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Development of Habitat Suitability Data
For Smallmouth Bass (*Micropterus dolomieui*)
And Rock Bass (*Ambloplites rupestris*) in
the Huron River, Michigan

presented by

John T. Monahan

has been accepted towards fulfillment
of the requirements for

M.S. degree in Fisheries and Wildlife

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# DEVELOPMENT OF HABITAT SUITABILITY DATA FOR SMALLMOUTH BASS (*Micropterus dolomieui*) AND ROCK BASS (*Ambloplites rupestris*) IN THE HURON RIVER, MICHIGAN.

By

John T. Monahan

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# ABSTRACT

## DEVELOPMENT OF HABITAT SUITABILITY DATA FOR SMALLMOUTH BASS (*Micropterus dolomieui*) AND ROCK BASS (*Ambloplites rupestris*) IN THE HURON RIVER, MICHIGAN.

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John T. Monahan

Past efforts to develop habitat suitability data for warmwater species are inadequate for current stream resource management. I developed habitat suitability data for smallmouth bass (*Micropterus dolomieui*) and rock bass (*Ambloplites rupestris*) to evaluate variability in habitat use between seasons and times of day. I also developed and evaluated an electrofishing design to sample habitat suitability data when standard procedures are not possible. Habitat use varied among both diel and seasonal time periods for both species. There were more noticeable differences in habitat use between seasons than between times of day. Consequently, habitat suitability data developed by temporal stratification of effort might be more accurate than past efforts. However, because temporal stratification of effort is costly, greatest benefit might be obtained by stratifying effort among seasons only. Finally, although the electrofishing design was preliminary, results suggest the method could be useful with further modifications and testing.

For my loving parents:

Dr. Alan R. and Mary E. Monahan

## ACKNOWLEDGMENTS

Before I list a few individuals that contributed significantly to the completion of this academic endeavor, I would like to thank the many. To my family, my friends, and my colleagues ... thank you. Were it not for your encouragement, your support, your sincere interest, and an excellent sense of humor my experience would not have been as enjoyable or as enlightening.

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## INTRODUCTION

Management of warmwater streams for their fisheries resource is an objective of both state and federal agencies that has received increased attention in recent years (eg. Bain and Boltz 1989, Lyons and Courtney 1990). Heightened interest in the many species living in these highly productive waters has collided with increased use of streams for irrigation (Bartholic et al. 1983), wastewater treatment, municipal and industrial supply, and hydro-electric power generation (Osborne et al. 1988, Peters 1982). Maintenance of acceptable levels of flowing water in the stream channel to sustain the values or uses of water (instream flow requirements; Loar and Sale 1981) includes biological, engineering, social, and economic concerns (Osborne et al. 1988). Conflict over water resource allocation can only be resolved by careful planning and through accurate and reliable analysis of the resource.

A popular technique used to solve complex water resource allocation issues is the Instream Flow Incremental Methodology (IFIM; Reiser et al. 1989). The technique was developed by the Instream Flow Group of the U. S. Fish and Wildlife Service to handle these types of conflicts in western states. The methodology quantifies fish (or fish food organism) habitat based on linear changes in channel characteristics, streamflow, water quality, and temperature as a function of discharge (Milhous et al. 1989). Habitat also includes a microhabitat component, defined as the distribution of hydraulic and structural features which represent the physical space occupied by the organism. Total habitat area is the area of overlap between suitable microhabitat and available habitat. IFIM uses total habitat area (Weighted Usable Area - WUA) as the decision variable in problem solving (Bovee 1982). Water rights are granted when acceptable changes in total habitat area are predicted, or when mitigation for anticipated loss of habitat is planned.

IFIM has recently been applied to warmwater streams (Herricks et al. 1980, 1982, 1983; Orth and Maughan 1982). Because the technique was developed in western coldwater streams biologists, managers, and policy makers question the applicability of the methodology to warmwater streams (Wiley et al. 1987). Assumptions made in IFIM may be violated if warmwater streams differ significantly from coldwater streams in hydrology, morphology, biology, or ecology. Furthermore, warmwater streams may be difficult to study using IFIM because they tend to be large, physically complex, species-rich, and often turbid. Consequently, resource agencies responsible for managing instream flows in warmwater streams may not be prepared to spend the time and money required to conduct stream habitat studies such as IFIM unless validity of the technique is demonstrated (Bain and Boltz 1989).

The most frequently criticized aspect of IFIM has been the assumption of a positive linear relationship between WUA and fish biomass (Orth 1987, Osborne et al. 1988). Orth (1987) illustrated that the failure of past efforts to demonstrate fish population response to changes in WUA (Conder and Annear 1987, Shirvell 1986, Scott and Shirvell 1987) could be the result of variability in habitat use with fish body size, season, time of day, activity, predation pressure, and competition. Failure of habitat suitability data to account for this variability could lead to error in calculating WUA, and consequently inhibit detection of fish population response to changes in weighted usable area.

Habitat suitability data are described in IFIM by a set of mathematical models (usually presented graphically) defined as habitat suitability indices (HSI). These models provide an important link between the hydrology of IFIM and the biology of a system. The validity of the link provided by HSI has been the focus of criticism of IFIM (Mathur et al. 1985, Moorhardt 1986). Consequently, the methods of development of HSI and the detail of information they contain has changed with time.

Habitat suitability data can be developed from literature review, expert opinion, and observational habitat sampling (Edwards et al. 1983). Several categories of HSI have been identified based on method of development. Descriptions of each type and its shortcomings are as follows (Edwards et al. 1983; see also Bovee 1982, 1986; Bovee and Cochnauer 1977):

> Category one models are developed from expert opinion, unpublished data and literature review. Most HSI are this type, yet this is the least reliable method. First, the models are not based on empirical measurements; rather they are an abstraction of qualitative observations. Second, the difficulty in assembling a panel of experts and interest groups can be overwhelming, and achieving consensus can be just as difficult. Bovee (1986) suggested that the Delphi technique (Zuboy 1981), an iterative survey format, may overcome the difficulties of personal bias and problems in assembling groups. Expert opinion is a valuable method of substantiating literature-based models, but only if consensus is reached. However, even if the experts reach consensus, the absence of field data still limits this technique's value. Literature may contain empirical measurements of habitat for the evaluation species, but its usefulness is often limited. The primary difficulty with literature is that measurements are rarely from the stream of interest. Therefore questions of transferability arise. Second, observations are more often qualitative and empirical data has to be derived. Therefore the accuracy of these models is questioned.

Category two (utilization) models are based on the frequency analysis of habitat variables measured at each sighting of a fish in its stream environment. These curve sets are considered more reliable than category one HSI because they are measured quantities, and can be very specific to the stream in which they are developed. However, the stream-specific nature of these models increases the potential for environmental bias. The significance of a habitat variable component may be over-represented, simply because that component dominates the study stream. For example, the substrate most suitable for adult smallmouth bass (*Micropterus dolomieui*) might be determined to be large cobble when in fact no other substrate was available, and therefore that was the only substrate used. Furthermore, utilization models might not be transferable to other streams that differ significantly in size and complexity of habitat traits from the stream where the data were collected.

Category three (preference) models are similar to category two models, except that an attempt is made to correct for environmental bias. This is accomplished by measuring the utilization of habitat variables by fish and the relative availability of all habitat variables. The utilization is then corrected by the availability, yielding a measure of preference (Bovee 1982):

$$\text{PREFERENCE} = \frac{\text{UTILIZATION}}{\text{AVAILABILITY}}$$

Preference data are more independent of the stream of interest than utilization data and are thus a closer approximation of the requirements of the evaluation species. The transferability of these models to other streams is greater than utilization models, but it is not free from error. Preference data are transferable to other streams only if the range of physical habitat attributes measured encompass all physical habitat attributes available in the stream to which the curves are to be transferred. There is high demand for HSI developed with preference data (Reiser et al. 1989), although very few have been compiled. Because preference curves are utilization curves corrected by availability information, 20 - 100 % more effort is needed to collect the additional information. The extra effort required to obtain availability data limits the production of more category three HSI. Although development of these type of curves can be expensive and time consuming, they are the most reliable data sets available, and are preferred by modelers (Reiser et al. 1989).

A fourth category of models has not developed beyond the conceptual stage. A proposed category four model is a cover-dependant, or season-dependant preference curve set. The model would describe different depth-velocity preferences as a function of the type of cover present or the time of year, with several curves representing each cover type or season. Category four models would not have the problems of literature-based curves because they require empirical data collection. Furthermore they would not have the problems of category two or three curves because the procedure controls for availability of habitat, and seasonal and diel variation in fish behavior. These curves should be transferable to any stream within the range of the species, in which the available habitat conditions is within the range of conditions in the river studied. These are termed conditional models and can be of any category or format, but are distinguishable by multiple sets of curves for each life stage.

There is a general lack of habitat suitability data for warmwater stream species (see Reiser et al. 1989). Furthermore, suitability indices that have been developed for smallmouth bass (Bain et al. 1982, Edwards et al. 1983, Aadland et al. 1991), do not account for behavioral variation in habitat use. Studies of habitat use by smallmouth bass have revealed variability in habitat use with fish body size, season, and time of day. Rankin (1986) demonstrated changes in habitat use by smallmouth bass with changes in fish size. Probst et al. (1984) observed variability in habitat use by both smallmouth bass and rock bass (Ambloplites rupestris) with respect to body size. Emery (1973) and Helfman (1981) observed positional changes by smallmouth bass and rock bass during the diel time period. Diel and seasonal differences in habitat use by smallmouth bass was observed by Munther (1970) in both natural and artificial streams. Todd and Rabeni (1989) observed diel patterns in habitat use modified by seasonal changes in water temperature. Similarly, Langhurst and Schoenike (1990) observed large scale movement of smallmouth bass in a Wisconsin stream, representing a shift in habitat use with seasonal temperature change. Because habitat suitability indices will need to be developed to study warmwater streams in the future, there is an opportunity to account for variability in habitat use with body size, season, and time of day, and to evaluate their importance in predictive models such as IFIM.

The preferred method to develop habitat suitability data (direct underwater observation), is frequently precluded by poor visibility (turbidity) or hazardous conditions in warmwater streams. The need to sample habitat data in these systems has challenged researchers to develop alternate approaches. Electrofishing gear has typically been use to collect habitat data in these circumstances (Orth 1981, Bain et al. 1985) but limitations of this equipment suggests modifications be made, or alternative methods be developed. Standard electrofishing approaches such as backpack electrofishing, barge electrofishing, and boat electrofishing tend to displace fish from original microhabitat locations (Bovee 1982). Furthermore, the time consuming effort of pre-placed (fixed) electrode equipment (Bain et al. 1985) might be circumvented by development of an alternative approach that has the mobility of standard approaches, but stealth of a pre-placed technique.

Objectives of my research were to: (1) develop habitat suitability index (HSI) models for smallmouth bass and rock bass in the Huron River, Michigan; (2) develop guidelines for the appropriate level of HSI data stratification and sample size requirements to capture the similarities and differences in diel and seasonal behavior patterns in the most efficient manner possible; and (3) design alternate sampling techniques and develop guidelines to promote the efficient, safe, and least biased collection of habitat suitability data of greatest comparable reliability as direct observation data.

## METHODS

### Study Area

The Huron River, Michigan is a mid-order warmwater stream that drains an area approximately 2,320 $km^2$, comprising the northern two-thirds of Washtenaw County, the southeast corner of Livingston County, the southwest corner of Oakland County, and small portions of Wayne, Monroe, and Ingham Counties. The basin collects an average of 78 cm rainfall and 95 cm snow annually. Three quarters of the precipitation is lost through evapo-transpiration, and most of the remaining water travels through the basin as surface runoff and enters Lake Erie through Point Mouillee Marsh several miles below the mouth of the Detroit River (Water Resource Commission 1957). Although much of the watershed was originally wetland, artificial drainage has increased surface flow, and dams were erected to control runoff. In the final 80 km of the river, a series of privately owned hydroelectric dams and power plants control the flow of water.

I studied a 16 km length of the river approximately 100 km from Lake Erie that begins at the Bell Road Bridge (Lat. $42^{0}24'$, long. $83^{0}55'$, SE 1/4 sec. 12, T.1 S., R.4 E., Washtenaw County) and continues southeast to the bridge on East Delhi Road (Lat. $42^{0}20'$, long. $83^{0}48'$, SE 1/4 sec. 2, T.2 S., R.5 E., Washtenaw County) 8 km northwest of Ann Arbor (Figure 1). The segment has an average width of 35 m and depth of 43 cm (Beam 1990). Just upstream of the Mill Creek confluence, the river has a drainage basin of 1,316 $km^2$ and an average discharge of 9.76 $m^3$/sec (USGS 1972). Mill Creek contributes an additional 1.99 $m^3$/sec from a drainage basin of 350 $km^2$. At the downstream end of the segment the drainage basin is approximately 1,800 $km^2$.

The midpoint of the study area is the town of Dexter, where Mill Creek joins. Agricultural runoff and treated wastewater effluent contribute substantial quantities of

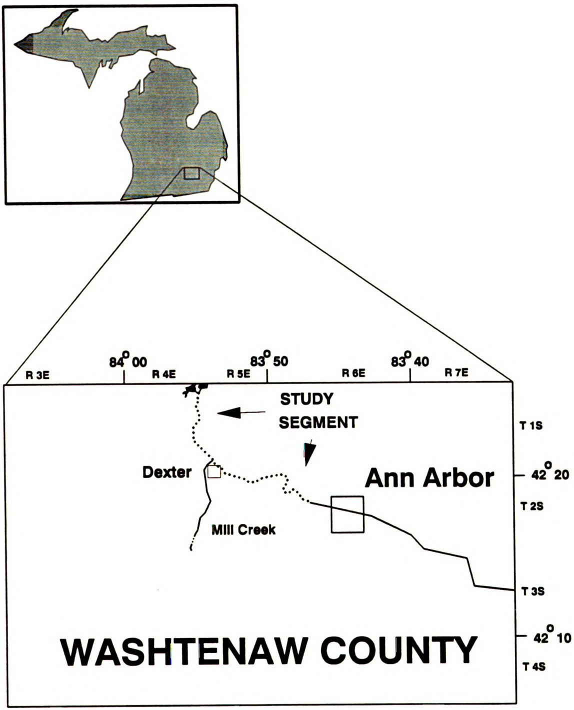


Figure 1. A map of Michigan illustrating the study length of the Huron River.

suspended matter to Mill Creek. As a result, high turbidity persists from the confluence of Mill Creek and the Huron River through the downstream reach. Turbidity is low in the reach upstream of Mill Creek, and this is the reach in which I used direct observation to collect habitat use data. The downstream reach is too turbid for this sampling procedure. Instead, I used the downstream reach for the development of alternate techniques.

## Stratification of Sample Effort

### Stratification by Habitat Type

To ensure equal effort among habitat types I stratified the research segment by habitat type. I canoed the entire length of the study section during baseflow conditions. With the guidance of Ken Bovee (U.S. Fish and Wildlife Service/NERC Project Officer), I classified a total of eight macrohabitat types based on depth, velocity, and amount of cover as follows:

SRL- Shallow run (a stream reach with unobstructed flow, 0-46 cm deep), with low cover (less than 30% of the cell surface area).

SRH- Shallow run with high cover (cover occupying 30% or more of the cell surface area).

DRL- Deep run (46 to 92 cm deep) with low cover.

DRH- Deep run with high cover.

SPL- Shallow pool (92 to 152 cm deep), with either an eddy or with slow flowing water caused by a velocity barrier, with low cover.

SPH- Shallow pool with high cover.

DPL- Deep pool ( >152 cm deep) with low cover.

DPH- Deep pool with high cover.

In addition, a minimum reach length of 46 m was necessary for habitat use sampling purposes. If a reach did not meet the minimum length requirement I added the reach to an adjacent habitat type, if similar, or disregarded the area during sampling. As a result, I defined a total of 99 reaches of different lengths. Because the proportion of the study segment in each habitat type differed among habitat types (Table 1), I used stratification of effort by habitat type to eliminate bias introduced by availability of habitat types.

## Temporal Stratification

I stratified effort along two time scales to control for diel and seasonal activity of fish. The diel stratification included three time periods:

Diurnal - Daylight hours.

Nocturnal - Hours of total darkness.

Crepuscular - Time between daylight and darkness.

Table 1. Abundance of eight habitat types as percent length in a 16 km segment of the Huron River, Michigan, and stratified by study reach.

| Habitat Type | % of Total Study Reach | % of Upstream Study Reach* | % of Downstream Study Reach* |
|---|---|---|---|
| DPH | 1.3 | 0.5 | 0.7 |
| DPL | 1.5 | 0.2 | 1.3 |
| SPH | 7.5 | 5.5 | 2.0 |
| SPL | 15.0 | 10.0 | 5.0 |
| DRH | 13.0 | 11.0 | 2.0 |
| DRL | 42.2 | 19.0 | 23.2 |
| SRH | 1.0 | 1.0 | 0.0 |
| SRL | 17.3 | 11.0 | 6.3 |
| OTHER** | 1.2 | 0.8 | 0.5 |

* Upstream or downstream of the confluence of the Huron River and Mill Creek at Dexter.

** Riffles/rapids: critical flow sections which were not included in the sample effort because they were infrequent, difficult to sample with direct observation, and did not meet the minimum length requirements.

The seasonal stratification of effort also consisted of three time periods:

Summer - June through October.

Winter - November through March.

Spring - May through July.

I sampled during daylight hours (primarily between 9:00 am and 6:00 pm) for diurnal observations, and darkest hours of the night (10:00 pm to 6:00 am) for nocturnal observations during the summers of 1989 and 1990. I concentrated crepuscular habitat use sampling during 30 minute periods around 7:30 pm, and 7:00 am in the late summer, 1990. Daylight hours varied with season, and times were corrected accordingly. Most of the sample effort was during the summer between June and October. Spring sampling began in mid-May and continued through the end of spawning in early July. Some overlap between summer and spring habitat use observation occurred in June and July. However, because spring sampling concentrated only on spawning activity, these seasons were distinguishable based on fish behavior. Winter observations were in January, 1990 only.

## Sampling Techniques

### Direct Underwater Observation

I used snorkeling to collect habitat suitability data because it is the least intrusive underwater observational technique (Bovee 1986), and the upstream reach of the river was conducive to this method. Furthermore, snorkeling allowed for immediate species and size identification, determination of fish position in the water column for focal point velocity measurements, and observation of fish behavior. Finally, I could easily mark the fish's position for subsequent habitat measurements.

I sampled by underwater observation with an equal effort, stratified random sample design. I sampled each of the eight habitat types an equal number of times within each level of temporal stratification. Second, I tried to sample each habitat type at high, medium, and low river discharge, for each level of temporal stratification. For a single sample effort, I randomly selected one of the eight habitat types, and randomly chose a stream reach of that habitat type as the sample site. This was repeated for each of the eight habitat types before an additional effort was made to sample the initial habitat type.

At each sample reach I randomly selected a side of the river (by coin toss) to sample. At this location I arranged use of the static-drop line method (Li 1988). The field crew strung a 16 mm diameter braided nylon rope across the river and secured it at both ends at the upstream end of the sampling location. Three 76 m long ropes (also 16 mm diameter braided nylon) were attached to the static line at 3, 9, and 15 m distances from the water's edge. After a waiting period of 30 minutes, observers snorkeled along each of the three ropes in an upstream direction, checking periodically to remain parallel to the other divers. Each observer was responsible for 3 m distances to either side of the drop line to which they were attached (total width of sample area= 18 m, or approximately half the channel width) and a 46 m length (total sample area= 823 $m^2$). When a diver observed a fish he/she would carefully approach to identify species and to estimate total length, which were relayed to a data recorder on shore or recorded on a diving slate. Before continuing underwater observation, the diver placed a weighted, numbered tag at the location of the fish, and recorded observations of the dominant substrate particle type, and percent embeddedness by fine particulates (Tables 2 and 3 respectively), cover type (Table 4), distance to physical structure (cover), and vertical position in one of three strata of the water column (Table 5). When the sample effort was completed, the divers retrieved the tags and recorded the following information from each tag location: water column depth, mean water column velocity, velocity at mid-point of occupied vertical stratum (focal point velocity), distance to and velocity of nearest shear line or fast water area (distance to adjacent velocity and adjacent velocity respectively).

I modified the direct observation approach for the winter and spring sampling conditions. During the winter of 1989/1990 the first few dives I arranged use of the static-drop line method. However, as a result of difficulties with equipment in cold conditions, and the absence of fish in all of the study areas first sampled, larger areas had to be

Table 2. Dominant particle size represented in 0.5 m diameter substrate surface below location of fish observation using a modified Wentworth classification (Bovee 1982).

| Classification | Particle Size - Definition |
|---|---|
| Vegetation | Submerged aquatic macrophytes |
| Sand-Silt | < 2 mm |
| Small Gravel | 2 - 8 mm |
| Medium Gravel | 8 - 25 mm |
| Large Gravel | 25 - 51 mm |
| Small Cobble | 51 - 152 mm |
| Large Cobble | 152 - 305 mm |
| Small Boulder | 305 - 610 mm |
| Large Boulder | > 610 mm |

**Table 3. Classification of percent embeddedness of dominant particle size by fine particulate matter (sand, silt, detritus; Bovee 1986; see also Platts et al. 1983).**

| Classification | Percent range |
| --- | --- |
| 1 | 0 - 25 |
| 2 | 25 - 50 |
| 3 | 50 - 75 |
| 4 | 75 - 100 |

Table 4. Numerical cover codes, assumed function, and physical description (Bovee 1986).

| Code[*] | Assumed Function | Physical Description |
|---|---|---|
| 1 | No Cover | No Cover |
| 2 | Small Velocity Shelter | Blunt object protruding 305 to 510 mm above substrate. |
| 3 | Medium Velocity Shelter | Blunt object protruding 510 to 710 mm above substrate. |
| 4 | Large Velocity Shelter | Blunt object protruding >710 mm above substrate. |
| 5 | Visual Isolation | Small complex (dense cluster of sticks- with average diameter between 5 mm and 75 mm- typically submerged riparian shrubs). |
| 6 | Combination | Simple Compound (one log> 250 mm diameter suspended off substrate). |
| 7 | Combination | Large Complex (numerous logs> 250 mm diameter). |
| 8 | Visual Isolation | Root wad (similar to code 5, except fish could not go between sticks, and typically associated with overhead cover). |
| 9 | Combination | Small simple compound (Similar to code 6 except diameter is between 75 and 250 mm, and may involve more than one log). |

[*]Cover codes were identified by physical description in the field and combined for data analysis based on function (i.e. 1= No Cover (1), 2= Velocity Shelter (2,3,4), 3= Combination (6,7,9), 4= Visual Isolation (5,8)).

Table 5. Code of stratum describing vertical position of fish.

| Code | Occupied Vertical Stratum |
|---|---|
| 1 | Uppermost one third of the vertical water column. |
| 2 | Middle one third of the vertical water column. |
| 3 | Lowermost one third of the vertical water column. |

sampled. S.C.U.B.A. equipped divers sampled deeper water, a preferred winter habitat reported from other streams (Munther 1970, Todd and Rabeni 1989). To maintain an equal effort in the other habitat types, a team of observers entered the river at a randomly selected point, and after evenly distributing across the entire channel width, drifted measured lengths of the river downstream. When fish were observed, the same protocol was used to collect habitat use data for this drift snorkeling approach as for the static-drop line approach.

I also used drift snorkeling to sample during the spring sampling period. I would randomly select a starting point and two teams of observers would drift downstream for a measured length. When a nest was observed one observer would record data while the other continued the drift. For either winter or spring sampling periods, I did not repeat observation in a section of stream until all sections observable with direct observation were sampled. However, I did use repeated observations in sections during the spring to confirm nest sightings and to monitor nest development.

Electrofishing

Although electrofishing was not intended to be a primary source of habitat suitability data, I developed and tested several electrofishing methods:

1. **Boat electrofishing-** Two booms suspended the anode off the front of the boat. Two to three

operators maneuvered the boat, and the cathode floated behind. One member of the crew operated the generator (Honda G-50, capacity for 300 and 600 volt output), variable voltage pulsator (VVP; Coffelt- Model # 15), controlled the boat position, while another netted fish and marked the sampled fish's position when first sighted. The third crew member transferred fish to a holding tank, recorded data and placed a tag at the fish's position. This method was used in water deeper than 1.5 m, and an outboard motor was often used to propel the craft. However, intrusiveness from the motor and boat made sampling difficult, and poor maneuverability made habitat measurement difficult.

2. **Free moving anode** - This design involved holding the boat in open water either by hand, or by anchoring it. One person operated the generator and VVP in the boat, assisted in sample processing and recorded data. One crew member used a 4.25 m fiberglass boom and 20 cm long (7.5 cm diameter) steel cylinidrical anode to sample fish. A 90 m electrical cord connected the VVP to the anode, which allowed free movement to place the anode at any chosen point within the 90 m radius. Two or more crew members were responsible for netting fish during sampling, placing marker tags on fish

locations, and processing the samples. This technique was more successful than boat electrofishing but its use was limited to shallow water. We also had problems with intrusiveness, in that walking on the streambed and shadows from observers and the anode seemed to affect fish position. However, the ability to move 90 m from the craft appeared to somewhat decrease the amount of disturbance to fish.

3. **Throwable anode** - Instead of using the bulky 4.25 m fiberglass boom and heavy steel cylindrical anode, I used a flexible 1.25 m PVC pipe boom (3.8 cm diameter), to which I connected a 25 cm diameter wire loop anode made of .64 cm diameter steel cable (Figure 2). I weighted the apparatus with goose decoy weights that were sealed inside the shaft of the apparatus. This apparatus was connected to the VVP by 45 m of electrical cable. I attached floats along the length of the cable except for the 9 m nearest the anode to allow for easy recovery and to prevent fouling.

I used the same procedure to select a sample reach as for the static-drop line approach. I began sampling at the lowermost point of the randomly chosen habitat type. At the starting point, we first sampled near-shore habitat. Rather than place the anode at the sample

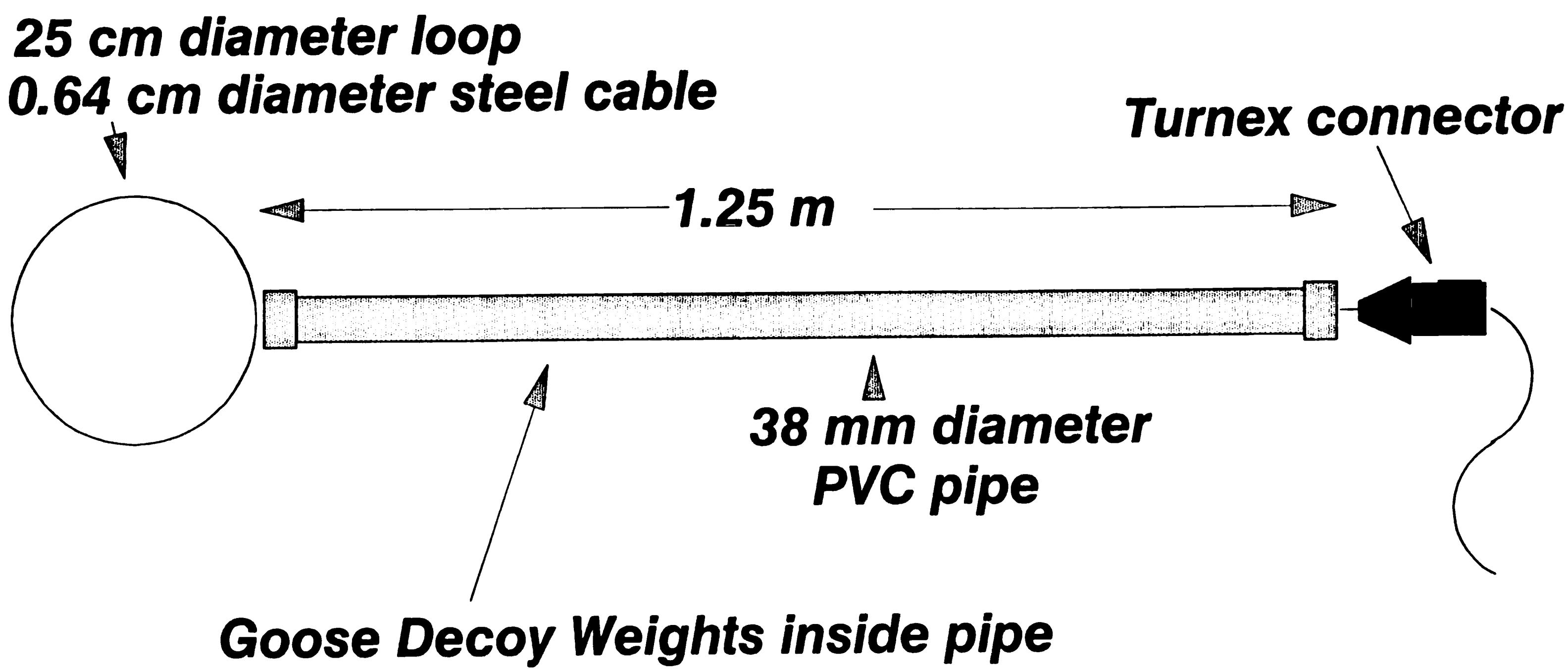


Figure 2. A diagram of the anode used in the throwable anode electrofishing design.

location, it was thrown to that location from a distance of 4 to 6 m. The anode sank to the bottom and was energized a maximum of 20 sec for the sample location. The area disturbed while sampling one location determined the distance to the next sample location. Most frequently, 6 m distances separated one sample location from the next. When fish were observed, the same protocol was used to collect habitat use data for this electrofishing approach as for the static-drop line approach. With the completion of habitat data measurements, the anode was thrown to the next sample location. This next location was a distance of 6 m (just greater than the area disturbed by the previous sample), and in a direction perpendicular to the flow. Thus 4 to 6 samples were made along a transect across the channel before moving upstream. After moving upstream (at least 6 m) the same procedure was used to sample along another transect across the channel. This cross-channel pattern was repeated until the entire habitat type was sampled, or until completion of sampling for the day. To maintain equal effort among habitat types, I recorded total electrofishing time in each habitat type, and sampled each habitat type the same amount of total electrofishing time.

I sampled with all three techniques with different degrees of success. However, I only made a between method comparison of the throwable anode electrofishing technique and direct underwater observation.

**Data Analysis**

I categorized habitat use observations by species, size class (Table 6), and temporal level of stratification (seasonal and diel) and constructed habitat utilization curves for each category. The curves described utilization of depth, mean column velocity, focal point velocity, adjacent velocity, distance to adjacent velocity, cover type, distance to cover type, and substrate type. Because cover type and substrate type are not continuous variables, curve building techniques used to describe habitat use for continuous variables such as depth and velocity cannot be used (Slauson 1988). Therefore I used two methods, histogram analysis for discrete variables and nonparametric tolerance limits for continuous variables, to develop curves. The curves were developed only for levels of stratification for which I obtained an adequate sample size.

Minimum Sample Size

To determine the minimum sample size for a particular level of stratification, I selected data sets with 100 or more observations as reference data sets. Eight data sets met this criterion: diurnal-summer (1989 and 1990 combined) habitat variables for adult, juvenile, and young-of-the-year

Table 6. Size class (life history stage) levels of stratification for smallmouth bass and rock bass.

| Life History Stage | Total Length (cm) Smallmouth Bass | Total Length (cm) Rock Bass |
|---|---|---|
| Young-of-the-year (YOY) | < 11 | < 6 |
| Juvenile (JUV) | 12 - 19 | 7 - 10 |
| ADULT (AD) | > 20 | > 11 |

smallmouth bass; nocturnal-summer (1989 and 1990 combined) habitat variables for adult, juvenile, and young-of-the-year rock bass; diurnal-summer (1989 and 1990 combined), adult rock bass; and crepuscular-summer (1990), adult rock bass. For each of these data sets I used both parametric and nonparametric methods to estimate the minimum sample size requirements.

I used a parametric analysis of minimum sample size by comparing each use frequency distribution to a normal distribution with this formula (Eckblad 1991):

$$N = \frac{(t)^2\ s^2}{(0.1*\text{Mean})}$$

N= estimate of the minimum sample size.

t= t-value of a normal distribution for a sample size n.

$s^2$= sample variance.

This method assumes that the data are distributed normally. Nearly all data sets of the continuous variables were normally distributed. Those that deviated most from normality were positively skewed. I used the skewness coefficient ($g_1$; Sokal and Rohlf 1981) to determine the severity of the skewness and used a $\log_{(10)}$ transformation for those data sets with a $g_1$ value greater than 1.75.

I also used a nonparametric analysis to determine the minimum sample size of each of the eight habitat variables, for all eight reference data sets. I excluded the vertical stratum variable from the analysis because over 90 percent of the observations made for both species and all sizes were in the bottom stratum. Furthermore, I only compared dominant substrate particle type between temporal strata.

I made use frequency distributions with standardized interval width for each habitat attribute between the eight reference data sets. For example, depth was assigned an interval width of 30.5 cm between all eight reference data sets. This facilitated visual comparison between data sets and standardized graph format. I then randomly selected 50 observations of one habitat attribute from a reference data set, and constructed a frequency distribution for those 50 observations. I developed a third frequency distribution of expected values by normalizing the use frequency distribution of the reference data set to a sample of 50.

I used a $X^2$ goodness-of-fit test to determine if the frequency distribution made from the random subsample differed significantly from the expected frequency distribution derived from the reference data set. A total of 100 iterations of this procedure was made on the same reference data set to estimate the probability that a random subsample of a size N would differ significantly from a reference data set of a larger N. If five or fewer iterations exceeded the $X^2$ statistic, a smaller subsample of N-10 was tested with the same procedure. This process was repeated until more than 5 iterations differed significantly from the $X^2$, or the conditions for $X^2$ testing were violated (Zar 1974). I used this procedure for all eight habitat variables for each of the eight reference data sets. The sample sizes recommended for the reference data set were used to set minimum sample sizes for levels of stratification with fewer than 100 observations.

Habitat Utilization Curve Development

The first step in analyzing suitability curve data is to produce a frequency plot, bar graph, or similar visual representation of the suitability data (Slauson 1988). I standardized interval width for each habitat variable based on smoothness of the distribution of each data set, and I visually compared utilization of each habitat variable for the different levels of stratification.

Absolute frequency distributions can be converted to relative frequency by dividing each interval by the frequency of the largest interval, or by the sample size (Bovee 1986, Slauson 1988). Because my data will be used for a number of different purposes, I did not make either conversion.

Bovee (1986) recommended use of the nonparametric tolerance limits method (Gosse 1982) to develop habitat utilization curves. The method is most useful when a researcher is limited to a small sample size. Because I did not expect large sample sizes for every level of stratification in my study, I used this method for all continuous habitat variables at all levels of stratification with adequate sample size. For curve development, the data for any one continuous habitat variable was arranged in order from lowest value to highest value. To normalize data, I assigned a weighting factor of 1 to the 50 percentile value, and 0.5, 0.2, 0.1, and 0.02 to the 75, 90, 95, and 99 percentiles of the populations, based on the following function (Gosse 1982):

$$NSI = 2(1-P)$$

NSI = Normalized Suitability Index.

P = The proportion of the observations under the curve segment.

Curve Comparison

I used three methods of comparison to evaluate habitat use data. First, I used nonparametric analysis of variance to test for variation in habitat use between levels of stratification. If the ANOVA showed a significant effect of stratification, I used Tukey's multiple range test (experiment wise alpha= 0.05) to determine which levels of stratification were significantly different (SAS 1985). Second, I visually compared graphs of rock bass habitat utilization in the Huron River to curves developed in Pennsylvania on Aughwick Creek (Mayhew 1982), Illinois in the Vermillion River system (Herricks and Gantzer 1982), and Tennessee on Piney River (Hill and Hauser 1985). Similarly, I visually compared graphs of smallmouth bass habitat utilization in the Huron River to smallmouth bass preference curves developed in Minnesota (Aadland et al. 1991), Massachusetts (Bain et al. 1982), and Oklahoma (Orth 1981). Third, I used nonparametric analysis of variance (SAS 1985) to determine similarities and differences between habitat use data collected by direct observation and by sampling with electrofishing gear.

## RESULTS

I sampled each of the eight habitat types by direct underwater observation five times during the diurnal time period, and four times during the nocturnal time period in the summer and fall of 1989 and 1990. In 1990 I sampled once in each habitat type during the diurnal-winter, diurnal-spring, and crepuscular-summer time periods. Finally, I sampled with the throwable anode electrofishing method a total of 30 minutes (estimated effective electrofishing time) in each of the six shallowest habitat types during the diurnal-summer time period of 1990.

I compiled a total of 1,868 observations of smallmouth bass and rock bass habitat use during three seasons and three times of day using two sampling techniques. However, more fish were observed than this number suggests. When more than one fish was observed in the same location, and only one set of measurements could be made, then only one observation was included in the compiled data. Although several fish per observation can be included in curve development by weighting each observation by the number of fish observed (Bovee 1986), I chose to use conservative methods to compare data between time periods.

I obtained 25 data sets by sorting observations by species, life history stage, time of day, season, and gear type (Table 7). The number of observations varied between levels of stratification. Most differences were due to differential effort between time periods.

The number of observations also differed between habitat characteristics within each level of stratification (Table 7). This resulted from an inability to measure and record every habitat characteristic at every sample location. For example, woody debris frequently confounded efforts to measure velocities at the location of fish using heavy cover, although measures of cover, distance to cover, depth, and substrate could be measured. Consequently, all observations were included in the complied data set and sorted into sample strata, regardless of the completeness of data for an observation.

**Minimum Sample Size**

Both methods used to estimate minimum sample size requirements were limited by test assumptions. The parametric approach could not be used for categorical variables, for continuous variables that were not normally distributed, or for variables which could not be transformed to a normal distribution. The estimates obtained by $X^2$ goodness-of-fit were all limited by the test assumption that no interval could have a value of zero, rather than by the

Table 7. Number of observations of eight habitat attributes within twenty five levels of data stratification based on temporal scale and data collection method.

| Stratification | | | | | Sample Size By Habitat Characteristic | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Size Class | Time | Season | Gear Type | Cover | Distance to Cover | Substrate | Depth | Mean Column Velocity | Focal Point Velocity | Adjacent Velocity | Distance to Adjacent |
| Rock bass | Adult | Diurnal | Summer/Fall | Direct Observation | 182 | 180 | 182 | 180 | 167 | 177 | 178 | 178 |
| | | Nocturnal | Summer/Fall | Direct Observation | 314 | 314 | 313 | 308 | 304 | 308 | 306 | 306 |
| | | Crepuscular | Summer/Fall | Direct Observation | 101 | 101 | 101 | 101 | 100 | 98 | 99 | 100 |
| | | Diurnal | Spring | Direct Observation | 42 | 43 | 43 | 43 | 43 | 42 | 43 | 43 |
| | | Diurnal | Winter | Direct Observation | 17 | 17 | 17 | 17 | 17 | 17 | n.a. | n.a. |
| | | Diurnal | Summer/Fall | Electrofishing | 88 | 88 | 89 | 89 | 89 | 87 | 89 | 89 |
| | Juvenile | Diurnal | Summer/Fall | Direct Observation | 52 | 52 | 53 | 53 | 52 | 48 | 53 | 53 |
| | | Nocturnal | Summer/Fall | Direct Observation | 197 | 197 | 197 | 197 | 194 | 196 | 196 | 195 |
| | | Crepuscular | Summer/Fall | Direct Observation | 16 | 16 | 16 | 16 | 16 | 15 | 16 | 16 |
| | Young/Juvenile | Diurnal | Summer/Fall | Electrofishing | 14 | 13 | 15 | 15 | 15 | 15 | 15 | 14 |
| | Young | Diurnal | Summer/Fall | Direct Observation | 13 | 10 | 12 | 12 | 12 | 12 | 12 | 12 |
| | | Nocturnal | Summer/Fall | Direct Observation | 223 | 223 | 223 | 221 | 221 | 220 | 220 | 220 |
| | | Crepuscular | Summer/Fall | Direct Observation | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Smallmouth bass | Adult | Diurnal | Summer/Fall | Direct Observation | 112 | 90 | 114 | 110 | 109 | 111 | 109 | 109 |
| | | Nocturnal | Summer/Fall | Direct Observation | 62 | 62 | 62 | 62 | 62 | 62 | 61 | 61 |
| | | Crepuscular | Summer/Fall | Direct Observation | 13 | 13 | 13 | 13 | 13 | 13 | 12 | 12 |
| | | Diurnal | Spring | Direct Observation | 66 | 66 | 65 | 66 | 66 | 57 | 66 | 66 |
| | | Diurnal | Winter | Direct Observation | 12 | 12 | 12 | 12 | 12 | 12 | n.a. | n.a. |
| | | Diurnal | Summer/Fall | Electrofishing | 26 | 26 | 26 | 26 | 25 | 26 | 26 | 24 |
| | Juvenile | Diurnal | Summer/Fall | Direct Observation | 100 | 86 | 102 | 102 | 101 | 102 | 102 | 102 |
| | | Nocturnal | Summer/Fall | Direct Observation | 32 | 32 | 32 | 32 | 32 | 32 | 31 | 31 |
| | Young/Juvenile | Diurnal | Summer/Fall | Electrofishing | 12 | 11 | 12 | 12 | 12 | 12 | 12 | 12 |
| | Young | Diurnal | Summer/Fall | Direct Observation | 104 | 93 | 104 | 103 | 101 | 103 | 102 | 102 |
| | | Nocturnal | Summer/Fall | Direct Observation | 25 | 19 | 25 | 24 | 25 | 24 | 25 | 25 |
| | | Crepuscular | Summer/Fall | Direct Observation | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |

subsample exceeding the $X^2$ test statistic for more that 5% of the iterations.

Estimation of Minimum Required Sample Size

The parametric test could only be used to estimate the minimum sample size requirements of half the habitat characteristics of each reference data set. Cover and substrate were excluded from the test because they were categorical variables. Distance to cover and distance to adjacent velocity were excluded from the analysis because they were neither normally distributed, nor could they be transformed to a normal distribution. Consequently depth, mean column velocity, focal point velocity, and adjacent velocity were the only variables tested with this method.

Estimates of minimum required sample size varied between habitat characteristics within each level of stratification (Table 8). Focal point velocity was the most consistent variable between levels of stratification, ranging from an estimated N of 11 to 32. This variable also consistently had one of the smallest required sample sizes. Estimates of minimum required sample size for depth were the largest and most variable among temporal strata. I used a $\log_{(10)}$ transformation of depth observations for four of the eight levels of stratification because the depth distribution was positively skewed ($g_1 > 1.75$). After the transformation, the estimate of minimum sample size for juvenile rock bass use of depth during the nocturnal-summer time period more closely resembled the estimates for the

Table 8. Minimum sample size requirements of several habitat attributes estimated by parametric analysis (Eckblad 1991) for eight reference data sets. Skewness is the value $g_1$ (Sokal and Rohlf 1981), the skewness coefficient.

| | | Habitat Characteristic | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species / Size Class | Time | Depth | | $Log_{(10)}$ Depth | | Mean Column Velocity | | Focal Point Velocity | | Adjacent Velocity | |
| | | n | N | n | N | n | N | n | N | n | N |
| **Rock Bass** | | | | | | | | | | | |
| Adult | Diurnal | 178<br>$g_1 = 1.96$ | 148 | 178 | 5 | 167<br>$g_1 = 1.47$ | 44 | 177<br>$g_1 = 1.32$ | 23 | 178<br>$g_1 = 0.81$ | 17 |
| | Nocturnal | 308<br>$g_1 = 4.89$ | 214 | 308 | 15 | 304<br>$g_1 = 1.13$ | 49 | 308<br>$g_1 = 1.40$ | 23 | 306<br>$g_1 = 1.54$ | 34 |
| | Crepuscular | 194<br>$g_1 = 1.2$ | 57 | | | 196<br>$g_1 = 1.86$ | 28 | 196<br>$g_1 = 1.39$ | 32 | 221<br>$g_1 = 1.36$ | 56 |
| Juveniles | Nocturnal | 197<br>$g_1 = 8.42$ | 541 | 197 | 31 | 194<br>$g_1 = 1.20$ | 57 | 196<br>$g_1 = 1.86$ | 28 | 196<br>$g_1 = 1.39$ | 32 |
| Young | Nocturnal | 221<br>$g_1 = 1.36$ | 57 | | | 221<br>$g_1 = 1.32$ | 46 | 220<br>$g_1 = 1.08$ | 22 | 220<br>$g_1 = 1.80$ | 33 |
| **Smallmouth Bass** | | | | | | | | | | | |
| Adult | Diurnal | 110<br>$g_1 = 1.90$ | 144 | 110 | 1 | 109<br>$g_1 = 0.75$ | 54 | 111<br>$g_1 = 0.62$ | 13 | 109<br>$g_1 = 0.71$ | 33 |
| Juveniles | Diurnal | 102<br>$g_1 = 1.08$ | 40 | | | 101<br>$g_1 = 0.00$ | 17 | 102<br>$g_1 = 0.46$ | 11 | 102<br>$g_1 = 1.33$ | 21 |
| Young | Diurnal | 103<br>$g_1 = 1.16$ | 33 | | | 101<br>$g_1 = 0.52$ | 50 | 103<br>$g_1 = 0.64$ | 29 | 102<br>$g_1 = 0.36$ | 30 |

other attributes within the same level of stratification. Results of this method (Table 8) were used only as reference for estimates developed using the nonparametric method because I obtained results for only four of the eight habitat characteristics, and because the results varied greatly between habitat attributes.

I also used nonparametric methods to estimate minimum required sample size (Table 9). I was able to test all eight habitat attributes using nonparametric methods. Although the estimates using this approach were more conservative than those using the parametric approach, results were comparable between the two techniques. Estimates for minimum required sample size ranged between 30 and 50. Results obtained with this method were less variable among strata, and between habitat attributes within strata, as compared to results obtained by parametric procedures.

I included data sets with more than 50 observations in curve building procedures, and excluded data sets with fewer than 30 observations. If a data set had between 30 and 50 observations, I referred to the minimum required sample size for the most similar reference data set.

Sample Size vs. Minimum Required Sample Size

Most levels of stratification of observational data for both species had sample sizes greater than 50 or fewer than 30 observations (Table 7). Therefore I did not have to make

Table 9. Minimum sample size requirements of eight habitat attributes estimated by $X^2$ goodness-of-fit analysis for eight reference data sets.

| Species SIZE CLASS | Time | Cover | Distance to Cover | Substrate | Depth | Mean Column Velocity | Focal Point Velocity | Adjacent Velocity | Distance to Adjacent |
|---|---|---|---|---|---|---|---|---|---|
| **Rock bass** | | | | | | | | | |
| ADULT | Diurnal | 40 | 40 | 30 | 30 | 40 | 30 | 50 | 30 |
| | Nocturnal | 30 | 30 | 40 | 30 | 30 | 30 | 30 | 30 |
| | Crepuscular | 50 | 30 | 30 | 30 | 30 | 30 | 40 | 30 |
| JUVENILE | Nocturnal | 30 | 30 | 40 | 30 | 40 | 40 | 40 | 30 |
| YOUNG | Nocturnal | 30 | 40 | 30 | 50 | 30 | 40 | 50 | 50 |
| **Smallmouth bass** | | | | | | | | | |
| ADULT | Diurnal | 50 | 30 | 40 | 30 | 30 | 30 | 30 | 30 |
| JUVENILE | Diurnal | 50 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| YOUNG | Diurnal | 40 | 30 | 30 | 40 | 30 | 30 | 50 | 30 |

any closer comparisons between observational data sets and minimum sample size requirements. Three data sets had between 30 and 50 total observations for at least one habitat attribute. I compared these data sets to the minimum required sample size of the most similar reference data set (Table 9). Thus, in addition to the eight reference data sets, these data sets were included in curve building procedures:

- adult rock bass during the diurnal-spring time period using direct observation,
- adult rock bass during the diurnal-summer time period using the electrofishing method,
- juvenile rock bass during the diurnal-summer time period using direct observation,
- adult smallmouth bass during the nocturnal-summer time period using direct observation,
- adult smallmouth bass during the diurnal-spring time period using direct observation.

**Curve Comparison**

I built habitat utilization curves (HSI) for the thirteen data sets with sufficient sample sizes, and use frequency histograms for the 12 additional data sets (Appendix A). I determined temporal variation in habitat use by visual comparison of graphs between time periods for each species, size class. I quantified observed differences between temporal strata by nonparametric analysis of variance.

Comparison Between Temporal Strata

Rock Bass

Visual comparison of graphs between diel time periods showed little difference in habitat use for adult rock bass. However, when I used nonparametric analysis of variance, several habitat use distributions were significantly different (Table 10). Adult rock bass used dense cover less frequently, greater distances from cover, finer substrate types, and slower adjacent velocities for the nocturnal time period (Figure A2) as compared to the diurnal time period (Figure A1). Adult rock bass used velocity shelters more frequently during the crepuscular time period (Figure A3) as compared to the diurnal time period (Figure A1). Adult rock bass used significantly greater distances to cover, and finer substrate size for the nocturnal time period (Figure A2) as compared to the crepuscular time period (Figure A3).

Habitat use also varied among seasons for this species, size class (Table 10). Adult rock bass used significantly greater distances to cover, deeper water, and greater distance to adjacent velocity during the diurnal-spring time period (Figure A4) than during the diurnal-summer time period (Figure A1). Visual comparison of habitat attributes did not appear different for all attributes identified as distinct by AVOVA. However, visual comparison showed differences between substrate used in the summer and

Table 10. Results of eight analysis of variance of rank (SAS 1985) and multiple comparisons (Tukey 1977) between temporal sampling strata and sampling techniques (* = significance at $P < 0.05$, n.s. = not significant).

| Data Sets Compared | Habitat Characteristic Compared | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cover | Distance to Cover | Substrate | Depth | Mean Column Velocity | Focal Point Velocity | Adjacent Velocity | Distance to Adjacent |
| Adult Rock Bass: Diurnal vs. Nocturnal- Summer/Fall | * | * | * | n.s. | n.s. | n.s. | * | n.s. |
| Adult Rock Bass: Diurnal vs. Crepuscular- Summer/Fall | * | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| Adult Rock Bass: Nocturnal vs. Crepuscular- Summer/Fall | n.s. | * | * | n.s. | n.s. | n.s. | n.s. | n.s. |
| Adult Rock Bass: Diurnal- Summer/Fall vs. Diurnal- Spring | n.s. | * | n.s. | * | n.s. | n.s. | n.s. | * |
| Adult Rock Bass, Diurnal- S/F: Direct Observation vs. Electrofishing | n.s. | n.s. | n.s. | * | * | * | * | * |
| Juvenile Rock Bass: Diurnal vs. Nocturnal Summer/Fall | * | n.s. | n.s. | n.s. | * | n.s. | * | n.s. |
| Adult Smallmouth Bass: Diurnal vs. Nocturnal Summer/Fall | * | * | * | * | * | * | * | n.s. |
| Adult Smallmouth Bass: Diurnal- S/F vs. Diurnal- Spring | * | n.s. | n.s. | * | * | * | * | * |

substrate outside the nest (substrate type prior to nest building) in the spring, although this was not tested statistically. Both the range of optimum suitability and the total suitable habitat range appeared similar for all other attributes between seasonal strata.

Juvenile rock bass used significantly different habitat types among diel time periods (Table 10). Juvenile rock bass used less complex cover structures more frequently, faster mean column velocities, and slower adjacent velocities during the nocturnal-summer time period (Figure A8) as compared to the diurnal-summer time period (Figure A7). However visual comparison showed these curves to be more similar than ANOVA results suggest. The only apparent difference between the two curve sets was a more frequent use of complex cover structures during daylight hours as compared to use of cover at night. I could not make any seasonal comparisons because effort was concentrated on spawning activity in the spring, and because winter sample sizes were too small.

No statistical comparisons could be made for young-of-the-year rock bass among diel or seasonal time periods. Diurnal-summer and crepuscular-summer sample sizes were too small to make comparisons, and we did not observe any young-of-the-year during the winter. The most noteworthy comparison that could be made was the difference in the number of observations made at night as compared to day. I compiled 220 to 223 observations for the nocturnal-summer time period, but only 10 to 12 for the diurnal-summer time period (Table 7) for young-of-the year rock bass.

Smallmouth Bass

I also compared diel and seasonal variation in habitat use by adult smallmouth bass (Table 10). This species, size class used denser cover, shorter distances to cover, finer substrate types, shallower water, slower mean column velocities, slower focal point velocities, and slower adjacent velocities during nocturnal-summer observations (Figure A15) than during diurnal-summer observations (Figure A14). Visual comparison of the curve sets confirmed the results of the analysis of variance. Adult smallmouth bass were obviously using different depths, velocities, substrate, and cover at day as compared to night. Similarly adult smallmouth bass used denser cover, shallower depth, slower mean column velocities, slower focal point velocities, and greater distance to adjacent velocities during the diurnal-spring sample effort (Figure A17) as compared to the diurnal-summer sample effort (Figure A14). Visual comparison of the graphs shows an even more obvious dichotomy to habitat use between seasons. Adult smallmouth bass were obviously using shallower water and much slower velocities in the spring than in the summer.

I could not make statistical comparisons of either juvenile or young-of-the-year smallmouth bass habitat use between diel or seasonal time periods due to insufficient sample sizes. However, visual comparison of juvenile smallmouth bass habitat use between diurnal-summer and nocturnal-summer time periods showed some differences. As for adult smallmouth bass, juvenile smallmouth bass used shallower water, more complex cover, and finer particulate substrate at night as compared to day.

Regional Comparison of Habitat Suitability Indices

Rock Bass

Visual comparison of regional variability in rock bass habitat use could only be made for adult and juvenile size classes, and for depth and mean water column velocity habitat attributes. No data were available for the Vermillion River system (Larimore and Garrels 1982) for juvenile rock bass. Also, no comparisons were made for young-of-the-year rock bass because too few of observations were made in the Huron River to develop curves for the diurnal time period.

Adult and juvenile rock bass used deeper water in the Huron River and a broader range of depths than in the other three rivers (Figures 3a and 4a respectively). Adult and juvenile rock bass used faster velocities and a broader range of velocities in the Huron River than in the other three rivers. Velocity utilization curves for adult and juvenile rock bass were very similar between Aughwick Creek (Mayhew 1982), Vermillion River system, and Piney River with an optimum velocity of 0 cm/sec (Figure 3b and 4b). In the Huron River, adult rock bass used a broader range of velocities (0 to 72 cm/sec), with optimum velocity ranging

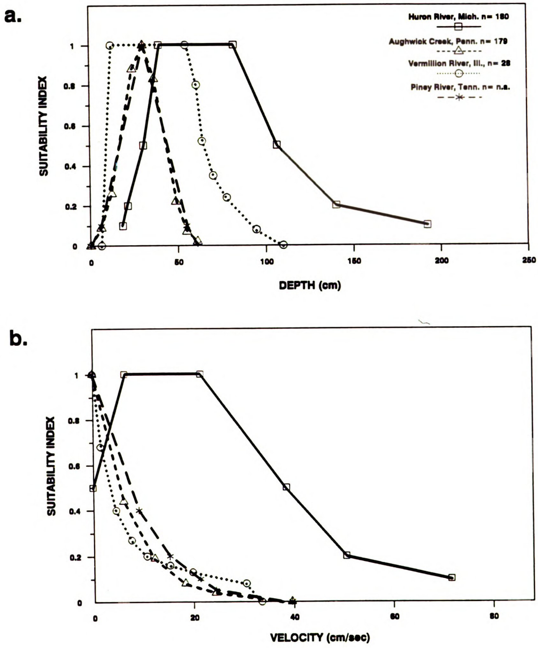


Figure 3. Graphical comparison of four habitat suitability models that describe adult rock bass use of depth (a.) and mean column velocity (b.) habitat attributes. Models were developed independently in Illinois (Herricks and Gantzer 1982), Tennessee (Hill and Hauser 1985), Pennsylvania (Mayhew 1982), and Michigan.

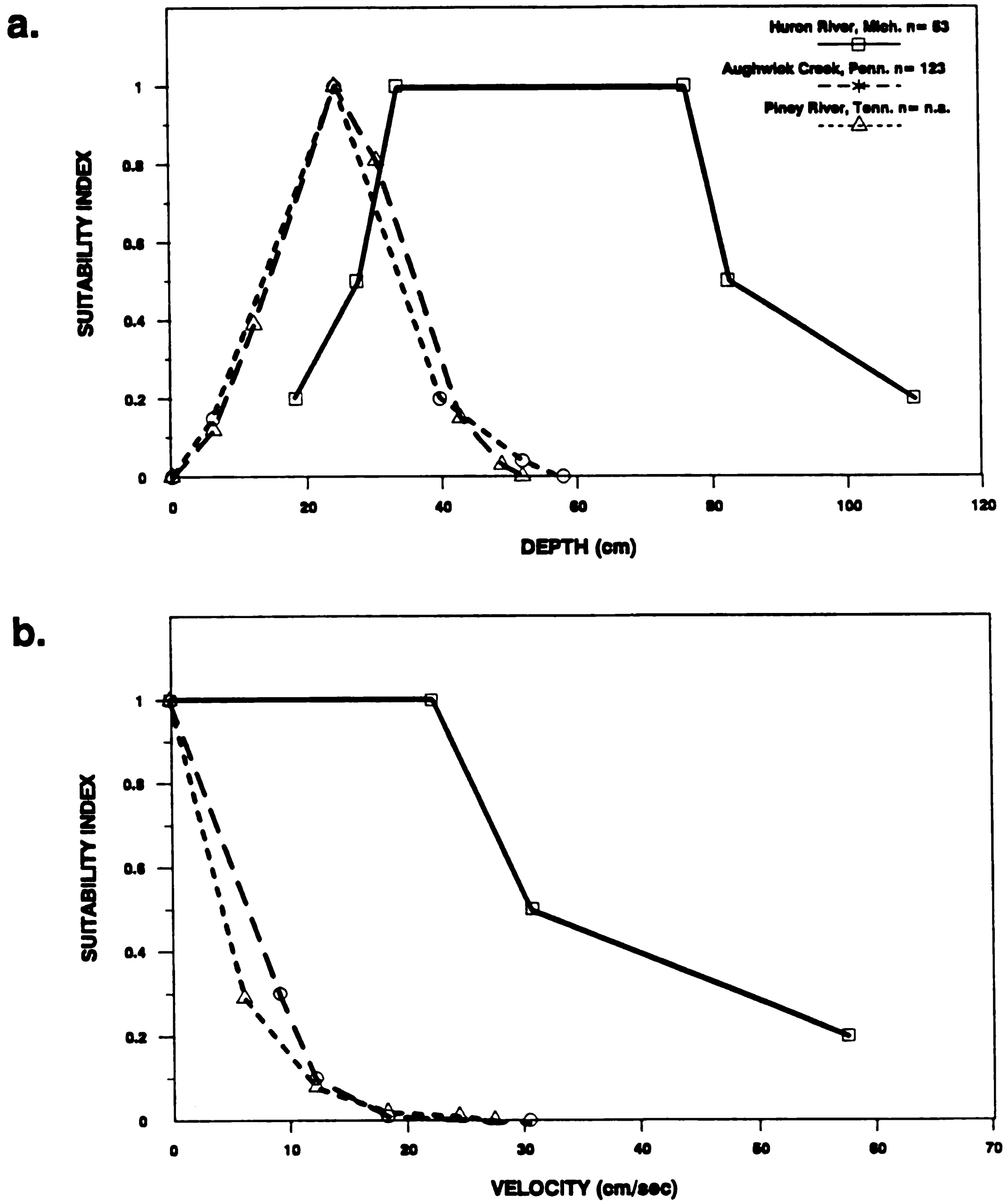


Figure 4. Graphical comparison of three habitat suitability models that describe juvenile rock bass use of depth (a.) and mean column velocity (b.) habitat attributes. Models were developed independently in Illinois (Herricks and Gantzer 1982), Tennessee (Hill and Hauser 1985), Pennsylvania (Mayhew 1982), and Michigan.

from 6 to 22 cm/sec (Figure 3b). Juvenile rock bass used a broader range of velocity (0 to 58 cm/sec) with optimum values between 0 and 22 cm/sec (Figure 4b).

## Smallmouth Bass

Visual comparison of regional variability in smallmouth bass habitat use was made between adult, juvenile, young-of-the-year, and spawning life history stages. I compared depth, mean water column velocity, and substrate habitat attributes between the streams.

The range of optimum depth suitability for adult smallmouth bass in the Huron River and Glover Creek, Oklahoma was broader than those developed for the Zumbro/Snake/Yellow Medicine Rivers, Minnesota and the West Deerfield River, Massachusetts. Although the range of optimum depth suitability for the Huron River was broad, it did not overlap optimum depth suitability for the West Deerfield River. Optimum depth suitability for the Huron River was equal to or greater than optimum depth suitability for Glover Creek and rivers in Minnesota for adult, juvenile, young-of-the-year, and spawning life history stages. However, optimum depth suitability for the Huron River was shallower than optimum depth suitability for West Deerfield River adult and juvenile size classes. Conversely, optimum depth suitability for the Huron River was deeper than optimum depth suitability for West Deerfield River young-of-the-year.

Mean column velocity curves for all three size classes of smallmouth bass for the diurnal-summer sample effort were most similar between the Huron River and rivers in Minnesota (Figure 5b, 6b, and 7b for adult, juvenile, and young-of-the-year respectively). The total range of suitable mean water column velocity in the Huron River was not broader than those found in the other three streams for adult, juvenile, or young-of-the-year size classes. The range of optimal suitability was broadest for the Huron River, but total range of suitability was broadest for rivers in Minnesota. Optimal suitable mean water column velocity was at or close to 0 cm/sec in Glover Creek and West Deerfield River. Smallmouth bass used faster velocities in Midwest streams than in streams in the South or Northeast. Young-of-the-year smallmouth bass HSI were not developed in Glover Creek, so no comparisons could be made.

The greatest degree of between stream variability in HSI for smallmouth bass was for the substrate habitat attribute. Optimal suitable substrate particle size varied between streams and life stages. Optimal particle size was gravel in Minnesota streams, cobble in the Huron River, boulder in Glover Creek, and boulder and bedrock in West Deerfield River for adult smallmouth bass (Figure 5c). Optimal particle size for juvenile smallmouth bass was: gravel and cobble in the Huron River; boulder in Minnesota streams; gravel, cobble, and boulder in Glover Creek; and all particle sizes in the West Deerfield River (Figure 6c).

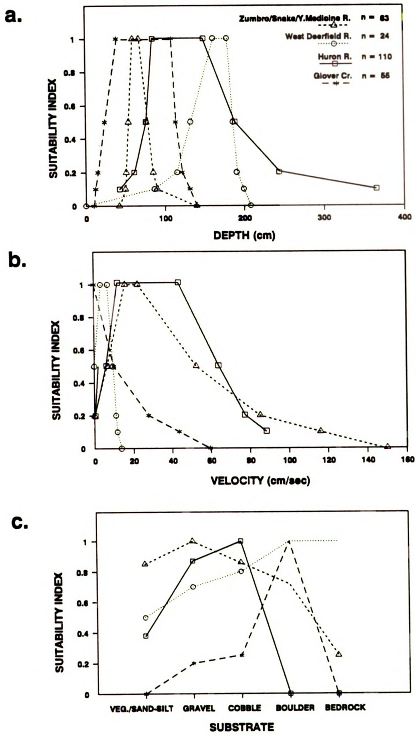


Figure 5. Graphical comparison of four habitat suitability models that describe adult smallmouth bass use of depth (a.), mean column velocity (b.), and substrate (c.) habitat attributes. Models were developed independently in Minnesota (Aadland et al. 1991), Massachusetts (Bain et al. 1982), Oklahoma (Orth 1981), and Michigan.

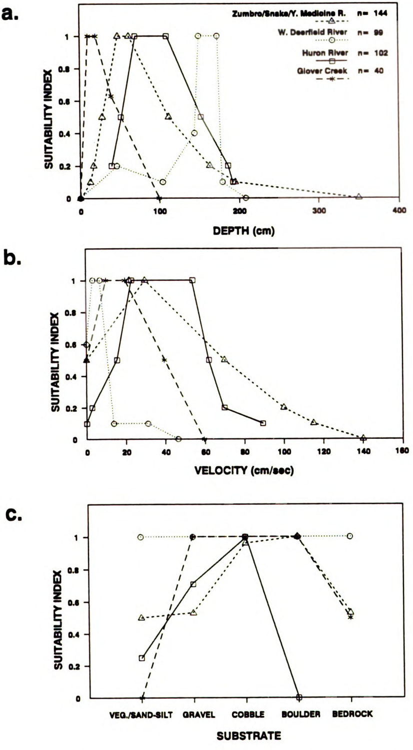


Figure 6. Graphical comparison of four habitat suitability models that describe juvenile smallmouth bass use of depth (a.), mean column velocity (b.), and substrate (c.) habitat attributes. Models were developed independently in Minnesota (Aadland et al. 1991), Massachusetts (Bain et al. 1982), Oklahoma (Orth 1981), and Michigan.

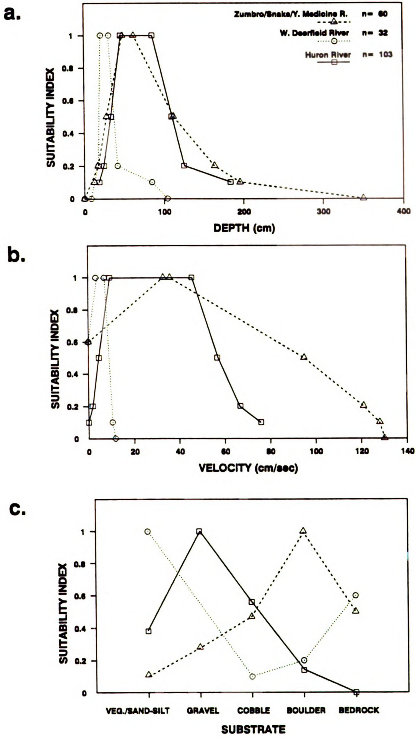


Figure 7. Graphical comparison of three habitat suitability models that describe young-of-the-year smallmouth bass use of depth (a.), mean column velocity (b.), and substrate (c.) habitat attributes. Models were developed independently in Minnesota (Aadland et al. 1991), Massachusetts (Bain et al. 1982), Oklahoma (Orth 1981), and Michigan.

Optimal particle size for young-of-the-year smallmouth bass was particularly variable (Figure 7c). Substrate of vegetation/sand-silt, gravel, and boulder were optimal in the West Deerfield River, Huron River, and rivers in Minnesota respectively. No HSI were available for young-of-the-year in Glover Creek (Orth 1981).

I could only make comparisons of HSI for spawning smallmouth bass during in the Huron River and rivers in Minnesota (Figure 8). Spawning smallmouth bass used similar substrate types in the Huron River and streams in Minnesota. In contrast, spawning smallmouth bass used faster velocities and greater depths in the Huron River as compared to rivers in Minnesota.

Alternate Sampling Technique

To evaluate the comparability of data collected by electrofishing to data collected by direct observation, I compared variation in habitat use between the two methods for adult rock bass during the diurnal-summer time period. I could not compare methods for any other temporal strata because electrofishing sample sizes were too small. There were significant differences in habitat use data between methods for depth, mean water column velocity, focal point velocity, adjacent velocity, and distance to adjacent velocity habitat attributes (Table 10). Adult rock bass were observed in significantly shallower water, slower mean column velocities, slower focal point velocities, slower adjacent velocities, and greater distance to adjacent

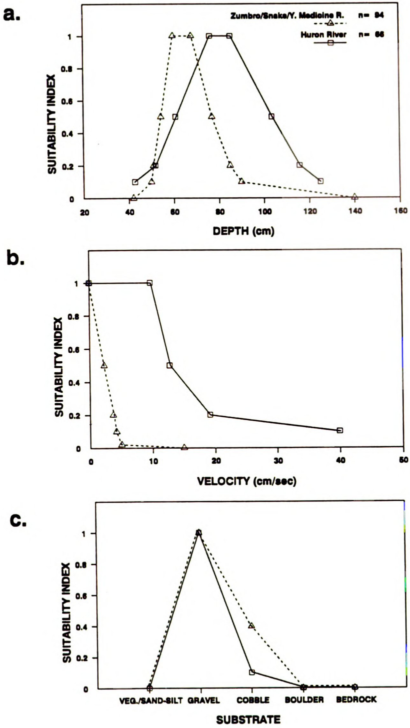


Figure 8. Graphical comparison of two habitat suitability models that describe spawning, adult smallmouth bass use of depth (a.), mean column velocity (b.), and substrate (c.) habitat attributes. Models were developed independently in Minnesota (Aadland et al. 1991) and Michigan.

velocities for the electrofishing method (Figure A6) as compared to direct observation (Figure A1). However, the two curve sets appear quite similar using a visual comparison. The only differences that were noticeable using visual comparison were for adjacent velocity and distance to adjacent velocity habitat attributes. Adult rock bass appear to have been sampled in slower adjacent velocities at greater distance to adjacent velocities with the electrofishing method as compared to the direct observation method.

## SUMMARY

1,868 observations were sorted into 25 levels of stratification based on species, life history stage, diel time period, season, and method of collection. Minimum required sample size estimates were made by goodness-of-fit (Zar 1974), and confirmed with estimates by t-test (Eckblad 1991). Minimum sample size estimates revealed five additional data sets to included in curve building procedures. The twelve data sets not used in curve building procedures were graphically represented by use frequency histograms.

Visual comparisons and comparisons by nonparametric ANOVA were made between temporal strata within species, size classes. Habitat use varied among both diel and seasonal time periods for both species, and for both adult and juvenile rock bass. There were more noticeable differences in habitat use between time periods for smallmouth bass than for rock bass. Furthermore, there were more noticeable differences in smallmouth bass habitat use between seasons than between day and night.

Visual comparisons were made between curves developed in the Huron River to curves developed in other states. Huron River HSI for rock bass use of depth and mean column velocity during the diurnal-summer time period were comparable to curves developed for streams in Pennsylvania, Illinois, and Tennessee. Both adult and juvenile rock bass were observed in deeper water and faster mean column velocities in the Huron River as compared to the other three streams. HSI describing smallmouth bass use of depth, mean column velocity, and substrate type during the diurnal-summer time period were similar to curves developed for streams in Oklahoma, Massachusetts, and Minnesota. Optimal habitat suitability values (SI= 1.0) were similar between streams, but ranges of optimum values were typically broader for the Huron River than for the other streams. The total range of depth, mean water column velocity, and substrate habitat attributes were within the range of suitable habitat values for the three other streams for all life history stages except spawning. For this life history stage comparisons could only be made to Minnesota streams. Smallmouth bass in the Huron River used deeper water and faster mean column velocities for spawning. However, spawning curves for suitable substrate were very similar between Midwest streams.

There were also significant differences in habitat use data between methods. Adult rock bass were found in significantly shallower water, slower mean water column velocity, slower focal point velocity, slower adjacent velocity, and greater distance to adjacent velocity for the electrofishing method as compared to direct observation. However, the differences between methods were very subtle, and were difficult to distinguish by visual comparison.

## DISCUSSION

### Minimum Sample Size

Minimum required sample size estimates obtained by goodness-of-fit were reasonable predictors. Herricks and Gantzer (1982) rated curves developed for species in the Vermillion River system (Larimore and Garrels 1982) based on initial numbers of observations. Their results were very similar to mine: less than 30 observations were considered to be "poor", 31-50 "fair", 51-75 "good", 75-100 "very good", and more than 100 observations per curve to be "excellent".

Results of the $X^2$ goodness-of-fit test also closely resembled guidelines for the minimum number of observations in criteria testing procedures, using the abbreviated convergence method (Bovee 1986). Twenty-five to 50 observations are recommended for comparison using the abbreviate convergence method. However, small sample size can contribute to disagreement between curves during comparison by abbreviated convergence (Bovee 1986), and can likewise contribute to differences between levels of stratification.

The importance of determining minimum required sample size estimates is exemplified by the five data sets included in curve building procedures. If minimum required sample size were set at 100, then these data sets would have been excluded from curve building and analytical procedures. Consequently, I would have only been able to compare habitat use between diurnal, nocturnal, and crepuscular-summer time periods for adult rock bass. This would have eliminated any comparison of diel variability in habitat use for smallmouth bass, or seasonal variability for either species. Furthermore, taking too many samples can be costly and time consuming (Eckblad 1991).

Finally, simply because there is agreement between minimum required sample size for smallmouth bass on the Huron River and smallmouth bass in Illinois ("good" > 50; Herricks and Gantzer 1982), does not mean these estimates are applicable to any data except those for which they were calculated. Because the iterative method I used to estimate minimum required sample size was time consuming, I would recommend development of an alternative method. An alternative would be to use Fisher's exact test (Zar 1974). Ghent (1972) demonstrates use of binomial coefficients to exact test contingency tables with R X C greater than 2 X 2. Furthermore, Ghent suggests that the binomial-coefficient method could be easily programmed to calculate R X C tables. Were a computer program designed that could easily handle R X C comparisons greater than 2 X 2, I believe it would be the statistical method of choice.

**Curve Development**

Development of habitat suitability data can be influenced by what seems an endless number of factors ranging from the general such as geography (Aadland et al. 1991) and climate (Langhurst and Schoenike 1990), to the specific such as predation, competition, and behavior (Werner and Mittlebach 1981, Gosse 1982, Schlosser 1987), and the technical such as data collection techniques (Bain et al. 1985) and curve building procedures (Bovee 1986, Slauson 1988). Although I concentrated my research effort on temporal variation in habitat use by smallmouth bass and rock bass in the Huron River, it is important to note that other factors may influence fish habitat use. I accounted for some of these sources of variability with a stratified experimental design, and analyzed variability among temporal scales. I assume that predation, competition, and other behavioral interactive factors were comparable across sample sites.

Diel Patterns in Habitat Use

### Rock Bass

Rock bass used distinctly different habitats between times of day. For example, adult rock bass were more frequently observed in areas with complex cover, in close proximity to cover, over coarse substrate, and associated with high adjacent velocity during the daytime (Figure A1); but were more frequently observed near simple cover, at a greater distance to cover, over fine particulate substrates, with slow adjacent velocities during nocturnal time periods (Figure A2). These differences can be explained by behavioral shifts to accommodate different resource needs at different times of the day.

During the crepuscular time period (Figure A3), adult rock bass used velocity shelters more frequently than during day (Figure A1) or night (Figure A2). Use of velocity shelters would generate focal points of low velocity nearest to fast velocities. Because drift increases with velocity (Waters 1969), a microhabitat location of slow velocity that is adjacent to a fast velocity area would maximize energy gain (Fausch 1984). That rock bass were most frequently observed using velocity shelters during the crepuscular time period also suggests that the positions were used to feed on drift, because drift peaks during crepuscular time periods (Waters 1962). Adult rock bass might use complex cover in daylight hours to minimize energy costs of high velocity areas (implied by coarse substrate and high adjacent velocity) and be hidden from predators. Conversely, under cover of darkness adult rock bass use lower velocity areas (implied by fine particulates and low adjacent velocities) at a greater distance from less complex cover structures. This may demonstrate a shift in position to an inactive habitat location where darkness precludes the need for heavy cover.

As for adult rock bass, juvenile rock bass used denser cover and faster adjacent velocities during the daytime (Figure A7) as compared to the night (Figure A8). Juvenile rock bass also used slower mean column velocities during the day as compared to night; but this may be an artifact of using complex cover at day as compared to night. Regardless, the importance of complex cover and fast adjacent velocities during the day as compared to the night was constant across size classes. The importance of complex cover during the day may also have been important for young-of-the-year rock bass. There were noticeably fewer observations of young-of-the-year rock bass during the daytime than there were at night. One reason for this difference could be that young-of-the-year rock bass could not be observed because they were well hidden in dense cover. The few observations made showed use of complex cover and visual isolation, almost to the exclusion of velocity shelter or no cover. This suggests a common diel activity pattern for all size classes of rock bass. The pattern of diel behavioral shifts in habitat use would appear related to: (1) foraging associated with aquatic invertebrate drift at dawn, (2) opportunistic feeding and predator avoidance at day , (3) foraging associated with aquatic invertebrate drift at dusk, and (4) rest and predator avoidance under cover of darkness.

Because the differences in habitat use between diel time periods was so subtle, the diel activity pattern may not necessitate movements of large distances in the stream. To minimize energy expenditure, rock bass would be best suited to use habitat areas that are in close proximity, during the different time periods. Thus differences in use of other habitat attributes such as mean water column velocity might not change across time periods even though a positional change may have occurred.

## Smallmouth Bass

Adult smallmouth bass showed distinct differences in use of all habitat characteristics except distance to adjacent velocity across diel time periods. As for adult rock bass, smallmouth bass exhibited diel patterns in habitat use that can be explained by similar behavioral shifts. These shifts were more noticeable than they were for rock bass, but were also more difficult to attribute to any one behavior.

Adult smallmouth bass were observed in simple cover types, at greater distances to cover, over coarser substrates, in deeper water, and in faster mean column, focal point, and adjacent velocities during the day as compared to night. Thus, adult smallmouth bass were associated with areas of higher activity during diurnal than nocturnal time periods. These positions may not be associated with any one feeding strategy because adult smallmouth bass will feed on fish, crayfish, or insects (Paragamian and Coble 1975, Probst et al. 1984). I could not determine the influence of feeding activity on habitat use because gut content was not sampled, and observations of feeding activity were infrequent. However, adult smallmouth are typically not drift feeders (Todd and Rabeni 1989), and the frequency of observations over coarse substrate suggests association with areas that concentrate crayfish (Munther 1970). I was not able to make comparisons to the crepuscular time period. However, Emery (1973) observed smallmouth bass feed opportunistically during the day, and peak in feeding activity during crepuscular hours.

Conversely, adult smallmouth bass were observed in habitats likely to be used for rest during the nighttime. Smallmouth bass used finer substrate, complex cover more frequently, shorter distances to cover, shallower water, and slower velocities at night as compared to day. Munther (1970) observed similar behavior by smallmouth in the Snake river during night observations.

No diel comparisons could be made for other life stages due to small sample sizes. However, observations appeared to support a common diel behavior pattern between smaller size classes of smallmouth bass that were comparable to diel behavior patterns in rock bass. In support of this observation, Todd and Rabeni (1989) and Probst et al. (1984) observed subadult rock bass in areas favorable for feeding on drift. Furthermore, Reynolds and Casterlin (1976) observed diel periodicity in activity of subadult smallmouth bass in a laboratory, that peaked during the crepuscular time period.

Although habitat use by adult smallmouth bass was strikingly different between diel strata, sources of variability were more difficult to infer than for rock bass. The infrequent use of low cover during the daytime suggests that predators may not influence habitat use by adult smallmouth bass in the Huron River. The most likely source of variability would be activity level, but there is disagreement in the literature regarding nocturnal activity. Muther (1970) and Emery (1973) observed no movement by smallmouth in the Snake River, Idaho or Georgian Bay and Algonquin Park, Ontario at night; but Todd and Rabeni (1989) suggest that smallmouth bass use boulder substrate to feed on crayfish at night in a Missouri stream. I did not find adult smallmouth bass using boulder substrates at night, and the use of slower velocities at night in the Huron River was also observed for inactive smallmouth in Idaho and Ontario (Munther 1970, Emery 1973).

## Seasonal Patterns in Habitat Use

### Rock Bass

Rock bass were observed in significantly different habitat between seasons. Pajak and Neves (1987) observed patterns in habitat use by rock bass that was characterized by distinct combinations of habitat attributes between seasons. This was also observed for rock bass in the Huron River. Habitat selection during the summer reflects the importance of habitat attributes that favor feeding, but habitat selection in the spring was significantly different (Table 10). Furthermore, visual comparison of observations made in the winter to other seasons reveals selection of a third distinct combination of habitat attributes.

Because the sample effort in the spring was timed to describe habitat use during the spawning period, shifts in habitat use can be explained by behavior changes related to spawning activity. Spawning rock bass used deeper and broader expanses of water (greater distance to adjacent velocity) with uniform velocity, and less dense cover (Figure A4) as compared to summer (Figure A1). This may reflect a decrease in the importance of feeding areas, and an increase in the need for areas with uniform flow to spawn. Furthermore, rock bass selected a relatively narrow range of depths and velocities during spring as compared to summer. This could be the result of insufficient spawning habitat available to rock bass in the Huron River. However, if there was sufficient spawning habitat, then rock bass may have sought out very specific combinations of habitat attributes for spawning purposes.

Because sample sizes were too small for winter observations (Table 7) no statistical comparisons could be made to summer or spring. However use of depth, velocity, and cover type during the winter (Figure A5) appear to be unique as compared to the summer (Figure A1) and spring (Figure A4). Adult rock bass were observed to use deep water, slow velocities, and visual isolation cover type more frequently in the winter as compared to spring and summer time periods. Pajak and Neves (1987) also observed a shift by rock bass to deep water habitat as water temperature cooled. Due to insufficient sample size for the winter sample effort, no comparisons could be made between seasons for subadult rock bass. However, I assume that subadult rock bass undergo shifts in habitat use comparable to those observed for adult rock bass, with the exception of spawning.

In contrast to diel periodicity in habitat use, seasonal differences may be influenced by several stimuli. Habitat use during the spring, summer, and winter appear to be controlled by unique stimuli for spawning, growth, and overwinter survival respectively. Although rock bass were observed in significantly different habitat between seasons, differences were generally subtle. Individual fish may need to move linearly within the stream to accommodate differences in habitat needs between seasons. However, the similarity of habitat attributes between seasons implies that most needs are met in a local area. The pattern of seasonal behavioral shifts in habitat use would appear related to: (1) feeding and maximum energy gain in the summer, (2) energy conservation and rest in the winter, and (3) perpetuation of the species at the expense of energy storage, and safety from predators.

## Smallmouth Bass

Perhaps the most noticeable shift in habitat use among temporal strata was that observed for adult smallmouth bass among seasons. Both visual comparison and comparison by nonparametric ANOVA revealed obvious differences in seasonal habitat use by smallmouth bass.

Smallmouth bass used significantly denser cover types, shallower water, slower mean column and focal point velocities, and larger expanses (greater distance to adjacent velocity) of water in spring as compared to summer. Because spring sampling was arranged to observe spawning activity, difference in habitat use can be attributed to behavioral shifts due to spawning. As for rock bass, the range of depths and velocities used during spring (Figure A17) were noticeably more constricted than summer (Figure A14). Again this reflects the importance of spawning habitat to Huron River bass. Either the availability of spawning habitat is limited in the Huron River, or smallmouth bass require very specific habitat conditions for spawning.

Due to insufficient sample size for the winter sample effort (Table 7), I could not statistically compare differences in habitat use to spring and summer. However, the few smallmouth bass observed were in deeper water, denser cover, and slower velocities in the winter (Figure A18) as compared to the summer (Figure A14). Munther (1970), Todd and Rabeni (1989), and Langhurst and Schoenike (1990) identified shifts in habitat use with colder water temperatures. All these studies agree that smallmouth bass seek out deeper water, and slower velocities in the winter. This may reflect a need to minimize energy expenditure in the winter that is accomplished by shifting to slower velocities. Furthermore, deep water might be important to prevent surface to bottom freezing, or for use as cover. Comparisons could not be made between seasons for subadult smallmouth bass. However, I assume that subadult smallmouth bass experience changes in habitat use that is similar to adult smallmouth bass for at least summer and winter.

As for rock bass, there are noticeable changes in habitat use between seasons for smallmouth bass. Although it is difficult to attribute to any one factor, smallmouth bass choose areas in the summer, winter, and spring that are favorable to feeding, overwinter survival, and spawning respectively. In contrast to rock bass habitat needs, habitat requirements are less likely to be satisfied at a local level for smallmouth bass because resource needs are so different between time periods. An area likely to satisfy the food requirements of a large predator such as an adult smallmouth bass is not likely to have the broad expanses of uniform, slow velocities, and fine substrate needed for spawning. Furthermore, areas likely to be used for spawning might not include shelter from harsh temperatures and ice formation in the winter. Consequently, smallmouth bass might move long distances in a stream if the habitat requirements cannot be satisfied at a local level (Langhurst and Schoenike 1990).

Regional Comparison of Habitat Suitability Indices

It was difficult to observe any regional pattern in habitat use by either smallmouth bass or rock bass. The curves were developed in different locations, by different research teams, with different sampling techniques, and different curve development procedures. Any pattern in habitat use between regions was probably confused by these sources of variability. Thus, the most useful information that could be inferred from regional comparison was that curves developed for smallmouth bass and rock bass on the Huron River were not "unreasonable" representations of habitat use for these species, compared to those used for other streams. This would appear to be especially true for smallmouth bass curves that were bound by curves developed elsewhere.

Alternate Sampling Technique

Hendricks et al. (1980) determined electrofishing to be the gear with the greatest applicability in studying fish in lotic systems. The use of electrofishing to study warmwater stream fish has had mixed results, however. Frequently, smallmouth bass will swim away from an electrical field (Bovee 1982, Dewberry 1978, Vannote 1963). This is especially troublesome to a researcher interested in obtaining point habitat use data. Not only is it difficult to sample the fish, but when a fish is sampled, it is doubtful that the fish was sampled in its original habitat position. Bain et al. (1985) developed a pre-placed electrofishing unit that minimized fright bias by positioning an anode at a predetermined sample location, waiting for fish to return to normal behavior, and then returning to sample the location. This technique was useful in sampling microhabitat data, but had several flaws. The area sampled was 23 $m^2$ or 5.7 $m^2$, depending on the anode used, and measurement of microhabitat was averaged among samples within the area. Thus microhabitat data were less accurate than point observations typically obtained by direct observation. Furthermore the method required a large amount of time to deploy, and empty samples were frequent.

The throwable anode electrofishing design appeared to work well to correct for inadequacies of the pre-placed grid electrofishing unit. As with the pre-placed grid electrofishing unit, the technique could not be used in water greater than wader deep. Furthermore the method biased data to shallow, slower velocity areas (Figure A6) as compared to direct observation (Figure A1). This could be the result of several factors. First, we may not have collected all the fish sampled with the apparatus due to poor visibility or high velocity. Fish sampled in turbid water may have been swept downstream undetected when the electrical field was turned off. This would be most likely to occur in deeper, fast velocity areas, thus biasing results to shallow, slow velocity areas. This bias could be corrected by using a seine at the downstream end to collect fish stunned by the electrical field but not observed by crew using dip nets to collect samples. Second, the small sample size of the electrofishing data set may bias observations with this technique. Larger sample sizes would have to be obtained to more carefully compare these methods.

Despite inadequacies of the method identified above, the throwable anode electrofishing design merits development and testing for these and other species. The advantages of the method are: high mobility and the ability to sample several areas in rapid succession (20-40 locations per hour), sampling of a small area (point observation data), low expense in addition to that typically incurred with electrofishing equipment, ease of design, reduced fright bias, and use in turbid water conditions when direct observation is not possible.

## CONCLUSIONS

Habitat suitability indices developed for smallmouth bass and rock bass in the Huron River varied among diel and seasonal levels of stratification. Differences between temporal strata were more noticeable for smallmouth bass than for rock bass. This suggests a greater complexity of habitat requirements for smallmouth bass than for rock bass. If habitat management practices concentrated on smallmouth bass habitat requirements, it is likely that rock bass habitat management considerations would be addressed. Similarly, variability in seasonal habitat use by smallmouth bass was more prominent than for diel habitat use. Consequently, efforts to improve stream fish habitat might consider the seasonal habitat constraints of a smallmouth bass population prior to making habitat alterations of a more ephemeral condition.

The importance of temporal variability in habitat use by smallmouth bass and rock bass has implications for both research and management. Stream population managers might not need to concern themselves with variability in habitat use among seasons and times of day if year to year samples are taken at the same season, time of day, and location. However, if repeated samples are made within a year, then the sample procedures should include all habitat locations occupied during the different seasons in each sample effort. Similarly, if repeated samples are made between day and night, then sample procedures should include all habitat locations occupied during the diel cycle in each sample effort.

For predictive models such as those used with IFIM, recommendations are not as simple. Because variability in habitat use may introduce error into a model, these time periods could be significant. Because temporal variability can be captured in habitat suitability indices, this error can be corrected. However, diel variability in habitat use by rock bass in the Huron River (for example) might not contribute significant error in predicting of WUA, so added effort of developing curves with this little added information may not be justifiable. Conversely, seasonal variability in habitat use by smallmouth bass might reflect significant changes in habitat use that would not be accurately predicted by simple HSI. Thus, addition of seasonal stratification of effort in developing HSI would be justifiable. This appears to be the case for smallmouth bass in the Huron River. I recommend stratification of effort among seasons to capture large scale variability in behavior patterns, and include finer scales when coarser scales are no longer adequate. These would result in development of category four HSI, contingent upon season.

Minimum required sample size estimates calculated by nonparametric means were useful during data analysis. I was able to include five data sets in curve building and analytical procedures that might have been overlooked using standard approaches. However, because the technique I used was labor intensive, another approach might be more useful.

Regional comparison of curves was inconclusive. Variability was substantial for both species and for all life history stages; but sources of variability were numerous. Greater similarity between regions might result from standardization of sampling protocol and analytical procedures. Conversely, differences might result, but might be identified as regional variability rather than random error.

The throwable anode electrofishing design was biased to shallow water and slow velocities, as compared to direct observation. Although the method was relatively untested, observations of point habitat data were obtained with less effort, similar bias, and at less expense than the fixed anode method. Future development of both design and technique might yield an efficient method to collect point observation microhabitat data in turbid, wadable streams.

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# APPENDIX

## Habitat Utilization and Suitability Curves

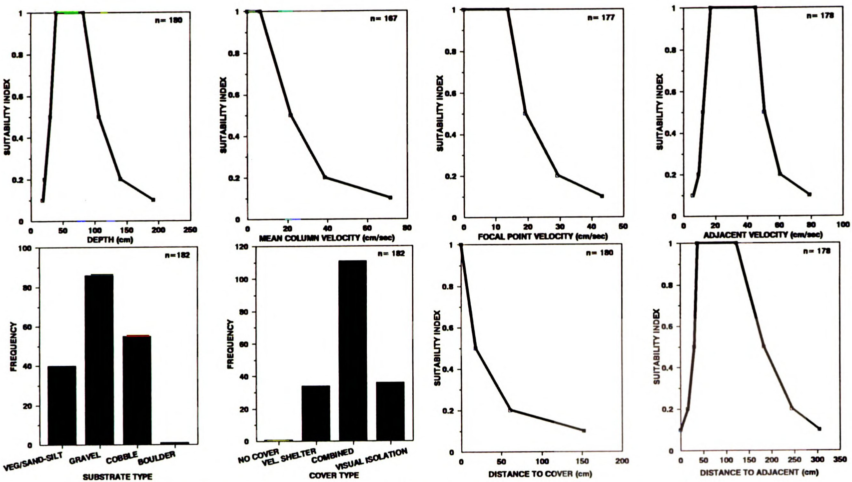


Figure A1. Adult rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

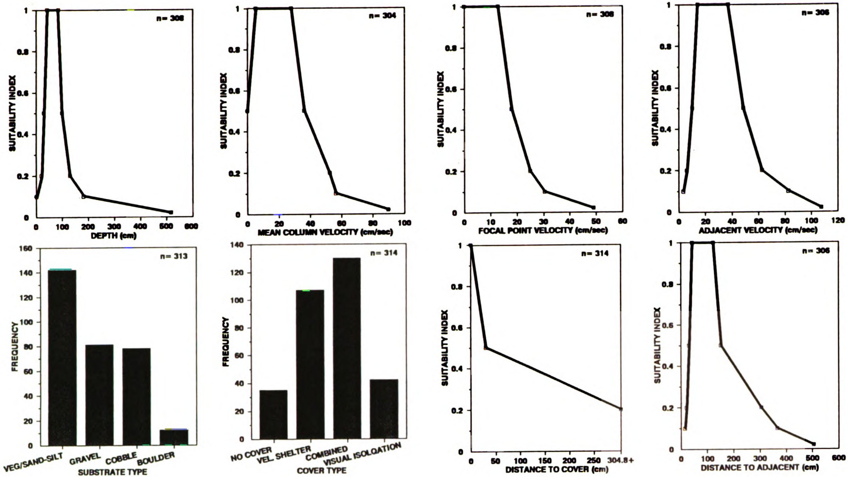


Figure A2. Adult rock bass use of eight habitat attributes in the Huron River, Michigan during the nocturnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

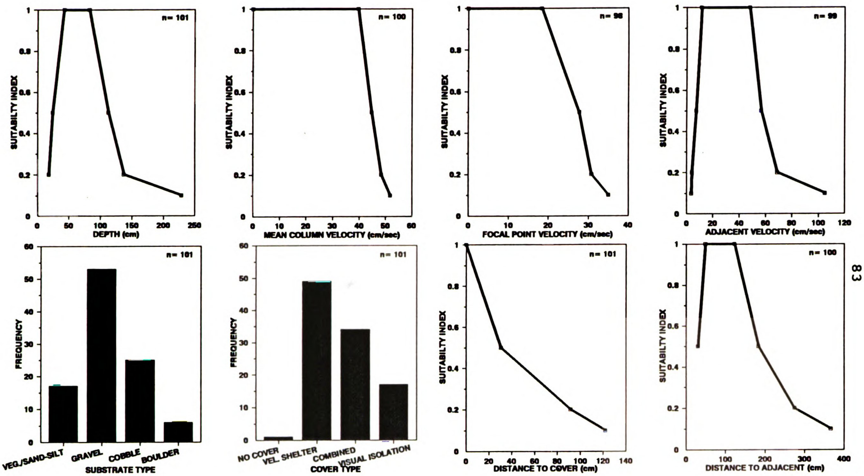


Figure A3. Adult rock bass use of eight habitat attributes in the Huron River, Michigan during the crepuscular-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

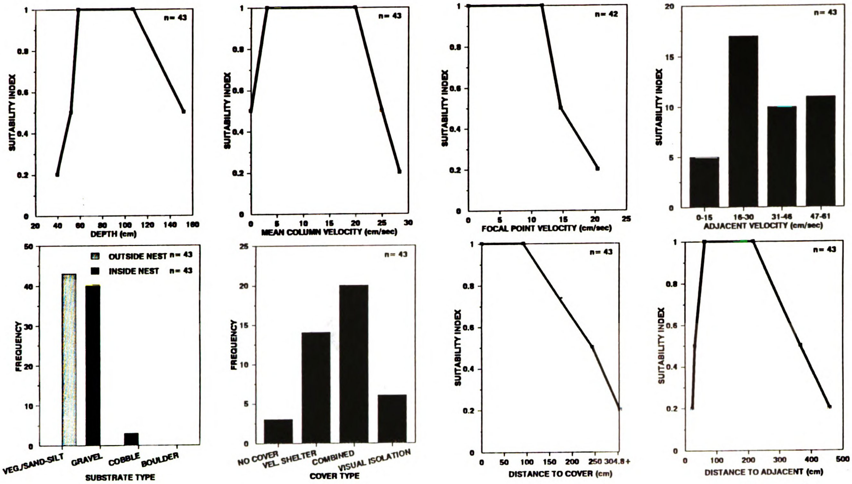


Figure A4. Adult rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-spring sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

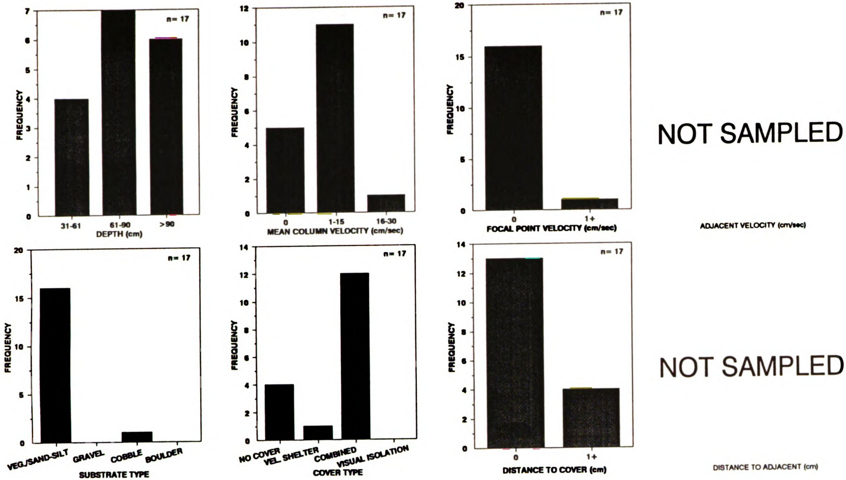


Figure A5. Adult rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-winter sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

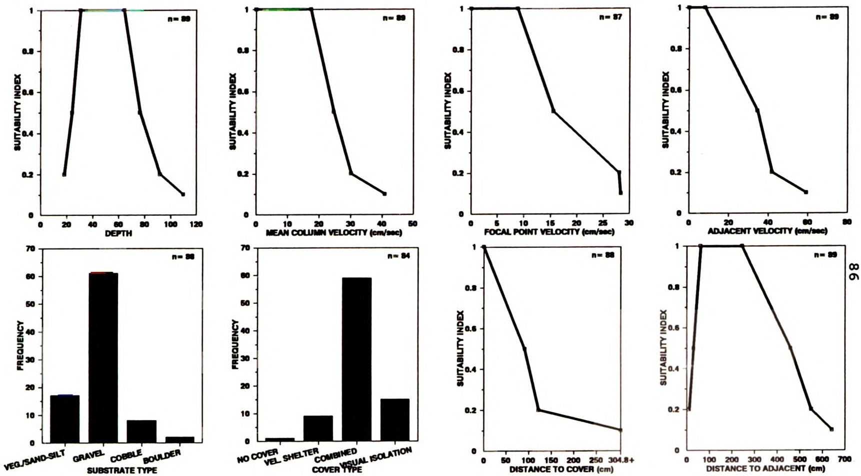


Figure A6. Adult rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by throwable anode electrofishing, and described by use frequency distributions.

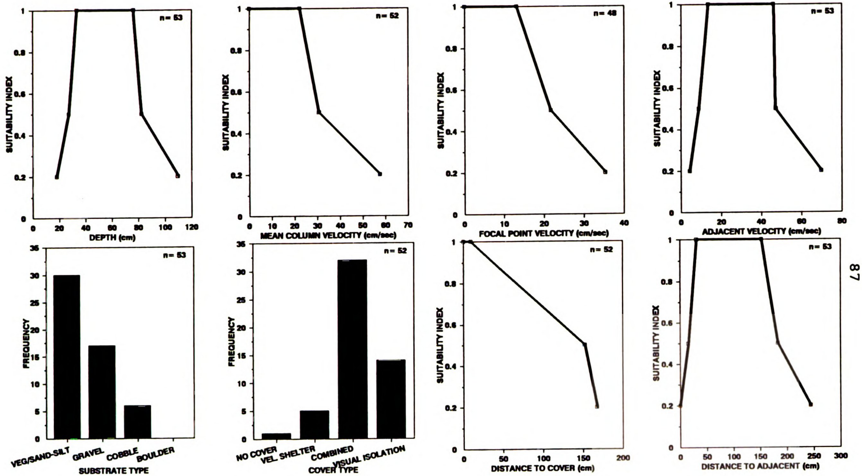


Figure A7. Juvenile rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

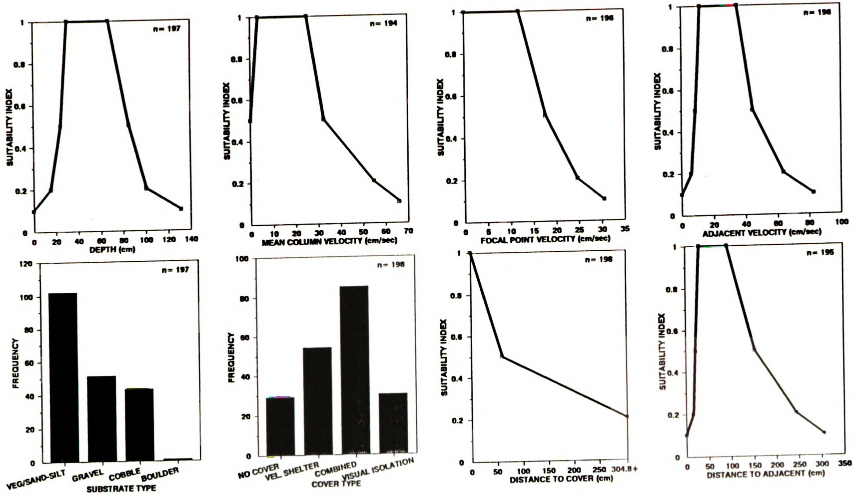


Figure A8. Juvenile rock bass use of eight habitat attributes in the Huron River, Michigan during the nocturnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

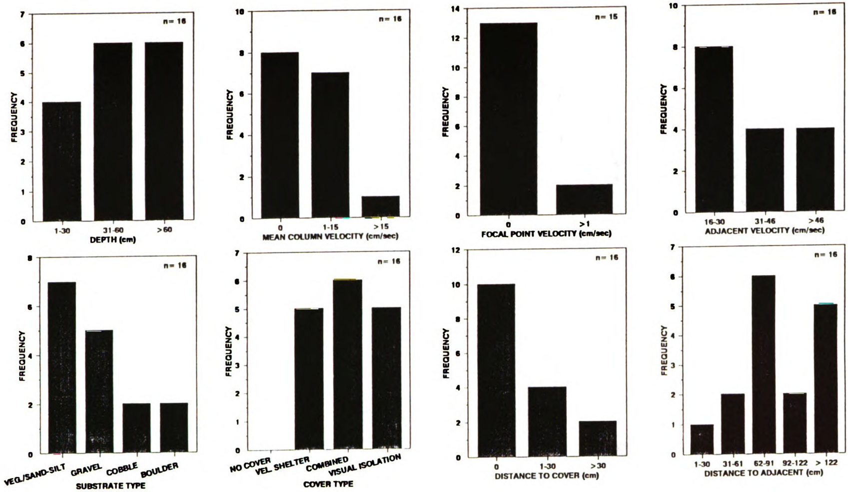


Figure A9. Juvenile rock bass use of eight habitat attributes in the Huron River, Michigan during the crepuscular-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

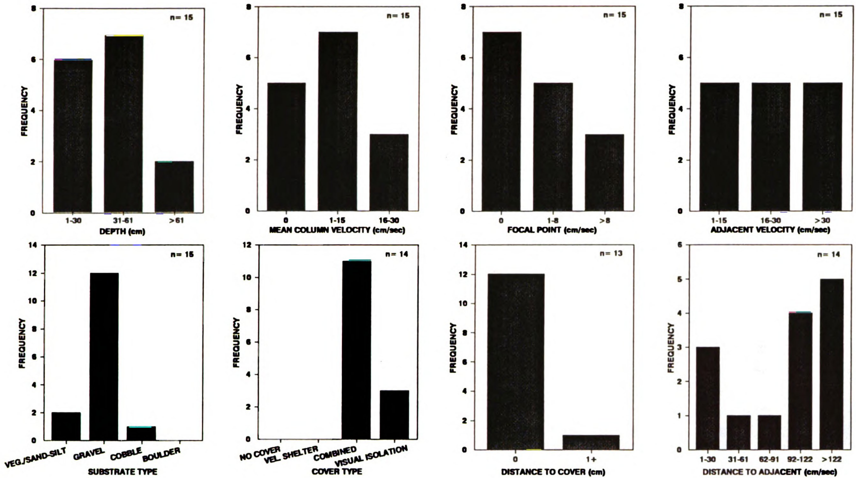


Figure A10. Juvenile and young-of-the-year rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by throwable anode electrofishing, and described by use frequency distributions.

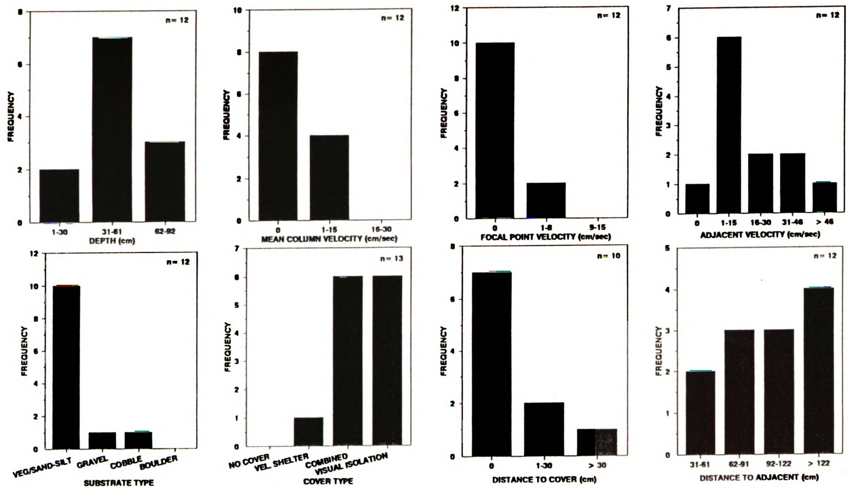


Figure A11. Young-of-the-year rock bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

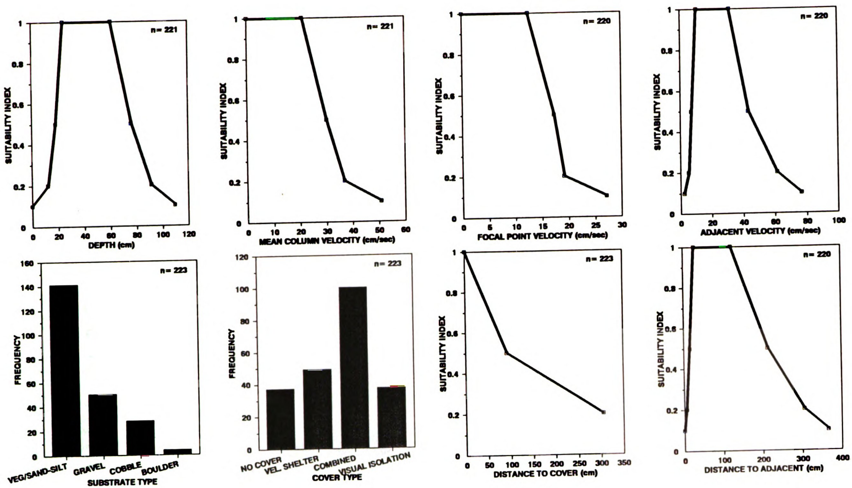


Figure A12. Young-of-the-year rock bass use of eight habitat attributes in the Huron River, Michigan during the nocturnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or by use frequency distributions.

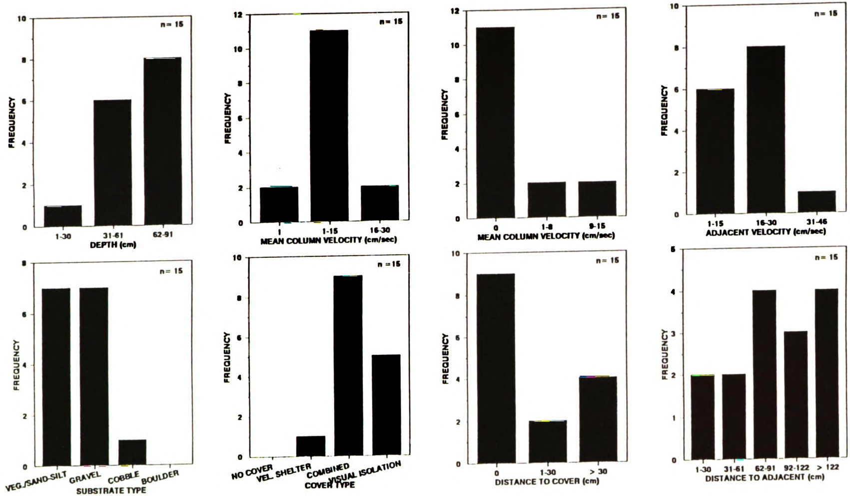


Figure A13. Young-of-the-year rock bass use of eight habitat attributes in the Huron River, Michigan during the crepuscular-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

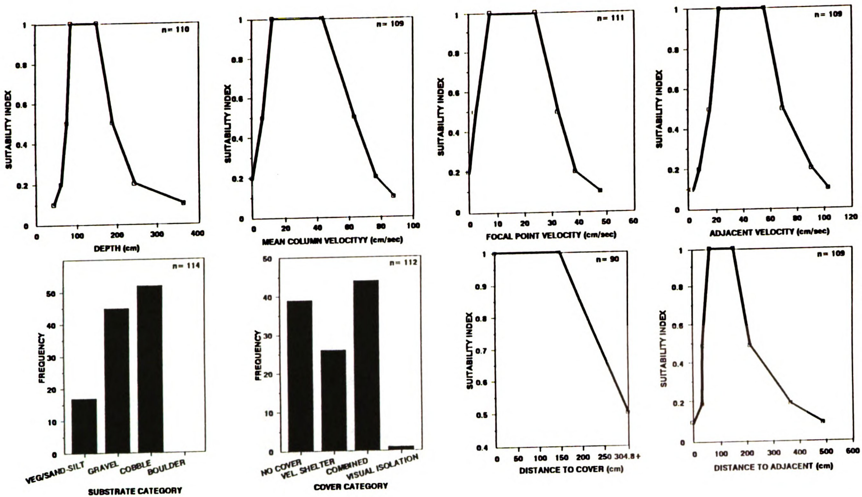


Figure A14. Adult smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

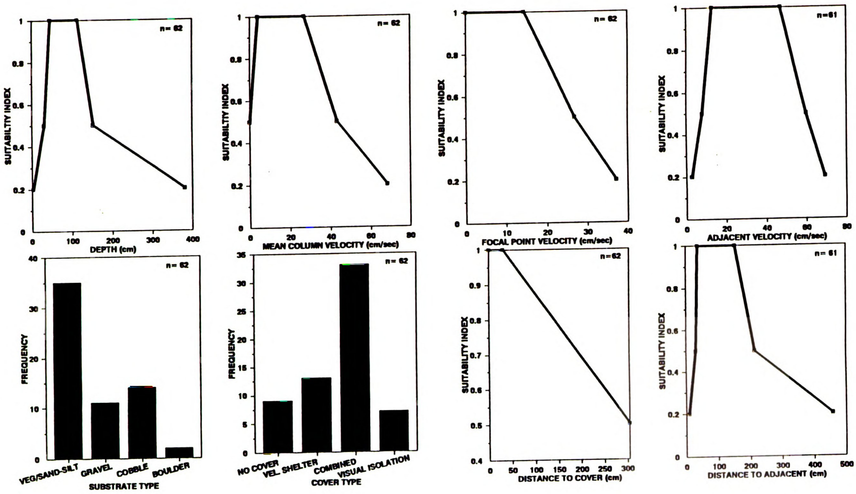


Figure A15. Adult smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the nocturnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

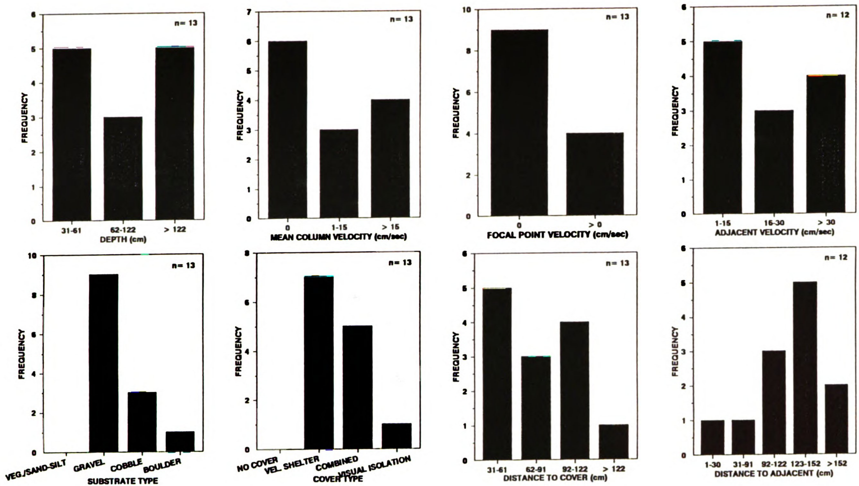


Figure A16. Adult smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the crepuscular-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

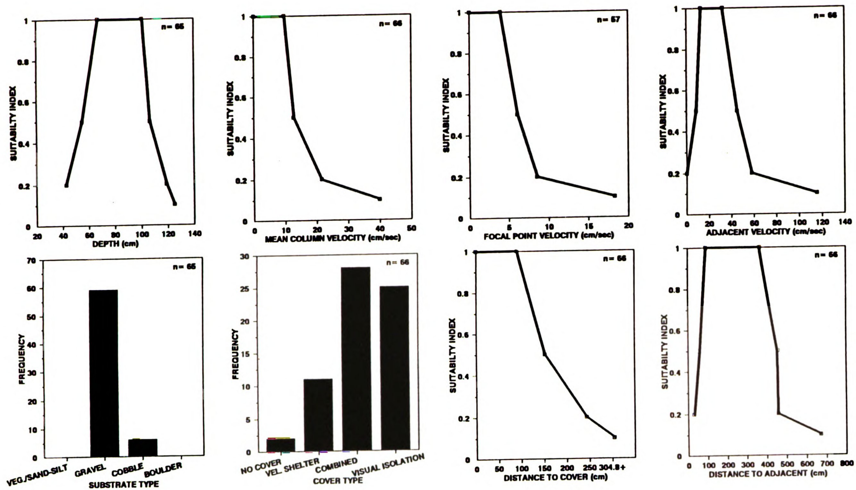


Figure A17. Adult smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-spring sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

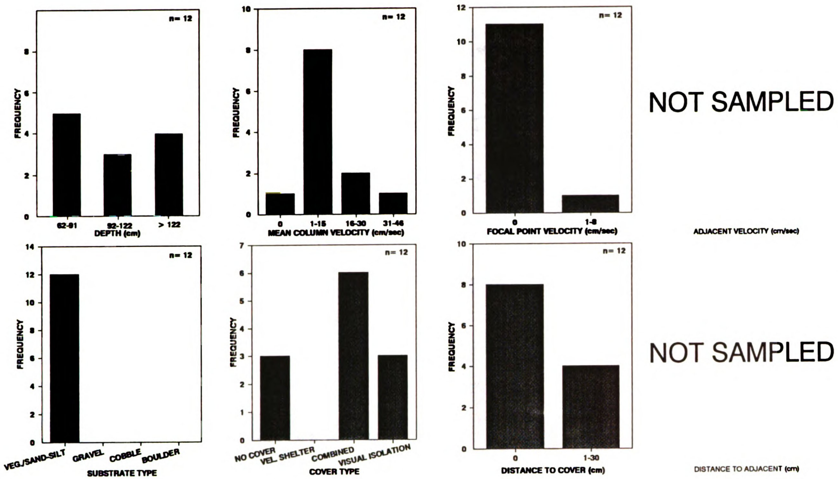


Figure A18. Adult smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-winter sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

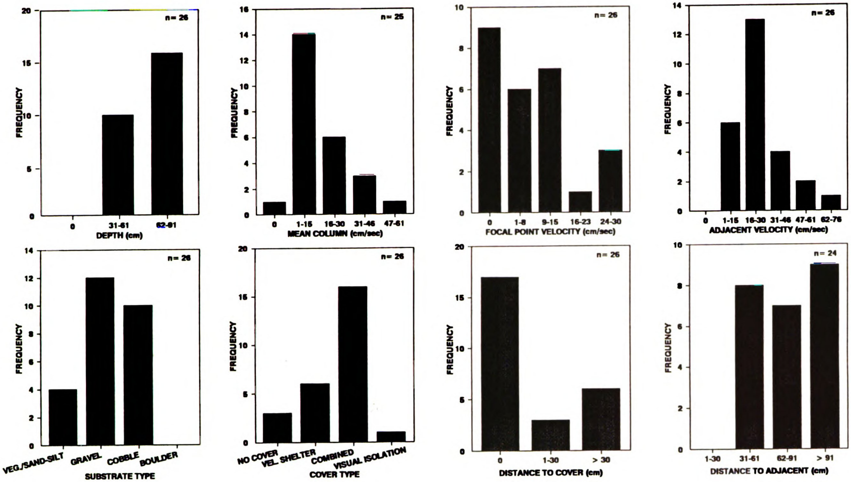


Figure A19. Adult smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by throwable anode electrofishing, and described by use frequency distributions.

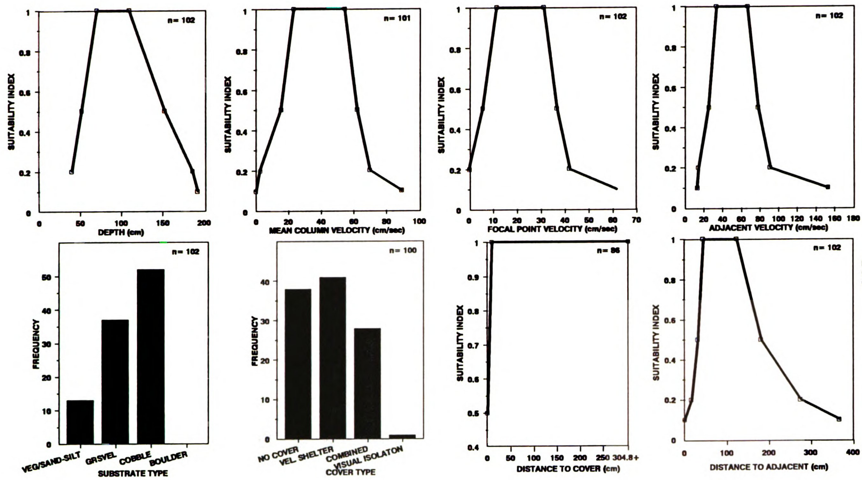


Figure A20. Juvenile smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

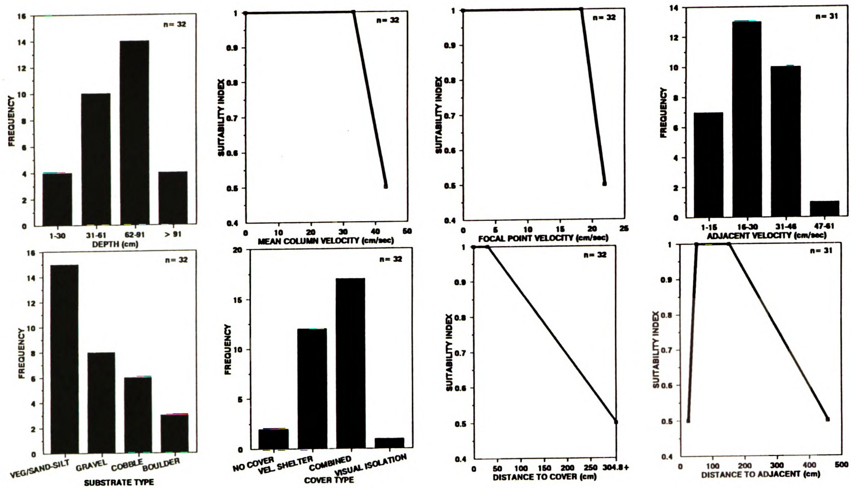


Figure A21. Juvenile smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the nocturnal-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

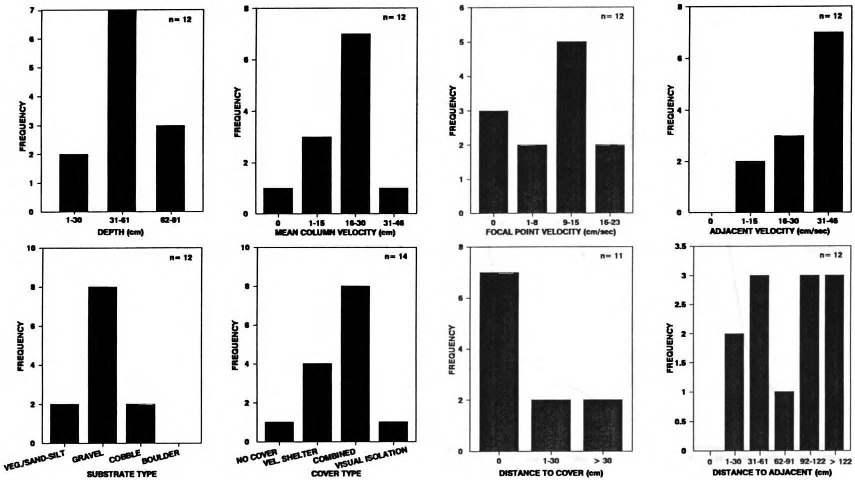


Figure A22. Juvenile and young-of-the-year smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by throwable anode electrofishing, and described by use frequency distributions.

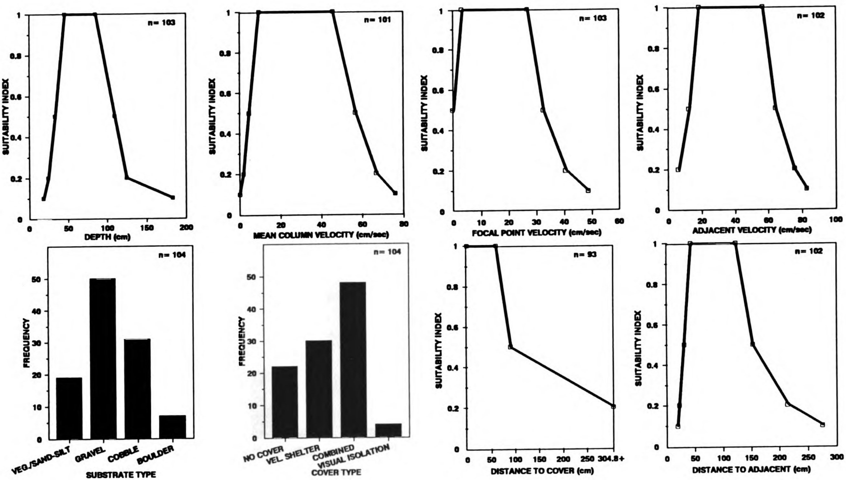


Figure A23. Young-of-the-year smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the diurnal-summer sample period. Habitat suitability data were collected by direct observation, and developed as HSI models by nonparametric tolerance limits (Gosse 1982), or described by use frequency distributions.

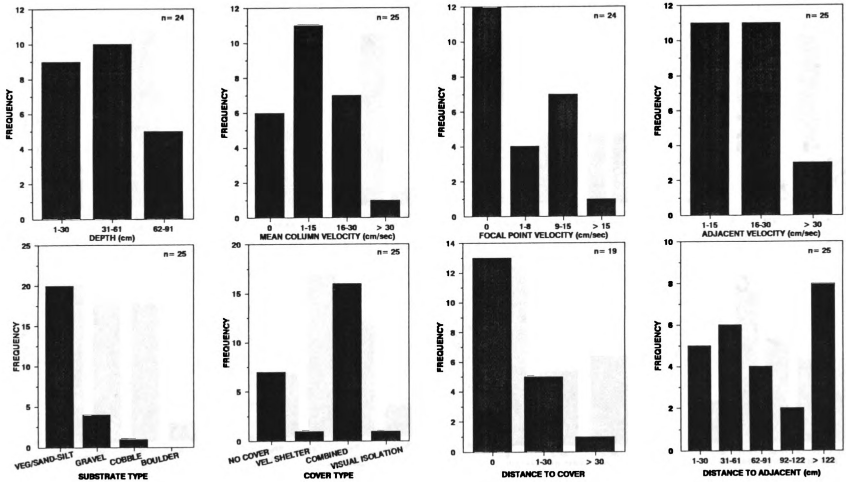


Figure A24. Young-of-the-year smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the nocturnal-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.

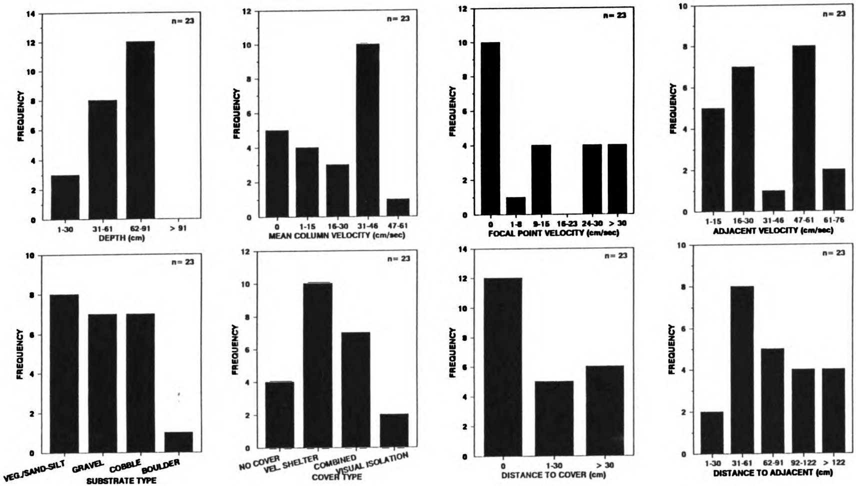


Figure A25. Young-of-the-year smallmouth bass use of eight habitat attributes in the Huron River, Michigan during the crepuscular-summer sample period. Habitat suitability data were collected by direct observation, and described by use frequency distributions.