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POPULATION DYNAMICS OF, AND HABITAT UTILIZATION BY, YOUNG-OF-THE-YEAR ROCK BASS (Ambloplites rupestris) AND SMALLMOUTH BASS (Micropterus dolomieui) IN A WARM-WATER STREAM

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POPULATION DYNAMICS OF, AND HABITAT UTILIZATION BY, YOUNG-OF-THE-YEAR ROCK BASS (*Ambloplites rupestris*) AND SMALLMOUTH BASS (*Micropterus dolomieui*) IN A WARM-WATER STREAM

By

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ABSTRACT

POPULATION DYNAMICS OF, AND HABITAT UTILIZATION BY, YOUNG-OF-THE-YEAR ROCK BASS (*Ambloplites rupestris*) AND SMALLMOUTH BASS (*Micropterus dolomieui*) IN A WARM-WATER STREAM

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The Red Cedar River, a warmwater stream in the south central portion of Michigan, supports nine species of centrarchids in its drainage area with the rock bass and the smallmouth bass being two of the predominant species. This thesis reports the usage of vegetative cover, densities, growth rates, and sources of predation on the young-of-the-year (YOY) of these two species.

Young-of-the-year rock bass and smallmouth bass primarily utilize the submergent macrophytes for cover. This was ascertained using a 1 m^2 throwtrap. Within this vegetation type there was always a small negative association between these two species. YOY rock bass densities do not appear to affect YOY smallmouth bass growth or vice-versa. Smallmouth bass growth was negatively correlated with its own density and positively correlated with temperature and dissolved oxygen. YOY rock bass growth seems to be unrelated to either abiotic parameters or cohort density.

Rock bass were not found to be piscivorous but juvenile smallmouth bass and largemouth bass were found to have age 0 rock bass in their stomachs.

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INTRODUCTION

From a preliminary study of the Red Cedar River in the summer of 1982 it was ascertained that both the rock bass and smallmouth bass were important components of the river's centrarchid complex. As in Linton's (1964) work on the Red Cedar River, the rock bass was the predominant species of the two. Since these two species are often associated in their distribution (Scott and Crossman 1973) and fall into the same feeding guild (Keast 1966), it seems reasonable that the large rock bass population could limit smallmouth bass production. Sanderson (1958) found that growth rates and condition factors of Potomac River smallmouth bass were inversely correlated with the population densities of rock bass and red breast sunfish. Pflieger (1966) suggested that competition between smallmouth bass fry and the young of other fish species might be intense since fry are severly limited in the size ranges of foods available.

Other researchers have suggested that competition may not be important in warm-water streams. Hall (1972) and Fisher and Likens (1973) suggested that food is rarely limiting to warm-water stream fishes because most of it is ultimately allochthonous in orgin, and small streams have a net export of energy. Keast (1966) suggested that members of the same feeding guilds, such as smallmouth bass and rock bass, may behaviorally avoid competion by segregating by time, place and method of feeding, and size of prey.

Since smallmouth bass and rock bass spawn at approximately the same time of year and the young-of-the-year (YOY) occur together in the shallow littoral zones of streams (George and Hadley 1979), I decided to focus my research on the distribution and densities of these two YOY centrarchids in the Red Cedar River, and investigate the factors regulating YOY smallmouth bass and rock bass growth. I hypothesized that the rock bass population was limiting YOY smallmouth bass growth through competition between the young.

As a measure of competition between the two species, cohort size and growth rates of both species were followed throughout the spring, summer, and fall. The distribution and densities of these two species in the emergent macrophytes, submergent macrophytes, and open water areas were also investigated to see if habitat partitioning occurred.

Supplementary information on predation of YOY smallmouth bass and rock bass by YOY, juvenile and adult fish, feeding periodicity of the young, and abiotic influences, such as temperature, dissolved oxygen, and discharge, on growth and survival of the YOY was collected. This information was useful in investigating what other mechanisms may be additionally influencing YOY rock bass and smallmouth bass growth.

It was hoped that a study of this breadth would indicate what factors may be controlling smallmouth bass and rock bass production in the Red Cedar River, and allow for a further more focused study of these parameters at a later date.

Description of the River and Study Sites

The Red Cedar River is a warm-water stream in the south central portion of the lower peninsula of Michigan. The stream originates as an outflow from Cedar Lake in Livingston County and flows for 49.25 miles in a northwesterly direction before reaching its confluence with the Grand River in the City of Lansing (Grzenda et al. 1968). The headwater drainage is principally marsh or wet land areas. Much of the upper portions of the watershed have been dredged to straighten and deepen the channel for agricultural purposes. Moving downstream, urban influences become increasingly evident with riparian zone elimination, wetland drainage, and municipal development to the waters edge.

The Red Cedar River receives the waters of twelve major tributaries, and drains a total area of about 472 square miles (Linton and Ball 1965) (Figure 1). The gradient of the main channel is relatively gradual from its source at Cedar Lake, at an elevation 934 feet above sea level, to 817 feet at its confluence with the Grand River, for an average fall of 2.5 feet per mile (Vannote 1963). Two United States Geological Survey (USGS) gaging stations are present on the main channel. The first is located 3.5 miles east of Williamston in Ingham County at an altitude of 870 feet.

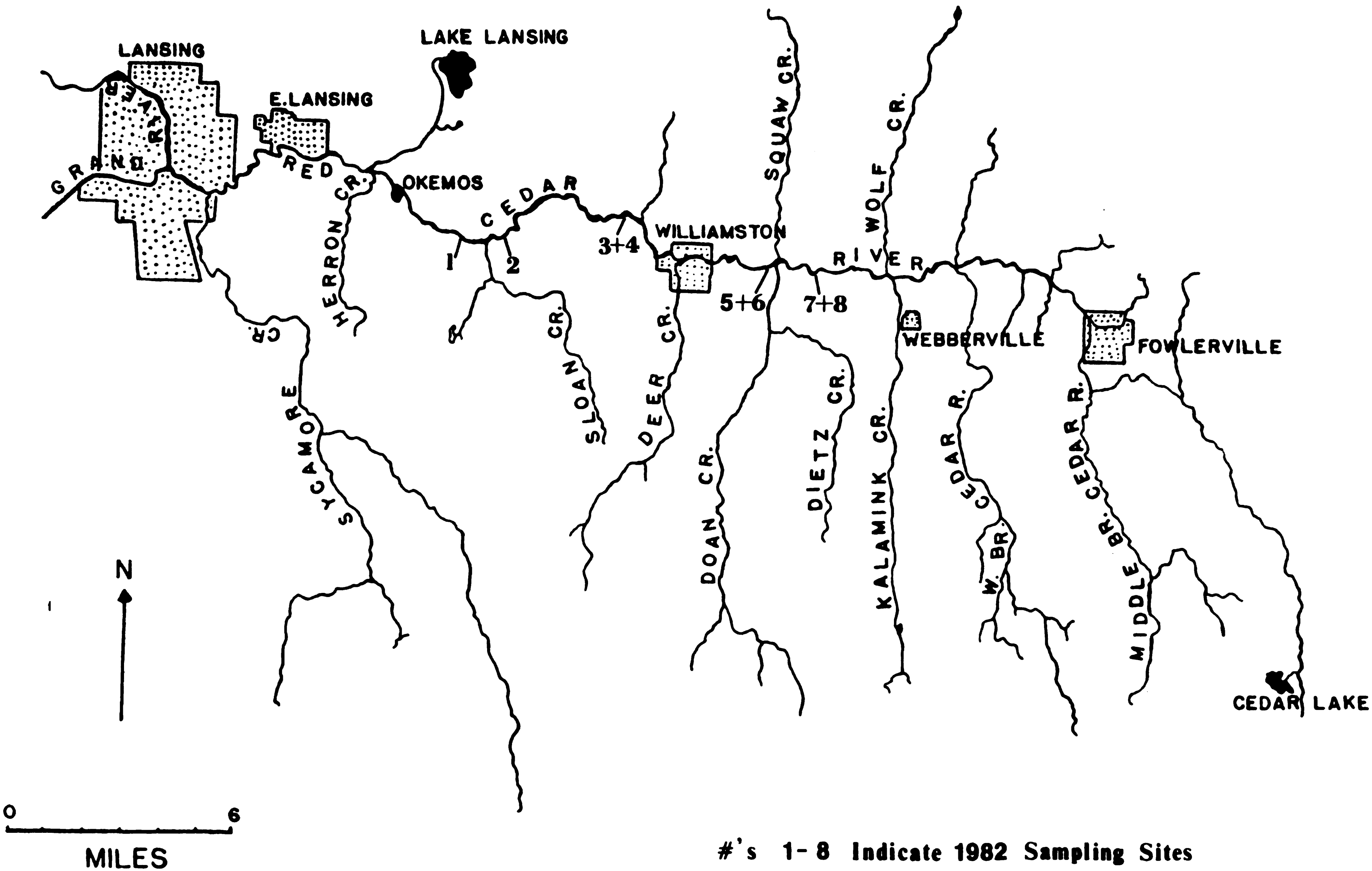

FIGURE 1: RED CEDAR RIVER WATERSHED

The second is located 5.6 miles upstream of its confluence with the Grand River on the Michigan State University Campus in Ingham County at an altitude of 824.39 feet (data furnished by USGS field office, Lansing, Michigan). One primary and eight secondary 100 meter study sites were located between these two gaging stations. The secondary locations were used for fish collection sites during the 1982 fish census and several for collections in subsequent years. The primary site was used for the collection of YOY distribution, density, and growth data in addition to fish census data.

The highest annual water levels and occasionally serious floods usually occur in the spring of the year during snow melt and spring rains and the period of lowest flow is usually in the late summer or fall of the year (Brehmer et al. 1968). A record discharge of 8000 cfs was recorded at the East Lansing gaging station on March 24, 1904 (data furnished by USGS field office, Lansing, Michigan). At Williamston a record discharge of 2640 cfs was reached on April 20th during the flood of 1975. A record low flow of 3 cfs was recorded at the East Lansing gaging station on July 31, 1931. Average discharge over a 53 year period at the East Lansing station was 206 cfs and over an eight year period at Williamston it was 102 cfs. October 1982 through September 1984 discharge data for both recording stations are presented in Appendix A, Tables A1-A4. During this time period the maximum, minimum, and mean discharge values at the East Lansing gaging station were 1260 cfs, 12 cfs, and 251 cfs respectively. The values for the Williamston gaging station were 498 cfs, 5.1 cfs, and 95.3 cfs respectively.

The primary study site at Sherwood Road was 236 meters long (Figure 2). The downstream portion of this site was characterized by several large snags with associated pools and a sand-silt substrate. Upstream of this was a large sand-gravel run containing large beds of submergent aquatic macrophytes (*Vallisneria americana* and *Saggitaria sp.*) bordered by beds of emergent aquatic macrophytes (*Saururus cernuus*). The stream margin contained several large log snags and tree root wads. In the summer months, the upper most section of this study site was a submergent macrophyte choked shallow gravel riffle bordered by a large bed of emergent aquatic macrophytes. In June of 1984, at a discharge of 32 cfs, 23.39 percent of the wetted stream bed in this study site was covered with submergent macrophytes and 5.67 percent with emergent macrophytes.

This site's accessibility, presence of submergent and emergent macrophyte beds, presence of large adult rock bass and smallmouth populations, and its use as a centrarchid nesting and nursery area made it an ideal research area.

The eight secondary 100 m study sites (Figures 1 and 2) were used for adult population estimates in a preliminary study in the summer of 1982. To allow for comparisons with the results of Linton and Ball's (1965) fish census, I established two of these study sites in their river section II, two sites in section III, and four sites in section IV.

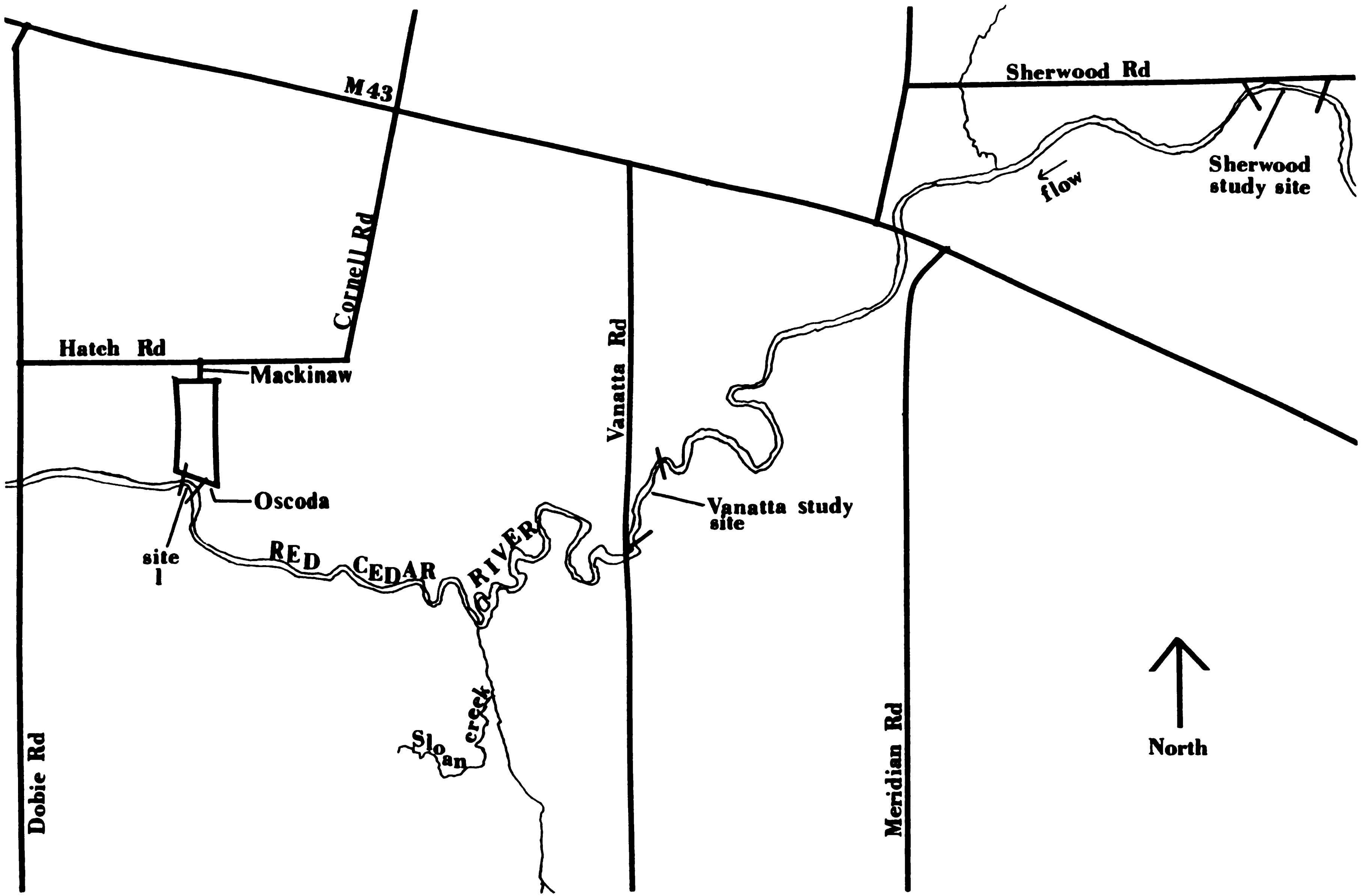

FIGURE 2: MAP OF THE VANATTA AND SHERWOOD STUDY SITE LOCATIONS

Site 1 was located about 1/4 mile South of Hatch Road. Site 2 was located at Vanatta Road and sites 3 and 4 were located immediately upstream of Zimmer Bridge. Sites 5 and 6 were located North of Douglas Road just East of Williamston, and sites 7 and 8 were located immediately upstream of the USGS gaging station on Perry Road (M-52). In 1983 and 1984 a 404 meter stretch at Vanatta Road (site 2) was sampled for fish.

An aquatic plant survey of the Vanatta and Sherwood study sections was conducted to better describe the vegetative habitat used by larval, juvenile, and adult fishes (Table 1). The emergent aquatic macrophyte *Saururus cernuus* and the submergent aquatic macrophytes *Vallisneria americana* and *Saggitaria sp.* were the species encountered most often. Adding additional structural complexity to the macrophyte beds were large conglomerates of epiphytic and benthic algae. In 1983, *Saururus cernuus* had a mean summer stem density of 106.86 stems per square meter (S.D.=22.69 N=22). Samplings in 1984 produced a mean summer stem density of 98.86 stems per square meter (S.D.=38.24 N=14). No meaningful stem densities could be calculated for the submergent macrophytes due to the morphology of the vegetation.

Table 1: List of the aquatic plants found in the Vanatta and Sherwood study sites, Red Cedar River, in the Summer of 1983

EMERGENT	FLOATING	SUBMERGENT
*Saururus cernuus**	*Lemna minor*	*Vallisneria americana**
Muhlenbergia sp.		*Saggitaria sp.**
Phalaris sp.		*Ceratophyllum demersum*
Rumex verticellata		*Drepanocladus sp.*
		Elodea canadensis
		Potamogeton sp.

*-species collectively constituting over 95 percent of the vegetative habitat present in the study sites.

METHODS AND MATERIALS

In 1982, 1983, and 1984 fish for the mark-recapture population estimates were collected with a 220 volt Homelite direct current generator which sat in an eight foot wooden boat. The three positive hand held electrodes were opposed by a metal negative electrode plate on the bottom of the boat. The five to six man crew started at the downstream end of the site and shocked upstream.

The fish were placed in square metal tubs in the boat with freshwater being added frequently to reduce the stress of deoxygenated water on the fish. At the completion of the run, the fish were weighed on a Chatellion 500 x 2 gram dietary scale, measured in millimeters total length (mm TL), and had scale samples taken for age and growth analysis. Centrarchid scales were collected from a point at the anterior insertion of the first dorsal fin just below the lateral line. On the marking runs, fish were given a site and date specific fin clip. All captured fish were released at the downstream end of a study site. At least one to two days were allowed for fish recovery and dispersion between marking and recapture runs.

Population estimates and age class estimates were calculated from the mark-recapture data using the Bailey formula (Bailey 1951):

$$N = \frac{M(C+1)}{R+1}$$

where: N = the population or age class estimate
M = the number of fish marked on the first run
C = the total number of fish captured on the subsequent run
R = the number of fish recaptured

Variance (V) was calculated using the following equation:

$$V = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)}$$

In November of 1983 and 1984 the margins of Sherwood study site were seined for YOY bass. This was done to obtain end of the growing season population size and growth estimates. A swath one meter wide was seined along the margins of the stream in the emergent macrophytes by two biologists. Only the stream margins were sampled because by November the instream vegetation had died and been uprooted and the YOY were concentrated in the emergent vegetation. The seine was 4 feet deep with a 1/4" mesh. Fish that were captured were preserved in 70 percent ethanol and were measured and weighed the next day in the lab. Lengths were recorded to the nearest 0.05 millimeters (mm) with dial calipers and weights were recorded to the nearest hundreth of a gram on an Ohaus top loading Brainweigh electronic balance, model B 300D. From this data, mean November fish size and the number of YOY fish per square meter of shoreline was calculated. Other stretches of the Sherwood study site were sampled with a DC backpack electroshocker. Fish again were preserved, measured, and weighed. These size and number estimates were then compared to the seining results to see if there was any gear size selectivity.

The size data was analyzed for similarities between gear types and years. Mann-Whitney U-tests (Siegel, 1956) were run on the mean length data between seining and electrofishing collections for both smallmouth bass and rock bass. This was to see if the collections could be pooled for further analysis between years. A Kolmogorov-Smirnov two sample test (Smirnov 1939) was used to test differences between mean total length data of YOY rock bass collected in 1983 and 1984. Insufficient numbers of smallmouth bass were collected in 1983 to allow for any statistical analysis of mean YOY fish size between years.

The primary gear used to collect YOY fish during the summer was a square meter throwtrap. This type of collection gear and its sampling efficiencies are described by Kushland (1981) and by Chubb (1985). My trap was constructed out of 3/8 inch smooth rolled steel rebar, two centimeter wide flat rolled steel for additional support,and the four sides were enclosed with hardware cloth with a mesh size of 6 squares to the centimeter. The trap was 76 centimeters high, and weighed 30 pounds. It was constructed out of steel so that it would fall quickly and be able to withstand a moderate current.

In 1983 only submergent and emergent macrophyte beds were sampled. In 1984 open water areas were additionally sampled. In an effort to minimize disturbance of the fish, sampling sites were approached slowly from downstream and the trap was thrown at least 2 meters upstream . Once the trap was on the bottom, the bottom edges were quickly sealed with the surounding substrates to prevent the loss of any fish if the bottom was not level. In the case of emergent vegetation samples, the vegetation was clipped away and stem densities recorded. In the submergent vegetation samples, the vegetation inside the trap was uprooted and rinsed in the trap to assure no fish were trapped in the macrophytes and discarded with the vegetation. Open water areas required no initial manipulation. Fish were removed from the throwtrap with a D-shaped dipnet and a small aquarium dipnet 10 by 6 inches. All large substrate was removed to ensure complete fish removal. Netting was continued until no fish were collected in three consecutive tries.

Within each throwtrap sample site, temperature, substrate, water depth, and dissolved oxygen data were collected. The location of each throwtrap site also was mapped precisely by triangulation, described later in the methods. All throwtrap samples were preserved in 95 percent ethanol and taken to the lab for picking. This was neccessary because large amounts of substrate, detritus and vegetation were often collected in the process of netting fish. In gravel samples a sugar flotation method was employed (Anderson 1958). This method was not used in samples containing vegetation or detritus. Fish collected in the throwtrap samples were identified using Auer's (1982) key to the Great Lakes Larval Fishes. Larval fish were routinely dabbed on a paper towel to remove excess moisture and were then weighed to the nearest thousandth of a gram on a Mettler analytical balance. The fish were then briefly emersed in glycerine, to prevent drying out, and placed on a Bell and Howell microfiche reader. This magnified image (24.2X) of the fish was measured and divided by the lens magnification power to arrive at the actual total length .

Standard length was also recorded so that a conversion factor from standard length to total length could be calculated and applied to those fish with damaged caudal fins. All fish were identified to the lowest taxonomic level except for minnows and suckers which were identified to family.

Throwtrap data were grouped by 7 day periods and the number of fish per square meter was calculated for each species in each habitat type. Grouped data were tested for normality using the test of symmetry for a small sample suggested in Snedecor (1938). Since the frequency distributions were approximately normal, a t-test was used to compare samples. Differences in calculated fish densities within a single week in the various habitat types were tested with a student's two tailed t-test between means of independant samples which do not have the same variance (Gilbert 1976).

As a measure of spatial distribution an index of dispersion (I) was calculated (Elliott 1971). This index will approximate 1.0 if there is agreement with a Poisson series, the accepted test for randomness. Associations among larval fish species, for both the 1983 and 1984 data in each habitat type sampled, were described using Forbe's coefficient (cf) (Cole 1949) where:

$$cf = (ab-bc)/((a+b)x(b+d)$$

and:
a = # of samples where both species were present
b = # of samples where only species A was present
c = # of samples where only species B was present
d = # of samples where both species were absent

Forbes's coefficient values of 0 indicate chance association, whereas values of +1 and -1 may indicate complete association and disassociation, respectively.

Total numbers of each species in the Sherwood study site were calculated by multiplying the throwtrap estimates of mean number of fish per square meter in each habitat type by the approximate number of square meters of each habitat type in the study area. The area of each habitat type at low flow was calculated using a Dietzgen compensating polar planimeter, Model D-1805 on a map of the study site drawn to scale. The map was produced from triangulation field measurements. The mapping procedure involved dividing the 236 meter Sherwood study site into 13 sections which allowed for a detailed vegetation and substrate map with limited effort. The location of each throwtrap sample site also was measured and placed on the map.

From the weekly grouped throwtrap sample data for YOY rock bass and smallmouth bass, the mean weekly size in millimeters total length was calculated for each species. Their individual growth rates (u), expressed as percent change in total length per day, were calculated using:

$$u = \frac{\ln TL_1 - \ln TL_0}{t_1 - t_0}$$

where: t_x = time (days)
TL = total length in millimeters at time t_x

Linear and exponential equations were calculated with the equation with the best fit to the data being plotted.

On July 15th, August 18th, and October 7th of 1983 several non study areas were electrofished using a back-pack shocker in order to assess diel feeding habits. Four sampling periods occurred on each date with the first beginning ten minutes prior to sunrise, the second at noon, the third between 6:00 and 8:00 pm, and the forth at midnight. Fish shocked were netted and placed in a chilled alcohol-ice slurry and later transfered to formaldehyde in the laboratory.

For each fish collected a length and weight was recorded and the stomach contents were evaluated. When fish were present in the diet the number and species of fish in the gut was recorded. Other food items in the stomach were identified to family when possible and counted. Each gut content was given a subjective numerical degree of digestion as follows: 1)not digested 2)partially digested 3)well digested 4)unidentifiable. From these values a mean degree of digestion was calculated for each time period and date. The mean number of food particles per fish stomach also was calculated for each date and time period. From these two indices it was possible to ascertain the peak feeding times of rock bass and smallmouth bass. In addition, YOY smallmouth bass collected in the 1984 throwtrap samples were examined for fish in their stomachs and the degree of digestion of their gut contents.

Temperature and dissolved oxygen data were collected using a Taylor minimum-maximum temperature thermometer, a YSI temperature, conductivity and salinity meter, a YSI dissolved oxygen, temperature meter, and a pocket hand held thermometer. Discharge data were taken from USGS gaging station records at Williamston and East Lansing. Additional discharge data were collected at the Sherwood study site on three occasions at three different flows so that a site specific discharge relationship could be established with the USGS data. A Price-pigmy current meter was used for this data collection. The change in discharge between Williamston and Sherwood was 29.84 percent of the change in discharge between Williamston and East Lansing. This was used to build a predictive equation for discharges at Sherwood site:

$$D_s = C(D_{EL} - D_W) + D_W$$

where:
D_s = predicted discharge at Sherwood site
D_W = discharge at USGS station in Williamston
D_{EL} = discharge at USGS station in East Lansing
C = a constant .2984

RESULTS

Fish Community Composition

In the summer of 1982 a mark-recapture census of the Red Cedar River fish populations was conducted, by electroshocking seven 100 meter sites, between East Lansing and Webberville (Figure 1). In this preliminary study the greatest number of rock bass (205 ± 31) per 100 meters of stream was located at site 4 followed in decreasing order of abundance by sites 8,7,3,1,5, 6 (Table 2). The largest number of smallmouth bass (*Micropterus dolomieui*) (24 ± 15) was located at site 1. All other sites each contained less than five smallmouth bass of any size. Green sunfish (*Lepomis cyanellus*) were most abundant at site 7 and pumpkinseed sunfish (*Lepomis gibbosus*) at site 8. The rest of the centrarchid complex, which had been previously documented in the Red Cedar River in earlier studies, were found infrequently (largemouth bass (*Micropterus salmoides*), the bluegill (*Lepomis macrochirus*) and the longear sunfish (*Lepomis megalotis*)) or not at all (black crappie (*Pomoxis nigromaculatus*) and warmouth (*Lepomis gulosus*)) in 1982. The black crappie was located in subsequent years of the study but the warmouth was never found within my study sections although it does exist in Lake Lansing, one of the lacustrine habitats within the watershed. The northern pike (*Esox lucius*) was found in greatest numbers at site 7.

In October of 1983 and 1984 a 404 meter stretch of stream at Vanatta Road was shocked. A 236 meter stretch of stream adjacent to Sherwood road was additionally

Table 2: Bailey fish population estimates for seven 100 meter study sites on the Red Cedar River in August of 1982 (± 95% confidence interval).

SPECIES	MACKINAC Site 1	ZIMMER Site 3	ZIMMER Site 4	DOUGLAS Site 5
RB	111±35	124±33	205±31	58±32
SMB	24±15	2±1	1±1	3±2
GSF	no est	24±15	nf	4±2
LMB	3±2	2±1	2±0	nf
PS	no est	nf	3±0	3±2
BG	no est	nf	1±1	2±1
LE	no est	nf	nf	nf
NP	no est	nf	3±0	1±0

SPECIES	DOUGLAS Site 6	PERRY Site 7	PERRY Site 8
RB	42±22	127±34	180±54
SMB	nf	2±1	nf
GSF	3±0	145±44	10±0
LMB	3±2	nf	nf
PS	6±4	5±2	24±12
BG	2±1	5±0	1±0
LE	nf	nf	nf
NP	nf	5±0	3±0

nf=not found, no est=no estimate attempted, RB=rock bass SMB=smallmouth bass, GSF=green sunfish, LMB=largemouth bass PS=pumpkinseed sunfish, BG=bluegill sunfish, LE=longear sunfish, NP=northern pike electrofished in October of 1984. The Sherwood Road site estimates present a partial picture of the community structure and composition for this section of the river (zone II) minus the cyprinids and catostomids for which no estimates were made (Table 3). Comparison of the 1983 and 1984 Vanatta Road site data show an increase in the estimated number of smallmouth bass in 1984 which was directly attributable to a preponderance of YOY. The estimated number of adult smallmouth bass declined however. The rock bass estimate was larger because of a great number of age 1+ fish surviving from a successful year-class in 1983. Although Vanatta Road site was larger than Sherwood Road site, fewer fish were found at the Vanatta Road site in 1984. This was most likely due to the substrate differences and the sites subsequent lack of instream submergent vegetation and its associated food resources. The Vanatta road site substrate was predominately sand and was frequently shifting and vulnerable to scouring not favoring plant attachment.

Discharge, temperature, and dissolved oxygen

In the spring of 1983 as discharge decreased, water temperature was increasing. By June 11 discharge had fallen below 200 CFS and the temperature was exceeding 65 degrees Fahrenheit. Nesting activities for both rock bass and smallmouth bass had begun. On June twenty-seventh, the Red Cedar River began rising to flood proportions, peaking on

Table 3: Bailey fish population estimates for Vanatta study site (404 meters) and for Sherwood study site (236 meters), Red Cedar River (± 95% confidence interval).

SPECIES	VANATTA OCTOBER 1983	VANATTA OCTOBER 1984	SHERWOOD OCTOBER 1984
rock bass	387±82	694±218	1374±137
smallmouth bass	132±39	268±56	758±149
YOY smallmouth bass	55±23	232±48	728±167
green sunfish	285±110	81±22	77±47
black crappie	3±0	nf	1±0
longear sunfish	48±18	10±5	2±1
bluegill sunfish	53±25	1±0	2±0
largemouth bass	23±7	14±7	10±5
pumpkinseed sunfish	nf	nf	nf
northern pike	2±1	nf	5±0
yellow bullhead	nf	2±0	15±7
black bullhead	nf	2±0	6±4
yellow perch	3±1	nf	nf
rainbow darter	no est	no est	667±376
johnny darter	no est	no est	425±292
blackside darter	no est	no est	983±477

nf=none found
no est=no estimate attempted

June twenty-ninth (Figure 3). In the spring of 1984 there was both a gradual temperature rise and a gradual discharge decline with no late spring flood (Figure 4). Associated with the flood of 1983 was a corresponding flushing of the stream. Early morning low dissolved oxygen values in the emergent macrophyte beds changed from 3.83 PPM during pre-flood conditions to 6.98 PPM following the flood (Table 4).

From June 15th to September 13th 1983, mean maximum and mean minimum water temperature values were 25.05°C (S.D.=1.34) and 21.04°C (S.D.=1.44) respectively. In 1984 during the same time period, mean maximum and minimum stream temperatures were lower than in 1983, with values of 22.64°C (S.D.=3.38) and 15.65°C (S.D.=2.38) respectively.

YOY Rock Bass and Smallmouth Bass

Comparing the November seining data between 1983 and 1984 (Table 5) it is evident that more YOY rock bass were present per square meter in the fall of 1983. It is also apparent that in 1984 more smallmouth bass per square meter remained in the fall than in 1983. I feel the seining data more adequately reflects the true YOY rock bass densities in 1984. When electrofishing many rock bass are stunned but due to their cryptic coloration can not be seen in the vegetation and leaf packs and thus are not captured. I feel the YOY smallmouth bass densities in 1984, on the other hand, are more accurately described by electroshocking. Only the smaller, smallmouth bass were captured by seining,

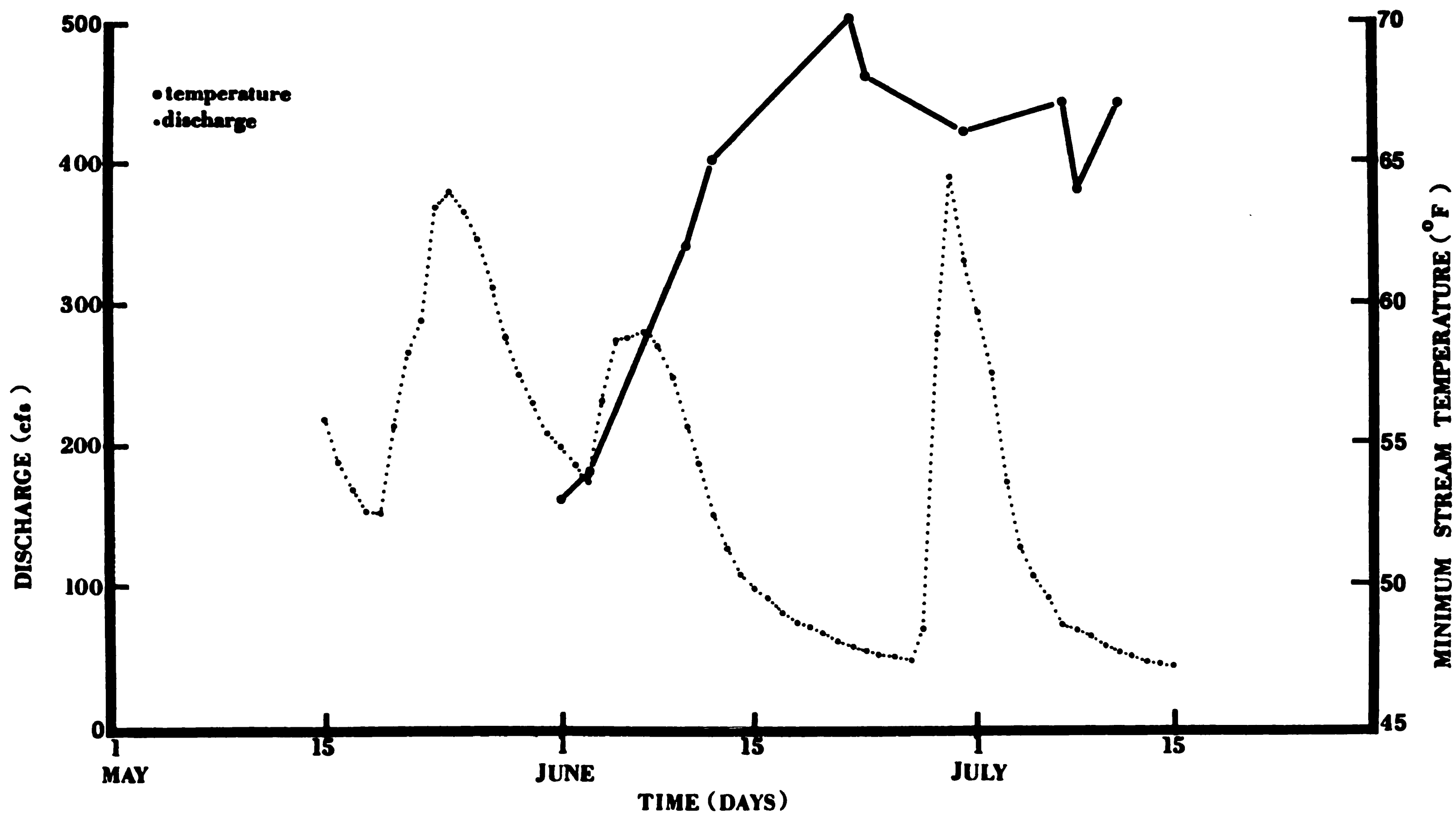

FIGURE 3: 1983 TEMPERATURE AND DISCHARGE

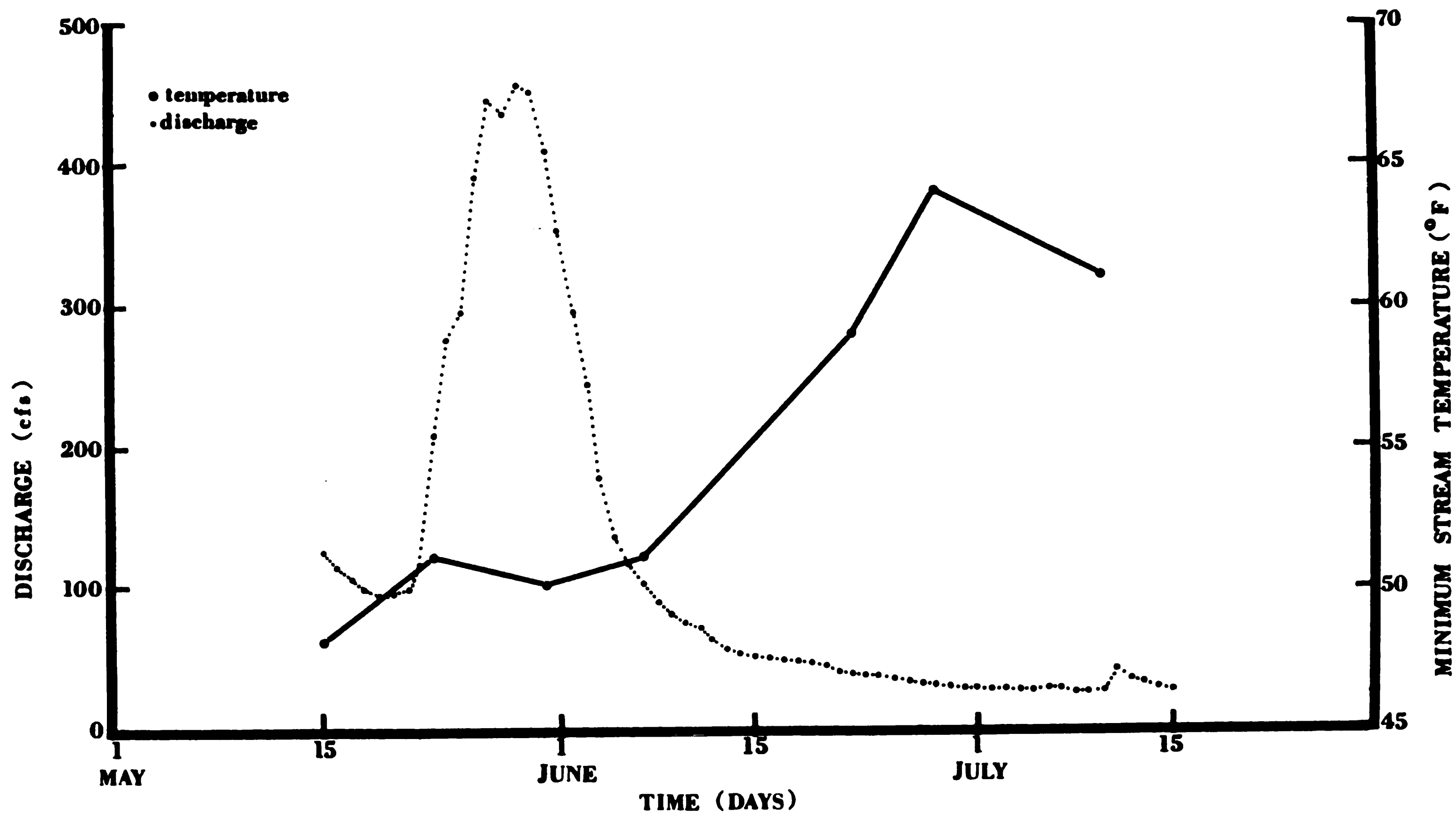

FIGURE 4: 1984 TEMPERATURE AND DISCHARGE

Table 4: Dissolved oxygen (ppm), temperature (degrees C), and percent oxygen saturation values for emergent vegetation beds (_Saururus cernuus_) in the Red Cedar River in the summer of 1983

DATE	JUNE 22-23	JULY 7-8	JULY 25-26	AUGUST 16-17
LOW DO	3.83	6.98	5.85	5.91
TIME	8:00 AM	6:00 AM	6:00 AM	8:00 AM
HIGH DO	5.42	8.84	7.70	8.21
TIME	6:00 PM	6:00 PM	2:00 PM	2:00 PM
LOW TEMP	21.94	17.91	22.16	21.24
TIME	8:00 AM	8:00 AM	4:00 AM	8:00 AM
HIGH TEMP	24.98	21.32	24.56	24.88
TIME	8:00 PM	6:00 PM	6:00 PM	2:00 PM
LOW % SAT	42	73	63	65
TIME	8:00 AM	6:00 AM	6:00 AM	8:00 AM
HIGH % SAT	64	98	91	98
TIME	6:00 PM	6:00 PM	2:00 PM	2:00 PM

DO=dissolved oxygen, TEMP=temperature
% SAT=percent saturation

Table 5: Comparison of end of the year numbers of young-of-the-year fish, per meter squared of emergent vegetation and mean fish total length at Sherwood site

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SEINING

NOVEMBER 1983	Rock Bass	Smallmouth
#/meter squared	.605	.005
mean size(mm)	37.65	70.50
sd	6.16	1
N	73	1

NOVEMBER 1984	Rock Bass	Smallmouth
#/meter squared	.195*	.025
mean size(mm)	39.55	55.13
sd	5.04	2.63
N	47	6

ELECTROFISHING

NOVEMBER 1983	Rock Bass	Smallmouth
#/meter squared	---	---
mean size(mm)	---	71.40
sd	---	1
N	---	1

NOVEMBER 1984	Rock Bass	Smallmouth
#/meter squared	.050	.095*
mean size(mm)	39.58	59.65
sd	5.03	5.13
N	12	23

---

*=most reasonable densities according to species catchability by different gears.

however, electrofishing was capable of shocking all sizes within the age 0 cohort. Smallmouth bass when shocked are also relatively easy to see and net.

The size data presented in Table 5 were analyzed for similarities between gear types and years. A Mann-Whitney test was run on the 1984 rock bass mean length data between the seining and electrofishing collections. This test indicated that the two groups were not significantly different and could be pooled. A common mean length of 39.56 mmTL with a standard deviation of 4.99 (N=59) was calculated. The 1983 YOY rock bass mean total length seining data was then compared to the 1984 pooled data using a Kolmogorov-Smirnov two group test. The two distributions proved not to be significantly different at the 0.05 level of significance although the 1984 mean total length was slightly larger than the 1983 mean total length when there were many more fish produced.

A Mann-Whitney test was also run on the November 1984 smallmouth bass mean total length data between the seining and electrofishing values. The test indicated that the two groups were significantly different, thus suggesting gear selectivity with this species. An insufficient number of smallmouth bass were collected in 1983 to allow for any statistical comparisons with the 1984 data. Visual inspection of the data indicates that the smallmouth bass were larger at the end of the summer in 1983 when there were fewer fish produced.

In the summer of 1983 forty-one one meter squared throwtrap samples were collected at the Sherwood study site between July fourteenth and August twenty-fourth. Twenty-one were in the emergent macrophytes and twenty in the submergent vegetation. In 1984, in an effort to sample all the major habitat types, open water areas were additionally sampled. A total of one hundred and thirty-four throwtrap samples were collected between June eighteenth and September sixth, consisting of twenty in the emergent macrophytes, eighty-three in the submergent macrophytes, and thirty-one in the open water. A total of 246 fish were collected in 1983 and 1003 fish in the 1984 throwtrap samples. In 1983 an average of 5.43 throwtrap samples were collected per field day and in 1984 an average of 5.58 throwtrap samples per field day. Mean sampling times for one person per throwtrap were greatest for the emergent macrophytes (45 minutes) and least for the open water (33 minutes). Woody structure was not sampled due to its relatively low abundance in the study site and its minor usage by YOY fish as was ascertained by sweepnet samples and electrofishing.

In 1984 out of a total of 134 samples collected, 10 species excluding cyprinids and catostomids were captured. Only four additional species, the green sunfish, the black crappie, the longear sunfish, and the yellow bullhead (Ictalurus natalis) were captured in the October 1984 electrofishing census (Table 3). The tadpole madtom was only collected by throwtrap in 1984. Nine of the species found in 1984 excluding cyprinids and catostomids were collected in the submergent vegetation in 68 samples. This habitat type also contained the largest mean number of species per throwtrap sample and the greatest number of species to be found in a single throwtrap sample, which were 2.25 and 6.0 respectively. Open water had the lowest mean number of species per throwtrap, which was 1.0.

Mean fish densities (# fish/m^2) were calculated for each sampling period and each habitat type for both the 1983 and 1984 throwtrap data (Tables 6a - 6b). Included in the calculations were all samples, regardless of whether or not they contained fish. These mean densities were used to indicate which habitat types, if any, were utilized more frequently than another or not utilized at all by an individual species. Visual inspection of the data indicates that YOY rock bass are found in vegetation in higher densities than in open water. In general, the rock bass in both 1983 and 1984 were also found in higher densities in the submergent aquatic macrophytes.

In 1984 the smallmouth bass were rarely found in the emergent macrophytes until November when the instream vegetation died and was uprooted. Like the YOY rock bass, YOY smallmouth bass were routinely collected in the submergent macrophytes on each sampling date. Only during June were the smallmouth bass captured in open water (Table 6b). At this time these fish were observed throughout the stream usually remaining within a few millimeters of the bottom. In June 1984 smallmouth bass densities exceeded rock bass densities but by July rock bass densities surpassed and

Table 6a: 1983 mean fish densities organized by sampling period and habitat type (#fish/square meter)

7/18,19,21/1983

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	0.11	1.56	6.89
SD	0.33	1.74	5.93
# samples with fish	1/9	5/9	9/9
Submergent macro.			
Mean density	nf	13.00	20.00
SD	--	16.97	21.21
# samples with fish	0/2	2/2	2/2

8/1,3,4/1983

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	1.31	6.37
SD	--	2.05	10.23
# samples with fish	0/8	4/8	8/8
Submergent macro.			
Mean density	nf	3.00	5.00
SD	--	2.71	3.79
# samples with fish	0/7	6/7	7/7

Table 6a (cont'd.)

8/8/1983

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	0.20	1.60
SD	--	0.45	2.30
# samples with fish	0/5	1/5	2/5
Submergent macro.			
Mean density	nf	6.00	12.00
SD	--	1.00	1.00
# samples with fish	0/1	1/1	1/1

8/24/1983

SPECIES	SMB	RB	ALL FISH
Emergent macro.	ns	ns	ns
Submergent macro.			
Mean density	nf	2.00	3.10
SD	--	1.89	2.02
# samples with fish	0/10	7/10	8/10

nf=none found, ns=not sampled, SMB=smallmouth bass
RB=rock bass, macro=macrophytes
ALL=all species captured combined
NOTE-all samples, including samples with zero fish, were used in density calculations

Table 6b: 1984 mean fish densities organized by sampling period and habitat type (#fish/square meter)

6/18,20,22/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	1.94	33.97
SD	--	2.41	71.40
# samples with fish	0/7	4/7	6/7
Submergent macro.			
Mean density	5.50	3.00	10.50
SD	12.99	6.39	19.47
# samples with fish	2/6	3/6	5/6
Open water			
Mean density	5.14	0.14	6.71
SD	4.56	0.38	6.78
# samples with fish	5/7	1/7	6/7

6/25,29/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	0.72	37.53
SD	--	1.25	38.49
# samples with fish	0/3	1/3	2/3
Submergent macro.			
Mean density	4.50	1.67	7.83
SD	3.83	4.08	8.06
# samples with fish	5/6	1/6	5/6
Open water			
Mean density	3.60	nf	6.60
SD	3.21	--	4.45
# samples with fish	4/5	0/5	4/5

Table 6b (cont'd.)

7/2,3,5/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	1.00	2.33
SD	--	1.00	2.31
# samples with fish	0/3	2/3	3/3
Submergent macro.			
Mean density	3.22	5.78	10.22
SD	3.77	4.08	6.91
# samples with fish	6/9	6/9	9/9
Open water			
Mean density	nf	nf	12.67
SD	--	--	20.23
# samples with fish	0/3	0/3	2/3

7/10,12,13/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	0.45	0.85	3.96
SD	0.63	0.86	2.92
# samples with fish	2/5	3/5	5/5
Submergent macro.			
Mean density	0.40	1.70	2.70
SD	0.70	3.09	3.37
# samples with fish	3/10	5/10	10/10
Open water			
Mean density	nf	nf	1.00
SD	--	--	0.0
# samples with fish	0/3	0/3	3/3

Table 6b (cont'd.)

7/16,18,20/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	nf	8.00
SD	--	--	1.00
# samples with fish	0/1	0/1	1/1
Submergent macro.			
Mean density	1.80	3.80	8.60
SD	1.62	3.94	4.58
# samples with fish	7/10	7/10	10/10
Open water			
Mean density	0.25	0.25	4.75
SD	0.50	0.50	7.09
# samples with fish	1/4	1/4	2/4

7/24,25,27/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	ns	ns	ns
SD	--	--	--
# samples with fish	0/0	0/0	0/0
Submergent macro.			
Mean density	1.00	1.85	6.69
SD	1.08	2.85	4.13
# samples with fish	8/13	5/13	13/13
Open water			
Mean density	nf	nf	1.00
SD	--	--	1.00
# samples with fish	0/1	0/1	1/1

Table 6b (cont'd.)

8/1,2/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	nf	2.00	5.00
SD	--	1.00	1.00
# samples with fish	0/1	1/1	1/1
Submergent macro.			
Mean density	1.33	2.00	8.00
SD	1.97	0.63	5.25
# samples with fish	3/6	6/6	6/6
Open water			
Mean density	nf	nf	4.00
SD	--	--	1.00
# samples with fish	0/1	0/1	1/1

8/20,21/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	ns	ns	ns
SD	--	--	--
# samples with fish	0/0	0/0	0/0
Submergent macro.			
Mean density	0.31	1.54	3.85
SD	0.75	1.61	2.48
# samples with fish	2/13	7/13	11/13
Open water			
Mean density	ns	ns	ns
SD	--	--	--
# samples with fish	0/0	0/0	0/0

Table 6b (cont'd.)

9/4,5,6/1984

SPECIES	SMB	RB	ALL FISH
Emergent macro.			
Mean density	ns	ns	ns
SD	--	--	--
# samples with fish	0/0	0/0	0/0
Submergent macro.			
Mean density	0.40	0.70	4.00
SD	0.70	0.67	2.21
# samples with fish	3/10	6/10	10/10
Open water			
Mean density	nf	nf	nf
SD	--	--	--
# samples with fish	0/1	0/1	0/1

nf=none found, ns=not sampled, SMB=smallmouth bass
RB=rock bass, macro=macrophytes
ALL=all species captured combined
NOTE-all samples, including samples with zero fish, were used in density calculations

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remained greater than smallmouth bass densities.

As a measure of spatial distribution, an index of dipersion (I) was calculated for both smallmouth bass and rock bass on each sampling date in each habitat type. In early June of 1984 shortly after the YOY swam-up from the nest the rock bass had a contagious distribution within both the emergent and submergent aquatic macrophytes (Table 7). The smallmouth bass had a contagious distribution within both the submergent macrophytes and the open water. Within one week, the YOY of both species were randomly distributed in either the emergent macrophytes or the open water but their distributions remained clumped within the submergent vegetation. By August both species were randomly distributed throughout the submergent macrophytes. This pattern followed for the YOY rock bass in 1983 also.

To see if bass were segregated by size and age between the habitat types further analysis of the throwtrap data was done (Table 8). YOY rock bass showed no apparent size differences between the vegetation types. Age 1+ rock bass were found exclusively in the submergent vegetation after June with fish age 2+ and older found in both vegetation types. Mean size of the YOY smallmouth bass that were captured in open water, was always smaller than the mean size of those in the vegetation. This could be a behavioral tendency governed by size dominance or food preference or it could be due to sampling error. Larger smallmouth bass in open water may be less susceptible to the throwtrap than they are in the vegetation.

Table 7: Spatial distribution of young-of-the-year smallmouth bass and rock bass within each major habitat type in 1983 and 1984

Sampling Period	Emergent Macrophytes		Submergent Macrophytes		Open Water	
	RB	SMB	RB	SMB	RB	SMB
1983						
7/18,19,21/83	rand	rand	cont	nf	ns	ns
8/1,3,4/83	cont	nf	rand	nf	ns	ns
8/8/83	rand	nf	rand	nf	ns	ns
8/24/83	ns	ns	rand	nf	ns	ns
1984						
6/18,20,22/84	cont	nf	cont	cont	rand	cont
6/25,29/84	rand	nf	cont	cont	nf	rand
7/2,3,5/84	rand	nf	cont	cont	nf	nf
7/10,12,13/84	rand	rand	cont	rand	nf	nf
7/16,18,20/84	nf	nf	cont	rand	rand	rand
7/24,25,27/84	ns	ns	cont	rand	nf	nf
8/1,2/84	rand	nf	rand	cont	nf	nf
8/20,21/84	ns	ns	rand	rand	ns	ns
9/4,5,6/84	ns	ns	rand	rand	nf	nf

rand=fish distributed randomly
cont=fish distribution is contagious
nf=none found
ns=not sampled
RB=rock bass
SMB=smallmouth bass

Table 8: Habitat partitioning by size: mean fish size by species, age, and date in each habitat type sampled

Sampling Date	Species, Age	Emergent Macrophytes Mean	SD	N	Submergent Macrophytes Mean	SD	N
1983							
7/18,19,21/83	RB ,YOY	10.81	3.69	14	8.83	2.15	26
8/1,3,4/83	RB ,YOY	15.68	6.07	10	19.85	7.10	15
	RB , 1+	---	---	0	66.05	4.38	2
8/8/83	RB ,YOY	14.97	1.00	1	20.54	8.39	6
1984							
6/18,20,22/84	RB ,YOY	7.71	0.78	9	8.03	0.53	18
	RB , 1+	46.07	3.38	3	---	---	0
	SMB,YOY	---	---	0	13.06	1.32	32
6/25,29/84	RB ,YOY	9.07	1.15	2	8.79	0.82	10
	SMB,YOY	---	---	0	17.24	2.77	27
7/2,3,5/84	RB ,YOY	8.33	1.99	2	8.94	1.88	45
	RB , 1+	---	---	0	45.80	2.67	2
	SMB,YOY	---	---	0	20.59	1.84	29
7/10,12,13/84	RB ,YOY	13.32	1.11	4	12.31	2.29	12
	RB , 1+	---	---	0	51.29	2.35	3
	SMB,YOY	30.11	1.00	1	22.74	5.01	4
7/16,18,20/84	RB ,YOY	---	---	0	14.25	5.21	32
	RB , 1+	---	---	0	61.84	6.69	4
	SMB,YOY	---	---	0	28.61	4.76	18
7/24,25,27/84	RB ,YOY	ns	ns	ns	18.83	5.74	21
	RB , 1+	ns	ns	ns	70.61	1.00	1
	SMB,YOY	ns	ns	ns	35.49	3.96	13
8/1,2/84	RB ,YOY	24.27	1.00	1	23.99	2.75	8
	RB , 1+	---	---	0	70.11	8.26	3
	SMB,YOY	---	---	0	40.35	4.76	8
8/20,21/84	RB ,YOY	ns	ns	ns	32.51	6.00	11
	RB , 1+	ns	ns	ns	70.49	5.92	7
	SMB,YOY	ns	ns	ns	49.95	3.64	4
9/4,5,6/84	RB ,YOY	ns	ns	ns	39.98	2.25	4
	RB , 1+	ns	ns	ns	67.08	1.00	1
	SMB,YOY	ns	ns	ns	51.99	3.45	4

Tabl

Samp
Date

1983

7/18

8/1,

8/8

1984

6/18

6/25

7/2,

7/1

7/1

7/2

8/

8/

9/4

Table 8 (cont'd.)

Sampling Date	Species, Age	Open Water Mean	SD	N
1983				
7/18,19,21/83	RB ,YOY	ns	ns	ns
8/1,3,4/83	RB ,YOY	ns	ns	ns
	RB , 1+	ns	ns	ns
8/8/83	RB ,YOY	ns	ns	ns
1984				
6/18,20,22/84	RB ,YOY	7.28	1.00	1
	RB , 1+	---	---	0
	SMB,YOY	11.74	1.34	35
6/25,29/84	RB ,YOY	---	---	0
	SMB,YOY	15.71	0.93	18
7/2,3,5/84	RB ,YOY	---	---	0
	RB , 1+	---	---	0
	SMB,YOY	---	---	0
7/10,12,13/84	RB ,YOY	---	---	0
	RB , 1+	---	---	0
	SMB,YOY	---	---	0
7/16,18,20/84	RB ,YOY	7.72	1.00	1
	RB , 1+	---	---	0
	SMB,YOY	24.56	1.00	1
7/24,25,27/84	RB ,YOY	---	---	0
	RB , 1+	---	---	0
	SMB,YOY	---	---	0
8/1,2/84	RB ,YOY	---	---	0
	RB , 1+	---	---	0
	SMB,YOY	---	---	0
8/20,21/84	RB ,YOY	---	---	0
	RB , 1+	ns	ns	ns
	SMB,YOY	ns	ns	ns
9/4,5,6/84	RB ,YOY	---	---	0
	RB , 1+	---	---	0
	SMB,YOY	---	---	0

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Associations among larval fish species in 1983 and 1984, in each habitat type sampled, were described using Forbe's coefficient (cf) (Table 9a and 9b). Both in 1983 and 1984 associations between YOY smallmouth bass and rock bass were negative ranging from -0.01 to -0.19 indicating a weak but consistent degree of disassociation. A two variable regression between the number of YOY smallmouth bass and the number of YOY rock bass, in each of the throwtrap samples (N=134), was calculated using the 1984 data. The correlation coefficient was -0.14, again indicating a weak negative relationship between the two species.

In addition to the October 1984 electrofishing estimate, the total numbers of each species in the Sherwood study site each sampling period were calculated. I took the throwtrap estimates of the mean number of fish per square meter in each habitat type from Tables 6a - 6d, and multiplied them by the estimated number of square meters of each habitat type in the study area. The resulting number of fish in each habitat type were summed to produce an estimate of the total numbers of each species in the study site (Tables 10a and 10b).

Growth estimates were calculated from the weekly grouped throwtrap data for YOY smallmouth bass in 1984 and YOY rock bass in both 1983 and 1984. Length frequency data for the smallmouth bass (Figure 5) confirms that this species successfully spawned only once in 1984, and that was in mid June. As summer progressed from June to late August

Table

1983

CYP
RB
JD
SMB

1983

CYP
RB
JD
SMB
RSD

-----

0 in
+1 in
-1 in
CYP=c
SMB=s
RSD=r

Table 9a: Daytime associations among larval fish species of the Red Cedar River in 1983, as measured by Forbe's coefficient (cf)

1983 EMERGENT MACROPHYTES

	RB	JD	SMB	BSD
CYP	.14	-.08	-.04	.03
RB		-.26	-.04	-.04
JD			.17	.17
SMB				-.04

1983 SUBMERGENT MACROPHYTES

	RB	JD	SMB	BSD	RBD
CYP	1.00	.14	--	.06	-.11
RB		.03	--	.01	-.04
JD			--	.47	-.11
SMB				--	--
BSD					-.11

0 indicates chance association
+1 indicates complete association
-1 indicates complete disassociation
CYP=cyprinids, RB=rock bass, JD=johnny darter
SMB=smallmouth bass, BSD=blackside darter
RBD=rainbow darter

Ta

RB
JD
SM

RB
JD
SM

RB
JD
SM

0
-1
-1

Table 9b: Daytime associations among larval fish species of the Red Cedar River in 1984, as measured by Forbe's coefficient (cf)

1984 EMERGENT MACROPHYTES

	RB	JD	SMB	BSD
CYP	-.03	-.13	.06	-.05
RB		-.04	-.01	.05
JD			.11	.20
SMB				-.05

1984 SUBMERGENT MACROPHYTES

	RB	JD	SMB	BSD	RBD
CYP	.10	.08	-.01	.03	.02
RB		.03	-.03	-.02	.01
JD			.01	.04	.04
SMB				-.02	.01
BSD					.05

1984 OPEN WATER

	RB	JD	SMB	BSD	RBD
CYP	0	-.21	-.17	-.03	-.06
RB		-.35	-.19	-.03	-.04
JD			0	.03	-.07
SMB				-.03	-.15
BSD					-.15

0 indicates chance association
+1 indicates complete association
-1 indicates complete disassociation
CYP=cyprinids, RB=rock bass, JD=johnny darter
SMB=smallmouth bass, BSD=blackside darter
RBD=rainbow darter

Tab

Sam
Dat

VOV

7/18
8/1,
8/8
8/24

RB

7/18
8/1,
8/8
8/24

DB=r
RB=r
samp

Table 10a: Total numbers of fish in the Sherwood study site based on the number of fish per meter squared in the different habitat types and the total areas of the various habitat types sampled in 1983

Sampling Dates	Emergent Macrophytes		Submergent Macrophytes		Open Water		Total Fish
	# of Fish	# of Samp	# of Fish	#of Samp	# of Fish	#of Samp	
YOY SMB							
7/18,19,21/83	33	9	0	2	ns	0	33*
8/1,3,4/83	0	8	0	7	ns	0	0
8/8/83	0	5	0	1	ns	0	0*
8/24/83	ns	0	ns	0	ns	0	0*
RB							
7/18,19,21/83	446	9	15346	2	ns	0	15818*
8/1,3,4/83	374	8	3541	7	ns	0	3935
8/8/83	52	5	7083	1	ns	0	7135*
8/24/83	ns	0	2361	10	ns	0	2361*

ns=not sampled, YOY=young-of-the-year, SMB=smallmouth bass RB=rock bass, *-estimate based on less than 3 throwtrap samples in one or more of the habitat types

Tab

Sam
Dat

XIY

6/1
6/2
7/2
7/1
7/1
7/2
8/1,
8/2
9/4,
10/

RB

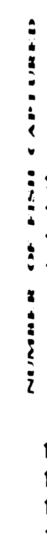
6/1
6/2
7/2,
7/1
7/1
7/2
8/1,
8/2
9/4,
10/

Da=
RB=
Samp

Table 10b: Total numbers of fish in the Sherwood study site based on the number of fish per meter squared in the different habitat types and the total areas of the various habitat types sampled in 1984

Sampling Dates	Emergent Macrophytes		Submergent Macrophytes		Open Water		Total Fish
	# of Fish	# of Samp	# of Fish	#of Samp	# of Fish	#of Samp	
YOY SMB							
6/18,20,22/84	0	7	6493	6	18404	7	24897
6/25,29/84	0	3	5312	6	12890	5	18202
7/2,3,5/84	0	3	3801	9	0	3	3801
7/10,12,13/84	124	5	472	10	0	3	596
7/16,18,20/84	0	1	2125	10	895	4	3020*
7/24,25,27/84	ns	0	1180	13	0	1	1180*
8/1,2/84	0	1	1570	6	0	1	1570*
8/20,21/84	ns	0	366	13	ns	0	366*
9/4,5,6/84	ns	0	472	10	0	7	472*
10/8,10/84	electroshocking YOY estimate						782±167
RB							
6/18,20,22/84	600	7	3541	6	501	7	4642
6/25,29/84	202	3	1971	6	0	5	2173
7/2,3,5/84	261	3	6823	9	0	3	7084
7/10,12,13/84	234	5	2007	10	0	3	2241
7/16,18,20/84	0	1	4486	10	895	4	5381*
7/24,25,27/84	ns	0	2184	13	0	1	2184*
8/1,2/84	443	1	2361	6	0	1	2804*
8/20,21/84	ns	0	1818	13	ns	0	1818*
9/4,5,6/84	ns	0	826	10	0	7	826*
10/8,10/84	electroshocking estimate						1374±137

ns=not sampled, YOY=young-of-the-year, SMB=smallmouth bass RB=rock bass, *-estimate based on less than 3 throwtrap samples in one or more of the habitat types


NUMBER OF FISH CAPTURED

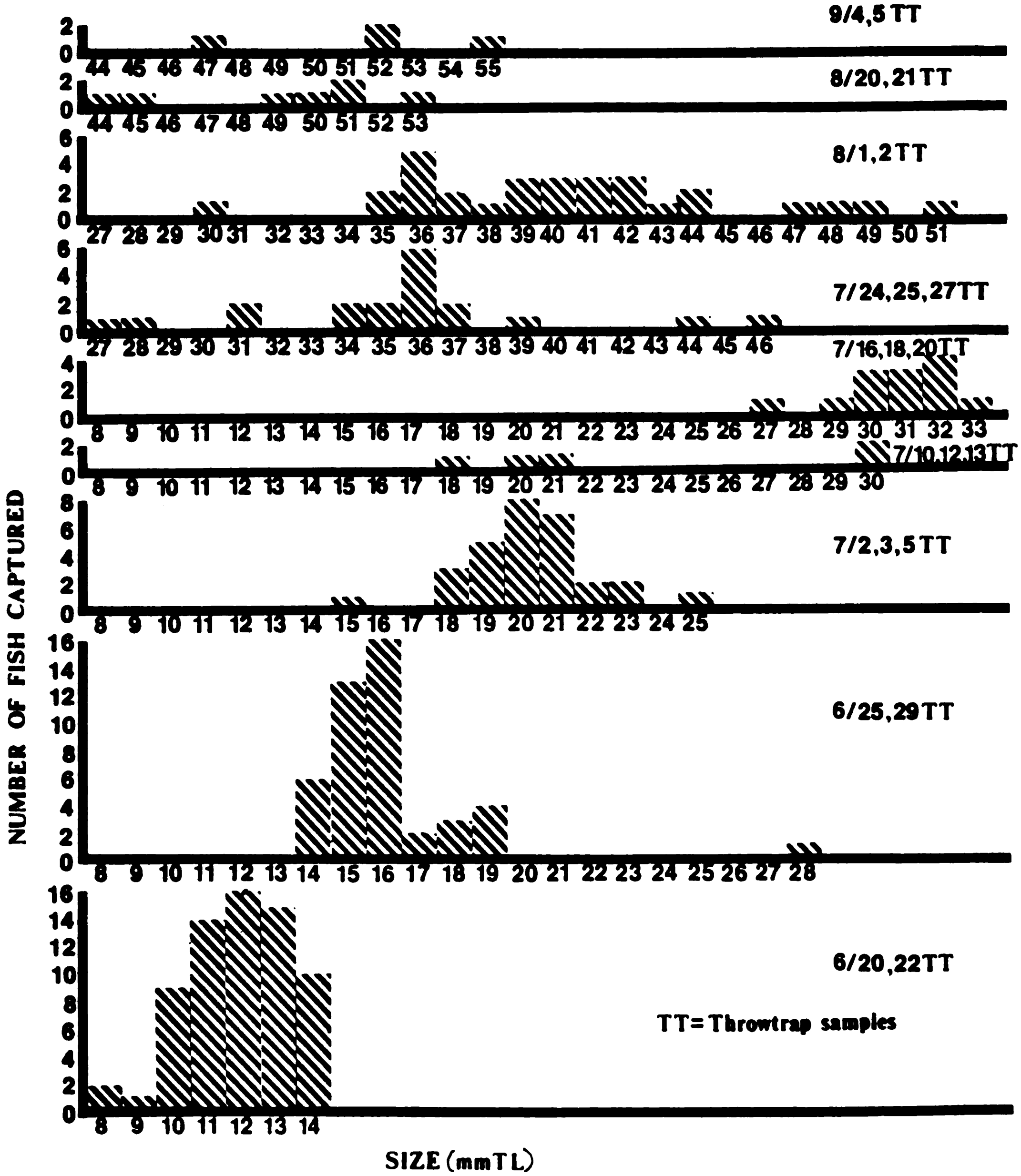


FIGURE 5: LENGTH FREQUENCY OF YOY SMALLMOUTH BASS IN 1984

differential growth rates were evident within the population. Smallmouth bass grew in length in a linear fashion until late August reaching a plateau by early September (Figure 6). Predicted larval hatch was June 9th at a size of 4.80 millimeters. A sweep net sample collected on June 17th before throwtrap sampling began agreed well with the throwtrap data. YOY population growth rates (u), expressed in percent change in total length per day, were calculated and plotted against time (Figure 7). An exponential curve fit the data best, particularily in early and late summer. However, between July second and July 18th, the growth rates suddenly increased. This could have been a sampling error or it could have been an actual fluctuation caused possibly by diet change or an increase in mean weekly temperature. In general though, as time increased u decreased. In Figure 7 (Equations 2 and 3), note that before and after the July increase in growth rate, that the lines depicting change in growth rate over time have essentially the same slopes. A plot of growth rate and size was also best described by an exponential fit with growth rate decreasing as size increased (Figure 8).

In October of both 1983 and 1984 YOY smallmouth bass were collected via electroshocking. The fish collected in 1983 as mentioned previously were much fewer in number but exhibited a larger mean size at the time of collection (Table 11). Using the listed hatching dates, a hatching size of 4.80 millimeters total length, and the October electroshocking mean total length, the mean daily individual

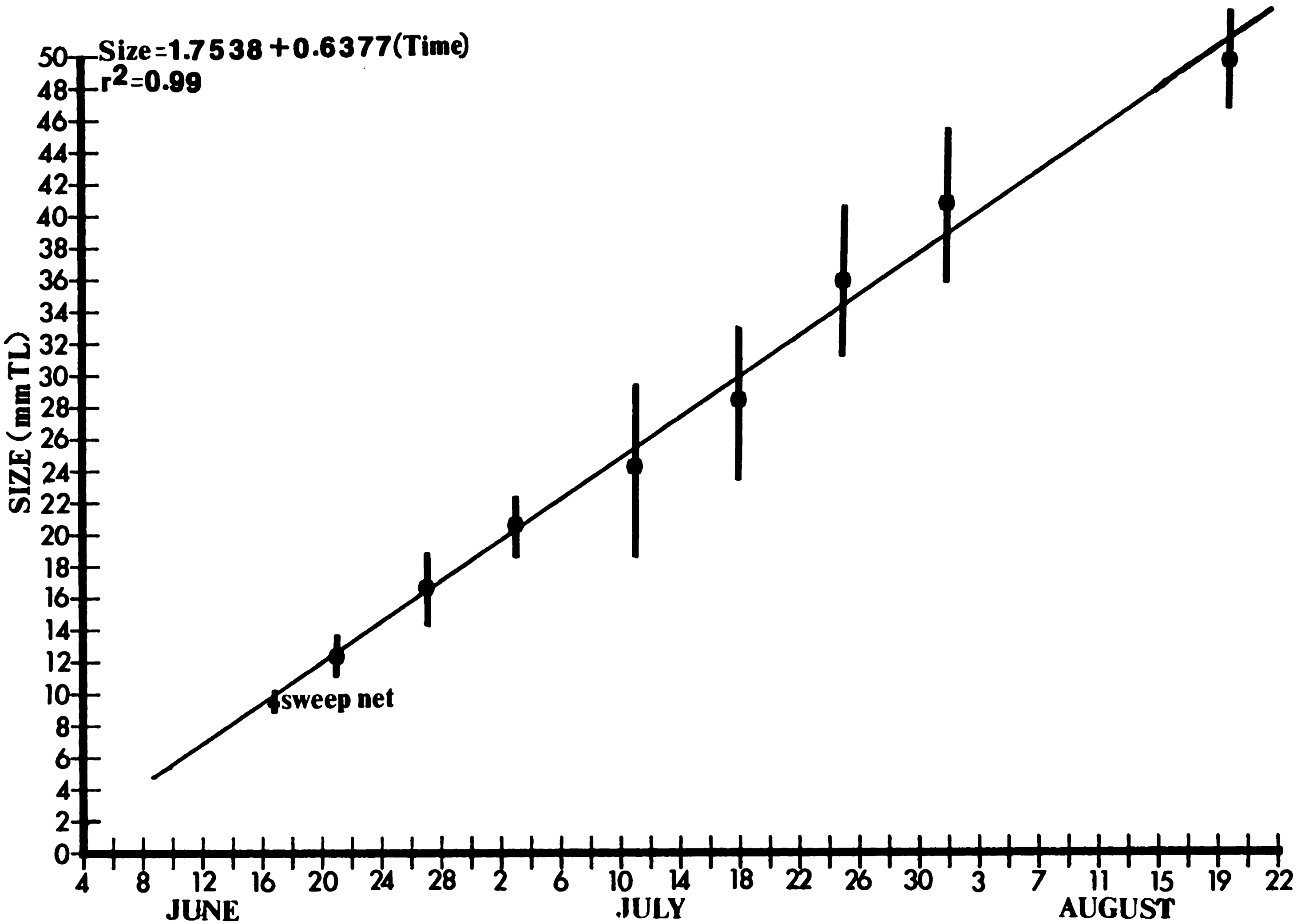


FIGURE 6: MEAN YOY SMALLMOUTH BASS SIZE IN MILLIMETERS TOTAL LENGTH IN THE SUMMER OF 1984±S.E.

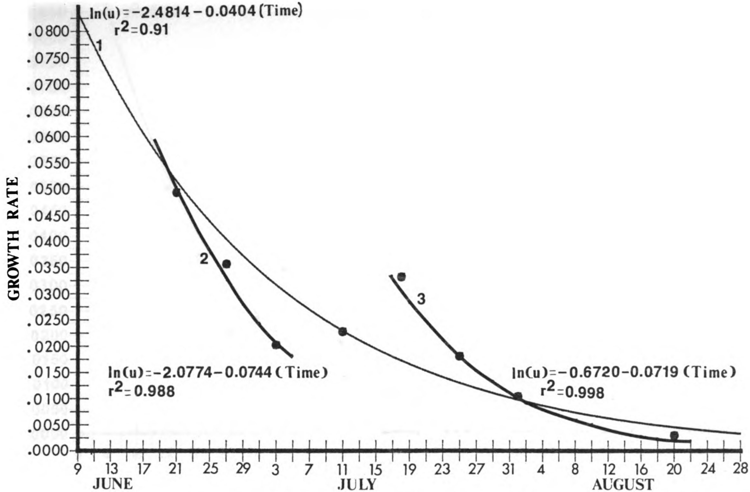


FIGURE 7: MEAN GROWTH RATE OF THE 1984 YOY SMALLMOUTH BASS VERSUS TIME

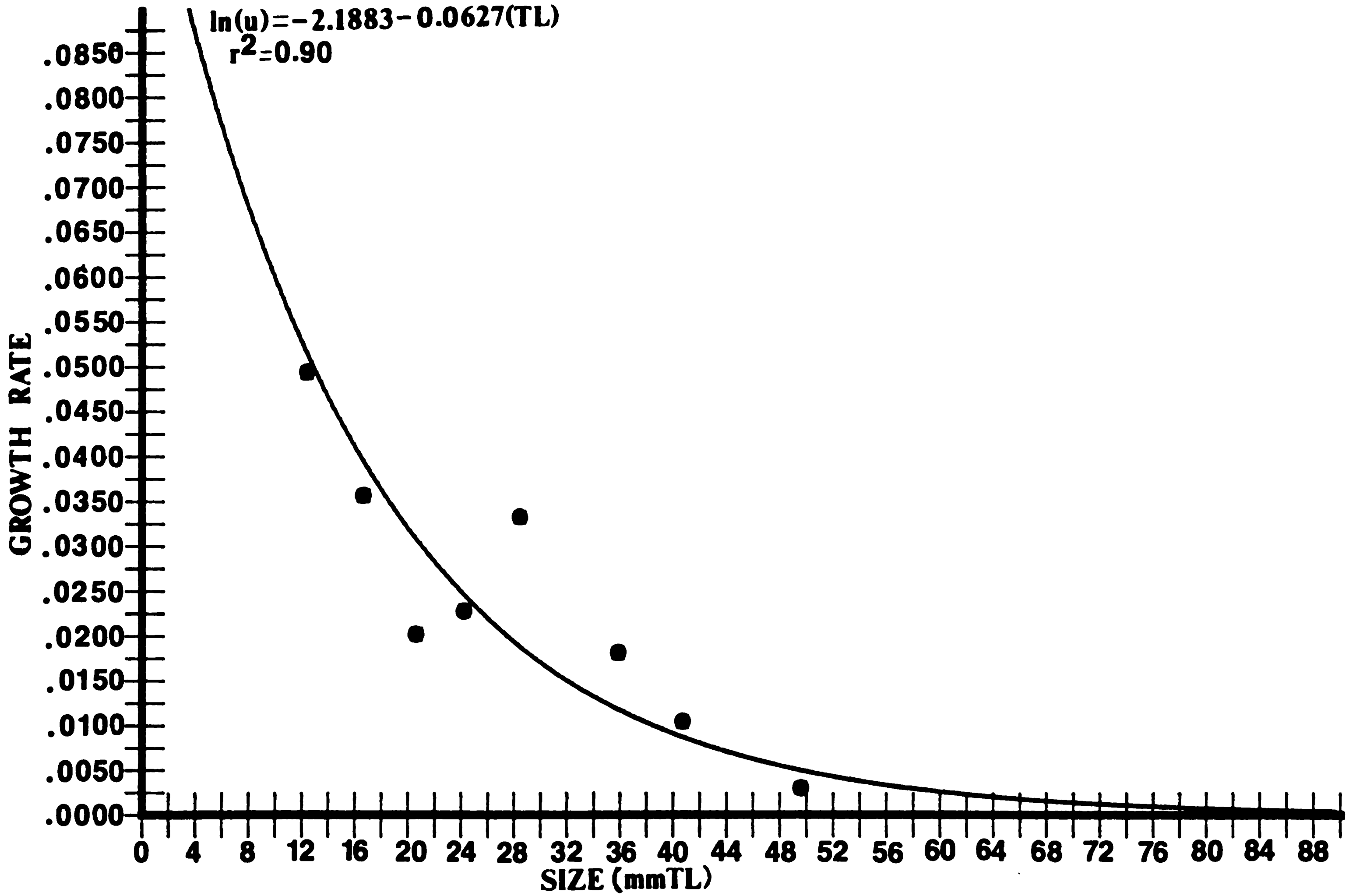


FIGURE 8: MEAN GROWTH RATE OF THE 1984 YOY SMALLMOUTH BASS VERSUS SIZE

Table 11: Smallmouth bass and rock bass young-of-the-year population growth rates (u=% change in total length per day) for June through October 1983 and 1984

SMALLMOUTH BASS

Year end sampling date (electrofishing)	10/9/84 (mm TL)	10/14/83 (mm TL)
Mean size	60.50	73.43
SD	7.75	6.92
N	195	23
Date of predicted hatch (4.80 mm TL)	6/9	6/19
Growing period (days)	122	117
Growth rate (u)	0.02077	0.02331

ROCK BASS

Year end sampling date (seining)	11/8/84 (mm TL)	11/8/83 (mm TL)
Mean size	39.55	37.65
SD	5.04	6.16
N	47	73
Predicted date that fish are 8.00 mm TL	6/27	6/23
Growing period (days)	135	139
Growth rate (u)	0.0118	0.0111

mm TL=millimeters total length

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growth rates (u) for both 1983 and 1984 were calculated.

YOY rock bass growth rate analysis was made on those fish collected in 1984 by throwtraps and in 1983 by throwtraps and drift net samples. The drift samples, which were collected for a different study, were used in the analysis because no other data was available for June and early July and because it is apparent that a number of these fish survived the flood and did contribute to the year class (Figure 9). It is apparent that spawning continued into early August and that there were still YOY rock bass 20-29 mm TL in the November 1983 sample in comparison to none in this size range in the November 1984 sample (Figure 10). The rock bass population also showed an increase in differential growth rates as time increased. Spawning in 1984 commenced in mid June and continued into mid July (Figure 11).

A plot of mean total length versus time for the 1983 YOY rock bass data was best fit by an exponential equation (Figure 12). Growth plateaus off by November (Table 11) when mean total length was 39.55 millimeters. No equation could be reasonably fit to the 1983 rock bass growth rate (u) versus size and the growth rate (u) versus time data due to continuous spawning into August. A plot of mean total length versus time for the 1984 YOY rock bass data was best fit by a linear equation (Figure 13). As was the case in 1983, growth increase in 1984 reached a plateau by November. Linear equations of growth rate (u) versus both size and time had very low correlation coefficients of -0.22 and

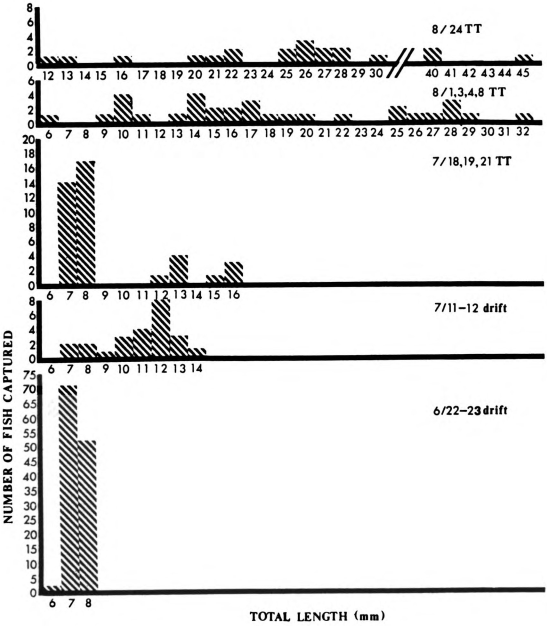

FIGURE 9 : LENGTH FREQUENCY OF YOY ROCK BASS IN 1983

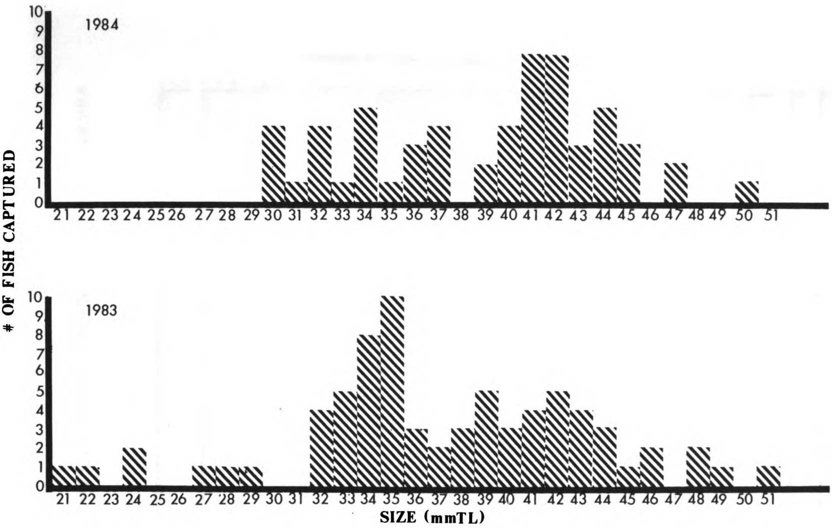

FIGURE 10: LENGTH FREQUENCY OF YOUNG-OF-THE-YEAR ROCK BASS CAPTURED IN NOVEMBER OF 1983 AND 1984

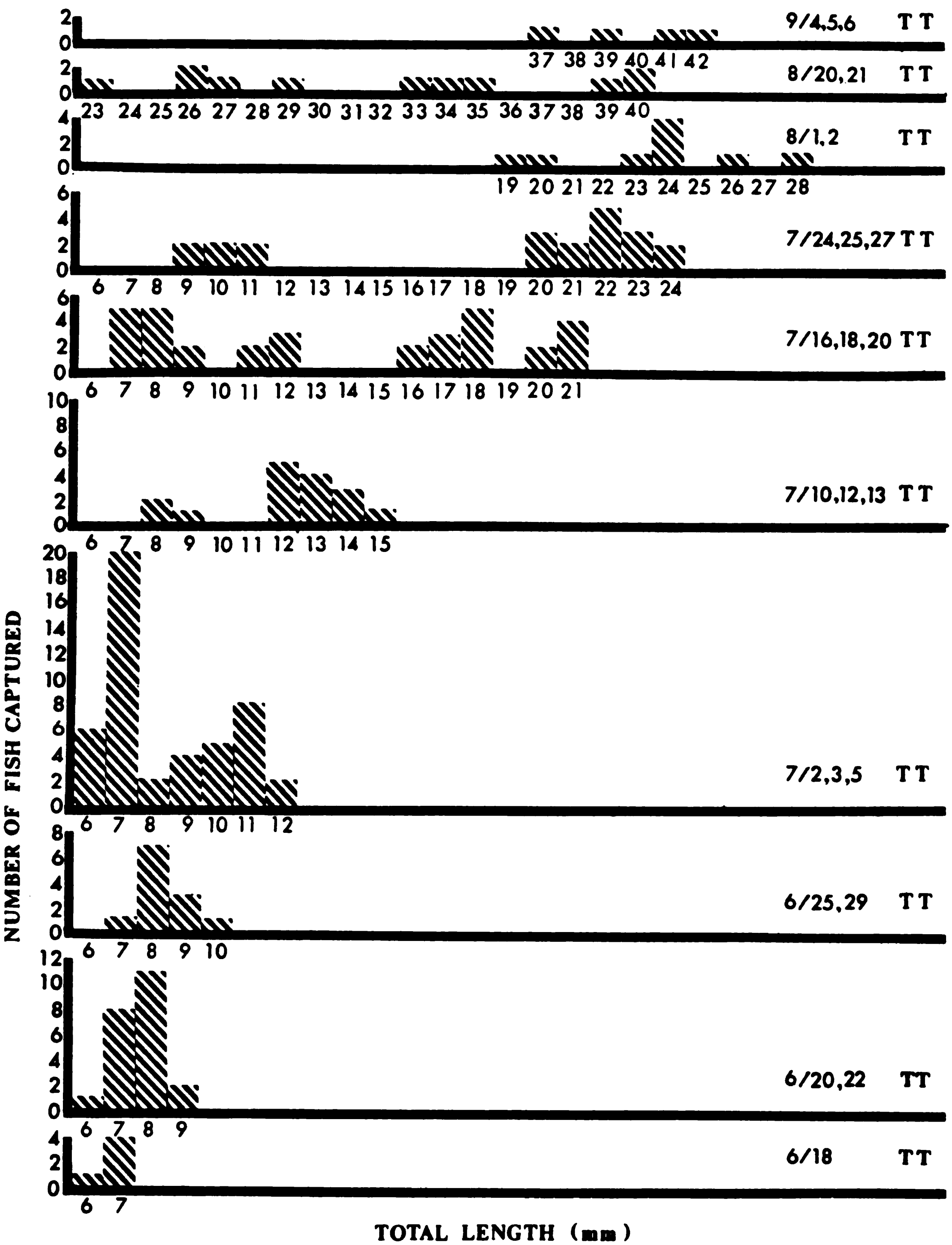

FIGURE 11: LENGTH FREQUENCY OF YOY ROCK BASS IN 1984

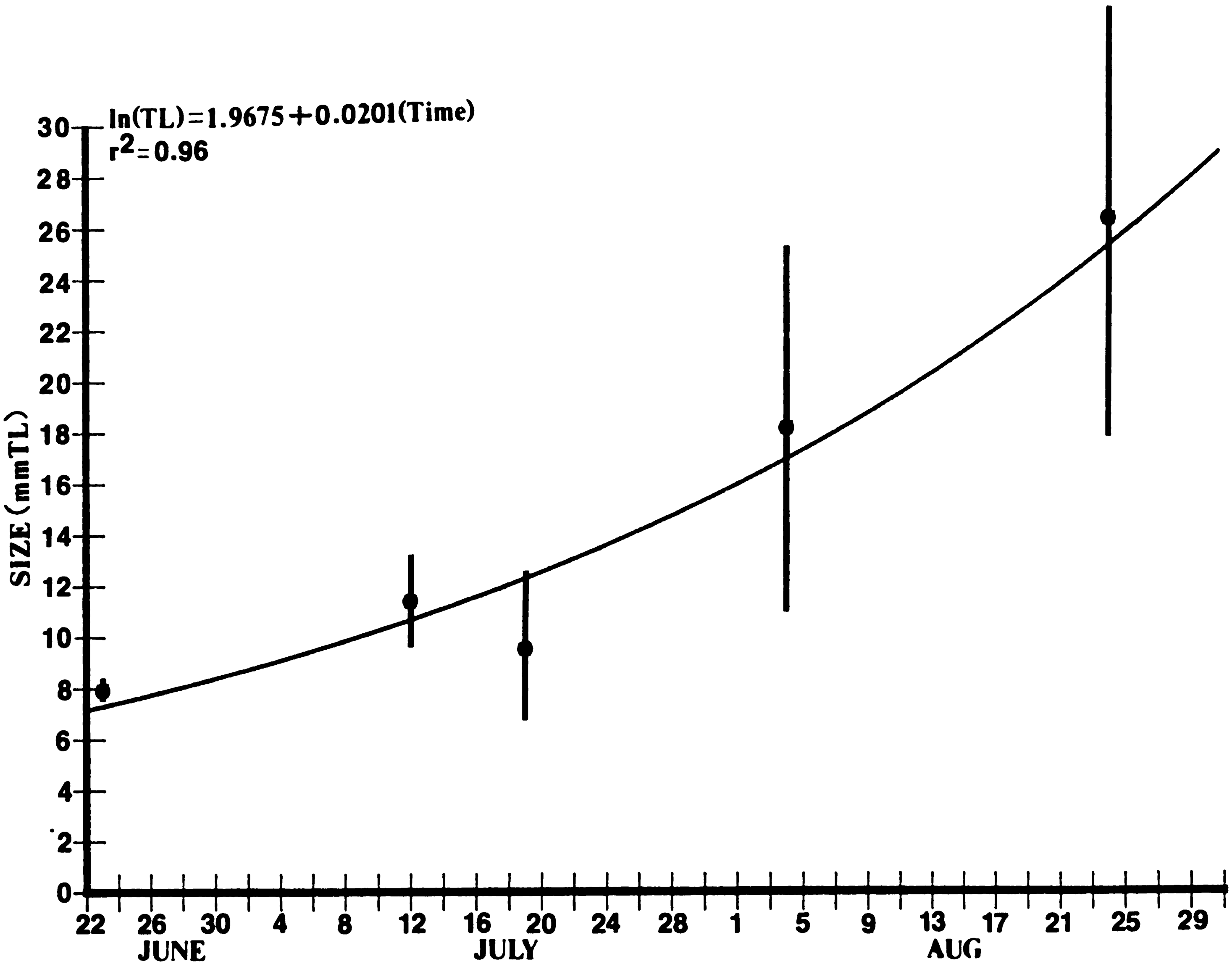

FIGURE 12: MEAN SIZE OF THE 1983 YOY ROCK BASS VERSUS TIME ± S.E.

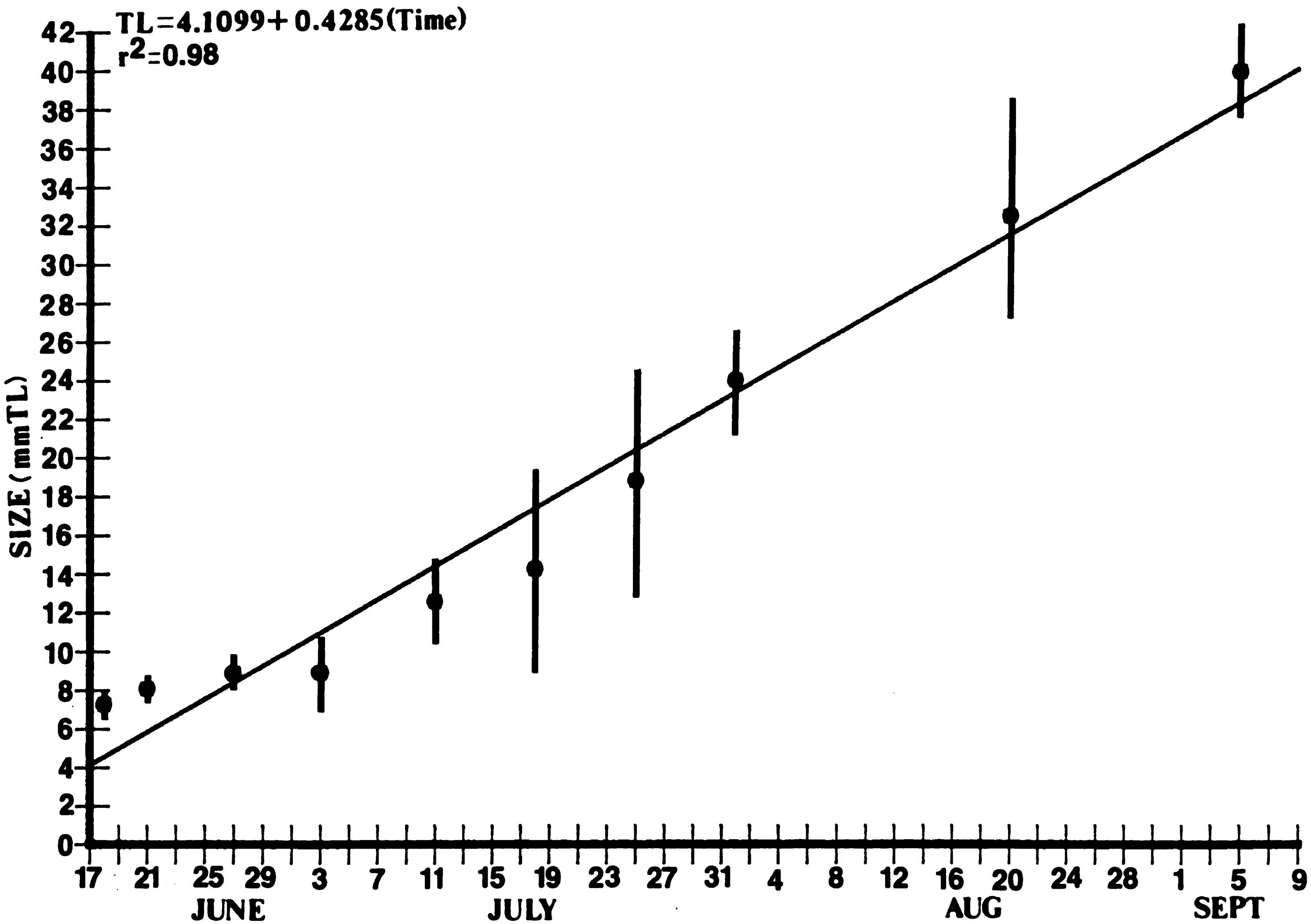

FIGURE 13: MEAN SIZE OF THE 1984 YOY ROCK BASS VERSUS TIME ± S.E.

-0.11 respectively. Insufficient data were present to divide the cohort into discrete spawning intervals which might have allowed for better growth rate-size and growth rate-time relationships.

In November of both 1983 and 1984 YOY rock bass were collected by seining and used to calculate their growth rate between the time they were 8.00 mm total length and the end of the growing season. As mentioned previously the rock bass in November 1984 were slightly larger than those in November 1983 and there were less fish in 1984 than in 1983 (Table 11). The growth rates in both years were nearly equal with the 1984 rate being slightly greater.

In an effort to ascertain the degree to which predation may govern smallmouth bass and rock bass interactions in the Red Cedar River, three twenty-four hour backpack shocking collections were made in the summer of 1983 for subsequent stomach analysis. A total of 278 stomachs of 12 resident species were examined for the presence of fish in their diets. Only in the stomachs of smallmouth bass, largemouth bass and northern pike were fish found (Table 12). The northern pike stomachs contained cyprinids. One smallmouth bass 8.0 cm TL contained two YOY rock bass and one 9.8 cm largemouth bass also had fed on one YOY rock bass.

To further investigate the impact of smallmouth bass YOY on rock bass YOY populations, seventy-seven YOY smallmouth bass collected in throwtrap samples between August 1st, 1984 (mean TL=39.4 mm, SD=4.25) and October 2nd, 1984 (mean TL=56.4 mm, SD=5.05) were examined for larval

Table 12: Number of fish in the diets of resident species in the Red Cedar River in the summer of 1983

SPECIES	# OF STOMACHS EXAMINED	# OF FISH IN THE STOMACHS
Rock bass	189	0
Pumpkinseed sunfish	3	0
Bluegill sunfish	1	0
Green sunfish	17	0
Longear sunfish	3	0
Smallmouth bass	17	2 YOY RB
Largemouth bass	4	1 YOY RB
Blackside darter	7	0
Rainbow darter	6	0
Johnny darter	2	0
Cyprinids	27	0
Northern pike	2	2 CYPRINIDS

YOY RB=young-of-the-year rock bass

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fish in their guts. None of the stomachs contained any fish and most contained microcrustaceans, and small emphemeropterans, dipterans, and hemipterans.

In 1983 a sample of 16 smallmouth bass ranging from 66 mm TL to 156 mm TL, (mean TL=83.18 mm, SD=45.49) were collected and examined to ascertain when peak feeding occurred. The data indicate that smallmouth bass fed primarily at sunrise and just prior to sunset. Fish also fed during the day with only 20% of stomachs examined being empty. At night 80% of the stomachs examined were empty and gut contents were well digested in those that weren't empty. The data suggest that smallmouth bass forage in hours when there is light. Throwtrap data implies that rock bass remain in cover during the day. One hundred fifty rock bass stomachs collected in 1983 were examined to ascertain peak feeding times (Tables 13a and 13b). In almost all cases the number of empty stomachs and the mean degree of digestion were greatest during the daylight hours and least during the night. This suggests that rock bass feed primarily at night.

Table 13a: Feeding periodicity data for rock bass 3.80 to 7.19 centimeters total length collected in the Red Cedar River in the summer of 1983

7/15/83

Sampling time	SR(6:13AM) 6:05AM	NOON 11:35AM	SS(9:14PM) 6:47PM	MID 11:33PM
N	6	6	2	5
# of empty guts	0/6	0/6	0/2	0/5
Mean # of food items per fish stomach ±SE	13.17 ±2.82	6.50 ±0.99	30.50 ±24.50	12.20 ±1.62
# of organisms ingested	79	39	61	61
Mean degree of digestion	2.10	2.90	1.70	2.70
SD	1.008	0.912	1.006	0.901

8/18/83

Sampling time	SR(6:48AM) 6:35AM	NOON 12:00	SS(8:35) 6:27PM	MID 12:00
N	1	1	3	2
# of empty guts	0/1	0/1	0/3	0/2
Mean # of food items per fish stomach ±SE	18.00 ±0	10.00 ±0	11.00 ±4.16	15.00 ±4.95
# of organisms ingested	18	10	33	31
Mean degree of digestion	3.06	3.50	2.24	1.94
SD	0.802	0.527	0.969	0.892

Table 13a (cont'd.)

10/7/83

Sampling time	SR(7:42AM) 7:30AM	NOON 12:50PM	SS(7:10PM) 7:30PM	MID 12:50AM
N	8	10	13	7
# of empty guts	0/8	0/10	0/13	0/7
Mean # of food items per fish stomach ±SE	19.75 ±6.42	5.70 ±0.99	5.54 ±1.20	9.71 ±2.14
# of organisms ingested	158	57	72	48
Mean degree of digestion	1.87	2.58	2.42	2.44
SD	0.746	0.925	1.079	0.943

SR=sun rise, SS=sun set, SE=standard error

Table 13b: Feeding periodicity data for rock bass 7.20 to 21.00 centimeters total length collected in the Red Cedar River in the summer of 1983

7/15/83

	SR(6:13AM)	NOON	SS(9:14PM)	MID
Sampling time	6:05AM	11:35AM	6:47PM	11:33PM
N	5	6	8	6
# of empty guts	0/5	0/6	1/8	0/6
Mean # of food items per fish stomach ±SE	7.20 ±1.39	3.83 ±0.75	1.50 ±0.33	9.50 ±1.06
# of organisms ingested	36	23	11	56
Mean degree of digestion	2.39	3.26	2.73	2.61
SD	0.964	0.864	1.104	0.802
% with crayfish	80	50	37.5	66.7

8/18/83

	SR(6:48AM)	NOON	SS(8:35)	MID
Sampling time	6:35AM	12:00	6:27PM	12:00
N	8	5	4	2
# of empty guts	0/8	1/5	1/4	0/2
Mean # of food items per fish stomach ±SE	6.38 ±0.53	1.40 ±0.51	1.00 ±0.58	6.50 ±5.50
# of organisms ingested	51	7	9	13
Mean degree of digestion	2.86	2.42	3.56	3.00
SD	0.895	0.787	0.527	0
% with crayfish	87.5	60	0	50

Table 13b (cont'd.)

10/7/83

	SR(7:42AM)	NOON	SS(7:10PM)	MID
Sampling time	7:30AM	12:50PM	7:30PM	12:50AM
N	5	6	6	5
# of empty guts	0/5	1/6	2/6	0/5
Mean # of food items per fish stomach ±SE	4.40 ±2.11	2.83 ±0.79	2.67 ±1.71	4.20 ±1.99
# of organisms ingested	39	17	16	21
Mean degree of digestion	2.31	2.88	2.44	2.19
SD	1.004	1.111	1.094	1.167
% with crayfish	0	33.3	33.3	40

SR=sun rise, SS=sun set, SE=standard error

DISCUSSION

The Red Cedar River has been the source of many studies documenting the changes in its biotic and abiotic parameters in the past 25 years. Over this time period upgraded wastewater treatment has resulted in decreased addition of biodegradable organics to the river, but because of increased urbanization in the basin, no net reduction in the nutrient load carried by the river has been realized (Burton and King 1983). Water quality appears to have been degraded substantially in the upper portion of the river since the 1960's but to be essentially unchanged in the lower areas in the face of increased upstream loading.

Macrophyte biomass production of the entire river appears to have decreased to values typical of pre-1958 conditions (Burton and King 1983). During the 1961 and 1962 seasons, Vannote's (1963) experimental study reach was approximately 50 percent covered with aquatic macrophytes. At the midpoint of Vannote's study site lies my Sherwood study site. In 1984, 29 percent of my study reach contained macrophytes. Burton and King suggested that such decreases could be related to changes in point-source inputs, but they felt it much more likely to be related to the flushing of silt out of the river as a consequence of high flows in the years 1968, 1969, 1975, and 1976 that exceeded average discharge.

Comparisons of the fish populations in the Red Cedar River in the 1960's and in this study only show a few small changes. In the 1960's the fish populations were studied and documented by Linton (1964; 1967) and Linton and Ball (1965). Since the sites sampled by Linton and by myself each had their own intrinsic habitat quality and carrying capacity, direct numerical comparisons of fish between zones was not attempted. However, species trends between zones for the two studies were compared. In comparisons between Linton's dry weight production of species of fish and my population estimates of each species in selected sections of zones II, III and IV, it appears that the rock bass has now become as abundant in zone IV as it was in zone II and III. Zone II still contains the best smallmouth bass population. As in Linton's study, smallmouth bass production readily fell off upstream of zone II.

Green sunfish numbers are greatest in the upstream section of zone IV followed by zone II. Linton found the greatest production of green sunfish in zone II. In Linton's study pumpkinseed production was greatest in zone IV. In this study the greatest numbers of pumpkinseeds were also found in zone IV. It appears that the centrarchid populations in zones II and III have not dramatically changed in structure from that documented by Linton in the early 1960's. Zone IV has shown an apparent increase in green sunfish and rock bass. This could be a result of the loss of the reservoir and dam at Willamston. The loss of the reservoir and its lentic environment, may also explain why no crappie or warmouth were collected in zone IV in the current study. In general, the most abundant fish in the Red Cedar River, other than minnows and darters, is and was the rock bass.

Aside from historical comparisons, this study served to investigate the early life history and behavior of the rock bass and the smallmouth bass and the causes for year class fluctuations in these two species. Emig (1966) summarized data showing that smallmouth bass move into spawning areas at temperatures from 4.4 to 15.6 degrees Celsius, and spawning activity commences at temperatures from 14.4 to 21.2 degrees Celsius, but a drop in temperature will cause nesting to stop. Scott and Crossman (1973) stated that nest building and spawning commences over a range of temperatures 55 •F to 68•F (12.8•C to 20.0•C) but egg deposition takes place mostly at 61•F to 65•F (16.1•C to 18.3•C). Stability of water levels in spring and early summer is necessary for successful spawning of smallmouth bass (Watson 1955).

In the Red Cedar River the stimulus to begin nest building also appears to be temperature related. Both the rock bass and the smallmouth bass usually spawn in mid May to late June when the water temperature exceeds 12.7•C. High stream discharges may deter spawning (Vannote 1963). In 1960, 1961, and 1962, smallmouth bass spawning was delayed until stream flows were less than 200 cfs in Vannote's study site (Figure 14). Smallmouth bass spawning began during a period of rapid temperature increases. Vannote suggested that the 1960 spawning season was delayed apparently by a period of high to moderate, fluctuating stream discharge.

The 11 percent to 15 percent failure of smallmouth bass

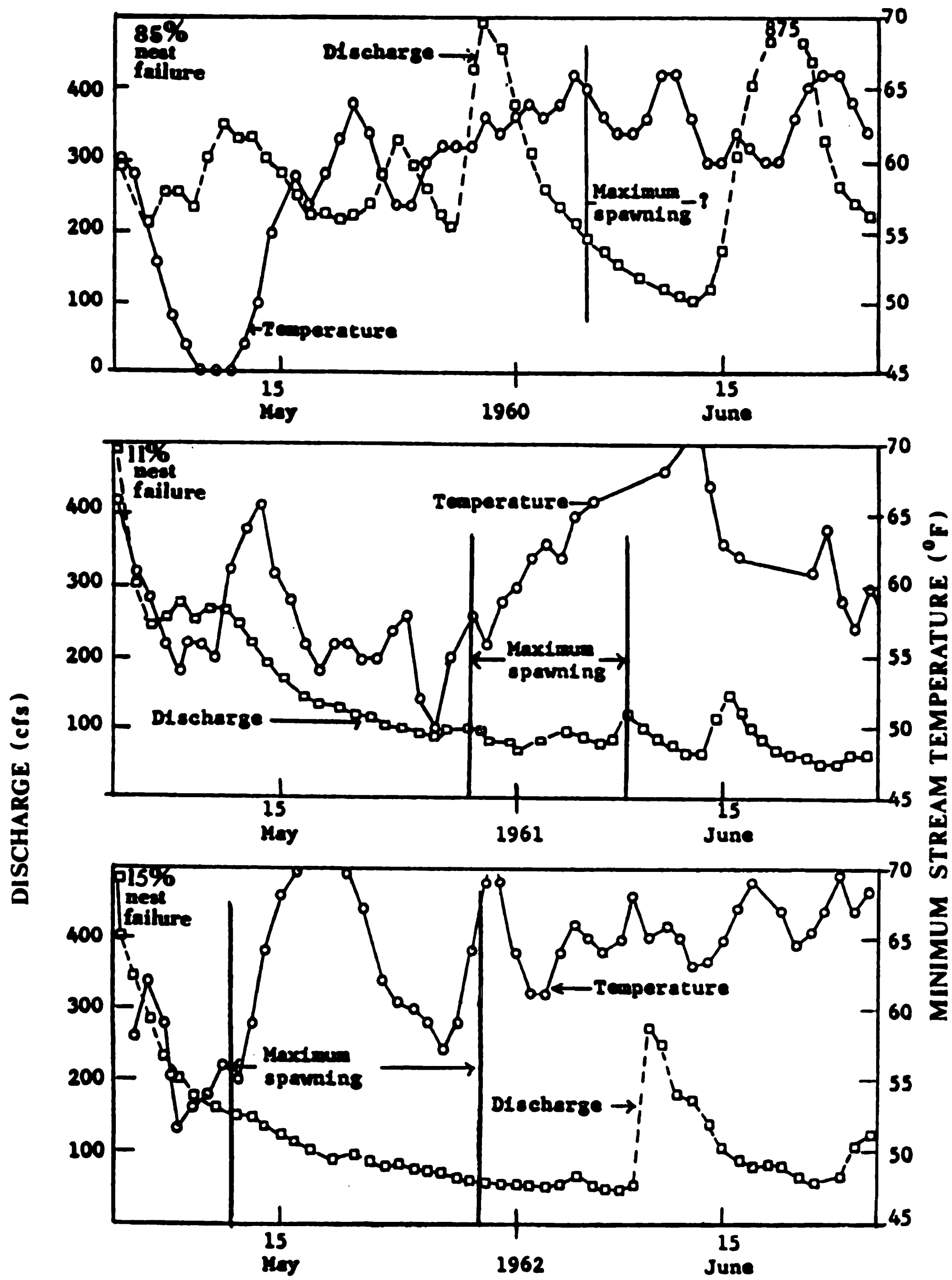

FIGURE 14: THE PERIODS OF MAXIMUM SMALLMOUTH BASS SPAWNING IN RELATIONSHIP TO STREAM DISCHARGE AND MINIMUM TEMPERATURE
from Vannote (PhD, 1963)

nests in 1961 and 1962 respectively, was attributed to low water temperatures following early spawning attempts (Vannote 1963). The 1961 temperature and discharge graph compares well with the 1984 temperature and discharge graph (Figure 4). According to Vannote, large bass invariably were the first spawners each year, and nesting attempts during the early favorable temperature periods were most vulnerable to subsequent low temperatures. In 1960 Vannote estimated an 85 percent failure of smallmouth bass nests. This data compares quite closely with my 1983 data. In 1983 the smallmouth bass either experienced a high nest failure or were subject to high mortality immediately following swim-up due to a large spate in late June (Figure 3). From literature values in Carlander (1977) I calculated that from nest building to swim-up would take a minimum of twelve days and a maximum of fifteen days. Therefore in 1983 fry were predicted to swim-up between June twenty-second and the twenty-fifth. On June twenty-seventh, only two to five days after predicted swim-up, the Red Cedar began rising to flood proportions peaking on June twenty-ninth. It is probable that this spring flood was what attributed to the poor smallmouth bass year class produced in the spring of 1983 in contrast to a much better one in the spring of 1984 during a gradual temperature rise and a gradual discharge decline.

A successful smallmouth bass nest will normally produce about 2000 fry (Scott and Crossman 1973), although the range can extend from 500 to 11,000 (Carlander 1977). Coble (1973) stated that counts of smallmouth bass fry in nests have ranged from 1000 to 5000 in studies by Doan (1940), Surber (1943), Sanderson (1958), Latta (1963), and Pflieger (1966). Vannote stated that 3000 fry were produced per successful nest in the Red Cedar River. My calculations concur with his estimate.

As is apparent, one of the most important characteristics of warm water streams, at least as far as the fish are concerned, is their tendency to fluctuate unpredictably in flow from season to season and from year to year (Moyle and Li 1979). Vannote (1963), Cleary (1956), and Surber (1942) among others, have singled out stream stage as the major factor in determining year class strength. The varability in year class strength is primarily the result of these unpredictable changes in the stream environment, which can favor one species over another. Differences in time of spawning were considered by Starrett (1951) to be one of the major reasons the species composition of the river showed considerable fluctuation from year to year. The fluctuations are related to the timing of floods and periods of low flow, which can occur at any time during the growing season. The floods wash away eggs and young (Larimore 1975).

Larimore indicated that destruction of the reproductive results was a complex relationship between several factors. Water temperature, velocity, turbulence, and turbidity are the primary environmental factors that change when warm-water streams are flooded. Water temperature usually drops because most spring floods come with cool, cloudy weather. Low temperature may not kill the fry but reduces their swimming ability (Larimore and Duever 1968). Webster (1948) demonstrated that thermal changes over a 30 minute period from 65 degrees to 75 degrees Fahrenheit or from 65 degrees to 50 degrees Fahrenheit caused no appreciable mortality on YOY smallmouth bass. Larimore and Duever explained that temperature changes may not directly cause the displacement of smallmouth bass fry, but the reduction in swimming ability associated with declining temperatures contributes to displacement of fry exposed to other physical changes accompanying flood waters. Loss of orientation may account for the frequent disappearance of entire year classes of fry from warm-water streams.

The delayed maturity/large size pattern is most characteristic of piscivores such as the smallmouth bass. These fishes usually do not spawn before their third summer of life and depending on size and species, produce 5,000 to 140,000 eggs per female (Moyle and Li 1979). The advantage of this life history strategy is that it allows a species to persist in some numbers even though periods when conditions for reproduction are unfavorable and to invest most of the energy ingested in the first two or three years into somatic growth rather than reproduction. If energetically and physiologically it is possible for a given fish, more than one distinct spawning period can occur in a given year. This is generally observed when the initial period has been disrupted in some manner. Males have been observed to participate in several spawnings under natural conditions

(Brown 1960; Pflieger 1966; Coble 1975). Inslee's (1975) report of multiple spawnings by individual smallmouth bass females in hatchery ponds indicates that such behavior may be possible in natural populations. No such second spawning of smallmouth bass was seen in the Red Cedar River following the spate in 1983. Lack of additional spawning after a flood may be potentially a function of sexual regression (Shuter et al. 1980). A factor which could stimulate this regression in males was proposed by Brown (1960). Because some suppression of feeding appears to be a concomitant of sexual activity in males (Heidinger 1975), the longer the breeding season and the higher the temperatures experienced, the greater the degree of starvation suffered by fish. It is conceivable that if sufficient stress is imposed on males through this mechanism, the production of sexual hormones may cease, thus permitting resumption of feeding and presumably initiating gonad regression and ending sexual activity.

The rock bass in 1983, unlike the smallmouth bass, succeeded in producing a large year class. This year class was even larger than the one produced in 1984, a year with a stable discharge and temperature record. The rock bass appears to be more physiologically and evolutionarily adapted to such a harsh and unstable environment. This species is classified by Moyle and Li (1979) as to having a moderate size/maturity time pattern. Fecundities range from 2000 to 25,000 eggs. Due to its smaller egg production relative to the smallmouth bass and smaller growth rates, the rock bass is therefore capable of spawning at a smaller size and age than the smallmouth bass. It is also more capable of multiple spawnings, perhaps an evolutionary adaptation to living in a harsh and fluctuating environment. Gross and Nowell (1980) indicated that twenty-four percent of the males in Lake Opinicon, Ontario spawn more than once during the summer. Females can also spawn again, as indicated by modal egg classes noted in the ovary. In 1983 in the Red Cedar River, the rock bass re-commenced spawning activities following the spate and continued on into early August. In 1984 rock bass spawned from mid June to mid July. It is perhaps this ability to continue spawning after a flood that makes the rock bass the most abundant centrarchid in the Red Cedar River.

The question arises however, why were more YOY rock bass produced in 1983, a spring with a major flood, than in 1984 a spring without a flood? Several reasons are possible. The first involves the rock bass unsuccessfully competing with the large numbers of smallmouth bass in 1984 in contrast to 1983 when the smallmouth bass were found in extremely low numbers. Growth rate analysis of the fish collected via drift net and throwtrap samples indicates that in 1984 the rock bass actually exhibited a slightly better growth rate than in 1983 thus indicating that competition with YOY smallmouth bass wasn't controlling year class size.

Water temperature is an equally plausible reason for the differences in the 1983 and 1984 rock bass year class sizes. Raney (1965) stated that rock bass spawning is initiated when the water warms to 20.5 °C and may continue up to 26 °C. It appears that water temperatures in 1983 may have been closer to the preferred spawning temperatures and lasted longer than in 1984. Throughout the summer of 1984 water temperatures routinely fell below 20.0 °C at night. Only during the spring flood in 1983 did the water temperatures fall below 20.0 °C.

Another possible reason for the larger 1983 rock bass year class involves the differences in the total number of adult rock bass present in both years. In 1983, according to the population estimates made from the electrofishing data, there were roughly four times the number of reproductive adult rock bass in the primary study sites than in 1984 (Appendix A, Table A5). According to Hile (1961) both male and female bass in Wisconsin are mature at age II and spawn the next spring at age III. Table A5 indicates that there were 221 reproductive rock bass in 1983 at the Vanatta site and only 50 in 1984. This alone could account for a good portion of the variation in rock bass year class sizes produced.

Macrophyte growth in the Red Cedar River is timed well with larval fish production. This is critical due to its importance as cover for larval fish. Throwtrap collections of YOY smallmouth bass and rock bass indicated their affinity for the instream submergent vegetation. Unlike many other studies where YOY smallmouth bass were segregated on a habitat axis (Wickliff 1920; George and Hadley 1979) these species were found in highest densities in the Red

Cedar River in the same habitat type. YOY smallmouth bass also utilized open water and rock bass also utilized the emergent vegetation. Studies of microhabitat preferences of warmwater fishes indicate that most species are quite flexible in this regard, and the degree of microhabitat specialization of a species may change in response to the number and kinds of other fishes present with it as well as the life history stage (Gee 1974; Mendelson 1975; Smith 1977).

Macrophyte growth in the Red Cedar is seasonal. The maximum production rate is attained by late June and rapidly diminishes thereafter (Vannote 1963). The total growing season is approximately 125 days. In mid-September large segments of the submergent macrophyte crop detach from the rooted portion and drift downstream. By the end of September virtually the entire community has detached. The YOY bass at this time become concentrated along the margins of stream in the dead, matted down, emergent macrophyte stalks.

A variety of studies suggest that prey vulnerability decreases as environmental complexity increases (Huffaker 1958; Glass 1971; Stein and Magnuson 1976; Saiki and Tash 1979). In a lab experiment predation success (number of captures) by largemouth bass was similar at 0 to 50 stems per square meter, declining to near zero at 250 and 1000 stems per square meter (Savino and Stein 1982). Emergent vegetation in the Red Cedar River had a stem density of approximately 100 stems per square meter and the instream vegetation's stem density was greater. In Savino's study as stem density increased, predator activity declined due to a decrease in behaviors associated with visual contact with prey. Cooper and Crowder (1979) also felt that vulnerability could be reduced in vegetation simply because random visual encounters between predator and prey are reduced. Reduced predation success by largemouth bass in habitats of increased complexity apparently is related to increases in visual barriers provided by plant stems as well as to adaptive changes in prey behavior.

In the Red Cedar River, the smallmouth bass is the most predominant piscivore. Stomach analysis of the smallmouth bass indicates that they do feed on YOY rock bass that may have strayed from the protection of the macrophyte beds. Brown (1984) in lab experiments showed that rock bass fry, which do not have the benefit of a guarding parent after they leave the nest, avoid all sizes of predators sooner than largemouth bass and must depend on avoidance plus other tactics such as freezing and hiding in vegetation to avoid a predator successfully. Gross and Nowell (1980) noted the ability of rock bass larvae to swim into the nest substrate when disturbed during a predatory assult. In the vegetation beds immobilization (Smythe 1970; Curio 1976) combines with cryptic coloration (Endler 1980) to permit prey to blend in with the background and avoid detection by visual predators.

Predation may be a major cause of death in warm-water stream fishes, but its significance in determining community structure is difficult to assess because environmental influences may mask its effects. The role of predation in shaping the fish community is perhaps best reflected in the life history patterns evolved by the fishes, as well as in distributional and behavioral patterns commonly observed. Predation appears to serve as a strong force regulating YOY rock bass behavior from an evolutionary standpoint. Prey species and sizes, such as the YOY rock bass, that are most vulnerable to predation tend to associate most closely with structure (Crossman 1959; Charnov et al. 1976; Stein 1977; VanDolah 1978). As mentioned previously the YOY rock bass remained hidden in the vegetation beds during the day.

Stomach analysis of the smallmouth bass indicated that this species foraged primarily during the early morning, evening, and some during the day. At night 80 percent of the stomachs examined were empty. Munther (1970) observed no movement by smallmouth bass in his river at night and in the laboratory his smallmouth bass fed during the day and went on or beneath the substrate during darkness. The rock bass was shown by Spencer (1939) to swim both during the day and night in the absence of a predator. Keast and Welsh (1968) investigating the daily feeding periodicities of rock bass, (100 to 170 mm) showed that there were two peaks in weight of stomach contents per gram of fish, one extending from about 9 PM to 1:30 AM and the second about noon. Spoor and Schloemer (1938) also noted the diurnal activity of rock bass in Muskellunge Lake. Activity in the rock bass peaked between 7 and 9 PM with the fish remaining relatively active throughout the night and showing only a slight increase in activity between 3 and 4 AM. The rock bass in the Red Cedar River showed a feeding peak around sunset and sunrise. They also fed during the night but feeding was always suppressed during the day. Keast (1977) indicated that most of the small age 0 and 1 fish hide by day in rock crevices in the shallows, and feed along the water's edge at night often in water only a several centimeters deep.

Zaret (1979) indicated that behavioral accommodation may occur when species such as the YOY rock bass are under predatory pressure. Studies have indicated that prey fish populations under intense predation pressures will evolve different behavioral patterns from populations of the same species under different predation pressures, and that this behavior is heritable (Seghers 1974a, 1974b). This could explain the nocturnal behavior of the rock bass. Throwtrap results also indicated that the YOY rock bass, although utilizing the same primary habitat as the YOY smallmouth bass, may be actively avoiding the smallmouth bass due to predatory pressures. Forbes coefficients and regression analysis between the two YOY species were consistently negative, although only to a slight degree.

YOY smallmouth bass also have evolved mechanisms to reduce predational losses. In Illinois smallmouth bass were observed returning to the nest site at night and being actively guarded by the male. If mortality is low on these young, intra-specific competition could greatly suppress growth rates. In the Red Cedar River, in 1984 a large year class of smallmouth bass was produced. These fish showed a much diminished growth rate in comparison to 1983 a year with a smaller year class. The 1984 year class was also much shorter at years end than was the 1985 year class (Appendix A, Table A6) which like 1983 was relatively sparse. From our limited data it appears that growth of the YOY smallmouth bass is highly correlated with cohort density. This has been noted in several other studies. Coble (1971) showed that smallmouth bass growth in a series of ponds was inversely related to population density. Hubbs and Bailey (1938) noted slow growth with high population density. The more abundant year classes in Lake Michigan also showed slower growth (Latta 1957).

However, unlike Sanderson (1958) who found that growth rates of Potomac River smallmouth bass were inversely correlated with the population densities of rock bass and redbreast sunfish, the Red Cedar River data showed that YOY smallmouth bass growth rates appear to be unrelated to YOY rock bass population size. George and Hadley (1979) stated that the faster growth of smallmouth bass produced size differences between the two species which increased with time. The size differences presumably reduce resource sharing by enabling smallmouth bass at any given time to catch larger prey than the rock bass.

Smallmouth bass growth rates are not strictly density dependant however. They could be partially temperature dependant. Laboratory studies of YOY smallmouth bass and yearlings have shown that optimum temperature for growth is between 25 and 29 °C (Maclean et. al. 1984), and that growth ceases at 35 °C (Rowan 1962; Peek 1965; Horning and Pearson 1973). Doan (1939) demonstrated in Lake St. Clair that growth in total length of the bass fry was reduced when drops in water temperature occurred from 22.8°C to 14.7°C between June 17th and June 20th. In the Red Cedar River in 1983 mean maximum and mean minimum temperatures for June 15th through September 13th exceeded the values recorded for 1984. Thus the better growth rate of the 1983 year class, and the poorer growth rate of the 1984 year class could in part be a function of these temperature differences. Fry and Watt (1957) demonstrated that initial year class strength of smallmouth bass was directly related to temperature from July through October of the first year of life.

Percent oxygen saturation may also have attributed to the differential YOY smallmouth bass population growth rates seen between the 1983 and 1984 year classes. The prolonged spring flooding in 1983 flushed the stream of autochthonous and allochthonous materials effectively reducing the amplitude and duration of low dissolved oxygen periods. This, coupled with warm stream temperatures in 1983, produced a higher daily average percent oxygen saturation than those of the system in 1984. This in its self could have induced greater growth rates in 1983. In 1984 the stream only experienced one short increased discharge event to act as a reset mechanism, and had a lower average summer water temperature than in 1983. Stewart et al. (1967) investigated the influence of oxygen concentrations on the growth of juvenile largemouth bass and found that growth and consumption rates increased with increases in dissolved oxygen to levels near saturation and declined with further increases of oxygen concentration. They also noted that growth of bass subjected alternately to low and high concentrations of dissolved oxygen for either equal or unequal portions of 24 hours was markedly impaired. Andrews et al. (1973) studied the influence of dissolved oxygen on the growth of channel catfish, Ictalurus punctatus. Growth rates of fish maintained at 36% air saturation were approximately half that of fish maintained at 60 and 100%. Chronic effects of low dissolved oxygen concentrations on the fathead minnow were studied by Brungs (1971). Fathead minnows were exposed to constant dissolved oxygen concentrations (1.0 - 5.0 mg/liter) for 11 months. Fry growth was reduced significantly at all concentrations below the control of (7.9 mg/liter).

Regardless of whether it is biotic or abiotic mechanisms that control growth, it is evident that the smallmouth bass populations have differential growth rates between years and within the same cohort during the same year. Individual fish may vary markedly in their growth rates, even under controlled conditions, leading to a broad size distribution among even-aged fish (DeAngelis and Coutant 1979). Size variations within a population of first-year fishes can have significant effects on the population dynamics and the ultimate number of adult recruits, because these variations influence competitive and cannibalistic relationships within species as well as predator-prey relationships among species. Wismer et al. (1985) suggested that YOY fish are spawned over a finite time period and are exposed to spatially and temporally changing physical conditions and food availabilities. It is thus unrealistic to expect that sizes of individual fish in a cohort will be even approximately the same at the end of the first year of growth. Typically a cohort contains a broad distribution of sizes. This was true for the smallmouth bass due to differential genetic growth potentials. It was also true for rock bass although much of it was due to the wide spawning window that this species utilized. This may have masked any genetic growth differences that occured.

Field and laboratory studies have demonstrated that the probability of survival for northern populations of smallmouth bass depends closely on the size attained before the first winter because winter mortality is significantly related to size (Oliver et al. 1979; Shuter et al. 1980; Wales 1981; Shuter et al. 1985). Size distributions in years of poor growth show a strong positive skew, fish less than 6.0 centimeters total length rarely survive the winter (Shuter et al. 1985). Most of the smallmouth bass population in the Red Cedar River in 1984 was smaller than 6.0 centimeters. Oliver et al. (1979) indicated that there were lower levels of dry weight/wet weight and ignitable wet/dry weight in dying fish than in living fish, tending to support the hypothesis that death is a result of exhaustion

of energy substrates. The data analysis of these studies supported that large smallmouth bass survive their first winter better than smaller ones. This component should be further studied for YOY rock bass and smallmouth bass in the Red Cedar River.

This study did clearly show the importance of vegetative habitat for YOY fish. Large woody snags and root wads were also important for adult rock bass and smallmouth bass as was ascertained by electrofishing. We should be concerned by the loss of this habitat. Vegetation beds and their associated food supplies are decreasing, partially due to natural cyclic processes and partially due to man-made impacts such as channelization which tends to destabilize stream systems during flooding. Large woody habitat is also being lost due to user preference conflicts. Often log jams are chain sawed to facilitate canoeing which destabilizes the fish structure during flood conditions. It is these structural components of the stream environment that we must protect and enhance if we are to establish a quality recreational fishery. Perry (1974) and Edwards (1977) found mitigation structures improved the bass population and sport fishery considerably on channelized portions of the Olentangy River, Ohio. With increased stream habitat management the Red Cedar River could provide an excellent sport fishery.

SUMMARY

1. The results of this thesis primarily support the importance of vegetative structure as cover for YOY fish in warmwater lotic systems.

2. YOY rock bass and smallmouth bass were found to primarily utilize submergent macrophytes during the day. Data analysis suggested that there was a weak degree of disassociation between the two species in this vegetation type.

3. YOY rock bass do not exhibit habitat partitioning by size between the emergent and submergent macrophyte beds.

4. Rock bass fed at night while smallmouth bass fed primarily at sunrise and prior to sunset with some feeding occurring during the day.

5. Smallmouth bass and largemouth bass were found to contain YOY rock bass in their stomachs during the day.

6. YOY rock bass growth rates do not appear to be affected by YOY smallmouth bass population density but do appear to be slightly affected by YOY rock bass population abundance.

7. YOY smallmouth bass growth rates do not appear to be affected by YOY rock bass population abundance but do appear in this limited data set to be dependent on YOY smallmouth bass population abundance, seasonal dissolved oxygen values, and or water temperature.

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APPENDIX A

Table A1: Mean daily discharge, in cubic feet per second, for the water year October 1982 to September 1983 in the Red Cedar River at the USGS gaging station near Williamston, MI

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	29	25	101	116	77	92	350	252	139	221	34	16
2	26	42	93	103	93	90	326	409	127	182	33	15
3	24	69	97	91	186	89	353	495	120	116	29	13
4	23	64	126	84	164	90	362	498	165	83	27	12
5	22	52	151	80	126	93	333	481	199	71	26	11
6	22	44	188	74	103	101	311	432	211	60	25	15
7	21	39	172	74	80	123	301	381	218	53	23	16
8	22	35	141	71	69	180	299	396	212	49	21	15
9	22	34	118	69	66	250	285	391	196	45	20	13
10	22	41	99	73	55	255	320	348	172	42	19	11
11	22	48	84	84	44	237	328	311	142	39	31	11
12	22	69	74	86	47	209	316	273	112	37	31	11
13	21	78	60	78	50	167	301	236	90	34	26	10
14	21	71	63	76	50	135	367	196	79	33	23	10
15	20	62	64	71	56	120	451	156	71	32	22	9.1
16	19	54	85	42	61	108	430	130	66	32	21	13
17	19	48	93	57	84	100	422	115	60	31	20	16
18	19	45	93	47	93	101	406	104	56	29	20	16
19	20	42	90	45	93	121	379	103	52	31	19	38
20	20	70	98	40	112	143	364	159	48	34	17	27
21	21	103	103	38	124	136	353	197	47	31	14	31
22	22	104	97	38	129	116	337	215	45	29	16	29
23	22	97	97	43	154	126	322	258	41	28	17	25
24	20	105	137	47	170	133	299	275	40	27	16	22
25	20	101	205	49	156	125	270	278	39	25	15	19
26	20	90	255	45	118	118	237	268	35	24	13	18
27	21	79	234	43	106	131	201	242	43	22	15	18
28	21	73	224	41	97	278	174	212	139	22	14	17
29	19	88	227	45	---	379	205	182	237	25	12	17
30	20	103	190	73	---	379	222	159	234	28	15	16
31	20	---	143	89	---	372	---	147	---	30	17	----
MEAN	21.4	65.8	129	64.9	98.7	164	321	268	115	49.8	21.0	17.0
MAX	29	105	255	116	186	379	451	498	237	221	34	38
MIN	19	25	60	38	44	89	174	103	35	22	12	9.1

DRAINAGE AREA=163 SQUARE MILES

Table A2: Mean daily discharge, in cubic feet per second, for the water year October 1982 to September 1983 in the Red Cedar River at the USGS gaging station near East Lansing, MI

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	62	57	236	279	205	208	760	540	339	462	55	38
2	55	92	219	247	198	202	705	980	311	411	57	36
3	51	170	264	222	403	194	820	1260	295	311	53	34
4	49	177	363	170	431	194	880	1190	387	219	49	31
5	42	135	399	180	283	198	790	1010	453	177	47	29
6	42	114	435	170	226	208	665	850	431	146	47	51
7	40	97	387	166	202	244	640	740	427	120	44	36
8	38	84	319	163	163	560	660	890	403	105	42	36
9	38	79	264	152	146	725	650	925	359	97	38	32
10	40	84	226	156	120	655	860	810	315	89	44	31
11	40	97	198	177	95	530	895	650	279	84	72	28
12	40	138	160	194	102	435	795	540	240	77	62	26
13	40	194	132	177	108	375	690	458	198	72	55	26
14	40	188	146	163	108	323	850	407	170	65	49	26
15	40	160	138	156	126	283	1080	367	160	65	42	26
16	40	138	174	89	146	250	1050	323	146	62	42	38
17	40	123	205	126	205	230	905	291	126	72	44	34
18	40	111	198	102	240	230	805	268	114	65	40	42
19	38	100	194	100	233	283	745	272	105	60	40	120
20	42	132	205	89	250	347	695	335	97	60	36	89
21	40	233	219	84	279	331	665	415	89	69	44	79
22	40	258	212	84	291	303	630	458	87	65	47	72
23	40	247	205	89	339	287	565	620	84	57	36	65
24	40	261	315	100	387	291	510	625	74	55	34	55
25	41	244	510	105	351	287	458	560	69	53	34	49
26	38	212	610	100	287	272	415	525	67	49	32	44
27	38	184	545	92	240	319	375	471	123	44	29	42
28	38	170	490	89	219	715	387	427	605	44	28	40
29	38	202	520	92	---	940	458	403	740	51	29	38
30	38	244	431	126	---	960	476	383	550	55	42	36
31	38	---	343	230	---	855	---	355	---	53	42	---
MEAN	41.5	158	299	144	228	395	696	592	261	110	43.7	44.3
MAX	62	261	610	279	431	960	1080	1260	740	462	72	120
MIN	38	57	132	84	95	194	375	268	67	44	28	26

DRAINAGE AREA=355 SQUARE MILES

Table A3: Mean daily discharge, in cubic feet per second, for the water year October 1983 to September 1984 in the Red Cedar River at the USGS gaging station near East Lansing, MI

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	34	47	208	92	74	132	399	291	540	34	23	16
2	34	53	174	92	74	146	351	250	448	34	23	16
3	32	65	149	95	82	132	307	230	379	34	38	16
4	32	67	135	97	92	123	279	212	303	32	26	17
5	34	65	129	102	102	123	299	205	230	32	24	18
6	34	62	142	105	105	120	379	191	191	36	24	17
7	34	60	156	105	97	97	419	180	166	34	40	21
8	38	55	117	100	92	79	387	177	142	32	91	20
9	38	55	149	100	89	100	347	174	129	31	38	20
10	38	55	149	92	89	102	307	166	120	34	38	21
11	36	62	156	89	126	89	268	163	108	65	31	28
12	38	62	268	84	323	79	247	160	95	49	26	24
13	62	62	466	84	645	87	254	177	87	44	23	38
14	74	60	476	84	905	92	268	194	79	36	21	34
15	72	62	431	82	720	102	343	198	77	34	20	49
16	60	87	375	79	555	323	411	188	72	31	18	38
17	53	114	315	79	495	530	471	174	67	28	18	34
18	51	117	219	79	480	431	610	166	65	26	20	29
19	47	111	142	79	462	347	645	163	62	26	18	28
20	44	120	163	84	431	323	585	166	60	26	16	26
21	44	129	180	87	383	525	515	174	57	24	15	26
22	51	126	152	92	335	705	458	214	53	24	15	24
23	60	177	135	87	295	660	466	331	51	24	14	23
24	65	244	126	77	268	565	520	435	49	23	14	23
25	62	226	114	69	240	610	540	448	49	24	14	36
26	57	191	100	72	216	730	505	640	44	24	12	40
27	55	163	97	77	194	730	453	715	42	26	13	49
28	51	208	97	77	174	650	411	680	40	26	14	51
29	49	268	100	77	123	570	363	695	38	28	14	47
30	47	247	97	77	---	510	327	700	34	28	15	42
31	44	---	95	74	---	444	---	635	---	24	15	---
MEAN	47.4	114	187	86.1	285	331	404	306	129	31.4	23.6	29.0
MAX	74	268	476	105	905	730	645	715	540	65	91	51
MIN	32	47	95	69	74	79	247	160	34	23	12	16

DRAINAGE AREA=355 SQUARE MILES
NOTE:PROVISIONAL DATA

Table A4: Mean daily discharge, in cubic feet per second, for the water year October 1983 to September 1984 in the Red Cedar River at the USGS gaging station near Williamston, MI

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	16	30	104	44	35	78	182	155	273	23	10	7.6
2	16	35	89	43	36	74	153	129	230	21	11	7.9
3	16	45	79	44	38	63	133	113	183	21	11	7.7
4	16	45	73	45	41	58	123	104	124	21	14	8.1
5	17	41	72	47	45	58	132	98	94	20	14	7.3
6	17	38	80	48	47	56	170	93	82	21	13	8.8
7	17	36	81	48	45	51	188	89	72	21	12	8.6
8	18	35	88	47	43	64	182	86	64	19	12	7.9
9	20	35	86	46	42	70	164	82	59	19	14	8.0
10	19	34	82	44	47	55	139	79	55	20	16	10
11	20	35	75	40	105	52	120	76	50	29	14	12
12	19	37	128	40	219	61	109	74	47	28	12	13
13	28	37	220	39	288	52	111	74	44	25	11	14
14	35	35	233	39	312	42	119	88	42	22	10	21
15	33	37	226	38	298	45	145	89	40	20	7.9	21
16	29	58	180	38	279	131	178	83	39	19	8.2	18
17	27	74	150	38	261	199	207	75	38	18	7.1	15
18	25	71	110	38	245	189	255	70	36	17	7.7	14
19	24	66	75	38	227	170	277	68	35	16	7.7	13
20	23	72	75	37	205	152	276	68	33	15	6.5	12
21	23	78	80	37	177	211	260	67	32	15	6.8	12
22	23	73	70	37	149	296	238	76	30	15	5.8	11
23	33	79	65	37	129	288	245	153	29	13	6.2	11
24	35	108	60	37	116	296	268	208	29	15	5.3	12
25	35	108	55	36	106	318	276	227	28	14	6.0	15
26	33	97	50	36	96	332	269	284	27	13	5.9	22
27	33	85	47	35	87	317	254	326	26	14	5.1	27
28	32	101	46	35	74	297	230	335	24	14	6.1	28
29	30	127	45	35	74	273	204	354	23	12	5.9	24
30	30	121	45	35	---	245	180	345	23	10	7.5	21
31	30	---	45	35	---	215	---	311	---	11	7.8	----
MEAN	24.9	62.4	94.0	39.9	133	155	193	144	63.7	18.1	9.27	13.9
MAX	35	127	233	48	312	332	277	354	273	29	16	28
MIN	16	30	45	35	35	42	109	67	23	10	5.1	7.3

DRAINAGE AREA=163 SQUARE MILES
NOTE:PROVISIONAL DATA

Table A5: Bailey population estimates of the numbers of rock bass in each age class at the Vanatta site (404meters) in 1983 and 1984 based on October mark-recapture electrofishing data

AGE	1983 POPULATION ESTIMATE		1984 POPULATION ESTIMATE
1	23		267
2	10		96
3	46		13
4	76		7
5	48	reproductive adults	10
6	44		17
7	2		1
8	5		2
Total # of adults	221		50

Table A6: End of the year numbers of young-of-the-year fish per meter squared of emergent vegetation captured by seining at Sherwood study site and the mean total length of fish captured in zone II by electrofishing in 1985

SEINING-Sherwood

NOVEMBER 1985	Rock Bass	Smallmouth
#/meter squared	.067	0
mean size(mm)	36.69	---
sd	1.95	---
N	7	0

ELECTROFISHING-Vanatta and Dobie Roads.

NOVEMBER 1985	Rock Bass	Smallmouth
#/meter squared	---	---
mean size(mm)	37.67	78.50
sd	1.53	6.61
N	3	4