DISTRIBUTION AND ABUNDANCE OF CENTRARCHIDS IN ALTERED AND UNALTERED SECTIONS OF CROW CREEK

A Thesis

by

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Cooperators:

U.S. Fish and Wildlife Service
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in cooperation with

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AN ABSTRACT OF A THESIS

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Master of Science in Biology

This study was conducted to determine the effects of channel modification on the abundance and distribution of centrarchids in Crow Creek. During 1975 and 1976 various physical characteristics were measured at eleven stations representing altered and unaltered sections of the channel. Leslie population estimates, habitat measurements at the point of capture, and regression analysis were used to determine abundance and habitat preferences of centrarchids. Structural and functional components of centrarchid communities were evaluated using diversity (H') and biomass dominance rank. Greatest densities of centrarchids occurred in habitats where there was an interspersion of pools, riffles, and cover. Centrarchid density was low in realigned sections of the channel that were devoid of cover and dominated by pool area. Cool water temperatures limited centrarchid abundance at upstream unaltered stations. Rock bass, longear sunfish, and smallmouth bass were the predominant species collected at the upstream stations. Green sunfish, bluegill, and spotted bass were the predominant species collected at downstream stations where channel alterations were more severe.

DISTRIBUTION AND ABUNDANCE OF CENTRARCHIDS IN ALTERED AND UNALTERED SECTIONS OF CROW CREEK, FRANKLIN COUNTY, TENNESSEE, AND JACKSON COUNTY, ALABAMA

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INTRODUCTION

Stream alteration has been widely employed during the past century. In earlier years channel alterations, facilitating drainage of agricultural lands, were not as extensive as subsequent stream modification projects because of equipment limitations. The major onset of channelization came with the increasing availability of heavy equipment, increased demand for developing floodplains, and involvement of federal agencies such as the U. S. Army Corps of Engineers, the U. S. Soil Conservation Service, and the Bureau of Reclamation. Today, channelization is used for flood control, navigation, highway construction, and drainage of agricultural lands, under the auspices of such laws as the Federal Flood Control Acts of 1948 and 1960 and under the small watershed program of Public Law 566. The literature is replete with information regarding the extensiveness of channel alterations and their impact upon the aquatic environment. For the most part, the long-term adverse effects of channelization can be attributed to inadequate channel design and to the lack of implementation of effective mitigational measures. Specific information regarding the environmental requirements of the stream biota is needed in making recommendations for mitigating the damaging effects of stream alteration.

Channelization effects on centrarchid species have not been well documented. This study was performed in conjunction with an evaluation contract awarded to Tennessee Technological University by the Soil

Conservation Service, U. S. Department of Agriculture, to evaluate the effects of channelization and mitigation structures in Crow Creek, Tennessee and Alabama. Objectives were to determine habitat preferences of centrarchids in Crow Creek and to determine factors influencing the distribution and abundance of centrarchids in altered and unaltered sections of the stream.

Chapter 2

LITERATURE REVIEW

Channelization has affected the quality of thousands of miles of streams and rivers throughout the United States. Little (1973) estimated that there has been approximately 35,000 miles of channel modification completed since 1940 by small watershed programs of the Soil Conservation Service and local flood control programs of the Corps of Engineers. This figure does not include the thousands of miles altered for major flood control and navigation, highway construction, and private drainage enterprises. Ash and Wall (1957) stated that the Corps of Engineers maintains 22,000 miles of inland waterways which have been affected to some degree by channel alteration. Martin (1969) estimated that approximately 25,000 miles of streams and rivers have been altered in 12 southeastern states. Thrienen (1971) reported a total of 29,000 miles of stream alteration in seven midwestern states. Investigations in Montana have reported 36% of 987 miles of stream surveyed have been altered (Peters, 1970).

The drastic effects of channelization on aquatic communities have been documented by many authors (Barton and Winger, 1973; Bayless and Smith, 1967; Congdon, 1973; Elser, 1968; Hansen and Muncy, 1971; Irrizarry, 1969; Morris et al., 1968; Nelson and Hill, 1960; Peters and Alvord, 1964; Trautman, 1939; Wharton, 1970; Whitney and Bailey, 1959). There are many ways in which stream alteration and channel realignment have affected aquatic ecosystems. Channel realignment has cut off meanders and caused the loss of many miles of aquatic habitat. Straightening of the channel has increased the gradient, thereby increasing water velocity and accelerating erosion. Increased turbidity and associated deposition of sediment, resulting from erosion, have drastically affected stream biota (Chutter, 1968; Cordone and Kelley, 1961; Hynes, 1970; King and Ball, 1964; Saunders and Smith, 1965; Sprules, 1941; Trautman, 1957; Van der Schalie and Van der Schalie, 1950). Brown (1960) found that increased current velocity destroyed smallmouth bass nests, interrupted breeding activities, and caused abandonment of the nests. Entire year classes of smallmouth bass have been lost in midwestern streams during floods that occur when the fry are less than 25 mm long (Larrimore and Duever, 1968).

When the natural meander pattern of the stream is removed by realignment, there is a subsequent loss of scour pools, undercut banks, and riffle areas. The overall result is a uniform channel exhibiting little habitat diversity. Funk (1973) stated that productivity of various trophic levels depends upon the physical diversity of the stream. Simplification of the stream environment results in simplification of its constituents. Loss of streamside vegetation from channel realignment or clearing and snagging may increase stream temperature (Hansen and Muncy, 1971) and cause changes in the stream biota. The loss of vegetation can also reduce the allocthonous material entering the stream, thus altering the trophic structure of the community (Egglishaw, 1964). Another effect of channelization may be a reduction in the availability of overhead cover which has been found to adversely affect fish populations (Boussu, 1954; Haines and Butler, 1969; Hobbs, 1947; Hunt, 1968; and Wesche, 1974).

Recognition of the extensiveness of channel alterations and their widespread impact upon the environment has led to the reevaluation of methods of channel alteration by federal agencies and initiated steps toward mitigating fish and wildlife losses. Various habitat improvement structures incorporated in altered streams have shown favorable results in mitigating fisheries' losses by increasing the number, depth and size of pools and by increasing overhead cover (Barton and Winger, 1973; Boussu, 1954; Greeley and Tarzwell, 1932; Harrison, 1962, 1963, 1964, 1965; Hunt, 1968; Saunders and Smith, 1962; Shetter et al., 1946; Tarzwell, 1937, 1938; White and Brynildson, 1967; and Wilkins, 1958).

Chapter 3

DESCRIPTION OF STUDY AREA

Crow Creek originates in south-central Tennessee and flows southwest into Alabama where it empties into Guntersville Reservoir of the Tennessee River system. Crow Creek is located on the Eastern Highland Rim of the Appalachian Mountains chain and it drains 159 square miles in Franklin and Marion Counties, Tennessee, and Jackson County, Alabama (Figure 1). The drainage elevation varies from 580 to 183 meters above sea level. The channel is 38 km long from headwaters to the mouth; the average gradient is 1.4 m/km; and stream sinuosity is approximately 1.3. The width of the floodplain gradually increases from 0.2 km at the headwaters to 2.5 km where the stream enters Guntersville Reservoir.

Geologic formations in the watershed are primarily sandstone plateaus and limestone valleys. The area is underlain by extensive subterranean streams with many springs and caves found in the area (SCS Watershed Work Plan, 1965). Limestone was a major industry for the valley in past years but only one quarry now remains in operation. Most of the floodplain is used for agricultural purposes, but there are a few logging operations scattered along the slopes bordering the creek.

Flood control assistance was applied for in 1956 by people living in the Crow Creek watershed. Approximately 7,500 acres of the floodplain were subjected to periodic flooding which occurred primarily during the growing season (April to November). Authorization for the project was granted in 1966, but construction did not begin until late 1971 and

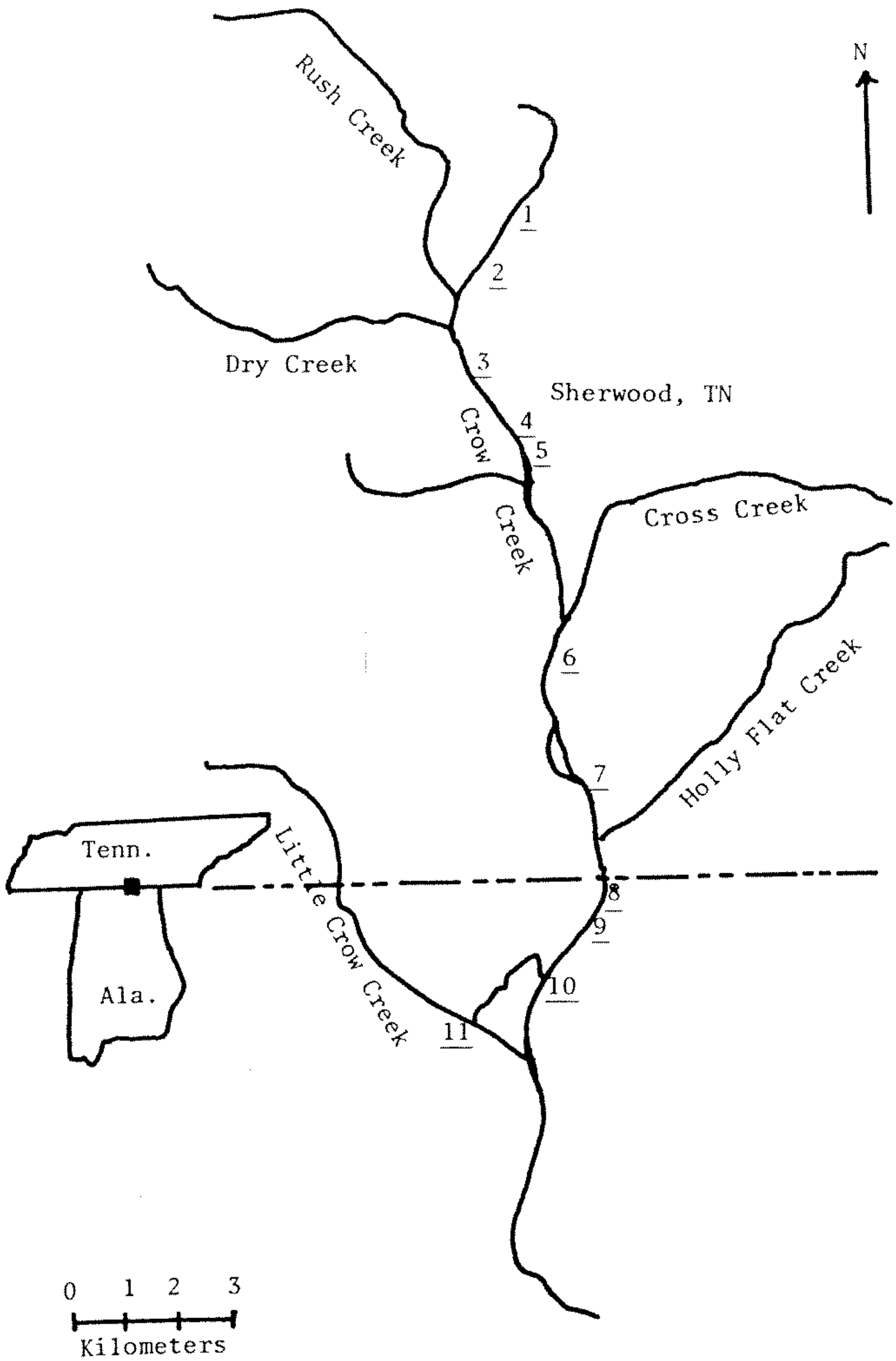

Figure 1. Map Showing Station Locations on Crow Creek

was completed in February, 1972. About 70 km of Crow Creek and its tributaries in Tennessee and 14 km of Crow Creek and 6 km of Little Crow Creek in Alabama have been modified. Channel modifications consisted of clearing and snagging, widening the channel along the natural stream course, and realignment of some sections of the stream. Stream mitigation structures were installed at two sites in 1971, at one site during 1973, and at two sites during 1975.

Physical characteristics of the Crow Creek Channel showed greater diversity at the upstream areas. This section of the stream was affected less by channel modification and, consequently, exhibited a greater abundance of riffles, pools, and cover. Physical diversity decreased as the extensiveness of channel modification increased going downstream. Realigned sections of the channel were normally devoid of canopy; exhibited greater channel width, few riffle areas, minimal cover, large pools and unstable banks. Placement of grade stabilization structures in series and at improper elevations resulted in the pooling of water at many of the downstream modified areas.

Chapter 4

METHODS AND MATERIALS

Eleven study sites were selected to represent unaltered, altered, and mitigated sections of Crow Creek (Table 1). Various physical features and characteristics of the centrarchid community were measured and observed at each study site. All data were collected during summer months when flow characteristics were stable.

Physical Measurements of the Stream Channel

Physical characteristics of the channel sections at each station were determined using topographic maps, depth contour maps, transverse cross section measurements, and gradient measurements of the stream. Subsections (100-150 m) at each station were used to facilitate the collection of fish population data. These subsections were selected on the basis of their representation of the whole station. Each subsection was staked at 15 m intervals and mapped using a plane table, alidade, and stadia rod. Topographic maps were drawn for each subsection during the summer of 1975 and again in the summer of 1976. Transverse cross-sectional profiles were determined at the 15 m intervals, and mean depth and channel width were measured. During 1976, mean current velocity was also determined at each cross section. Current velocity was measured at one-quarter, one-half and three-quarters of the stream width using a Kahl dial current meter. The following major habitat areas were indicated on topographic maps and their percentages of the

Table 1

Location and General Description of all Stations on Crow Creek.

Stations	Stream Distance (km from Origin)	Description
		Legend of Study Stations
1	1.82 to 2.22	Unaltered station upstream from channel construction work. Abundant canopy. Stable banks. Alternating riffle-pool sequence. Predominately rubble-gravel sand substrate. Extensive overhead cover provided by root systems, logs and overhanging vegetation. Cool water temperature maintained by springs in immediate area.
2	2.72 to 3.12	Banks cleared and snagged. Predominated by pool area with gravel and sand substrate. Two riffle areas were present; one riffle consisted of stable rubble-gravel substrate and the other was shifting gravel and sand. Unstable banks. Minimal cover. Cool water temperatures maintained by upstream springs.
3	4.51 to 4.91	Altered station widened along east bank. Extensive cover provided by riprap which was installed during 1973 and 1974. Alternating riffle-pool sequence. Small rubble and gravel riffle substrate. Pool substrate primarily silt and sand. Stable banks. Minimal vegetative cover.
4	6.26 to 6.66	Altered station widened along the east bank. Single row sheet-pile dam and a paired deflector located 30 m. downstream from the dam were installed during summer of 1974. Banks partially stabilized. Riffle substrates were gravel and sand. Pool substrates sand and silt. Some vegetative cover was present. Canopy was less than 5%.
5	7.20 to 7.60	Altered station widened along east bank. Extensive cover provided by riprap along east bank. West bank primarily unstable. Alternating riffle-pool sequence. Riffle

Table 1 (continued)

Legend of Study Stations		
Stations	Stream Distance (km from Origin)	Description
		substrate stable--predominantly rubble and gravel. Pool substrate composed of silt and sand. Minimal vegetative cover. Canopy less than 5%.
6	10.67 to 11.07	Realigned section of channel. Two mitigation structures constructed during the summer of 1975. A concrete cap lowhead dam created a pool extending several hundred meters upstream. This area was devoid of canopy and cover and exhibited steep unstable banks. A short riffle and a large scour pool were found below this structure. Deposition of gravel from the scour pool formed a small riffle immediately downstream from the pool. A double deflector dam was located 91 km downstream from the other structure. A riffle and pool were formed immediately below this structure.
7	13.40 to 13.80	The upstream portion of this station was realigned. A double row sheet-pile dam created an extensive pool area upstream from the structure. A large riffle area, comprised of riprap material, rubble, and gravel was formed between and below the pilings. A large deep pool was scoured immediately downstream from this riffle. Vegetative cover was abundant downstream from the lowhead dam. Canopy was minimal. Banks were steep and unstable.
8	16.75 to 17.15	Realigned section of the channel. Canopy completely absent. Banks steep and unstable. Four lowhead dams were installed in series (122 m. apart) during 1973. Lowhead dams created extensive pooling. Small riffle areas were associated with the spill areas of the structures.
9	17.17 to 17.57	Widened along west bank. Extensive riffle area composed of bedrock, rubble, and gravel. Vegetative cover was moderately

Table 1 (continued)

Stations	Legend of Study Stations: Stream Distance (km from Origin)	Description
		abundant. Pools were relatively shallow. Banks were steep and unstable. Canopy less than 10%.
10	19.18 to 19.58	Realigned section of channel with stream mitigation structures placed in series (122 m. apart) during 1971. A sheetpile dam was installed at the upstream end of the station with three wooden lowhead dams located downstream. Steep banks were partially stabilized with riprap. One small riffle was located in the spill area at the sheetpile dam. Canopy and vegetative cover were absent.
11	19.73 to 20.13	Unaltered station located at the confluence of Little Crow Creek and the original Crow Creek Channel, now considered part of Little Crow Creek. Extensive canopy cover. Root systems, vegetative overhang, and logs provide abundant instream cover. Riffle areas absent. Substrate predominantly sand. Stable banks.

total area were determined with a planimeter. These areas were defined as follows:

Pool - Area of the stream with depth greater than 0.3.

Slow shallow - Area of the stream with depth less than 0.3 m and exhibiting slow current velocity (flat water).

Riffle - Area of the stream with depth less than 0.3 m and exhibiting fast current velocity (broken water).

Vegetative Cover - Area of the stream that has log, brush, root and vegetative overhang cover.

Riprap Cover - Area of the stream with rock riprap cover.

Stream sinuosity was measured for the entire study section (0.4 km) at each station. Sinuosity was the ratio of thalweg length to the straight line downstream distance of the channel.

Substrate samples were collected for a riffle and pool area, within each subsection, at each station during 1976. Three samples for each riffle and each pool were collected with a core sampler and taken to the laboratory for sieve analysis. Mean particle size was determined by techniques described by Inman (1952). Mean substrate particle size for each channel subsection was determined by the weighted average of the amount of pool area and its mean particle size and amount of riffle area and its mean particle size.

Water temperature was measured at all stations during June, July, and August of 1975 and 1976 with a mecuric thermometer.

Fish Investigations

Fish were sampled at each station during the summer of 1975 and 1976 using electrofishing with pulsating D.C. current supplied by a Sears 1100 watt generator (9.5 amp, single phase A.C.) and a rectifier.

Sampling in 1975 began on June 8 and was completed on August 8. Sampling during 1976 began June 8 and was completed by June 24. A small aluminum boat was used as the negative electrode (cathode) and two hand-held probes were the positive electrodes (anode). Where depth prevented wading, a single probe (anode) was attached to the boat, and the boat was pulled through the section with rope. Block nets were placed at the upstream and downstream ends of 100 to 150 m subsections to prevent movement of fish into or out of the area. Three and occasionally four shocking trials through the station were used for the removal of fish. The fish collected during each trial were identified, counted, weighed, measured, and released below the downstream block net. During 1976, the point of capture for each fish was marked on topographic maps for that station to show distribution in relation to habitat characteristics (overhead cover, pool area, riffle area, etc.).

Data Analysis

Population estimates and confidence limits were calculated following procedures outlined by Ricker (1975) for the Leslie catch per unit effort technique. In some cases, where low numbers of a species were collected, population estimates could not be used. In these cases actual numbers collected were used in the determination of abundance, composition, and species diversity. The number of fish was converted to number per hectare for comparative purposes.

Linear regression analysis was used to determine the physical parameters most important in determining fish distribution in Crow Creek. Number /ha for each fish species at Stations 1-11 were used as the dependent variables. All physical data were initially considered in the selection of the independent variables. Physical data and fish population estimates from Stations 1-11 for 1975 and 1976 were combined for regression analysis procedures. Correlation coefficients were calculated from regressions of dependent variables with independent variables. Independent variables that exhibited correlation coefficients significantly different from zero ($|r| = 0.36$; $P = 0.05$; 20 df) were selected for further analysis. Correlation coefficients were then computed for regressions between independent variables that were suspected of expressing the same parameter. When two independent variables exhibited a high correlation with each other, the variable showing the more consistently higher correlation with dependent variables was selected for final evaluation. Independent variables selected included: percent total cover; percent pool area; percent riffle area; percent slow shallow area, and mean summer water temperature (J,J,A). Substrate particle size, average velocity, gradient, sinuosity, and average width showed no significant correlation with the dependent variables. Cross-correlations were found to exist between average depth and percent pool area, percent riprap cover and total cover, and percent vegetative cover and total cover. Correlation coefficients were subjected to a statistical "t"-test, where the hypothesis $|r| \neq 0$ was tested for at the 0.05 and 0.01 significance levels.

Centrarchid diversity (H') was calculated according to the following equation:

$$H' = -\Sigma (p_i \log_{10} p_i)$$

Where p_i was the proportion (by number) of the community belonging to the ith species (Pielou, 1975).

This index was originally proposed (Shannon and Weaver, 1949) as a measure of the information content of a code. Diversity values depend on both species richness (the number of species) and evenness of representation of species within the community. Evenness (J') was calculated as:

$$J' = \frac{H'}{\log_2 s}$$

Where s equals the species richness and H' equals diversity (Pielou, 1975).

Evenness values range from 0 to 1 with 1 representing the greatest evenness of representation of species within a community. A predominance of one species or a few species in a community would be represented by J' close to 0.

Chapter 5

RESULTS

Physical Characteristics

Physical characteristics measured during the summers of 1975 and 1976 are shown in Tables 2 and 3, respectively. Major discrepancies between the 1975 and 1976 data were due to differences in water level at the time of analysis, physical changes at stations where structures were installed, and changes in bottom configuration due to scouring action.

Mean depth was greatest at stations that had grade stabilization structures, with the exception of Station 4 which had the lowest mean depth (0.32 m). Stations 6, 7, 8, and 10 had mean depths exceeding 0.78 m. Stations without structures did not exceed 0.57 m in depth. The maximum mean depth of 0.95 m was found at Station 8. The height of the instream structures at Stations 6, 7, 8, and 10 created large pool areas upstream from the structures which contributed to the greater depths at these stations. The physical diversity of the structured areas was substantially reduced since pooling of water behind mitigation structures resulted in more uniform channel characteristics.

Mean channel width generally increased going downstream. Realigned sections of the channel (Stations 6, 7, 8, and 10) and those sections widened along one bank (Stations 3, 4, 5, and 9) exhibited the greatest channel widths. Station 1 had the smallest mean width (9.15 m) and Station 10 had the greatest mean width (19.3 m).

Table 2

Physical Characteristics of Stations 1 Through 11 on Crow Creek, Summer of 1975.

Parameter	Station										
	1	2	3	4	5	6	7	8	9	10	11
Mean Depth (m)	0.32	0.42	0.37	0.30	0.54	0.64	0.50	0.91	0.41	0.89	0.32
Mean Width (m)	9.78	9.96	13.53	12.31	13.89	17.98	15.33	17.28	14.93	19.50	14.10
Gradient (%)	0.23	0.12	0.09	0.19	0.08	0.24	0.31	0.15	0.16	0.11	0.01
Sinuosity	1.09	1.39	1.13	1.03	1.16	1.01	1.03	1.0	1.08	1.05	1.03
Pool Area (%)	73.0	74.2	35.0	13.6	57.5	65.3	83.1	87.2	54.6	77.2	21.4
Slow Shallow Area (%)	6.2	14.7	56.7	74.6	22.4	28.3	9.8	11.9	29.7	19.7	78.6
Riffle Area (%)	20.8	11.1	8.3	11.8	20.1	6.4	7.1	0.9	15.7	3.1	0.0
Vegetative Cover Area (%)	6.5	1.5	2.5	1.5	0.0	1.6	1.4	0.0	0.0	0.4	7.9
Rock Cover Area (%)	0.0	0.0	25.9	0.0	40.7	10.6	3.6	2.8	10.0	12.1	0.0
Total Cover (%)	6.5	1.5	28.4	1.5	40.7	12.2	5.0	2.8	10.0	12.5	7.9
Mean Summer Temperature (J,J.A) (°C.)	17.0	19.5	22.3	24.7	25.0	22.7	24.0	26.7	26.3	26.3	23.0

Table 3

Physical Characteristics of Stations 1 Through 11 on Crow Creek, Summer of 1976.

Parameter	Station 1	2	3	4	5	6	7	8	9	10	11
Mean Depth (m)	0.40	0.51	0.51	0.32	0.57	0.80	0.78	0.95	0.46	0.89	0.50
Mean Width (m)	9.15	10.58	10.47	15.43	12.80	18.68	17.04	17.95	13.83	19.30	13.85
Gradient (%)	0.23	0.13	0.12	0.18	0.08	0.33	0.29	0.14	0.14	0.05	0.01
Sinuosity	1.09	1.39	1.13	1.03	1.16	1.01	1.03	1.00	1.08	1.05	1.03
Pool Area (%)	46.7	53.1	52.6	21.4	54.1	64.1	72.9	82.8	42.8	85.3	41.4
Slow Shallow Area (%)	48.4	44.0	36.2	45.4	23.7	28.1	14.7	15.2	43.5	11.9	58.6
Riffle Area (%)	4.9	2.9	12.2	33.2	22.2	7.8	12.4	2.0	13.7	2.8	0.0
Vegetative Cover Area (%)	7.3	6.8	2.8	1.5	0.0	1.0	0.0	0.0	0.0	0.0	4.9
Rock Cover Area (%)	0.0	0.0	14.2	1.1	17.7	3.7	6.6	2.2	10.0	9.9	0.0
Total Cover (%)	7.3	6.8	17.0	2.6	17.7	4.7	6.6	2.2	10.0	9.9	4.9
Mean Summer Temperature (J,J,A) (^{o}C.)	15.7	18.7	22.3	26.0	24.2	24.3	26.2	25.7	25.7	26.7	22.8
Mean Substrate Particle Size (mm)	1.4	2.3	2.7	2.8	4.9	1.4	1.4	1.0	2.1	2.0	0.4
Mean Velocity (cm/sec)	8.0	6.0	10.0	19.0	25.0	21.0	13.0	3.0	10.0	8.0	8.0

A high percentage of pool area and low percentage of riffle area were typical of realigned stations. Stream mitigation structures which were improperly placed with respect to distance between structures and elevation created large pools extending several hundred meters upstream at Stations 6, 7, 8, and 10. The percent of pool area at these stations ranged from 65.3% to 87.2% during 1975 and 54.1% to 85.3% during 1976. Riffle areas at these stations were generally confined to a small area immediately below the mitigation structures. An extensive riffle was formed below the grade stabilization structure at Station 7 by the displacement of riprap material during high flow. The percent of riffle area at Stations 6, 7, 8, and 10 ranged from 0.9% to 7.1% during 1975 and from 2.0% to 12.4% during 1976. Percent riffle area was greatest at those stations that were widened along one bank (Stations 3, 4, 5, and 9). Percent riffle area at these stations ranged from 8.3% to 20.1% during 1975 and from 12.2% to 33.2% during 1976. Slow shallow areas were also abundant at these stations because of the increased width from channel alteration and the absence of improperly designed structures. Percent shallow water area at Stations 3, 4, 5, and 9 ranged from 22.4% to 74.6% during 1975 and from 23.7% to 45.4% during 1976.

Vegetative cover which included logs, brush (submerged and surface), and root systems was abundant in the unchannelized areas of the stream (Station 1, 2, and 11). Sections of stream that were altered along one side retained some vegetative cover but those sections that were realigned were virtually devoid of such cover. Vegetative cover ranged from 0.0% to 7.9% of surface area during 1975 and from 0.0% to 7.3%

during 1976 at the 11 study sites. The amount of cover was greatest at Stations 1 and 11. Trees provided much of the cover at these stations. Root systems stabilized the upper strata of the bank while undercutting of the lower strata provided an abundance of cover. Fallen trees were also important in contributing to the amount of cover and increasing the physical diversity by interrupting flow patterns. Altered sections of the stream were generally devoid of trees along the bank, consequently minimizing the amount of available cover and potential cover (fallen trees).

Riprap was present at Stations 3 through 8 and 10. The most riprap cover was 17.7% at Station 5. Cover at Stations 4, 5, 7, 8, and 10 was primarily in areas adjacent to the stream mitigation structures where riprap was installed for stabilization. Stations with the highest percent of total cover were in areas where there was a high percent of riprap cover.

Mean summer (J,J,A) water temperature ranged from 17.0^{o} C. (Station 1) to 26.7^{o} C. (Station 8) during 1975 and from 15.7^{o} C. (Station 1) to 26.7^{o} C. (Station 10) during 1976. There was a general increase in temperature proceeding downstream from Station 1. Springs and the presence of canopy at the upstream stations maintained lower water temperatures in these sections of the stream. Increased pooling and loss of canopy contributed to the increased temperature in the downstream reaches.

Mean substrate particle size ranged from 0.4 mm (Station 11) to 4.9 mm (Station 5). Sand was the predominant pool substrate and gravel and rubble substrates predominated the riffle areas. Generally those stations with large pool areas exhibited the smallest mean substrate particle size (Stations 6, 7, 8, and 10).

Mean current velocity varied from 3 cm/sec (Station 8) to 24 cm/sec (Station 5). Stations with confined channels and minimal pooling had the highest velocities and areas with extensive pooling had the lowest velocities. Mean current velocities for Stations 6 and 7 were moderately high because of the localized effect of the lowhead dams at these sites.

General Fish Population Characteristics

During the 1975 and 1976 survey, 50 species of fish representing 13 families were collected from Crow Creek (Table 4). This wide variety of species was apparently related to the diversity of habitat throughout the stream and to movement of fish upstream from Guntersville Reservoir.

The upstream stations (Stations 1 and 2) supported rainbow trout, white suckers, rock bass, longear sunfish, stonerollers, banded sculpin, northern hogsuckers, and blacknose dace. Fishes collected at Stations 3, 4, and 5 included smallmouth bass, rock bass, longear sunfish, northern hogsuckers, black redhorse, stonerollers, darters, common shiners, and banded sculpins. Channel characteristics of Stations 3, 4, and 5 exhibited greater flow, greater average width, and slightly warmer water temperature than found at the two upstream stations. Fish found in the downstream area (Stations 6 - 11) were primarily warmwater species. Largemouth bass, redear sunfish, bluegill, green sunfish and black red-horse were common. Channel characteristics of the downstream stations were generally less diverse than at the upstream stations. Several

Table 4

List of Fish Species Collected From Crow Creek, Franklin County, Tennessee, and Jackson County, Alabama, During 1975 and 1976.

Scientific Name	Common Name
Atherinidae	
Labidesthes sicculus (Cope)	Brook Silverside
Catostomidae	
Carpiodes velifer (Rafinesque)	Highfin Carpsucker
Catostomus commersoni (Lacepede)	White Sucker
Hypentelium nigricans (LeSueur)	Northern Hogsucker
Minytrema melanops (Rafinesque)	Spotted Sucker
Moxostoma duquesnei (LeSueur)	Black Redhorse
Centrarchidae	
Ambloplites rupestris (Rafinesque)	Rock Bass
Lepomis cyanellus (Rafinesque)	Green Sunfish
Lepomis gulosus (Cuvier)	Warmouth
Lepomis macrochirus (Rafinesque)	Bluegill
Lepomis megalotis (Rafinesque)	Longear Sunfish
Lepomis microlophus (Gunther)	Redear Sunfish
Micropterus dolomieui (Lacepede)	Smallmouth Bass
Micropterus punctulatus (Rafinesque)	Spotted Bass
Micropterus salmoides (Lacepede)	Largemouth Bass
Clupeidae	
Alosa chrysochloris (Rafinesque)	Skipjack Herring
Dorosoma cepedianum (LeSueur)	Gizzard Shad
Cottidae	
Cottus carolinae (Gill)	Banded Sculpin
Cyprinidae	
Campostoma anomalum (Rafinesque)	Stoneroller
Cyprinus carpio (Linnaeus)	Carp
Hemitremia flammea (Jordan and Gilbert)	Flame Chub
Hybopsis amblops (Rafinesque)	Bigeye Chub
Notropis ardens (Cope)	Rosefin Shiner
Notropis atherinoides (Rafinesque)	Emerald Shiner
Notropis cornutus (Mitchill)	Common Shiner
Notropis spilopterus (Cope)	Spotfin Shiner
Notropis telescopus (Cope)	Telescope Shiner
Notropis whipplei (Girard)	Steelcolor Shiner
Pimephales notatus (Rafinesque)	Bluntnose Minnow
Rhinichthys atratulus (Hermann)	Blacknose Dace
Semotilus atromaculatus (Mitchill)	Creek Chub

Table 4 (continued)

Scientific Name	Common Name
Cyprinodontidae	
Fundulus catenatus (Storer)	Northern Studfish
Fundulus notatus (Rafinesque)	Blackstripe Topminnow
Fundulus olivaceus (Storer)	Blackspotted Topminnow
Ictaluridae	
Ictalurus melas (Rafinesque)	Black Bullhead
Ictalurus natalis (LeSueur)	Yellow Bullhead
Ictalurus punctatus (Rafinesque)	Channel Catfish
Lepisosteidae	
Lepisosteus osseus	
Percidae	
Etheostoma blennioides (Rafinesque)	Greenside Darter
Etheostoma flabellare (Rafinesque)	Fantail Darter
Etheostoma jessiae (Jordan and Brayton)	Blueside Darter
Etheostoma kennicotti (Putnam)	Stripetail Darter
Etheostoma rufilineatum (Cope)	Redline Darter
Etheostoma simoterum (Cope)	Tennessee Snubnose Darter
Etheostoma stigmaecum (Jordan)	Speckled Darter
Percina caprodes (Rafinesque)	Logperch
Stizostedion canadense (Smith)	Sauger
Petromyzontidae	
Lampetra aepyptera (Abbott)	Least Brook Lamprey
Salmonidae	
Salmo gairdneri (Richardson)	Rainbow Trout
Sciaenidae	
Aplodinotus grunniens (Rafinesque)	Freshwater Drum

sections of the downstream area were realigned which resulted in greater erosion and loss of bank cover. Large pool areas with slow water velocities were typical of these sections of the stream.

Highfin carpsucker, carp, spotted sucker, skipjack herring, drum, gizzard shad, and sauger were also collected at the downstream stations. These fish were all mature and it is presumed they moved upstream from Guntersville Reservoir. The grade stabilization structure at Station 7 apparently prevented further upstream migration of these species.

Centrarchid Abundance

Density (No/ha) of centrarchid populations at Stations 1-11 is shown in Figures 2 through 6. Specific data for 1975 and 1976 population estimates are found in the Appendix, Tables 1 through 15.

Centrarchid density at the upstream unaltered stations (Stations 1 and 2) was low, ranging from 53 to 200/ha during 1975 and 1976. Cooler water temperatures may have limited their abundance at these two stations. Rock bass exhibited the highest density (47/ha - 1975, 78/ha - 1976) of the three species collected at Station 1. Rock bass were the most abundant species collected at Station 2 (133/ha - 1975, 90/ha - 1976). Longear sunfish, green sunfish, bluegill, and smallmouth bass were also collected at Station 2. Population estimates for these species did not exceed 33/ha.

Station 11 was also unaltered and exhibited an abundance of vegetative cover. High densities of centrarchids were collected at this station (563/ha - 1975, 862/ha - 1976). Bluegill (83/ha - 1975, 383/ha - 1976) and longear sunfish (293/ha - 1975, 284/ha - 1976) were

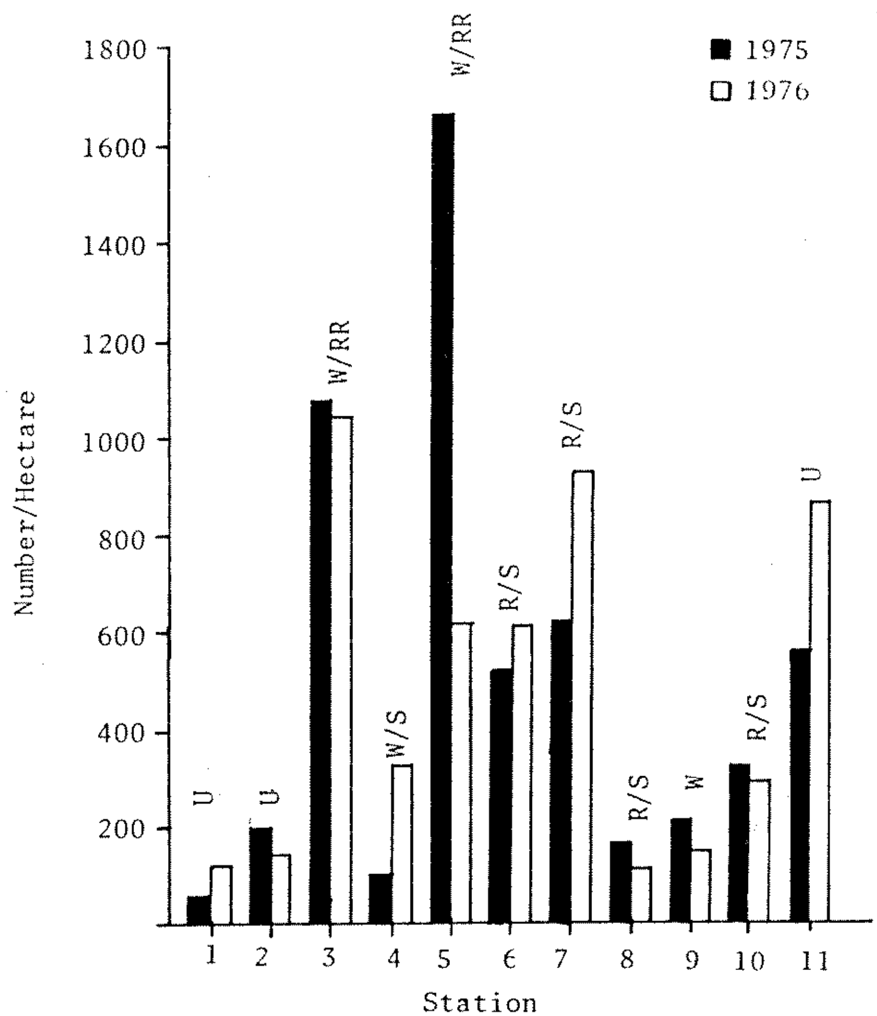

Figure 2. Centrarchid Density (Number/Hectare) at Altered and Unaltered Stations (U-Unaltered, W-Channel Widened Along One Bank, R-Channel Realigned, S-Mitigation Structures, RR-Riprap) on Crow Creek, 1975 and 1976

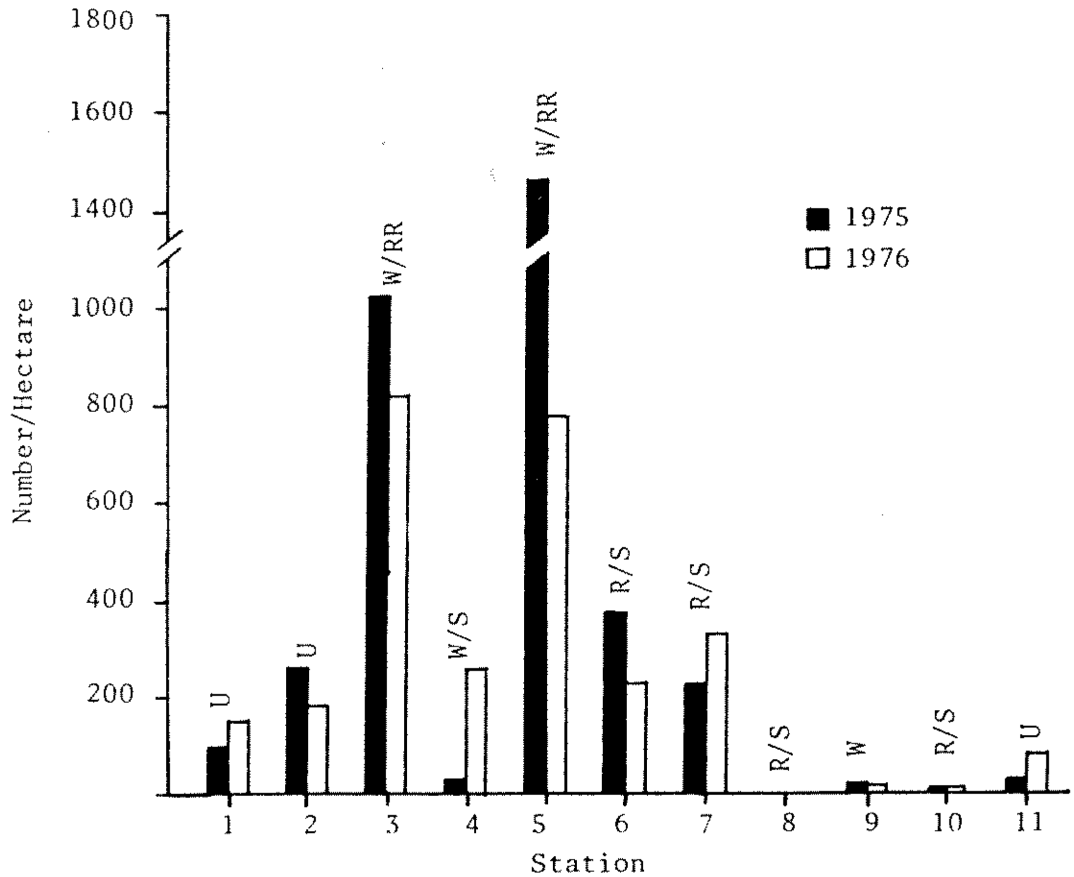

Figure 3. Rock Bass Density (Number/Hectare) at Altered and Unaltered Stations (U-Unaltered, W-Channel Widened Along One Bank, R-Channel Realigned, S-Mitigation Structures, RR-Riprap) on Crow Creek, 1975 and 1976

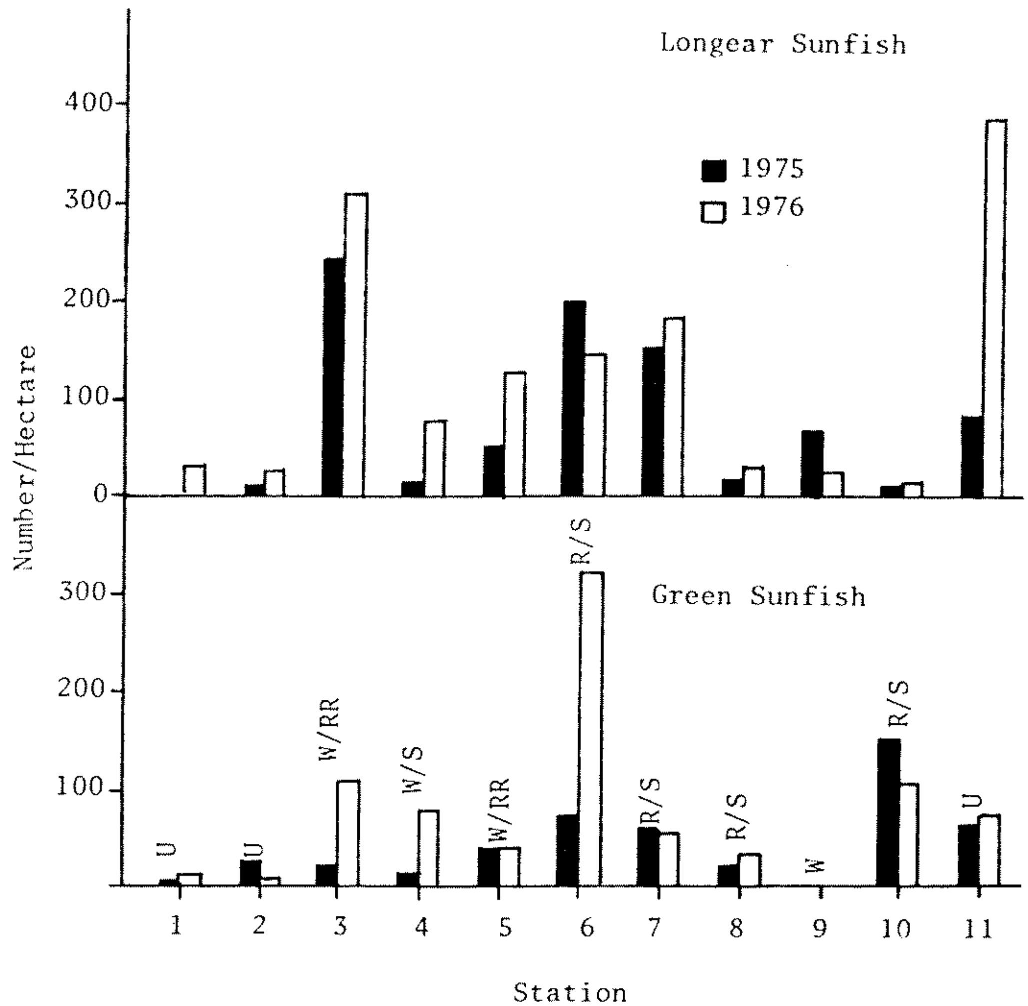

Figure 4. Density (Number/Hectare) of Longear Sunfish and Green Sunfish at Altered and Unaltered Stations (U-Unaltered, W-Widened Along One Bank, R-Channel Realigned, S-Mitigation Structures, RR-Riprap) on Crow Creek, 1975 and 1976

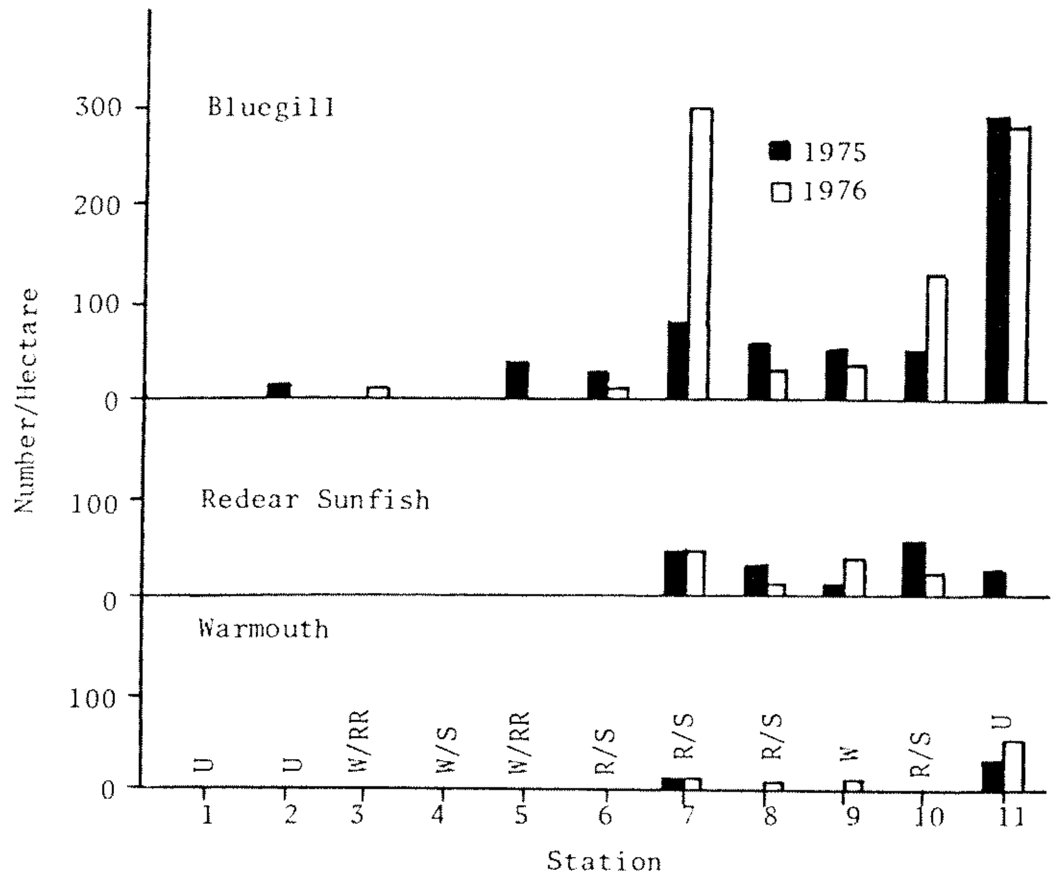

Figure 5. Density (Number/Hectare) of Bluegill, Redear Sunfish, and Warmouth at Altered and Unaltered Stations (U-Unaltered, W-Channel Widened Along One Bank, R-Channel Realigned, S-Mitigation Structures, RR-Riprap) on Crow Creek, 1975 and 1976.

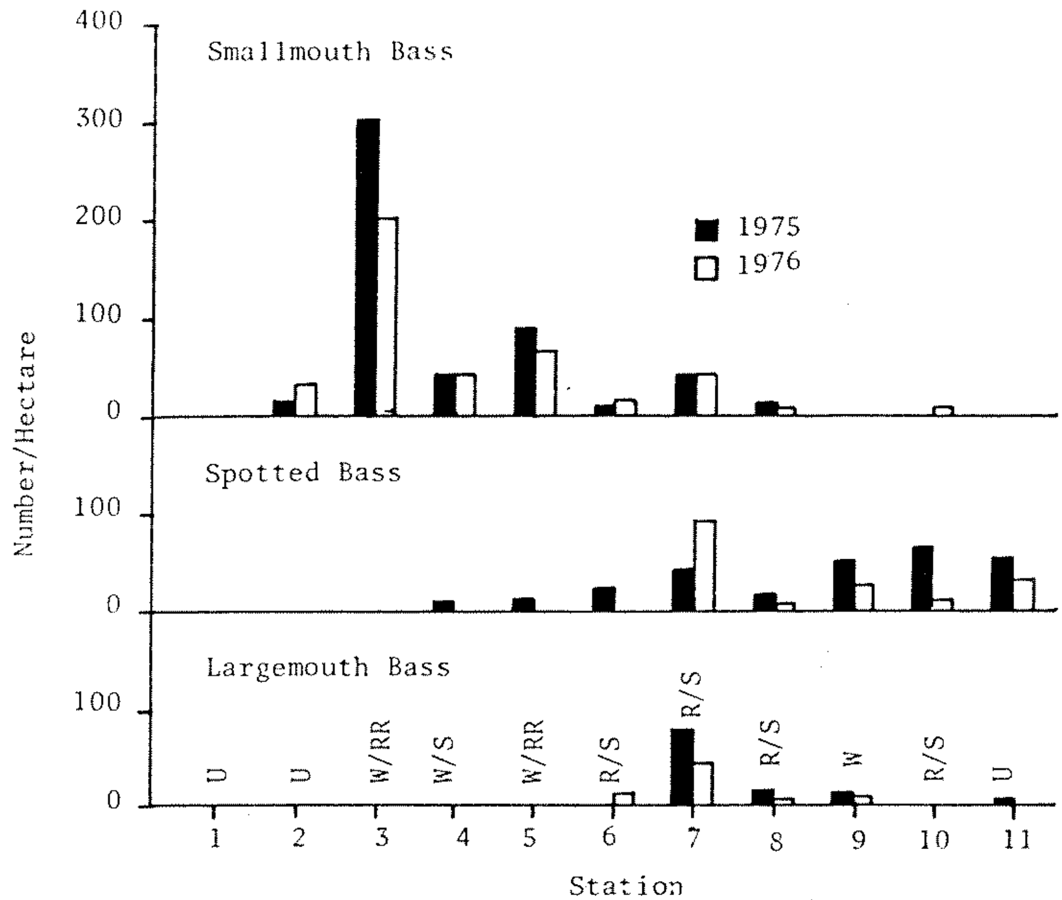

Figure 6. Density (Number/Hectare) of Smallmouth Bass at Altered and Unaltered Stations (U-Unaltered, W-Widened Along One Bank, R-Channel Realigned, S-Mitigation Structures, RR-Riprap) on Crow Creek, 1975 and 1976

the predominant species collected at Station 11. Other species collected included rock bass, green sunfish, redear sunfish, warmouth, spotted bass, and largemouth bass.

Stations 3, 4, 5, and 9 were widened along one bank. Extensive areas of the banks at Stations 3 and 5 were ripraped. Centrarchids were abundant in the ripraped area. Centrarchid density at Stations 3 and 5 was high, ranging from 618/ha (Station 5 - 1976) to 1658/ha (Station 5 - 1975). Rock bass was the most abundant species collected at Stations 3 (513/ha - 1975, 409/ha - 1976) and 5 (1427/ha - 1975, 386/ha - 1976). Longear sunfish and smallmouth bass exhibited high densities at Station 3, ranging from 202/ha to 308/ha for 1975 and 1976. These two species also ranked second and third in abundance at Station 5; however, their densities did not exceed 125/ha. Other species collected at Stations 3 and 5 included bluegill, green sunfish, and spotted bass.

Centrarchid densities were much lower at Stations 4 and 9 (100 to 327/ha for 1975 and 1976) than at Stations 3 and 5. Smallmouth bass was the most abundant species collected at Station 4 during 1975 (43/ha). Rock bass (128/ha), longear sunfish (78/ha), and green sunfish (78/ha) were the predominant species collected at Station 4 during 1976. Spotted bass were also collected at this station. Longear sunfish (52/ha), bluegill (52/ha), and spotted bass (51/ha) were the predominant species collected at Station 9 during 1975. Bluegill (39/ha) and redear sunfish (35/ha) predominated the centrarchid community at Station 9 during 1976. Other species collected at Station 9 included rock bass, warmouth, and largemouth bass.

The upstream portions of Stations 6 and 7 were realigned. Structures placed at a high elevation, at Stations 6 and 7, created a head sufficient to scour deep pools immediately downstream. Centrarchids were collected in abundance in these pool areas. Few fish were collected in the realigned sections of the channel located upstream from the structures. Extensive pooling, unstable banks, and the absence of cover characterized the habitat in these areas. Centrarchid abundance was high at Stations 6 (519/ha - 1975, 607/ha - 1976) and 7 (625/ha - 1975, 925/ha - 1976). Rock bass, longear sunfish, and green sunfish were the predominant species collected at Station 6. Population estimates for these species ranged from 71/ha to 323/ha during 1975 and 1976. Longear sunfish was the most abundant species (202/ha) collected during 1975 and green sunfish was the most abundant species (323/ha) collected during 1976. Rock bass, longear sunfish, and bluegill were the most abundant species collected at Station 7. Longear sunfish was the predominant species collected at Station 7 during 1975 (156/ha). Bluegill was the most abundant species (304/ha) collected during 1976. Other species collected at Stations 6 and 7 included redear sunfish, warmouth, smallmouth bass, largemouth bass, and spotted bass (< 90/ha).

Stations 8 and 10 were completely realigned and the series of lowhead dams created pool areas of moderate depth. Centrarchid densities were much lower at these stations, ranging from 115/ha (Station 8 - 1976) to 326/ha (Station 10 - 1975), than at Stations 6 and 7. Fish were collected in greatest frequency along the ripraped areas near the structures. Centrarchid density and the area of riprap were greater at Station 10 than at Station 8.

Bluegill was the predominant species (59/ha) collected at Station 8 in 1975. Other species collected included longear sunfish, green sunfish, redear sunfish, warmouth, smallmouth bass, spotted bass, and largemouth bass. Population estimates for these species did not exceed 33/ha during 1975 or 1976. Seven species of centrarchids were collected at Station 10. Green sunfish was the predominant species collected during 1975 (147/ha) and bluegill predominated during 1976 (130/ha). Smallmouth bass, rock bass, and longear sunfish were collected in low abundance ($<$ 14/ha) and redear sunfish and spotted bass were collected in moderate abundance (10 to 62/ha).

Centrarchid Percent Composition

Percent composition of the centrarchid species collected at Station 1-11 during 1975 and 1976 is shown in Figure 7. Species composition at stations located in the upstream section of the study area (unaltered Stations 1 and 2; widened Stations 3, 4, and 5) was predominated by rock bass. Percent composition of rock bass at these stations ranged from 39.0% (Station 4 - 1976) to 87.4% (Station 1 - 1975). Species ranking second in percent composition fluctuated between green sunfish, longear sunfish, and smallmouth bass. Percent composition for any one of the second-ranked species did not exceed 23.8% at Stations 1-5 during 1975 and 1976.

Species composition in the downstream section of the study area (Stations 6-11) was predominantly by longear sunfish, green sunfish, and bluegill. Species composition was predominated by longear sunfish at Stations 6, 7, and 9 during 1975 and at Station 11 during 1976.

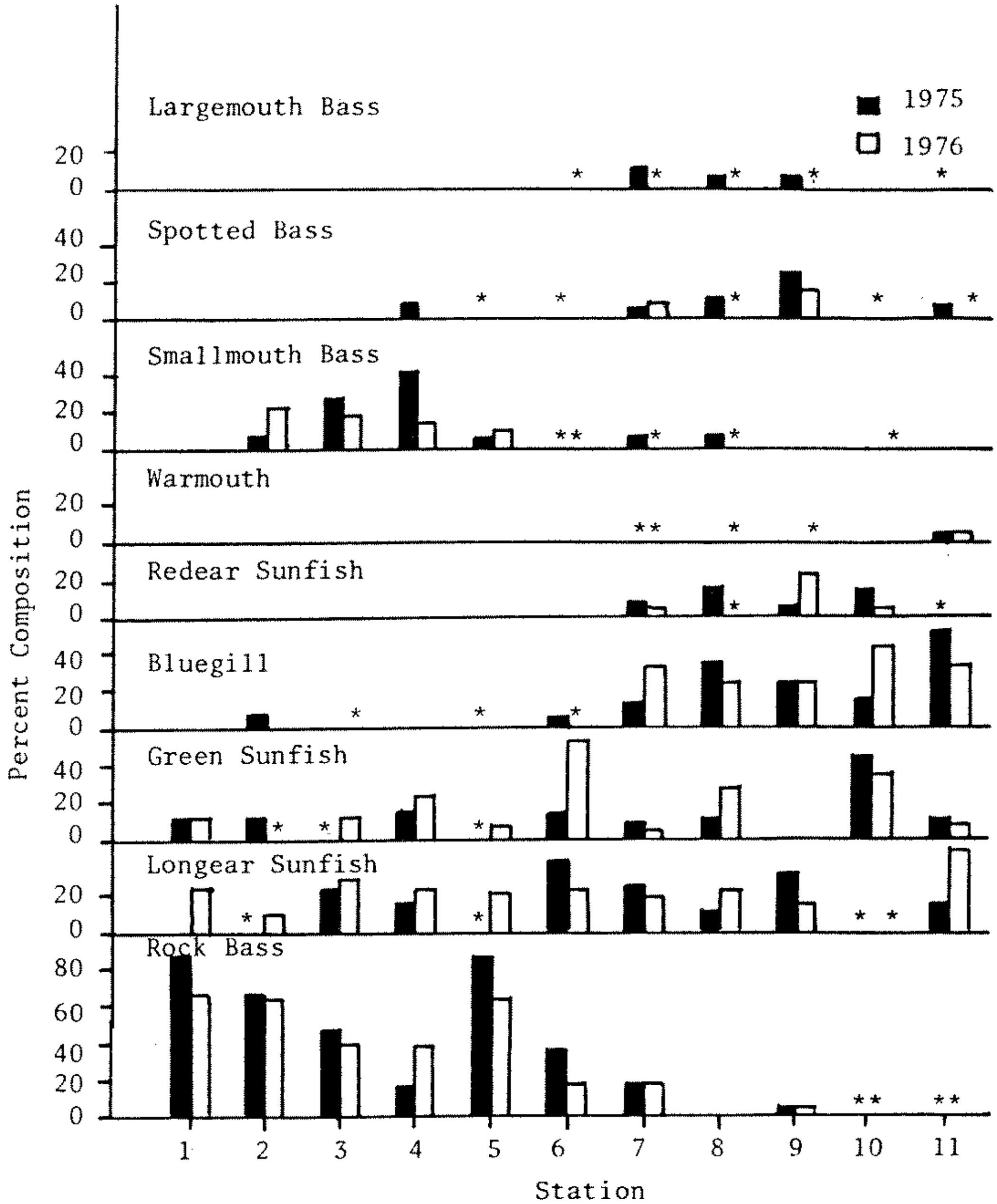

Figure 7. Percent Composition (by Number) of Centrarchid Species Collected at Stations 1 Through 11 on Crow Creek, 1975 and 1976. (* - Indicates Percent Composition Less Than 5.0 Percent)

Percent composition of longear sunfish at these stations ranged from 25.0% (Station 7) to 44.4% (Station 11). Bluegill predominated the species composition at Stations 8 (35.7%) and 11 (52.0%) during 1975 and Stations 7 (32.8%), 9 (26.4%), and 10 (44.9%) during 1976. Green sunfish percent composition was higher than other species collected at Station 10 (45.1%) during 1975 and at Stations 6 (53.3%) and 8 (28.9%) during 1976. The black bass species, warmouth, redear sunfish, and rock bass, were collected at the downstream stations but generally accounted for a small percentage of the species composition of these stations.

Centrarchid Habitat Preference

Correlation analysis of regressions between centrarchid No/ha and physical parameters (Table 5) and observed frequency of occurrence of centrarchids in major habitat zones (Tables 6 - 9) were used to evaluate habitat preference of centrarchids at the 11 study sections.

Rock Bass

Rock bass were collected at all stations except Station 8. Highest concentrations of rock bass were found in pool areas, bordered by abundant cover (rock riprap and vegetation), immediately below riffle areas. Regression analysis showed a strong positive correlation between rock bass density and percent cover ($P < 0.01$) and with percent riffle area ($P < 0.05$) (Table 5).

Information presented in Table 6 also indicates that areas with cover were preferred over other habitats. Vegetative cover was found

Table 5

Regression Analysis of the Number per Hectare of Species of Centrarchids (Dependent Variables) and Physical Parameters (Independent Variables) from Stations 1 Through 11, Crow Creek, 1975 and 1976.

	Correlation Coefficient (r)				
Species	Percent Pool	Percent Slow Shallow	Percent Riffle	Percent Total Cover	Avg. Summer Temperature (J,J,A)
Rock Bass	-0.07	-0.07	+0.37*	+0.89**	+0.02
Longear Sunfish	-0.20	+0.24	-0.10	+0.20	-0.01
Green Sunfish	+0.07	-0.10	-0.13	-0.06	+0.12
Bluegill	-0.01	+0.17	-0.45*	-0.14	+0.24
Redear Sunfish	+0.39*	-0.28	-0.27	-0.15	+0.48*
Warmouth	-0.27	+0.44*	-.38*	-0.18	+0.01
Smallmouth Bass	-0.23	+0.20	+0.17	+0.61**	-0.05
Spotted Bass	+0.19	-0.09	-0.21	-0.10	+0.43*
Largemouth Bass	+0.34	-0.32	-0.06	-0.20	+0.24

* Significant at 0.05 level.

** Significant at 0.01 level.

Table 6

Percent Frequency of Occurrence of Rock Bass and Longear Sunfish in Major Habitat Areas of the Study Sites at Crow Creek, 1976 (Percent of Total Sampling Area Composed of the Particular Habitat Classification in Parentheses.)

Species/ Station	Habitat Classification					Number Collected
	Slow Shallow	Riffle	Pool	Vegetative Cover	Riprap Cover	
Rock Bass						
1	0.0(48.4)	0.0(4.9)	0.0(46.7)	100.0(7.3)	-	10
2	0.0(44.0)	7.7(2.9)	7.7(53.1)	84.6(6.8)	-	12
3	0.0(36.2)	0.0(12.2)	6.0(52.6)	3.0(2.8)	91.0(14.2)	64
4	0.0(45.4)	0.0(33.2)	7.7(21.4)	61.5(1.5)	30.8(1.1)	6
5	0.0(23.7)	0.0(22.2)	13.8(54.1)	-	86.2(17.7)	80
6	9.1(28.1)	0.0(7.8)	4.5(64.1)	31.8(1.0)	54.5(3.7)	22
7	0.0(14.7)	0.0(12.4)	7.6(72.9)	-	92.4(6.6)	34
9	100.0(43.5)	0.0(13.7)	0.0(42.8)	-	-	1
10	0.0(11.9)	0.0(2.8)	0.0(85.3)	-	100.0(9.9)	1
11	0.0(58.6)	-	0.0(41.4)	100.0(7.7)	-	2
Longear Sunfish						
1	0.0	0.0	0.0	100.0	-	4
2	0.0	0.0	0.0	100.0	-	2
3	7.2	0.0	0.0	26.2	66.6	51
4	0.0	9.1	0.0	90.9	0.0	10
5	0.0	0.0	20.0	-	80.0	20
6	8.3	0.0	8.3	20.8	62.5	25
7	21.7	0.0	17.4	0	60.9	31
8	0.0(15.2)	0.0	0.0(82.8)	-	100.0(2.2)	5
9	100.0	0.0	0.0	-	-	3
10	0.0	0.0	0.0	-	100.0	3
11	0.2	-	0.0	99.8	-	88

Table 7

Percent Frequency of Occurrence of Green Sunfish and Bluegill in Major Habitat Areas of the Study Sites at Crow Creek, 1976

	Habitat Classification					
Species/ Station	Slow Shallow	Riffle	Pool	Vegetative Cover	Riprap Cover	Number Collected
Green Sunfish						
1	0.0	0.0	0.0	100.0	-	2
2	0.0	0.0	0.0	100.0	-	1
3	0.0	0.0	0.0	9.9	90.1	11
5	0.0	0.0	0.0	-	100.0	6
6	4.5	0.0	7.6	7.6	80.3	70
7	10.0	10.0	0.0	-	80.0	10
8	0.0	0.0	0.0	-	100.0	6
10	0.0	0.0	0.0	-	100.0	17
11	20.0	-	50.0	30.0	-	12
Bluegill						
3	0.0	0.0	0.0	100.0	0.0	2
6	50.0	0.0	0.0	0.0	50.0	2
7	0.0	2.2	19.5	-	78.3	69
8	0.0	0.0	33.3	-	66.7	3
9	0.0	0.0	100.0	-	-	4
10	0.0	0.0	20.0	-	80.0	18
11	0.6	-	0.0	98.4	-	62

Table 8

Percent Frequency of Occurrence of Smallmouth Bass and Spotted Bass in Major Habitat Areas of the Study Sites at Crow Creek, 1976.

Species/ Station	Habitat Classification					Number Collected
	Slow Shallow	Riffle	Pool	Vegetative Cover	Riprap Cover	
Smallmouth Bass						
2	0.0	0.0	20.0	80.0	-	5
3	0.0	0.0	9.7	9.7	80.6	33
4	0.0	0.0	66.7	33.3	0.0	6
5	0.0	0.0	21.4	-	78.6	15
6	0.0	0.0	0.0	0.0	100.0	3
7	12.5	12.5	0.0	-	75.0	8
8	0.0	0.0	100.0	-	0.0	1
Spotted Bass						
7	0.0	6.7	26.7	-	66.6	22
8	0.0	0.0	100.0	-	0.0	1
9	0.0	0.0	100.0	-	-	3
10	0.0	0.0	0.0	-	100.0	1
11	0.0	0.0	0.0	100.0	-	1

Table 9

Percent Frequency Occurrence of Largemouth Bass, Redear Sunfish, and Warmouth in Major Habitat Areas of the Study Sites at Crow Creek, 1976

Species/ Station	Habitat Classification					Number Collected
	Slow Shallow	Fast Shallow	Slow Deep	Vegetative Cover	Riprap Cover	
Largemouth Bass						
6	0.0	0.0	0.0	0.0	100.0	2
7	0.0	0.0	33.3	-	66.7	9
9	0.0	0.0	100.0	-	0.0	1
10	0.0	0.0	100.0	-	-	2
Redear Sunfish						
7	0.0	0.0	10.0	-	90.0	10
9	0.0	0.0	100.0	-	0.0	1
10	50.0	0.0	50.0	-	-	4
11	0 0	0.0	66.6	-	33.3	3
Warmouth						
7	0.0	0.0	0.0	-	100.0	2
9	0.0	0.0	0.0	-	100.0	1
13	10.0	-	0.0	90.0	-	10

at six of the 11 study sites and contributed from 1.0% to 7.3% of the area at these sites (Table 6). Rock riprap cover was also present at six stations and accounted for 1.1% to 14.2% of the area at these sites. Percent of the rock bass collected in cover areas (vegetative and riprap) ranged from 84.6% at Station 2 to 100% at Stations 1, 10, and 11. This indicates that areas with cover were highly preferred by rock bass since a great percentage of those collected came from a small percentage of the sample area. It was observed that cover bordering pool areas below riffles was more frequently utilized by rock bass than cover found in association with other areas of the study sections. Frequency of occurrence of rock bass in other habitat areas ranged from 0.0% to 13.8% with the exception of Station 9 where only one rock bass was collected in a slow-shallow water area.

Longear Sunfish

Longear sunfish were most frequently collected in pool areas that were associated with vegetative cover; however, rock riprap cover was used frequently by longear sunfish. Longear sunfish were collected in greatest abundance at Stations 3, 5, 6, 7, and 11 (Table 6). Rock riprap and/or vegetative cover was found at all of these stations. The frequency of occurrence of longear collected in cover areas ranged from 60.9% at Station 7 to 100% at Stations 1, 2, 8, and 10 (Table 6). Other habitat areas where longear were collected were those with slow current velocities (slow shallow and slow deep areas).

There were no significant correlations between longear sunfish density and the physical parameters tested.

Green Sunfish

Green sunfish were collected at all stations except Station 9. General distribution patterns showed preference for pool areas and cover. Physical parameters showed no significant correlation with green sunfish density. Frequency of occurrence of green sunfish was greatest in rock riprap cover and ranged from 80% to 100% (Table 7). Green sunfish were collected more frequently in vegetative cover areas at stations without rock riprap. Other areas where green sunfish were less frequently collected included shallow and deep areas with slow current velocities.

Bluegill

Bluegill were collected at all stations except Stations 1 and 4. Density of bluegill showed a negative correlation with percent riffle area ($P < 0.05$). Bluegill were collected most frequently in pool and cover areas (Table 7). At Stations 3 and 11, they were almost exclusively collected in vegetative cover areas. The frequency of occurrence of bluegill collected in riprap areas at Sations 6, 7, 8, and 10 ranged from 50% to 80%.

Smallmouth Bass

Smallmouth bass density showed a strong positive correlation with the percent of cover area ($P < 0.01$) (Table 5). This relationship is also shown in Table 8, where the frequency of occurrence of smallmouth bass was greatest in association with cover areas at five of the seven stations where smallmouth bass were collected. It was observed that cover bordering pool areas immediately downstream from riffles was preferred by smallmouth bass.

Spotted Bass

Spotted bass density showed a significant positive correlation with the average summer water temperature ($P < 0.05$) (Table 5). They were collected most frequently in pool areas and in riprap cover adjacent to pool areas. At Station 7, a total of 22 spotted bass were collected, of which 66.6% were collected in the riprap pool area immediately below the lowhead dam (Table 8).

Largemouth Bass and Redear Sunfish

Largemouth bass and redear sunfish exhibited similar patterns of habitat preference and distribution. Both exhibited highest correlations with percent pool area and average summer water temperature (positive correlation) and with percent slow shallow areas (negative correlation) (Table 5). Largemouth bass and redear sunfish were primarily collected in the pool areas associated with cover. The highest density of these two species was found in the riprap bordered pool, created immediately below the lowhead dam at Sation 7.

Warmouth

Warmouth densities were the lowest of the nine species of centrarchids collected in Crow Creek. Their abundance was greatest at Station 11 where there was an abundance of slow shallow area and vegetative cover. Warmouth density showed a significant positive correlation ($P < 0.05$) with percent slow shallow area and significant negative correlation ($P < 0.05$) with percent riffle area (Table 5). Warmouth were almost exclusively collected in vegetative and riprap cover areas (Table 9).

Centrarchid Diversity

Diversity indices were used to evaluate the centrarchid community structure. Diversity (H'), evenness (J'), species richness (s), and abundance (No/ha) of centrarchids for Stations 1 through 11 on Crow Creek during the summers of 1975 and 1976 are shown in Figures 8 and 9.

During 1975, diversity of centrarchids ranged from 0.55 at Station 1 to 2.85 at Station 7. In 1976, diversity values ranged from 0.70 at Station 1 to 2.73 at Station 9. Diversity values were highest at Stations 7, 8, and 9 and lowest at Stations 1, 2, and 5 during both 1975 and 1976. Diversity of centrarchids showed little relationship with their abundance. High diversity values were found where species richness and evenness values were high.

Regression analysis was used to determine if any significant relationships existed between centrarchid diversity and physical characteristics of the channel (Table 10). There was no significant correlation ($P < 0.05$) with centrarchid diversity and percent riffle area, percent cover, mean current velocity, or mean depth. Mean summer water temperature was the most highly correlated variable with centrarchid diversity ($r = 0.64$; $P < 0.01$). Mean channel width also showed a significant correlation with centrarchid diversity ($r = 0.49$; $P < 0.01$). Mean channel width and water temperature generally increased going from the upstream study sections to the downstream sections of the channel. Rock bass and smallmouth bass were the predominant species of centrarchids collected at the upstream stations (Stations 1 through 5). Green sunfish, longear sunfish, and bluegill were the predominant species

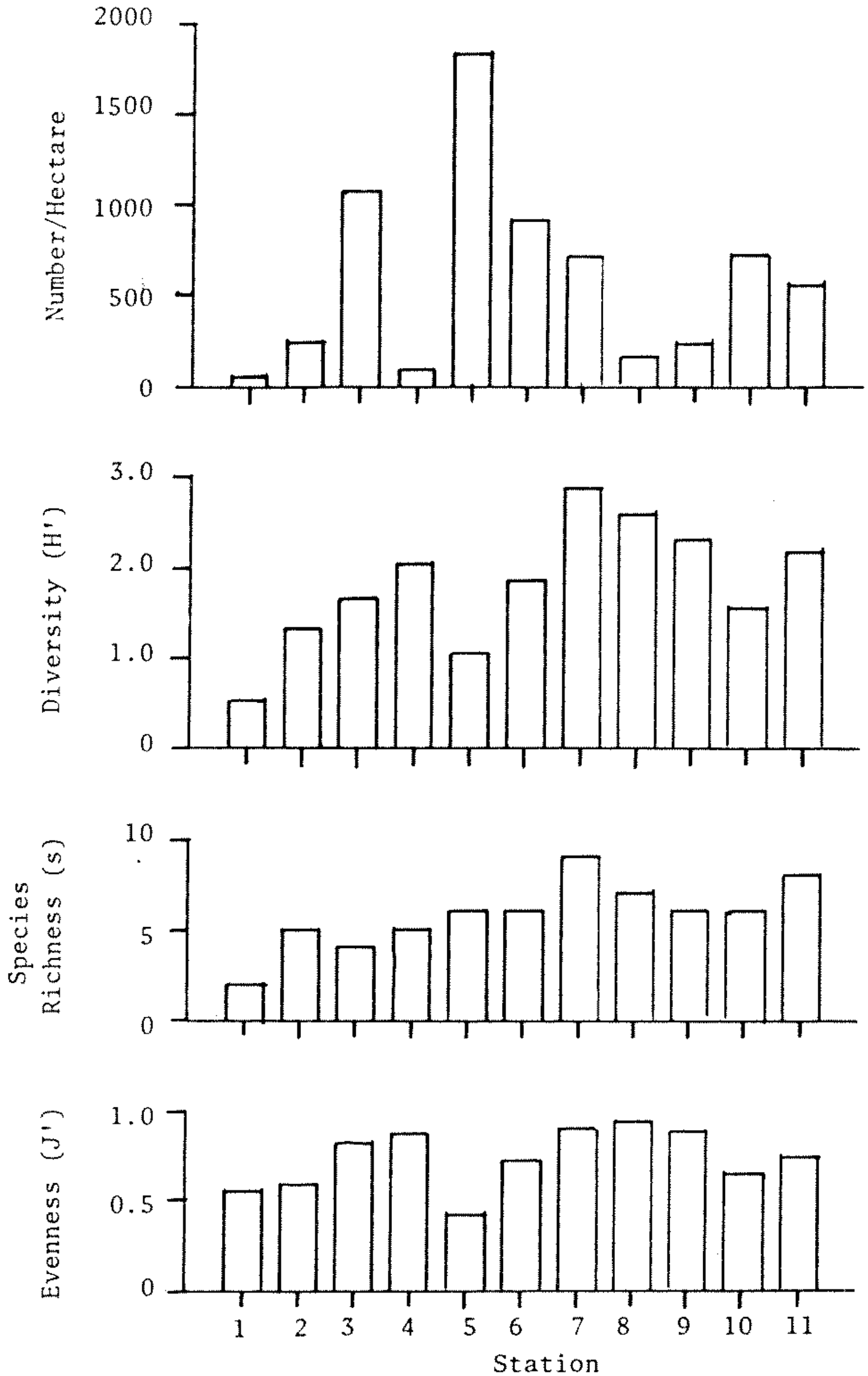

Figure 8. Centrarchid Density (Number/Hectare), Diversity (H'), Species Richness (s), and Evenness (J') at Stations 1 Through 11, Crow Creek, 1975

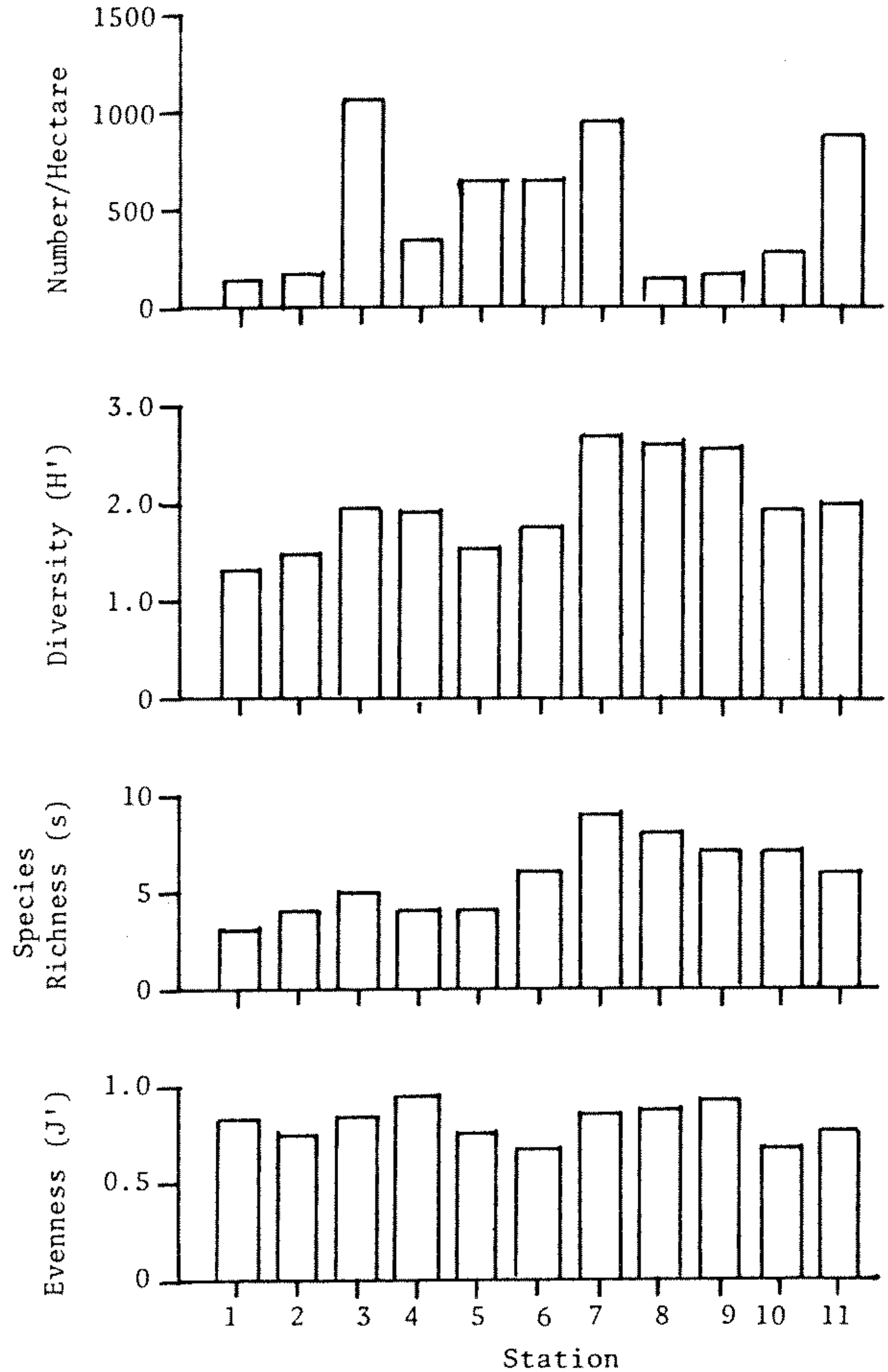

Figure 9. Centrarchid Density (Number/Hectare), Diversity (H'), Species Richness (s), and Evenness (J') at Stations 1 Through 11, Crow Creek, 1976

Table 10

Regression Analysis of Centrarchid Species Diversity (Dependent Variable) and Physical Parameters (Independent Variable) from All Stations on Crow Creek, Summers of 1975 and 1976.

Physical Parameters	r[1]	Sample Size	Significance[2]
Percent Riffle Area	-0.35	22	Not significant
Percent Cover	-0.19	22	Not significant
Mean Current Velocity	-0.27	11	Not significant
Mean Depth	0.31	22	Not significant
Mean Width	0.49	22	Significant ($P < 0.01$)
Mean Summer Water Temperature	0.64	22	Significant ($P < 0.0005$)

[1] Correlation coefficient (r).

[2] $r \neq 0$ if $t \geq t_{0.05}$.

Table 11

Percent Composition (by Number) of the Predominant Species of Centrarchids Collected at Stations 1 Through 11 at Crow Creek, Summers of 1975 and 1976.

	1975		1976	
Station	Percent of Total Number	Predominant Species	Percent of Total Number	Predominant Species
1	87	Rock bass	64	Rock bass
2	67	Rock bass	62	Rock bass
3	48	Rock bass	39	Rock bass
4	42	Smallmouth bass	39	Rock bass
5	86	Rock bass	62	Rock bass
6	39	Longear sunfish	53	Green sunfish
7	25	Longear sunfish	33	Bluegill
8	36	Bluegill	29	Green sunfish
9	31	Longear sunfish	26	Bluegill
10	45	Green sunfish	46	Bluegill
11	52	Bluegill	44	Longear sunfish

of centrarchids collected at Stations 6 through 11 (Table 11). The distinct separation in centrarchid species' dominance between the upstream and downstream stations may have partially attributed to water temperature differences between sections of the channel. Most centrarchid species, with the exception of rock bass and smallmouth bass, normally prefer waters with warmer temperatures than found at Stations 1 through 5 (Bietinger, et al., 1975; Ferguson, 1958; Hallam, 1959; Neill and Magnuson, 1974).

The low number of species collected at the upstream stations provides a greater opportunity through reduced interspecific competition for one species to strongly dominate the community structure. This results in lower evenness values and, consequently, lower diversity. This is indicated in Table 11 by the higher range in percent composition of those particular species of centrarchids that were found in greatest abundance at the upstream stations where cold water temperatures limited species richness. During 1975, the percent composition of the predominant centrarchid species at Stations 1 through 5 ranged from 42% to 87% and ranged from 25% to 52% at Stations 6 through 11. A similar trend in percent composition of the dominant species of centrarchids was observed during 1976.

Centrarchid Functional Components

Centrarchids are considered to be facultative carnivores. They feed primarily on insects, crustaceans, and small fish (Carlander, 1977; Pflieger, 1975; Smith, 1979). Centrarchid species in Crow Creek were grouped into the following three functional units:

Primary facultative carnivores--bluegill, longear sunfish, and redear sunfish.

Secondary facultative carnivores--rock bass, green sunfish, and warmouth.

Tertiary facultative carnivores--smallmouth bass, largemouth bass, and spotted bass.

Species of centrarchids were grouped into their respective functional units based on similarities in morphological and behavioral adaptations to feeding.

Mouth size is perhaps the most important morphological adaptation separating the three functional units. Werner (1977) stated that mouth size and other morphological features enable green sunfish to consume larger food items than bluegill. The small more protrusible mouth of bluegill permits the efficient exploitation of smaller food items such as chironomids and zooplankton. Comparative food habit studies indicate that centrarchids in the primary functional unit are more specialized for obtaining smaller foods (Applegate, et al., 1966; Gerking, 1954, 1962; Keast, 1970; Moffet and Hunt, 1943; Werner and Hall, 1976; Werner, 1977). The larger mouth size of warmouth is related to its more piscivorous diet (Forbes, 1903; Guillory, 1978; Larrimore, 1957). Black bass species exhibit the largest mouth size and consume much larger prey items than other centrarchids.

Body shape of the different species of centrarchids also indicates a difference in function. The primary facultative carnivores exhibit a more laterally compressed body and larger fins. Werner and Hall (1977) stated that in bluegill this allows them to maneuver easily for the capture of prey that must be gleaned in large numbers from vegetation, the bottom,and open water. An increasingly fusiform body shape is seen going from the secondary to tertiary facultative carnivores. The fusiform body shape of these fish increases their capture efficiency of prey that require pursuit (Werner and Hall, 1977). The streamlined body shape of species in these functional units also permits easier movement in waters exhibiting faster current velocities.

Structural differences in the centrarchid populations between the upstream and downstream stations revealed similar differences in the dominance of particular functional components of centrarchid populations between these sections of the channel. Examination of the biomass dominance rank of centrarchid functional units, Tables 12 and 13, indicate a shift in dominance from secondary facultative carnivores (primarily rock bass) at Stations 1 through 6 to primary facultative carnivores (bluegill, longear sunfish, and redear sunfish) at Stations 7 through 11. This was particularly evident for data collected during 1976 (Table 13).

Regression analysis of biomass (kg/ha) of the different centrarchid functional units (dependent variables) and mean depth, percent riffle area, and percent cover (independent variables) are shown in Table 14. The independent variables were limited to a few physical characteristics that encompassed a broader number of physical characteristics. For example, mean depth increased with mean channel width going from upstream to downstream sections of the channel; the percent riffle area correlated directly with current velocity and inversely with percent pool area. Mean depth showed no relationship with any of the centrarchid functional units. There was no relationship between percent riffle area and biomass

Table 12

Biomass Dominance Rank of Functional Components of the Centrarchid Populations Found at Stations 1 Through 11, Crow Creek, during 1975.

Station	[1]Primary Facultative Carnivores		[2]Secondary Facultative Carnivores		[3]Tertiary Facultative Carnivores	
	Dominance Rank	Biomass (kg/ha)	Dominance Rank	Biomass (kg/ha)	Dominance Rank	Biomass (kg/ha)
1	2	0.0	1	4.27	2	0.0
2	3	0.89	1	9.24	2	8.08
3	3	4.75	2	24.44	1	31.18
4	3	0.08	1	0.53	2	0.48
5	3	3.62	1	62.67	2	9.26
6	2	5.72	1	10.39	3	1.60
7	2	5.81	3	5.62	1	31.58
8	1	4.45	3	0.85	2	4.42
9	2	2.59	3	0.58	1	8.21
10	3	3.94	2	5.30	1	7.00
11	1	18.39	3	3.54	2	0.99

[1] Primary Facultative Carnivores = longear sunfish, bluegill, and redear sunfish.

[2] Secondary Facultative Carnivores = rock bass, warmouth, and green sunfish.

[3] Tertiary Facultative Carnivores = smallmouth bass, largemouth bass, and spotted bass.

Table 14

Regression Analysis of Functional Components of the Centrarchid Populations (Dependent Variables) with Mean Depth, Percent Riffle Area, and Percent Cover (Independent Variables) from Stations 1 Through 11 at Crow Creek, Summers of 1975 and 1976.

Dependent Variables	Independent Variables Sample Size	[1] r	[2] Significance
	Mean Depth		
[3] Primary Facultative Carnivores	22	0.10	Not Significant
[4] Secondary Facultative Carnivores	22	-0.08	Not Significant
[5] Tertiary Facultative Carnivores	22	-0.07	Not Significant
	Percent Riffle Area		
Primary Facultative Carnivores	22	-0.36	Significant ($P < 0.05$)
Secondary Facultative Carnivores	22	0.02	Not Significant
Tertiary Facultative Carnivores	22	0.11	Not Significant
	Percent Cover		
Primary Facultative Carnivores	22	0.03	Not Significant
Secondary Facultative Carnivores	22	0.80	Significant ($P < 0.01$)
Tertiary Facultative Carnivores	22	0.42	Significant ($P < 0.05$)

[1] Correlation Coefficient (r).

[2] $r \neq 0$ if $t \geq t_{0.05}$.

[3] Primary Facultative Carnivores = longear sunfish, bluegill, and redear sunfish.

[4] Secondary Facultative Carnivores = rock bass, warmouth, and green sunfish.

[5] Tertiary Facultative Carnivores = smallmouth bass, largemouth bass, and spotted bass.

of secondary and tertiary facultative carnivores. The primary facultative carnivores showed a significant negative correlation with percent riffle area ($r = 0.36$; $P < 0.05$). This may reflect their preference for the large pooled areas of the downstream study sections where they were found to be the predominant functional component of the centrarchid populations. Percent cover was highly correlated with secondary ($r = 0.80$; $P < 0.01$) and tertiary facultative carnivores ($r = 0.42$; $P < 0.01$). This relationship may be related to their feeding behavior of waiting to ambush prey rather than actively searching for prey (Larrimore, 1957; Werner and Hall, 1977). The primary facultative carnivores showed no relationship with the amount of cover in the study sections.

Chapter 6

DISCUSSION

Physical characteristics of study sections where the channel was realigned varied considerably from physical characteristics found at the unaltered stations and those stations where the channel had been widened along one bank.

Water temperature increased going from upstream to downstream stations. Realigned sections of the channel exhibited higher water temperatures. The absence of overhead canopy, larger surface area, and higher turbidity at these stations contributed to higher water temperatures. The realigned stations were located several miles downstream from the headwaters and were, consequently, affected less by the inflow of cooler spring waters. Realigned stations had high banks that confined flows during periods of greatest discharge and, as a result, contributed to increased current velocities. Increased current velocities resulted in erosion of the unstable banks and greater turbidity in these sections of the channel.

Physical diversity was greatest at stations that were unaltered or widened along one bank. Physical characteristics contributing to the diversity of these stations included the combination of riffle, pool and slow shallow water areas, and an abundance of cover created by logs, brush, vegetative overhang, tree roots, and rock riprap. Physical characteristics at realigned stations showed little diversity. Improper placement of instream grade stabilization structures resulted in large pooled areas and small riffles which were associated with the immediate area below the grade stabilization structures. Pooling behind instream mitigation structures was particularly evident at Stations 6, 7, 8, and 10. The large pool areas created at Stations 6 and 7 were the result of the high elevation of the instream structure at each of these stations. Pooling at Stations 8 and 10 resulted from improper horizontal placement and elevation of the structures. Instream mitigation structures at Stations 8 and 10 were placed in series but were too close to each other to allow the formation of scour pools and resulting depositions creating riffle areas.

Funk (1973) stated that: a diverse fish fauna, including a variety of species of sport fish and forage fish, usually occurs naturally and is desirable. These fish depend for sustenance upon a very diverse assemblage of bottom organisms which in turn feed chiefly on a diverse group of algae and organic material. Productivity at each trophic level depends upon the physical diversity of the stream. Extensive sun-drenched shallows with stable substratum are required for the periphyton. Diverse but stable substratum in riffles and pools is required to establish a diversity of benthic organisms. Most sport and forage fishes feed in riffles or shallows but require deep pools and a diversity of cover. In general, then, the more diversity that can be incorporated into a stream alteration project, the less will be the environmental impact. Abundance of centrarchids in Crow Creek clearly demonstrates this principle. Their abundance was greatest at those stations that exhibited a diversity of physical habitat with the exception of Stations 1 and 2 where cold water temperatures were a limiting factor. High densities of centrarchids occurred at Stations 3 and 5 where the channel was widened and riprap cover was abundant. Centrarchid abundance was low at those stations that had been realigned and where improper placement of instream structures pooled water throughout the station (Stations 8 and 10). Although Stations 6 and 7 were realigned, high densities of centrarchids were found in the riffle-scour pool areas created immediately below the lowhead dams. Few fish were collected upstream from these structures. The high elevation of the structures allowed the formation of favorable habitat immediately downstream but, consequently, pooled water several hundred yards upstream creating channel conditions exhibiting little physical diversity.

One of the most important factors affecting spacial distribution of centrarchids was the presence or absence of protective cover, i.e., vegetative or rock riprap. Several authors have documented the importance of cover to stream fishes. Vannote and Ball (1972) found that failure of bass to spawn on favorable substrate was due to the lack of residing cover. Laser et al., (1969), while investigating fish distribution in the Skunk River in Iowa, found that green sunfish occupied pools in close association with cover in the form of submerged small trees and branches. Smallmouth bass in the Skunk River preferred pools below riffle areas where some cover was present. Trautman and Gartman (1974) stated that green sunfish were tolerant to turbidity, siltation, and organic pollutants but intolerant to recently channelized streams devoid of logs, brush, or deep pools. Haines and Butler (1969) found that yearling smallmouth bass in an aquarium were highly shelter oriented during daylight hours. Other authors have documented the importance of cover to salmonids in streams (Boussu, 1954; Chapman, 1966; Hunt, 1968; and Wesche, 1974). All species of centrarchids in Crow Creek were found in close association with vegetative and/or rock riprap cover.

Rock riprap was an important source of cover in the realigned sections of Crow Creek that were devoid of vegetative cover. Menzel and Firestine (1976) found that of 15 rock bass collected in a channelized stream in Iowa, 13 were collected where rock riprap was found. Larger size riprap was more suitable as cover because it provides more hiding space. The importance of riprap as protective cover in realigned sections of the channel is particularly evident during the high flows encountered during flood periods. Centrarchids in Crow Creek showed preference to cover located near deep pools located immediately below riffle areas. Centrarchids were most likely attracted to these areas because of the abundance of cover associated with deep pools, vegetative and rock riprap cover, and the abundance of fish food organisms found in the riffle areas.

Centrarchid species diversity was greatest at the downstream areas of Crow Creek. Water temperature differences between the upstream and downstream sections of the channel affected the number of species of centrarchids collected and, therefore, affected the diversity index values between stations. Temperature preference studies indicate that the majority of species in the centrarchid family are found in association with warmer water temperatures generally greater than 25^{o} C., with the exception of rock bass and smallmouth bass

(Bietinger et. al, 1975; Ferguson, 1958; Hallam, 1959; Neil and Magnuson, 1974). Cooler water temperatures in the upstream sections of the channel limited the species richness to primarily rock bass and smallmouth bass. Downstream sections of the channel, exhibiting less canopy and greater width and depth, exhibited warmer water temperatures and, consequently, more centrarchid species were collected at these areas. Differences between the physical characteristics of the channel at the study sites may have also affected the structural components of the centrarchid populations. Generally, bluegill dominated the percent composition of centrarchids at those stations exhibiting high percentages of pool area. Rock bass dominated in areas that exhibited high percentages of protective cover and riffle area.

Diversity values were lower where the habitat suitability for a particular species of centrarchid was high. Diversity depends on the evenness of abundance and the number of species present (Pielou, 1975). Where habitat is particularly suited to one species, the resulting high densities of that species may suppress the density of other closely related species or completely eliminate them, depending on their adaptive flexibility and the availability of suitable alternative habitat. This causes a reduction in evenness values and/or species richness, resulting in lower diversity values.

Centrarchids are considered to be facultative carnivores as indicated by their food habits (Carlander, 1977; Pflieger, 1975; Smith, 1979). Centrarchid species in Crow Creek were grouped into three functional units according to similarities in morphological and behavioral adaptations to feeding. Primary facultative carnivores included bluegill, longear sunfish, and redear sunfish. Warmouth, rock bass, and green sunfish were categorized as secondary facultative carnivores. The tertiary facultative carnivores included smallmouth bass, spotted bass, and largemouth bass. Tertiary facultative carnivores are perhaps the easiest functional unit to differentiate morphologically. Their fusiform body and large mouth enable them to prey effectively upon larger food items (small fish and crayfish). The secondary facultative carnivores exhibit a smaller mouth size than bass but larger than that of the primary facultative carnivores. They also exhibit a moderately fusiform body that enables greater maneuvering for capturing prey that require pursuit. Primary facultative carnivores are morphologically specialized for consuming smaller food organisms. Comparative food habit studies indicate their preference for smaller food items (Applegate et al., 1966; Gerking, 1954, 1962; Keast, 1970; Moffet and Hunt, 1943; Werner and Hall, 1976; Werner, 1977). Primary facultative carnivores also exhibit greater habitat flexibility than secondary facultative carnivores (Werner and Hall, 1977; Werner et. al., 1977).

A shift in the dominance (percent composition of biomass) of centrarchid functional components was noted between the upstream and downstream stations on Crow Creek. Secondary facultative carnivores dominated the upstream sections of the channel and primary facultative carnivores dominated the downstream sections of the channel. These longitudinal changes cannot specifically be attributed to the effects of channel alteration because of the lack of prechannelization data on the centrarchid populations. However, the change in functional dominance does indicate a greater disparity between habitat characteristics of the upstream and downstream areas of Crow Creek. Downstream stations generally exhibited greater amounts of pool area and less protective cover. Regression analysis showed a highly significant relationship ($P < 0.015$) with biomass of secondary facultative carnivore and protective cover. The secondary facultative carnivores sit and wait to ambush their prey (Larrimore, 1957; Werner and Hall, 1977). Hiding cover is then a necessary habitat requirement for these species of centrarchids to acquire food effectively.

Where environmental perturbations decrease the abundance of food organisms and/or alter the species complexes, it may favor species in the primary facultative carnivore group, because of their wider habitat flexibility. This may be related to their feeding behavior of actively searching for food rather than waiting to ambush their prey. Generally, primary facultative carnivores were dominant at those stations that were realigned. Mitigation structures of these stations created large pool areas. Several authors have reported that the presence of open water refuge in lakes may explain the success of bluegill in natural associations where it is often the dominant species (Brown and Ball, 1942; Keast, 1970; Werner et al., 1977). The presence of abundant pool area in streams may also provide a similar refuge for primary facultative carnivores. Small food organisms, predominately chironomids and oligochaetes, were collected in these areas of Crow Creek (Winger et. al, 1976). This food base would offer no advantage to secondary and tertiary facultative carnivores because of their different trophic morphological adaptions. Those sections of the channel that had high percentages of riffle area were dominated by secondary facultative carnivores which were morphologically better adapted to the habitat.

Chapter 7

CONCLUSIONS

1. Physical characteristics of the channel showed greater diversity at the upstream study sites (Stations 1 through 5) than at downstream stations (Stations 6 through 11). Channel modifications at the upstream study sites were restricted to widening of the channel on one bank along the stream's natural course and snagging and clearing of vegetation along the wetted perimeter. Channel alteration at downstream stations resulted in realignment of much of the channel.

2. Uniform channel characteristics existed in the downstream areas. Placement of grade stabilization structures in series and at improper elevations decreased physical diversity by pooling large areas of water above the structures.

3. Water temperature generally increased going from upstream to downstream. Abundant overhead canopy and springs contributed to lower water temperature in the upstream areas. Higher water temperatures were recorded at the downstream areas where overhead canopy was less abundant and where placement of instream structures created large pool areas.

4. Vegetative cover was greater in unaltered areas and those areas where the channel was widened along one bank. Realigned sections were virtually devoid of vegetative cover. Rock riprap used for bank stabilization and placed around instream structures generally provided the largest percentage of overhead cover at realigned stations.

5. The density of centrarchids was greatest at those stations that exhibited a diversity of physical characteristics, with the exception of Stations 1 and 2 where cold water temperatures limited centrarchids. Low centrarchid densities were found at those stations that had been realigned, where large pool areas were created because of the close spacing between structures and their high elevation.

6. Deep pools were scoured below several of the lowhead dam structures. Concentrations of centrarchids were found in close association with these structures; however, few were collected in the large pool areas created upstream from these structures.

7. Smallmouth bass, rock bass, and longear sunfish exhibited similar distribution patterns. These species were found in greatest abundance in the upstream and midstream sections of the study area where there was an established riffle-pool sequence and where vegetative and rock riprap cover was abundant.

8. Spotted bass, largemouth bass, redear sunfish, bluegill, green sunfish, and warmouth preferred the large pool areas and warmer water temperatures found in the downstream section of the study area. Percent of overhead cover (rock riprap and vegetative) influenced their distribution within this area.

The abundance of vegetative cover and cover created by rock riprap was the primary factor influencing spacial distribution of centrarchids within the study sections. Deep pools, bordered with cover and found immediately below riffle areas, were preferred.

10. Diversity of centrarchids was lowest at the upstream stations (Stations 1 through 5). Low diversity at these stations

was primarily attributed to cooler water temperatures, which limited species richness. Diversity values were also suppressed by the unevenness of distribution of species densities at several stations. The low evenness of centrarchid species distribution at these stations may be attributed to a predominance of habitat suitable to a particular species of centrarchid.

11. The disparity between physical characteristics of the upstream and downstream sections of the channel was indicated by a shift in dominance (percent composition of biomass) of functional components of the centrarchid populations. Large pooled areas of the downstream sections of the channel were generally dominated by primary facultative carnivores (Bluegill, longear sunfish, and redear sunfish). Secondary facultative carnivores (green sunfish, rock bass, and warmouth) dominated at the upstream stations. Their dominance was primarily influenced by the availability of hiding cover.

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A P P E N D I X

Table 1

Area of the Stream Sampled by Electrofishing at Each Station on Crow Creek, 1975 and 1976.

	Area Sampled (Hectares)	
Station	1975	1976
1	0.15	0.14
2	0.12	0.14
3	0.20	0.18
4	0.12	0.18
5	0.10	0.21
6	0.21	0.22
7	0.24	0.24
8	0.17	0.18
9	0.18	0.14
10	0.19	0.21
11	0.23	0.23

Table 2

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Rock Bass in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	7	7.0*			
2	16	19.3	0.0	46.3	0.46
3	94	102.5	94.7	110.2	0.57
4	2	2.0*			
5	91	142.7	42.7	242.7	0.29
6	35	38.8	34.9	42.6	0.54
7	24	26.2	13.1	39.3	0.59
8	0	0.0			
9	2	2.0*			
10	1	1.0*			
11	4	4.0*			
		1976			
1	10	10.9	3.0	18.7	0.54
2	12	12.6	12.2	13.1	0.63
3	64	73.7	10.7	136.6	0.47
4	14	23.0	3.1	42.9	0.27
5	80	81.0	72.2	89.7	0.56
6	21	24.0	0.0	48.1	0.52
7	34	39.5	13.0	66.0	0.47
8	0	0.0			
9	1	1.0*			
10	1	1.0*			
11	9	9.7	4.5	14.8	0.64

*Population estimate equal to total number collected.

Table 3

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Green Sunfish in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	1	1.0*			
2	3	3.0*			
3	4	4.0*			
4	1	2.0*			
5	4	4.0*			
6	15	15.0*			
7	14	14.0	7.9	19.9	0.71
8	3	3.0*			
9	0	0.0			
10	28	28.0*			
11	14	14.2	1.6	26.9	0.62
		1976			
1	2	2.0*			
2	1	1.0*			
3	11	19.8	0.0	92.1	0.24
4	2	14.0*			
5	7	8.4	7.5	9.3	0.36
6	70	71.1	67.9	74.3	0.77
7	10	12.7	0.0	72.8	0.37
8	6	6.0*			
9	0	0.0			
10	17	22.3	8.2	36.4	0.29
11	12	16.2	0.0	68.3	0.35

*Population estimate equal to total number collected.

Table 4

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Longear Sunfish in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	1	1.0*			
3	45	47.8	21.3	74.3	0.57
4	2	2.0*			
5	5	5.0*			
6	13	42.4	0.0	126.7	0.11
7	14	37.5	0.0	711.5	0.14
8	3	3.0			
9	11	11.5	7.9	15.0	0.71
10	1	1.0*			
11	18	19.1	15.0	23.2	0.64
		1976			
1	4	4.0*			
2	2	2.0*			
3	51	55.4	42.3	68.4	0.58
4	14	14.0	2.3	24.2	0.74
5	20	26.3	8.2	44.5	0.30
6	25	31.4	20.5	42.3	0.41
7	31	43.4	23.5	63.3	0.34
8	5	5.5	0.5	10.6	0.58
9	3	3.0*			
10	3	3.0*			
11	88	88.0	36.7	138.1	0.69

*Population estimate equal to total number collected.

Table 5

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Bluegill on the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	2	2.0*			
3	0	0.0			
4	0	0.0			
5	4	4.0*			
6	7	7.0*			
7	15	19.9	0.0	45.3	0.38
8	9	10.0	0.0	29.2	0.33
9	9	9.4	8.0	10.8	0.63
10	8	10.0	1.3	18.8	0.42
11	58	67.3	21.2	103.4	0.50
		1976			
1	0	0.0			
2	0	0.0			
3	2	2.0*			
4	0	0.0			
5	0	0.0			
6	2	2.0*			
7	79	72.9	64.9	81.0	0.63
8	5	5.0*			
9	4	5.4	0.0	11.5	0.36
10	18	27.2	18.1	36.3	0.24
11	62	65.3	48.8	81.7	0.67

*Population estimate equal to total number collected.

Table 6

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Warmouth Bass in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	0	0.0			
7	2	2.0*			
8	0	0.0			
9	0	0.0			
10	0	0.0			
11	6	7.7	4.9	10.6	0.39
		1976			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	0	0.0			
7	2	2.0*			
8	1	1.0*			
9	1	1.0*			
10	0	0.0			
11	9	12.0	0.0	34.4	0.38

*Population estimate equal to total number collected.

Table 7

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Redear Sunfish in the Study Sections at Stations 1 Through 11 at Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	0	0.0			
7	12	10.8	0.8	20.8	0.83
8	5	5.0*			
9	2	2.3	0.0	6.4	0.50
10	10	10.0*			
11	6	5.6	2.8	8.4	0.90
		1976			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	0	0.0			
7	12	11.1	5.5	16.7	0.90
8	1	1.0*			
9	4	4.9	0.0	27.6	0.42
10	3	4.0	0.0	8.8	0.27
11	0	0.0			

*Population estimate equal to total number collected.

Table 8

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Smallmouth Bass in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	2	2.0*			
3	37	61.3	0.0	185.3	0.27
4	5	5.1	4.4	5.8	0.78
5	9	9.1	8.7	9.4	0.88
6	2	2.0*			
7	9	10.5	1.3	19.8	0.46
8	2	2.0*			
9	0	0.0			
10	0	0.0			
11	0	0.0			
		1976			
1	0	0.0			
2	5	4.6	1.6	7.6	0.88
3	33	36.4	27.1	45.7	0.56
4	8	7.9	5.1	10.7	0.76
5	15	14.0	9.1	18.9	0.60
6	3	3.0*			
7	7	7.7	0.0	21.0	0.50
8	1	1.0*			
9	0	0.0			
10	1	1.0*			
11	0	0.0			

*Population estimate equal to total number collected.

Table 9

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Spotted Bass in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	1	1.0*			
5	1	1.0*			
6	5	4.6	1.6	7.6	0.88
7	10	10.0*			
8	3	3.0*			
9	9	10.5	6.0	15.0	0.49
10	12	12.0*			
11	9	10.5	6.0	15.0	0.49
		1976			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	0	0.0			
7	22	22.0	13.0	30.5	0.73
8	1	1.0*			
9	3	3.2	1.5	5.0	0.64
10	2	2.0*			
11	6	7.0	0.0	19.2	0.50

*Population estimate equal to total number collected.

Table 10

Population Estimates, Confidence Limits (95 Percent Significance Level), and Catchability for Largemouth Bass in the Study Sections at Stations 1 Through 11, Crow Creek, 1975 and 1976.

Station	Number Collected	Population Estimate	Lower Limit	Upper Limit	Catchability
		1975			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	0	0.0			
7	19	19.0	18.9	19.2	0.95
8	2	2.0*			
9	3	3.0*			
10	0	0.0			
11	1	1.0*			
		1976			
1	0	0.0			
2	0	0.0			
3	0	0.0			
4	0	0.0			
5	0	0.0			
6	2	2.0*			
7	11	10.7	8.2	13.3	0.84
8	1	1.0*			
9	2	2.0*			
10	0	0.0			
11	0	0.0			

*Population estimate equal to total number collected.

Table 11

Number and Biomass per Hectare of Centrarchids Collected at Stations 1, 2 and 3 During 1975 and 1976 at Crow Creek.

	1975		1976	
Station Species	Density No./Hectare	Biomass kg/Hectare	Density No./Hectare	Biomass kg/Hectare
Station 1				
Rock Bass	46.6	4.20	77.9	5.57
Green Sunfish	6.7	0.07	14.3	0.22
Longear Sunfish			28.6	0.70
Station 2				
Rock Bass	133.0	8.91	90.0	10.80
Green Sunfish	25.0	0.34	7.1	0.18
Bluegill	16.7	0.56		
Longear Sunfish	8.3	0.33	14.3	0.36
Smallmouth Bass	16.7	8.08	32.9	2.55
Station 3				
Rock Bass	512.5	24.11	409.4	21.98
Green Sunfish	20.0	0.33	110.0	2.33
Bluegill			11.1	0.96
Longear Sunfish	239.0	4.75	307.8	8.79
Smallmouth Bass	306.5	31.18	202.2	18.41

Table 12

Number and Biomass per Hectare of Centrarchids Collected at Stations 4 and 5 During 1975 and 1976 at Crow Creek

Station / Species	1975 Density No./Hectare	1975 Biomass kg/Hectare	1976 Density No./Hectare	1976 Biomass kg/Hectare
Station 4				
Rock Bass	16.7	0.35	127.7	4.25
Green Sunfish	16.7	0.18	77.8	1.17
Longear Sunfish	16.7	0.08	77.8	2.36
Smallmouth Bass	42.5	0.28	43.9	5.15
Spotted Bass	8.3	0.20		
Station 5				
Rock Bass	1427.0	60.96	385.7	18.75
Green Sunfish	40.0	1.71	40.0	0.50
Bluegill	40.0	0.79		
Longear Sunfish	50.0	2.83	125.2	5.02
Smallmouth Bass	91.0	9.09	66.7	6.21
Spotted Bass	10.0	0.17		

Table 13

Number and Biomass per Hectare of Centrarchids Collected at Stations 6 and 7 During 1975 and 1976 at Crow Creek.

	1975		1976	
Station / Species	Density No./Hectare	Biomass kg/Hectare	Density No./Hectare	Biomass kg/Hectare
Station 6				
Rock Bass	184.8	6.34	109.1	4.78
Green Sunfish	71.4	4.05	323.2	3.40
Bluegill	29.2	0.08	9.1	0.33
Longear Sunfish	201.9	5.64	142.7	2.09
Smallmouth Bass	9.5	0.77	13.6	1.66
Spotted Bass	21.9	0.83		
Largemouth Bass			9.1	0.76
Station 7				
Rock Bass	109.2	4.87	164.6	7.28
Green Sunfish	58.3	0.53	52.9	1.30
Warmouth Bass	8.3	0.22	8.3	0.09
Bluegill	82.9	3.22	303.8	14.48
Longear Sunfish	156.3	0.94	180.8	4.31
Redear Sunfish	45.0	1.85	46.3	1.42
Smallmouth Bass	43.8	4.28	32.1	4.17
Spotted Bass	41.7	13.73	91.7	12.00
Largemouth Bass	79.2	13.60	44.6	4.25

Table 14

Number and Biomass per Hectare of Centrarchids Collected at Stations 8 and 9 During 1975 and 1976 at Crow Creek.

Station / Species	1975 Density No./Hectare	1975 Biomass kg/Hectare	1976 Density No./Hectare	1976 Biomass kg/Hectare
Station 8				
Green Sunfish	17.6	0.85	33.3	0.42
Warmouth Bass			5.6	0.03
Bluegill	58.8	2.07	27.8	0.81
Longear Sunfish	17.6	0.24	26.2	0.76
Redear Sunfish	29.4	1.14	5.6	0.27
Smallmouth Bass	11.8	0.94	5.6	0.26
Spotted Bass	17.6	0.76	5.6	0.39
Largemouth Bass	11.8	2.72	5.6	0.69
Station 9				
Rock Bass	11.1	0.58	7.1	0.05
Warmouth Bass			7.1	0.08
Bluegill	52.2	1.69	38.6	2.08
Longear Sunfish	63.9	0.47	21.4	0.39
Redear Sunfish	12.8	0.43	35.0	2.24
Spotted Bass	51.3	4.32	22.9	2.33
Largemouth Bass	16.7	3.91	14.3	1.23

Table 15

Number and Biomass per Hectare of Centrarchids Collected at Stations 10 and 11 During 1975 and 1976 at Crow Creek

	1975		1976	
Station Species	Density No./Hectare	Biomass kg/Hectare	Density No./Hectare	Biomass kg/Hectare
Station 10				
Rock Bass	5.3	0.02	4.8	1.14
Green Sunfish	147.3	5.28	106.2	2.48
Bluegill	52.6	1.62	129.5	4.84
Longear Sunfish	5.3	0.29	14.3	0.50
Redear Sunfish	52.6	2.03	19.0	1.38
Smallmouth Bass			4.8	0.43
Spotted Bass	63.2	7.00	9.5	0.56
Station 11				
Rock Bass	17.4	0.73	42.2	0.07
Green Sunfish	61.7	0.74	70.4	1.45
Warmouth Bass	33.5	2.07	52.1	1.48
Bluegill	292.6	14.51	283.9	10.60
Longear Sunfish	83.0	2.63	382.6	4.94
Redear Sunfish	24.3	1.25		
Spotted Bass	45.7	0.83	30.4	0.47
Largemouth Bass	4.3	0.16		