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HABITAT USE AND DIET OF SMALLMOUTH BASS (Micropterus dolomieu) AND CATOSTOMID FISHES IN TWO WARMWATER RIVERS

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Michael Joseph Flaherty

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Major professor

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HABITAT USE AND DIET OF SMALLMOUTH BASS (*Micropterus dolomieu*) AND CATOSTOMID FISHES IN TWO WARMWATER RIVERS

By

Michael Joseph Flaherty

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ABSTRACT

HABITAT USE AND DIET OF SMALLMOUTH BASS (*Micropterus dolomieu*) AND CATOSTOMID FISHES IN TWO WARMWATER RIVERS

By

Michael Joseph Flaherty

Habitat use and diet were described for smallmouth bass (*Micropterus dolomieu*) and several catostomids, as preliminary information to determine if competition might occur between them in warmwater streams. Fish were sampled during the summer and fall from two rivers. Habitat utilization was determined by the use of a prepositioned electrofishing unit and underwater observations. I found that the use of depth, velocity, substrate and cover were most similar for juvenile smallmouth bass and adult northern hog suckers (*Hypentelium nigricans*) in the Red Cedar River and juvenile smallmouth bass and at least one life stage of either white sucker (*Catostomus commersoni*) or northern hog sucker in the Flat River. Sucker and smallmouth bass diets were significantly different, however, overlap occurred. Competition for food might occur if preferred prey is limited. Future studies into competitive interactions between smallmouth bass and catostomids should be directed at diet and habitat utilization associated with varied fish densities.

For my wife, Liss, and two boys, Ryan and Jacob, who more than anyone, have knowingly or unknowingly shared in the sacrifice, and given the support, needed for me to finish.

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Field and laboratory work would have been impossible without the around the clock help of Dean Pinzino, Rich Tryon and Kevin Shinn. Often field work would have been canceled if it was not for the host of undergraduate students, graduate students, professors, professionals and my wife who were all willing to stand in, without compensation, to round out my field crew.

Finally, I thank all the staff of New York State's Department of Environmental Conservation Bureau of Fisheries. For without their support, encouragement, advice and flexibility my finishing this thesis would have been difficult.

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INTRODUCTION

Warmwater streams are becoming increasingly recognized for their fishing value, in particular for smallmouth bass (*Micropterus dolomieu*). Some states, like Michigan (Department of Natural Resources, DNR), have initiated a series of fisheries investigations of these systems.

Some have hypothesized that interactions between smallmouth bass and catostomids (suckers) may limit bass populations in warmwater streams. Recent rotenone surveys on some of Michigan's southern streams by the Michigan DNR have revealed much higher densities of suckers than was once believed to exist (Personal Communication, 1988, P. W. Seelbach, Michigan Department of Natural Resources, Ann Arbor). Despite mixed findings, there is evidence of high sucker densities in lake and cold-water stream environments having a negative impact on coexisting fish populations (Rawson and Elsey 1950; Flick and Webster 1975; Holey et al. 1979; Magnan 1988; Hayes et al. 1992). The ecological effects of high densities of suckers on coexisting warmwater stream fish populations are unknown.

The description of diet and habitat use of smallmouth bass and suckers in warmwater streams is a necessary first step in evaluating interspecific interactions between these fish. Young of the year (YOY) smallmouth bass have been found to feed primarily on zooplankton and benthic invertebrates (Surber 1939; Scott and Crossman 1973; Coble 1975; George and Hadley 1979; Dowling 1987; Aadland et al. 1989). The diet of some size classes of suckers (Scott and Crossman 1973; Eder and Carlson 1977; Ahlgren 1990) may be similar to what has been found in YOY smallmouth bass. Larger smallmouth bass have been found to consume mostly fish and crayfish (Scott and Crossman 1973; Coble 1975; Probst et al. 1984). Smallmouth bass and suckers have naturally coexisted in Michigan rivers (Hubbs and Lagler 1958), and Scott and Crossman (1973) report that competition is unlikely between bass and suckers. When sucker densities become very high, however, sucker choice of habitat could locally deplete food resources or displace other fishes.

Studies describing habitat use, diet, growth and relative abundance concurrently for coexisting smallmouth bass and catostomids are needed to evaluate hypotheses about the effects (positive or negative) of suckers on smallmouth bass populations.

For this study two streams in the south-central portion of the lower peninsula of Michigan were chosen to achieve the following three objectives: (1) to determine habitat use by smallmouth bass and catostomids of all size classes throughout the day and night from July through October, (2) to describe the diet of smallmouth bass and catostomids of all size classes, and (3) to test for differences between habitat use and diet of all size classes of smallmouth bass and suckers.

Description of Rivers and Study Sites

I sampled fish and habitat characteristics from two warmwater tributary streams of the Grand River, Michigan (Figure 1). The two streams chosen for this study, the Red Cedar and Flat Rivers, are quite different, as explained below.

Red Cedar River

The Red Cedar River begins as the outflow of Cedar Lake in Livingston County. From its origin to its confluence with the Grand River, in the City of Lansing, the Red Cedar River is impounded several times over its 79.3 km length. The gradient of the main channel is relatively gradual from its source at Cedar Lake, at an elevation 284.9 m above sea level, to 249.2 m at its confluence with the Grand River, for an average fall of 0.45 m/km (Dowling 1987). The flow in the Red Cedar River can fluctuate greatly, which is typical of many warmwater streams. Mean April flow at East Lansing is 499 cfs while mean August flow is 52 cfs. Groundwater input is low for the Red Cedar River with most of its flow coming from runoff. Mean August base flow per acre is 0.00023 cfs. Agricultural and urban development on top of only moderately permeable soils are the cause of

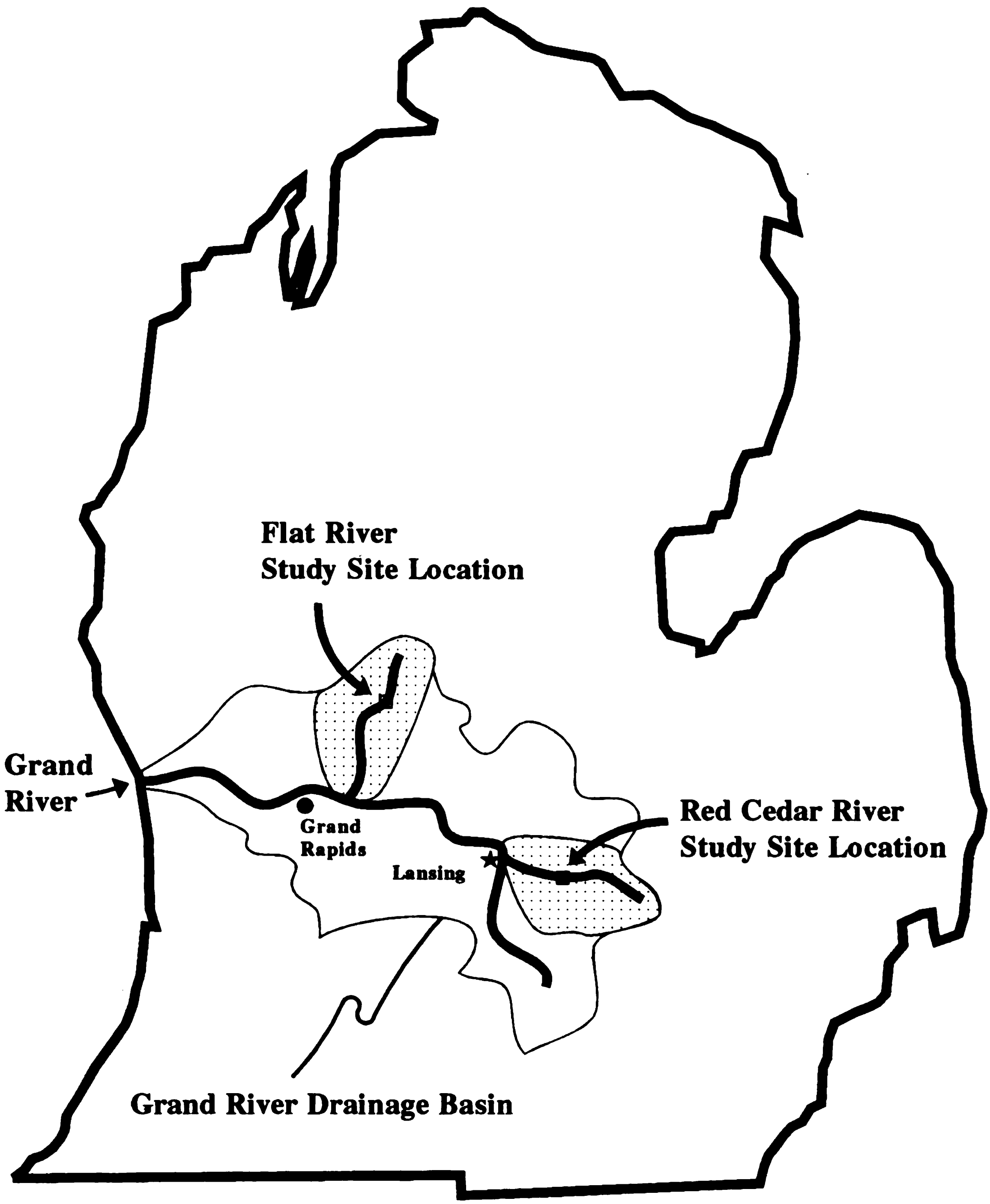

Figure 1. Flat and Red Cedar River study site locations. Also shown are the corresponding drainage basins for each river and their relative location within the Grand River drainage basin.

this.

A 1000 m section of the Red Cedar River approximately 1000 m downstream from the Zimmer Road bridge near Williamston, N½, SW¼, Sec. 27, R1E, T4N, Ingham County was chosen for study in 1988. Linton and Ball (1965) described this section from the Zimmer Road bridge downstream 13.7 km as having a sand bottom in a large portion and gravel and boulders in most of the remaining portion. There are no urban areas in this part of the river except for Okemos at the extreme lower end. Gradient for the section surrounding this site was determined to be 0.278 m/km.

Due to sampling gear limitations and inherent problems with the habitat use determination methods employed in 1988 a new, smaller, section of each river was needed in order to use improved methods for 1989. The section of the Red Cedar River that was used in 1988 proved to be too deep for adequate electrofishing at all times of the year. This section also did not have a good mixture of run, riffle and pool sections within close enough proximity of one another for the new method that was to be used. A 400 m section 3 km upstream of the Grand River Avenue bridge at Meridian Park, Okemos, S½, NW¼, Sec. 28, R1E, T4N, Ingham County, was found to satisfy the above needs and was used for the 1989 field season. This section had moderately deep runs, a small deep pool in the center and a 60 m riffle at the upper end.

Flat River

The source of the Flat River is from several lakes in the area of Six Lakes, northern Montcalm County. From its origin to the confluence with the Grand River in Lowell, Kent County, the river is approximately 109.48 km in length. Water draining from springs and marshes keep stream flows fairly stable. Mean April and August flows at Smyrna are 763 cfs and 255 cfs. Mean August base flow per acre is 0.00076 cfs. Despite the higher base flow per acre, water temperatures fluctuated more in the Flat River in the summer of 1988 (a drought year) than in the Red Cedar River. Minimum daily temperatures were consistently lower however in the Flat River during this time period. Land use within its drainage is typically agricultural. Most of the stream is bordered by riparian vegetation and runs through sandy glacial-outwash soils. This results in the Flat River being described as a relatively clear stream, quite different from many of the other Grand River tributaries.

Two sections totaling 2000 m of the Flat River, N½, Sec. 19, R7W, T11N, between the Miller Road and Lake Road bridges, between the towns of Langston and Entrican, Montcalm County were chosen in 1988. These sections are in the same portion of the river used and described by Rankin (1986). This section is typically shallow, with long shallow pools, and has runs with moderate vegetation. One 30 m riffle exists in the lower section. In 1988 a 20 m study site within a run section with good substrate and structural cover diversity was chosen to perform underwater observations for assessment of microhabitat use by suckers and smallmouth bass young of the year.

The corresponding 1989 section was started 270 m upstream from the Lake Road bridge and continued upstream 400 m.

METHODS

Habitat Use and Availability

In 1988 I used underwater observations to assess habitat use of suckers and smallmouth bass in the Flat River. The Red Cedar River proved to be too turbid for underwater observations. In 1989 I used a prepositioned electroshocking unit to randomly sample areas for habitat use and availability determinations in both rivers.

1988

A 20 m long study site within the lower sample section of the Flat River was chosen to perform underwater observations for the assessment of microhabitat use by suckers and smallmouth bass. This section appeared to have good numbers of young smallmouth bass and suckers in early June. This section was primarily run habitat with good substrate and cover diversity.

The available habitat within this section was determined the day prior to underwater observations in the following manner. The study section was divided into twenty transects perpendicular to the thalweg. Each month a total of thirty points along these transects were randomly selected. At each of these chosen points the available physical habitat was determined by measuring mean water column depth, current velocity, substrate composition, and cover in a 400 cm^2 quadrant.

Depth was measured at four locations within each quadrant. Current velocity was measured in the center of the quadrant at the depth of 0.6 of water depth as the standard single estimate of mean water column velocity (Bovee and Milhous 1978). When water depth was greater than 0.75 m or obstructions made a 0.6 depth velocity reading uncharacteristic for the site, depths of 0.2 and 0.8 of water depth were taken, and the readings averaged, to give an estimate of mean water column velocity.

Substrate size was estimated using a modified Wentworth scale (Bovee and Milhous 1978). The percentage of each substrate type was recorded visually and dominant substrate type was used for habitat use and availability comparisons. The dominant substrate was defined as the substrate comprising the greatest percentage of the quadrant. Cover categories included open water, large rocks and boulders, vegetation or sticks, single log, and complex (two or more of the above, stream edge or undercut bank).

The day after habitat availability was measured underwater observations were made in the same area to determine habitat use by fish. Flows remained stable between habitat use and availability measurements. Using a mask and snorkel, I moved slowly upstream through the area in a zigzag pattern. The locations of undisturbed smallmouth bass and suckers were marked with lead weight markers affixed with fluorescent tape. I immediately recorded the estimated length of the fish and its distance from the bottom. After the area was thoroughly observed, water column depth, mean current velocity, focal point velocity, percent composition of substrate, and cover in a 400-cm^2 quadrant directly around the marked fish was measured.

Frequency of occurrence distributions for the use and availability of mean depth, mean current velocity, dominate substrate, and cover were compared in several ways. Chi-square tests were used for most comparisons despite the fact that many of the contingency tables had more than 20% of the habitat categories with less than five observations. Conventionally this would not meet the criteria needed for the test to be valid (Brase and Brase 1983). Nue et al. (1974), however, cited Roscoe and Byars (1971) as stating that if the overall average of all intervals is six or more then the test may be considered valid (for the 0.01 level of significance of the test).

A chi-square test of independence was used to determine if available habitat was independent of sampling period. In the first test the distributions from all sample periods were included in a contingency table. When a difference was detected (χ^2: $P<0.05$) then sample periods within summer and fall were tested. If availability distributions within a season were similar (χ^2: $P>0.05$), the data were combined.

Habitat use distributions for each sampling period were combined, within season, when habitat available was tested as similar between those periods. A chi-square goodness-of-fit test was used to test for a difference between habitat use and availability. When use was different (χ^2: $P<0.05$), or chi-square assumptions could not be met, an electivity index was used to determine which intervals differed most.

An electivity index described by Strauss (1979) was used to measure the fish's selection or avoidance of intervals within habitat variables. For each interval of a habitat variable's distribution the electivity (L) is:

$$L = r - p;$$

r is the proportion of all the observations of a size class of a species that used the microhabitat interval and p is the percentage available in the study section. Electivities were incorporated into the habitat use frequency distributions by subdividing them as Moyle and Baltz (1985) did:

-1.00 to -0.50	strong avoidance	**(--)**;
-0.49 to -0.26	moderate avoidance	**(-)**;
-0.25 to +0.25	neutral selection	**(0)**;
+0.26 to +0.49	moderate selection	**(+)**;
+0.50 to +1.00	strong selection	**(++)**.

When habitat available was similar between seasons a chi-square test of independence was used to determine if use was independent of season. If a difference was detected or chi-square assumptions could not be met *L*-values were used to determine which intervals differed the most.

1989

In 1989 I used a prepositioned electroshocking unit to sample discrete habitats. This method was chosen for 1989 because of the following advantages over underwater observations (Larimore and Garrels 1985; Bain et al. 1985; and Bain 1988): fish position is not altered due to fright response or attraction to a diver, visibility problems (i.e. water clarity, daylight and complex cover types) does not limit its use, and fish can be collected for measurement, age determination and identification.

Run, riffle, and pool habitat types were characterized according to guidelines found in Orth (1983). Habitat types were located and mapped in one 400 m section of each stream. Transects were created across the section at 8-m intervals perpendicular to the thalweg by driving stakes above the high water mark (or at the highest point that the stream would still be wadable), on each side of the stream. Each stake was consecutively numbered and affixed with a small piece of reflective tape to aid in locating it with a flashlight at night. Cells, 8 m by 1.5 m, parallel to the thalweg, were formed by measuring across each transect at

1.5 m intervals. Each cell was then categorized as either run, riffle or pool based on the earlier map and given a unique identification number (Figure 2).

A prepositioned area electrofishing device (Figure 3) driven by a 230 volt, 3250 watt AC generator was used to capture fish from the 12 m^2 (1.5 m x 8 m) area cells. Alternating current was chosen because it does not have the galvanotaxis properties of direct current. The lack of galvanotaxis is essential to the habitat use study since only fish in the discrete area being shocked are of interest since this is where habitat parameters are measured. This device was modified from similar units designed by Bain et al. (1985) and Aadland et al. (1989).

Sites (cells) sampled within the 400 m stretch of stream were chosen through a stratified random sample of the three habitat types. Each month an independent set of sample sites was chosen randomly for each day and night. Twenty sites (five riffles, five pools, and ten runs) for the Flat River and twenty-two sites (two additional run sites) for the Red Cedar River were sampled once during the night and once during the day during each month from July through October. The number of sampled cells for each habitat type arbitrarily decided upon based on the availability of that habitat type and time constraints.

Each of the cells was sampled in random order. This was time consuming because it often required walking from one end of the site to the other several times. However,

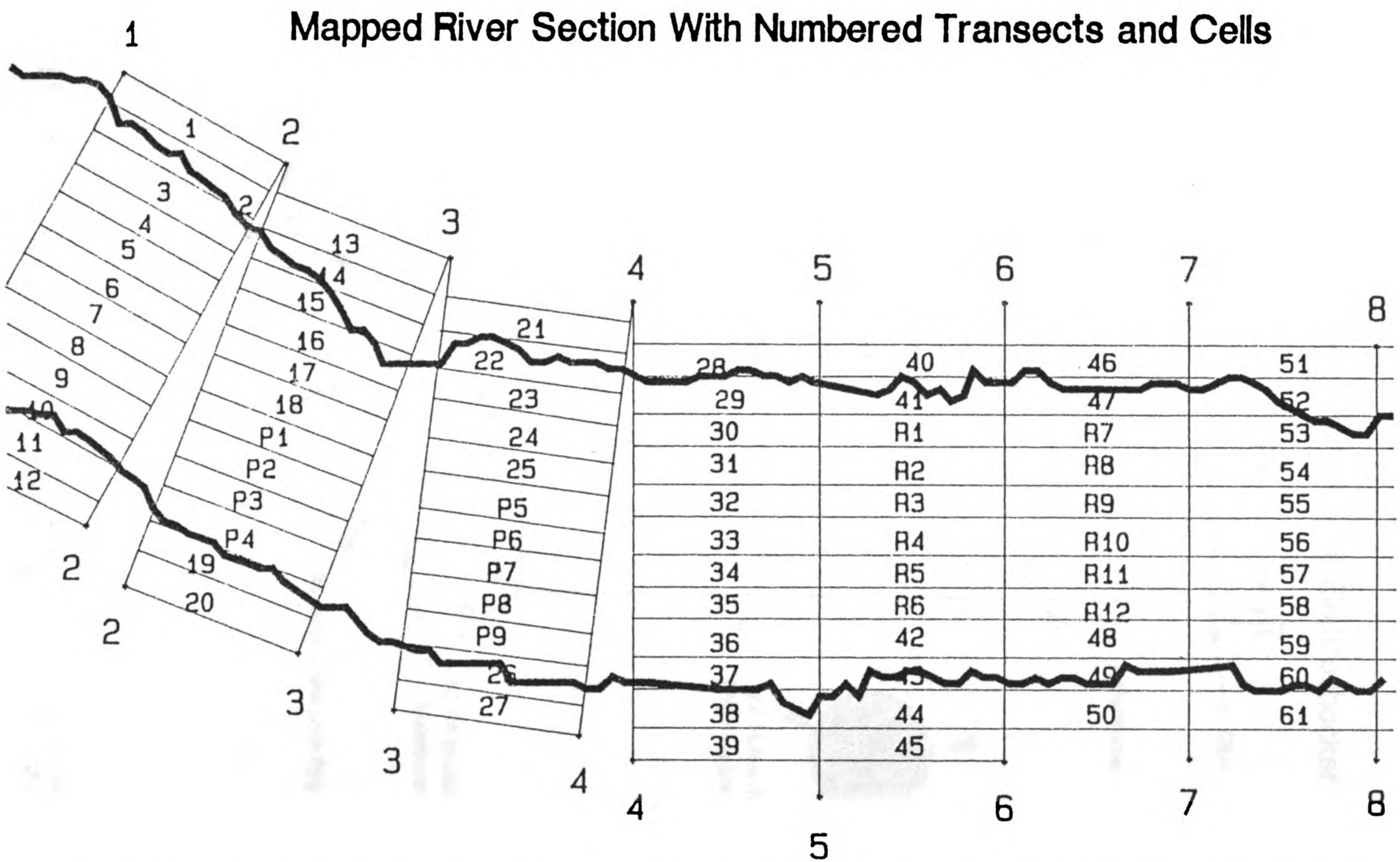

Figure 2. A hypothetical example of a mapped river section showing transects and unique identification numbers for run (1-60), riffle (R1-R12) and pool (P1-P9) cells.

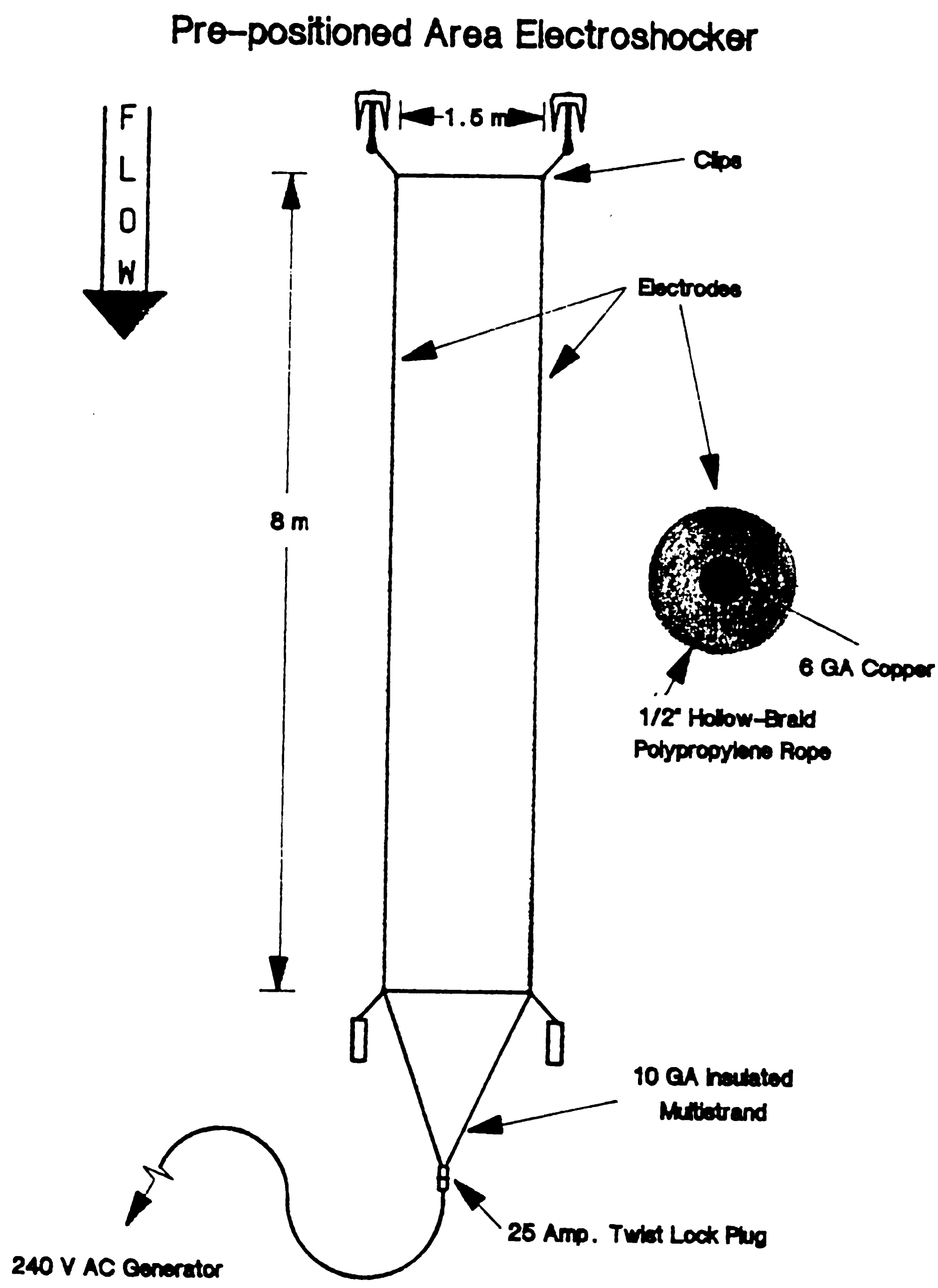

Figure 3. Diagram of the prepositioned area electrofishing device used for sampling discrete habitat sites.

it alleviated bias associated with the possible fright response of fish to the investigators systematically working their way through the stream.

In order to consistently find the sample cells, the distances between transect stakes (visible in the bank over the term of the study) were used to locate the four corners of the site. Each corner of the sample cell was temporarily marked with either wire flags, 1.5 m steel dowels or lead weights with streamers attached. The anchors attached to the unit were then set so that the unit was spread to the respective corners of the marked site. The markers were then removed except when the boundaries of the unit were not visibly obvious. Once the unit was set, it was left undisturbed in the stream for a minimum of 12 minutes. This period of time was necessary to allow the fish to return to the area after initial disturbance and resume their presumed natural behavior. Bain et al. (1985) determined that no significant difference was detected between waiting eleven minutes and up to 89 minutes from when the area was initially disturbed.

A crew of at least three people used the unit. One person was stationed at the generator and was in control of the electric flow to the unit. The other two were stationed downstream of the electrodes with a 2-m wide bag-seine net (Figure 4). The distance the net was held downstream from the electrodes was determined by the net holders and generally was as close to the electrodes as thought possible

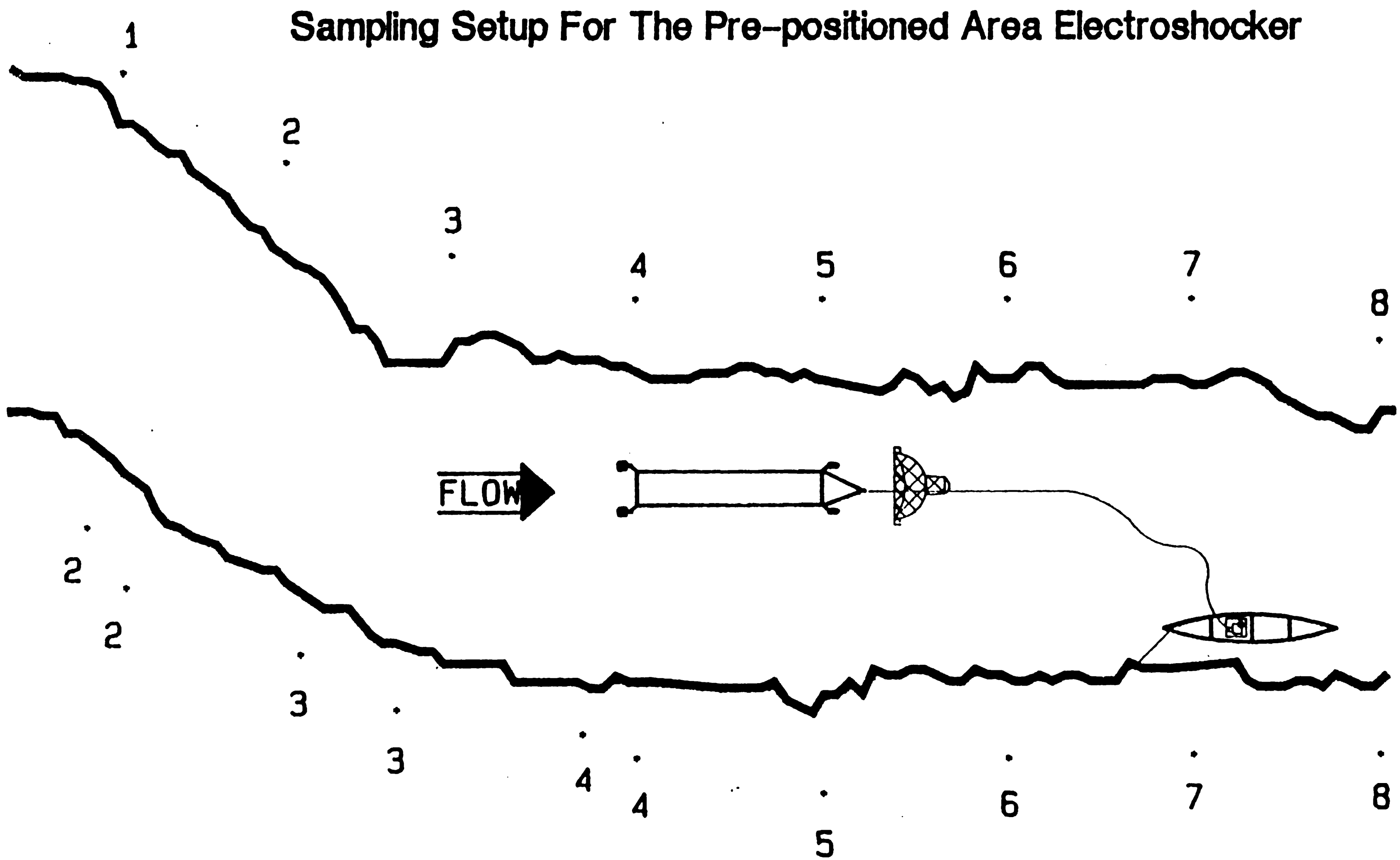

Figure 4. Sampling setup of the prepositioned area electroshocking unit.

without being detected by the fish (approximately 0.5 to 3.5 m). Each net holder, when possible, also used a dip net to capture fish as quickly as possible. Once the crew was in place, the unit was plugged into the generator and the electric current was applied to the unit for twenty seconds. The unit was then unplugged and the generator shut off before the generator tender joined the other crew members in collecting fish. This third person would go into the sampled site and, using a dipnet, hands, or feet, probe the bottom for other fish and guide them into the downstream net. During dark sampling periods a hand held, battery powered, 500,000 candle power spotlight and smaller waterproof flashlights were occasionally used to aid in finding shocked fish. With time we felt this was not necessary.

I recorded species of all fish caught along with the lengths and weights of smallmouth bass and suckers. Data for each species were divided into three size classes based on a modification of life stage sizes determined by Aadland et al. (1989)(Table 1).

The sampling system was designed to assess habitat use by size group according to season [summer (July and August), fall (September and October)], and time of day [daylight (0.5 hour after sunrise to 0.5 hour before sunset), and night (0.5 hour after sunset to 0.5 hour before sunrise)]. Habitat parameters (mean current velocity, mean water column depth, percent composition of substrate and structural cover) were recorded within the area shocked to determine habitat use. Also, due to the random selection of sites, these data were also used for a measure of available physical habitat and an estimate of fish abundances.

The stratified random sampling method required a method of weighting each run, riffle and pool sample due to nonproportional sampling effort. Random observations of resource availability and observations of fish habitat use were treated similarly. The weighted frequency (f_j) in interval j of a frequency distribution is:

$$f_j = \sum (L_i/l_i)\, n_{ij} \;;$$

i = habitat type (e.g., 1 = run; 2 = riffle; 3 = pool); j = some interval in the distribution of a variable such as mean water column velocity (e.g., 0-0.2 m/s); n_{ij} = number of observations in habitat type i at the jth interval; L_i = total area of habitat type i; and l_i = area of habitat type i sampled (Baltz 1990). These weighted proportions were converted to weighted observations by multiplying the calculated proportion for each habitat interval by the sample size.

A chi-square test of independence (SAS 1985) was used on the weighted observations to test if distributions of habitat available were independent (P=0.05) of sampling period. As with the 1988 data, most of these comparisons had more than 20% of the habitat intervals with less than five observations. Therefore the more liberal criteria of Roscoe and Byars (Neu et al. 1974) were also used for the

Table 1. Length groups (mm total length) used for three size classes of smallmouth bass and each species of sucker collected, modified from Aadland et al. (1989).

Common Name	YOY	Juvenile	Adult
Smallmouth bass	<100	100 - 189	>189
White sucker	< 70	70 - 155	>155
Northern hog sucker	< 75	75 - 151	>151
Golden redhorse sucker	<100	100 - 251	>251

1989 analysis.

Habitat utilization distributions often did not meet the criteria of a chi-square goodness of fit test for comparisons of use between seasons and time periods. Sample sizes were typically too low to give an overall average for all intervals of six or more expected observations. For this reason electivity indices were used to illustrate the selection or avoidance of habitat intervals. Electivities were not reported for sample sizes less than five.

A Chi-square analysis was used to test the null hypothesis that the distribution of habitat intervals for all time periods combined was independent of fish species and size class. A contingency table of weighted observations was used. A decomposition of the contingency table, as described by Freeman (1987), allowed for individual size classes of fish to be removed or combined until the critical value ($P = 0.05$) was reached. Those species size classes remaining were considered to have similar distributions.

Diet

In 1988 I collected fish by electrofishing monthly from July through October in the Flat River and in July and August in the Red Cedar River. Flow conditions were too high for effective and safe electrofishing in September and October in the Red Cedar River. The electrofishing equipment consisted of a 230 volt, 3500 watt, direct current generator mounted in a small hull-negative boat with two hand held positive electrode wands. A crew of at least three people made one pass through the entire section(s) of each river and fish were dip netted as they were stunned. In 1989 I collected fish as sites were electrofished for habitat use determination using a prepositioned area electroshocking unit.

Smallmouth bass and suckers were processed as quickly as possible for future analysis of stomach contents. Length and weight of all suckers and smallmouth bass were recorded. Approximately 20% of the suckers sampled were immediately packed in ice for further processing. Smallmouth bass stomach contents were obtained by stomach flushing.

Stomach flushing was conducted using the following procedures. A rubber suction bulb affixed with a piece of teflon tubing of an appropriate diameter for the fish was inserted down the esophagus and into the stomach. Water was forced into the stomach from the rubber bulb and back out of the mouth so the contents could be collected in a plastic jar. The jar was then immediately packed in ice.

Several bass, inadvertently killed during collection and processing, were dissected after their stomachs were flushed. I found the above method to be efficient in removing all of the stomach contents from the smaller bass.

Some problems were encountered with flushing crayfish from the stomachs of larger bass. This may have resulted in biased diet data for some of the larger bass in 1988. Stress to the fish caused by trying to remove these larger prey items was evident. To alleviate this unnecessary stress the larger fish many times were released and the larger prey items, when visible, were noted as not being removed.

In 1989 I used an alternative method (Personal Communication, 1988, Luther Aadland, Minnesota Department of Natural Resources) for larger smallmouth bass. A polished PVC tube of appropriate diameter (up to 20 mm diameter) was inserted down the esophagus and into the stomach of the bass. The tube was filled with water, the end loosely sealed with the palm of the hand, and the tube removed. This dislodged the larger contents and the stomach was then flushed in the same manner as in 1988.

In the laboratory the entire gastrointestinal tract was removed from the sacrificed suckers and placed in water-filled jars. All smallmouth bass and sucker stomach samples were stored in a freezer.

All diet items from all smallmouth bass stomach content samples were identified and counted. The sucker gastrointestinal tracts, however, were subsampled due to the difficulty found in identifying and counting diet items. Only the foregut, up to the first bend, of each sucker tract was examined for diet items. This allowed for easier identification of prey items since they had been digested for a shorter time. This also reduced the volume of contents examined and therefore saved time.

The diet items for all fish were categorized into ten broad groups based primarily on the habitat where that food item normally resides. Groups of Surface, Riffle, Pool, Chironomid, Crayfish, Fish, Other, Unknown, Detritus, and Zooplankton were used (Table 2). Habitat groups for aquatic insects were determined, in part, by using the ecological descriptions provided by Merritt and Cummins (1984).

The data were presented as both percent occurrence and percent composition. Percent occurrence of a diet group was calculated as the percentage of stomachs (not including empty stomachs) that contained at least one representative diet item from that group. Percent composition was calculated by dividing the number of organisms found of a given group by the sum of all the organisms found in all the stomachs.

Detritus could not be enumerated, and zooplankton were often in poor condition and could not be reliably counted. We therefore visually estimated the percent volume of these diet items. This did not affect the calculation of percent occurrence but percent composition could not be calculated or statistically tested with the other diet groups. The average percent volume of detritus and zooplankton (for all stomachs) were reported instead.

A chi-square analysis was used to test the following null hypothesis: that the distribution among the number of diet items found for each diet group was independent of fish

Table 2. Diet items, and their respective diet group, found in the stomachs of suckers and smallmouth bass. Aquatic insect habitat associations based on the ecological descriptions of Merritt and Cummins (1984).

SURFACE

Order Odonata (Adult)
Order Hemiptera
  Gerridae
Order Coleoptera
  (Terrestrial)
 Suborder Adephaga
  Gyrinidae
Order Hymenoptera
  Vespidae
  Formicidae
Spiders (terrestrial)
Water Mites (Hydracarina)

RIFFLE

Order Ephemeroptera
  Siphlonuridae
  Baetidae
  Oligoneuriidae
  Heptageniidae
  Ephemerellidae
  Leptophlebiidae
Order Plecoptera
  Pteronarcyidae
  Perlidae
Order Trichoptera
  Hydropsychidae
  Hydroptilidae
  Limnephilidae
Order Lepidoptera
  Pyralidae
Order Coleoptera
 Suborder Polyphaga
  Psephenidae
   (Dascillidae)
  Elmidae
Order Diptera
  Tipulidae
  Simuliidae
Order Amphipoda (Scuds)
  Gammaridae

CRAYFISH

Crayfish

FISH

Various species

ZOOPLANKTON

Cladocera
Copepoda

POOL

Order Ephemeroptera
 Ephemeridae
   Ephemera spp.
   Hexagenia spp.
  Tricorythidae
  Caenidae
  Polymitarcyidae
Order Odonata
 Suborder Anisoptera
  Gomphidae
  Unknown
Order Hemiptera
  Corixidae
Order Coleoptera
 Suborder Polyphaga
  Hydrophilidae
Vegetation and Wood

OTHER

Order Ephemeroptera
 *Ephemeridae
  Unknown
Order Odonata
 Suborder Zygoptera
  Calopterygidae
  Coenagrionidae
  Unknown
Earthworms
Leeches
Shells
Eggs
Debris

* Except Ephemera spp. and Hexagenia spp. which are in the pool group

CHIRONOMID

Order Diptera
  Chironomidae

DETRITUS

Detritus

UNKNOWN

Unknown Order Plecoptera
Unknown Order Hemiptera
Unknown Order Trichoptera
Unknown Order Lepidoptera
Unknown Order Coleoptera
Unknown Order Diptera
Unknown

species and size class. A contingency table was set up with the observations within in each cell being the total number diet items of a diet group found in all the stomachs of a given species size class over the course of the study. A decomposition of the contingency table, as described by Freeman (1987), allowed for individual size classes of fish to be removed or combined until the critical value (P=0.05) was reached.

Growth Rates and Abundance Estimates

Scale samples from the area mid-way between the lateral line and directly below the emargination of the dorsal fin of the smallmouth bass were taken for age analysis (Ambrose 1983). Scales were aged by three individuals. Final age determination was discussed between the three people when discrepancies arose in order to reach a consensus. I calculated mean length at age for each month in each year.

For the 1989 field season abundance estimates were taken throughout the summer. The abundance estimates were obtained through the use of the prepositioned electrofishing device described above. For each habitat type (run, riffle, pool) the number of fish collected for all the sites within that habitat was divided by the area that was actually sampled to obtain a density. The overall abundance for the study section was calculated by weighting the above fish/hectare of habitat by the percent composition of that habitat type within the section and summing the results of each habitat type. This calculation involves essentially the same weighting as for habitat use and availability (Baltz 1990).

RESULTS

Habitat Availability

Available habitat did not remain constant over the study period. In 1988 available depths and current velocities in the Flat River differed (χ^2: $P<0.05$) between summer and fall sampling periods (Figure 5). Within summer and fall periods depths were similar. I therefore combined both availability and use data for these periods. Dominant substrate and cover types were similar between all four sampling periods in 1988 (χ^2: $P>0.05$) and all periods were combined (Figure 6).

Available dominant substrates in the Red Cedar River and available depths and average current velocities in the Flat River similar (χ^2: $P>0.05$) between summer and fall 1989 (Figures 7 and 8). Aquatic macrophytes became very abundant over the course of the summer in the Red Cedar River and then started to die during the last days of the fall sampling period. I believe this is the primary reason for available cover differences in the Red Cedar River between seasons. Available habitat between day and night for both rivers were comparable for all four habitat variables (χ^2:

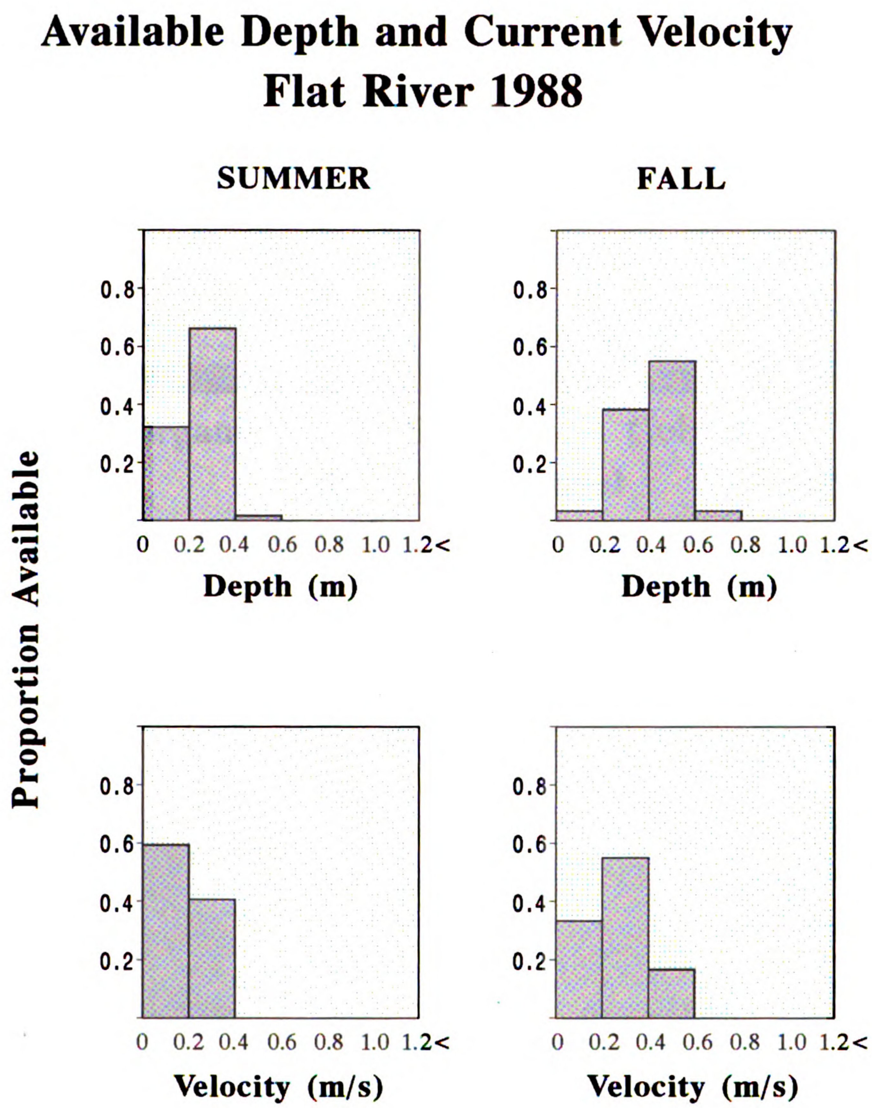

Figure 5. Available depths and current velocities for the summer and fall sampling periods in a 20 m section of the Flat River 1988. Distributions were different between seasons at the 0.05 level of significance (χ^2).

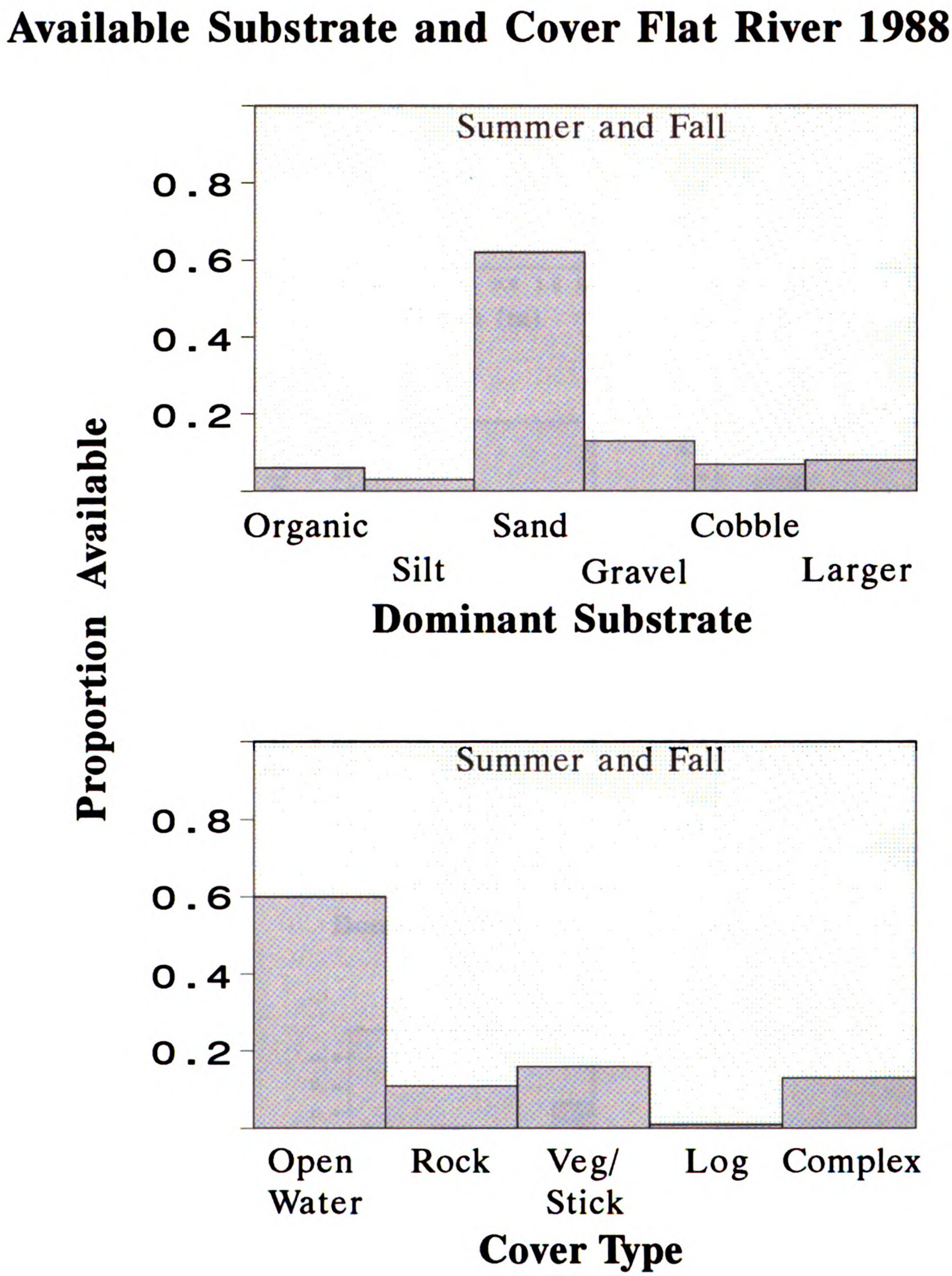

Figure 6. Available dominant substrate and cover (all sampling periods combined) in a 20 m section of the Flat River 1988. Summer and fall distributions were similar at the 0.05 level of significance (χ^2).

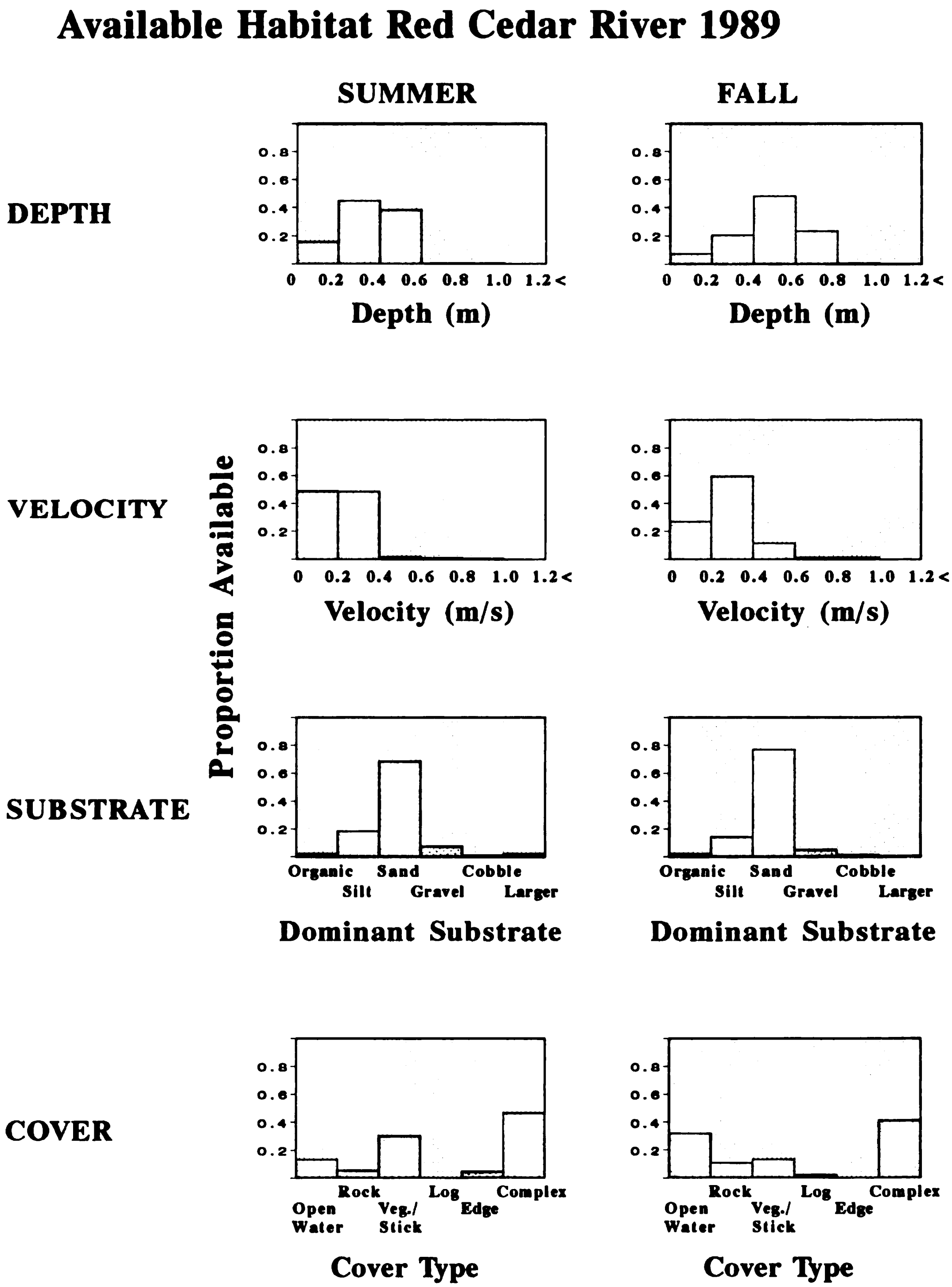

Figure 7. Available depth, current velocity, dominant substrate and cover for the summer and fall sampling periods in a 400 m section of the Red Cedar River 1989. Dominant substrate was similar (χ^2: $P > 0.05$) between summer and fall.

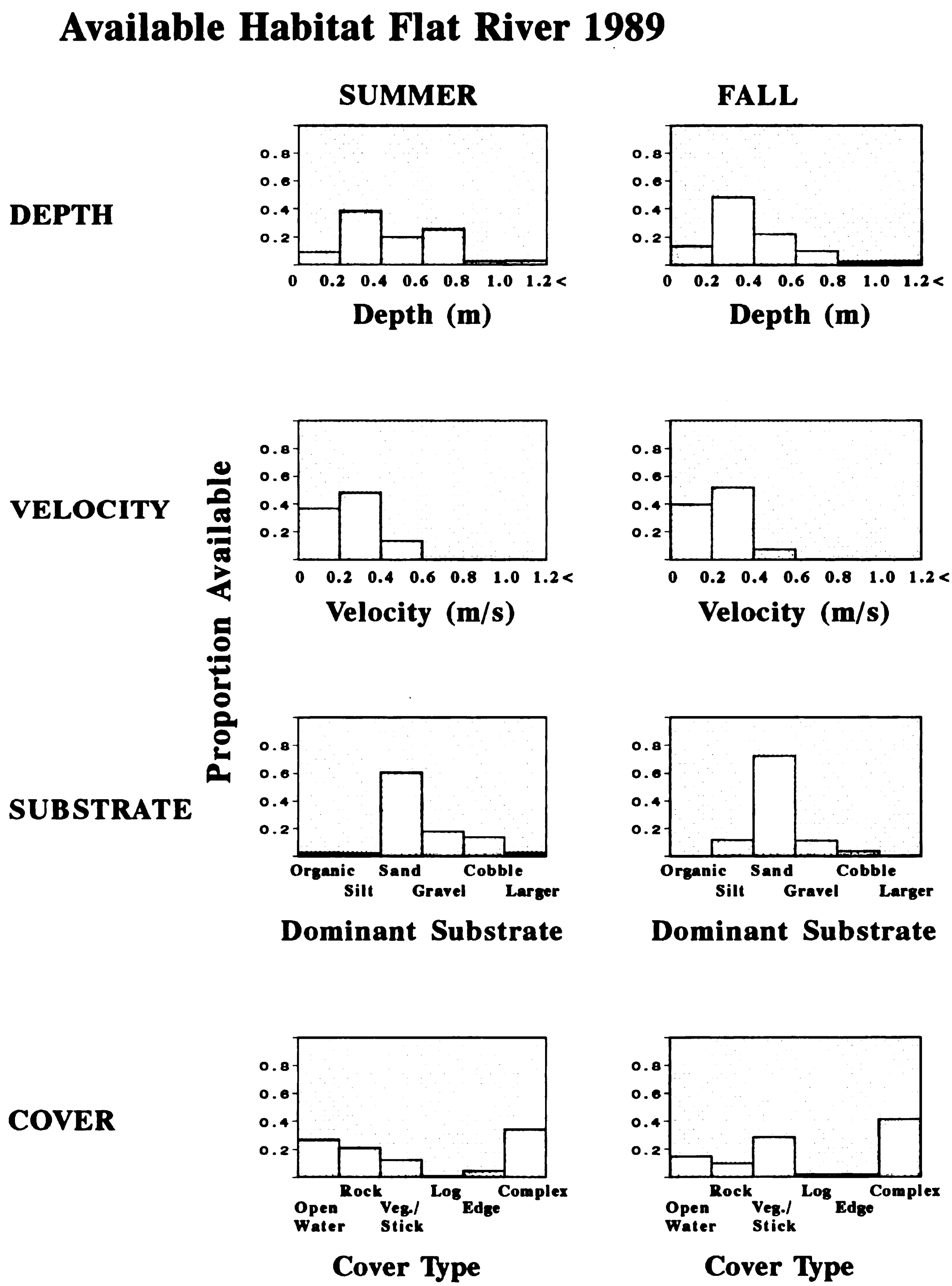

Figure 8. Available depth, current velocity, dominant substrate and cover for the summer and fall sampling periods in a 400 m section of the Flat River 1989. Depth and current velocity were similar (χ^2: P>0.05) between summer and fall.

$P>0.05$).

Habitat Use

Smallmouth bass, white sucker and northern hog sucker habitat use was determined for 1989 however YOY, juvenile and adult size classes were not always represented. Data from 1988 was limited to smallmouth bass YOY.

Smallmouth bass

I found that smallmouth bass use slow, shallow water early in life and deeper, faster water as juveniles and adults (Figures 9 and 10). The Dominant substrate used was sand, with other types in proportion to that available (i.e. *L*-index category=0 across all substrate types: Figure 11). Most life stages used areas with cover more than areas of open water, with the exception being Red Cedar River adults (Figure 12). These adults selected open water habitats that were deep but devoid of cover.

I found that YOY smallmouth bass primarily used depths between 0.2 and 0.6 m, which were proportionate to that available in both rivers, (based on *L*-indices: Figures 9 and 13). All 52 YOY smallmouth bass observed in 1988 were within 0.12 m of the bottom with 94% being within 0.05 m of the bottom. Red Cedar River YOY selected (see *L*-indices) water between 0.4 and 0.6 m in the fall (Figure 14) and had the tendency to move into shallow (less than 0.2 m) water during the nights (Figure 15).

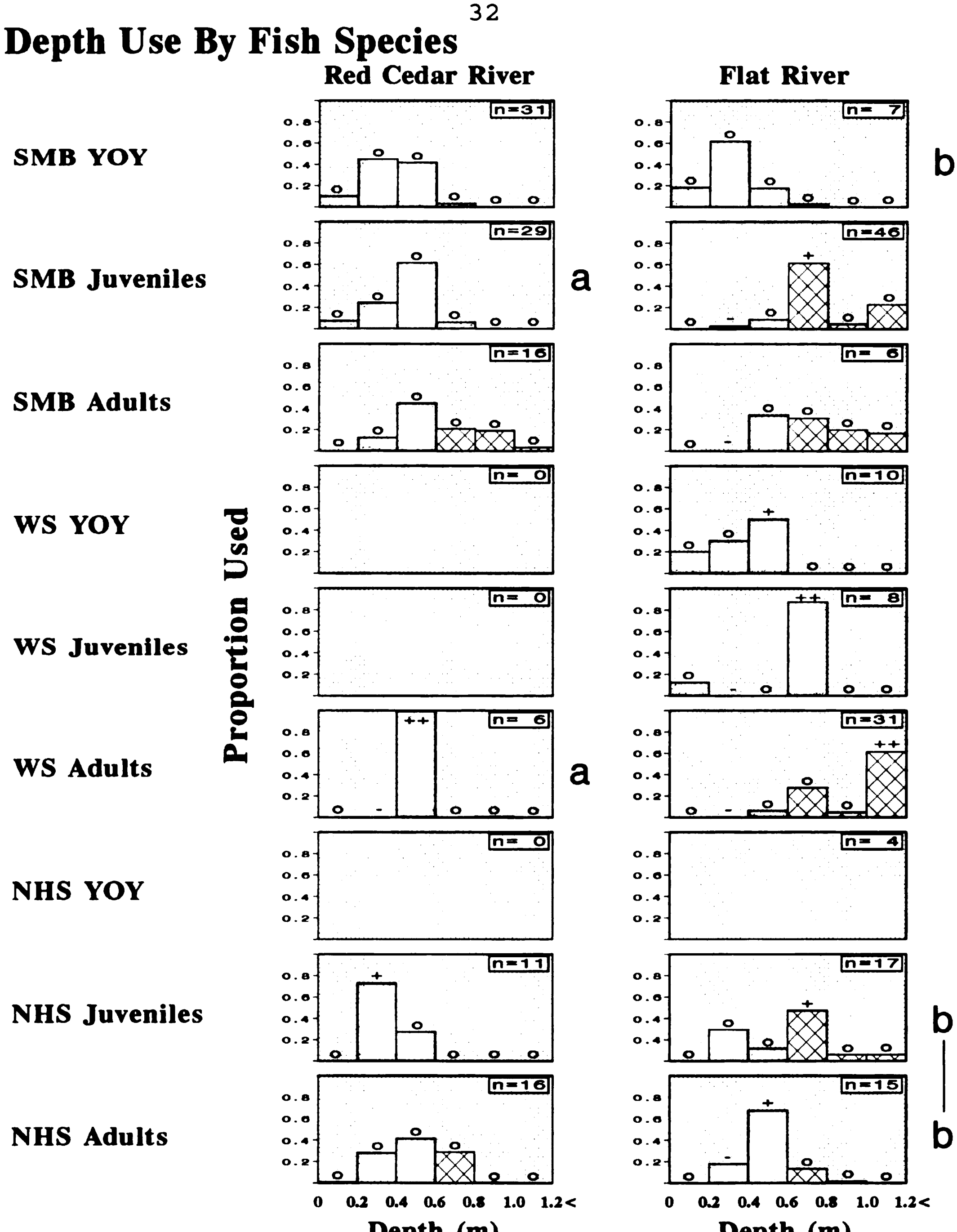

Figure 9. Weighted proportion of depths used by each size class of smallmouth bass (SMB), white sucker (WS), and northern hog sucker (NHS) for the entire 1989 sampling period. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++). Cross-hatched bars were combined for χ^2 tests and like letters indicate species lifestages that were similar ($P>0.1$). Lines connecting letters indicate lifestages that were combined for the test.

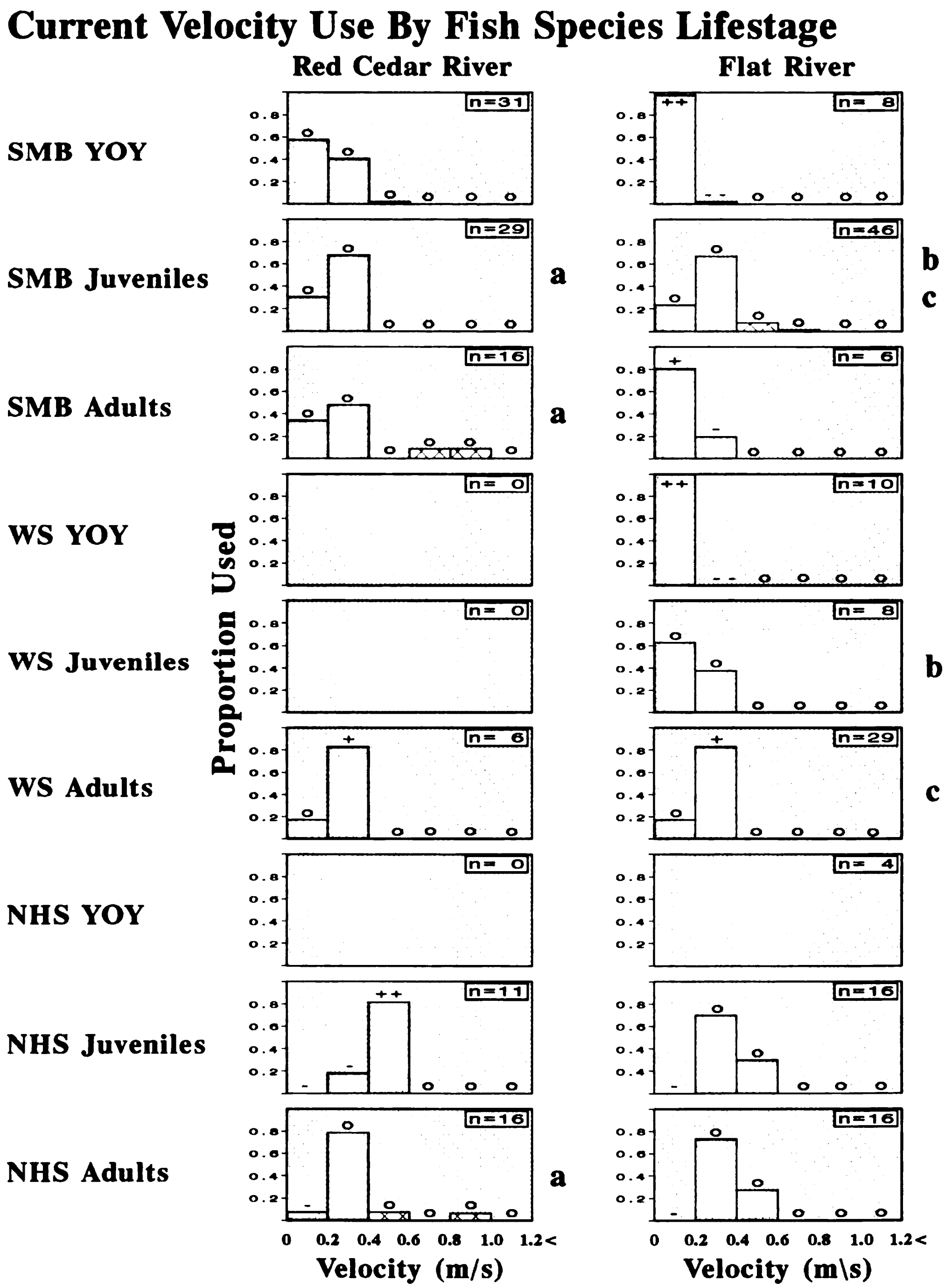

Figure 10. Weighted proportion of current velocities used by each size class of smallmouth bass (SMB), white sucker (WS), and northern hog sucker (NHS) for the entire 1989 sampling period. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++). Cross-hatched bars were combined for χ^2 tests and like letters indicate species lifestages that were similar (at least $P>0.05$).

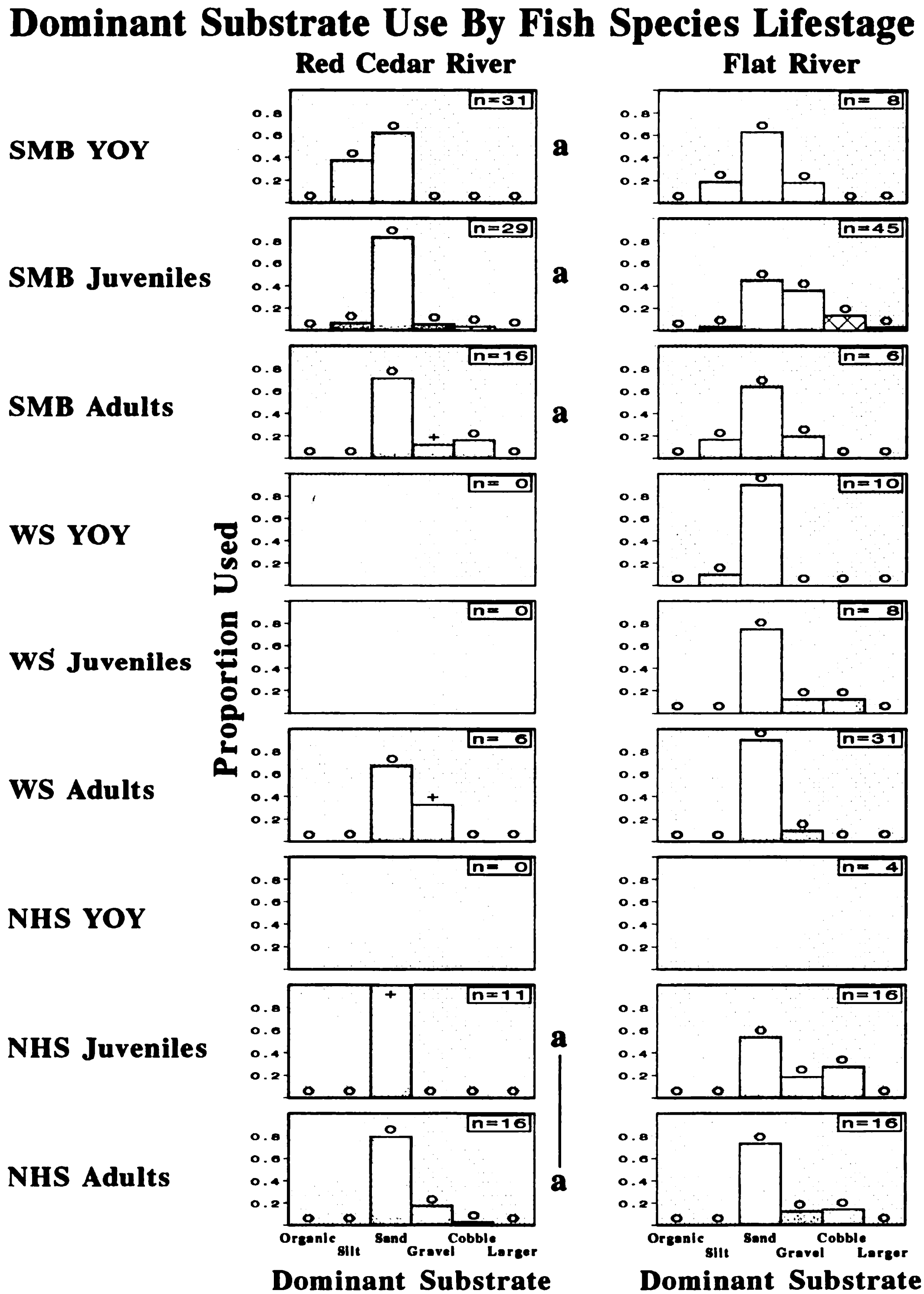

Figure 11. Weighted proportion of substrate types used by each size class of smallmouth bass (SMB), white sucker (WS), and northern hog sucker (NHS) for the entire 1989 sampling period. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++). Cross-hatched bars were combined for χ^2 tests and like letters indicate species lifestages that were similar (at least $P>0.05$). Lines connecting letters indicate lifestages that were combined for the test.

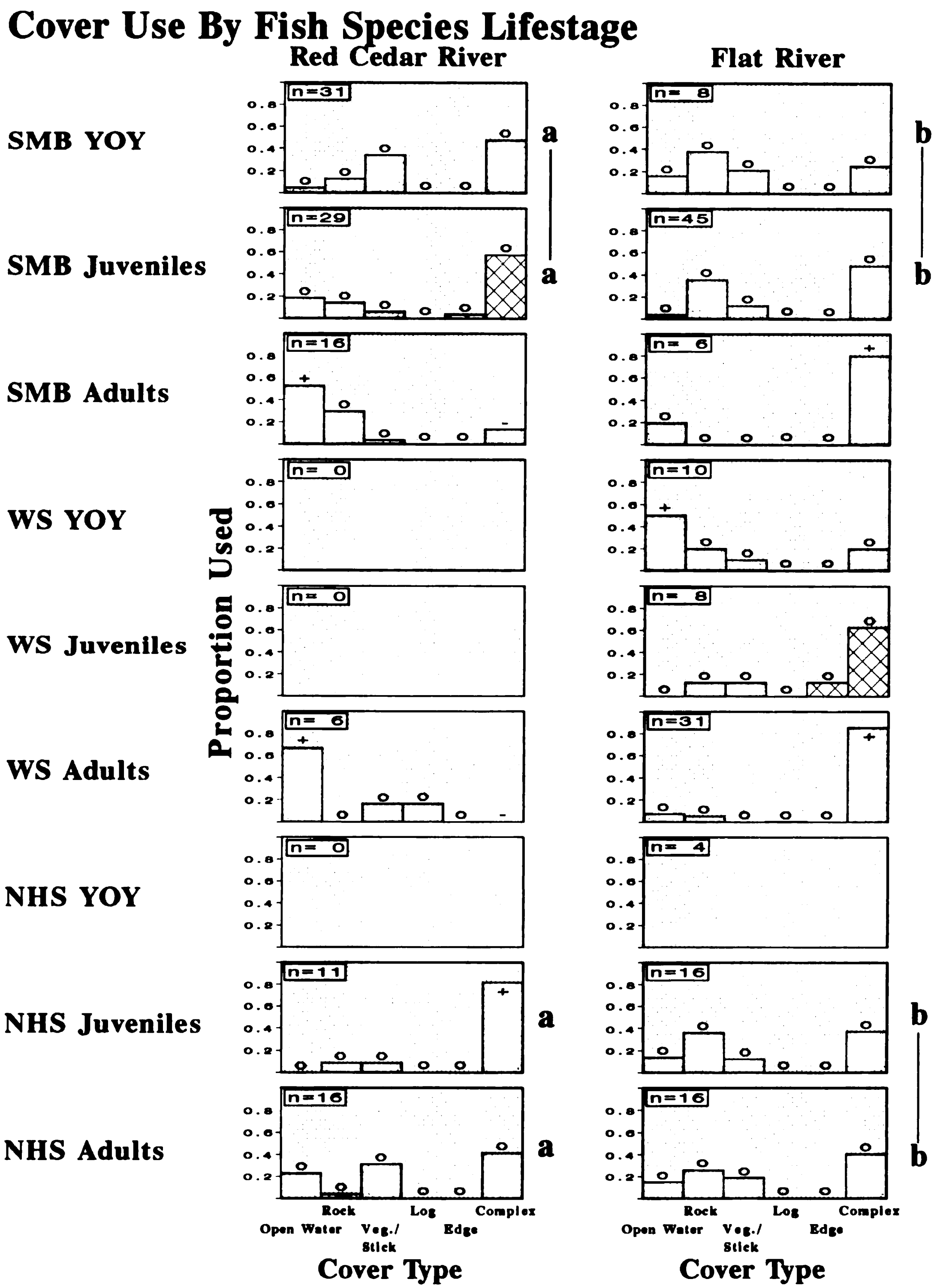

Figure 12. Weighted proportion of cover types used by each size class of smallmouth bass (SMB), white sucker (WS), and northern hog sucker (NHS) for the entire 1989 sampling period. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++). Cross-hatched bars were combined for χ^2 tests and like letters indicate species lifestages that were similar (at least $P>0.05$). Lines connecting letters indicate lifestages that were combined for the test.

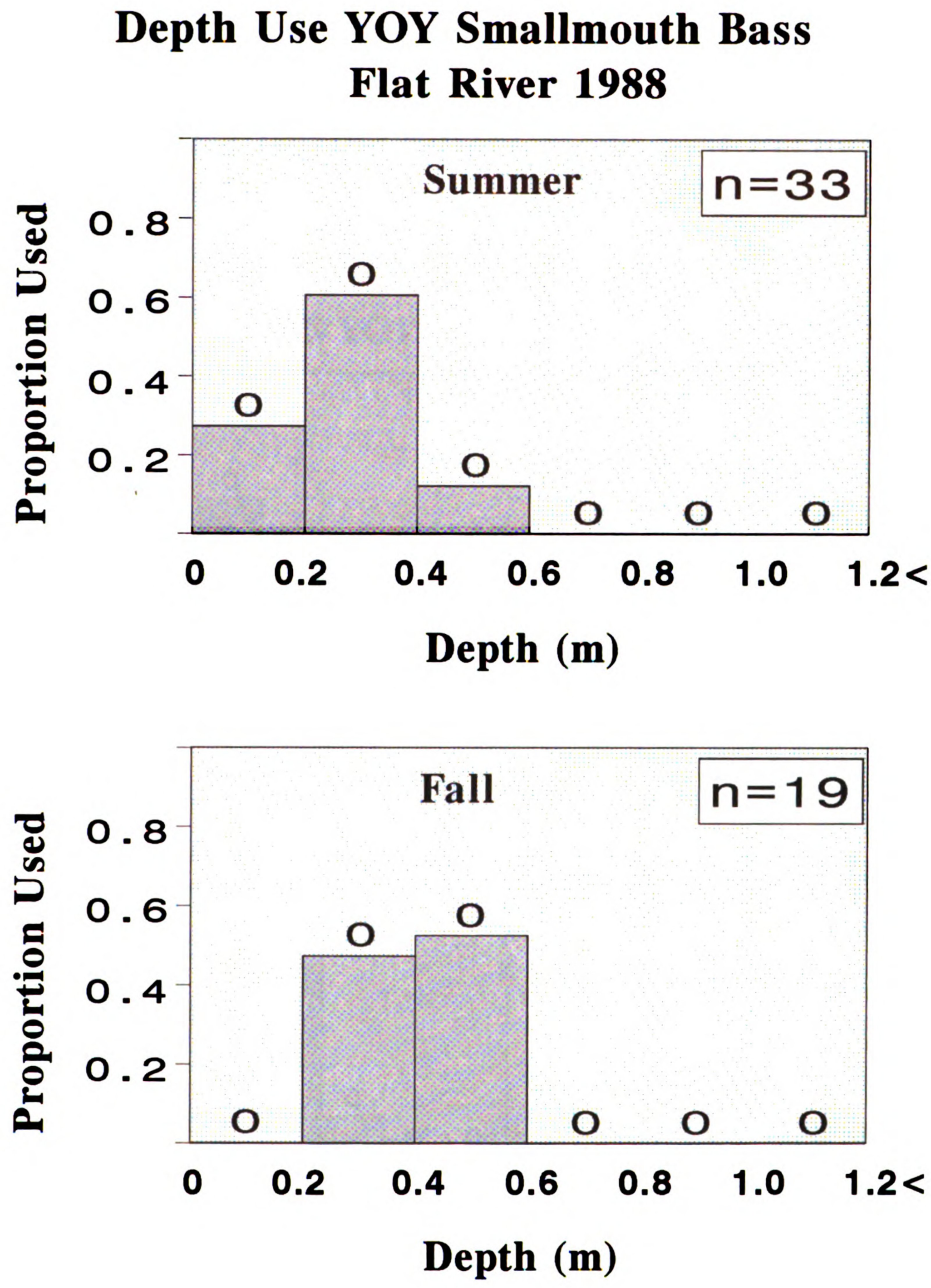

Figure 13. Proportion of depths used by YOY smallmouth bass with 1988 sampling periods within summer and fall combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

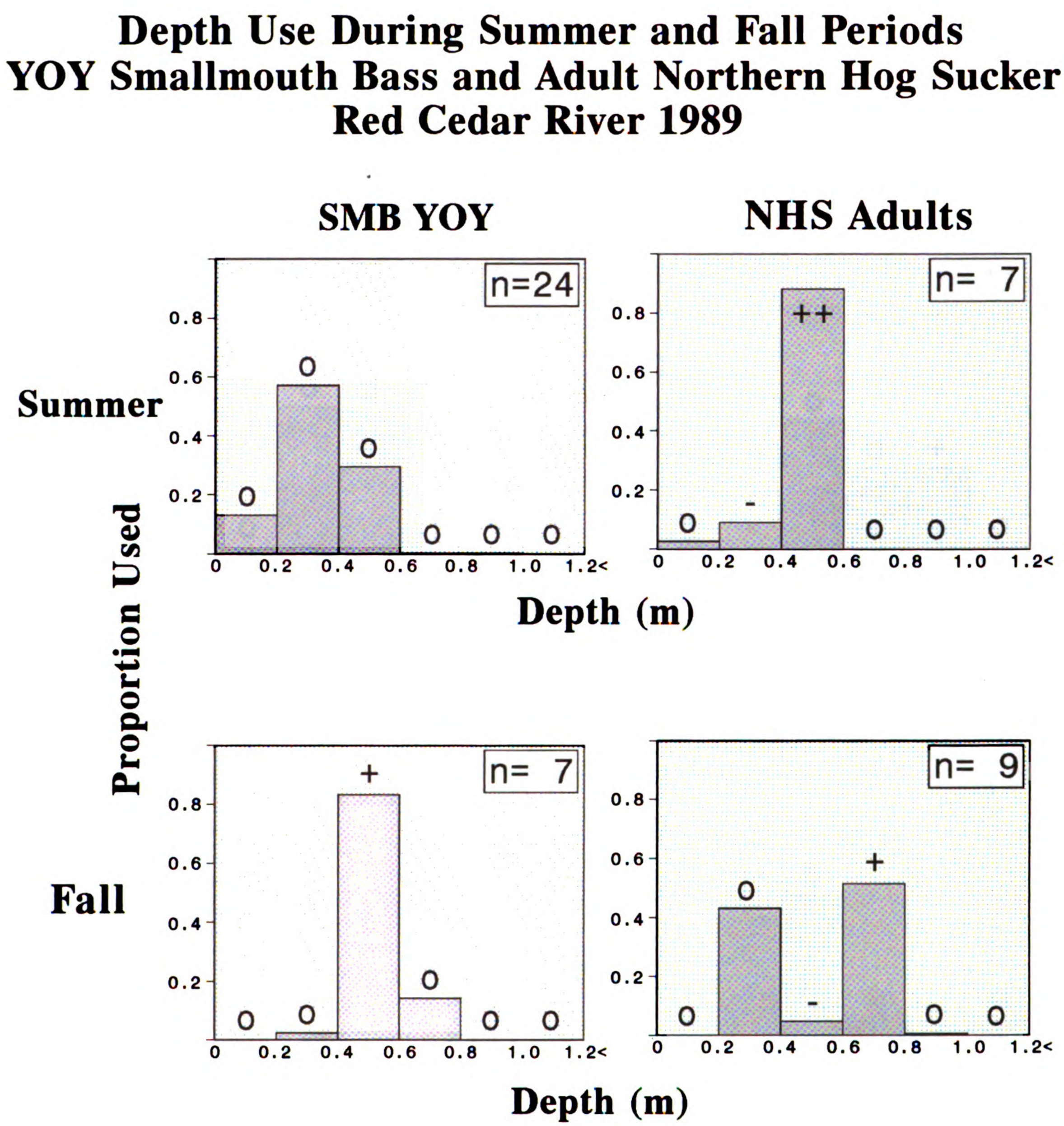

Figure 14. Proportion of depths used by YOY smallmouth bass (SMB) and Adult northern hog suckers (NHS) with 1989 sampling periods within summer and fall combined for the Red Cedar River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

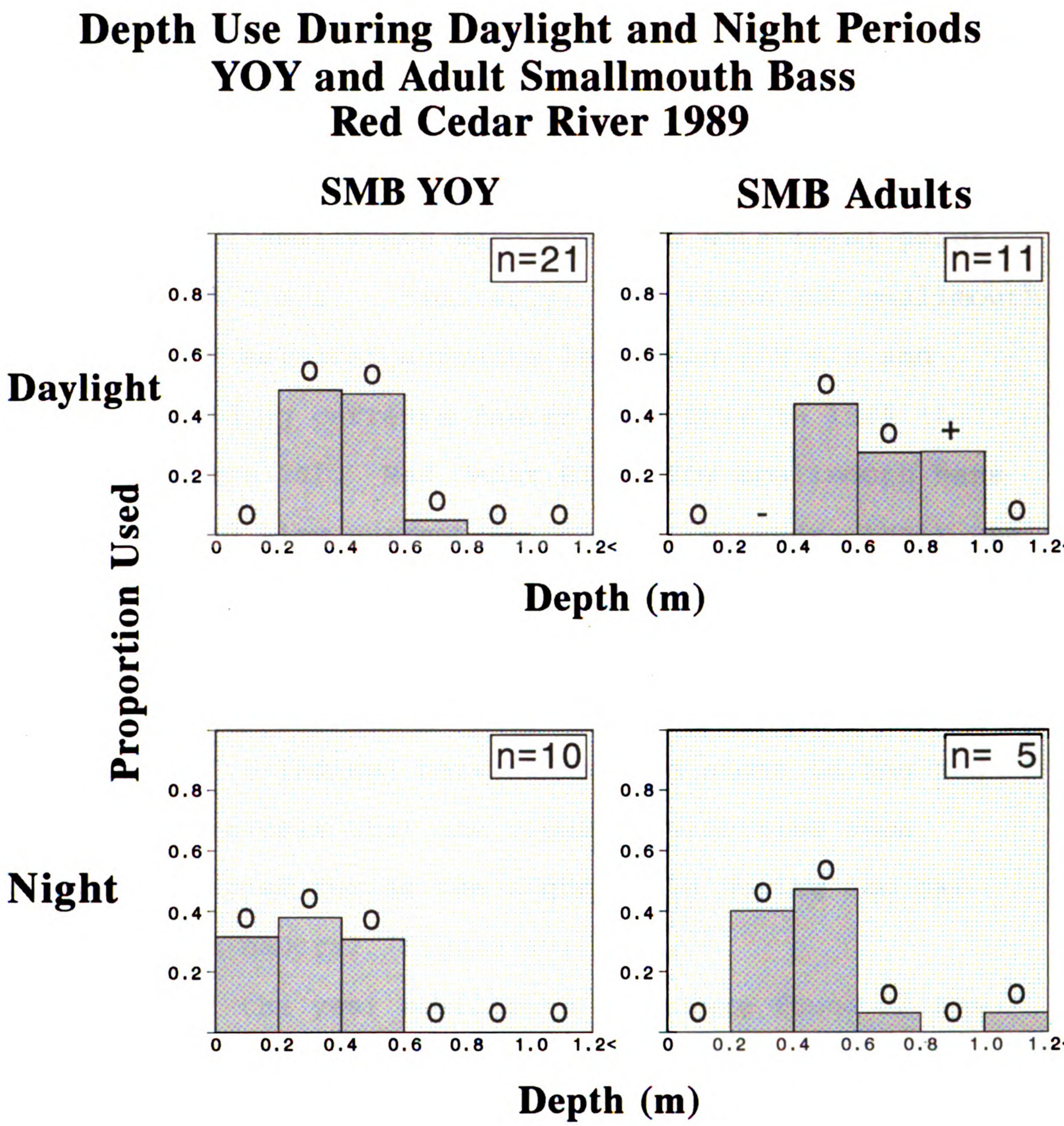

Figure 15. Proportion of depths used by YOY and adult smallmouth bass with 1989 sampling periods within day and night combined for the Red Cedar River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

Young of the year smallmouth bass clearly selected areas of slow current velocity. I found, during underwater observations, most often YOY smallmouth bass were inhabiting average water column velocities between 0 and 0.4 m/s (Figure 16). Focal point velocities however were $\leq$0.2 m/s in 98% of the observations (mean=0.075 m/s). In early July 63% of the YOY smallmouth were observed with focal point velocities of 0 m/s. Similarly, Flat River YOY smallmouth bass strongly selected currents less than 0.2 m/s and strongly avoiding currents faster than this in 1989 (*L*-indices: Figure 10). Red Cedar River YOY smallmouth bass similarly used slow current velocities, however, their use of these areas was nearly equal to that available (Figure 10). This was possibly due to the fact that slow water was limited in the Flat River, resulting in higher *L*-indices. A comparison of *L*-indices between day and night in the Red Cedar River reveals that the slowest velocities were strongly selected during the night while during the day selection was neutral (Figure 17).

Young of the year smallmouth bass were found to use sand dominated substrates most frequently (Figures 11 and 18). Sand was also the dominant substrate available. Red Cedar River YOY strongly selected silt bottom types during the night (Figure 19). Flat River YOY selected cobble and larger substrates during the fall (Figure 18). This is significant because available substrates were not different between summer and fall.

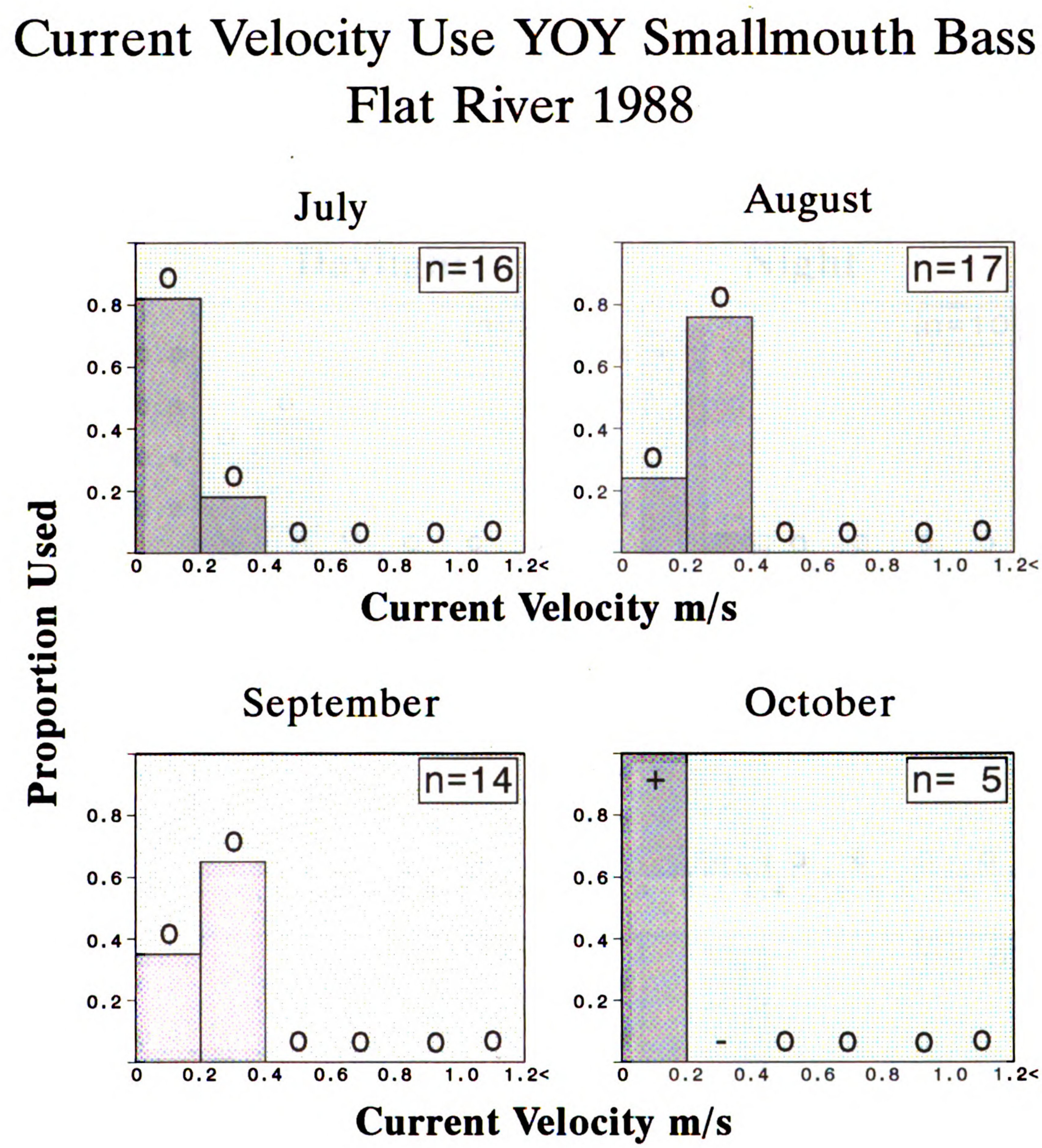

Figure 16. Proportion of current velocities used by YOY smallmouth bass for each sampling period in 1988 for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

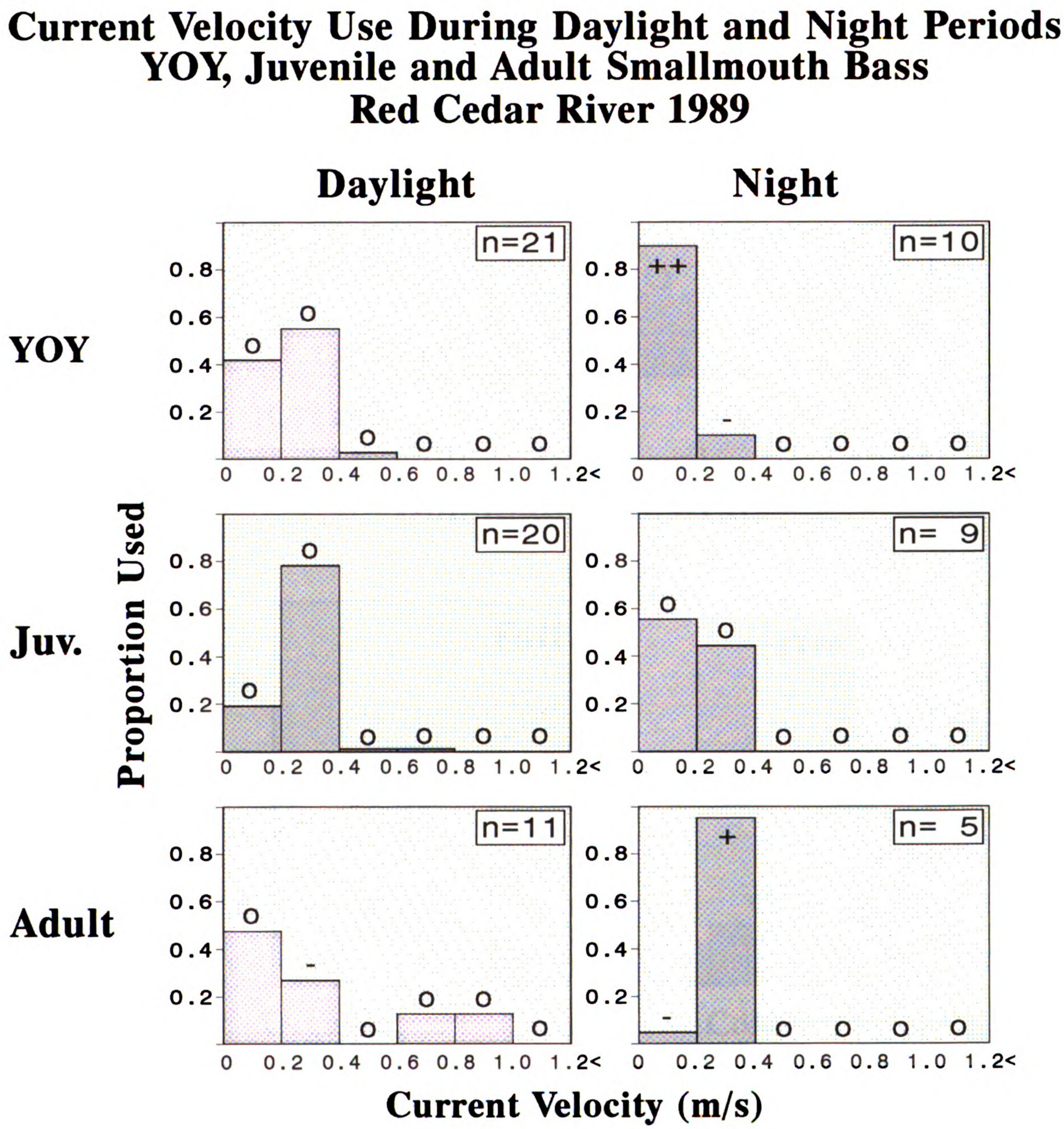

Figure 17. Proportion of current velocities used by YOY, juvenile and adult smallmouth bass with 1989 sampling periods within day and night combined for the Red Cedar River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

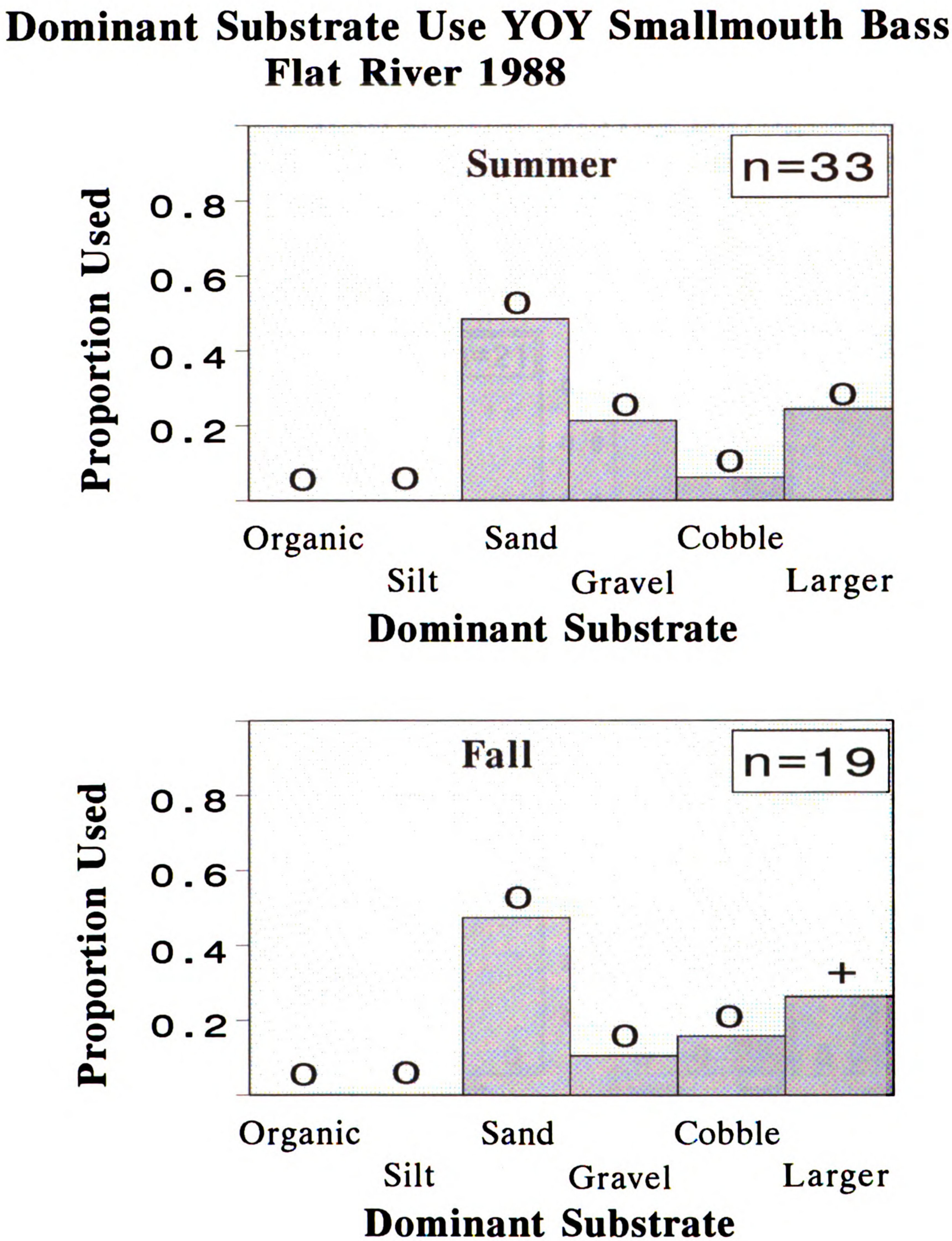

Figure 18. Proportion of dominant substrates used by YOY smallmouth bass with 1988 sampling periods within summer and fall combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

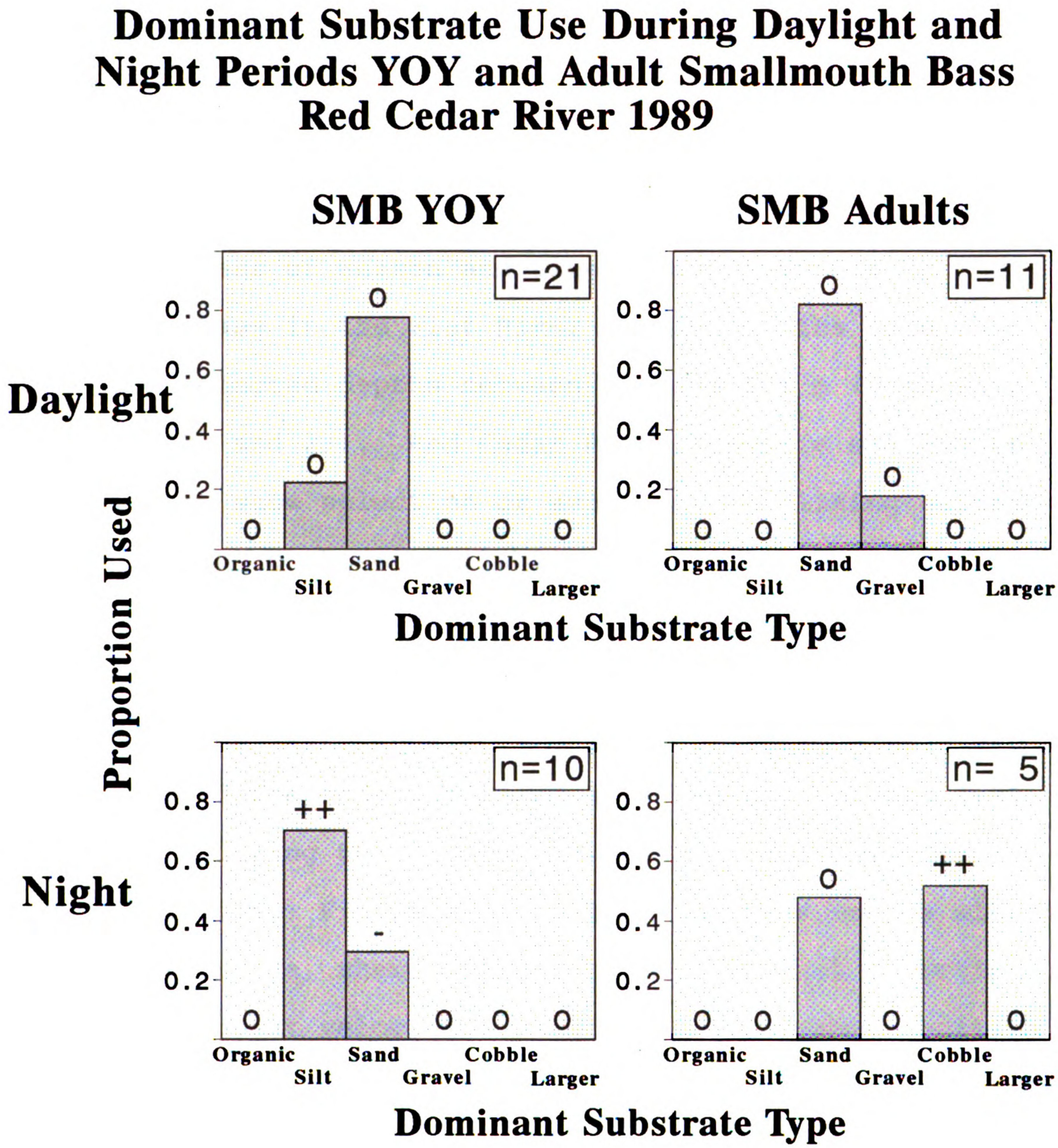

Figure 19. Proportion of dominant substrates used by YOY, and adult smallmouth bass with 1989 sampling periods within day and night combined for the Red Cedar River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

In 1988 Flat River smallmouth bass YOY selected rocky or complex cover types and avoided open water habitats based on *L*-indices (Figure 20). Red Cedar River YOY showed a tendency to avoid open water and strongly select complex cover areas during the night, and select vegetation or sticks during the day (*L*-indices: Figure 21).

Regardless of season and time of day juvenile smallmouth bass in the Flat River avoided depths less than 0.4 m and selected depths between 0.6 and 0.8 m (*L*-indices: Figure 9, 22 and 23). Red Cedar River juvenile smallmouth bass did not show selection or avoidance, utilizing depths in proportion to those available (*L*-indices: Figure 9). Smallmouth bass juveniles showed neutral selection in velocity overall (Figure 10) with most of the juveniles being collected from runs. Flat River juvenile smallmouth bass selected the moderate current velocities between 0.21 and 0.4 m/s during the summer while avoiding the slowest water (*L*-indices: Figure 24). Despite *L*-index values within the neutral range, there appears to be a general selection of slower current velocities at night and faster velocities during the day for juveniles in both rivers (Figures 17 and 25).

Juvenile substrate-use distributions were very close to available substrate distributions. Flat River juveniles used substrate in proportion to that available. The exception was the use of areas containing primarily gravel during daylight (Figure 26). Gravel was often the dominate

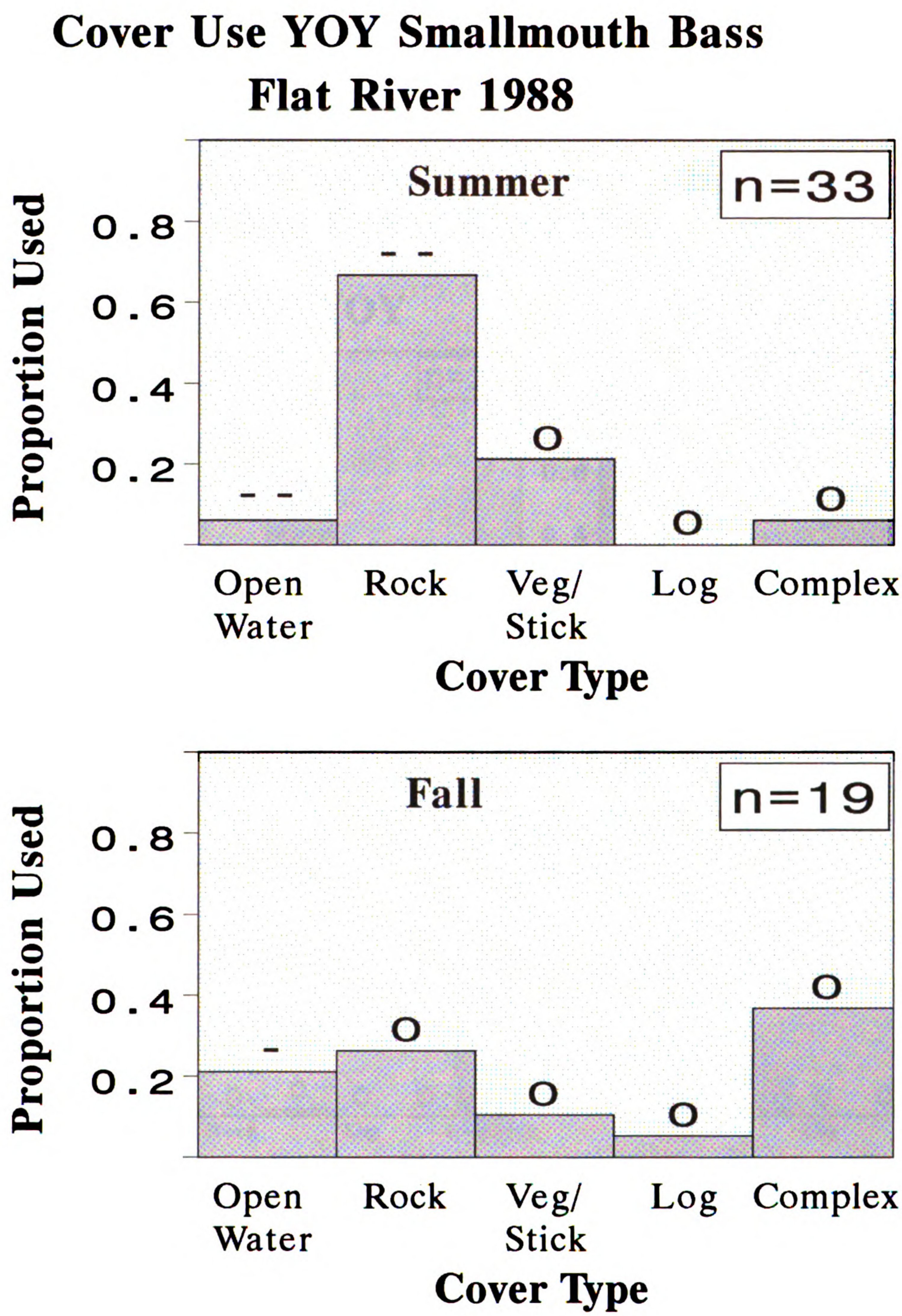

Figure 20. Proportion of cover types used by Flat River YOY smallmouth bass with 1988 sampling periods within summer and fall combined. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

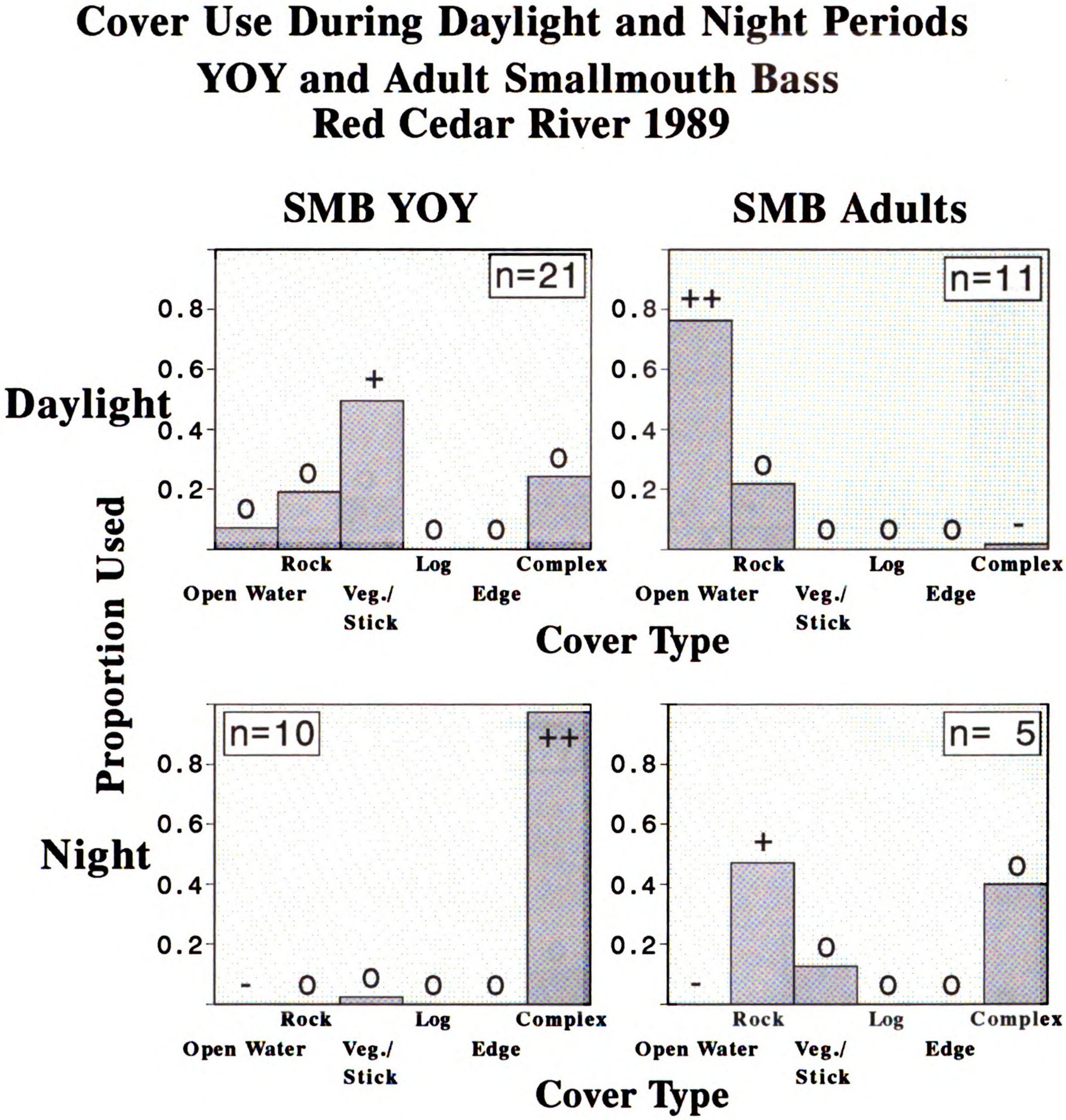

Figure 21. Proportion of cover types used by YOY and adult smallmouth bass with 1989 sampling periods within day and night combined for the Red Cedar River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

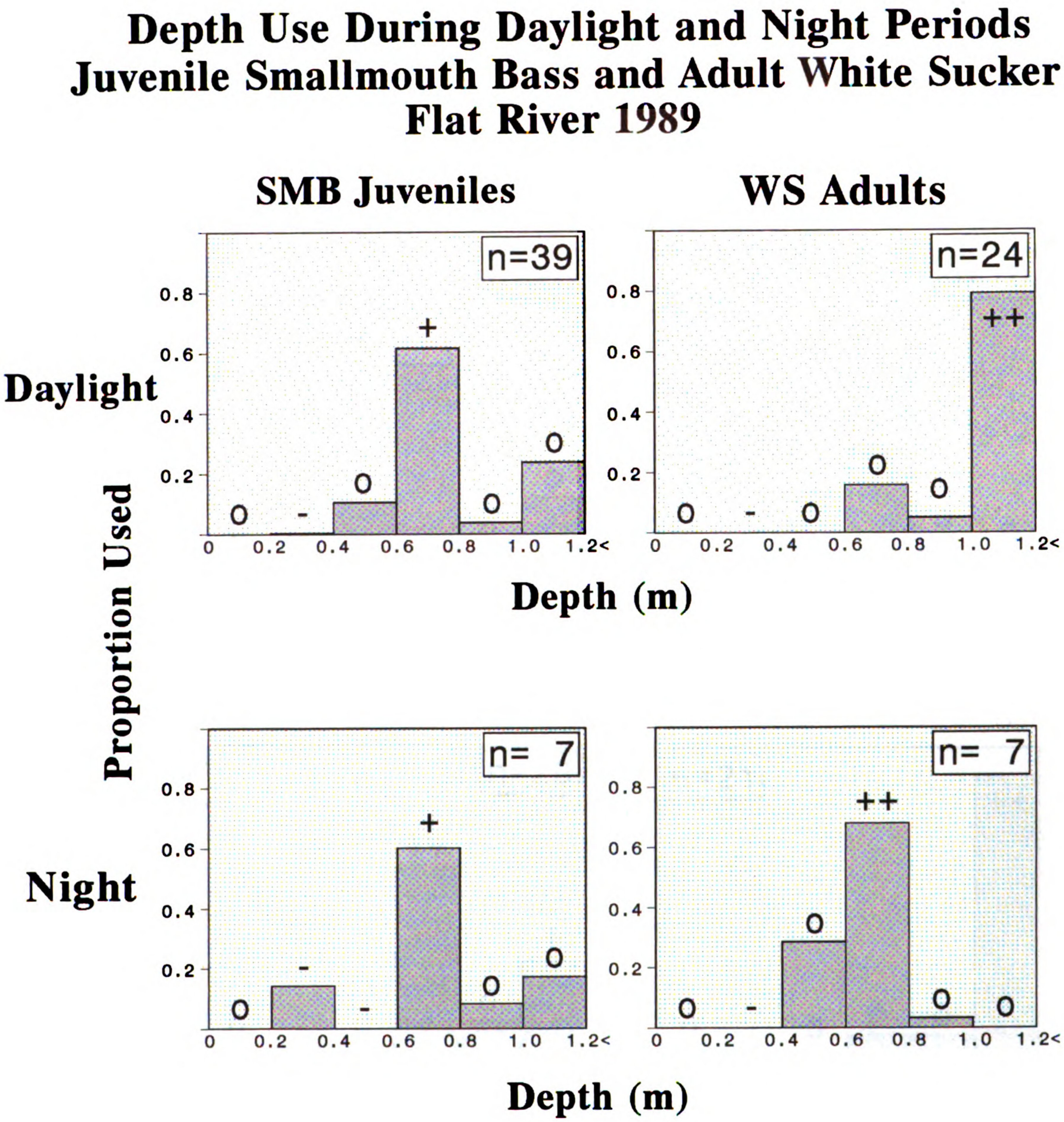

Figure 22. Proportion of depths used by juvenile smallmouth bass (SMB), and adult white sucker (WS) with 1989 sampling periods within day and night combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

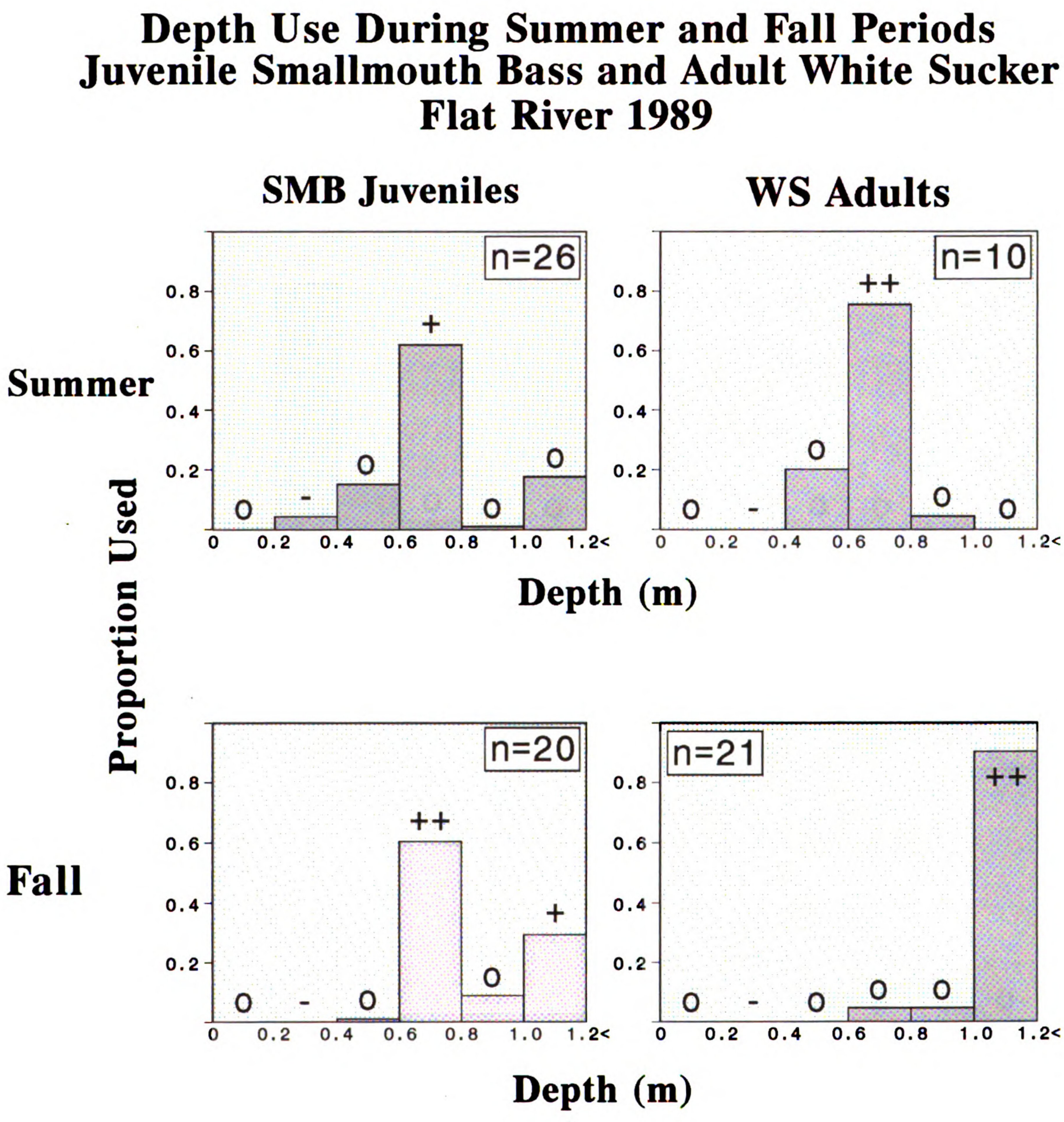

Figure 23. Proportion of depths used by juvenile smallmouth bass (SMB), and adult white sucker (WS) with 1989 sampling periods within summer and fall combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

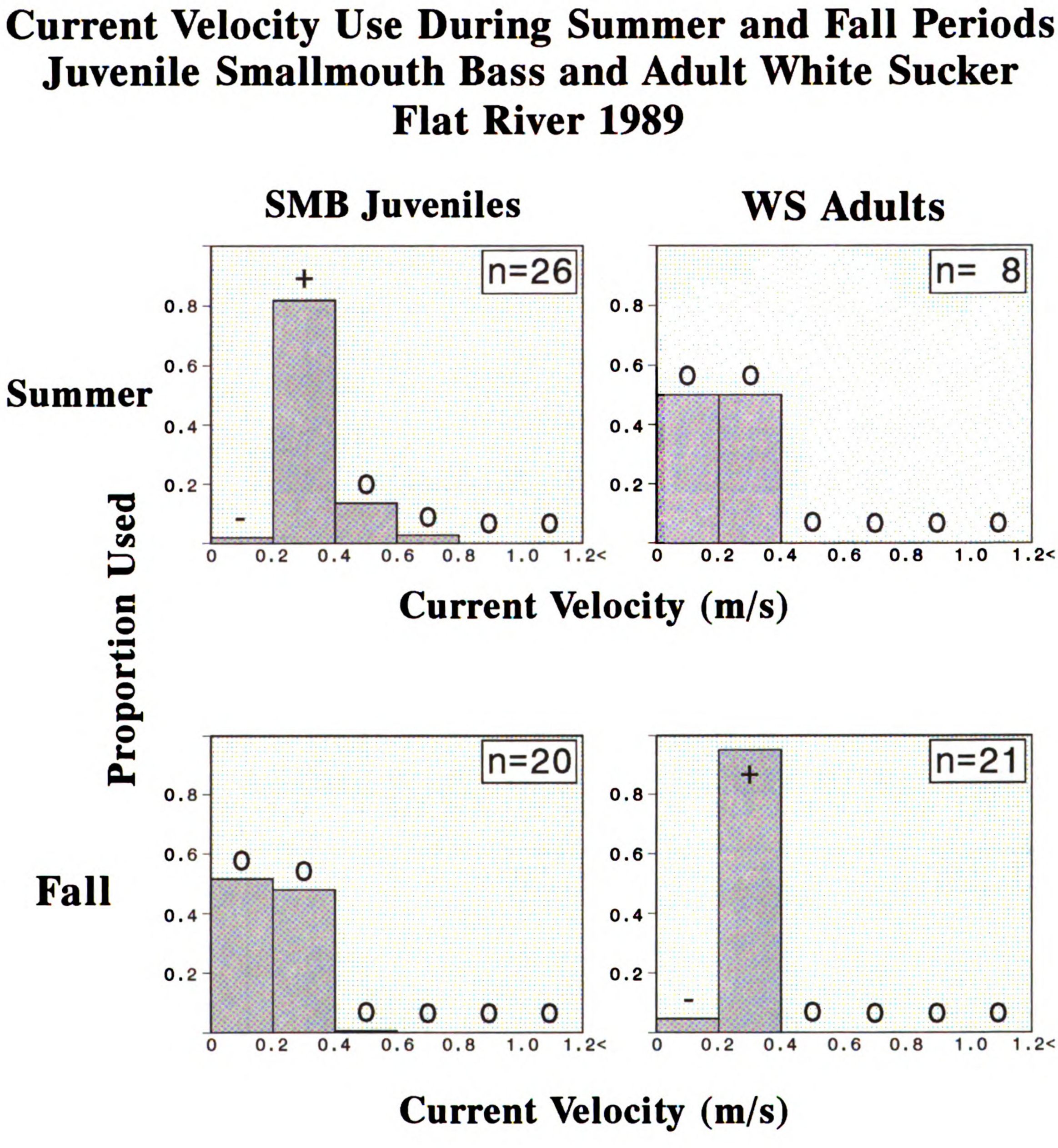

Figure 24. Proportion of current velocities used by juvenile smallmouth bass (SMB), and adult white sucker (WS) with 1989 sampling periods within summer and fall combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

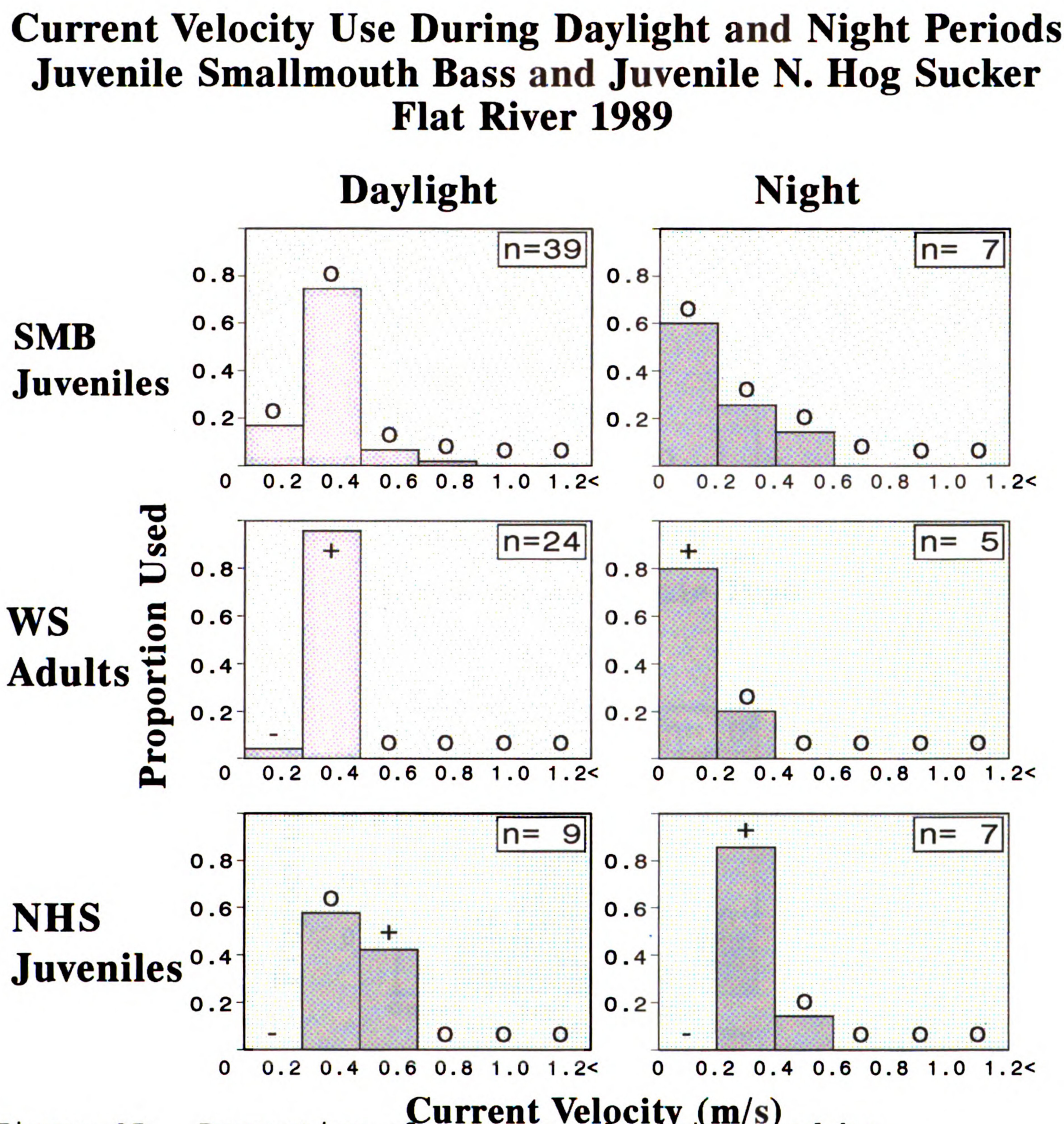

Figure 25. Proportion of current velocities used by juvenile smallmouth bass (SMB), adult white suckers (WS), and juvenile northern hog suckers (NHS) with 1989 sampling periods within day and night combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

Dominant Substrate Use During Daylight and Night Periods Juvenile Smallmouth Bass Flat River 1989

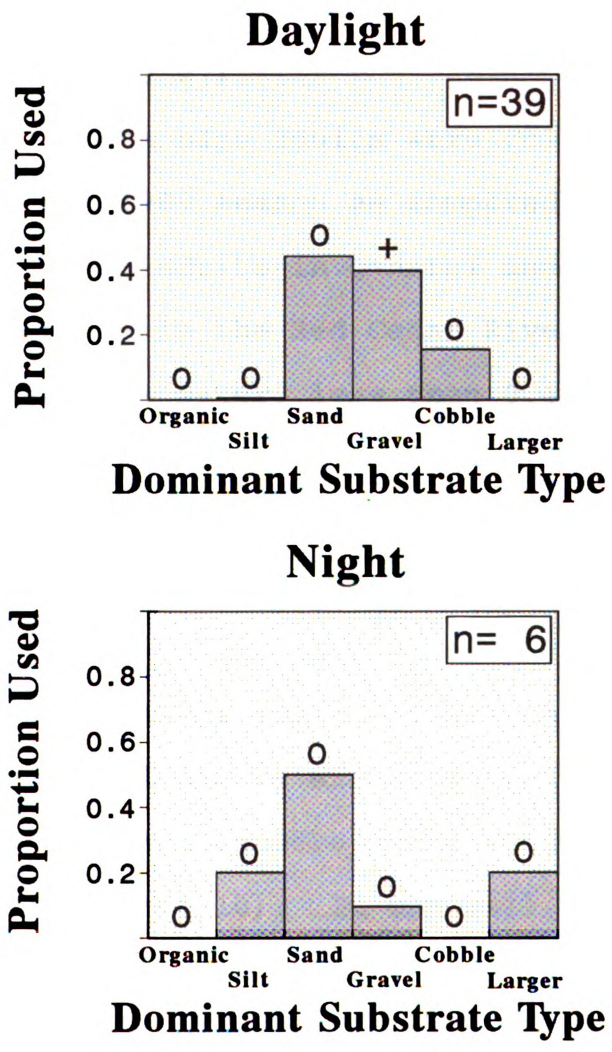

Figure 26. Proportion of dominant substrate used by juvenile smallmouth bass with 1989 sampling periods within day and night combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

substrate found in the runs having moderate current velocities.

The distribution of cover types used by juvenile smallmouth bass, overall, was similar to that found as available in both rivers. Flat River juveniles did show a greater tendency to select areas containing complex cover during the night (Figure 27).

Only six smallmouth bass adults were collected in the Flat River during the 1989 season as compared to 16 in the Red Cedar River. These adults in general used deeper water (Figure 9). Adult bass in the Red Cedar River did show some avoidance of the shallow water, less than 0.4 m, during the day, selecting depths between 0.8 and 1.0 m in greater proportion to that available based on *L*-indices (Figure 15). At night these adults primarily used depths between 0.21 and 0.6 m.

Current velocity use by adult smallmouth bass was not clearly defined by small sample sizes, especially in the Flat River. Generally adults were associated with slow current velocities (Figure 10). In the fall, during the daylight collection period on the Red Cedar River, some adults were found to be using the relatively fast current velocities between 0.61 and 1.0 m/s (Figure 17). These areas were also fairly deep, which may have also been providing cover for these adults.

Adult smallmouth bass overall use of substrate compared well to the overall available substrate (Figure 11). Red

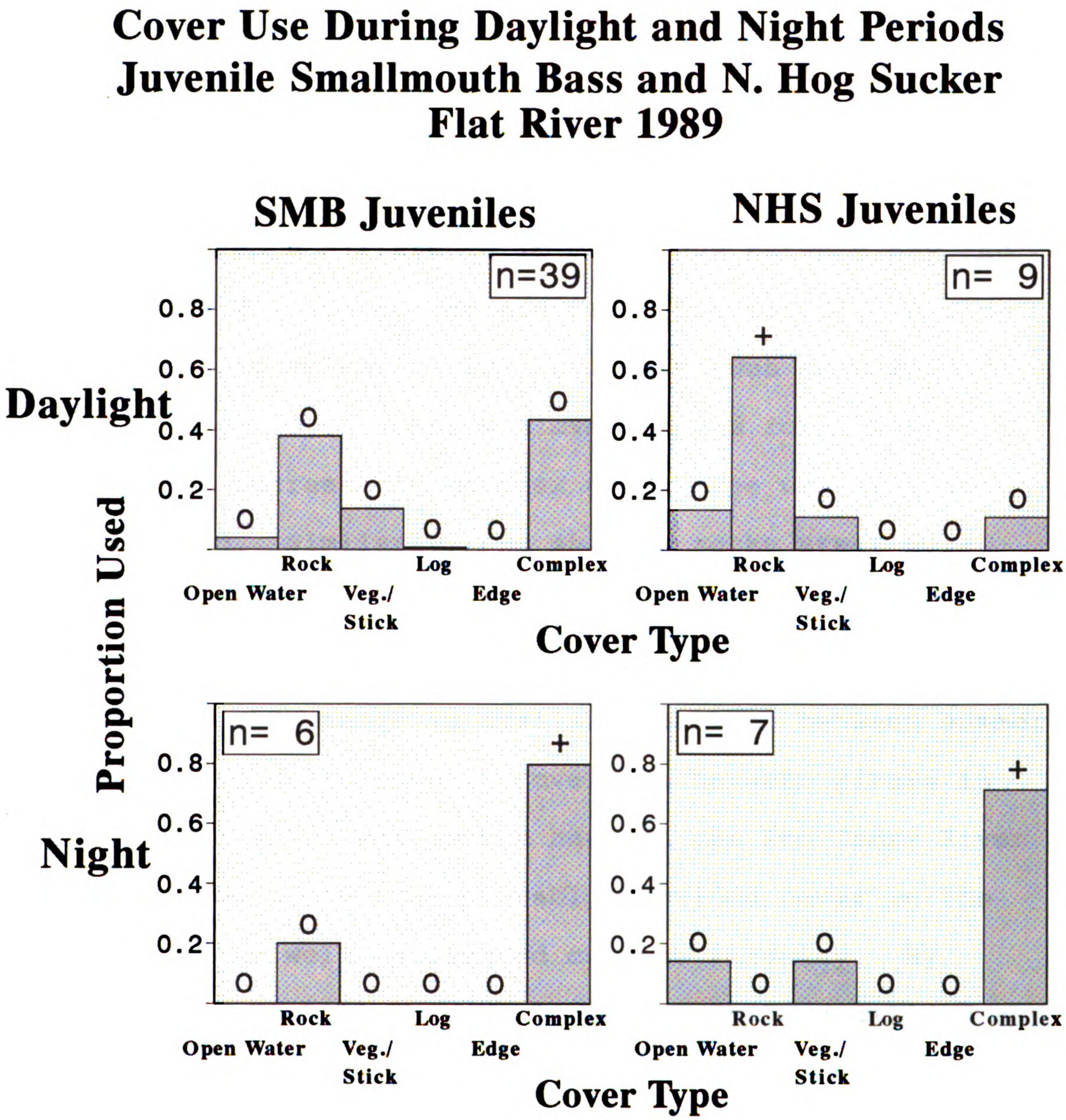

Figure 27. Proportion of cover types used by juvenile smallmouth bass (SMB) and juvenile northern hog suckers (NHS) with 1989 sampling periods within day and night combined for the Flat River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

Cedar River adult smallmouth bass exhibited strong selection, based on *L*-indices, of cobble substrate in the fall compared to the summer (Figure 28) and during the night compared to the day (Figure 19).

Adult smallmouth selected areas with complex cover combinations in the Flat River (Figure 12). Red Cedar River adults exhibited a difference in cover use between day and night (Figure 21) and summer and fall (Figure 29). During the day a strong selection for open water was seen and during the night open water was avoided and rocks were selected. An increase in complex cover type use at night was also noted. Similarly, the shallow rocky areas were selected during the fall while open water was selected in the summer. This seasonal change may have been, in part, attributed to the change in available habitat between summer and fall. The difference in cover use between rivers is understandable since smallmouth bass in the Red Cedar River were using slow pools that probably provided cover in the form of depth as well as reduced current velocity. By comparison the Flat River's pools were much less defined and could actually be considered deep runs compared to the Red Cedar River.

White sucker

I found YOY white suckers used areas of slow, shallow water, often devoid of cover. As juveniles, they inhabited deeper water with moderate to slow currents and as adults

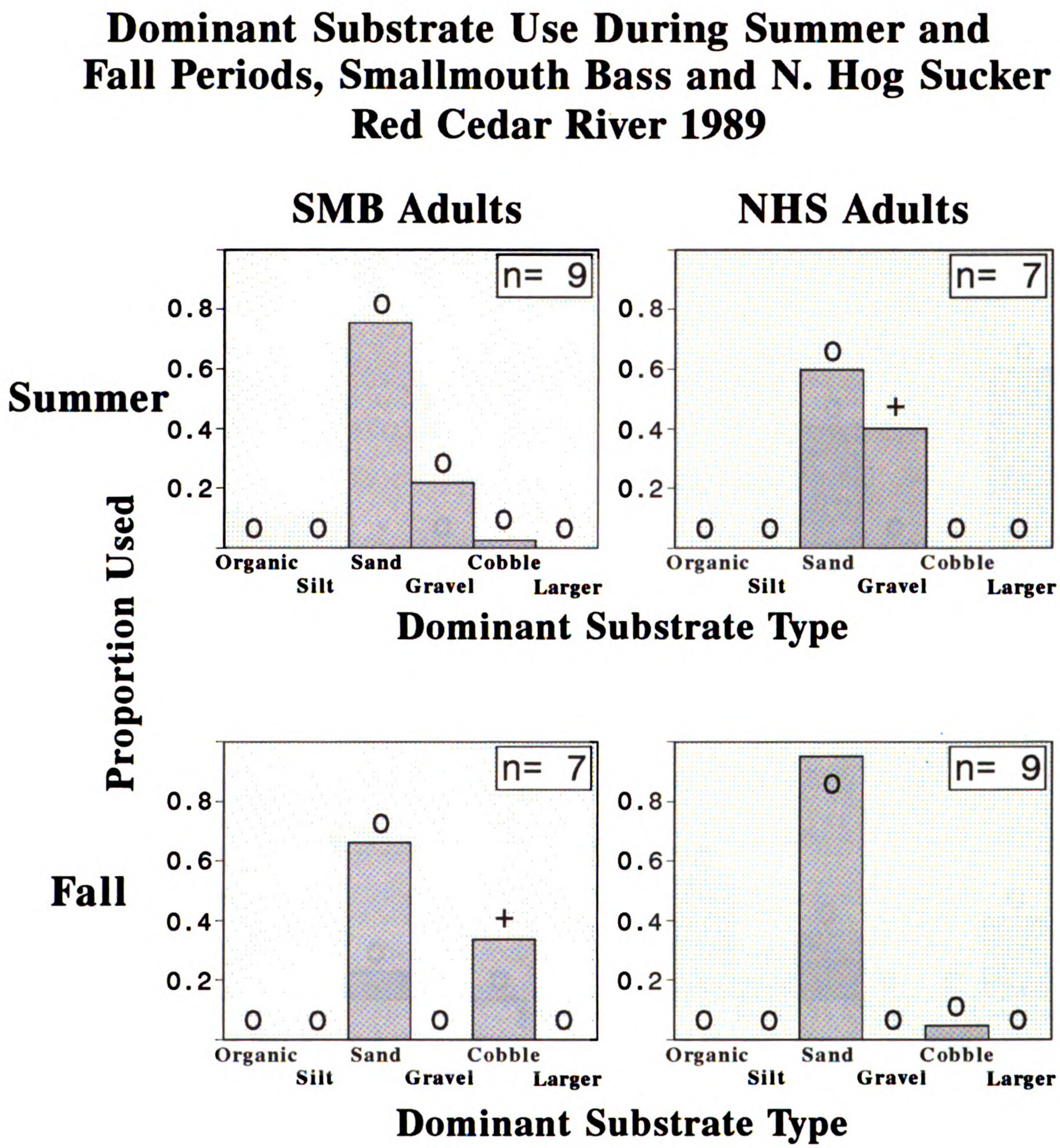

Figure 28. Proportion of substrate types used by adult smallmouth bass (SMB) and adult northern hog suckers (NHS) with 1989 sampling periods within summer and fall combined for the Red Cedar River. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

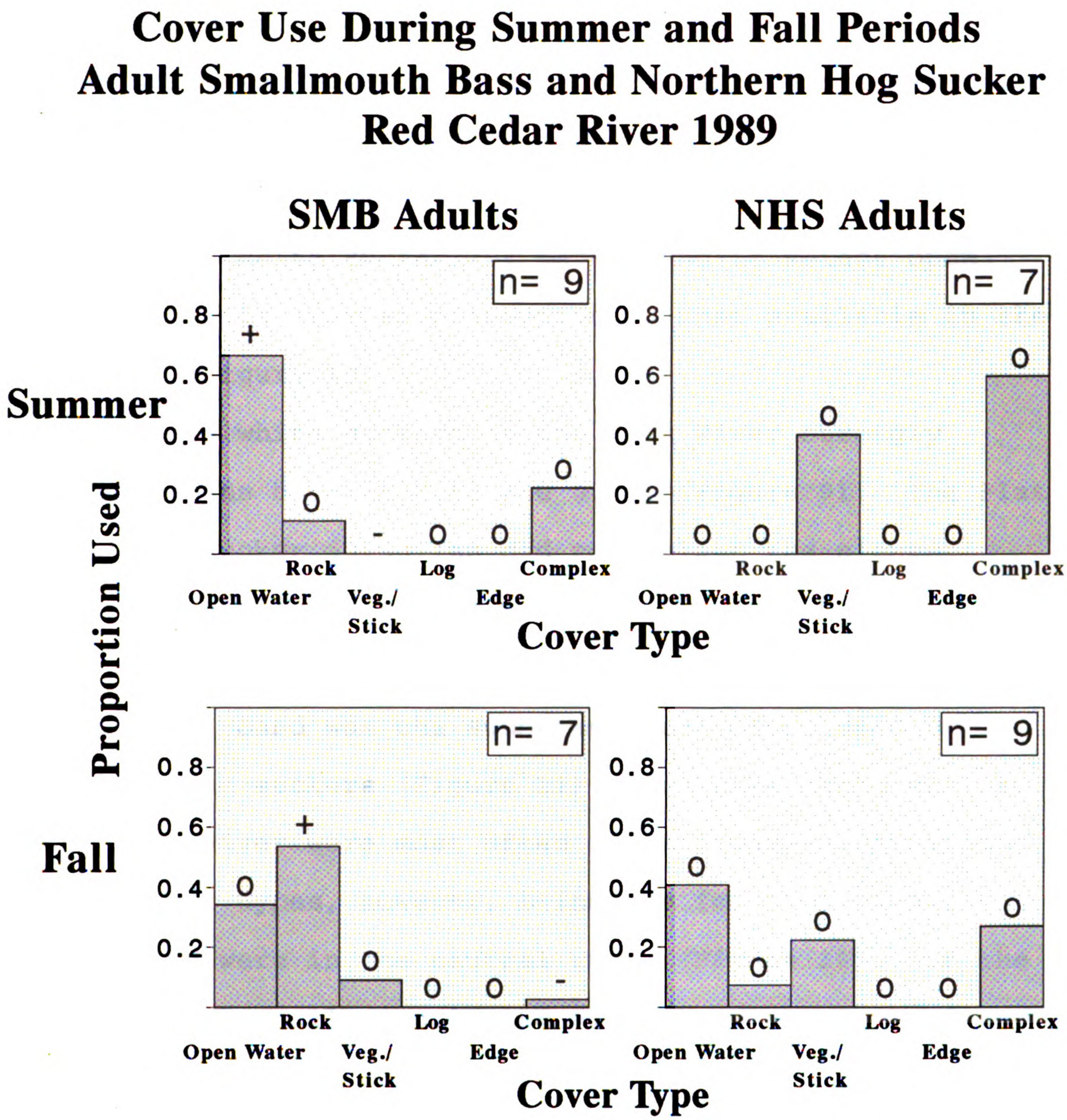

Figure 29. Proportion of cover types used by adult smallmouth bass (SMB) and adult northern hog suckers (NHS) with 1989 sampling periods within summer and fall combined for the Red Cedar River. Available habitat between summer and fall was not equal. Also included are the corresponding electivity categories: strong avoidance (--), avoidance (-), neutral (o), selection (+), and strong selection (++).

they avoided shallow water.

Young of the year white suckers in the Flat River appeared to select depths between 0.41 and 0.6 m (Figure 9). All YOY white suckers were found in current velocities below 0.2 m/s (Figure 10). Dominate substrate used was sand, and, *L*-indices indicate use was proportionate to that available (Figure 11). White sucker YOY were found to select open water habitat in greater proportion to that available in the Flat River (Figure 12).

Juvenile white suckers in the Flat River strongly selected depths between 0.61 and 0.8 m (Figure 9). The Flat River white sucker juveniles did not select the slowest current velocities as strongly as did the YOY, however, all were found in current velocities between 0 and 0.4 m/s (Figure 10). Sand was the substrate most often used by juvenile white suckers (Figure 11). Juvenile white suckers in the Flat River were most often found in areas containing complex cover types, however, *L*-indices for the overall study period were in the neutral range (Figure 12). Of the eight juveniles collected in the Flat River none were found to be in the open water habitats.

Water depths between 0 and 0.4 m were avoided by adult white suckers in both rivers (Figure 9). Flat River white sucker adults were found most often in water deeper than 0.6 m. In the Flat River there was strong selection of depths between 0.61 and 0.8 m during the summer and night periods. Deeper water was selected during the fall and daylight periods (Figures 22 and 23). The Red Cedar River adult white suckers strongly selected depths between 0.41 and 0.6 m (Table 9).

In both rivers adult white suckers selected velocities between 0.21 and 0.4 m/s in greater proportion to that available (Figure 10). During the daylight and fall periods Flat River adult white suckers selected velocities between 0.21 and 0.4 m/s (Figures 24 and 25). Slower velocities between 0 and 0.2 m/s were selected during the night (Figure 25).

White sucker adults in both rivers were most often associated with sand substrates. Red Cedar River adults however selected gravel substrate in greater proportion to that available (Figure 11). Adults in the Flat River consistently selected complex cover types throughout the study period, while Red Cedar River adults selected open water habitats (Figure 12). As was mentioned for this same comparison of adult smallmouth bass in the Red Cedar River, these open water areas were often pools that provided cover in the form of water depth.

Northern hog sucker

I found that juvenile and adult northern hog suckers avoided slow currents and primarily used fast, moderately deep water. Juvenile northern hog suckers appeared to select depths between 0.61 and 0.8 m in the Flat River and depths between 0.21 and 0.4 m in the Red Cedar River (Figure

9). Juvenile northern hog suckers in both rivers avoided the slowest current velocities between 0 and 0.2 m/s (Figure 10). Red Cedar River juveniles also avoided velocities between 0.21 and 0.4 m/s and strongly selected velocities between 0.41 and 0.6 m/s (*L*-indices: Figure 10). Most of the juveniles in the Flat River were found in the 0.21 and 0.4 m/s velocity range.

The dominate substrate used for juvenile northern hog suckers over the entire sampling period in both rivers was sand (Figure 11). Red Cedar River juveniles were found almost exclusively over sand substrates.

Juvenile northern hog suckers used primarily complex cover types in both rivers (Figures 12). Flat River juveniles selected rock cover during the day, corresponding to the fast currents they selected at this time (Figure 25), and typically used complex cover at night (Figure 27).

Adult northern hog suckers were found most often in depths between 0.41 and 0.6 m. Flat River adults actively selected these depths (*L*-indices: Figure 9). Distributions of summer and fall available depths were not comparable in the Red Cedar because of higher water conditions during the fall. Adult northern hog suckers in the Red Cedar River strongly selected depths between 0.41 and 0.6 m in the summer and selected slightly deeper water in the fall (Figure 14).

Adult northern hog sucker current velocity use was very similar between the two rivers. Adults avoided the slowest current velocities and used faster currents in proportion to that available (Figure 10). Adults in the Flat River were found most often over sand but used substrates in proportion to that available (Figure 11). Red Cedar River adults were also found over sand most often but showed selection of gravel substrate in the summer when compared to the fall (Figure 28). Adults used cover in proportion to that available, with complex cover being used most often (Figure 12). Red Cedar River adults also used open water areas heavily in the fall compared to summer (Figure 29).

Other catostomids

Golden redhorse, greater redhorse and spotted suckers were collected over the course of this study in the Red Cedar River. Only four golden redhorse, however, were collected during the habitat use collections in 1989. From these fish it appears that deep (greater than 0.6 m) slow (less than 0.4 m/s) water was used with substrate and cover types varying.

Smallmouth Bass and Sucker Interactions

Habitat use for depth, velocity, substrate and cover were most similar for juvenile smallmouth bass and adult northern hog suckers in the Red Cedar River. Habitat use was also found to be similar between Flat River juvenile smallmouth bass and at least one life stage of either white sucker or northern hog sucker for each habitat category.

Use of depth was similar (χ^2: $P>0.05$) between juvenile smallmouth bass and white sucker adults in the Flat River (Figure 9). Depth use of Red Cedar River YOY and juvenile smallmouth bass were similar (χ^2: $P>0.05$) to the combined juvenile and adult northern hog suckers (Figure 9).

Use of current velocity was similar between Flat River juvenile smallmouth bass, white sucker juveniles and adults when all were tested together in one contingency table (χ^2: $P>0.025$). When smallmouth bass juveniles were tested against white sucker juveniles and adults separately χ^2-probabilities were greater than 0.05 and 0.1 respectively (Figure 10). These higher probabilities however have a greater chance of error than when all three were tested in one contingency table. Red Cedar River adult northern hog suckers, and adult and juvenile smallmouth bass each had similar (χ^2: $P>0.1$) current velocity use distributions (Figure 10).

Use of dominate substrate in the Flat River were similar (χ^2: $P>0.05$) between the combined YOY and juvenile smallmouth bass, combined YOY and juvenile white sucker and combined juvenile and adult northern hog suckers (Figure 11). Substrate used by all size classes of Red Cedar River smallmouth bass were similar (χ^2: $P>0.1$) to juvenile and adult northern hog suckers combined (Figure 11). Use of cover was similar between YOY and juveniles of both smallmouth bass and northern hog suckers in both rivers (Figure 12).

Diet

As smallmouth bass grew from YOY to adult stages, riffle and pool invertebrates, along with chironomids, were found less in the diet, and crayfish and fish increased as a percentage of diet items (Figures 30 and 31).

White sucker juveniles and adults fed mostly on chironomid larvae (Figures 30 and 31). Percent occurrence was found to be at least 90% for each life stage in each river. Riffle organisms did not appear in the diet until white suckers were in the juvenile stage (Figure 31).

Riffle invertebrates were found frequently in all life stages of northern hog suckers (Figures 30 and 31). Percent composition results indicate that riffle organisms are more heavily fed upon as northern hog suckers grew from YOY to adult. All of the size classes however had chironomid larvae as a major component of their diet. Adult golden redhorse fed almost exclusively on chironomid larvae (Figure 30).

Surface, riffle, pool, chironomid, crayfish and fish diet group distributions were found to be different between all groups of suckers and bass. Even with the fish and crayfish groups removed the distributions still tested as different (χ^2: $P > 0.05$).

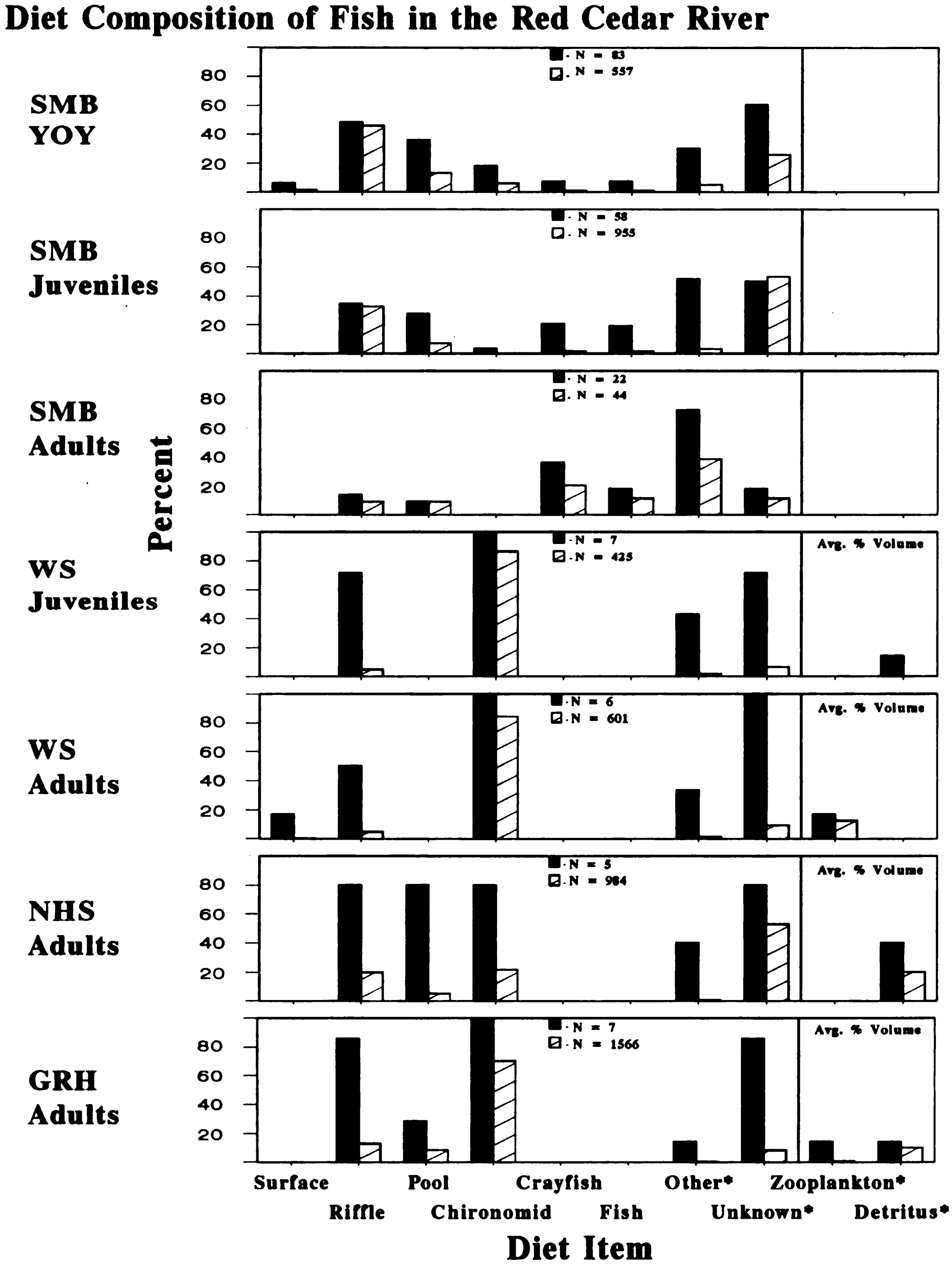

Figure 30. Percent occurrence (solid bars) and percent composition (cross-hatched bars) of diet items found in the stomachs of smallmouth bass (SMB), white sucker (WS), northern hog sucker (NHS) and golden redhorse suckers (GRH) in the Red Cedar River. Zooplankton and detritus is shown as the average percent volume instead of percent composition. Diet items marked with a "*" were not included in χ^2 tests between species.

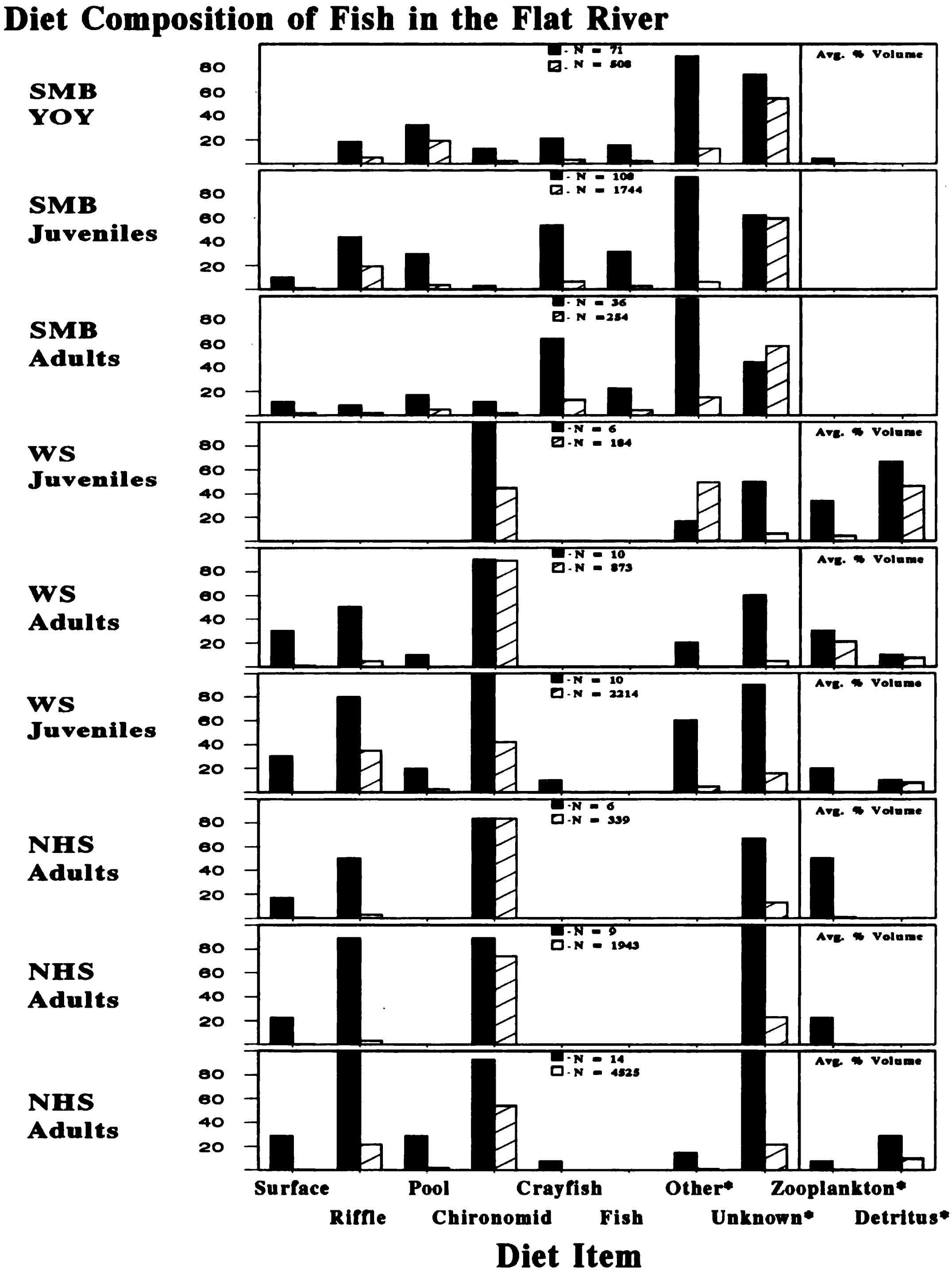

Figure 31. Percent occurrence (solid bars) and percent composition (cross-hatched bars) of diet items found in the stomachs of smallmouth bass (SMB), white sucker (WS) and northern hog sucker (NHS) in the Flat River Cedar River. Zooplankton and detritus is shown as the average percent volume instead of percent composition. Diet items marked with a "*" were not included in χ^2 tests between species.

Smallmouth Bass Growth

Scale samples as well as weights and lengths were taken from most of the smallmouth bass sampled. A summary of the lengths of smallmouth bass at age are shown in Table 3 for the Red Cedar River and Table 4 for the Flat River.

Based on length at age of older fish, the growth of Flat River bass appears to be greater than for bass from the Red Cedar River. Both rivers fall below the regional average found by Carlander (1977) for older ages in Michigan, Minnesota and Wisconsin. Young of the year growth varied widely between river and year. Overall the YOY from both rivers were close to the average YOY for the region (Carlander 1977).

Relative Abundance

There were noticeably fewer young of the year smallmouth bass in both rivers in 1989 compared to 1988. Abundance estimates from 1989 are shown for both rivers in Table 5. Young of the year smallmouth bass and suckers were collected sporadically throughout the 1989 sampling period.

Since YOY are typically abundant relative to juveniles and adults, comparisons between sucker and bass abundances may actually be more meaningful when the YOY are excluded. The density of smallmouth bass juveniles and adults combined were nearly equal in both rivers (200/hectare). When comparing sucker and bass numbers excluding YOY a 1.5 to 1

Table 3. Mean length (mm) at age of smallmouth bass by month, Red Cedar River, 1988 and 1989.

Year and Month		Age 0+	1+	2+	3+	4+	5+	6+
1988								
June	Length	23	101	---	237	---	---	---
	Number	22	13	0	2	0	0	0
July	Length	52	123	142	289	288	352	---
	Number	64	10	4	1	2	1	0
August	Length	71	149	---	286	325	---	362
	Number	67	9	0	3	1	0	1
1989								
July	Length	87	95	161	232	328	346	390
	Number	4	11	5	3	2	1	1
August	Length	---	101	188	224	220	---	---
	Number	0	15	5	1	1	0	0
Sept.	Length	94	111	211	253	---	---	366
	Number	4	6	2	3	0	0	1
Oct.	Length	99	108	---	---	335	---	---
	Number	4	5	0	0	1	0	0

Table 4. Mean length (mm) at age of smallmouth bass by month, Flat River, 1988 and 1989.

Year and Month		Age 0+	1+	2+	3+	4+	5+	6+
1988								
June	Length	32	125	148	250	318	328	485
	Number	17	15	1	1	5	1	1
July	Length	63	170	172	226	329	360	344
	Number	44	11	13	3	7	4	1
August	Length	89	173	203	331	346	347	---
	Number	54	8	16	5	1	2	0
Sept.	Length	88	178	---	---	---	---	---
	Number	36	1	0	0	0	0	0
Oct.	Length	86	115	---	---	---	---	---
	Number	12	1	0	0	0	0	0
1989								
July	Length	---	126	219	264	---	---	---
	Number	0	18	2	2	0	0	0
August	Length	---	146	---	---	---	---	---
	Number	0	7	0	0	0	0	0
Sept.	Length	61	149	293	---	355	---	---
	Number	1	8	2	0	1	0	0
Oct.	Length	62	144	---	---	---	---	---
	Number	4	12	0	0	0	0	0

Table 5. Abundance estimates (fish/hectare) for the Red Cedar and Flat Rivers in 1989. Also included are relative abundances for each habitat type, for each size class, of smallmouth bass, white sucker, northern hog sucker and golden redhorse.

	Red Cedar River				Flat River			
	Fish/	Fish/Hectare of			Fish/	Fish/Hectare of		
	Hectare	Run	Riffle	Pool	Hectare	Run	Riffle	Pool
Smallmouth bass								
All sizes	396	404	285	365	256	240	233	516
Young of the year	198	208	89	102	50	52	0	60
Juvenile	173	176	136	60	191	178	213	376
Adult	25	20	60	203	15	10	20	80
White sucker								
All sizes	57	62	0	20	197	176	127	515
Young of the year	0	0	0	0	60	62	107	0
Juvenile	0	0	0	0	50	52	20	20
Adult	57	62	0	20	87	62	0	495
Northern hog sucker								
All sizes	113	102	258	20	217	228	276	20
Young of the year	0	0	0	0	28	30	20	0
Juvenile	38	30	136	0	127	136	85	0
Adult	75	72	122	20	62	62	171	20
Golden redhorse								
Adult	1	0	0	80				

ratio of suckers to bass was seen in the Flat River while there was a 1 to 1.17 ratio in the Red Cedar River. Sucker density was higher in the Flat River at 137 white suckers and 189 northern hog suckers per hectare compared to 57 white suckers and 113 northern hog suckers per hectare in the Red Cedar River.

The abundance estimates were divided into habitat types. These relative abundances between habitat types can crudely give some indication of habitat use. They especially illustrate the apparent importance of pool habitat sites for the Flat River white sucker adults while YOY rely heavily on riffles. The use of riffles by northern hog suckers can also be seen clearly. Caution is advised however for comparisons between rivers using these abundance estimates since the habitat categorization that was used was very subjective and not directly comparable between rivers.

DISCUSSION

Smallmouth Bass and Sucker Interactions

My habitat-use results indicate that smallmouth bass and suckers at times live in similar habitats. Although not statistically similar, sucker and smallmouth bass diets were shown to be similar in some ways. The diet of smallmouth bass and suckers of all size classes contained chironomids. The reduction in the availability of this food type or others in the Flat and Red Cedar Rivers could drastically alter the diets of all these fish. Limited food resources could potentially result in competition between smallmouth bass and suckers in streams.

Ahlgren (1990) found that white sucker juveniles have the ability to separate invertebrates from detritus. The amount of detritus consumed was inversely related to the availability of preferred diet items. Since white suckers were not consuming much detritus in my study, preferred diet items were probably not limited at the time of my study. The percent volume of detritus in the stomach of white sucker may therefore be a good indicator of limited chironomid numbers. Since many fish rely on chironomids the potential for competition could be high in areas where this food is limited.

Food resources did not appear to be limited for suckers during the period of my study, however, the availability of some food items could have changed seasonally. Competition for diet items could therefore occur in the winter if food availability is low. The slower metabolism of fish (due to cold temperatures) during the winter however may not require as much food consumption and therefore minimize competition at this time.

Riffle diet items made up a large portion of YOY smallmouth bass diets. The diet and habitat use of northern hog suckers were both riffle oriented. Smallmouth bass typically inhabited slower current velocities than did northern hog suckers in my study. One possible explanation for the similarity of riffle organisms in their diet is based on underwater observations. Juvenile and YOY smallmouth bass were often observed feeding in the sediments disrupted by chubs (*Nocomis* spp.) and northern hog suckers. This same relationship between smallmouth bass and northern hog suckers was noted by Dewberry (1978) and Rankin (1986) and with black redhorse, *Moxostoma duquesnei*, by Bowman (1970). Rankin (1986) found this relationship between smallmouth bass and northern hog suckers to be the preferred method of foraging for smallmouth bass in the Flat River. One year he found that 33% of his observations of smallmouth bass between 40 and 180 mm exhibited this behavior. This is likely a very efficient way to forage without expending as much energy as it would take to find food in the strong current of a riffle. It may also enable bass to feed on resources not otherwise available.

Ahlgren (1990) found that white sucker juveniles have two distinctive feeding behaviors: spitting and filtering. In both cases debris was expelled. The high amount of debris and riffle diet items found in smallmouth bass juvenile and YOY stomachs and the often observed behavior of feeding behind other fish, may be related to this feeding technique in suckers.

Other species of suckers may be as selective in their method of feeding in the substrate as Ahlgren (1990) found for white suckers. I found that northern hog suckers had little detritus in their diet. They, however, were typically collected in areas not associated with soft sediments.

With only slight differences in the habitat use of white sucker YOY, juveniles and adults and the same life stages of smallmouth bass it appears that these species may often inhabit the same areas. The difference in the diets of these species could reflect the unlikelihood of competition for food between them. Conversely, my findings could have been influenced by the interaction of fish and the resulting alteration of their diet due to this interaction.

Studies of species interactions in warmwater streams reveal that most techniques designed to define species/habitat associations produce such complex patterns of overlap that the study has limited meaning. Many studies do indicate overlap in diet and spatial location within streams, however the controlling factors involved are usually not associated with any interaction between species (Moyle and Li 1979). Moyle and Li (1979) suggested that the physical and chemical characteristics of a stream are the most important determining factor of species composition. Beyond species composition however the predictability of the fish community as far as numbers and biomass depends on the stability of the stream and the severity and timing of uncontrollable events such as floods and droughts. The instability and diversity of the environment that warmwater stream fish live in may rarely allow competing species to reach levels such that competition for food or space is a limiting factor.

Habitat Use and Diet

Smallmouth bass

I found YOY smallmouth bass to use depths between 0.2 and 0.6 m. Rankin (1986) found that smallmouth bass consistently avoided shallow areas (<0.45 m) of the stream. Rankin's observations however were limited to shallow pools in the Flat River during the day. He did note that during one year of his study there was a definite difference in depth use between size classes of smallmouth bass. During this year he found, as I did, that small bass consistently selected shallower depths than larger bass. Other researchers have found that the degree of microhabitat specialization of a species may change in response to the number and kinds of other fish present as well as the life history stage ((Gee 1974, Mendelson 1975, and Smith 1977 in Dowling 1987); Werner and Mittelbach 1981; Power et al. 1985; Schlosser 1987). One explanation for the difference in use of shallow water by YOY smallmouth bass in Rankin's (1986) study was explained by the presence of greater numbers of large smallmouth bass and rock bass. Consistent numbers of smallmouth bass YOY were seen during underwater observations in July, August and September in my study, however, in October a sharp drop was seen. This coincided with a noticeable disappearance of large bass from the study section and no apparent reduction in YOY presence during electrofishing. Movement of larger bass in the fall to overwintering areas has been shown in several rivers (Langhurst and Schoenike 1990). Once large bass were gone the YOY may have dispersed out of the 20 m area used for underwater observations into areas they did not inhabit before for fear of predation by large bass.

I found YOY smallmouth bass to inhabit slow current velocities most of the time during this study. This same finding has been documented many times in the literature (Dowling 1987, Probst et al. 1984; Sechnick et al. 1986; McClendon and Rabeni 1987).

The fact that YOY smallmouth bass were found in faster current velocities in the Red Cedar River than in the Flat River may explain the much higher average percent composition of riffle organisms in their diets. The Red Cedar River riffle margins also often contained high emergent weed growth where YOY smallmouth bass seemed to gain shelter. The bordering emergent weeds of the Red Cedar River riffles may also trap riffle species that drift into this area of reduced current. The use of this type of shelter is consistent with other studies describing young smallmouth bass habitat use in warmwater streams (Dowling 1987, Probst et al. 1984; Sechnick et al. 1986; McClendon and Rabeni 1987). Munther (1970) noted the propensity of bass to occupy areas near the edge of the current. Due to the relatively large (12 m^2) area shocked, often the edge of a current break went through the middle of the sampled area.

Inactivity of smallmouth bass at night could explain the use of slower currents during the night by YOY. Dowling (1987) found, for bass between 66 and 156 mm, the peak feeding time was at sunrise and just prior to sunset, however, they also fed during the day. Rankin (1986) noted YOY bass feeding actively up to 60% of the time during the day and Munther (1970) noted little movement of YOY smallmouth bass at night. Some of the slowest water was found in the very shallow sections along or near the edge of the rivers. At night YOY bass may be using these areas as resting habitat or may not utilize these areas as heavily during the day due to risk of predation from above.

I found the diet of YOY smallmouth bass during this study was very similar to those found in the literature. Dowling (1987) found YOY smallmouth bass to feed primarily on microcrustaceans, ephemeropterans, dipterans and hemipterans in the Red Cedar River. Representatives from these three insect orders also made up a good portion of the smallmouth bass YOY diets in my study. However, depending on the family of Ephemeroptera and Diptera, the diet item may have been categorized as either riffle or pool diet groups in my study. Aadland et al. (1989), using taxonomic groupings for aquatic insects orders, found smallmouth bass fingerlings (60 to 99 mm in length) to have diets comprised of 65% Pool Taxa (which included all dipterans and hemipterans) and approximately 35% Riffle Taxa (which included all ephemeropterans). Surber (1939) found siphlonurid, baetid and heptageniid ephemeropterans (all riffle diet group) and chironomids to be the main food items for smallmouth bass fingerlings.

Surber (1939) found zooplankton played a minor role in the diet of bass in his study. George and Hadley (1979) also noted zooplankton were eaten by smallmouth bass smaller than 40 mm. The relative lack of zooplankton found in the diets of smallmouth bass in my study may have been because collections did not begin until most YOY were greater than 40 mm in length.

Fish and crayfish were found in the stomachs of smallmouth bass YOY in both the Red Cedar and Flat Rivers. Despite many references for larger bass feeding on crayfish, little has been reported for YOY. Probst et al. (1984) found no relation between smallmouth bass length and size of crayfish eaten. George and Hadley (1979) stated that apparently smallmouth bass fed on the largest organism that they could digest. They however found no crayfish in YOY smallmouth bass stomachs despite an abundant crayfish population in their study river. One possible difference is that the August average length of Flat River and Red Cedar River smallmouth bass YOY in 1988 were 89 mm and 71 mm, respectively, compared to the 51 mm average that George and Hadley found on August 23, 1977. Livingstone and Rabeni (1991) suggested one possible reason for YOY smallmouth bass not having crayfish in their diet might be that obtaining crayfish may be more difficult than small minnows and therefore minnows may be favored as a more profitable food source. Livingstone and Rabeni (1991) also suspected that by not feeding on crayfish, YOY smallmouth bass may reduce intraspecific competition, for crayfish as prey, with larger size classes of smallmouth bass.

Surber (1939) also found that some fry, even at an average length of 10 mm, had consumed fish. Coble (1975) cited Wickliff (1920) and Pflieger (1966) as reporting that fish may become an important part of the diet of smallmouth bass when the bass are as small as approximately 15 mm. George and Hadley (1979) found fish to enter the diet of smallmouth bass when the bass reached 13 mm and that they became important prey for smallmouth bass above 40 mm.

Juvenile smallmouth bass appeared to be the least restricted in habitat use with most intervals within each habitat category being represented. I found the majority of juvenile smallmouth bass in current velocities of 0.21 to 0.4 m/s. Other studies show similar results in midwest streams (Aadland et al. 1989 and Monahan 1991). Monahan (1991), however, cited Orth (1981) and Bain et al. (1982) as finding slower preferred velocities. Often juvenile smallmouth bass have been observed following northern hog suckers (Rankin 1986). The higher velocities used by northern hog suckers could have led juveniles into this higher velocity water. Conversely the loss in resolution of microhabitat due to the relatively large (12 m^2) area sampled could have affected my results. Substrate use (being dominated by sand) also may not be realistic due to the loss in resolution of using only the dominate substrate type in a 12 m^2 area. My underwater observations were more like the results found in the literature. Direct observation of fish is also the method that was used in the majority of the other habitat use studies for small fish. Other studies have documented cobble and rubble as the preferred substrate (Coble 1975; Edwards et al. 1983; Monahan 1991). Cover use by juvenile smallmouth bass in my study was primarily complex cover types and rocks.

Juvenile smallmouth bass were found to feed on a variety of different food items, in particular crayfish, fish, and riffle and pool insects. This is similar to what has been found in others studies (Doan 1940; Webster 1954; Coble 1975; Edwards et al. 1983; Probst et al. 1984 and Aadland et al. 1989). Probst et al. (1984) found fish and crayfish to be the primary forage of smallmouth bass between 100 and 254 mm. Benthic invertebrates such as Siphlonuridae and Perlidae (all riffle organisms) were also found, but to a lesser extent than fish and crayfish (Probst et al. 1984).

Adult bass in my study used fairly deep areas, with a variety of cover types and open water, during the day and in the summer, and moved into shallow rocky areas at night and during the fall. These findings are similar to the literature and held true for my study except that Red Cedar

River smallmouth bass were found in shallow water in the fall. I found virtually no adult fish in the Flat River during fall 1988. The shallow habitat that held adult bass throughout the summer no longer held adults the following fall. I believe smallmouth bass often migrate in the fall in search of deep rocky substrates as an overwintering area.

Munther (1970) could only find bass in deep water (>2.3 m) in late fall. Most were found in still, rocky pools at least 3.6 m deep. Langhurst and Schoenike (1990) found that smallmouth bass (>200 mm, total length) migrated 69 to 87 km downstream when water temperatures fell below 16° C in autumn and adults (>280 mm) migrated sooner than the subadult bass. These fish were presumably seeking deeper pools for overwintering.

My 1989 prepositioned area electroshocker results indicate that rocky substrate may be more important than depth in the fall. My Red Cedar River results indicate selection of shallow depths with rocky cover in the fall. Depth was not considered to be as important to smallmouth bass as other factors by several other researchers (Paragamian 1981; McClendon and Rabeni 1987; Todd and Rabeni 1989). Munther (1970) found that sand was used very little by adult smallmouth bass (122 to 480 mm in length) and broken rock substrate was preferred. Others have similarly shown the importance of cobble and boulders (Paragamian 1981; Sechnick et al. 1986; Todd and Rabeni 1989).

Adult smallmouth appeared to select areas with complex cover combinations in the Flat River. In contrast, the Red Cedar River adults appeared to select areas of open water or with single logs over all others. One explanation for this difference between rivers is that smallmouth bass in the Red Cedar River were using pools, providing cover from depth alone. By comparison the Flat River's pools were much less defined and were comparable to many of the Red Cedar River runs. Coble (1975) mentions that bass use deep, dark, quiet water for cover.

Adult smallmouth bass fed on primarily fish and crayfish, with all other diet groups being represented about equally. The propensity of adult smallmouth bass to feed on crayfish and fish is well documented in the literature (Coble 1975; Paragamian and Coble 1975; Edwards et al. 1983). The identification of fish species in the diet of adult smallmouth bass was rarely possible in my study. From my prepositioned electrofishing data there appeared to be a greater abundance of forage-size fish found in riffles as compared to pools. Aadland et al. (1989), however, found the abundance of pool and riffle species of fish to be just about equal in smallmouth bass stomach contents. Adult bass may rely heavily on riffles as either feeding habitat, or as an area that one of their primary forage items is in greatest abundance. The pools may serve as important refuge for adults since very few forage fish were found here. This low abundance of forage fish could also be caused by the presence of the predatory bass. The bass could attack most of the forage fish that wander into their home pool. This would keep the number of fish down and chase other fish away. The most productive areas for large, actively feeding, bass might therefore be in a pool directly below a productive riffle or in the tail of a pool if they exist. These areas may also be prime areas for eating crayfish (Mather and Stein 1991).

The difference seen in the abundance of forage fish in each habitat type was not observed with crayfish in my study. Although crayfish were not sampled for abundance they appeared to be equally abundant in run, riffle and pools sites. Stein and Magnuson (1976) and Mather and Stein (1991) indicated that crayfish do have habitat preferences and they change their habitat, among other behaviors, in the presence of smallmouth bass. Crayfish abundance in certain habitats may influence smallmouth bass habitat use (Todd and Rabeni 1989). Coble (1975) noted that smallmouth bass diet was influenced by prey abundance and also mentioned the importance of prey availability. Probst et al. (1984) showed that despite the abundance of many size classes of crayfish, adult bass were found to have medium size (24 to 46 mm) crayfish in their stomachs 90% of the time. Stein and Magnuson (1976) further showed that the largest crayfish, especially male crayfish, did not alter their habitat use as strongly in the presence of bass. This was possibly due to the fact that smallmouth bass may not commonly attack them. Crayfish found in smallmouth bass stomachs were not measured in my study. I believe, however, that many were larger than 46 mm, especially in the larger adults. Probst et al. (1984), however, found no relation between smallmouth bass length and the size of crayfish eaten.

White sucker

Habitat use for white suckers paralleled that for smallmouth bass where YOY used slow shallow water, adults used moderately deep water avoiding the shallows and juveniles were intermediate. Substrate use differed whereby white suckers preferred sandy substrates and were more likely to choose areas with no cover or with no selection of any one particular cover type more than its availability. Aadland et al. (1989) categorize white sucker YOY as shallow pool guild, juveniles as riffle guild, and adults as pool guild.

Over all size groups, white suckers consumed chironomids more often than any other diet item. Others have reported similar findings for the St. Vrain and South Platte Rivers, in Colorado (Eder and Carlson 1977) and in New York streams (Stewart 1926 in Eder and Carlson 1977).

I found pool invertebrates to be an important component of the diet of white sucker YOY. Riffle organisms were not found in YOY diets but were important to juveniles and adults in the Flat River The slow current velocities used by white sucker YOY may explain why riffle organisms were not seen in their diet. Adult white sucker diets contained few pool diet items despite the sucker's high rate of occurrence in pool habitats. Pools are known to be a common habitat for many chironomids. Some chironomids may also be found in the interstitial spaces of coarse substrate in swifter water. Possibly if chironomid identification was taken to the level of genus or species some of this large component of the diet could have been categorized as either riffle or pool diet group and used to better define the areas used for feeding by white suckers.

The average percent volume of detritus was relatively low compared to some other studies. White suckers in the South Platte and Saint Vrain Rivers had percent volumes of detritus and sand combined of 83% and 74% respectively (Eder and Carlson 1977). Eder and Carlson further report that the availability of preferred prey items (chironomids) were limited and competition between white sucker and carp for these items was occurring. Ahlgren (1990) reported that juvenile white suckers can separate detritus from invertebrates and that detritus is ingested intentionally when preferred invertebrate prey are scarce. Ahlgren found ash-free dry mass (AFDM) to change from 5% during high abundance of invertebrates in July to 95% during low invertebrate abundance in October. The low percent volume in white sucker stomachs in the Flat and Red Cedar Rivers may indicate that during the times of my collections the availability of their preferred diet items was not limited.

Zooplankton was consumed by white suckers more than any other species in my study. Several sources document the propensity of white suckers to feed on zooplankton, however most are from ponded waters (Ahlgren 1990; Hayes 1956 in Eder and Carlson 1977).

Northern hog sucker

Of all species observed, it appears that the northern hog suckers' changes in habitat use with size, relate to similar diet shifts. It appears that the areas that they inhabit are the areas where they feed. Lobb and Orth (1991) determined YOY and juvenile northern hog suckers were best categorized as life stages that reside in habitats along the edge of pools. Lobb and Orth (1991) discuss how others have categorized juveniles as being widely distributed among habitats but most common at the heads of pools while adult northern hog suckers were in faster water (Finger 1982). Lobb and Orth (1991) further cited Schlosser (1982) who considered northern hog suckers to be raceway-pool guild members. Aadland et al. (1989) categorize northern hog sucker YOY as shallow pool, juveniles as riffle, and adults as run guilds.

Other catostomids

Golden redhorse are abundant in many Michigan streams such as the Looking Glass, Kalamazoo and Red Cedar Rivers. I was able to collect only limited data on these fish.

Aadland et al. (1989) categorized adult golden redhorse as run guild and YOY golden redhorse as shallow pool guild. From my study golden redhorse diet appeared to be similar to white sucker adult diet in the Red Cedar River. Additional study of golden redhorse diet is needed.

Smallmouth Bass Growth

Length at age data indicates that YOY smallmouth bass growth was better in 1988 in the Flat River while 1989 was better for YOY in the Red Cedar River. The Red Cedar River YOY smallmouth bass were 87 mm in July 1989. This was based on a sample of only four fish collected at the end of the month. In August of 1988 the smallmouth bass averaged 71 mm in the Red Cedar River. The site these fish were sampled from changed in the Red Cedar River from 1988 to 1989 and therefore comparisons between years should be cautious.

Young of the year smallmouth bass were encountered more frequently in both rivers in 1988 than in 1989, however no abundance estimates were made in 1988 for direct comparison between years. Dowling (1987) found an inverse relationship between cohort size and growth in the Red Cedar River. This could explain the difference seen in the Red Cedar River YOY growth if abundance was indeed less in 1989 compared to 1988. This same relationship was not seen in the Flat River where growth was considerably less in 1989 than in 1988. Furthermore, Flat River YOY bass growth was considerably less than Red Cedar River YOY bass growth in 1989 despite

YOY abundance estimates of 50/hectare and 198/hectare respectively. This population density difference, however, is of limited usefulness in comparing growth since the population density must be related to the carrying capacity of each stream. Carrying capacity is not known and would be difficult to determine. Other differences between rivers may have had an affect on this such as temperature and time of spawning.

Relative Abundance

The 1989 young of the year smallmouth bass year class may have been reduced in size due to high water that occurred in June of 1989. For the month of June the mean, maximum, and minimum flows for the Red Cedar River at Williamston were 16.7, 29 and 8 cfs respectively in 1988 compared to 306, 637 and 132 cfs in 1989. Dowling (1987) mentioned that the timing of floods can dictate the success of a smallmouth bass year class. Larimore (1975) found that fry had problems maintaining themselves in current above 0.18 m/s and were nearly all displaced at this velocity during darkness.

My abundance estimates should not be expanded to the river as a whole. Especially for comparison to estimates found historically for the Red Cedar River (Linton and Ball 1965). I feel my estimates were reasonable for the small section of river I studied. The section I studied, having only one small pool and one riffle, probably was not comparable to Linton and Ball's, which contained four pools and two riffles. This may be reflected in the relatively low number of white suckers and redhorse I found. Linton and Ball found total sucker densities using electrofishing gear and a Peterson mark recapture estimate were 621 during 1959, 403 in the summer of 1960, 1851 in the fall of 1960, 406 in the summer of 1961, and 986 in August 1962. A follow-up rotenone survey in 1962 revealed 1043 suckers/hectare suggesting that population estimates during the previous three years may have underestimated sucker densities (Linton and Ball (1965).

Linton and Ball (1965) found smallmouth bass to be more abundant in the zone where my study site was located than at the other locations on the Red Cedar River. They also determined sucker densities in this zone to be high to normal for the river. They found densities of 287 smallmouth bass, 480 white suckers, 349 northern hog suckers and 215 redhorse per hectare during the rotenone survey in 1962. My estimates were 396 smallmouth bass, 57 white suckers and 113 northern hog suckers.

The time of sampling can have a profound affect on what may be found. Langhurst and Schoenike (1990) found smallmouth bass (>200 mm, total length) to migrate 69-87 km downstream when water temperatures fell below 16°C in autumn. Adults (>280 mm) migrated sooner than the subadult bass. Therefore relative abundance estimates could be drastically influenced by these movements that could concentrate fish in relatively unproductive summer habitat or underestimate the abundance of bass using the prime summer habitat.

Assumptions

Many assumptions were made throughout this study, some are discussed below. The Flat River pool sites were similar to the Red Cedar River run sites. The Flat River study section could be considered a long run with a riffle at the upstream end. Despite this, and other differences in habitat, most habitat use results (i.e. depth, velocity, substrate, and cover distributions) were similar between fish of the same species and size in both rivers.

Dominate substrate may not accurately describe the substrate used by the individual fish that were shocked from the area. Often the small patches of less dominate substrate types were the suspected original locations of the collected fish. Underwater observations in 1988 were particularly insightful in this regard. A smaller area shocked would undoubtedly improve the resolution of this measurement but would add greatly to the effort that would be required to obtain adequate sample sizes during a sampling period. Cover use may be more insightful for this purpose since the presence of any rubble sized rock or larger was taken into account for the cover distributions. Additionally depth and velocity use from 1989 does not represent the actual focal point velocity or distance the fish may have been off of the bottom. Underwater observations were more helpful in determining microhabitat use of this type.

Results of diet analysis were compared to fish habitat use and probable prey location. The actual distribution of prey across habitat types and the actual availability of prey was not determined. By using the habitat use distributions (depth, velocity and substrate), assumptions were made as to the type of area where the fish were actually located (i.e. run, riffle or pool) at the time of collection since the original categorization of run, riffle and pool did not remain constant through the study. The location where the fish was caught may, or may not, be at all associated with that fish's feeding habitat. Klauda (1975) noted that adult smallmouth bass spent less then 1% of their time feeding. Therefore, for some species or size classes, the likelihood of collecting these fish in the areas where they are feeding may be remote. The type of organism that they are feeding on may give clues as to where the fish may have actively fed or the critical habitats that might be needed for their forage to be present. Resource availability estimates were not conducted due to time constraints and the complex problem of trying to determine the apparent resource availability with the actual resource available to the fish. Volume or weight measurements of diet items were not taken. A more thorough analysis could have been made with the addition of volume measurements and some measure of resource availability (Larimore 1957; Wallace 1981; Bowen 1983).

SUMMARY

Smallmouth bass and suckers were not proven to be competing with one another for habitat or diet in the Red Cedar or Flat Rivers. Sucker habitat use was similar to that of smallmouth bass in several ways but diet was found to be different. White sucker diets were found to have relatively little detritus which is an indication of good availability of preferred prey.

Smallmouth bass abundance was high and growth was slightly below average for adults in both rivers. YOY growth was average in both streams but varied widely as did abundance from year to year. Abundance of smallmouth bass was higher and sucker abundance was lower in the Red Cedar River compared to the Flat River.

The difference in diet and good growth and abundance in both rivers suggest that despite some habitat overlap interspecific competition is not occurring in these rivers. Manipulating sucker densities, while comparing the above mentioned factors, could indicate if competition might occur under different conditions.

The diversity of species in warmwater streams and complex nature of their interaction would make the results of sucker density manipulations difficult to predict.

Additional studies are therefore needed before sucker removal is used as a management technique to improve smallmouth bass populations in warmwater streams.

IMPLICATIONS FOR MANAGEMENT

Further study is needed in order to assess the possibility of sucker competition with smallmouth bass. Sucker removal projects may not, as mentioned by Holey et al. (1979), be successful in meeting the management objective of increased growth or abundance of gamefish, especially in a system where other fishes at the same trophic level as suckers are abundant. Warmwater stream environments are typically rich in species diversity and quite likely other fishes would share, possibly with smallmouth bass, in the added resources that would become available after sucker removal. The presence of suckers may even make resources available that other fish may not be able to easily feed on in their absence (i.e. northern hog suckers/smallmouth bass). Further knowledge about the role that suckers play in smallmouth bass streams may shed light on determining at what level suckers may negatively or positively impact bass populations if at all. As recommended by Holey et al. (1979), studies trying to assess this should quantify growth, abundance, and food habits of suckers, of several other fish species at the same trophic level as suckers, and of any species that prey extensively on suckers for a number of years before and after sucker removal. They also suggest, as I do, that the abundance in the environment of the foods eaten should be closely monitored at the same time. Winter periods should be included in any study and an assessment of the energy needs of fish given the decreased metabolic rate at this time should be considered.

Overall it appears, from the literature, that year to year differences in the timing of floods and droughts may have the single greatest effect on smallmouth bass densities in streams. Those streams that naturally minimize the effects of drought and flood will have more stable fish populations. This stability however often comes in the form of high groundwater input and low direct surface runoff. These conditions are more characteristic of coldwater streams that are not as suitable thermally for smallmouth bass.

Although smallmouth bass can live in a variety of different stream types, only certain streams provide ideal conditions for stable smallmouth bass populations. Trying to alter species composition in favor of smallmouth bass growth and abundance will probably be met with variable results since the physical nature of the stream will ultimately control the system.

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APPENDIX

Red Cedar River and Flat River Daily Maximum and Minimum Water Temperatures

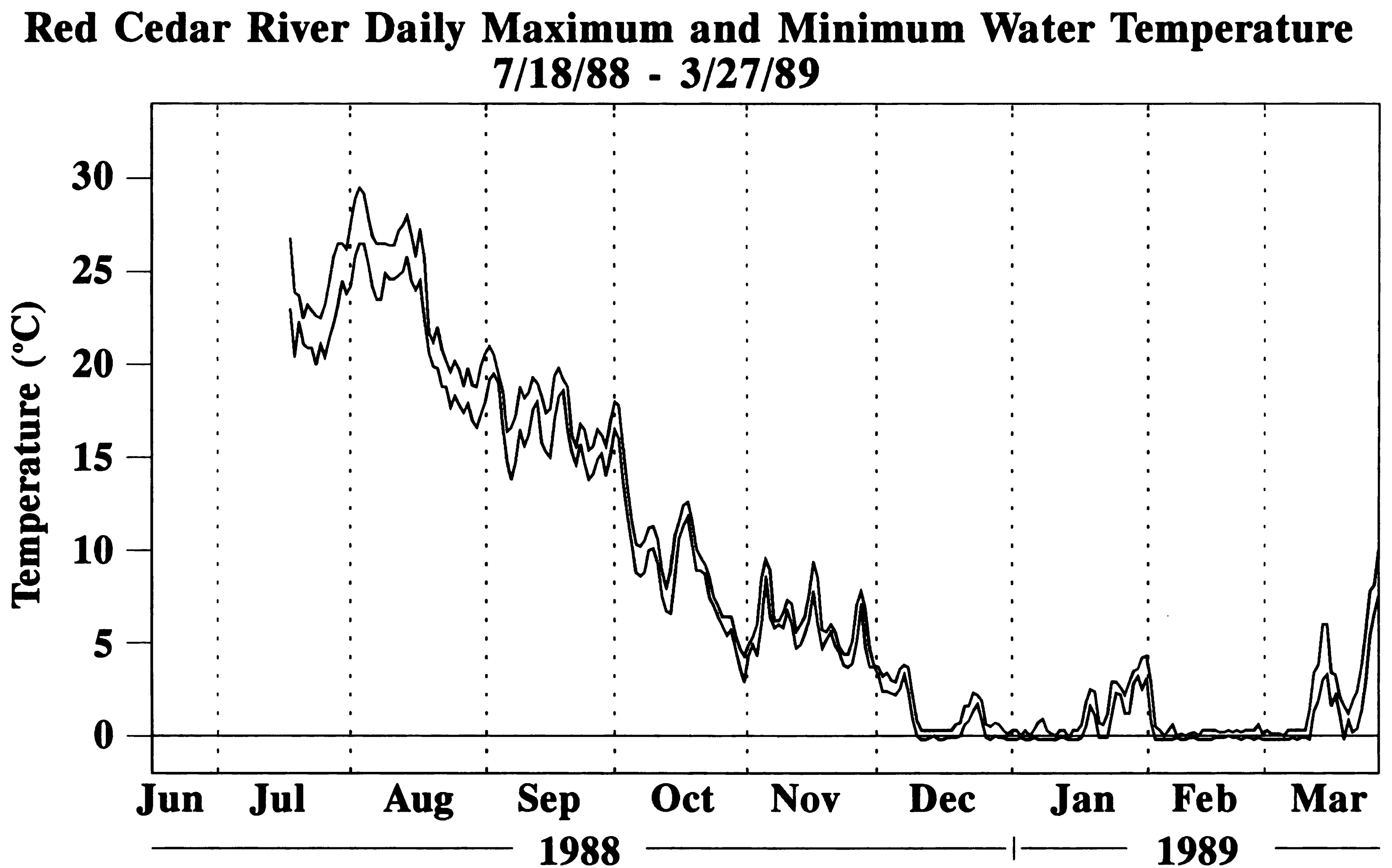

Figure 32. Red Cedar River daily maximum and minimum water temperatures taken with a continuous reading Ryan thermometer at the Zimmer Road bridge, Williamston, from 18 July 1988 - 27 March 1989.

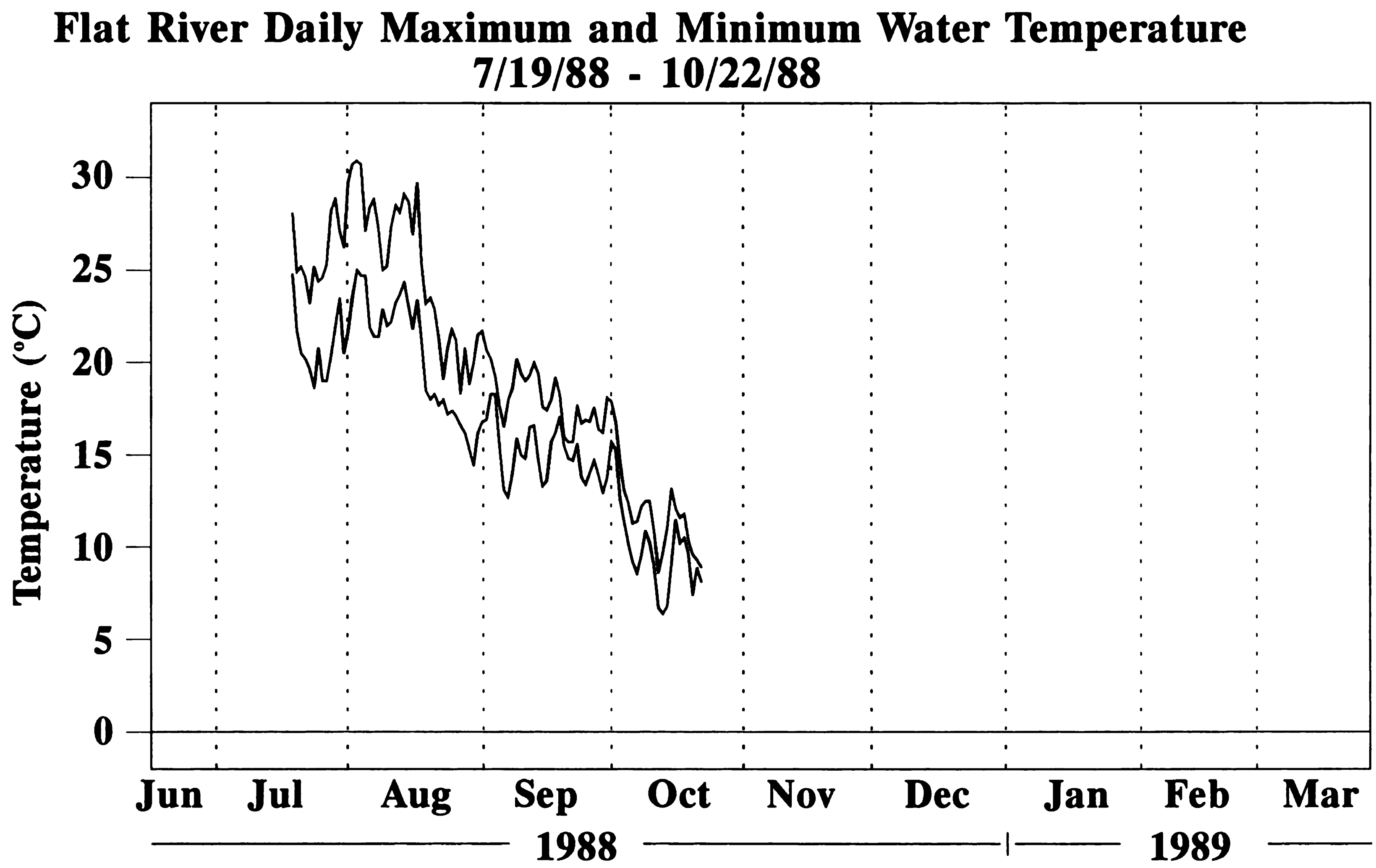

Figure 33. Flat River daily maximum and minimum water temperatures taken with a continuous reading Ryan thermometer near the Miller Road bridge from 19 July 1988 - 22 October 1988.

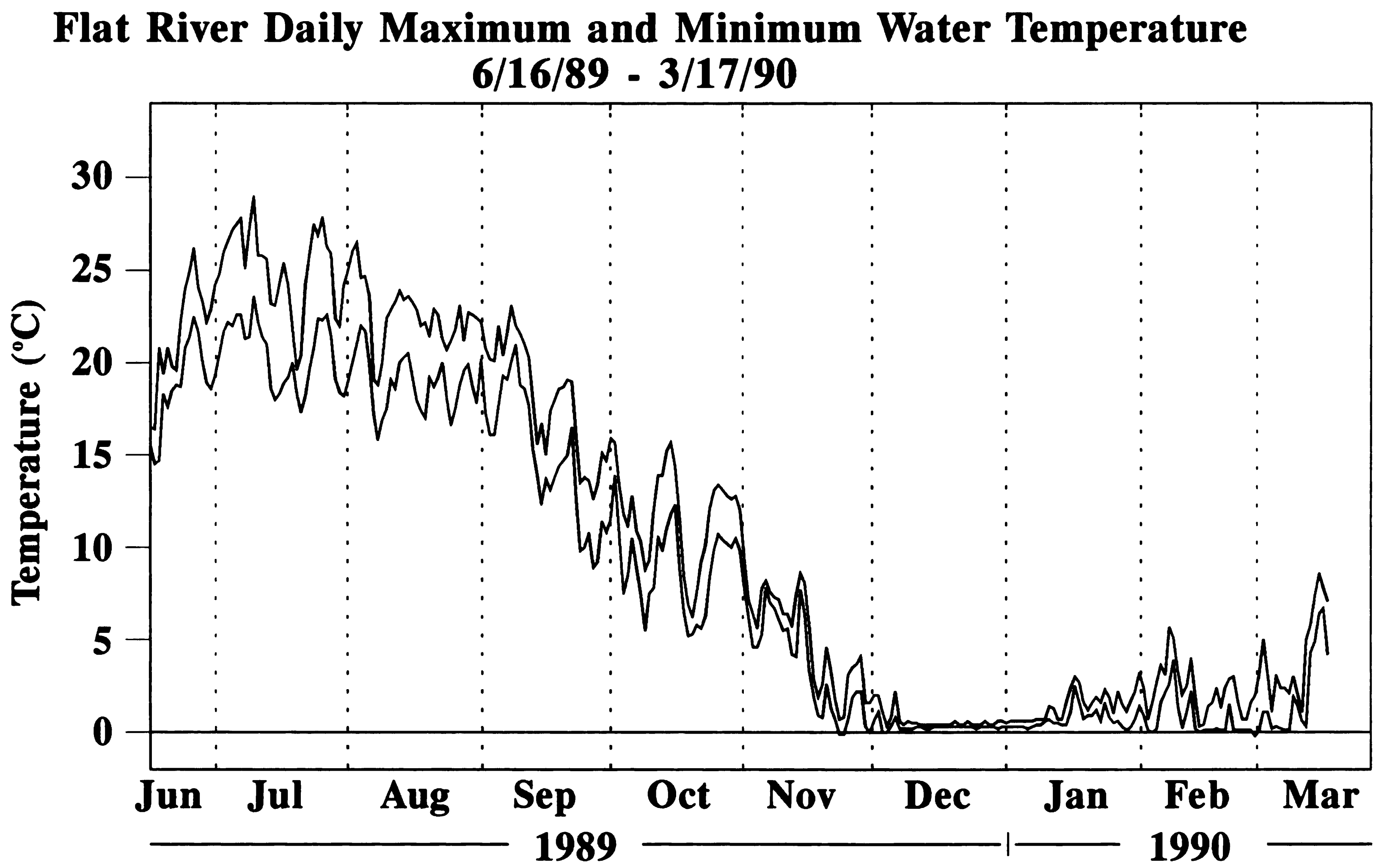

Figure 34. Flat River daily maximum and minimum water temperatures taken with a continuous reading Ryan thermometer between the Miller Road and Lake Road bridges from 16 June 1989 - 17 March 1990.