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Daily and Seasonal Movement, as Related to Habitat Use, of Smallmouth Bass in the Huron River, Michigan

Jennifer D. Beam

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DAILY AND SEASONAL MOVEMENT, AS RELATED TO HABITAT USE, OF SMALLMOUTH BASS IN THE HURON RIVER, MICHIGAN.

by

Jennifer D. Beam

A Thesis Submitted in Partial Fulfillment of the
Requirements for the degree of Master of Science

School of Natural Resources
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1990

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Table of Contents

List of Figures

List of Tables

Abstract

Work on smallmouth bass biology over the years has focussed on lake and impoundment populations. Most stream habitat studies have used mark-recapture or visual observation to monitor fish. This study used radiotelemetry to monitor seasonal and daily movement and to determine habitat selection of smallmouth bass.

Radio transmitters were implanted in 18 smallmouth bass 253 to 466 mm in total length, from the Huron River, Michigan between November 1987 and July 1989. Fish were located twice a week during spring/summer and once a week during fall/winter. Position determination was used to monitor habitat use, total range, home site use, and active displacement. Habitat selection was determined by comparing transect measurements in areas used compared to those available but not used.

Movement of smallmouth bass was variable, but all fish had a small total range and limited activity levels. Larger fish had significantly greater total ranges than smaller fish (r=0.66). The smallest total range was 20 m and the largest was 370 m. There was no significant difference between spring/summer and fall/winter ranges. Mean active displacement varied between 10 m and 136 m, with no significant difference between spring/summer and fall/winter displacements. As with range, there was a positive linear relationship between total fish length and mean active displacement (r=0.67) i.e. larger fish tended to be more active.

Change in home site was not a common occurrence. Typically, each fish utilized one home site during the tracking period.

Smallmouth bass were found exclusively in medium gradient stretches. These areas were characterized by moderate width and depth, pools below obstructions, silt absent in the stream channel unless behind obstructions, and the wake (disturbed area) downstream of obstructions less than 1 m long, but without bubbling.

In every instance, when fish were stationary, they were in association with cover. There was a significant selection for logs, log complexes, and other (root wads, man-made objects, etc.). These habitat types typically contained low velocity, silt and sand substrates, and were close to shore.

Introduction

The smallmouth bass (*Micropterus dolomieui*) is an important gamefish in warmwater rivers in Michigan. In order to manage this species, information concerning movement and habitat use must be obtained. Current management strategies are aimed at increasing the number and size of catchable fish (Merna 1989); this is being done by the use of catch-and release regulations. If smallmouth bass are relatively sedentary in the Huron River, then special regulations could improve fish numbers. Trophy size brown trout have been found to routinely leave protected areas of the Au Sable River, thus eliminating the beneficial effects of such regulations (Clapp 1988). Therefore, movement data must be gathered before special regulations of this type are attempted.

If fishing mortality is not the limiting factor for the population, habitat may be. Smallmouth bass have been shown to exhibit habitat preferrences, with cover being an important variable (Angermeier and Karr 1984, Rankin 1986, Carline et al. 1986). By knowing the habitat preference of smallmouth bass, a stream can be managed to provide more preferred habitat for the species.

In determining habitat preference for a fish species, a fish is observed in some manner, and its habitat is measured at the point of observation. In this way the habitat which is used can be separated from that which is available, but not used. There have been various ways in which an individual fish position has been defined. One of the most straightforward methods is by direct observation (Klauda 1975, Carline et al. 1986, Hampton & Aceituno 1988). Mask and snorkel as well as scuba have been used to observe fish in the water. These methods are limited, however, by depth and turbidity. Another form of direct observation is that of bank observation. Rankin (1986) used this method to test the results of his lab experiments on habitat preference. This method is limited even more by depth and turbidity, in addition to being limited by surface disturbances caused by overhead cover.

A method which overcomes some of the problems associated with visual observations is electrofishing. Electrofishing can be attempted in more turbid waters, but has depth limitations (Orth et al. 1984). Several studies have compared electrofishing with other fish location methods. Orth et al. (1984) tested electrofishing versus angling as a method of sampling smallmouth bass and green sunfish habitat preferences. Their results showed significant differences between the two sampling methods, which they assumed resulted from electrofishing being less effective in deep pools, and thus skewing the electrofishing results towards those individuals which preferred shallower habitat.

The use of radiotelemetry showed the most promise for habitat study of smallmouth bass in the Huron River, Michigan. The cost of transmitters would limit the number of individuals which could be monitored, but each measurement could be done with a minimum disturbance to the fish. Also , one could continuously monitor an individual fish, and thus gain detailed information concerning behavior over time. One could detect change in behavior of a single fish over seasons or days, thus eliminating bias between fish. And telemetry was not limited by depth, turbidity, time of day, or visual obstruction (Winter 1983, Clapp 1988).

Electrofishing has been compared to radiotelemetry and found to exhibit biases in habitat selection studies. Tyus (1988) compared habitat preference data of Colorado squawfish (Ptychocheilus lucius) obtained by radiotelemetry and electrofishing, and found differences in depth preferences. Researchers have attributed electrofishing bias to a "herding" of fish caused by electrofishers themselves; a phenomenon termed "fright bias" by Bain (1988). As the team proceeded through the river, fish were flushed toward cover, and thus were over-represented in shallower areas.

Movement data can be obtained simultaneously using radiotransmitters. Also, movement studies have been made of smallmouth bass using various other methods, such as mark-recapture (Fajen 1962, Larimore 1952). While more fish can be used in tagging studies than in telemetry, the investigator obtains no information on daily activity, or of the location of the fish during the time it was free. There are also biases inherent with the method of recapture which may only recover fish when they are occupying certain areas. For example, Munther (1970) could not locate smallmouth bass in deep pools because of limitations of electrofishing. Considering the above limitations, telemetry was chosen as the best method to study both habitat choice and movement of smallmouth bass in the Huron River.

Work on smallmouth bass biology over the years has mostly focussed on lake and impoundment populations (Beeman 1924, Latta 1963, Peterson & Myhr 1977, Hubert & Lackey 1980). The geographical range of the smallmouth bass covers a large scope of habitat types and temperature regimes. Stream populations of smallmouth bass have a variety of habitat types available depending on location (Todd & Rabeni 1989, Munther 1970, Hubert 1981). For this reason, one must use caution when making generalizations concerning habitat preferences.

I expected smallmouth bass to use areas with a variety of cover types and velocities available. Edwards et al. (1984) worked in the Olentangy River in Ohio which had been channelized, so that the river had a bottom configuration that was homogeneous. This river is located slightly south of the Huron River, but is fairly comparable. Artificial riffles and pools were constructed, and the benthic invertebrate and fish communities monitored. They found an increase in diversity and biomass of benthic invertebrates as well as an increase in smallmouth bass numbers and condition in the mitigated sections.

I predicted from past works that smallmouth bass in the Huron River would be relatively sedentary. In Missouri, Fajen (1962) found that smallmouth were a sedentary species when subjected to a stable flow regime. In his mark-recapture study, he found 77% of the bass in stable pools either remained in, or returned to, their home pools. Fish originally tagged in unstable pools were found most frequently (77% of the time) in other than their home pool at the time of recapture. The Huron River flow regime is stable enough that the runs and pools do not change in accessibility during the course of the summer, making them comparable to Fajen's stable pools.

The reach of the Huron River chosen for this study represents typical warmwater river habitat in Michigan. It is accessible due to the presence of various parks along its course, and a road (Huron River Drive) which borders the river for the duration of the study reach and beyond. There are good fish population and fishing pressure data for this stretch as a result of a Michigan Department of Natural Resources (MDNR) study which has been in progress since 1984. No other warmwater river in Michigan has been studied this intensively.

The purpose of this study was to evaluate movement and habitat preferences of smallmouth bass in the Huron River. The specific objectives were 1) to evaluate seasonal and daily movement of smallmouth bass to determine home range and stability of site locations, and 2) to determine habitat selection of smallmouth bass, and compare selected sites to those generally available to determine site preference. In order to accomplish these objectives, 18 smallmouth bass from the Huron River were implanted with transmitters and followed between November 1987 and November 1989.

Methods

Study Area

This study was conducted on 16 km of the Huron River, centered around Dexter, Michigan (Figure 1). The Huron River is a warmwater river which originates in western Oakland County and flows to Lake Erie. It is a fifth order stream throughout the study area with a drainage area of 1789 km^2 at the downstream edge of the study reach (699 mi^2). The average discharge (up to 1972) was 9.76 m^3/s (345 cfs) at North Territorial Bridge (USGS 1988).

The study stretch has an average width of 35 m and depth of 43 cm. There are few deep pools exceeding 3 m, and most pools are in the range of 2 m deep. Development along the river is fairly limited due to the large amount of land set aside as parks, such as Hudson Mills, Dexter-Huron, and Delhi. There are many wooded areas bordering the river which provide shade. The area from Mast Road to Delhi Park is under an experimental catch-and-release regulation for bass which began in May 1989.

There are numerous lakes upstream of the study area, which tend to have a stabilizing effect on flow. Downstream, there are numerous dams which impede the migration of fish. At the mid-point of the study reach, Mill Creek enters the Huron. This fourth order tributary (average discharge 1.99 m^3/s (70.5 cfs)) drains agricultural land, and is a major source of turbidity, especially during run-off.

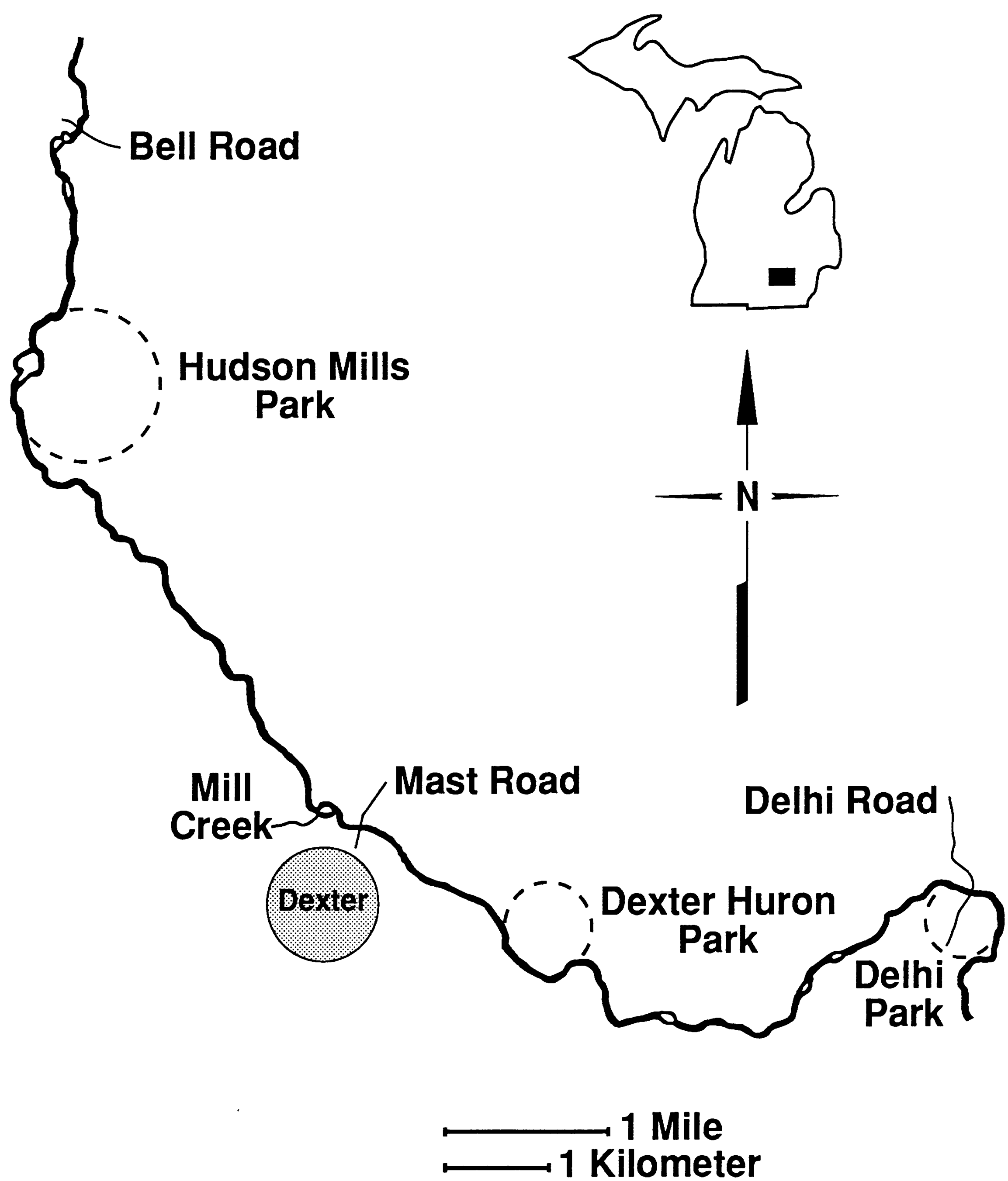

Figure 1. Map of the 16 km study stretch on the Huron River, Washtenaw County, Michigan.

The fauna of the reach under study is typical of warmwater streams in Michigan (Brown & Funk 1945, Smith et al. 1981). The most prevalent game fishes are smallmouth bass *Micropterus dolumieui*, and other centrarchids such as rock bass, *Ambloplites rupestris* and various species of *Lepomis*. Also present in large numbers are the suckers (catostomids) and, to a lesser extent, carp *Cyprinus carpio*. Cyprinids are well represented, with various shiners and chubs also found.

The temperature regime in the Huron, in years of average precipitation, is driven by a large percentage of surface water with a base flow supported by ground water. During 1988, there were less than normal levels of precipitation, and changes in river stage over time illustrate the presence of a base flow (Figure 2), which in the absence of surface runoff, can be attributed to ground water sources. During this drought year, average water temperature at a given air temperature was approximately 5 C below values for a more normal year, due to the greater proportion of ground water to surface water (Table 1). Minimum temperature in winter was -1C and maximum in summer was 25C (data taken from a recording thermometer in the study reach).

Implanting Procedures

Fish for implantation were collected using hook and line or DC electrofishing. They were implanted on the river bank except in November 1987, when they were taken to the laboratory. Fish were

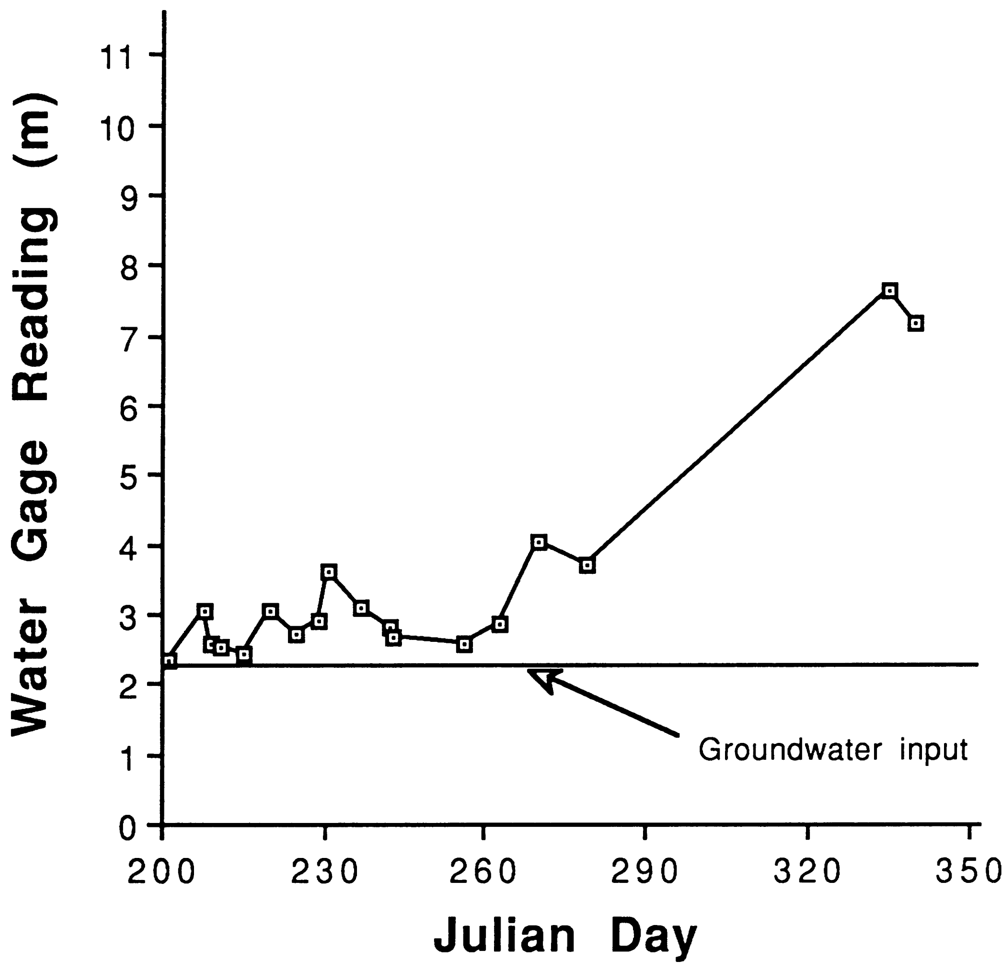

Figure 2. Graph of water level as read off a water gage at Mast Road in the Huron River. These data were collected during 1988, which was a drought year.

Table 1. Comparison of maximum paired water temperature (C) and air temperature (C) ranges during 1987 (a normal precipitation year) and 1988 (a drought year). Water temperature data obtained from a recording thermometer at Zeeb Road in the Huron River in July of each year. The thermometer does not read above 25 C.

1987 (Normal)		1988 (Drought)	
Air	Water	Air	Water
26.7-27.8	23.0-23.8	26.7-27.8	17.5-19.0
28.3-29.4	23.5-25.0	28.3-29.4	17.8-20.5
30.0-31.1	25+	30.0-31.1	20.2-22.0
31.7-32.8	25+	31.7-32.8	21.5
33.3-34.4	25+	33.3-34.4	18.2-22.8
35.0-36.1	25+	35.0-36.1	22.0-23.2
36.7-37.8	25+	36.7-37.8	22.0-23.0

submerged in a 200 mg/l solution of tricane methanesulfonate (MS-222) until they lost equilibrium. An incision, approximately 3 cm long, was made ventrally between the pelvic girdle and vent. A transmitter was inserted and the incision was closed using non-dissolving black monofilament sutures. An injection of oxytetracyclene (equaling 75 mg/kg) was made at the site of incision to prevent infection. Fish were held in the stream until they regained equilibrium (approximately 30 min.), and were then released.

The transmitters used (from AVM Instrument Company; Livermore, CA, type SM1) were 6 cm long, 1-2 cm in diameter, and weighed 7 g or 14.5 g, depending on battery size. Transmitters had an internal loop antenna. A Floy anchor tag (Floy Tags and Manufacturing, Inc.; Seattle, WA) was affixed to each transmitter for identification purposes. The transmitters were encased in surgical wax before implantation.

Transmitter weight was kept at or below 2% of body weight, to minimize transmitter effect on fish behavior (Winter 1983). Each transmitter was tuned to a different frequency in the range from 49 to 50 MHz.

Transmitters were implanted in 18 smallmouth bass between November 1987 and July 1989 (Table 2). Two implants were unsuccessful due to transmitter failure upon release of the fish into the water. Two other transmitters were recovered from the river with no sign of the fish. These fish were assumed to have died, although expulsion of transmitters from live fish has been

Table 2. Implant and tracking data for 18 smallmouth bass observed between November 1987 and November 1989. M=lost fish, F=failed transmitter, R=recovered transmitter.

Date implanted	Water temperature (C)	Total length (mm)	Days tracked
9 November 1987	---	448	189 (R)
25 May 1988	17.5	274	2 (M)
		253	2 (M)
		287	118
		276	100
		269	65
		259	100
		371	434
25 November 1988	3.5	328	77
		348	133
		364	0 (F)
27 November 1988	6.7	297	0 (F)
23 May 1989	17.8	461	80
		466	50 (R)
		410	79

Table 2, Continued.

Date implanted	Water temperature (C)	Total length (mm)	Days tracked
18 July 1989	24.0	320	26
		394	87
		300	87

documented (Chisholm & Hubert 1985, Lucas 1989). The fish implanted in November 1987 was not used in tracking analyses because I had no way of determining when it died. Two additional fish were lost after 16 days and assumed to have been removed by anglers, as the transmitters were never located. Contacts less than 14 days were not used in data analyses, which eliminated 4 of the above fish.

Location Procedures

I attempted to locate each fish twice a week at various times of day. These locations were all made during the daylight hours (between dawn and dusk). During winter months each fish was located once a week when possible.

Fish were located using a scanning receiver (Challenger 200) and 60 cm loop antenna (Advanced Telemetry Systems; Isanti, MN). After first location from canoe, more specific triangulation was done on foot in the river from one point upstream and one downstream of the fish. Each location was referenced to shore landmarks. Because of time involved in triangulation, accurate measurements of location could only be made when fish were stationary. On consecutive outings, I would first search the area where the fish was previously found. If this failed to produce a signal, I would then expand the search to the entire study reach.

Using the null zone of the antenna, as well as the maximum signal strength , I was able to determine location of the fish by triangulation with an accuracy of approximately 1 m^2. This was verified by visual observation (using mask and snorkel) as well as by flushing fish after detection, which resulted in a sudden drop in signal strength.

The location of each fish was noted and later transferred to aerial photos and topographic maps. River stage was also recorded at time of location. At a later date, habitat measurements were taken at the site surrounding the fish, and depth was correlated to river stage on the location date. This was accomplished by subtracting (or adding) the difference between river stage at time of location from that during habitat measurement.

Habitat Measures

Habitat measurements were taken during all seasons except winter, when shelf ice and water depth made river entry unsafe. As soon as possible after a fish location had been determined, habitat measurements were taken. At each position where a fish had been found, a 10 x 10 meter square was roped off around the fish location, with the shore comprising one side of the square. (When fish were stationary, they were always within 10 meters of shore.) This 10 x 10 m quadrat was transversed by three transects which were perpendicular to shore (Figure 3). The three transects were termed "midstream", which contained the fish location, "upstream", which was 5 m upstream, and "downstream", which was 5 m downstream.

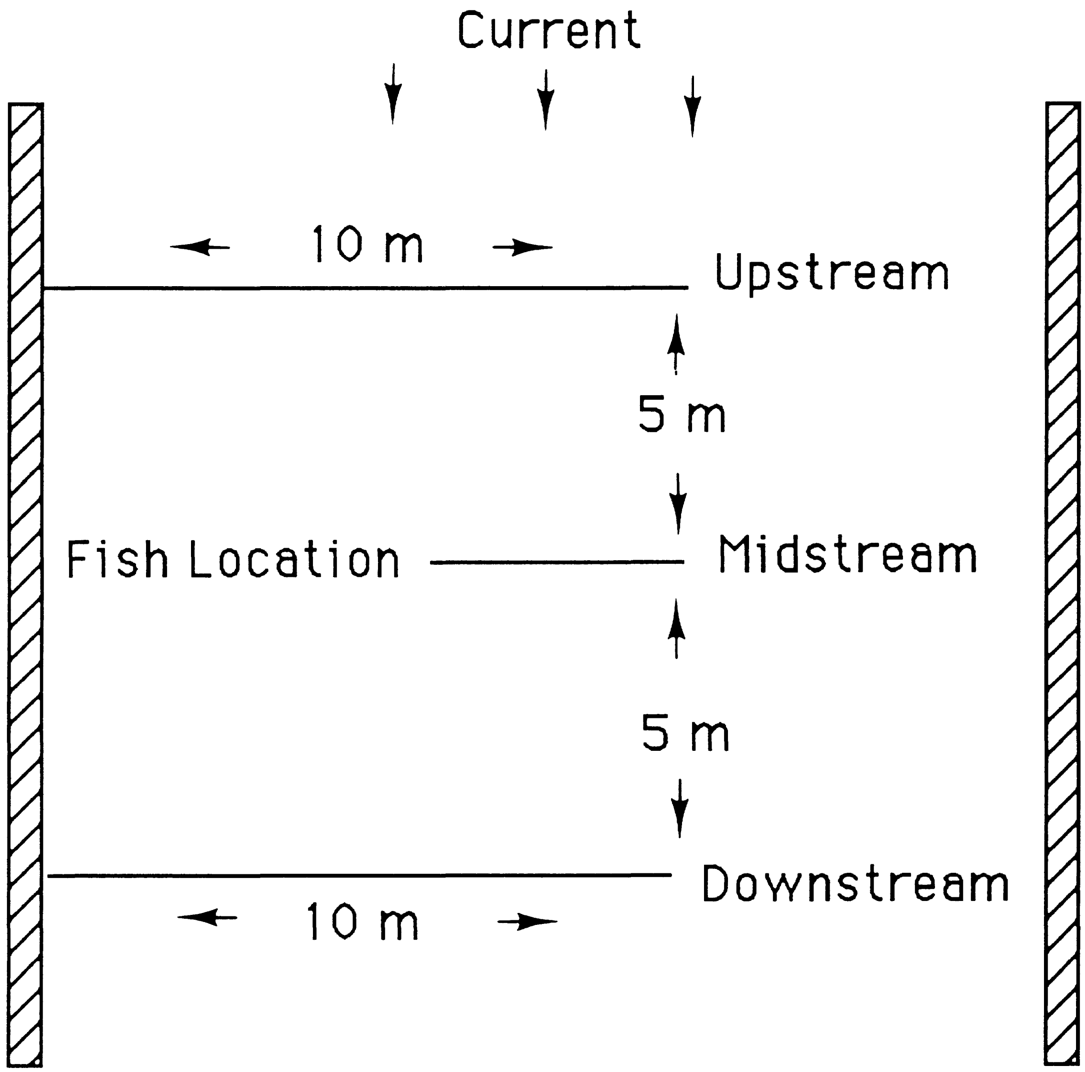

Figure 3. Transect design for habitat evaluation. Depth, substrate type, cover type, and bottom and mean velocity were estimated at 1 m intervals along the three transects (upstream, midstream and downstream).

Measurements of depth, substrate type, cover, mean velocity and bottom velocity were taken at one meter intervals along the three transects. Depth, mean velocity, and bottom velocity were point values. Substrate type and cover were estimated over a 30 x 30 cm square below each meter mark. Substrate type, estimated by sight, was divided into primary and secondary, and was characterized according to definitions modified from Lane (1947) (Table 3). Primary substrate was that on the bottom, and secondary covered the surface of the bottom; i.e. gravel covered by silt would be defined as gravel primary with silt secondary. Cover was classified into 6 types: Log, Boulder, Log Complex, Vegetation, Other, and None (Table 4). Velocity measurements were taken using a pygmy Gurley meter (Teledyne Gurley; Troy, NY). Mean velocity was estimated as the velocity at 60% of the depth of the river as measured from the surface (Hynes 1970).

To estimate available habitat, the study reach was divided into gradient types of High, Medium and Low. High gradient was defined as riffles, with disturbance of water around obstructions enough to produce bubbling , and velocity such that silt was not present. Medium gradient was defined as areas where pools formed downstream of obstructions, silt was not found in the stream channel unless behind obstructions, and the wake (disturbed area) downstream of obstructions was >1m, but without bubbling. Low gradient sections did not have major pools behind obstructions, silt was present in the main channel, and the wake behind obstructions was <1m.

Table 3. Definition of substrate size, modified from Lane (1947), for use in habitat description.

Substrate type	Particle size (mm)
Silt	<0.062
Sand	0.062 - 2.0
Gravel	2.0 - 64.0
Cobble	64.0 - 256.0

Table 4. Definition of cover types used for description of habitat.

Cover type	Definition
Boulder	Any particle >25.6 cm in diameter.
Log	Limb > 5.0 cm in diameter.
Vegetation	Living plant material in, or protuding from, the water.
Log Complex	Limb > 5.0 cm in association with other branches or debris.
Other	Any material which provides protection from the current or sunlight and is not otherwise defined. (e.g. root wads, picnic tables.)
None	No material present which could provide protection from the current or the sun.

Each gradient type was sampled to determine if there were significant differences between types. The sampling method used was as follows: The entire study reach was canoed and gradient type noted. A stopwatch was used to measure the time required to canoe each continuous stretch of one gradient type. When gradient type changed, landmarks were noted and the stopwatch stopped and restarted until the gradient type again changed. Random sample sites were chosen by time and gradient section (e.g. 3 min., 10 sec. into medium gradient stretch number 3). The river was again canoed and random sample sites located by stopwatch. At the pre-selected sample time, a float with an anchor was thrown from the canoe. Cross-sections of the river from shore to shore were then made, one which passed over the float, one 5 m upstream of the float and one 5 m downstream. Depth, substrate type (both primary and secondary), and cover type were measured across each cross-section at 1 m intervals. Bottom and mean velocity were measured at three points on each cross-section; at 1/4, 1/2, and 3/4 of the transect distance. Additional transects were sampled until the allowable error of each parameter was $< 20\%$ ($a=0.10$).

Statistical Analyses

The three gradient types were analyzed using a t-test ($p=0.05$) to determine if they were significantly different with respect to width, depth, substrate type, cover type, and velocity.

Strauss' (1979) electivity index was used to determine if fish showed a preference for certain types of substrate, cover, depth, or velocity. This parameter (L) ranges in value from -1 to +1. A value of zero indicates no preference, a positive value indicates a preference, and a negative value indicates avoidance. Because of uneven sample size per transect, the frequency of each value was used for comparisons. A t-test was used to test for significant deviation from zero of L values (p=0.05).

Three variables were investigated with regard to movement: total range, home site use, and active displacement. Home site is defined here as in Clapp (1988) as any area where the fish has been located 5 times or more, or an area where the fish has returned after leaving that site. This area is always within each fish's range. Total range is defined as the total linear distance between the extreme upstream and downstream locations of the fish. Because movement data were point values, the distance between consecutive sitings is an estimate of minimum distance moved during that time interval. I will use the term active displacement to describe this distance (Clapp et al. 1989).

Total range was plotted for each fish and a t-test was applied to determine if there were significant differences between fish. A Wilcoxon rank-sum test (Walpole and Myers 1985) was applied to determine if there were significant differences between spring/summer and fall/winter total ranges. Fall/winter was defined as the time when water temperature was ≤20 C and falling, and spring/summer as when water temperature was ≥10C and rising (Todd and Rabeni 1989) . Simple linear regression was used to determine if range size was related to other parameters.

Mean active displacements per bass were grouped seasonally, and compared using a Wilcoxon rank-sum test (Walpole and Myers 1985). To test for a relationship between active displacement and number of days since last location, a simple linear regression was used. Kolomov-Smirnov test (Conover 1980) was used to compare frequency distributions of upstream and downstream displacement for spring/summer and fall/winter periods.

Results

Movement

Movement of smallmouth bass was variable, but all fish had a small total range and limited activity. Larger fish had significantly greater total ranges than smaller fish (r=0.66) (Figure 4). The smallest total range was 20 m and the largest was 370 m (Table 5). There was also a significant linear relationship between number of days tracked and total range size (r=0.88±0.06), reflecting increased home range with increased days between locations. There was no significant difference between spring/summer and fall/winter ranges (Wilcoxon rank-sum test, p>0.05).

There was no significant relationship between active displacement and days between finds (r=0.40); therefore, active displacement was not corrected for number of days between finds. Mean active displacement varied between 10.0 m and 135.7 m, with no significant difference between spring/summer and fall/winter displacements (Wilcoxon rank-sum test, p>0.05 Table 5). As with range, there was a positive linear relationship between total fish length and mean active displacement (r=0.67, Figure 5), i.e., larger fish tended to be more active. This relationship also held true when mean active displacement was calculated using only active displacements with nearly an equal number of days between finds (7 ± 4 days, r= 0.80, Table 6).

Frequency distributions of upstream and downstream active

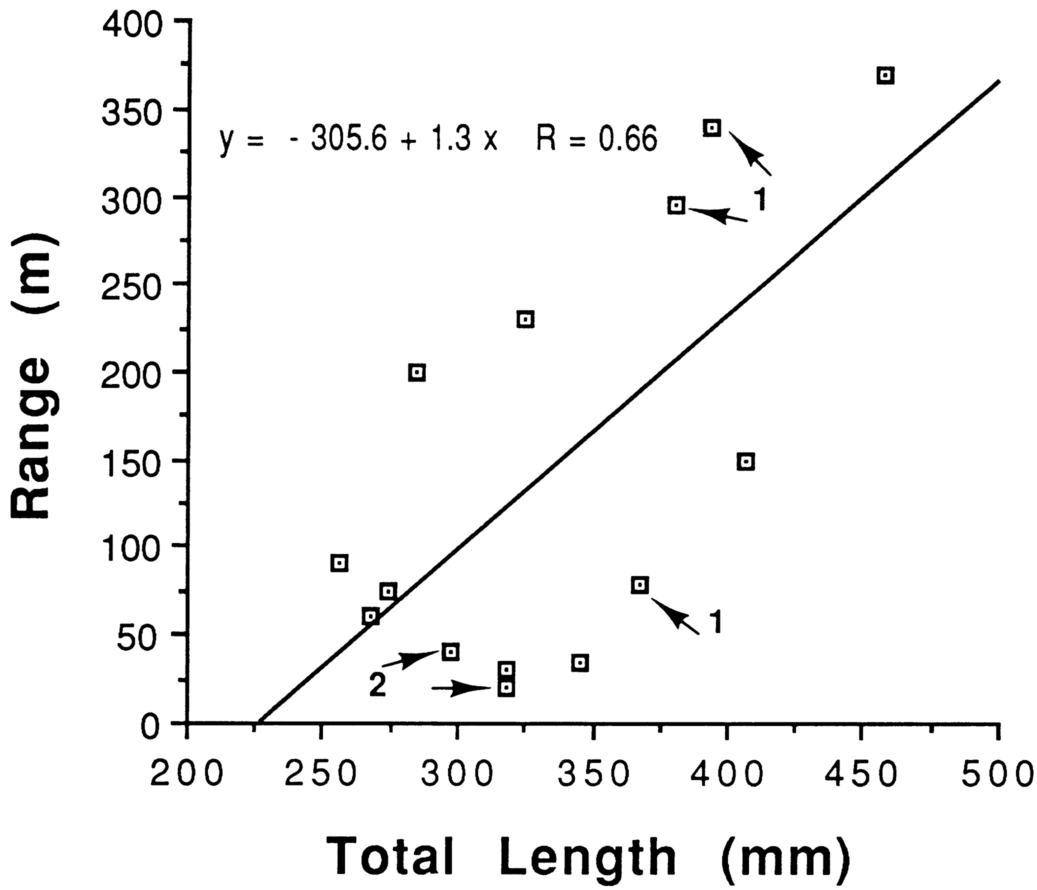

Figure 4. The relationship between total length and total range size for smallmouth bass tracked between May 1988 and November 1989. Each point represents either a spring/summer or fall/winter range. Two fish (1 and 2) were tracked for longer than one season; lengths were estimated for a typical growing season.

Table 5. Total range during a season and average displacement per day of fish tracked between May 1988 and November 1989. Two fish (1 and 2) were tracked for longer than one season; lengths were estimated for a typical growing season. Standard deviation in parentheses.

Total length (mm)	Tracking duration (days)	Total range (m)	Number of home sites	Mean active displacement (m)
Spring/Summer				
259	100	90	1	18.7 (15.8)
269	65	60	1	14.0 (11.4)
276	100	75	2	18.7 (19.6)
287	118	200	1	65.0 (85.4)
300(2)	87	40	1	15.0 (12.9)
320	26	30	1	30.0 (0)
371(1)	117	79	1	18.4 (19.4)
397(1)	117	340	2	78.0 (88.2)
410	79	150	2	48.7 (50.4)
461	80	370	1	135.7 (101.1)
Fall/Winter				
320(2)	30	20	0	10.0 (14.1)
328	77	230	1	86.0 (93.8)
348	133	35	1	10.0 (12.2)
384(1)	200	295	1	91.6 (78.8)

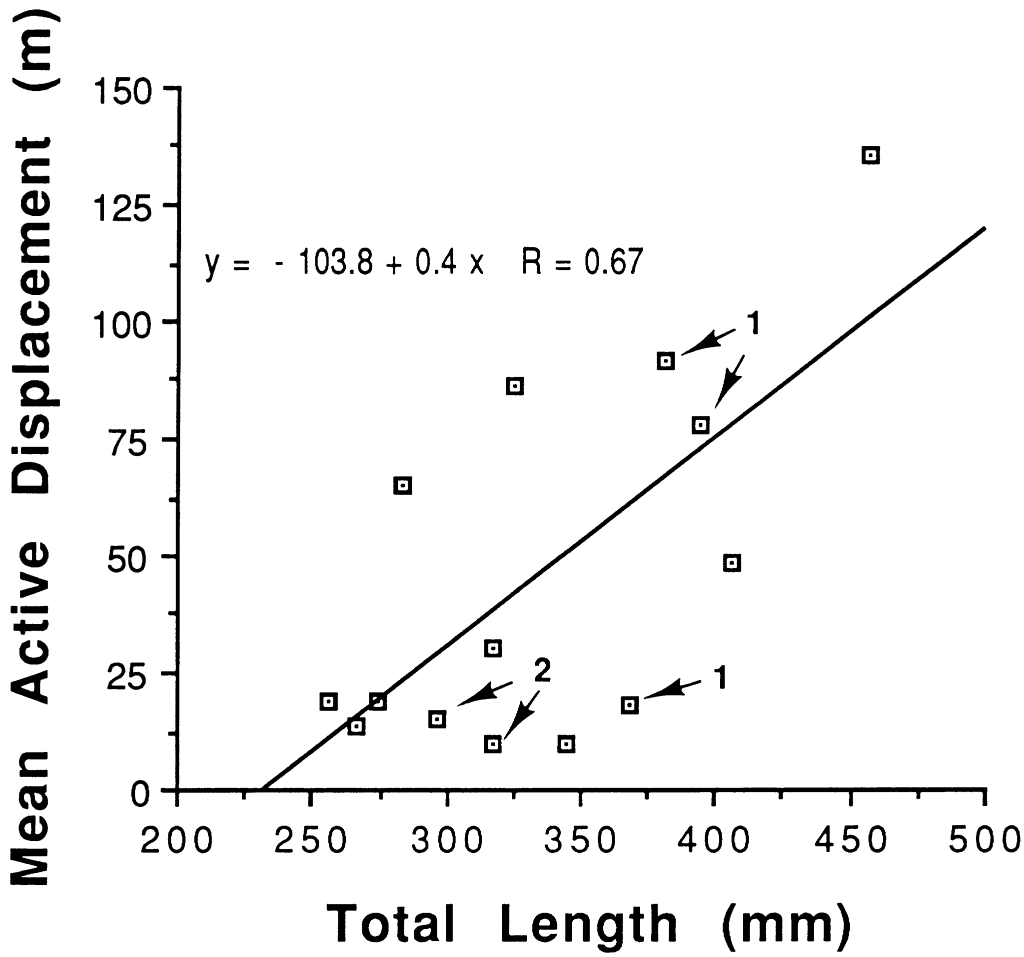

Figure 5. The relationship between total length and mean active displacement for smallmouth bass tracked between May 1988 and November 1989. Each point represents either a spring/summer or fall/winter value. Length of two fish (1 and 2) was estimated after change in season.

Table 6. Mean average displacement of smallmouth bass tracked between May 1988 and November 1989. Comparison between means using all sitings, and those 7 ± 4 days apart. Two fish (1 and 2) were tracked for longer than one season; lengths were estimated for a typical growing season. Standard deviation in parentheses.

Total length (mm)	Mean active displacement 7 ± 4 days (m)	Mean active displacement (m)
Spring/Summer		
259	11.0 (5.5)	18.7 (15.8)
269	10.0 (0)	14.0 (11.4)
276	13.8 (24.3)	18.7 (19.6)
287	10.0 (0)	65.0 (85.4)
300(2)	5.0 (7.1)	15.0 (12.9)
320	30.0 (0)	30.0 (0)
371(1)	10.0 (14.1)	18.4 (19.4)
397(1)	38.3 (29.9)	78.0 (88.2)
410	56.9 (55.6)	48.7 (50.4)
461	125.0 (122.9)	135.7 (101.1)
Fall/Winter		
320(2)	0 (0)	10.0 (14.1)
328	100.0 (106.1)	86.0 (93.8)
348	15.0 (12.2)	10.0 (12.2)
384(1)	37.8 (23.5)	91.6 (78.8)

displacement for spring/summer and fall/winter showed no significant difference between the two seasons (Kolomov-Smirnov, $p<0.05$ Figure 6). The fish moved upstream as often as downstream in spring/summer (40.9% vs. 39.4%) and fall/winter (41.7% vs. 37.5%).

Change in home site use was not a common occurrence (Table 5). Typically, each fish utilized one home site during the tracking period. Therefore, analyses of distance between home sites was not performed.

Habitat Use

Habitat characteristics (stream width, depth, velocity, and substrate) differed considerably between sites with different gradients, indicating that separation of habitat by gradient type (high, medium, and low) was valid. There were significant differences in mean width and depth across the three types (Figures 7 and 8). There were also enough significant differences in cover availability and substrate type to warrant keeping the three gradient types separate (Tables 7, 8, and 9). Therefore, habitat (depth, current, cover, and substrate) preference comparisons were made between occupied transects and medium gradient random transects. I assumed that tagged fish preferred this type, as all fish tracked were found in this type. I examined in detail which parameters in this gradient type were positively selected.

In every instance, when fish were stationary, they were in

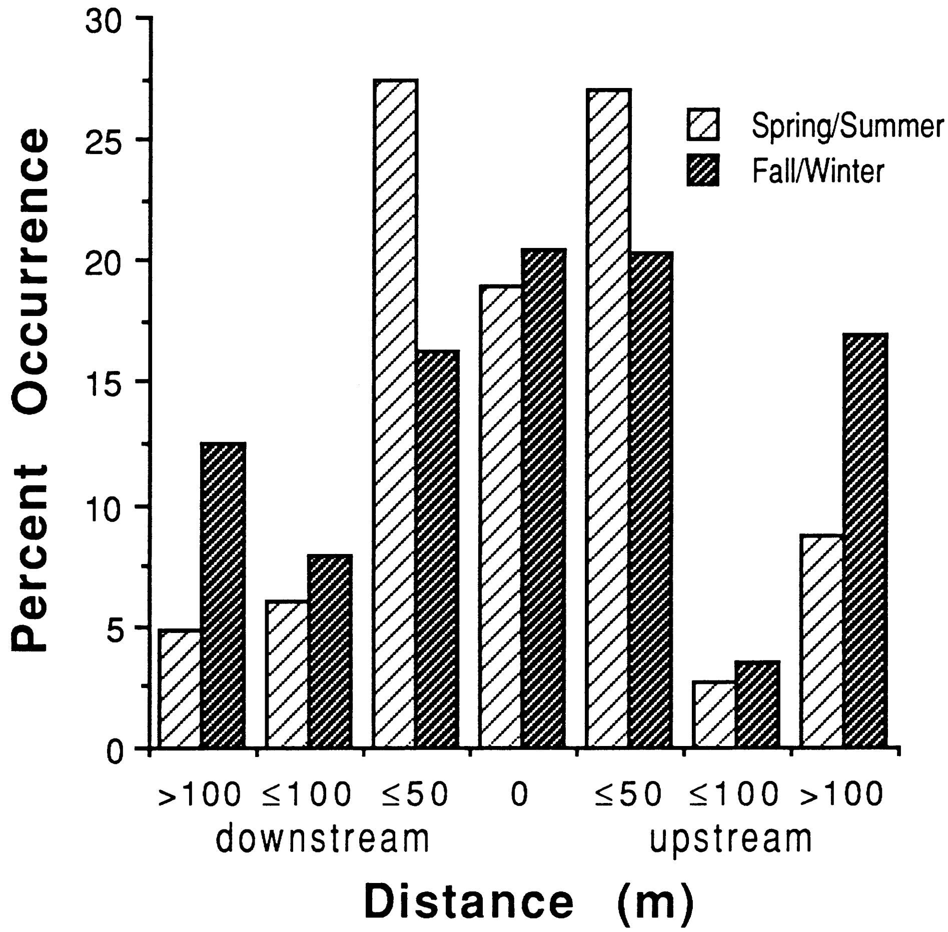

Figure 6. Frequency distribution of upstream and downstream displacement for fish tracked between May 1988 and November 1989.

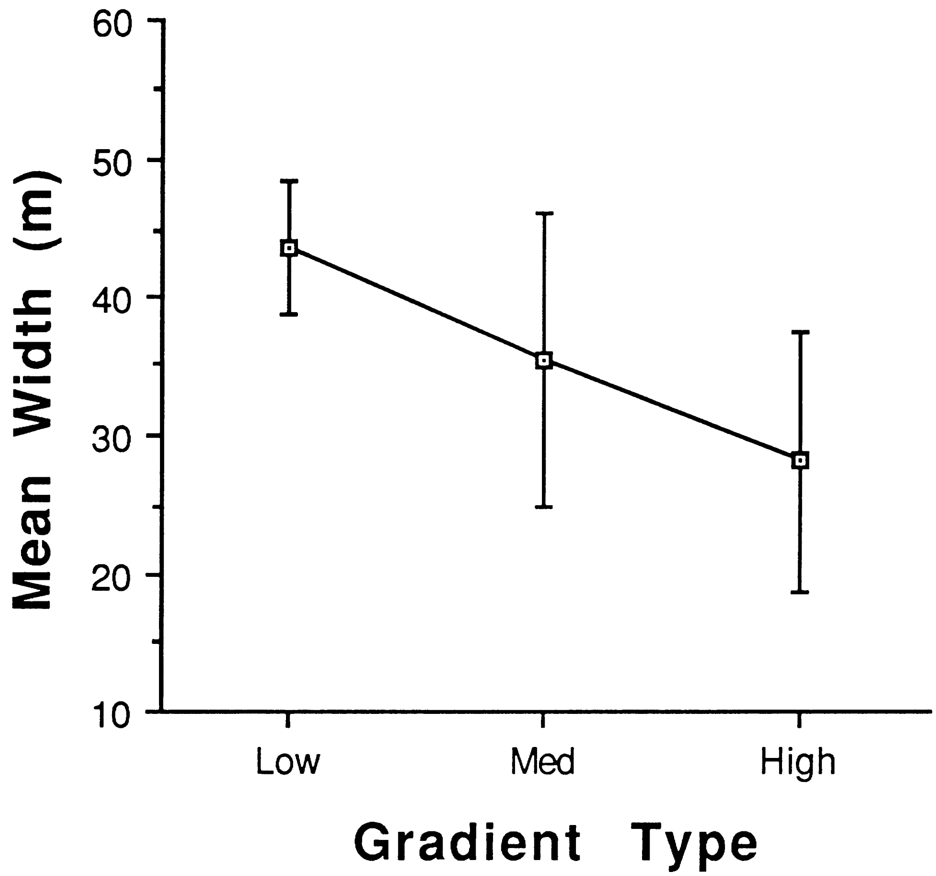

Figure 7. Mean width of river in three gradient types. Horizontal bars indicate mean ± one standard deviation. There is a significant difference between each consecutive type (p=0.05).

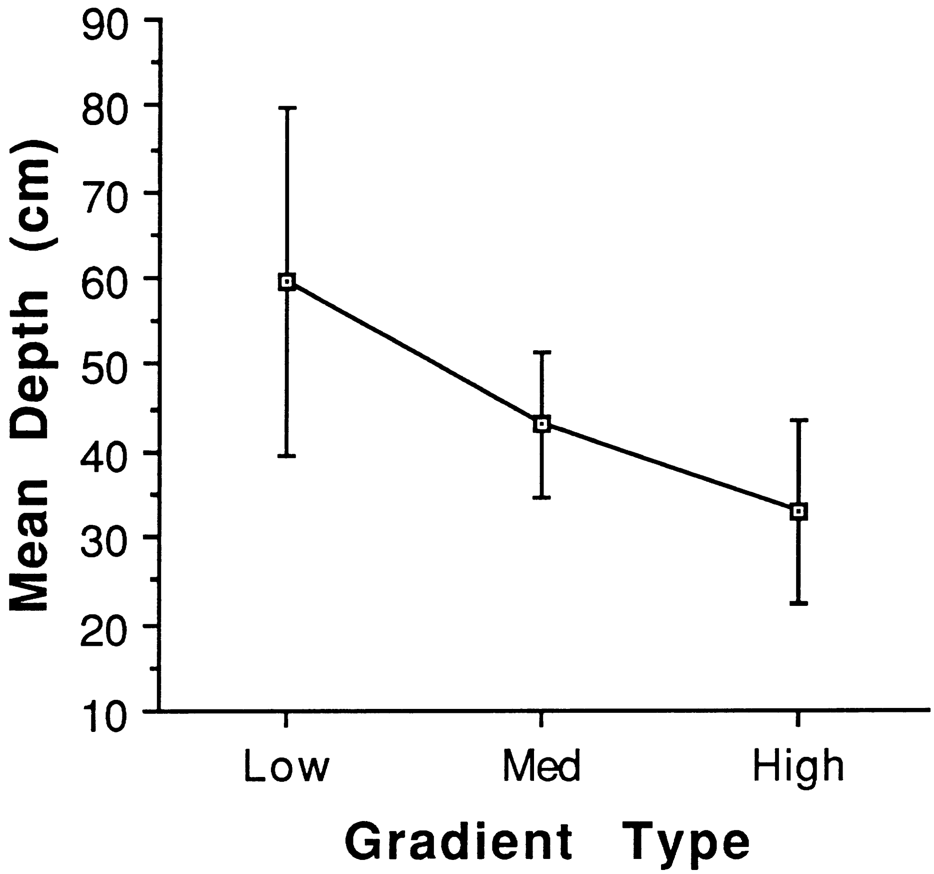

Figure 8. Mean depth of river in three gradient types. Horizontal bars indicate mean ± one standard deviation. There is a significant difference between each consecutive type (p=0.05).

Table 7. Total percent of available cover in low, medium, and high gradient sections. Data were analyzed using a t-test (p=0.05); single √ denote a significant difference (p<0.05) between adjacent columns; √√ indicates p<0.10 .

Cover type	Gradient type Low		Medium		High
Boulder	10.35		8.31	√	36.81
Log	4.05		4.14	√ √	2.42
Vegetation	12.07		5.18		6.13
Log complex	5.61		3.78	√ √	1.12
Other	1.52		1.44		0.67
None	66.38	√	77.16	√	52.83

Table 8. Total available primary substrate in low, medium, and high gradient sections. Data were analyzed using a t-test (p=0.05). Single √ denote a significant difference between adjacent columns.

	Gradient type			
Substrate type	Low		Medium		High
Silt	24.75	√	11.13	√	0.47
Sand	34.52		42.32		36.92
Gravel	32.50		43.09		51.06
Cobble	8.22		3.47	√	11.55

Table 9. Total available secondary substrate in low, medium, and high gradient sections. Data were analyzed using a t-test ($p=0.05$); single √ denote a significant difference between adjacent columns ($p<0.05$); √√ indicates ($p<0.10$).

Substrate type	Gradient type Low		Medium		High
Silt	71.76	√	45.57	√	16.89
Sand	2.86		3.33		0.72
Gravel	8.94	√ √	15.34		20.32
Cobble	16.44	√	35.74	√	62.06

association with cover. Therefore, every 10 m^2 habitat quadrat which was set up to measure habitat use contained some cover. Point measurements taken along the transects contained cover 50.6% of the time (Figure 9). The most common types of cover in these transects were log complexes and logs. Smallmouth bass used the "no cover" category far less often than it was available in the random transects (Figure 10). Logs, log complexes, and other categories were used significantly more frequently than they occurred (Strauss' electivity index, $p<0.05$). Log complexes, logs, and other also occurred at a higher frequency in occupied transects than in random ones.

Considering smallmouth bass selection of cover - substrate, velocity, and depth were selected for in a predictable fashion. The most prevalent substrate types in the quadrats were sand primary with silt secondary (Figure 11). Over 50% of the point values could be described in this manner. These substrate types are often found behind current obstructions, such as logs and log complexes. However, substrate choice was not statistically different from that available (Strauss' electivity index $p<0.05$, Tables 10 and 11). Gravel and cobble were more prevalent in the random than in occupied transects, while all other comparisons were not significant.

Velocity in the occupied quadrats was similar to that found in log complexes and downstream of logs. Velocity was low, with 51.4% of the bottom velocity measurements equal to zero (Figure 12). Velocity was 6 cm / sec in 10.8 % of the measurements

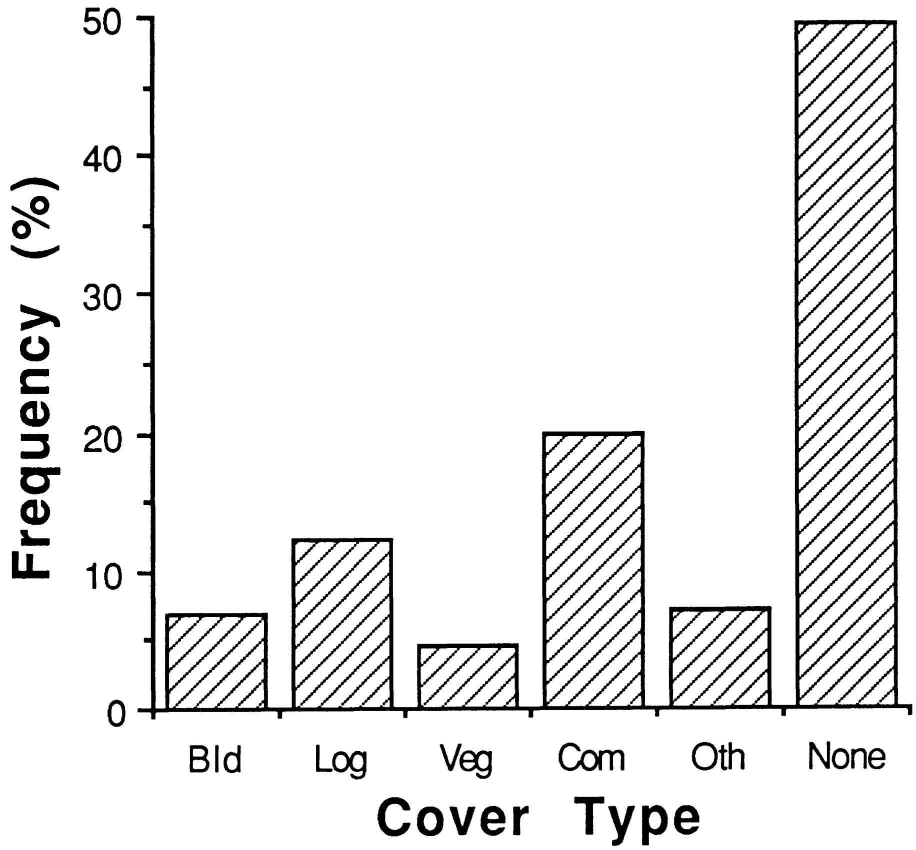

Figure 9. Distribution of cover types in occupied transects for smallmouth bass tracked between May 1988 and November 1989. bld=boulder, log=log, veg=vegetation, com=log complex, oth=other.

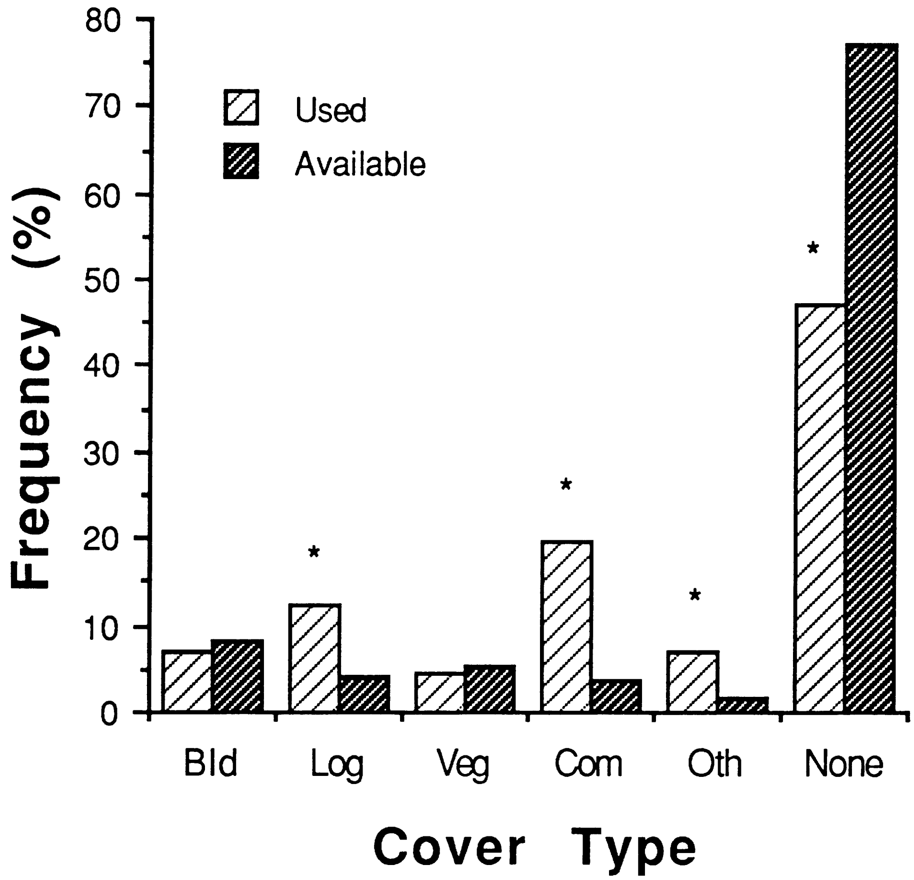

Figure 10. Comparison of cover found in used and available transects . Asterisk indicates significant difference, as determined by Strauss' electivity index, between used and available (p=0.05).

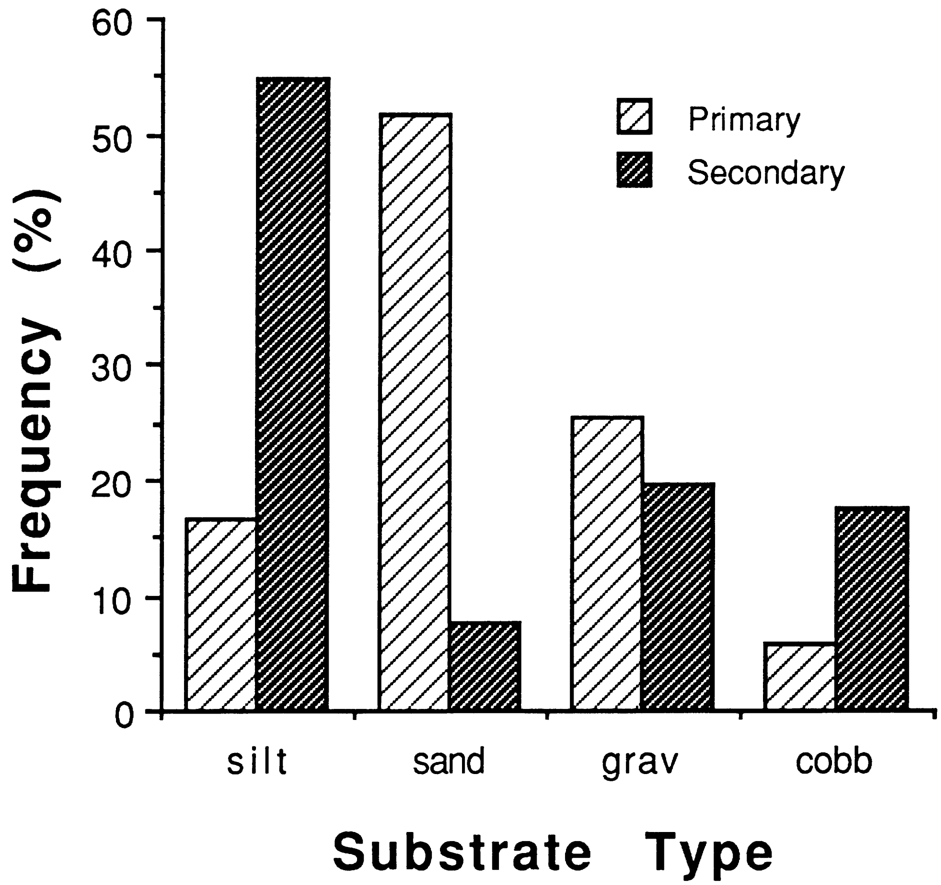

Figure 11. Distribution of substrate types in occupied transects for smallmouth bass tracked between May 1988 and November 1989. grav = gravel, cobb = cobble, sand=sand, silt=silt.

Table 10. Comparison of used and available primary substrate using Strauss' (1979) electivity index. Asterisk denotes a significant deviation from zero (p=0.05).

Substrate type	Test outcome
Silt	L=0.0501
Sand	L=0.0937
Gravel	L=-0.1713*
Cobble	L=0.0241

Table 11. Comparison of used and available secondary substrate using Strauss' (1979) electivity index. Asterisk denotes a significant deviation from zero (p=0.05).

Substrate type	Test outcome
Silt	L=0.0918
Sand	L=0.0430
Gravel	L=0.0436
Cobble	L=-0.1785*

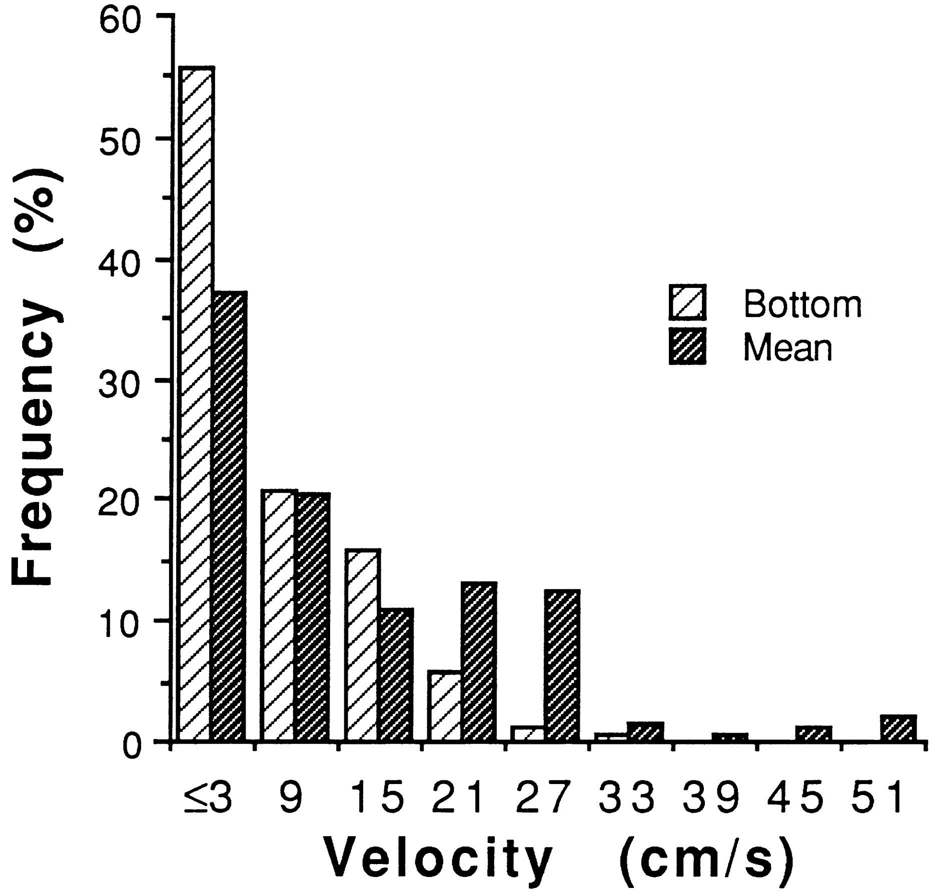

Figure 12. Distribution of velocity (bottom and mean) in occupied transects for smallmouth bass tracked between May 1988 and November 1989.

(11.0% for mean velocity).

Depths in occupied quadrats varied significantly from those in random transects (Kolmogrov-Smirnov two-sample test, p=0.05), however there was no discernible trend. Depths in the quadrats ranged from 0 the 120 cm (Figure 13). There was significantly more water 20 cm in depth available than was utilized (L=-0.0746). For no other depth was there a significant difference.

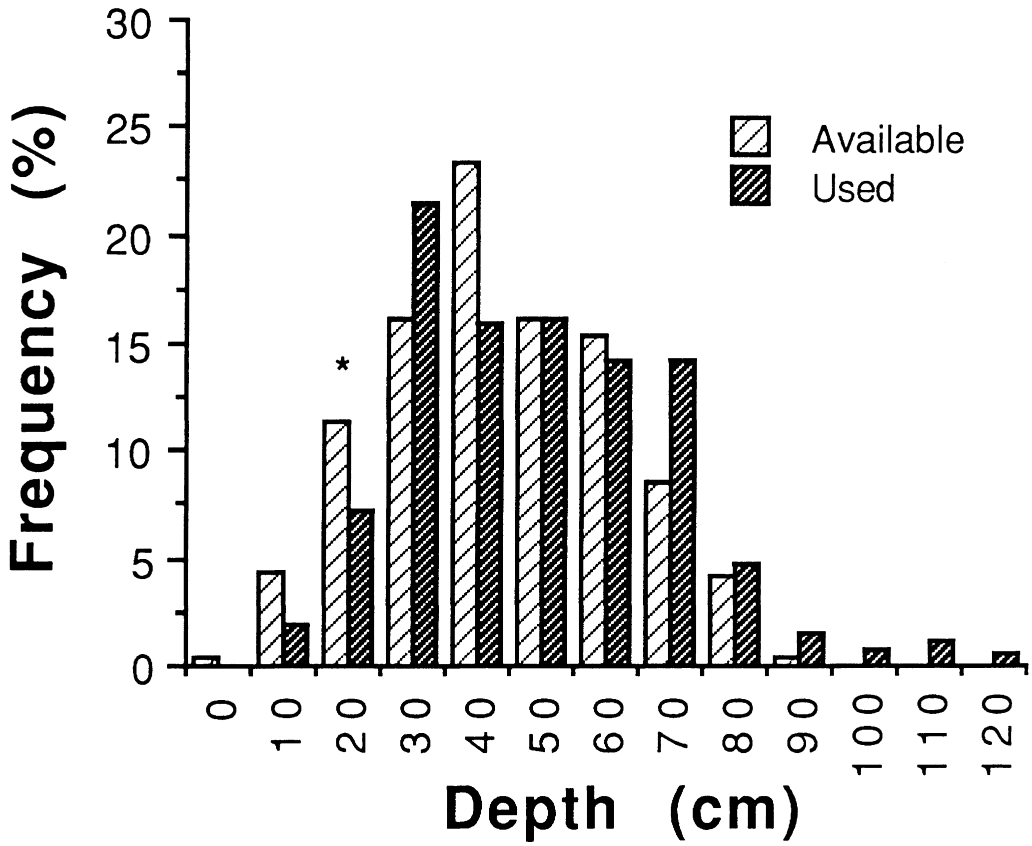

Figure 13. Comparison of depth point values in random transects and transects in the occupied quadrats. Asterisk indicates significant difference, as determined by Strauss' electivity index, between used and available (p=0.05).

Discussion

Smallmouth bass in the Huron River were relatively sedentary. Their total range varied from 30 to 370 m of river, with no significant difference between seasons. When they were inactive, they were found in association with cover; most commonly a log or log complex. These were also the most prevalent types of cover available in the Huron River. No significant preference could be detected for a certain depth, substrate, or velocity range.

Movement

The limited total range found for Huron River smallmouth bass (30 to 370 m) was similar to that found in other studies. Funk (1957) found 63% of the smallmouth bass he tagged moved less than one mile from their release site. Gerber & Haynes (1988) determined that 73% of their observations were within 200 m of the center of activity. Although Todd & Rabeni (1989) defined range as area, rather than linear distance traveled, their findings were comparable also; mean 100% home range was 1,092 m^2.

Smallmouth bass in this study exhibited an increase in total range with increased total length (Fig. 4). Gerking (1953) suspected the same relationship held for streams in Indiana. This relationship is most likely due to foraging behavior. Rankin (1986) found that "large" bass (20-38 cm) spent 40-50% of their time actively cruising. A larger piscivore may need to travel greater distances to meet food requirements (Latta 1963, Clapp 1988). Todd & Rabeni

(1989) did not observe this relationship between fish size and home range size in their study. This disagreement was found, even though their fish were of comparable size to the fish in my study.

Range and displacement of smallmouth bass did not change over the seasons, with the exception of one large movement (1.5 km) by one fish in the spring. This spring movement was assumed to be related to spawning activity, as it occurred as water temperature increased past 15 C, and smallmouth start spawning activity as water temperatures exceed 15 C (Hubbs & Bailey 1938, Pflieger 1975, Becker 1983). One additional fish moved 1.5 km downstream before the 14-day acclimation period was over. This large movement was attributed to adaptation of the fish to transmitter implantation, and was not considered in data analyses.

Smallmouth bass in the Huron River did not conform to previous ideas about winter movement patterns. They were found to have the same total range and mean active displacement in winter as in summer. Collection barriers (high fall water levels due to lake draw-down) and transmitter battery limitations made cross-season tracking of fish difficult. Two fish were tracked beginning in spring/summer and continuing into fall/winter, with no migration documented.

Several authors have stated that smallmouth bass become dormant in the winter months. Hubbs & Bailey (1938) documented cases of smallmouth bass holding up in crevices and logs for the winter . Beeman (1924) did not believe that smallmouth bass hibernated in the ponds he studied, but that they ate little , and that their movements became sluggish. Todd & Rabeni (1989) found that activity decreased with temperature, but that smallmouth bass continued to move to some extent. Their ideas, as well as my results, are contrary to past works (Coble 1975). In streams where the winter temperatures are colder than the Huron River, it may not be physically possible for fish to remain active. The Huron River may have extremely low (<0 C) winter temperatures infrequently enough that the population can continue to be active.

Activity

I did not track fish during the night, as smallmouth bass have been found to be inactive during this time period (Gerber & Haynes 1988, Todd & Rabeni 1989). Although I did not take specific measurements of activity, I did find results similar to Gerber & Haynes (1988) concerning midday activity; I rarely found fish stationary at midday in summer. They could usually be identified swimming in the channel during the 1000 to 1400 time slot. This observation is contrary to other studies (Todd & Rabeni 1989, Coble 1975), which may be due to the depth regime in the Huron River. Many of the past studies (Larimore 1952, Gerking 1953, Fajen 1962) have dealt with rivers that have distinct pool and riffle patterns. The study reach of the Huron River has a fairly uniform depth distribution, which may offer the smallmouth bass more freedom of movement without being exposed to shallow water.

Homing was observed in virtually every case upon release of implanted fish. Fish were released within 500 m of their capture site, and all returned to the capture site upon release. Larimore (1952) studied homing of displaced smallmouth bass and found a high percentage of fish returned to their home pool upon release. They were even found to return after being displaced several times. Gerber & Haynes (1988) observed that displaced smallmouth bass returned to their home tributary and set up home ranges after being moved into Lake Ontario. The ability to return to a site, after displacement from it, is one of the definitions of home site (Clapp 1988), and clearly smallmouth bass have that capability.

Habitat Selection

When smallmouth bass were stationary, they were found in cover, and the point estimates reflected this with a negative selection toward "No Cover" (L= -0.30, p=0.05). The three categories that showed a statistically significant difference between habitat available and habitat selected were log complexes, logs and other. "Other" was made up of man-made objects (ie. picnic tables, boards) and root wads. During much of 1988 root wads were unavailable to the smallmouth because of record low water levels. Todd & Rabeni (1989) found a selection for root wads in all seasons but winter. Perhaps if the water levels had been normal, I would have seen a greater selection for this habitat type.

Although no specific measurements were taken of habitat parameters during the winter months , I observed smallmouth bass using similar types of cover during this time. Todd & Rabeni (1989) observed a switch in cover preference to boulders during the winter. The Huron River contains very few boulders, which may explain smallmouth bass preference for other types of cover. One additional type of cover used in the winter was shelf ice. Smallmouth bass used shelf ice as overhead cover, as the areas where it occurred usually did not contain any other observable form of cover.

The other two significant cover preferences in the summer were for logs and log complexes (woody structures), which were the most prevalent type of cover available in the Huron River. Munther (1970) and Hubert (1981) found that smallmouth bass preferred boulders exclusively, but the rivers they studied did not have the amount of woody structure as is found in the Huron River. Todd & Rabeni (1989) reported results similar to mine, and found the use of woody structures was greatest during summer daylight hours.

The smallmouth bass in this study were presumed to be using woody structures for cover from current or light, and as a food source. Coble (1975) found that smallmouth bass will select for areas which provide cover from current and light. Carline et al. (1986) determined that, in the laboratory, smallmouth bass selected these types of areas. Since their study design offered cover in the absence of prey, they assumed that the smallmouth bass were using structure as resting areas. In a natural setting invertebrates and small fish use woody structures as substrate and cover (Angermeier & Karr 1984). This habitat thus provides smallmouth bass not only with a resting area , but also a source of food. In their study on importance of woody debris, Angermeier & Karr (1984) found that smallmouth bass avoided reaches were debris had been removed. They also found benthic invertebrates were more prevalent on the side of the river which contained woody debris than on the side where it had been removed. These findings support my hypothesis that smallmouth bass use cover as a current block and food source.

Woody structures increase heterogeneity in the river by diverting flow, which can cause formation of pools and eddies (Angermeier & Karr 1984). Edwards et al. (1984) found benthic and drift species of invertebrates, as well as the smallmouth bass population, were higher in areas of the channelized Olentangy River which had been mitigated with artificial riffles and pools. They credited increased biomass to increased structural diversity of the mitigated stretch. Lack of diversity may have been the reason that Gerking (1949) did not find many smallmouth bass in his study reaches. His methods called for the removal of all debris that would impede seining, thus he may have decreased diversity in structure, and found few smallmouth bass.

The types of cover selected in the Huron River were also those found in association with the shoreline. The importance of shoreline cover in the Huron River is manifested in population estimates conducted by Michigan Department of Natural Resources (MDNR). In stations where islands are present, smallmouth bass population estimates are higher (James W. Merna, MDNR, personal communication). This may be due, in part to the types of cover found in association with shorelines, as islands double the amount of shoreline in an area.

Although radio-tagged bass were always found within 10 m of the shore, they did not show preference for a particular depth. The distribution of depth in the occupied quadrats differed statistically from random quadrats, but there was no clear trend toward deeper or shallower than average water. The smallmouth bass were still located in near-shore areas during the winter, although not necessarily in deeper water. This is contrary to Munther's (1970) work, as he could not locate smallmouth bass in less than 2.3 m (8 ft.) of water using electrofishing gear when water temperature dipped below 15.5 C (60 F). Smallmouth bass in the Huron River had few deep areas to use in winter, and they did not use those available to them. Perhaps the slightly deeper water which was available was not deep enough to hold water which was significantly higher in temperature.

It is difficult to separate the selection for cover from substrate, since silt and sand are commonly found behind obstructions in the medium gradient stretches. However, the smallmouth bass did not seem to prefer one particular substrate over another. Paragamian (1981), using mark-recapture population estimates coupled with habitat evaluation, found that increased proportions of gravel and cobble between reaches corresponded with substantial increases in the density of <200-mm smallmouth bass. He did not compare substrate used to that available in his study however, and did not measure cover. Perhaps if comparisons were made between cover and substrate, he would have found that areas with more gravel and cobble also contained more cover.

Assumptions and Biases

No tracking was done during the night. It was assumed that the smallmouth bass in the Huron River would behave similarly to those reported (Gerber & Haynes 1988, Todd & Rabeni 1989) and be stationary at night. If this was not the case, the smallmouth bass could have had a larger total range than calculated. However, there is no reason to believe that the smallmouth bass in the Huron River would move a greater distance at night than they did during the daylight hours, as the fish were not significantly farther from their home site in the early morning hours than at other times of day.

A critical assumption in this study was that the level of habitat evaluation was appropriate. By measuring point values in a transect 10m x 10m around the fish location, an approximation was made as to the type of surroundings a smallmouth prefers. Others have measured habitat preferences at a focal point (Orth et al. 1984), and considered that one point to be the best representation of preferred habitat. However, in stream improvement projects, one cannot manage a stream for point values, but for area values (Heggenes 1988). I chose to place importance on the habitat surrounding the fish, and not just the habitat at its nose. I believe this is a more valid and realistic approach than using only focal point values.

An assumption evident in any radiotelemetry study is that the transmitter will not affect behavior of the animal. By keeping the transmitter weight below 2%, I kept any adverse effect to a minimum (Winter 1983). Crumpton (1982) monitored the effects of transmitters on largemouth bass, and found no significant difference in movement patterns between implanted fish and control fish.

Sample sizes in telemetry studies are small, and generalizations are made from the behavior of a limited number of individuals. It is assumed that the animals used exhibit "average" behavior. Funk (1957) speculated that some populations are made up of a sedentary group of individuals and a mobile one. However, he stated that the sedentary group was predominant in smallmouth bass. In this study, I assume that the fish used represented the only behavior group present.

Radiotelemetry was the method selected to study habitat choice because it minimized "fright bias" or "herding" which often accompanies other methods (Bain 1988, Tyus 1988). However, in order to determine a fish position, it was often necessary to approach quite close to the fish, which may have caused it to flee. To minimize any effect I may have had on the fish, I was careful to only take habitat measurements on smallmouth bass that were stationary from the time of initial siting. Any fish which moved after being detected were not examined for habitat preference.

The tendency to home may have affected my habitat preference data. Because of collection limitations, most fish were captured in medium gradient stretches. Therefore, the sample population may have been composed of smallmouth bass which prefer medium gradient. Orth et al. (1984) encountered a similar limitation when developing habitat suitability curves using fish captured by electrofishing due to its increased efficiency in shallower water. However, in MDNR population estimates, adult population sizes are found to be larger in the medium gradient stretches than in the high or low (James W. Merna, MDNR, personal communication); therefore I believe that sampling smallmouth bass in medium gradient stretches represents the preferred habitat of the majority of fish in the size class used.

The findings concerning winter movement were based on one winter's data. Small changes in winter temperatures could greatly affect the activity of fish. If the water temperature had been as little as one degree colder, the river would have been a much more harsh environment. Perhaps the differences seen between winter movement in my study and other published ones centered on the fact that temperature regimes were not comparable. As Moyle & Baltz (1985) stress, it is important to compare like systems when applying habitat use data, but one can be sure that all biotic and abiotic factors are never similar between streams. Therefore, the measurement of available habitat is just as important as that which is used if comparisons are to be made.

Conclusions

This study made no measurement of how critical cover is, and care must be taken not to assume that cover is the most important variable. As Larrimore and Garrels (1985) point out, an animal may spend most of its time in one place (e.g. log complex), but an area used less often may be critical to survival (e.g. spawning area). Many habitat variables cannot separated, because they are related. It would appear that cover determines where a stationary bass is found - but depth, velocity, light, substrate, and distance from shore are all linked to the type of cover used. Laboratory work has helped to separate these variables to a certain extent (Carline et al. 1986), and has shown that fish will chose areas of cover even when food is not available. In their laboratory study, fish were assumed to be using cover exclusively as a current break, as no food was available in the tank.

Regardless of the function of cover, smallmouth bass were found in association with cover when stationary. The types of cover used most often were logs and log complexes; these were also the most abundant types. Radio-tagged smallmouth bass were fairly sedentary, moving between 30 and 370 m total, with movement patterns not changing appreciably between seasons. Total range and mean active displacement increased with total length of fish, indicating that larger fish are more active, and cover a larger area. However, these movements and ranges are still limited compared to other stream-dwelling fish (Clapp 1988).

My findings suggest that in streams where cover is scarce, smallmouth bass populations may be limited by cover. I do not believe that cover is limiting for adult bass in most areas of the Huron River study reach. Creel census data and population estimates indicate that fishing pressure is currently limiting the adult population (Merna 1989). Perhaps if harvest is reduced, habitat improvement would help to further increase the smallmouth bass population.

The movement data indicate that special regulations, such as catch-and-release fishing, could be successful for limiting fishing mortality on smallmouth bass. Due to the limited movement exhibited by these fish, I can be reasonably certain that smallmouth bass will not routinely move out of a regulated area.

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