CENTRARCHID POPULATION RESPONSES TO HABITAT ENHANCEMENT STRUCTURES IN THE NORTH FORK OF THE ILLINOIS BAYOU: A STREAM OF THE BOSTON MOUNTAIN ECOREGION ON THE OZARK NATIONAL FOREST

By

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PREFACE

This project was conducted under a Cooperative agreement between Oklahoma State University and the United States Forest Service. The purpose of this research was to determine if installation of instream habitat structures enhances fisheries on the Ozark National Forest. Protection of riparian areas is given high priority on National Forests, therefore intense modifications of streamside zones are done only when necessary to correct or prevent problems. Management for multiple use objectives is also important and structures were designed and placed to minimize visual impacts and provide for the safety of all users. The experimental design would have been better if not for these considerations.

My thanks to the faculty and staff at OSU who have provided the sort of academic environment which fosters this type of research project. My major advisor, Dale Toetz, has given direction to my studies and helped me design this project. Committee members Tony Echelle and Al Zale provided insights which were helpful in developing a research project.

The Supervisor's Office of the Ozark National Forest provided invaluable help at all levels. I am very grateful to Forest Supervisor Lynn Neff and Fisheries, Wildlife and Range Staff Officer Gary Hartman for making this cooperative agreement available. Craig Hilburn, Forest Fisheries Biologist, helped with all levels of this project and I could not have completed it without his assistance, insight and encouragement. My thanks also to S. Duzan and D. Rambo for their help with field work.

The Bayou Ranger District of the Ozark National Forest provided help and support. Thanks to District Ranger Franklin Lewis for allowing me to do this project on the district and providing people to assist me. Public affairs specialist Tracy Powers on the district and providing people to assist me. Public affairs specialist Tracy Powers assisted with field work and photography. I thank District Biologist Steve Osborne for his help to me, and the following persons from the Bayou Ranger District who helped with fish collections; J. Andre, F.C. Duvall, C. Mackey, S. Smith, W. Robinson, and S. Wilhelm.

The Arkansas Game and Fish Commission supplied equipment which allowed completion of the project. Special thanks go to J. Ahlert, L. Claybrook, S. Filipek, B. Limbird, S. Sanger, B.Wagner and D. Wilson.

My brothers and sisters, cousins, aunts, uncles, nieces and nephews have provided twenty-five years of inspiration and encouragement. The Dellwood Family of Memphis, especially Father and Billy, has helped me keep fish and myself in perspective. Nobody accomplishes anything alone and I owe Mary, Beth, Marley and all of my friends near and far thanks. *Signum Fidei!*

My folks took me fishing before I could walk and truly inspired my love for life, fish, and science. Although neither one of them got to see me finish this, I know they've both been with me all the way. Thanks Dad and Mom.

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CHAPTER I

INTRODUCTION

Smallmouth bass (*Micropterus dolomieu*), spotted bass (*Micropterus punctulatus*), and green sunfish (*Lepomis cyanellus*) are the most popular gamefishes in the rivers of the Boston Mountains region of the Ozark Uplift (Shackleford 1987). Increasing the populations of these fishes, particularly smallmouth bass, is one goal of fishery resource management in the area. In this report I examine the possibility of using habitat enhancement structures to improve the sport fishery in the Boston Mountain Ecoregion of the Ozark National Forest.

Clear, cool streams are characteristic habitat for smallmouth bass (Carlander 1977). Deep pools with abundant shade and cover, moderate current and a gravel or cobble substrate are optimal habitat (Caine 1949; Coble 1975; Pflieger 1975; Okeyo and Hassler 1985). Smallmouth bass seek protection from light throughtout their lives and utilize cover structures such as boulders, stumps, rootwads and fallen trees (Caine 1949; Coble 1975; Miller 1975; Hubert and Lackey 1980; Okeyo and Hassler 1985; Sechnik et al. 1986; Todd and Rabeni 1989).

Smallmouth bass prefer pH levels of 5.7 to 9.0 and require more than six mg/l dissolved oxygen for optimal growth (Bulkley 1975; Clady 1977). They prefer temperatures from 19 to 22^{o} C (Coble 1975).

Smallmouth bass presence is highly correlated with cover, especially log complexes. Smallmouth less than 350 mm, total length, often use vegetation and boulders, but are found in open water more often than larger fish (Probst et al. 1984). Habitat suitability index models for smallmouth bass and green sunfish both show a positive correlation between cover and abundance of the species (Stuber et al. 1982; Edwards et al. 1983). Most pools in Boston Mountain streams have little or no woody cover. The hydrology of streams in the area, namely the sudden high spring flows, is not conducive to maintaining large wooden structures in the water. Water quality in the streams of the Boston Mountains is within the range required for smallmouth bass. For this research project, woody structures were added to the North Fork of the Illinois Bayou to assess their value in increasing populations. Habitat enhancement for smallmouth bass populations is not a standard management practice. Resource managers generally rely on catch limits, seasons and length limits for smallmouth management. It seems likely, however, that habitat enhancement could become as important to bass management as it has been to salmonid management (Paragamian 1981).

Although use of habitat structures has been investigated for many species of fish, managers of salmonid fisheries have been especially active in employing these techniques. Some projects have resulted in population increases of invertebrates, and subsequently increases in trout populations and their terrestrial predators (c.f. Burgess and Bider 1980). Fish are dependent upon both physical characteristics of their environment and other forms of aquatic life (Foltz 1982). When a stream in Illinois had large woody debris cleared from one side and added to the other, both fish and benthic invertebrate abundances increased on the side with woody structure (Angermeier and Karr 1984).

House and Boehne (1986) compared biomass of coho salmon (*Oncorhyncus kisutch*) in two sections of the same river. One section had been logged and cleared twenty years previous and hence had no large woody debris. The other section was in a mature mixed-conifer section and had abundant woody debris. The section with woody structure had significantly higher salmonid biomass than the cleared section. After structure enhancement in the cleared section, no significant difference in biomass was found between the two sections. Moore and Gregory (1988) noted an increase in the density of age-0 cutthroat trout (*Salmo clarki*) in habitat enhanced areas. In a study on Prince

Edward Island, the standing crop of brook trout (*Salvelinus fonitnalis*) fingerlings was above average in the year following habitat enhancement. The numbers of age one and older trout were effectively doubled, but there was no noticeable change in growth (Saunders and Smith 1962).

Artificial structures have been tested as fish attractors in marine environments. Such structures were proven to attract forage fish such as, round scad (*Decapterus punctatus*), Spanish sardines (*Sardinella anchovia*) and scaled sardines (*Harengula pensacolae*), and the design of structures was an important factor in determining which species were attracted (Klima and Wickham 1971). Similar structures were also shown to increase the abundances of sportfish. Greater catches of little tunny (*Euthynnus alletteratus*), king mackerel (*Scomberomorus cavalla*) and dolphin (*Coryphaena hippurus*) were recorded around experimental structures (Wickham et al. 1973).

Habitat structure is, however, not always effective as a means of increasing density. In a New York study there was no significant difference in biomass, average weight, or number of rainbow trout (*Oncorhynchus mykiss*) between altered and unaltered areas (Boreman 1974). Habitat enhancement projects for centrarchids have had mixed results. Spotted bass utilize artificial brush cover for nesting, but smallmouth bass do not (Vogele and Rainwater 1975). Half-log structures have been used to increase both numbers of nests and numbers of successful nests of smallmouth bass (Hoff 1989). Stumps were investigated as fish attractors in an Alabama-Mississippi lake and neither largemouth bass (*Micropterus salmoides*) nor bluegill sunfish (*Lepomis macrochirus*) showed a preference for the stump areas over other areas (Timmons and Garrett 1985).

Aside from changes in relative density, changes in species relative abundance and size structure are also likely to occur around structures and in entire pools. Micropterine basses are the top predators in these ecosystems, and changes in their populations could affect the populations of other species. Size related segregation of fishes has been noted in some studies. Meffe and Sheldon (1988) noticed size classes of some species were well separarted, probably indicating larger fish use different habitats than the smaller fish. Brown trout (*Salmo trutta*) prefer littoral areas during the first one to two years, but as they age they prefer benthic or pelagic areas (Haraldstad and Jonsson 1983). Mahon and Portt (1985) documented a similar pattern with several species including one centrarchid, rock bass (*Ambloplites rupestris*). He suggested streams would be ideal for field manipulations to study fish segregation.

This project consisted of anchoring log structures in the North Fork of the Illinois Bayou and assessing their effects on centrarchid density, condition, species abundance and size structure. The purpose of this study is to determine the value of adding structure to the rivers in this region. The information obtained here will assist fisheries habitat managers in understanding how they can manipulate streams of the Ozark National Forest for the benefit of the recreational fishery.

CHAPTER II

SITE DESCRIPTION

The Boston Mountains lie north of the Arkansas River Valley in northwestern Arkansas. They are the highest and most eroded in the Ozark Highlands, all of which were uplifted 280 million years ago (Shackleford 1987). Surface rock is predominately sandstone and shale of the Atoka Formation (Robison and Buchanan 1988). The terrain is exceptionally steep; local relief may exceed 300 m. Bluffs of 100 m are common on mountainsides. Spring runoff is rapid and water levels rise quickly, annually scouring the streams (Shackleford 1987).

Pools alternate with riffles in these streams and substrate type is generally a combination of gravel, cobble, boulders and bedrock. The shales associated with this region are thought to be responsible for the characteristic greenish-blue tinge of the water (Shackleford 1987). Except for the spring, and sometimes winter , when these rivers rise quickly following heavy rains, surface flow is intermittent with isolated pools and intergravel flow (Shackleford1987).

The North Fork of the Illinois Bayou lies in Pope County, Arkansas and is representative of Boston Mountain streams (Figure 1). The North Fork originates in north central Pope County and flows south to its confluence with the Middle and East Forks forming the Illinois Bayou. The Illinois Bayou flows into Dardenelle Reservior on the Arkansas River, but a low-water dam has separated it from the river since 1907. The Ozark National Forest contains ninety-five per cent of the North Fork corridor, the area within one quarter mile of each bank. The section of river studied is contained on the USGS Simpson Quadrangle map. Table 1 lists the longitude and latitude of the pools.

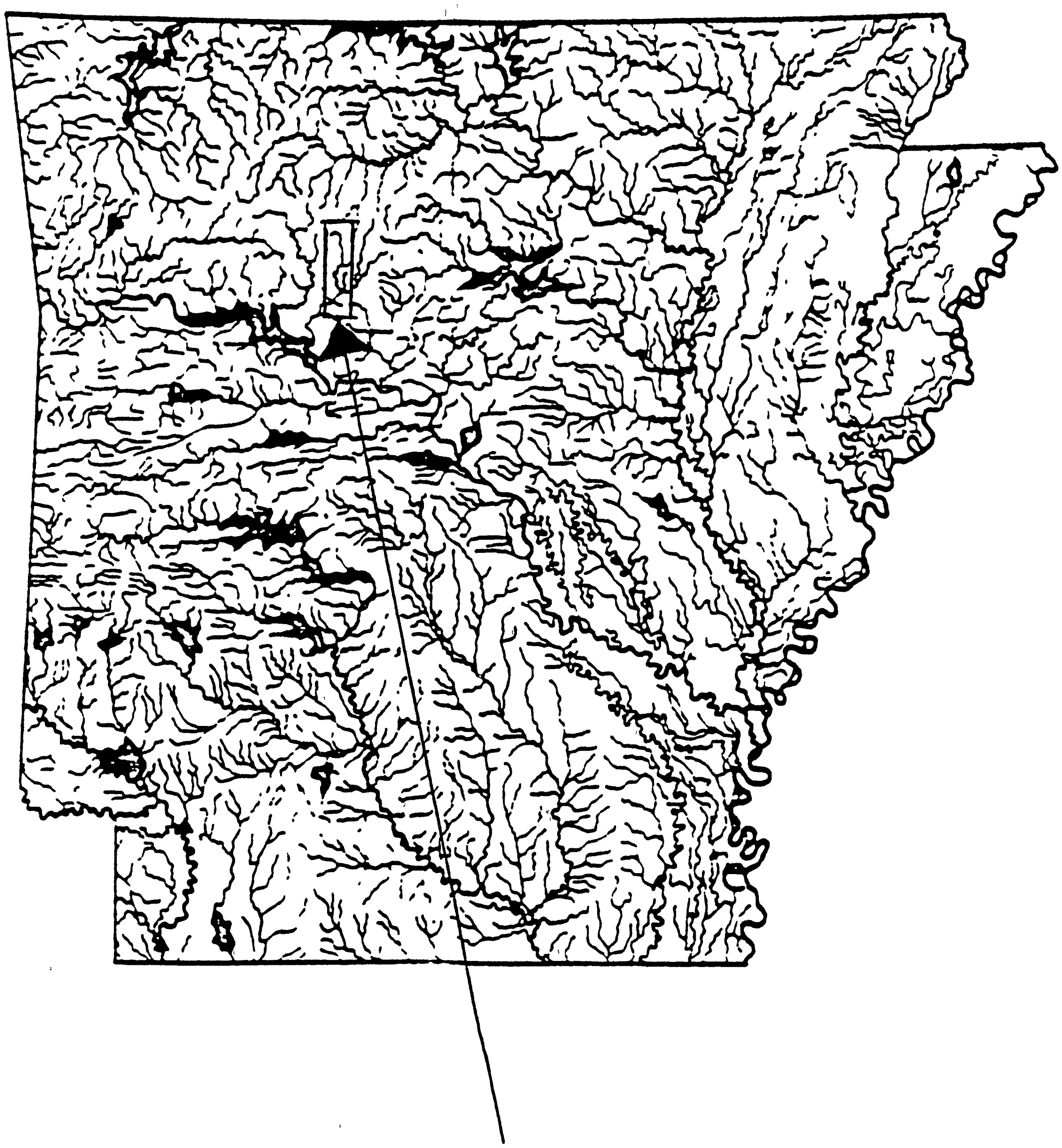

Figure 1. Location of the North Fork of the Illinois Bayou

TABLE 1

LOCATIONS OF STUDY SITE POOLS

Pool	West Longitude	North Latitude
B	93° 01' 18"	35° 35' 07"
C	93° 01' 14"	35° 35' 07"
D	93° 01' 13"	35° 35' 07"
E	93° 00' 42"	35° 35' 15"
F	93° 00' 28"	35° 35' 55"
G	93° 00' 28"	35° 36' 00"

Six pools were chosen for this project (Figure 2) They are referred to as pools B, C, D, E, F and G. They all lie in a 2-km stretch of the river. Pool B is the fartherest downstream. It lies immediately below a ford on the river. Pool C lies upstream of the same ford. A riffle separates pool D from pool C. Several hundred meters farther upstream lies pool E. The area between D and E is mostly dry streambed during the summer. Pool E lies immediately upstream of a ford. Pool F lies a few hundred meters upstream from E. A riffle separates pool F from pool G.

Streamside vegetation is similar around all pools. Water willow (*Justicia americana*) is present in the very shallow water near the ends of the pools. Common alder (*Alnus* sp.) overhangs the banks in sections along all of the pools. Common trees include sweetgum (*Liquidambar Styraciflua* L.), sycamore (*Platanus occidentalis*), birch (*Betula nigra*), cedar (*Juniperus virginiana*), cottonwood (*Populus deltoides*) and sugar maple (*Acer saccharum*). Smartweed (*Polygonum* sp.) and cane (*Arundinaria* sp.) are present in some areas.

There are approximately 12,150 ha in the watershed upstream from these pools. Most of the area is forested. The forest types include both shortleaf pine (*Pinus echinata*) and white oak (*Quercus alba*). Much of the area near the river was farmland before 1940. It has been returned to forest, since becoming a part of the Ozark National Forest.

The stream is popular for fishing and canoeing and there are occasional weekend campers around all of the pools. Visitation increases during deer hunting season.

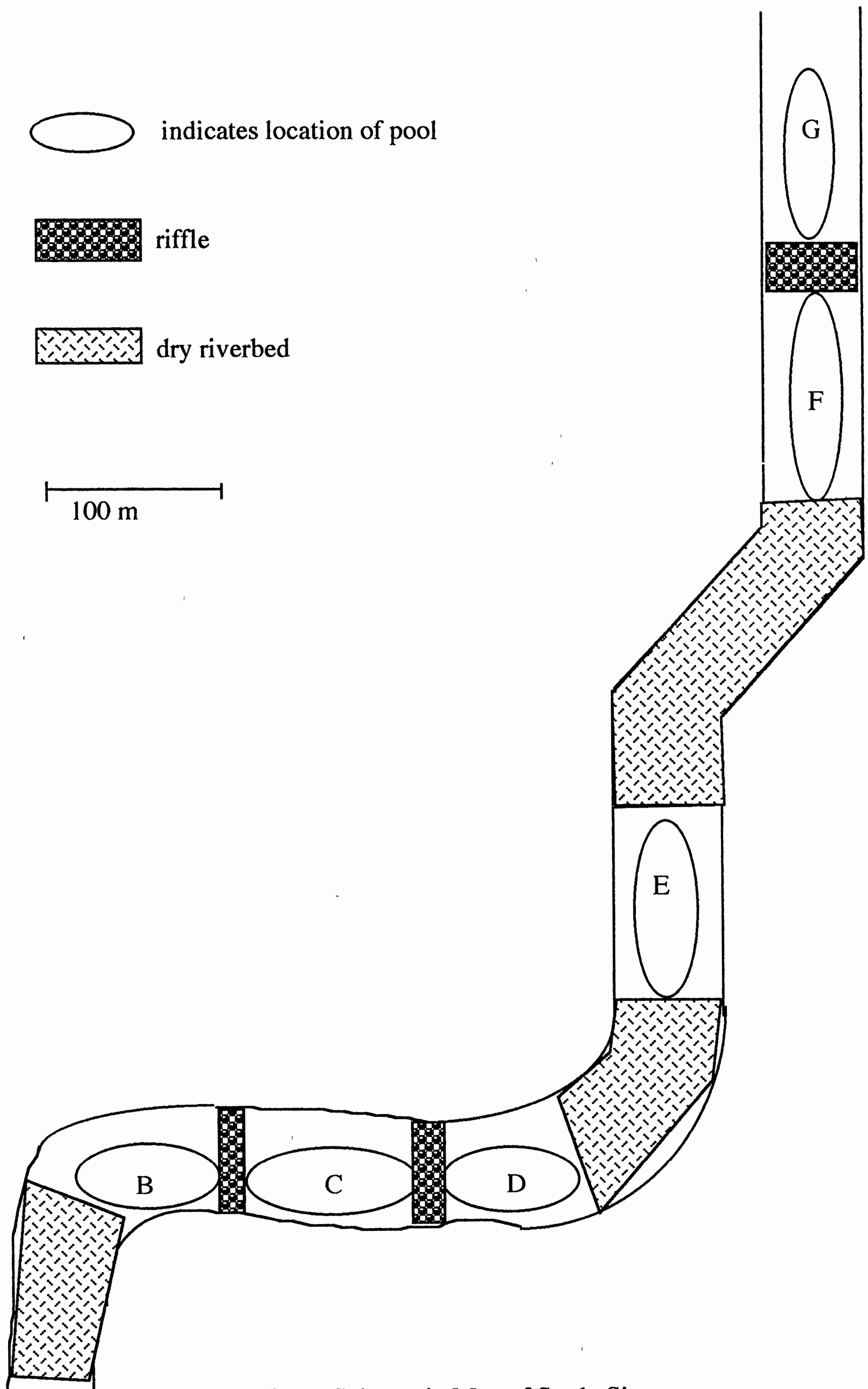

Fig. 2 Schematic Map of Study Site

CHAPTER III

METHODS AND MATERIALS

General Information

The six pools on the North Fork of the Illinois Bayou were chosen during the summer of 1990. Roads do not provide access to much of the river and transporting equipment to such areas was not feasible. There are many small, shallow pools on the river and also several large, deep pools. The study pools were selected based on similarity of size, accessibility and inclusion in the Ozark National Forest. The pools lie close together; thus flow, watershed use, and nutrient inputs are similar.

Habitat Inventory

Habitat characteristics of the pools were inventoried using the criteria developed for the BASS (Basin Area Stream Survey) method, which was created for use on Arkansas streams. Length of the pool was measured from the edge of the water on each end of the pool. Width was measured every 30m, along the length of the pool and transects were established at those points. Depths were measured at five points along each transect; both banks, and at points which were 1/4, 1/2 and 3/4 of the width of the transect from the left bank. Substrate types were inventoried visually and recorded along each transect. Bank angle and stability were estimated at each transect. Bank angle was 90^{o} along vertical banks and 180^{o} where the bank was essentially horizontal. Stability was 100 percent along solid rock or fully vegetated banks and estimated based on the amount of rock or vegetation in other cases. Canopy closure was measured at each bank and at the middle of each transect using a Model C spherical densiometer (Paul E. Lemmon, Forest Densiometers). These measurements were made in the fall of 1990 and repeated in the fall of 1991.

Hach chemical test kits were used to measure pH, dissolved oxygen, nitrates and phosphates. Turbidity was measured using a Hach Turbidimeter. These water quality measurements were done once in the fall of 1991 as part of the BASS inventory. Conductivity and temperature were measured in two pools during fish sampling in 1990.

Addition of Structure

Pools C, F and G were selected to be experimental pools while pools B, D and E remained as controls . Pools F and G were chosen as experimental pools because material for woody structures was readily available near the pools. Pool C was chosen randomly. The experimental pools had woody structures added to increase the surface area of structure in those pools. Dead, downed logs and trees available near the pools provided the material for the structures.

Small logs and branches were lashed to larger logs with plastic coated wire to create structures with interstitial space. Aircraft cable was used to secure structures to standing trees and prevent them from washing away during high flows.

The total surface area of structures (summed length x width across all structures) added to each pool was approximately 10% of the surface area of water in each pool. Structures were kept close to the bank , on short cables to insure neither the structures themselves nor the cables created a safety hazard to canoeists or others. All structures were placed in the river after fish were collected from the pools in 1990. Figure 3 shows the locations of structures in each pool. The structures were visually surveyed in 1991 before fish sampling to verify their presence.

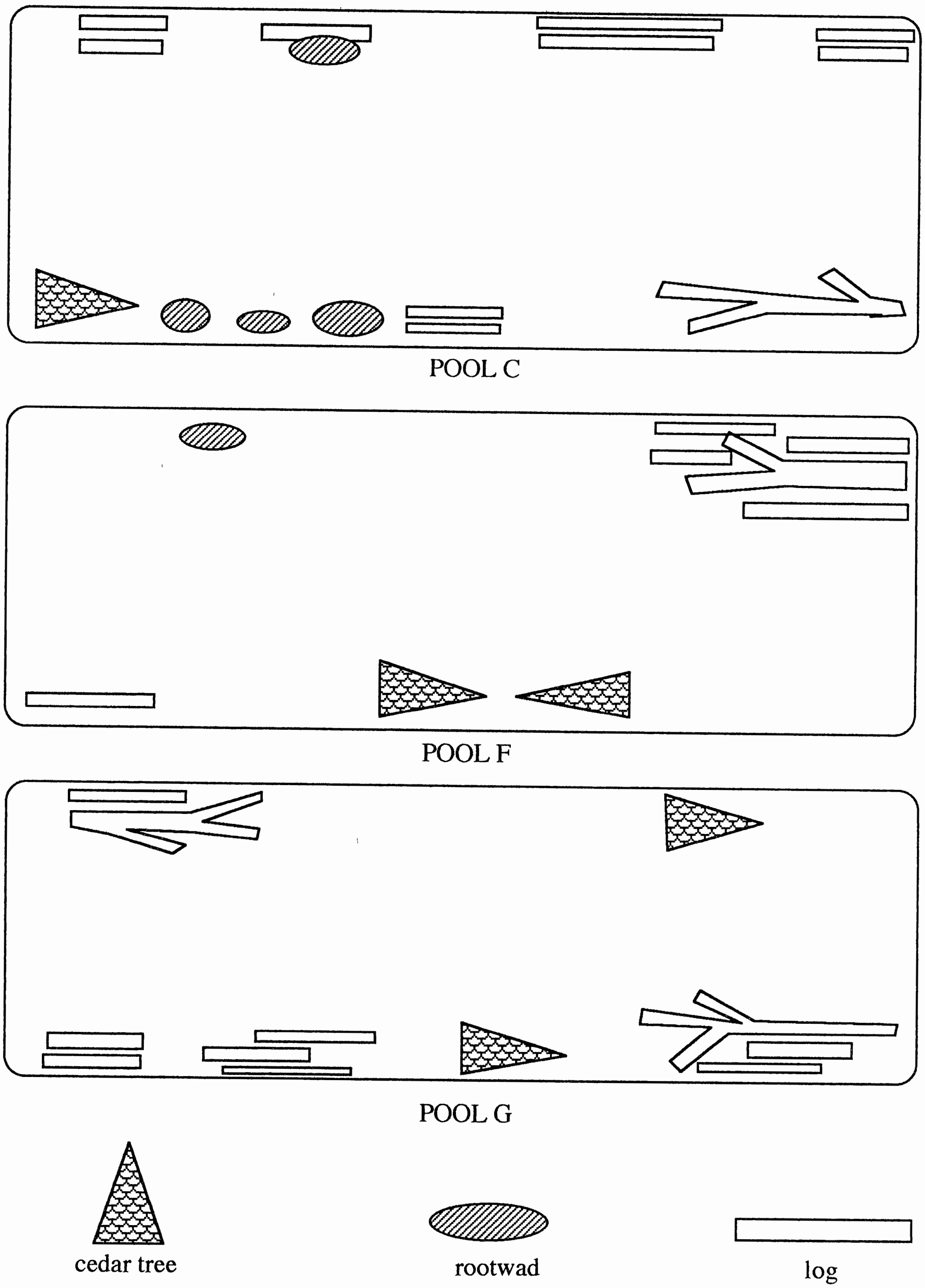

Figure 3. Placement of Structures in Pools

Fish Collection

Fish were first collected from the study sites on September 11, 12, and 13, 1990. Two pools were electrofished each day. Collections were made with an electrofishing boat 3.5 m long by 1m wide with a Smith-Root Type VIA Electrofisher (1008 volts, 4amps) and a three-person crew (driver and two netters) . Dipnets were 2.4 m long and had 0.6 cm mesh. For each pool, one pass of the sampling included shocking along each bank and in the middle of the pool. Three complete passes were made in each pool. All fish collected were identified to species and counted. Centrarchids were also weighed and measured. All fish were returned to the water.

Fish sampling was repeated three times in the fall of 1991with the same gear used in 1990. The first sample (a) was taken August 7, 8, and 9. The second sample (b) was taken October 1, 2 and 3. The final sample (c) was done October 23, 24, and 25. Again two pools were electrofished each day, except for the last day when only one was done. The same three pass collecting scheme used in 1990, was repeated in 1991. The first pass of the 1991 sample was, however, broken into three transects, one along the right bank, one on the left, and one in the middle of the pool. The left bank, right bank and middle were assigned numbers, and a random number table determined the order transects were sampled in each pool. Twenty minutes was allowed to elapse between sampling each transect so fish would not be disturbed away from their usual locations. Fish from each transect were counted, weighed and measured as before. Fish were returned to the water immediately after measuring. Fish taken during each pass had one fin clipped before they were returned to the water to insure no fish were counted twice. After the fish had been sampled from each bank and the middle , two more complete passes were made to complete a three-pass sample similar to that done in 1990.

Statistical Analyses

Relative Density

For smallmouth bass, spotted bass, green sunfish and longear sunfish, the relative densities from 1990 were compared to those of 1991 in two ways. Each species was analyzed separately. For each pool the number collected in 1990 was compared to the average of the three sampling periods of 1991using a t-test. The standard deviation was estimated from the 1991 sample. All statistical tests in this and following sections follow Steel and Torrie (1980). Additionally, the 1990 relative density estimate for each pool was subtracted from the average of the 1991 densities to determine the amount and direction of change in each pool. A t-test compared the amount of change in the three control pools to the change in the three experimental pools.

Condition Factors

Condition coefficients, K_{TL}, were calculated for smallmouth and spotted bass taken in 1991. The following equation was used to calculate K_{TL}:

$$K_{TL} = \frac{\text{weight of fish (grams)}}{\text{length of fish (cm)}^3}$$

Values of K_{TL} increase with fish length (Anderson and Gutreuter 1983), thus only fish which were at least stock length (see below) were used. The data from the control pools were combined and compared to the data from the experimental pools to determine if the addition of structure enhanced condition. A t-test was used to compare the average K_{TL} values from the experimental pools with those from the control pools.

Relative Abundance

The abundances of four centrarchid species were expressed as percentages of the total number of centrarchids collected in an area. These percentages were determined for green sunfish, longear sunfish, smallmouth bass and spotted bass along each bank and the middle of all pools. These numbers were analyzed using an analysis of variance (ANOVA) to determine if the relative abundances of each species were different among banks, pools, or between control and experimental pools. Arcsine transformations are not recommended for large percentage ranges and therefore were not done (Steel and Torrie 1980). Shadow bass (*Ambloplites ariommus*), were not included in these calculations because they were rare.

Size Segregation

Longear sunfish, green sunfish, smallmouth bass and spotted bass length data were divided into length groups based on the minimum lengths for stock and quality fish (Gablehouse 1984). No stock or quality lengths have been suggested for longear sunfish. The other lengths were determined based on the world record length for the species as follows. The largest longear sunfish reported in Carlander (1977) was 220 mm. Assuming 250 mm to be the maximum size for longear sunfish and employing the percentages Gablehouse used to establish stock, quality and memorable lengths for other species (20-26% for stock length, 36-41% for quality length and 54-58% for preferred length), minimum lengths were calculated for use in this study (Table 2).

TABLE 2

MINIMUM LENGTHS FOR GROUPS OF CENTRARCHIDS

Species	Stock Length (mm)	Quality Length (mm)	Preferred Length (mm)
Green Sunfish	80	150	200
Longear Sunfish	60	100	145
Smallmouth Bass	180	280	350
Spotted Bass	180	280	350

For each species the number of fish collected from the stock length group was divided by the total number of fish collected from the population in an area to determine the relative population density (RPD) of stock length fish. These RPDs were analyzed using an ANOVA to determine if banks, pools or addition of habitat affected size distribution. Similarly RPDs were also determined and analyzed for quality length fish.

CHAPTER IV

RESULTS

Habitat Measurements

The lengths of the pools ranged from 128 to 187 m in 1990 and from 134 to 191 m in 1991. Pool B was the shortest in both years, while pools C and F were longest in 1990 and 1991, respectively. The average width of the pools ranged from 21.5 to 28.0 in 1990 and 21.4 to 28.3 in 1991. Pool D was the smallest in both years and pool C was the widest. Appendix A contains all of the physical habitat data.

In 1990 the maximum depths of the pools ranged from 2.8 meters in pool B to 1.1 meters in pool C. In 1991 the maximum depths ranged from 2.9 meters to 1.2 meters with the extremes being in the same pools as before.

Substrate types were predominately cobble, boulder, and gravel. Pool D was the exception having 42% bedrock. Fine substrate was present in four pools but was never more than 10% of the substrate in a pool. Only pool G had sand, and there it comprised only 6.2% of the substrate.

Bank stability was high in pools B, C, D and E being above 80 in all locations save one in pool D. Pools F and G had much lower stability, as low as 10% in one area and below 60% in half of the locations. Bank angles ranged from 70 degrees to 175 degrees. Canopy closure in the center of the pools ranged from 4% to 69%. Canopy closure at the banks of pools B, C and D ranged from 50% to 90%, while closure on the banks in pools E, F, and G ranged from 20% to 50%.

Dissolved oxygen levels were between 11 and 12 mg/l in all of the pools. The range of pH was from 6.6 to 6.8. Neither nitrates or phosphates could be detected with the equipment used. Turbidity ranged from 2.8 to 3.5 NTU. Conductivity was measured in pools B and E, and was found to be 29.8 micromhos/cm^2 in both locations. Temperature in the same pools was 20.4^o C. These measurements were made during the first day of fish collection in 1990. Appendix B contains the rest of the water quality data.

Fish Collected

In 1990 there were nine families represented in a sample of 736 individuals ; Atherinidae, Catostomidae, Centrarchidae, Cyprinidae, Esocidae, Fundulidae, Ictaluridae, Percidae and Petromyzontidae. Nineteen species were identified. The centrarchids were shadow bass, green sunfish, longear sunfish, smallmouth bass and spotted bass.

In the first sample in 1991, 1244 fish were collected. The same nine families were present as in 1990, and 22 species were identified. Two species of Cyprinidae (*Notropis greenei* and *Notropis whipplei*) and two Catostomids (*Moxostoma duquesni* and *Erimyzon oblongus*) not previously found were identified. One Ictalurid species (*Noturus exilis*) found in 1990 was not present in this sample. Two Percids (*Percina maculata* and *Etheostoma whipplei*) not found in 1990 were identified in 1991 while one (*Percina caprodes*) found in 1990 was not present.

In the second 1991 sample, 1538 fish were collected. Twenty-six species from the same nine families were identified. All of the species found in 1990 were represented in this sample. One Percid (*Percina maculata*) found in the first 1991 sample was not present, but four (*Percina caprodes*, *Etheostoma punctulatum*, *E. spectabile* and *E.zonale*) were found in this sample which were not represented in the first. One Ictalurid (*Noturus exilis*) not found in the first 1991 sample was present in the second, while one Cyprinid (*Notropis whipplei*) found in the first was not present in the second.

The third sample in 1991 could not be completed due to inclement weather. Five of the six pools had been sampled before several inches of overnight rain caused the river to rise almost one meter. For this reason, pool B was not sampled a third time. The total number of fish collected from five pools was 899. Twenty-two species from the same nine families were present. All of the species present in this sample had been identified in previous samples. Appendix C contains complete lists of collected fish.

In 1990 black redhorse (*Moxostoma duquesni*) were apparently recorded as golden redhorse (*Moxostoma erythurum*) . Likewise wedgespot shiners (*Notropis greenei*) were recorded as bigeye shiners (*Notropis boops*) in 1990.

Numerous lamprey ammocoetes were found in both years. Because no adult lampreys were collected, the species is not known. Other fish collections from the same river have not recorded lampreys. Distribution and occurrence patterns would suggest the lampreys are *Ichthyomyzon cataneus*, but *Ichthyomyzon gagei* is a possibility.

Structure Addition

The structures were placed in the river in the Fall of 1990. All of the structures were still in place in the summer of 1991. Additional woody structure deposited in the pools, by the river, during the winter or spring was not noted.

Statistical Analysis

Relative Density

The t-tests of relative densities between 1990 and the mean of the three samples made in 1991 revealed only one significant difference. Namely, there was a significant decline in the relative density of smallmouth bass in pool B (Table 3).

TABLE 3

RELATIVE DENSITIES OF FOUR CENTRARCHID SPECIES

Pool	1990	1991a	1991	1991c	df	t-value
Green Sunfish						
B	58	34	48	-	1	-1.717
C+	44	26	95	67	2	0.539
D	21	30	65	55	2	1.609
E	26	19	115	92	2	0.984
F+	39	42	38	62	2	0.646
G+	30	36	56	62	2	1.565
Longear Sunfish						
B	88	77	60	-	1	-1.622
C+	87	122	265	73	2	0.665
D	49	78	143	74	2	1.273
E	60	41	146	60	2	0.399
F+	60	66	61	74	2	1.067
G+	52	130	83	90	2	1.932
Smallmouth Bass						
B	8	2	3	-	1	-11.00**
C+	4	7	13	6	2	2.15
D	6	8	7	2	2	-0.16
E	5	8	6	3	2	0.48
F+	7	13	8	1	2	0.001
G+	6	5	4	2	2	-2.61
Spotted Bass						
B	2	2	5	-	1	0.707
C+	2	3	6	2	2	0.802
D	2	5	4	2	2	1.093
E	3	1	3	3	2	-0.580
F+	3	6	2	3	2	0.322
G+	3	4	3	3	2	0.572

+ indicates experimental pool
** indicates significance at the 1% level

The tests comparing the mean change across the three control pools with the grand mean across the three experimental pools was significant for one of the four species, longear sunfish (Table 4).

TABLE 4

RESULTS OF T-TESTS FOR CHANGES IN RELATIVE DENSITIES IN EXPERIMENTAL VS. CONTROL POOLS

Species	df	t-value
Green Sunfish	2	1.173
Longear Sunfish	2	-5.022**
Smallmouth Bass	2	-1.915
Spotted Bass	2	0.070

**indicates significance at the 1% level

Condition Factors

Condition coefficients were calculated for stock length smallmouth and spotted bass taken in 1991. Nineteen stock length smallmouth bass were collected on the first two sampling dates (6 from control pools, 13 from experimental pools), none were taken in the third sample. Twelve stock length spotted bass were collected during the three samples (5 from control pools, 7 from experimental pools). The K_{TL} values for the fish from control pools were not significantly different from those of experimental pools (Table 5).

TABLE 5

COMPARISON OF CONDITION FOR MICROPTERINE BASSES

Pools	N	Mean K_{TL}	Standard Deviation	Effective df	t-value
Smallmouth Bass					
Control	6	1.088	0.183	7	0.021
Experimental	13	1.092	0.089		
Spotted Bass					
Control	5	1.200	0.119	7	0.324
Experimental	7	1.261	0.081		

Relative Abundance

Relative abundances of all four species were not significantly different for any habitat, bank or pool (Table 6).

TABLE 6

RESULTS OF ANOVAS FOR DIFFERENCES IN RELATIVE ABUNDANCES

		F-values			
Source	df	Green Sunfish	Longear Sunfish	Smallmouth Bass	Spotted Bass
Habitat Enhancement	1	0.002	0.197	0.103	0.392
Pool	5	0.718	0.240	0.602	1.254
Bank	17	1.053	1.681	2.145	0.861

Size Segregation

The RPDs for all four species were analyzed using an ANOVA similar to that for species composition. Significant segregation was found in pools among quality length green sunfish and for banks for quality length longear sunfish (Table 7). The lower numbers of smallmouth and spotted bass did not provide enough data for RPD ANOVAs. The data for stock length smallmouth bass were likewise meager but the results of the ANOVA are included here.

TABLE 7

RESULTS OF ANOVAS FOR SIZE SEGREGATION

		F-values				
		Green Sunfish		Longear Sunfish		Smallmouth Bass
Source	df	Stock	Quality	Stock	Quality	Stock
Habitat Enhancement	1	2.637	0.036	0.353	0.997	0.003
Pool	5	1.260	6.509**	0.481	1.097	0.793
Bank	17	0.719	0.036	1.155	3.602**	0.501

** indicates significance at the 1% level

Summary

Table 8 summarizes all of the statistical analysis. The symbols used are as follows; plus sign indicates positive effect, minus sign indicates negative effect, equal sign indicates no effect, pound sign indicates there was a difference which was neither positive nor negative, and ND means an appropriate analysis was not done.

TABLE 8

SUMMARY OF STATISTICAL ANALYSES

	Green Sunfish	Longear Sunfish	Smallmouth Bass	Spotted Bass
Relative Density:				
1990 vs 1991	=	=	- (Pool B only)	=
control vs exp	=	+	=	=
Condition	ND	ND	=	=
Size Segregation	#	#	=	ND
Relative Abundance	=	=	=	=

CHAPTER V

DISCUSSION

The habitat-enhanced, experimental pools gained more longear sunfish, on the average, than did the control pools. Berra and Gunning (1970) found longear sunfish were one of the first fish to repopulate an area. Longear sunfish are able to detect and exploit habitat changes more quickly than many other species and this might account for the higher average density gain in structurally enhanced pools.

Smallmouth bass relative density decreased in pool B from 1990 to 1991 as shown in Table 8. Pool B, a pool without structural enhancement, was the only pool which had a significant population decline. Green sunfish and longear sunfish also decreased in pool B, although those changes were not significant. It is the only pool which did not have population increases. Increasing smallmouth bass density was the goal of habitat enhancement. Smallmouth bass density did increase in some pools, but the increases were not significant and cannot be attributed to structural enhancement.

Pool B was only sampled twice and this may contribute to the apparent decreases in densities. Pool C lies immediately upstream from B across a ford. Pool C is an experimental pool and although no density changes there were significant, some fish which normally would have been in pool B may have chosen the enhanced habitat in pool C.

Condition coefficients of smallmouth bass and spotted bass were not significantly different in control and experimental pools. Carlander (1977) reports several ranges of condition coefficients, K_{TL} for smallmouth bass; 1.08-1.44 in Iowa, 1.20-1.46 in Alabama and 1.22-1.94 in Illinois. The values found here are at the lower end of these ranges. For spotted bass Carlander (1977) reports ranges of 1.12-1.19 in Alabama and 0.78-1.86 in Louisiana. The spotted bass from the North Fork are at the middle to upper end of these ranges.

Stock size longear and green sunfish, respectively, showed no preferences for any particular pools or banks. The larger, quality length, green sunfish showed a preference for some pools over others. Adult green sunfish are territorial and have a well-defined, small home range (Carlander 1977). Larger fish are more inclined to select particular pools.

Quality length longear sunfish showed preferences for some banks over others. The diet of longear sunfish is primarily composed of insects. Larger longear sunfish (>102 mm) depend on terrestrial insects for 37 per cent of their food while smaller longear sunfish only eat 9 per cent terrestrial insects (Applegate et al. 1966). The shoreline areas with more insects should have a larger ratio of quality length longear sunfish.

The lack of multiple samples in 1990 weakens statistical analysis, but the high variability of the 1991 data indicates multiple samples probably would not have yielded different results. Tree leaves on and in the water during the last 1991 sample made fish more difficult to see and may have contributed to the lower number of fish taken during that sample. There is no known reason for the variation between the first two 1991 samples.

CHAPTER VI

RECOMMENDATIONS

Future research on this river should include tagging and radio telemetry to determine habitat use of smallmouth bass during different seasons and flow conditions. The rapid flow changes in these streams may present some unique movement patterns. A clear understanding of habitat use and yearly movements will be of assistance in designing and locating structures. Large structures which could provide refuge from high flows might be more effective at increasing densities.

The dead trees along the banks should be cabled in place parallel to the banks as they fall. Although their immediate value as fisheries habitat improvements is unproven, they will provide protection for eroding banks and therefore will ultimately be beneficial.

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APPENDIXES

APPENDIX A

PHYSICAL HABITAT MEASUREMENTS

TABLE 9

1990 LENGTH AND WIDTH MEASUREMENTS

Pool	Length (m)	Average Width (m)
B	128	24.1
C	187	28.0
D	179	21.5
E	185	21.8
F	156	22.5
G	162	24.9

TABLE 10

1991 LENGTH AND WIDTH MEASUREMENTS

Pool	Length (m)	Average Width (m)
B	134	24.2
C	185	28.3
D	180	21.4
E	191	22.4
F	155	22.6
G	161	25.2

TABLE 11

1990 DEPTH MEASUREMENTS

Pool	Left Bank	1/4 Width	1/2 Width	3/4 Width	Right Bank
B	0.7	1.2	1.1	0.7	0.1
	0.1	1.2	1.2	1.1	0.2
	0.0	2.8	1.9	0.7	0.5
C	0.0	0.9	1.0	0.8	0.0
	0.2	0.9	0.8	0.8	0.1
	0.7	0.6	0.2	0.3	0.8
	0.0	0.3	0.4	0.3	0.4
	0.0	1.1	0.9	0.3	0.3
D	0.2	0.9	1.5	1.4	0.0
	0.1	1.0	1.3	1.2	0.8
	0.0	0.6	1.2	1.2	0.0
	0.0	0.2	0.5	0.2	0.0
	0.0	0.9	1.0	0.8	0.0
E	0.0	0.4	0.8	1.1	0.5
	0.0	0.1	1.0	1.4	1.1
	0.3	1.3	1.7	1.8	0.7
	0.3	1.1	1.3	1.3	0.0
	0.2	1.1	0.9	0.6	0.3
F	0.0	0.4	0.9	0.8	0.0
	0.0	1.3	1.8	1.8	0.1
	0.0	1.1	1.3	1.3	0.0
	0.0	0.5	0.5	0.9	0.6
G	0.0	0.6	0.6	0.7	0.4
	0.0	0.6	0.8	1.0	0.7
	0.1	0.5	0.6	1.2	0.0
	0.0	0.3	0.2	0.3	0.0

TABLE 12

1991 DEPTH MEASUREMENTS

Pool	Left Bank	1/4 Width	1/2 Width	3/4 Width	Right Bank
B	0.6	1.3	1.2	0.8	0.1
	0.1	1.2	1.2	1.3	0.3
	0.0	2.9	2.0	0.8	0.4
C	0.0	0.9	1.1	1.0	0.0
	0.2	0.8	0.9	0.9	0.1
	0.8	0.6	0.3	0.3	0.8
	0.0	0.3	0.5	0.3	0.5
	0.0	1.2	0.9	0.3	0.2
D	0.3	0.8	1.8	1.5	0.0
	0.1	1.1	1.3	1.3	0.8
	0.0	0.6	0.9	1.1	0.0
	0.0	0.3	0.4	0.3	0.0
	0.0	1.2	1.0	0.9	0.0
E	0.0	0.4	0.9	1.2	0.3
	0.0	0.2	1.1	1.5	1.3
	0.4	1.2	1.6	1.6	0.4
	0.3	1.3	1.2	1.5	0.0
	0.1	1.2	0.8	0.4	0.2
F	0.0	0.3	0.9	0.8	0.0
	0.0	1.1	2.0	2.0	0.1
	0.0	1.3	1.5	1.6	0.0
	0.0	0.5	0.3	0.6	0.4
G	0.0	0.7	0.7	0.8	0.3
	0.0	0.8	0.9	1.1	0.8
	0.2	0.7	0.5	1.4	0.0
	0.0	0.4	0.2	0.3	0.0

TABLE 13

1990 SUBSTRATE TYPES

Pool	Bedrock %	Boulder %	Cobble %	Gravel %	Sand %	Fine %
B	16.7	11.7	45.0	26.6		
C	7.0	3.0	46.0	38.0		6.0
D	42.0	29.0	19.0			10.0
E		64.0	36.0			
F		17.5	52.0	4.0		12.5
G		18.8	27.5	38.7	6.2	8.8

TABLE 14

1991 SUBSTRATE TYPES

Pool	Bedrock %	Boulder %	Cobble %	Gravel %	Sand %	Fine %
B	16.7	11.7	45.0	26.6		
C	7.0	3.0	46.0	38.0		6.0
D	42.0	29.0	19.0			10.0
E		60.0	40.0			
F		18.8	66.2	5.0		8.0
G		17.5	28.8	37.5	6.2	10.0

TABLE 15

1990 STREAMSIDE COVER AS PERCENT OF BANK LENGTH

Pool	Large Woody	Small Woody	Undercut Bank	Terrestrial Vegetation	Boulder	Bedrock Ledge
B	1	1	10	50		
C	3		30	60		
D	1		20	40	25	
E	5		10	25	20	2
F	15		5		1	
G	5		2		10	

TABLE 16

1991 STREAMSIDE COVER AS PERCENT OF BANK LENGTH

Pool	Large Woody	Small Woody	Undercut Bank	Terrestrial Vegetation	Boulder	Bedrock Ledge
B	1	1	10	50		
C	15		30	60		
D	1		20	40	25	
E	7		10	30	15	2
F	30		7		2	
G	15		2		10	

TABLE 17

CANOPY CLOSURE

Pool	Left Bank	Middle	Right Bank
B	50	30	75
	75	30	80
	80	40	90
C	75	30	60
	80	30	50
	80	30	50
	75	35	55
	80	40	60
D	75	40	60
	70	35	60
	70	60	50
	75	40	55
	70	45	60
E	20	12	20
	20	15	30
	25	20	45
	30	20	45
	25	20	30
F	30	20	30
	30	25	40
	40	25	30
	30	25	30
G	30	25	35
	30	25	30
	40	25	45
	40	25	50

TABLE 18

1990 BANK ANGLE AND STABILITY MEASUREMENTS

	LEFT BANK		RIGHT BANK	
Pool	Bank Angle	Stability %	Bank Angle	Stability %
B	80	90	90	80
	80	90	90	90
	170	100	90	100
C	90	100	120	90
	80	80	90	90
	90	90	70	90
	120	100	90	100
	120	100	80	90
D	120	100	100	80
	90	90	90	85
	135	100	130	60
	150	100	100	90
	120	90	140	100
E	170	100	80	90
	160	100	80	100
	90	90	90	100
	80	90	90	100
	90	100	100	100
F	145	90	135	30
	160	60	95	10
	120	70	120	50
	160	100	100	70
G	160	100	120	100
	130	50	90	100
	90	70	110	80
	120	40	135	50

TABLE 19

1991 BANK ANGLE AND STABILITY MEASUREMENTS

	LEFT BANK		RIGHT BANK	
Pool	Bank Angle	Stability %	Bank Angle	Stability %
B	80	90	90	80
	80	90	90	90
	160	100	90	90
C	90	100	110	90
	85	80	90	95
	90	95	70	90
	125	100	90	100
	120	100	85	95
D	115	100	100	85
	90	90	90	85
	130	100	125	60
	150	100	110	90
	120	90	130	100
E	175	100	80	100
	160	100	85	100
	90	95	90	90
	85	90	90	95
	90	100	110	100
F	140	85	125	40
	150	50	90	15
	120	60	120	50
	160	100	110	70
G	160	100	120	100
	130	50	90	100
	90	65	100	85
	115	40	140	50

APPENDIX B

CHEMICAL HABITAT MEASUREMENTS

TABLE 20

WATER QUALITY MEASUREMENTS

Pool	pH	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)
B	6.8	3.2	11	<5	<1
C	6.8	3.0	11	<5	<1
D	6.8	2.8	12	<5	<1
E	6.6	3.5	11	<5	<1
F	6.7	3.5	12	<5	<1
G	6.7	3.1	12	<5	<1

APPENDIX C

FISH COLLECTED

TABLE 21

SUMMARY OF ALL FISH COLLECTED

Species	1990	Numbers of Fish 1991a	1991b	1991c
ATHERINIDAE				
Labidesthes sicculus	9	4	12	12
CATOSTOMIDAE				
Erimyzon oblongus	-	3	10	6
Hypentelium nigricans	2	6	7	4
Moxostoma duquesni	-	39	30	42
Moxostoma erythurum	33	18	9	4
CENTRARCHIDAE				
Ambloplites ariommus	7	16	18	5
Lepomis cyanellus	218	186	417	338
Lepomis megalotis	366	513	758	371
Micropterus dolomieu	35	42	41	14
Micropterus punctulatus	22	20	23	13
CYPRINIDAE				
Campostoma anomalum	25	65	3	2
Notropis boops	91	234	54	2
Notropis greenei	-	7	26	10
Notropis whipplei	-	2	-	-
Pimephales notatus	1	96	88	41
ESOCIDAE				
Esox americanus	1	2	4	1
FUNDULIDAE				
Fundulus olivaceous	1	5	14	21
ICTALURIDAE				
Ameiurus natalis	9	1	5	4
Noturus exilis	2	-	1	1
PERCIDAE				
Etheostoma blennoides	1	6	1	-
Etheostoma punctulatum	-	-	3	-
Etheostoma spectabile	-	-	2	-
Etheostoma whipplei	-	3	4	3
Etheostoma zonale	-	-	1	1
Percina caprodes	3	-	1	-
Percina maculata	-	1	-	-
Percina nasuta	1	3	1	1
PETROMYZONTIDAE				
Ichthyomyzon sp.	13	7	5	2

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