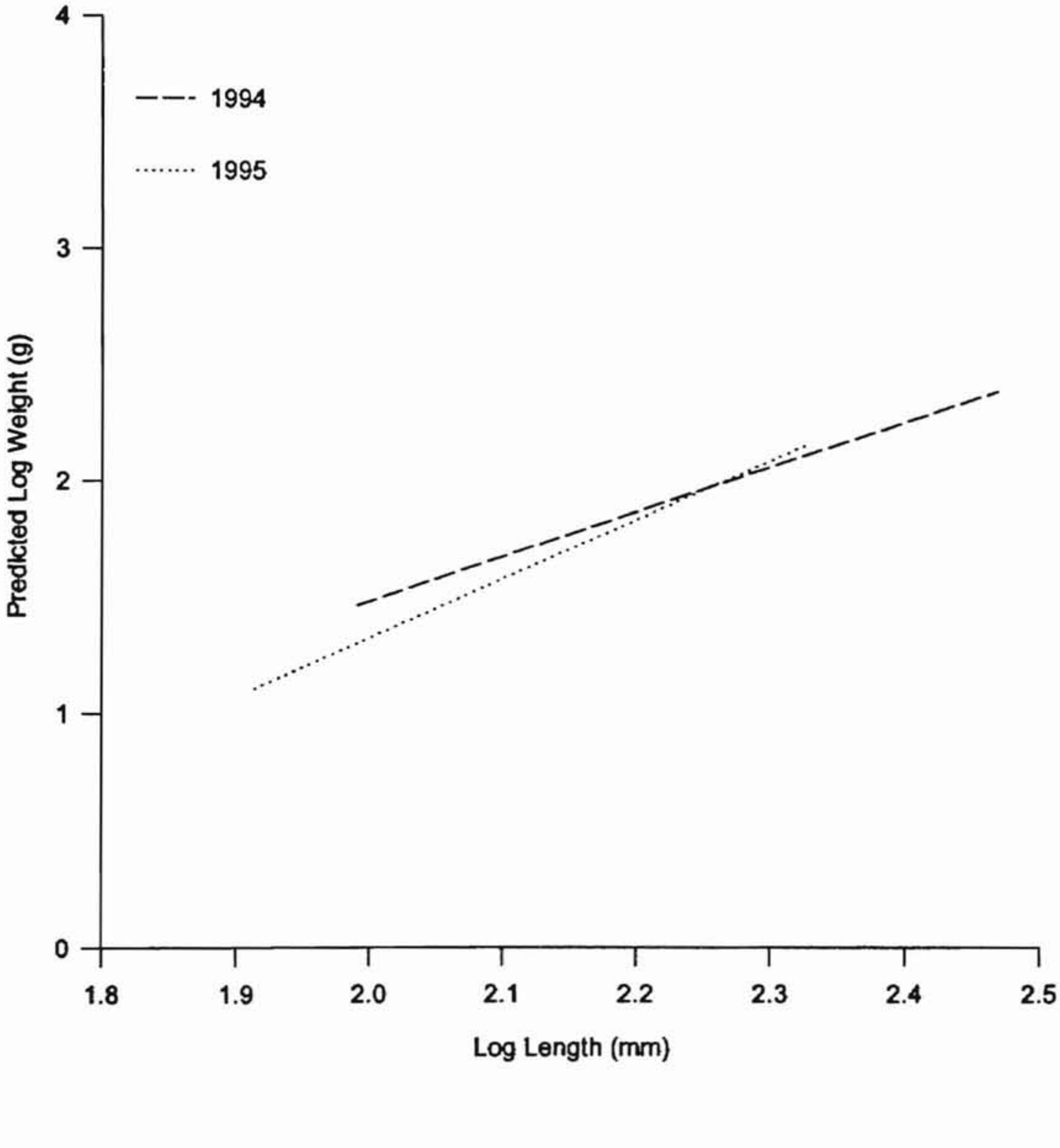

1995
Baron Fork Creek
Glover River
Predicted Log Weight (g)
Log Length (mm)
Stock Length (mm)
Quality Length (mm)
Preferred Length (mm)
0
1
2
3
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5

Appendix S.--Between-year comparison of the relation between log length (mm) and predicted log weight (g) for bluegill sunfish collected from Baron Fork Creek, Oklahoma, 1994 and 1995.

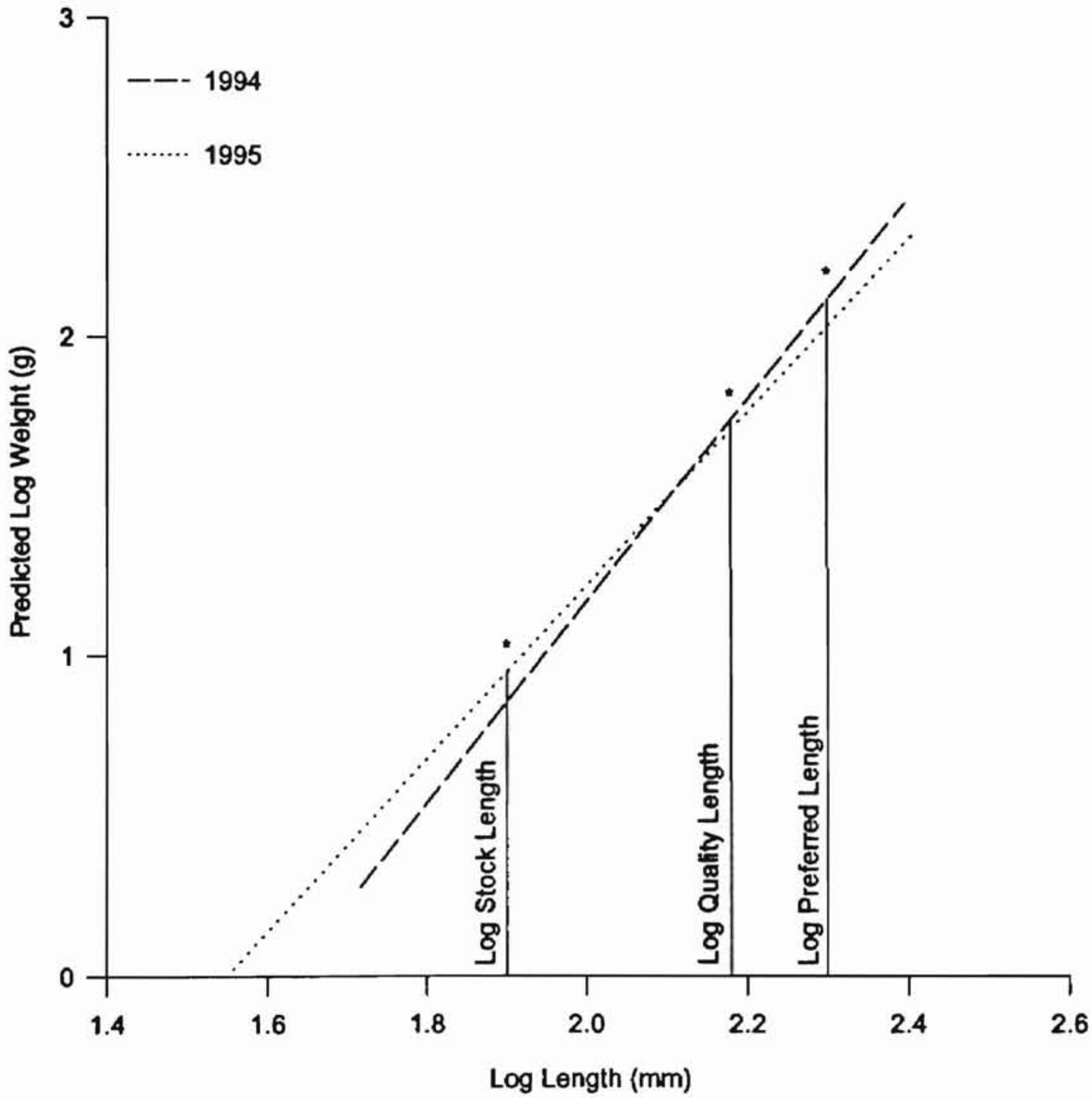


3
2
1
0
1994
1995
Predicted Log Weight (g)
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
Log Length (mm)

Appendix T.–Between-year comparison of the relation between log length (mm) and predicted log weight (g) for rock bass collected Baron Fork Creek, Oklahoma, 1994 and 1995.


4
3
2
1
0
Predicted Log Weight (g)
1994
1995
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
Log Length (mm)

Appendix U.--Between-year comparison of the relation between log length (mm) and predicted log weight (g) for green sunfish collected from Glover River, Oklahoma, 1994 and 1995.



3
2
1
0
1994
1995
Predicted Log Weight (g)
Log Stock Length
Log Quality Length
Log Preferred Length
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Log Length (mm)

CHAPTER III

SAMPLING CONSIDERATIONS FOR SPORT FISH IN EASTERN OKLAHOMA STREAMS

Paul E. Balkenbush

Oklahoma Cooperative Fish and Wildlife Research Unit

Department of Zoology, Oklahoma State University

Stillwater, OK 74078

Abstract.–We investigated two aspects of fish population size estimation related to stream sampling surveys: (1) the effects of sample site selection bias on fish abundance estimates, and (2) the use of fish habitat preferences for expanding population size estimates. Mean sport fish density, depth, and cover for high and low use areas in Baron Fork Creek were not significantly different. Conversely, high use areas in Glover River had higher sport fish densities, were deeper, and had more instream cover than low use areas. Mesohabitat specific catch-per-unit-effort rates for black bass species in Baron Fork Creek indicated that we correctly predicted mesohabitat use from preferences reported in the literature about 50% of the time, and that fish were not evenly distributed throughout the stream, but were aggregated by mesohabitat units. Ranking mesohabitats into use categories (high, medium, and low) for weighting expanded estimates of black bass abundance reduced unweighted estimates for smallmouth bass and black bass by 23% and 7% in Baron Fork Creek and 49% and 9% in Glover River, respectively. Biologists can overcome these biases and improve abundance estimates by using probability sampling routines and considering habitat use during population monitoring surveys.

Fish population density estimates provide the basic information needed to answer research questions and make management decisions about fisheries (Van Deventer and Platts 1983; Van Den Avyle 1993). Surveys of fish populations allow assessment of impacts of angler exploitation and the environment on fish stocks, fluctuation in fish density, and effects of management actions (Van Den Avyle 1993). Management decisions derived from these surveys have both biological and socioeconomic implications for a fishery (Hightower and Geaghan 1984; Thompson 1992). Therefore, survey data must be collected with a sound sampling design in an unbiased fashion in order to yield the information needed to achieve the objectives of a management plan (Johnson and Nielsen 1983).

Population sampling allows one to make inferences about the population by looking at only a portion of it (Johnson and Nielsen 1983; Thompson 1992). The main uncertainty in sampling is that only part of the population is observed (Thompson 1992), and the estimate of its size depends on the portions of the population sampled (Thompson 1992). Therefore, areas sampled must contain representative parts of the population, or bias is introduced into the estimate. Biased results consistently differ in the same direction from true values for the population (Hightower and Geaghan 1984; Moore 1985).

Randomization, or probability sampling, is often used to reduce bias that can inadvertently influence an experiment or survey (Krebs 1989; Thompson 1992; Wilde and Fisher 1996), and statistical conclusions can only be made for populations sampled according to the laws of chance (Skalski and Robson 1992). Even so, failure to randomize is a common source of bias in fisheries data (Hightower and Geaghan 1984). Limited access to sampling sites (Krebs 1989) and the widespread use of non-probability (e.g., fixed station) sampling procedures restrict the usefulness of survey data (Wilde and Fisher 1996).

Sampling frequently occurs where it is convenient, or is least threatening to those doing the sampling (Johnson and Nielsen 1983; Moore 1985), especially in stream fisheries investigations. Streams often occur in remote areas where roads are sparse, and their shallow nature can preclude the movement of sampling equipment to remote sites by water. Additionally, most stream access is privately owned and permission is needed for entrance. Therefore, stream sampling usually occurs at easily accessible (high) public access areas where roadways intersect streams at bridge and low-water crossings and in areas that are deep enough (e.g., pools) for gear maneuverability.

When stream fish population sampling occurs in high public access areas, the resulting data may reflect sampling bias. Human activity in these areas, such as angling and swimming, could directly remove or indirectly displace fish. For example, high access areas (e.g., bridge crossings) presumably have high angling pressure and harvest rates, whereas private or remote (low access) areas have restricted shoreline access and usually less angling pressure. Intense exploitation associated with high access areas can reduce standing crop (Fajen 1975), and production (Reed and Rabeni 1989), which may result in bias toward underestimating fish population densities. In addition, bridge structures and other channel modifications that alter stream habitat at high access areas may influence fish distributions and abundance.

Besides anthropogenic influences, biological populations are naturally distributed in such a complex manner that abundance estimates based on sampling in convenient or high access areas may be invalid (Krebs 1989). For example, stream fish are not uniformly distributed throughout a study reach, but they are associated with certain habitat types (Funk and Pflieger 1975; Paragamian and Coble 1975; Hendricks et al. 1980; Paragamian 1981; McClendon and Rabeni 1987; Hankin and Reeves 1988; Todd and Rabeni 1989; Lyons 1991). Presumably, suitable habitat is available in some form at most locations in a stream; however, not all stream locations are equally used (Todd and Rabeni 1989). This difference in longitudinal distribution and habitat-based aggregation of stream fish makes site-to-site comparisons of population estimates difficult (Hendricks et al. 1980; Thompson 1992), and expanded abundance estimates misleading (Funk 1975; Paragamian and Coble 1975; Hawkins et al. 1993).

We investigated two aspects of fish population size estimation related to stream sampling surveys: (1) the effects of sampling site selection bias on fish abundance estimates, and (2) the use of fish habitat preferences for expanding population size estimates. To evaluate sampling site selection bias, we compared the abundance of sport fish (centrarchids) in two eastern Oklahoma streams at easily accessible public use areas, which had high angling pressure and recreational activities, to that at remote areas where public access was limited and angling pressure was low. To expand population estimates of three black bass species in these two streams, we mapped mesohabitat types, quantified their areas with the aid of geographic information systems (GIS) technology, and coupled this information with literature-based and observed habitat preferences to weight abundance estimates by habitat type.

Methods

Study Area.--Baron Fork Creek and Glover River are scenic and unregulated waterways in eastern Oklahoma with viable fisheries. Baron Fork Creek is in the Ozark Plateau region of east central Oklahoma (Figure 1) and is characteristic of streams in this region with clear and cool water, stable base flow maintained by springs, and a gravel dominated substrate. Baron Fork Creek originates in Arkansas, then flows westward for 56.9 km (OKWRB 1990) through Adair and Cherokee counties, Oklahoma draining 936 km^2 (Storm et al. 1996) before it joins the Illinois River above Lake Tenkiller. Major land use in the basin includes pasture or rangeland, native forests (OSEI 1996), and numerous poultry producing operations (Nolan et al. 1989). Glover River is in the rugged and remote Ouachita Mountains of southeastern Oklahoma (Figure 2) and is typical of streams in this region with stream bottoms dominated by emergent bedrock and flow fed primarily by runoff. Glover River begins in Pushmataha and Leflore counties, Oklahoma and flows southerly for 54.2 km (OKWRB 1990) through McCurtain County, Oklahoma draining 876 km^2 (Orth and Maughan 1984) before joining the Little River. The basin is heavily forested and supports intensive silviculture activities, including clear-cutting of forests and associated road building (Rutherford et al. 1992).

Baron Fork Creek and Glover River also differ in the type and ease of access to the stream for recreation and sampling. The land bordering Baron Fork Creek is mostly private, and public use within our study area was restricted to three high access areas, two highway bridge crossings and a confluence access area at the Illinois River, maintained by the Oklahoma Scenic Rivers Commission. In Baron Fork Creek, favorable flow and substrate conditions and permission to enter private lands allowed us to transport sampling gear to remote (low access) areas between high access sites. Conversely, the Weyerhaeuser Company grants unlimited public access to the land bordering the Glover River study area. However, the remote nature of this stream limits physical access to low-water bridge crossings (high access areas) and some unimproved logging roads (low access areas) that end at the stream. Additionally, low summer flows and exposed bedrock substrate prohibited movement of sampling equipment up or downstream from high to low access sites. We entered low access areas in Glover River by driving remote logging roads with Weyerhaueser Company road maps until we were close enough to carry sampling equipment to the stream.

Sampling site bias.--Stream study reaches were defined, and potential sampling sites were chosen along a 16.7 km section of Baron Fork Creek (Figure 1), and a 38.6 km section of Glover River (Figure 2). Study sites were randomly selected at each stream from a pool of potential sampling sites including both high and low access areas. Randomly selected sampling sites included two high access sites (Eldon bridge and Welling bridge) and two low access sites (Eddings hole and poultry farm cut-bank) on Baron Fork Creek (Figure 1) and two high access sites (forks and Golden Gate bridge) and four low access sites (Arkansas crossing, Boy Scout hole, Carter Creek, and Southworth hole) on Glover River (Figure 2). Sport fish (Micropterus spp., Lepomis spp., rock bass Ambloplites rupestris, and warmouth Chaenobryttus gulosus) and stream habitat were sampled at these sites during October 1993 and from August through October 1994 and 1995 (N = 20) when the streams were at or near base flow. Legal descriptions and vernacular references of sampling localities are available in Appendix A.

Fish were sampled at randomly selected sites by electrofishing with pulsed direct current from a boat equipped with a Smith-Root 2.5 GPP electrofisher. Before sampling, each site was block-netted at the upstream and downstream end with block nets (55m × 1.8m net with 12.7mm^2-mesh) to prevent emigration or immigration. The area of each site was calculated by multiplying mean stream width between the block nets by site length. The enclosed areas were thoroughly sampled twice to mark and recapture marked fish. After each sampling run, captured fish were held in an instream pen for subsequent processing. Following the first electrofishing (marking) run, captured fish were marked (partial caudal fin clip) and released back into the enclosed area and left undisturbed for about two hours to allow them to disperse. After the second electrofishing (recapture) run, collected fish were examined for marks and released. Total number of fish captured and number of marked fish was recorded for estimates of population size (Ricker 1975).

Captured and recaptured fish from each site were pooled and total population estimates were calculated using Chapman's (1951) modification of the Petersen estimate. Approximate confidence limits, based on either Poisson, binomial, or normal distributions, were calculated by the methods of Seber (1973). Density (no./ha) was estimated by dividing estimated population size by area sampled at each site. We analyzed density estimates from 1993, 1994, and 1995 for each stream and access type with $\underline{t}$-tests to examine the null hypothesis that mean density (no./ha) did not differ between high and low access areas. For this comparison we made the following assumptions: (1) angler harvest and/or recreational activity was greater at high than at low access areas; (2) habitat was similar between high and low access areas; and (3) fish abundance for each access type was similar among years.

We tested assumptions 2 and 3 with data collected at the high and low access areas. To test the assumption that habitat was similar between high and low access areas, stream depth and instream cover were measured at each site with the transect method described by Todd and Rabeni (1989). Measurements were taken along transects across the stream beginning at the upstream end and proceeding to the downstream end of each site. Frequency of transect locations was based on relative homogeneity of habitat. Depth and cover were measured at four equally spaced stations along each transect. Individual depth measurements were scaled to the maximum depth to account for variation caused by extremely deep or shallow sites. Principal instream cover features at each station were classified into one of the following nine categories: (type 1) open water areas with small grain or bedrock substrates that were free of obstructions such as submerged or floating woody debris; (type 2) open water areas with course grain substrates and/or uneven channel contours (bedrock ledges); (type 3) areas with inundated or exposed brush piles, rootwads, or log jams along the channel margins; (type 4) areas with shoreline oriented undercut banks or bedrock ledges; (type 5) areas with instream woody debris (e.g., rootwads, brush piles and log jams); (type 6) areas with partially submerged branches from off-stream plants; (type 7) areas with overhanging canopy from terrestrial plants extending to or near water level; (type 8) areas with instream vascular plants; and (type 9) areas with fabricated structures (low-water crossings and suspension bridges). For each stream, we tested for differences in standard depth with a _t_-test and for differences in cover with a Chi-square test for each stream. Cover types found fewer than eight times in each access area could not be confidently analyzed with Chi-square tests and were excluded. We tested the assumption that mean fish abundance for each access type was similar between 1994 and 1995 for each stream with a t-test. This assumption could not be verified for 1993 because fewer than two samples were collected from each access type.

Population expansion--A base map of both study reaches was created from United States Department of Agriculture - Agricultural Stabilization and Conservation Service 1:7,920 scale aerial photographs. Each reach was delineated on the photographs, the wetted perimeter was digitized using GRASS GIS software, and the base maps were printed for use in the field. Stream mesohabitats were classified in the field using a hierarchical system based on morphological and hydraulic properties of the stream channel (McCain et al. 1990; Hawkins et al. 1993; Rabeni and Jacobson 1993). Meso-scale habitat classification was desirable because it can be visually determined, it is general enough to allow extrapolation of habitat relationships among streams (Hawkins et al. 1993), and fish abundances are known to vary at this level (Hawkins et al. 1993 and Rabeni and Jacobson 1993). In Baron Fork Creek, mesohabitats were classified and recorded on base maps for the entire reach during July 1995. However, because of the large size of the Glover River, all mesohabitats in the study reach could not be classified, so we sampled portions of it. We stratified the Glover River reach into three sections based on gradient (Figure 2), and divided the strata into sampling sections that were 17 mean stream widths long (about one and one-half riffle-pool sequences; Simonson et al. 1994). The number of sections needed to estimate the aerial coverage of each mesohabitat type in our study reach with 90% confidence was calculated and proportionately allocated among the three strata (Thompson 1992). Mesohabitats were classified in these areas and recorded on base maps during May 1996. Subsequently, classified mesohabitats from both streams were digitized into the GIS (Figure 3), and the total area (ha) and percent area of each mesohabitat type was calculated for Baron Fork Creek, and proportionately estimated from sub-sampled habitat for Glover River.

Mesohabitat use by smallmouth bass Micropterus dolomieu, largemouth bass Micropterus salmoides, spotted bass Micropterus punctulatus, and these black bass species in aggregate was predicted for each stream. Species-specific summer habitat preferences for depth, velocity, substrate, and cover by adult fish was derived from the literature (Munther 1970; Carlander 1977; Edwards et al. 1983; Rankin 1986; Todd and Rabeni 1989; Aadland 1993; Rabeni and Jacobson 1993) for comparison with similar mesohabitat characteristics described by McCain et al. (1990; Table 1). Literature derived habitat preferences were as follows: smallmouth bass use moderate to deep depths, moderate to low current velocities, and coarse to medium substrates (Appendix B); largemouth bass use deep to moderate depths, low currents, and fine to coarse substrates (Appendix D); spotted bass use deep to moderate depths, low to moderate currents, and medium to coarse substrates (Appendix E); and these black bass species are habitat generalists that use deep to moderate depths, low to moderate current velocities, and coarse to medium substrates (Appendix F). All species use several cover types including logs, root wads, rocks, and vegetation (Appendix B and Appendixes D - E). Comparisons of these habitat preferences with mesohabitat characteristics were scored based on the following decision rules: no matching characteristics = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics in reverse order = 0.7; and all characteristics match in exact order = 1.0. Scores over all mesohabitat features (depth, velocity, substrate and cover) were summed for each mesohabitat type and assigned a use type (high, medium, or low) by the following criteria: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. For example, smallmouth bass prefer moderate to deep water, whereas glides (GLD) are moderate to shallow, the first characteristic (moderate) matches, and the second characteristic (deep versus shallow) differs; so the score is 0.7 (Appendix B). This process was repeated until all habitat features were considered and the scores summed. Finally, the total score for glides (2.7) was within the range of 1.4 to 2.7 and predicted to be a medium use habitat (Appendix B).

Predicted mesohabitat use by each species was verified for Baron Fork Creek to assess ranking accuracy. Sections of stream were randomly chosen, to reduce logistic demands, by the methods described for classifying Glover River habitat (two strata; Figure 2). Mesohabitat units ($\underline{N}$ = 49) within these sections, including a channel confluence pool ($\underline{N}$ = 1), a trench chute ($\underline{N}$ = 1), pocket water

(N = 3), low gradient riffles (N = 4), lateral scour pools (N = 7), backwater pools (N = 8), mid-channel pools (N = 8), runs (N = 8), and glides (N = 9), were located on the stream base maps and fish were collected in each mesohabitat unit by electrofishing with pulsed direct current. While electrofishing, total sampling time and number of fish of each species captured was recorded for subsequent estimates of catch-per-unit-effort (CPUE) relative abundances. These CPUE values were compared with similar values reported for the Illinois River drainage and northeastern Arkansas by Stark and Zale (1991). Catch-per-unit-effort results from Stark and Zale (1991) were separated into three categories of observed abundance (high, medium, and low) and used to rank sampled mesohabitats into observed-use categories based on the CPUE. Mesohabitat types not sampled were ranked by computing a mean CPUE for the major habitat category (i.e., riffle, pool, or run) the mesohabitat type belonged to, and classifying this value following the previous protocol. Error matrices were calculated for the original habitat use predictions in Baron Fork Creek to assess classification accuracy (Story and Congalton 1986). Due to logistical constraints, we did not sample mesohabitats in Glover River, so the observed use values for mesohabitats in Baron Fork Creek were used. Lastly, we used GIS to reclassify the mesohabitat maps for both streams into observed use types (Figure 3), and to calculate the areal coverage (ha) and percent area of each use category.

To compute weighting factors for expanding estimates of abundance for each species and stream, we used mean mesohabitat CPUE values for observed habitat use types. Weighting factors were calculated by dividing mean CPUE values for each use type by the highest CPUE rate for a use type and weighting observed habitat use types into a range from zero to one. Expanded abundance estimates, for smallmouth bass and black bass were derived by multiplying mean density (no./ha) in each stream (Chapter 1) by area sampled (ha). These values were then weighted by multiplying the expanded estimates by the weighting factors and compared with unweighted expanded abundance estimates. Low sample sizes of largemouth bass and spotted bass (Chapter 1) precluded us from calculating abundance estimates for these species in both streams.

Results

Sampling site bias.--A total of 4,283 sport fish representing nine species including largemouth bass, smallmouth bass, spotted bass, warmouth, rockbass, green sunfish Lepomis cyanellus, orangspotted sunfish Lepomis humilis, bluegill Lepomis macrochirus, longear sunfish Lepomis megalotis, and redear sunfish Lepomis microlophis were captured in 20 samples from the two streams. Of the 1,245 fish collected from Baron Fork Creek, 51% (eight species) were from high access areas, and 49% (nine species) were from low access areas. Similarly, of the eight species collected in Glover River, 60% (1,826 fish) were from high access areas, and 40% (1,212 fish) were from low access areas. Smallmouth bass dominated the black bass catch in both high and low access areas in each stream, followed in order by largemouth bass and spotted bass in Baron Fork Creek, and spotted bass and largemouth bass in Glover River. In Baron Fork Creek, longear sunfish dominated the sunfish catch in high access areas followed in order by rockbass and bluegill, but low access areas were dominated by bluegill, followed by longear sunfish and rockbass. Both access areas in Baron Fork Creek had appreciable numbers of green sunfish. Sunfish in high and low access areas in Glover River were dominated by longear sunfish, followed in order by green sunfish, and bluegill. Species infrequently captured were redear sunfish, warmouth, and orangespotted sunfish. Three catfish species (channel catfish Ictalurus punctatus, yellow bullhead Ictalurus natalis, and flathead catfish Pylodictis olivaris) were collected but were excluded from the samples because of gear inefficiency (Reynolds 1983).

Fish densities at the 10 sites ranged widely (444-8,721 fish/ha, Appendix C) but were not significantly different within high and low access areas between 1994 and 1995 in Baron Fork Creek (t = -0.0732; P = 0.9483; and t = -1.1459; P = 0.3705, respectively) or Glover River (t = -0.6749; P = 0.5693; and t = -2.0288; P = 0.1796, respectively). Confidence intervals around the population estimates (Appendix C) were large, illustrating the small sample size and low recapture rates of marked individuals. Mean fish density for high and low access areas in Baron Fork Creek (Figure 4) were not significantly different (t = -0.488; P = 0.641). Contrastingly, fish were significantly more abundant in high than in low access areas in Glover River (t = 2.703; P = 0.047; Figure 4). High standard errors around the means for high and low access areas in both streams suggest the data are quite variable (Figure 4).

In the test of habitat differences between high and low access areas, we found habitat to be similar between access types in Baron Fork Creek but different between access types in Glover River. In Baron Fork Creek, mean standard depth (t = 0.918; P = 0.359; N = 476) was similar between access types. However, high access areas in Glover River were significantly deeper (t = 4.471; P = 0.001; N = 244) than low access areas. We found three major cover habitats in Baron Fork Creek: areas with no available cover (type 1; N = 334), areas with instream large rocks or bedrock ledges (type 2; N = 80), and shoreline woody debris (type 3; N = 23). Glover River also had appreciable amounts of type 1 (N = 79) and type 2 (N = 220) cover. In Baron Fork Creek, cover types 1, 2, and 3 did not differ between high and low access areas (X^2 = 4.796; df = 2; P = 0.091). Conversely, in Glover River, low access areas were disproportionately dominated by type 2 cover (X^2 = 7.698; df = 1; P < 0.006) compared to high access areas.

Population expansion.–A total of 17 mesohabitat categories were found in the two streams; these represented three habitat categories: riffles (edgewater, low gradient riffle, high gradient riffle, and cascade), runs (glide, run, step run, pocket water, and trench chute), and pools (secondary channel pool, backwater pool, plunge pool, lateral scour pool, mid-channel pool, channel confluence pool, corner pool, and step pool; Table 1). Mesohabitat characteristics of depth, velocity, substrate, and cover were generally similar within each habitat category (Table 1). In Baron Fork Creek, 61% of the habitats were pools (seven classes), 34% were runs (five classes), and 5% were riffles (three classes; Table 2 - 5). Similarly, the Glover River reach had 5% riffles (three classes), but runs (13%; four classes) were less abundant, and pools (83%; seven classes) were more abundant than in Baron Fork Creek (Table 6).

Predictions of species-specific mesohabitat use were variable within the major habitat categories, except riffles, which were in low use by all species and black bass combined in each stream (Table 2 - 6). In Baron Fork Creek, run habitats were rated medium and high use for smallmouth bass (46% and 54%, respectively; Table 2) and black bass (91% and 9%, respectively; Table 5), but they were rated low and medium use for largemouth bass (46% and 54%; Table 3) and spotted bass (0.4% and 99.6%; Table 4). Use of pools was the most diverse among species. For example, smallmouth bass ratings for pools, in descending order, were medium (59.7%), high (40%), and low use (0.3%; Table 2), whereas these habitats were rated high use for spotted bass and black bass (87.7%), followed by medium (12%) and low use (0.3%; Tables 4 and 5, respectively). Similarly, 97% of pools were rated high use by largemouth bass. In Glover River, runs were rated high (83%) and medium (17%) use for smallmouth bass and black bass, but were rated mostly low use for spotted bass (100%) and largemouth bass (97%). Most of the pools were rated high use for largemouth bass, spotted bass, and black bass (≥ 97%), whereas medium use classes dominated the pool category (89%) for smallmouth bass, followed by high (8%) and low (3%) use classes. Individual mesohabitat scores and predicted use classifications for each species and black bass are in Appendix B and Appendixes D - F.

To verify mesohabitat use predictions, a total of 163 black bass, including 16 spotted bass (10%), 64 largemouth bass (39%), and 83 smallmouth bass (51%), were captured during 3.63 hours of electrofishing. Based on the observed CPUE of these species in high, medium, and low use mesohabitats, our overall prediction accuracy for mesohabitat use in Baron Fork Creek was below 50% for all species, except largemouth bass (65%; Figure 5). Among species, we were most successful in predicting low use habitats (100% - 86% correct), followed by high (83% - 61% correct), and medium use predictions (≤ 15% correct; Figure 5).

Observed mesohabitat use in Baron Fork Creek was markedly different from expected use in the run and pool categories, but riffles remained in low use by all species and black bass (Tables 2 - 5). Run classes were observed to be in mostly low use by largemouth bass (54%; Table 3) and spotted bass (100%; Table 4), but mostly high (90.7%) and medium (8.9%) use by smallmouth bass (Table 2). Use of pools was similar among largemouth bass, spotted bass, and black bass combined, with most classes (≥ 99.8%) being highly used (Tables 3 - 5). Contrastingly, only 52.2% of pools were in high use by smallmouth bass, followed by medium (47.6%) and low (0.2%) use observations (Table 2).

The areal coverage of observed habitat use was similar within species, except smallmouth bass, and between streams. For example, most of the study area in each stream consisted of high use habitat for all black bass and largemouth bass, followed in descending order by low and medium use sections (Tables 7 - 8). Likewise, high use habitats for spotted bass were common in both streams, followed by a many but fewer low use areas, and no medium use areas (Table 8). High use habitats also were dominant in the Baron Fork Creek study area for smallmouth bass, followed by medium and low use areas; however, mostly medium use habitats, with some high and low use sections for this species occurred in Glover River.

Estimates of abundance for smallmouth bass and black bass were markedly reduced by using habitat weighting factors in each stream (Table 7). Unweighted estimates overestimated smallmouth bass abundance by 23% in Baron Fork Creek, and a striking 49% in Glover River. This disparity was not as high for black bass, with unweighted estimates being inflated by only 7% in Baron Fork Creek, and 9% in Glover River. Habitat weighting factors for future estimates of largemouth bass and spotted bass abundance are available in Table 8. Our mean CPUE estimates for mesohabitat use types indicate that high use habitats be given full weight (1.0), and low use habitats be given no weight in expansion calculations for these species. In medium use habitats, expanded abundance estimates for largemouth bass should be reduced by 87%; weighting factors are unavailable for habitats in medium use by spotted bass.

Discussion

Sampling site bias.--Our estimates of sport fish abundance showed bias associated with sampling at high versus low access areas in Glover River, but not in Baron Fork Creek. However, data supporting this conclusion were highly variable, which is partly attributable to low sample sizes and low recapture rates of marked fish. With more samples and/or higher recapture rates, the variance around the mean of these abundance estimates would presumably have decreased and statistical results would be more conclusive. We used our data to estimate sample size needed to detect a difference between these two sample means (Steel and Torrie 1980). We found 154 high and low access areas would be needed to detect a minimum difference of 100 fish/ha in Baron Fork Creek. In Glover River, 81 samples of the two access types would be needed to consistently find differences of 1000 fish/ha. While the minimum detectable difference between sample means can be increased, thereby reducing sample size requirements, meaningful comparisons of fish populations are compromised by the smaller number of samples. For all practical purposes, data sharing would be needed to achieve confidence in statistical results.

The differences we observed in fish abundance between high and low access areas in Glover River may be attributable to habitat effects. It is well documented that abundance and distribution of stream fish is correlated with habitat (Paragamian 1981; McClendon and Rabeni 1987; Todd and Rabeni 1989; and Lyons 1991). Rankin (1986) reported that smallmouth bass generally preferred habitats with coarse substrate in deep areas. Todd and Rabeni (1989) noted smallmouth bass were commonly associated with a rocky substrate, and Rabeni and Jacobson (1993) observed most adult smallmouth bass in deep pools with variable substrates. Low access areas in Glover River had a higher availability of course grained substrates and bedrock ledges, and were significantly deeper than high access areas. Low water bridges at most high access areas in Glover River may reduce channel scouring and cause fine grain substrates to be deposited above and below these structures. We did not, however, detect a habitat effect in Baron Fork Creek. Bridges over this stream are suspended above the water and do not obstruct flow; consequently, we found no differences in depth and cover between access areas. Study reaches without channel modifications (e.g., low-water bridges) at high access sites should be better suited for comparisons of fish abundance between access types because differences can be attributed to angler effort and harvest, and not to anthropogenic influences on stream hydraulics.

Our assumption that angler effort, harvest, and other human activities, which could displace sport fish, were greater at high access areas than low access areas seems reasonable. Martin (1995) noted that 90% of anglers in Glover River were using high access areas, but angler preference for these sites was not as apparent in Baron Fork Creek. However, high access areas in Baron Fork Creek were heavily used by non-angling recreationalists. Similarly, we observed many human activities, including fishing and swimming, in the two streams, and most of these activities occurred at high access sites. It also appeared that most anglers we observed were harvesting the fish they caught. While it is known that these activities can influence standing crop and production at high access areas, it is not known how quickly fish communities recover from these perturbations. Stream fish densities in low access areas may be high enough that these fish quickly disperse into voids left in high access areas depleted by harvesting fish (Funk 1975). Other factors of these activities, such as swimmers disturbing stream benthos, may serve to increase fish densities at these sites temporarily. Testing for differences in angler effort, harvest, and human activities and the associated sport fish response between high versus low access areas would augment our understanding of stream sampling biases.

Although our results are inconclusive regarding sampling bias, it is prudent to assume that data collected primarily from high access areas do not accurately describe whole populations; inferences based on such sampling should be made cautiously. Biologists can overcome bias during surveys and improve estimates of population size by optimizing their sampling design with probability sampling routines (Wilde and Fisher 1996). For example, random, stratified random, and systematic sampling will help ensure that data have not been compromised by preferences of the sampler (Johnson and Nielson 1983; Wilde and Fisher 1996), and that estimates can be applied to the entire population, not just the locations sampled (Wilde and Fisher 1996). Using these methods in complex natural ecosystems is appropriate and yields reliable comparisons or unbiased estimates (Krebs 1989; Thompson 1992).

Population expansion.--Combining meso-scale hierarchial assessment techniques with GIS proved extremely effective for quantifying habitat in both streams to expand our population estimates from sampling sites to the entire reaches. Besides providing geo-referenced maps of habitat location and size, measurements of habitat and total stream areas were calculated more accurately than with previous methods (e.g., visual estimation; Hankin and Reeves 1988). The final maps provided a clear picture of major habitat features, while mesohabitat characteristics described the gradient, substrate, and cover within the stream reaches (McCain et al. 1990). We emphasize, however, that the time investment to create the habitat maps was considerable. For example, it took 160 person-hours to trace, digitize, register, plot, and classify the Baron Fork Creek reach. However, we felt the investment was worthwhile. The information, stored in a GIS database, can be used for other fisheries endeavors such as determining habitat limitations in a population, optimizing habitat restoration, and constructing statistically sound sample survey designs (Hawkins et al. 1993). This information must be periodically updated, especially in alluvial streams, to reflect changes in stream habitat over time.

Our verification study showed that we were able to predict mesohabitat use by black bass species correctly on average about 50% of the time. A potential weakness in our method was in using coarse-scale, literature-based definitions of species-specific habitat preferences to rank mesohabitats into use categories. Although we consistently found agreement among authors about habitat preferences, our scoring categorization and ranking procedures were subjective. While ranking habitat use with existing information (e.g., published literature) is efficient, the technique needs further refinement for accurate mesohabitat use predictions without a pilot field study.

Ranking habitat use from empirical information is more costly, but the resulting data will likely provide a more accurate measure for calculating reach-specific habitat weighting factors. Additionally, one can determine mesohabitat use without having to account for the variability between habitat in the study reach and the reaches assessed in the literature. Once CPUE values are calculated, the habitat weighting factors should remain consistent over time unless there is a change in stream habitat or the fish population. However, if population surveys occur at different times of year, weighting factors should be estimated by season where habitat use is known to vary (Rabeni and Jacobson 1993). Similar estimates from Glover River would help to describe habitat use and to calculate reliable weighting factors for this stream.

Our CPUE results from mesohabitat sampling of fish further show the need for considering habitat use during population monitoring surveys. Black bass in Baron Fork Creek were not evenly distributed, but were aggregated by meso-scale habitat units; a frequent conclusion of previous studies (e.g., Funk and Pflieger 1975; Paragamian and Coble 1975; Hendricks 1980; Paragamian 1981; McClendon and Rabeni 1987; Hankin and Reeves 1988; Todd and Rabeni

1989; Lyons 1991). If habitat-based aggregation occurs in Glover River, as would be expected, expanding abundance estimates from a limited number of samples would yield biased estimates of true fish abundance (Funk 1975; Paragamian and Coble 1975; Hankin and Reeves 1988; Hawkins et al. 1993). Thus, weighted estimates for smallmouth bass and black bass in each stream (Table 7) more accurately describe the true population size and will ultimately yield more useful and well-founded management decisions for these species.

We know of few other studies that have attempted to expand fish abundance estimates by habitat use (e.g., Hankin 1986; Hankin and Reeves 1988). This confounds among-study comparisons of fish population estimates. To weight estimates effectively, standard habitat classification procedures are needed (McCain et al. 1990; Hawkins et al. 1993). If methods used by agencies for identifying habitat classes are not clear and repeatable, comparisons of weighted population estimates will be invalid. A hierarchial classification scheme (e.g., McCain et al. 1990; Hawkins et al. 1993; Rabeni and Jacobson 1993) can provide a means to standardize identification of channel units (Hawkins et al. 1993), but the habitat types must be consistently classified among basins or the comparison of estimates will remain compromised (Hawkins et al. 1993). McCain et al. (1990) noted that classifying habitat is a subjective process where accuracy hinges on consistency, and a basic knowledge of stream processes and the classification system. While the classification of stream habitat is quite variable between researchers, using a simple classification scheme, increasing observer training, and averaging results from two or more people will enhance the quality of the data (McCain et al 1990; Roper and Scarnecchia 1995), and increase the comparative usefulness of weighted population estimates.

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Table 1.–Depth, velocity, substrate, and cover characteristics of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat acronyms are as follows: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Habitat	Depth	Velocity	Substrate	Cover
		Riffles		
EGW	shallow	low	coarse	none
LGR	shallow	high, turbulent	coarse	none
HGR	shallow to moderate	high, turbulent	coarse	none
CAS	shallow to moderate	high, turbulent	bedrock, boulder	none
		Runs		
GLD	moderate to shallow	moderate to low	medium to coarse	none
RUN	moderate to shallow	moderate to high	coarse to medium	boulder
SRN	moderate to shallow	moderate to high	coarse	boulder
POW	moderate to deep	moderate to high	coarse to medium	boulder, logs
TRC	moderate to deep	moderate to high	coarse to bedrock	none
		Pools		
SCP	shallow	low	fine	none
BWP	moderate to shallow	low	fine	boulders, root wads, logs
PLP	deep to moderate	low to moderate	fine to coarse	logs
LSP	deep to moderate	low to moderate	fine to coarse	logs, root wads, bedrock, boulders
MCP	deep to moderate	low	fine to coarse	logs, rocks
CCP	deep to moderate	low to moderate	fine to coarse	logs, rocks
CRP	deep to moderate	low to moderate	fine to coarse	none
STP	moderate to shallow	moderate to high	coarse	boulder

Table 2.–Type, amount, and expected use by smallmouth bass of 15 mesohabitats found in Baron Fork Creek, Oklahoma in 1995. Observed mesohabitat use was determined by scoring mean electrofishing catch-per-unit-effort rates (no./hr) based on the following decision rules: low = ≤ 1; medium = 2 - 21; and high = > 21. Mesohabitat acronyms are as follows: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; GLD = glide; RUN = run; POW = pocket water; TRC = trench chute; SRN = step run; SCP = secondary channel pool; BWP = back water pool; CRP = corner pool; LSP = lateral scour pool; MCP = mid-channel pool; PLP = plunge pool; and CCP = channel confluence pool.

Habitat type	Percent area	Number of hectares	Expected habitat use	Mean CPUE ± SD (N)	Observed habitat use
			Riffles		
EGW	0.10	0.05	low	0 ± - (4) [a]	low
LGR	5.30	2.71	low	0 ± 0 (4)	low
HGR	0.06	0.03	low	0 ± - (4) [a]	low
			Runs		
GLD	15.53	7.95	medium	29 ± 46 (9)	high
RUN	13.92	7.13	high	57 ± 42 (8)	high
POW	3.01	1.54	high	10 ± 17 (3)	medium
TRC	0.14	0.07	medium	0 ± - (1)	low
SRN	1.35	0.69	high	36 ± 43 (21) [b]	high
			Pools		
SCP	0.16	0.08	low	23 ± 28 (24) [c]	high
BWP	5.77	2.95	medium	31 ± 42 (8)	high
CRP	1.53	0.79	medium	23 ± 28 (24) [c]	high
LSP	24.13	12.36	high	23 ± 19 (7)	high
MCP	28.86	14.78	medium	17 ± 18 (8)	medium
PLP	0.05	0.03	high	23 ± 28 (24) [c]	high
CCP	0.09	0.05	high	0 ± - (1)	low
Totals	100	51.20			

[a] No habitats were sampled; hence, values represent a mean CPUE ± SD for all riffle mesohabitats.
[b] No habitats were sampled; hence, values represent a mean CPUE ± SD for all run mesohabitats.
[c] No habitats were sampled; hence, values represent a mean CPUE ± SD for all pool mesohabitats.

Table 3.–Type, amount, and expected use by largemouth bass of 15 mesohabitats found in Baron Fork Creek, Oklahoma in 1995. Observed mesohabitat use was determined by scoring mean electrofishing catch-per-unit-effort rates (no./hr) based on the following decision rules: low = ≤ 1; medium = 2 - 4; and high = > 4. Mesohabitat acronyms are as follows: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; GLD = glide; RUN = run; POW = pocket water; TRC = trench chute; SRN = step run; SCP = secondary channel pool; BWP = back water pool; CRP = corner pool; LSP = lateral scour pool; MCP = mid-channel pool; PLP = plunge pool; and CCP = channel confluence pool.

Habitat type	Percent area	Number of hectares	Expected habitat use	Mean CPUE ± SD (N)	Observed habitat use
			Riffles		
EGW	0.10	0.05	low	0 ± 0 (4) [a]	low
LGR	5.30	2.71	low	0 ± 0 (4)	low
HGR	0.06	0.03	low	0 ± 0 (4) [a]	low
			Runs		
GLD	15.53	7.95	low	3 ± 6 (9)	medium
RUN	13.92	7.13	medium	0 ± 0 (8)	low
POW	3.01	1.54	medium	0 ± 0 (3)	low
TRC	0.14	0.07	low	0 ± - (1)	low
SRN	1.35	0.69	medium	1 ± 4 (21) [b]	low
			Pools		
SCP	0.16	0.08	medium	23 ± 17 (24) [c]	high
BWP	5.77	2.95	high	24 ± 22 (8)	high
CRP	1.53	0.79	medium	23 ± 17 (24) [c]	high
LSP	24.13	12.36	high	29 ± 15 (7)	high
MCP	28.86	14.78	high	20 ± 14 (8)	high
PLP	0.05	0.03	high	23 ± 17 (24) [c]	high
CCP	0.09	0.05	high	0 ± - (1)	low
Totals	100	51.20			

[a] No habitats were sampled; hence, values represent a mean CPUE ± SD for all riffle mesohabitats.
[b] No habitats were sampled; hence, values represent a mean CPUE ± SD for all run mesohabitats.
[c] No habitats were sampled; hence, values represent a mean CPUE ± SD for all pool mesohabitats.

Table 4.--Type, amount, and expected (uncorrected) use by spotted bass of 15 mesohabitats found in Baron Fork Creek, Oklahoma in 1995. Observed mesohabitat use was determined by scoring mean electrofishing catch-per-unit-effort rates (no./hr) based on the following decision rules: low = ≤ 1; medium = 2 - 5; and high = > 5. Mesohabitat acronyms are as follows: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; GLD = glide; RUN = run; POW = pocket water; TRC = trench chute; SRN = step run; SCP = secondary channel pool; BWP = back water pool; CRP = corner pool; LSP = lateral scour pool; MCP = mid-channel pool; PLP = plunge pool; and CCP = channel confluence pool.

Habitat type	Percent area	Number of hectares	Expected habitat use	Mean CPUE ± SD (N)	Observed habitat use
			Riffles		
EGW	0.10	0.05	low	0 ± 0 (2) [a]	low
LGR	5.30	2.71	low	0 ± 0 (2)	low
HGR	0.06	0.03	low	0 ± 0 (2) [a]	low
			Runs		
GLD	15.53	7.95	medium	0 ± 0 (3)	low
RUN	13.92	7.13	medium	0 ± 0 (4)	low
POW	3.01	1.54	medium	0 ± - (1)	low
TRC	0.14	0.07	low	0 ± - (1)	low
SRN	1.35	0.69	medium	0 ± 0 (9) [b]	low
			Pools		
SCP	0.16	0.08	low	37 ± 14 (8) [c]	high
BWP	5.77	2.95	medium	42 ± 20 (3)	high
CRP	1.53	0.79	medium	37 ± 14 (8) [c]	high
LSP	24.13	12.36	high	34 ± 15 (3)	high
MCP	28.86	14.78	high	34 ± 10 (2)	high
PLP	0.05	0.03	high	37 ± 14 (8) [c]	high
CCP	0.09	0.05	high	34 ± 14 (8) [c]	high
Totals	100	51.20			

[a] No habitats were sampled; hence, values represent a mean CPUE ± SD for all riffle mesohabitats.

[b] No habitats were sampled; hence, values represent a mean CPUE ± SD for all run mesohabitats.

[c] No habitats were sampled; hence, values represent a mean CPUE ± SD for all pool mesohabitats.

Table 5.–Type, amount, and expected use by black bass (smallmouth bass, largemouth bass, and spotted bass combined) of 15 mesohabitats found in Baron Fork Creek, Oklahoma in 1995. Observed meso-habitat use was determined by scoring mean electrofishing catch-per-unit-effort rates (no./hr) based on the following decision rules: low = ≤ 1; medium = 2 - 32; and high = > 32. Mesohabitat acronyms are as follows: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; GLD = glide; RUN = run; POW = pocket water; TRC = trench chute; SRN = step run; SCP = secondary channel pool; BWP = back water pool; CRP = corner pool; LSP = lateral scour pool; MCP = mid-channel pool; PLP = plunge pool; and CCP = channel confluence pool.

Habitat type	Percent area	Number of hectares	Expected habitat use	Mean CPUE ± SD (N)	Observed habitat use
			Riffles		
EGW	0.10	0.05	low	0 ± - (4) [a]	low
LGR	5.30	2.71	low	0 ± 0 (4)	low
HGR	0.06	0.03	low	0 ± - (4) [a]	low
			Runs		
GLD	15.53	7.95	medium	32 ± 45 (9)	high
RUN	13.92	7.13	medium	62 ± 43 (8)	high
POW	3.01	1.54	high	13 ± 23 (3)	medium
TRC	0.14	0.07	medium	0 ± - (1)	low
SRN	1.35	0.69	medium	39 ± 44 (21) [b]	high
			Pools		
SCP	0.16	0.08	low	53 ± 46 (24) [c]	high
BWP	5.77	2.95	medium	67 ± 60 (8)	high
CRP	1.53	0.79	medium	53 ± 46 (24) [c]	high
LSP	24.13	12.36	high	64 ± 46 (7)	high
MCP	28.86	14.78	high	37 ± 21 (8)	high
PLP	0.05	0.03	high	53 ± 46 (24) [c]	high
CCP	0.09	0.05	high	0 ± - (1)	low
Totals	100	51.20			

[a] No habitats were sampled; hence, values represent a mean CPUE ± SD for all riffle meso-habitats.

[b] No habitats were sampled; hence, values represent a mean CPUE ± SD for all run meso-habitats.

[c] No habitats were sampled; hence, values represent a mean CPUE ± SD for all pool meso-habitats.

Table 6.–Type, amount, and expected use by smallmouth bass, largemouth bass, spotted bass, and black bass (smallmouth bass, largemouth bass, and spotted bass combined) of 14 mesohabitats found in Glover River, Oklahoma in 1996. Expected habitat use is based on mean electrofishing catch-per-unit-effort rates (no./hr) ± standard deviation and sample size (N) by mesohabitat type for these species in Baron Fork Creek, Oklahoma during 1995 (Tables 2 through 5). Mesohabitat acronyms are as follows: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; POW = pocket water; SRN = step run; SCP = secondary channel pool; BWP = back water pool; LSP = lateral scour pool; MCP = mid-channel pool; PLP = plunge pool; and CCP = channel confluence pool.

Habitat type	Percent area	Number of hectares	Expected Habitat Use			
			SMB	LMB	SPB	BASS
			Riffles			
LGR	2.40	3.43	low	low	low	low
HGR	1.54	2.21	low	low	low	low
CAS	0.73	1.05	low	low	low	low
			Runs			
GLD	0.34	0.48	high	medium	low	high
RUN	5.02	7.18	high	low	low	high
POW	2.16	3.10	medium	low	low	medium
SRN	5.26	7.53	high	low	low	high
			Pools			
SCP	0.07	0.10	high	high	high	high
BWP	0.57	0.81	high	high	high	high
LSP	2.06	2.95	high	high	high	high
MCP	73.74	105.65	medium	high	high	high
PLP	0.26	0.37	high	high	high	high
CCP	2.39	3.43	low	low	high	low
STP	3.47	4.97	high	high	high	high
Totals	100	143.26				

Table 7.–Type, amount, and weighting factors for smallmouth bass and black bass (smallmouth bass, largemouth bass, and spotted bass combined) observed mesohabitat use (pooled) in Baron Fork Creek (1995) and Glover River (1996), Oklahoma. Mean electrofishing catch-per-unit-effort rates (no./hr) ± standard deviation and sample size (N) were calculated by averaging similar values for each observed mesohabitat use type from Tables 2 and 5. Abundance values are based on the mean density (no./ha) of smallmouth bass and black bass in Baron Fork Creek (107 ± 12 and 181 ± 49, respectively) and Glover River (112 ± 84 and 145 ± 38, respectively), Oklahoma during 1994 and 1995 (Chapter 1) multiplied by area (hectares). Estimates of abundance are both unweighted and weighted by mean CPUE rates for observed mesohabitat use. Habitats comprising pooled mesohabitat use are available in Tables 2, 5, and 6.

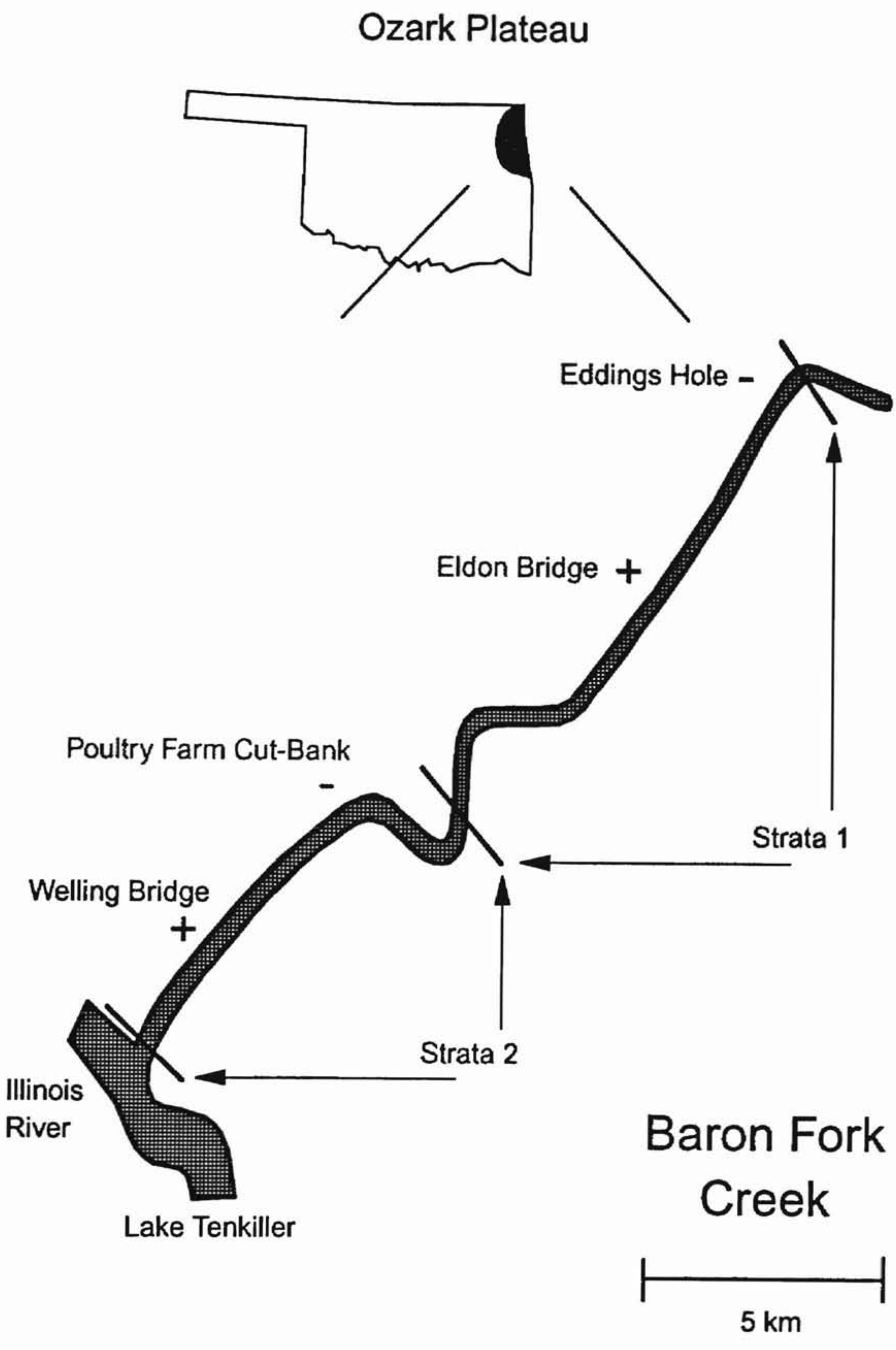
Observed habitat use (pooled)	Percent area	Number of hectares	Mean CPUE ± SD (N)	Weighting factor	Abundance	
					unweighted	weighted
			Baron Fork Creek - Smallmouth Bass			
low	5.69	2.91	0 ± 0 (5)	0	311	0
medium	31.87	16.32	14 ± 5 (2)	0.45	1746	786
high	62.44	31.98	31 ± 12 (8)	1	3422	3422
Totals	100	51.21			5479	4208
			Baron Fork Creek - Black Bass			
low	5.69	2.91	0 ± 0 (5)	0	527	0
medium	3.01	1.54	13 ± - (1)	0.25	279	70
high	91.30	46.76	51 ± 13 (9)	1	9269	9269
Totals	100	51.21			10075	9339
			Glover River - Smallmouth Bass			
low	7.06	10.12	0 ± 0 (4)	0	1133	0
medium	75.90	108.75	14 ± 5 (2)	0.45	12180	5481
high	17.05	24.39	31 ± 12 (8)	1	2732	2732
Totals	100	143.26			16045	8213
			Glover River - Black Bass			
low	7.06	10.12	0 ± 0 (4)	0	1467	0
medium	2.16	3.10	13 ± - (1)	0.25	450	112
high	90.79	130.04	51 ± 13 (9)	1	18850	18850
Totals	100	143.26			20767	18962

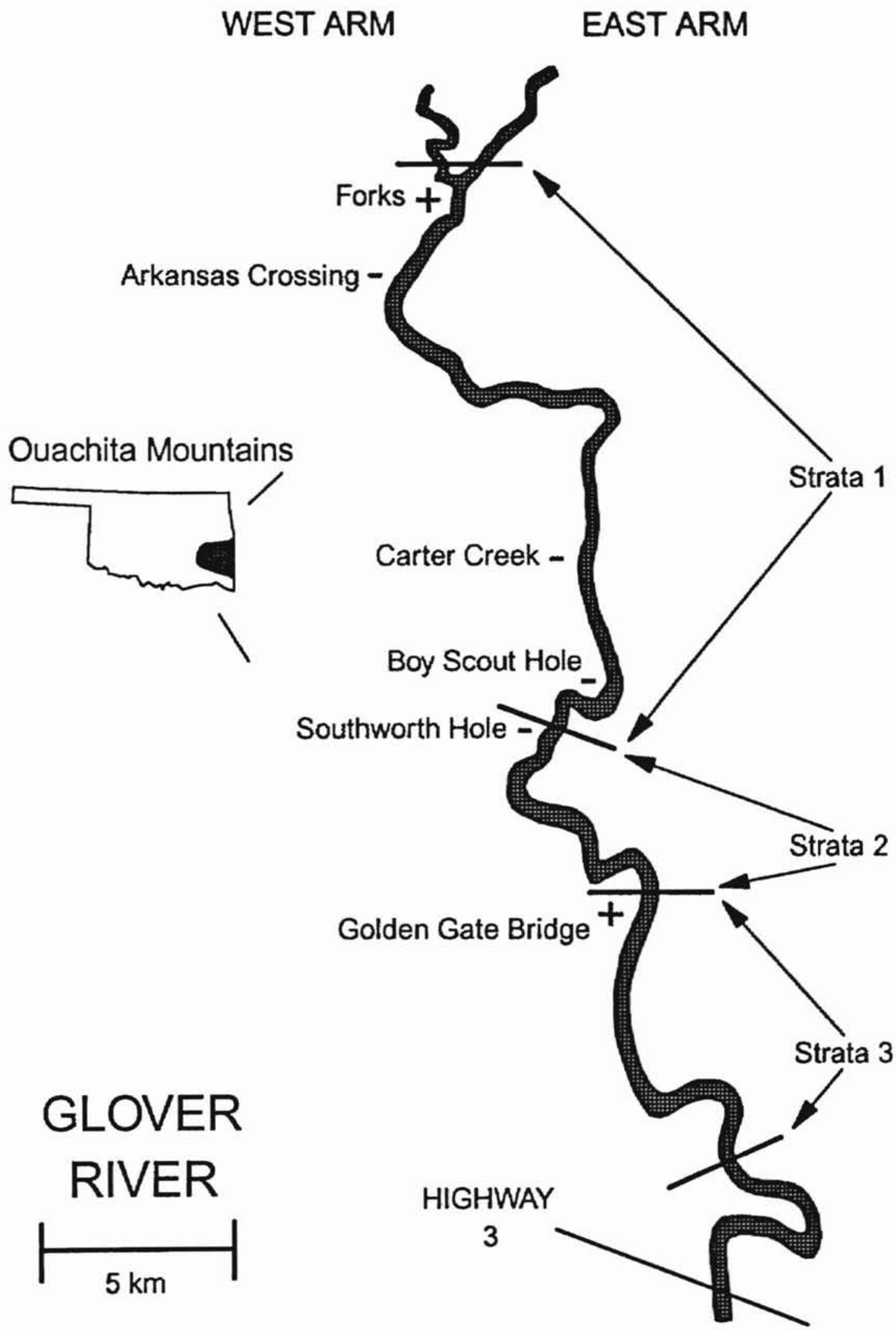
Table 8.–Type, amount, and weighting factors for largemouth bass and spotted bass observed mesohabitat use (pooled) in Baron Fork Creek (1995) and Glover River (1996), Oklahoma. Mean electrofishing catch-per-unit-effort rates (no./hr) ± standard deviation and sample size (N), were calculated by averaging similar values for each observed mesohabitat use type from Tables 3 and 4. Habitats comprising pooled mesohabitat use can be found in Tables 3, 4, and 6.

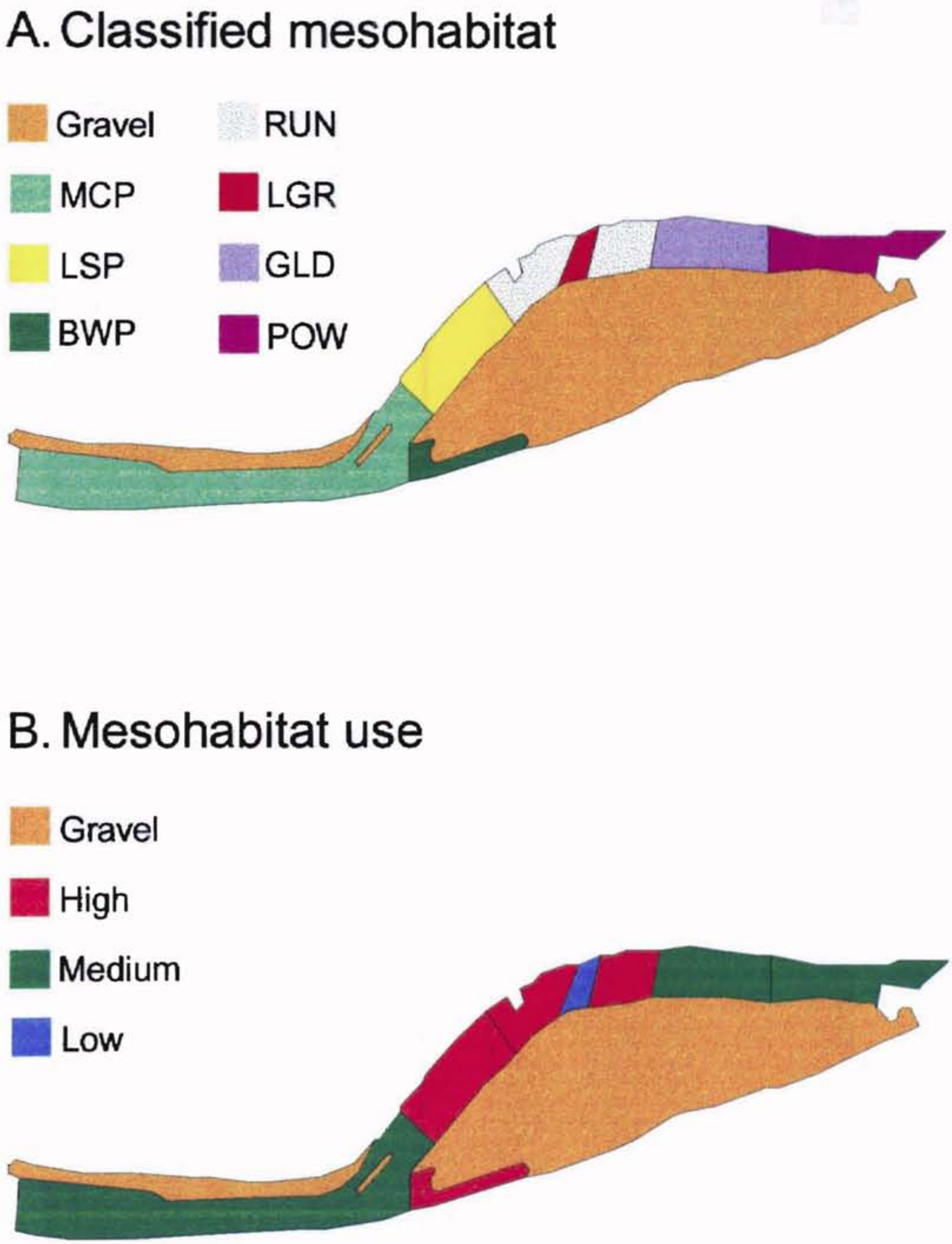
Observed habitat use (pooled)	Percent area	Number of hectares	Mean CPUE ± SD (N)	Weighting factor
		Baron Fork Creek - Largemouth Bass		
low	23.97	12.28	0 ± 0 (5)	0
medium	15.53	7.95	3 ± - (1)	0.13
high	60.50	30.98	24 ± 23 (6)	1
Totals	100	51.21		
		Baron Fork Creek - Spotted Bass		
low	39.41	20.18	0 ± 0 (5)	0
high	60.59	31.03	36 ± 3 (7)	1
Totals	100	51.21		
		Glover River - Largemouth Bass		
low	19.50	27.94	0 ± 0 (7)	0
medium	0.34	0.49	3 ± - (1)	0.13
high	80.17	114.85	24 ± 3 (6)	1
Totals	100	143.26		
		Glover River - Spotted Bass		
low	17.45	25.00	0 ± 0 (7)	0
high	82.56	118.28	37 ± 3 (7)	1
Totals	100	143.26		

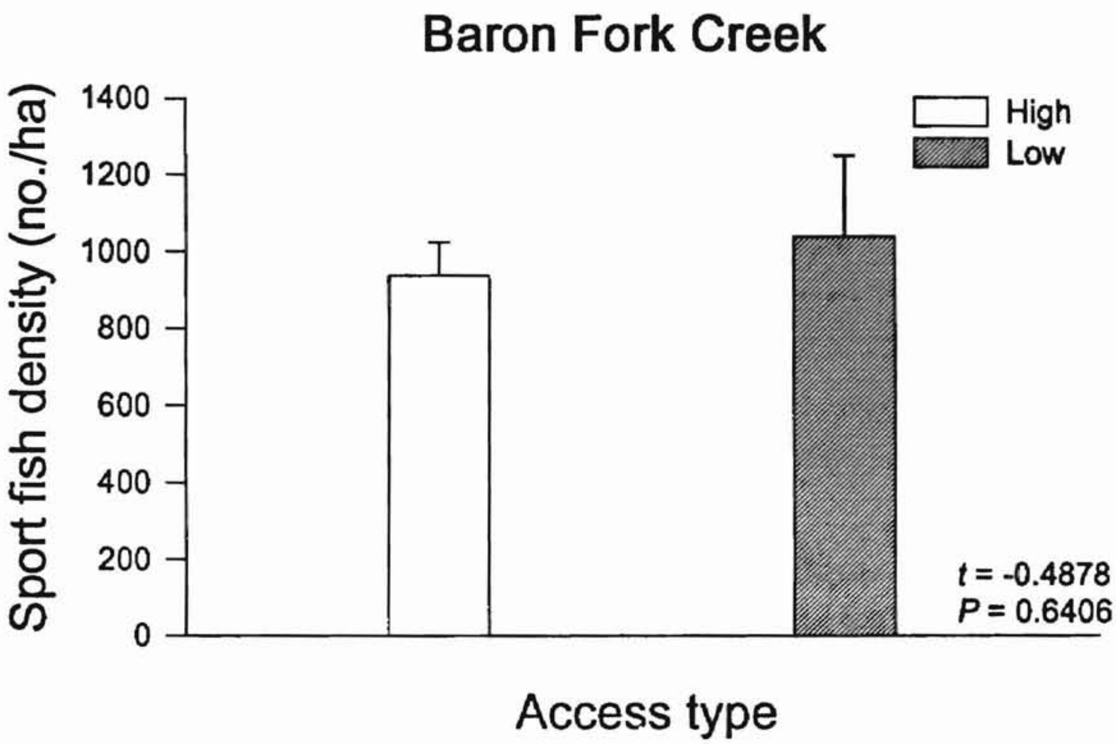
Figure Captions

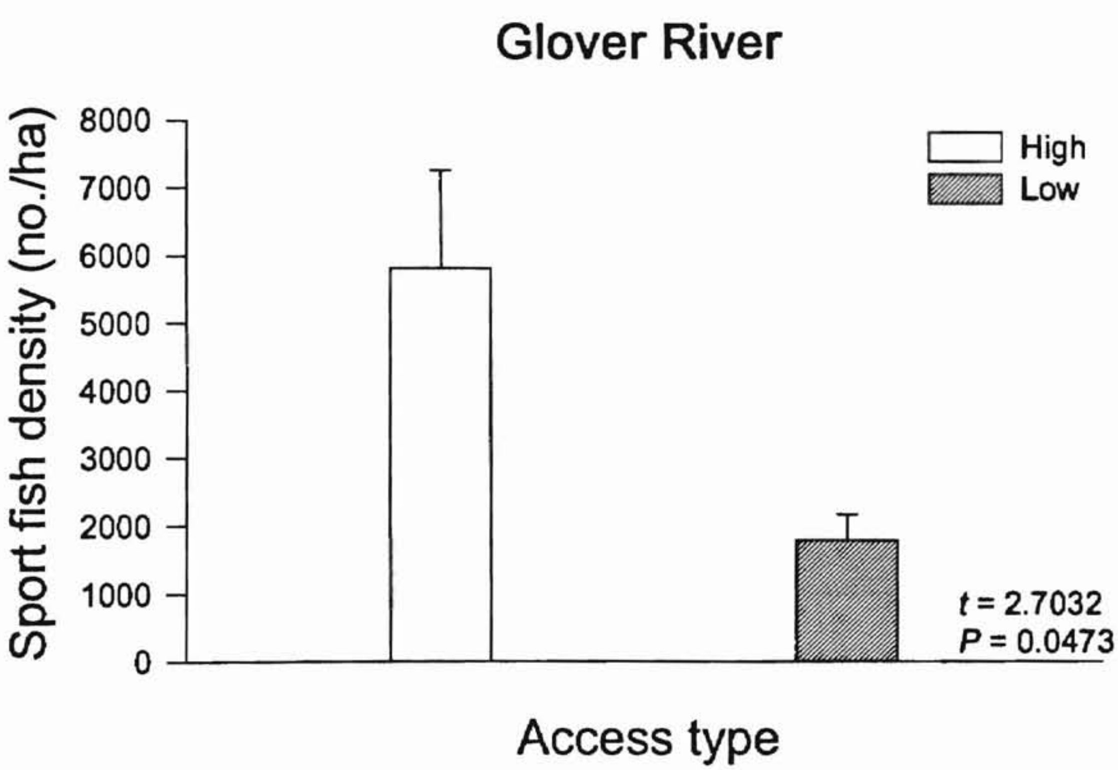
1. Study area on Baron Fork Creek in the Ozark Plateau region of eastern Oklahoma. Plus signs denote high use and minus signs denote low use sampling sites. Arrows denote the two strata where mesohabitat specific black bass sampling occurred.
2. Study area on Glover River in the Ouachita mountains of southeastern Oklahoma. Plus signs denote high use and minus signs denote low use sampling sites. Arrows denote the three strata where sections of mesohabitat were classified.
3. A 578-m section of Baron Fork Creek showing classified mesohabitat and mesohabitats reclassified into observed use by black bass. Mesohabitat acronyms are as follows: MCP = mid-channel pool; LSP = lateral scour pool; BWP = backwater pool; RUN = run; LGR = low gradient riffle; GLD = glide; and POW = pocketwater.
4. Comparison of mean sport fish density (no./ha) ± standard error between high and low use areas in Baron Fork Creek and Glover River, Oklahoma. Statistical values are the results of a Student's _t_ test; _P_ = 0.05.
5. Smallmouth bass, largemouth bass, spotted bass, and black bass predicted mesohabitat use rank error matrices for mesohabitats classified in Baron Fork Creek, Oklahoma during 1995.


Ozark Plateau
Eddings Hole -
Eldon Bridge +
Poultry Farm Cut-Bank
-
Strata 1
Welling Bridge
+
Strata 2
Illinois
River
Lake Tenkiller
Baron Fork
Creek
5 km


WEST ARM
EAST ARM
Forks +
Arkansas Crossing -
Ouachita Mountains
Strata 1
Carter Creek -
Boy Scout Hole -
Southworth Hole -
Strata 2
Golden Gate Bridge +
Strata 3
GLOVER RIVER
HIGHWAY 3
5 km


A. Classified mesohabitat
Gravel
RUN
MCP
LGR
LSP
GLD
BWP
POW
B. Mesohabitat use
Gravel
High
Medium
Low


Baron Fork Creek
Sport fish density (no./ha)
1400
1200
1000
800
600
400
200
0
High
Low
t = -0.4878
P = 0.6406
Access type


Glover River
Sport fish density (no./ha)
8000
7000
6000
5000
4000
3000
2000
1000
0
High
Low
t = 2.7032
P = 0.0473
Access type

a. Smallmouth bass

Observed

Expected	High	Mediu m	Low	Total	Error
High	11	3	4	18	0.39
Medium	10	4	13	27	0.85
Low	0	0	4	4	0
Total	21	7	21	49	
Error	0.48	0.43	0.81		0.61

b. Largemouth bass

Observed

Expected	High	Mediu m	Low	Total	Error
High	20	0	4	24	0.17
Medium	0	0	11	11	1
Low	2	0	12	14	0.14
Total	22	0	27	49	
Error	0.09	-	0.56		0.35

c. Spotted bass

Observed

Expected	High	Mediu m	Low	Total	Error
High	4	0	1	5	0.20
Medium	18	0	21	39	1
Low	0	0	5	5	0
Total	22	0	27	49	
Error	0.82	-	0.81		0.82

d. Black bass in aggregate

Observed

Expected	High	Mediu m	Low	Total	Error
High	13	2	4	19	0.32
Medium	17	4	5	26	0.85
Low	0	0	4	4	0
Total	30	6	13	49	
Error	0.57	0.33	0.69		0.57

Appendix A.--Legal descriptions and vernacular references of sample localities in Baron Fork Creek and Glover River, Oklahoma. Abbreviated site names correspond to those in Figures 1 and 2.

Appendix A.--Legal descriptions and vernacular references of sample localities in Baron Fork Creek and Glover River, Oklahoma. Abbreviated site names correspond to those in Figures 1 and 2.

SITE	DESCRIPTION
EB	Baron Fork Creek: Illinois River; Cherokee Co., OK; T17N, R23E, SE 1/4 Section 27. From 200 m upstream of the Eldon bridge up to the eastward bend in the stream.
WB	Baron Fork Creek: Illinois River; Cherokee Co., OK; T16N, R23E, NE 1/4 Section 18. Pool above, underneath, and below the Welling bridge down to the riffle head.
EH	Baron Fork Creek: Illinois River; Cherokee Co., OK; T17N, R23E, SE 1/4 Section 14. Private property of Elmo Eddings.
PF	Baron Fork Creek: Illinois River; Cherokee Co., OK; T16N, R23E, NW 1/4 Section 9. Private property, cut bank near the poultry farm 1/2 mile upstream of Camp Heart O' Hills.
AC	Glover River: McCurtain Co., OK; T3S, R22E, NW 1/4 Section 13. Pool 1/4 mile upstream from "Arkansas" low-water crossing near campsite on west side of stream.
BS	Glover River: McCurtain Co., OK; T4S, R23E, SW 1/4 Section 8. Dierks boy scout camp access, private property.
CC	Glover River: McCurtain Co., OK; T4S, R23E, NW 1/4 Section 5. Pool upstream from the mouth of Carter Creek in Glover River, remote.
FK	Glover River: McCurtain Co., OK; T3S, R23E, NW 1/4 Section 7. From low-water bridge upstream to the forks.
GG	Glover River: McCurtain Co., OK; T4S, R23E, NE 1/4 Section 32. From "Golden Gate" low-water bridge downstream to bend in stream.
SH	Glover River: McCurtain Co., OK; T4S, R23E, NE 1/4 Section 18. One mile downstream from Dierks boy scout camp access, remote.

Appendix B.--Predicted use by smallmouth bass of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned a use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Appendix B.–Predicted use by smallmouth bass of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned a use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Habitat type	Habitat feature (score): Depth	Velocity	Substrate	Cover	Total score	Predicted use
			Riffles			
EGW	shallow (0.0)	low (0.3)	coarse (0.7)	none (0.0)	1.0	low
LGR	shallow (0.0)	high, turbulent (0.0)	coarse (0.3)	none (0.0)	0.3	low
HGR	shallow to moderate (0.3)	high, turbulent (0.0)	coarse (0.7)	none (0.0)	1.0	low
CAS	shallow to moderate (0.3)	high, turbulent (0.0)	bedrock, boulder (0.7)	none (0.0)	1.0	low
			Runs			
GLD	moderate to shallow (0.7)	moderate to low (1.0)	medium to coarse (1.0)	none (0.0)	2.7	medium
RUN	moderate to shallow (0.7)	moderate to high (0.7)	coarse to medium (0.7)	boulder (1.0)	3.1	high
SRN	moderate to shallow (0.7)	moderate to high (0.7)	coarse (0.7)	boulder (1.0)	3.1	high
POW	moderate to deep (1.0)	moderate to high (0.7)	coarse to medium (1.0)	boulder, logs (1.0)	3.7	high
TRC	moderate to deep (1.0)	moderate to high (0.7)	coarse to bedrock (0.7)	none (0.0)	2.4	medium
			Pools			
SCP	shallow (0.0)	low (0.3)	fine (0.0)	none (0.0)	0.3	low
BWP	moderate to shallow (0.7)	low (0.3)	fine (0.0)	boulders, root wads, logs (1.0)	2.0	medium
PLP	deep to moderate (0.7)	low to moderate (0.7)	fine to coarse (0.7)	logs (1.0)	3.1	high
LSP	deep to moderate (0.7)	low to moderate (0.7)	fine to coarse (0.7)	logs, root wads, bedrock, boulders (1.0)	3.1	high
MCP	deep to moderate (0.7)	low (0.3)	fine to coarse (0.7)	logs, rocks (1.0)	2.7	medium
CCP	deep to moderate (0.7)	low to moderate (0.7)	fine to coarse (0.7)	logs, rocks (1.0)	3.1	high
CRP	deep to moderate (0.7)	low to moderate (0.7)	fine to coarse (0.7)	none (0.0)	2.1	medium
STP	moderate to shallow (0.7)	moderate to high (0.7)	coarse (0.7)	boulder (1.0)	3.1	high
			Smallmouth Bass Habitat Preferences			
—	moderate to deep	moderate to low	coarse to medium	logs, root wads, boulders	—	—

Appendix C.--Petersen mark-recapture population estimates and 95 percent intervals and total density (individuals/ha) estimates calculated for sport fish (Micropterus spp., Lepomis spp., Ambloplities rupestris, and Chaenobryttus gulosus) collected at 10 low and 10 high use areas in Baron Fork Creek and Glover River, Oklahoma from 1993 - 1995. Abbreviated site names correspond to those in figures 1 and 2.

Appendix C.–Petersen mark-recapture population estimates and 95 percent intervals and total density (individuals/ha) estimates calculated for sport fish (Micropterus spp., Lepomis spp., Ambloplities rupestris, and Chaenobryttus gulosus) collected at 10 low and 10 high use areas in Baron Fork Creek and Glover River, Oklahoma from 1993 - 1995. Abbreviated site names correspond to those in figures 1 and 2.

Site	Access use type	Size (ha)	Population estimate	95 percent confidence interval	Density (no./ha)
			Baron Fork Creek		
EB - '93	high	0.17	169	86 - 836	994
EB - '94	high	0.40	257	178 - 441	643
EB - '95	high	0.41	373	319 - 455	910
WB - '94	high	0.45	534	364 - 928	1187
WB - '95	high	0.30	288	174 - 693	960
EH - '94	low	0.46	543	376 - 929	1180
EH - '95	low	0.50	713	495 - 1207	1426
PC - '94	low	0.32	142	89 - 315	444
PC - '95	low	0.43	479	347 - 749	1114
			Glover River		
FK - '94	high	0.80	478	335 - 787	598
FK - '95	high	0.12	901	785 - 1070	7508
GG - '93	high	0.24	1194	825 - 2009	4975
GG - '94	high	0.24	2093	1311 - 3450	8721
GG - '95	high	0.21	1532	1287 - 1939	7295
AC - '94	low	0.40	348	253 - 542	870
AC - '95	low	0.52	1231	736 - 2337	2367
BS - '94	low	0.42	820	463 - 1724	1952
BS - '95	low	0.55	1617	1105 - 2608	3038
CC - '93	low	0.72	1464	891 - 2476	2033
SH - '93	low	1.17	554	216 - 1228	474

Appendix D.--Predicted use by largemouth bass of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned a use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Appendix D.--Predicted use by largemouth bass of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned a use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Habitat type	Habitat feature (score): Depth	Velocity	Substrate	Cover	Total score	Predicted use
			Riffles			
EGW	shallow (0.0)	low (1.0)	coarse (0.3)	none (0.0)	1.3	low
LGR	shallow (0.0)	high, turbulent (0.0)	coarse (0.3)	none (0.0)	0.3	low
HGR	shallow to moderate (0.3)	high, turbulent (0.0)	coarse (0.3)	none (0.0)	0.6	low
CAS	shallow to moderate (0.3)	high, turbulent (0.0)	bedrock, boulder (0.3)	none (0.0)	0.6	low
			Runs			
GLD	moderate to shallow (0.3)	moderate to low (0.3)	medium to coarse (0.7)	none (0.0)	1.3	low
RUN	moderate to shallow (0.3)	moderate to high (0.0)	coarse to medium (0.7)	boulder (1.0)	2.0	medium
SRN	moderate to shallow (0.3)	moderate to high (0.0)	coarse (0.3)	boulder (1.0)	1.6	medium
POW	moderate to deep (0.7)	moderate to high (0.0)	coarse to medium (0.7)	boulder, logs (1.0)	2.4	medium
TRC	moderate to deep (0.7)	moderate to high (0.0)	coarse to bedrock (0.3)	none (0.0)	1.0	low
			Pools			
SCP	shallow (0.0)	low (1.0)	fine (0.7)	none (0.0)	1.7	medium
BWP	moderate to shallow (0.3)	low (1.0)	fine (0.7)	boulders, root wads, logs (1.0)	3.0	high
PLP	deep to moderate (1.0)	low to moderate (0.7)	fine to coarse (1.0)	logs (1.0)	3.7	high
LSP	deep to moderate (1.0)	low to moderate (0.7)	fine to coarse (1.0)	logs, root wads, bedrock, boulders (1.0)	3.7	high
MCP	deep to moderate (1.0)	low (1.0)	fine to coarse (1.0)	logs, rocks (1.0)	4.0	high
CCP	deep to moderate (1.0)	low to moderate (0.7)	fine to coarse (1.0)	logs, rocks (1.0)	3.7	high
CRP	deep to moderate (1.0)	low to moderate (0.7)	fine to coarse (1.0)	none (0.0)	2.7	medium
STP	moderate to shallow (0.3)	moderate to high (0.0)	coarse (0.3)	boulder (1.0)	1.6	medium
			Largemouth Bass Habitat Preferences			
—	deep to moderate	low	fine to coarse	logs, root wads, vegetation	—	—

Appendix E.–Predicted use by spotted bass of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Appendix E.–Predicted use by spotted bass of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Habitat	Habitat feature (score)				Total	Predicted
type	Depth	Velocity	Substrate	Cover	score	use
			Riffles			
EGW	shallow (0.0)	low (0.7)	coarse (0.3)	none (0.0)	1.0	low
LGR	shallow (0.0)	high, turbulent (0.0)	coarse (0.3)	none (0.0)	0.3	low
HGR	shallow to moderate (0.3)	high, turbulent (0.0)	coarse (0.3)	none (0.0)	0.6	low
CAS	shallow to moderate (0.3)	high, turbulent (0.0)	bedrock, boulder (0.3)	none (0.0)	0.6	low
			Runs			
GLD	moderate to shallow (0.3)	moderate to low (0.7)	medium to coarse (0.7)	none (0.0)	1.7	medium
RUN	moderate to shallow (0.3)	moderate to high (0.3)	coarse to medium (1.0)	boulder (1.0)	2.6	medium
SRN	moderate to shallow (0.3)	moderate to high (0.3)	coarse (0.3)	boulder (1.0)	1.9	medium
POW	moderate to deep (0.7)	moderate to high (0.3)	coarse to medium (0.7)	boulder, logs (0.7)	2.4	medium
TRC	moderate to deep (0.7)	moderate to high (0.3)	coarse to bedrock (0.3)	none (0.0)	1.3	low
			Pools			
SCP	shallow (0.0)	low (0.7)	fine (0.0)	none (0.0)	0.7	low
BWP	moderate to shallow (0.3)	low (0.7)	fine (0.0)	boulders, root wads, logs (1.0)	2.0	medium
PLP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.3)	logs (1.0)	3.3	high
LSP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.3)	logs, root wads, bedrock, boulders (1.0)	3.3	high
MCP	deep to moderate (1.0)	low (0.7)	fine to coarse (0.3)	logs, rocks (1.0)	3.0	high
CCP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.3)	logs, rocks (1.0)	3.3	high
CRP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.3)	none (0.0)	2.3	medium
STP	moderate to shallow (0.3)	moderate to high (0.3)	coarse (0.3)	boulder (1.0)	1.9	medium
			Spotted Bass Habitat Preferences			
—	deep to moderate	low to moderate	medium to coarse	logs, root wads, boulders	—	—

Appendix F.--Predicted use by black bass (smallmouth bass, largemouth bass, and spotted bass combined) of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned a use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Appendix F.--Predicted use by black bass (smallmouth bass, largemouth bass, and spotted bass combined) of 17 mesohabitats found in either Baron Fork Creek (1995) or Glover River (1996), Oklahoma. Mesohabitat features of and smallmouth bass preferences for depth, velocity, substrate, and cover were compared and scored based on the following rules: no matches = 0.0; one match with second characteristic = 0.3; one match with first characteristic = 0.7; two matches with both characteristics = 0.7; and exact match = 1.0. Total scores were assigned a use type by the following criterion: low = 0.0 - 1.3; medium = 1.4 - 2.7; and high = 2.8 - 4.0. Mesohabitat acronyms include: EGW = edgewater; LGR = low gradient riffle; HGR = high gradient riffle; CAS = cascade; GLD = glide; RUN = run; SRN = step run; POW = pocket water; TRC = trench chute; SCP = secondary channel pool; BWP = back water pool; PLP = plunge pool; LSP = lateral scour pool; MCP = mid-channel pool; CCP = channel confluence pool; CRP = corner pool; and STP = step pool.

Habitat type	Habitat feature (score)				Total score	Predicted use
	Depth	Velocity	Substrate	Cover		
			Riffles			
EGW	shallow (0.0)	low (0.3)	coarse (0.7)	none (0.0)	1.0	low
LGR	shallow (0.0)	high, turbulent (0.0)	coarse (0.7)	none (0.0)	0.7	low
HGR	shallow to moderate (0.3)	high, turbulent (0.0)	coarse (0.7)	none (0.0)	1.0	low
CAS	shallow to moderate (0.3)	high, turbulent (0.0)	bedrock, boulder (0.7)	none (0.0)	1.0	low
			Runs			
GLD	moderate to shallow (0.3)	moderate to low (0.7)	medium to coarse (0.7)	none (0.0)	1.7	medium
RUN	moderate to shallow (0.3)	moderate to high (0.3)	coarse to medium (1.0)	boulder (1.0)	2.6	medium
SRN	moderate to shallow (0.3)	moderate to high (0.3)	coarse (0.7)	boulder (1.0)	2.3	medium
POW	moderate to deep (0.7)	moderate to high (0.3)	coarse to medium (1.0)	boulder, logs (1.0)	3.0	high
TRC	moderate to deep (0.7)	moderate to high (0.3	coarse to bedrock (0.7)	none (0.0)	1.7	medium
			Pools			
SCP	shallow (0.0)	low (0.7)	fine (0.0)	none (0.0)	0.7	low
BWP	moderate to shallow (0.3)	low (0.7)	fine (0.0)	boulders, root wads, logs (1.0)	2.0	medium
PLP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.7)	logs (1.0)	3.7	high
LSP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.7)	logs, root wads, bedrock, boulders (1.0)	3.7	high
MCP	deep to moderate (1.0)	low (0.7)	fine to coarse (0.7)	logs, rocks (1.0)	3.4	high
CCP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.7)	logs, rocks (1.0)	3.7	high
CRP	deep to moderate (1.0)	low to moderate (1.0)	fine to coarse (0.7)	none (0.0)	2.7	medium
STP	moderate to shallow (0.3)	moderate to high (0.3)	coarse (0.7)	boulder (1.0)	2.3	medium
			Black Bass Habitat Preferences			
—	deep to moderate	low to moderate	coarse to medium	logs, root wads, boulders	—	—

VITA

Paul Eugene Balkenbush

Candidate for the Degree of

Master of Science

Thesis: POPULATION BIOLOGY, MANAGEMENT, AND SAMPLING CONSIDERATIONS FOR BLACK BASS AND SUNFISH IN TWO EASTERN OKLAHOMA STREAMS

Major Field: Wildlife and Fisheries Ecology

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma, June 24, 1968, the son of James W. and Elizabeth J. Balkenbush.

Education: Graduated from Putnam City North High School, Oklahoma City, Oklahoma in May 1986; received Bachelor of Science degree in Conservation (Wildlife option) from Southeastern Oklahoma State University in May 1993; completed the requirements for the Master of Science degree at Oklahoma State University in December 1996.

Professional Experience: *Fisheries*: graduate research assistant for the Oklahoma Cooperative Fish and Wildlife Research Unit, July 1993 - August 1996; summer biologist aide for Oklahoma Department of Wildlife Conservation (ODWC), May - August 1990 - 1992. *Wildlife*: biologist aide for ODWC, Sept. 1991 - April 1992 and Sept. 1990 - March 1991; hunter check station operator for ODWC, Nov. 1990, 1991, and 1992.

Organizational Memberships: American Fisheries Society; Oklahoma and Texas Chapters of the American Fisheries Society; Alpha Chi National College Honor Scholarship Society.