Evaluation of Habitat Enhancement Structure Use by Spotted Bass

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ABSTRACT -- Habitat enhancement is a common and effective method used to positively influence fish populations. However, there is a paucity of species-specific evaluations of stream habitat enhancement structures for warmwater fishes. We evaluated use of half-log, rootwad enhancement structure, and simulated undercut bank (LUNKERS) by adult and juvenile spotted bass (*Micropterus punctulatus*) in natural and experimental streams. Enhancement structures were installed in Otter Creek, Kansas. Adult spotted bass use of natural and enhancement structure was documented weekly during summer and fall of 2001 and 2002 with radiotelemetry. Mean total length (TL) of adult fish was 292 mm (SE = 13 mm). Half-logs were selected positively by adult spotted bass even though availability was low. Habitat use by juvenile spotted bass was evaluated in an experimental stream. Mean TL of juvenile fish was 92 mm (SE = 3 mm). Rootwad enhancement structures were selected negatively and half-logs were selected positively by juvenile spotted bass. Half-logs were used by adult and juvenile spotted bass, not influenced by sedimentation in Otter Creek, and the least expensive to install (US$212/m^2). Thus, we recommend half-logs for lotic spotted bass habitat enhancement projects.

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Spotted bass (*Micropterus punctulatus*) is a major sport fish and predator native to southeastern Kansas streams (Cross and Collins 1995); however, its densities are relatively low and populations are vulnerable to overharvest (Tillma et al. 1998, Horton et al. 2000). Therefore, increasing spotted bass populations is a long-term goal of the Kansas Department of Wildlife and Parks. Research by Tillma et al. (1998) and Horton and Guy (2002) shows that spotted bass population characteristics and habitat use are strongly associated with large woody debris (LWD), natural rootwads, and undercut banks. Horton and Guy (2002) found natural cover structure use was non-random and spotted bass used LWD, natural rootwads, and undercut banks significantly more than open water and overhanging vegetation. Habitat improvement is a common method used to enhance fish populations and usually is accomplished by installing habitat enhancement structures (hereafter called enhancement structures) that alter habitat characteristics such as stream velocity, overhead cover, depth, and substrate. Research on instream habitat enhancement and restoration techniques used to enhance fish populations historically has concentrated on salmonids (Riley and Fausch 1995, Huusko and Yrjänä 1997, Giannico 2000, Roni and Quinn 2001, Roni et al. 2001).

Habitat use studies on *Micropterus* spp. that include information on more than one life stage are rare. Futhermore, information concerning enhancement structure use by *Micropterus* spp. on low gradient or warmwater streams is limited (Edwards et al. 1984, Carline and Klosiewski 1985). Documenting habitat use of adult fishes in lotic environments commonly is conducted by visual observation or biotelemetry (Rankin 1986, Todd and Rabeni 1989, Horton and Guy 2002). Contrastingly, small body size decreases the visibility of fish and increases the relative size of implanted transmitters, which increases the likelihood of abnormal effects on behavior and growth (Mellas and Haynes 1985, Adams et al. 1998). The turbid nature of many low-gradient streams adds to the difficulty of visually documenting habitat use. Thus, little information exists on evaluation of appropriate instream enhancement structures for adult and juvenile spotted bass.

We concentrated our study on cover structure and compared spotted bass use of both natural and enhancement structures. The objective of our study was to evaluate use of three types of enhancement structures by adult and juvenile spotted bass to determine the most appropriate structures for lotic enhancement projects. Adult habitat use was documented in a Kansas stream by using biotelemetry. Juvenile habitat use was documented visually in an experimental stream to avoid difficulties with observations of small fish in a natural stream. We predicted that juvenile and adult spotted bass positively would select enhancement structures because of the rheotactic behavior of most centrarchids.

METHODS

Natural Stream

Instream cover structure evaluation for adult spotted bass was conducted in Otter Creek, within the Flint Hills region of Kansas. Otter Creek is a fourth order tributary (Strahler 1964) located in the Fall River Wildlife Management Area, Greenwood County, Kansas. The mean annual discharge is 2.3 m^3/s and has varied from 0.016 m^3/s to 6.5 m^3/s during the past 54 years (United States Geological Survey 2003). Sand and gravel dominate the substrate of Otter Creek. The study reach was approximately 1.5 km long and 9.6 km upstream from the confluence with the Fall River.

Three types of enhancement structures were installed in pool habitat in Otter Creek: rootwad enhancement structures, LUNKERS (i.e., a wooden structure providing bank cover for fish as described by the Federal Interagency Stream Restoration Working Group [1998]), and half-logs (Fig. 1). Rootwad enhancement structures and LUNKERS were installed in spring 2001 and half-logs were installed in spring 2002. Twelve LUNKERS (Fig. 1a) were constructed from untreated oak (*Quercus* spp.) and installed end-to-end in three groups of four structures as described by Vetrano (1988) and Proboszcz (2003). Five rootwad enhancement structures (Fig. 1b) were constructed from either American elm (*Ulmus americana*) or green ash (*Fraxinus pennsylvanica*) and installed in groups of one or two at least 2 m from each LUNKERS grouping. Site characteristics and access determined the number of rootwad enhancement structures installed near each LUNKERS grouping. Twelve modified Hunt (1993) design half-logs (Fig. 1c) were constructed of oak and installed at approximately 100 m intervals throughout the study reach.

Area of all cover structure (both natural and enhancement) was measured and mapped (Binns and Eiserman 1979). A cover structure was considered an object capable of concealing a fish greater than or equal to 200 mm total length (TL) from overhead view (modified from Riley and Fausch 1995). All mapped structures were underwater and at least 0.2 m long and 0.2 m wide (Simonson et al. 1994, Riley and Fausch 1995). Distance to nearest bank was measured from the structure center to the bank and distance to nearest structure was measured between the closest edges of both structures. Natural structure consisted of: natural rootwad, LWD, and undercut bank. Enhancement structure consisted of: rootwad enhancement structure, half-log, and LUNKERS. Depth was measured at each structure to the nearest 0.01 m (Simonson et al. 1994) and point velocity was measured to the nearest 0.01 m/s. New natural structure was mapped after water level changed greater than 1 m or when new structure became available. Morphometric maps depicting site dimensions and structure locations were produced and used to record fish locations (White and Garrot 1990).

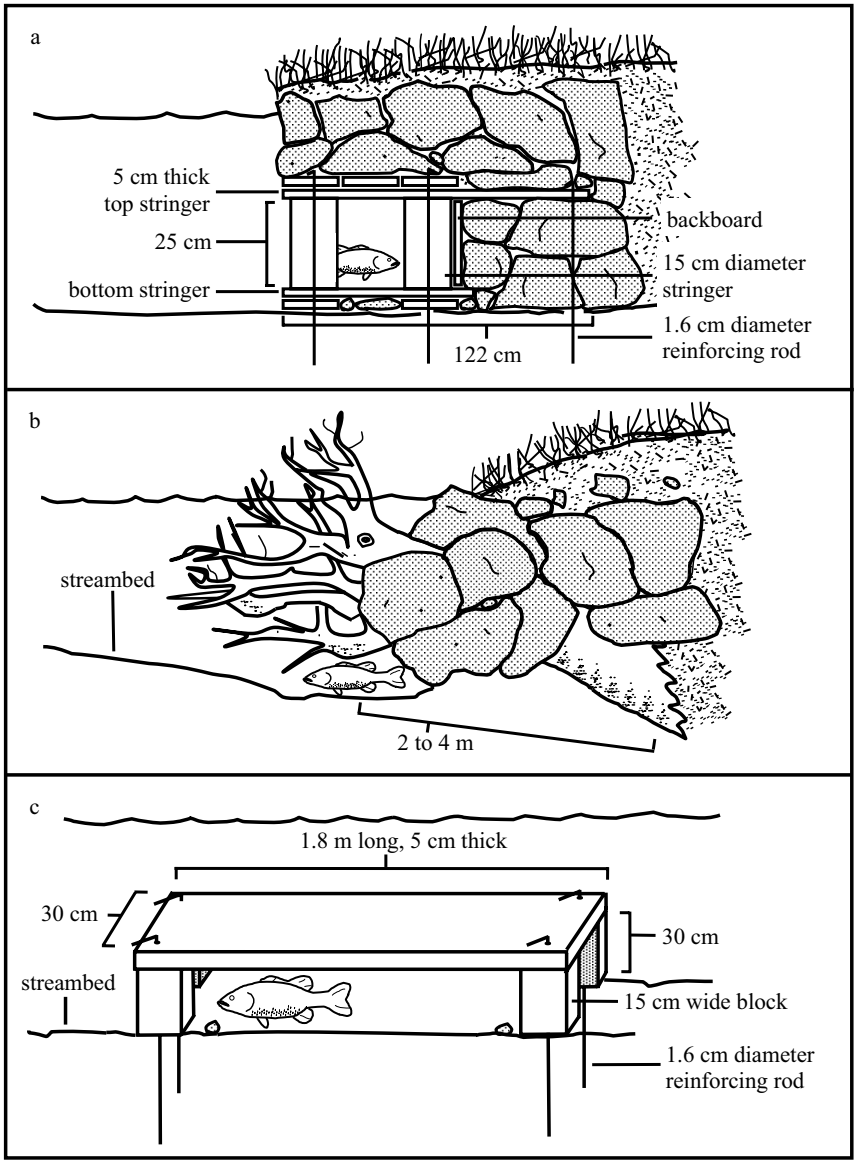

Figure 1. Lateral view of an installed LUNKERS (a) and rootwad enhancement structure (b). Side view of a modified Hunt half-log (c).

Spotted bass adults were sampled in the study reach by using Coffelt VVP 15 boat-mounted DC electrofishing gear. Instream live wells were used to hold fish for 2 hr to alleviate stress caused by electrofishing. According to methods from Horton and Guy (2002), we implanted fish with radio transmitters. Transmitters were 24 mm long, 13 mm wide, and 7 mm deep, weighed 3.6 g and had a 140 d life-span. Twenty six adults were implanted with transmitters.

Accuracy and precision of locations was estimated by concealing a transmitter downstream of the study reach while the tracker was not present. The distance between the location identified by the tracker and the true location was considered location error. This exercise was repeated five times by two trackers.

Tracking commenced one week following implantation as recommended by Gallepp and Magnuson (1972). Individuals were tracked from June 13 to September 2 in 2001 and from June 11 to November 14 in 2002. Tracking was conducted once a week over a 24 hr period, in which eight, 2 hr tracking periods were selected. Two periods always encompassed the crepuscular times of day. The beginning of the other six tracking periods were selected randomly from the remaining 2 hr periods available in the 24 hr period. Each fish was located from the bank during each 2 hr period. Structure use and time were recorded at each location.

Only individuals that were located greater than or equal to 20 times and had enhancement structure available in their home range were used in the analyses. Home range was defined as the area of stream reach remaining after eliminating 2.5% of the most upstream and downstream locations (Matheney and Rabeni 1995). Availability and use of natural and enhancement structure in a home range were determined for each fish from morphometric maps. Available structure (LWD, half-logs, undercut banks, LUNKERS, natural rootwads, and rootwad enhancement structures) was defined as its proportion of stream surface area in each home range. Use was defined as the proportion of locations recorded in a structure.

Analyses of the natural stream study followed methods of White and Garrot (1990) and Neu et al. (1974). Selection analysis was confined to natural and enhancement structure located in pool habitat. A chi-square goodness of fit test was used to determine if individual fish used structure in equal proportion to availability. For all fish that demonstrated unequal proportionate use of structure in comparison to availability, a method developed by Neu et al. (1974) was used to determine selection type (positive or negative) for each structure type. Ninety percent Bonferroni confidence intervals were constructed for the proportion of use of each structure type by individual fish and was compared to the proportion of availability. Structure use confidence intervals overlapping the proportion of availability indicate neutral selection (i.e., use in equal proportion to availability) for that structure. Structure use confidence intervals greater than the proportion of availability indicate positive selection for that structure. Conversely, confidence intervals less than the proportion of availability indicate negative selection for that

structure. Analysis of variance and least-squares means with a Bonferroni adjustment were used to determine if structure types were different in velocity, area, depth, distance to nearest bank, and distance to nearest structure.

Experimental Stream

During September and October 2001, ten juvenile spotted bass were collected with seines from Deep Creek in the Flint Hills physiographic region, Kansas. Mean TL of juvenile fish was 92 mm (SE = 3 mm). Individuals were transported to the laboratory and held separately in 38 l aquaria. They were held for at least 2 d before being placed in the experimental stream. Individuals were fed live invertebrates and red shiners (*Cyprinella lutrensis*) daily.

Enhancement structure evaluation for juvenile spotted bass was conducted in a Frigid Units® oval experimental stream. The experimental stream was 410 cm in length and had a channel width of 41 cm, and two basins (i.e., pools) with a diameter of 124 cm. The pools were located at opposite ends of the oval. Water depth was kept at 35 cm in the channels and 60 cm in the basins. Water temperature varied from 21.9º C to 25.5º C and dissolved oxygen varied from 3.2 mg/l to 6.3 mg/l. Velocity was maintained by two submersible pumps and varied from 0 m/s to 1.45 m/s in the stream. A grid was marked on the walls and floor of the stream to facilitate precise fish location. The grid was marked at 15.2 cm intervals along the length of the channel (X axis), 7.6 cm intervals across (Y axis), and 5.1 cm depth intervals (Z axis). Timed incandescent lights were used to produce a photoperiod of 14 hr light and 10 hr dark. All enhancement structures were constructed of wood, were similar in design to structures installed in Otter Creek, and had an overhead area of 0.08 m^2. An empty space (hereafter called open water area) of the same area as each enhancement structure was included in the study to determine the relative selection of open water in the experimental stream. Half-log, rootwad enhancement structure, LUNKERS, and open water area were arranged randomly among four positions (two positions in each basin) for each fish. Ten trials were conducted, each testing one fish individually in the experimental stream. Each fish was released at a randomly selected position in the stream and allowed to acclimate for 36 hr, after which 2 d of observation followed. Observations were made from behind a black curtain with viewing slits to prevent disturbing the fish. Observations were made six times daily, once during each of the following time periods: 0700-0900 hr, 1000-1200 hr, 1300-1500 hr, 1500-1700 hr, 1700-1900 hr, and 1900-2100 hr. During each time period, spotted bass were assigned a location and habitat type every 30 s for 15 min. Temperature and dissolved oxygen were measured once during each time period. Light intensity and current velocity were measured in structure and open water habitats after all fish were observed.

Selection analysis for the experimental stream study was conducted as in the natural stream study. Analysis of variance and least-squares means with a Bonferroni adjustment were used to determine if there was a difference between mean light intensity and velocity

among half-log, rootwad enhancement structure, LUNKERS, and open water area. Two-tailed t-tests were used to determine if there were differences in velocity between experimental and natural stream enhancement structure types. All statistical analyses were conducted by using SAS (SAS Institute Inc. 2000). An alpha level of 0.05 was chosen to determine statistical significance in the natural and experimental stream studies.

RESULTS

Natural Stream

Installed rootwad enhancement structures and LUNKERS remained in place and available after a discharge event of 50 m^3/s on June 14, 2001. However, 90% of LUNKERS and rootwad enhancement structures were either filled with sediment or dislodged by a discharge event of 220 m^3/s on June 20, 2001. The structures were then excavated and made available for the remainder of the 2001 tracking period. One hundred percent of LUNKERS and 80% of rootwad enhancement structures were filled with sediment for the entire duration of tracking in 2002 following a discharge event of 450 m^3/s on September 18, 2001. Nine half-logs (75%) were available throughout 2002. Two of the three remaining half-logs were dislodged during a discharge event of 150 m^3/s on June 21, 2002 and the other half-log was dislodged at an unknown time. Sedimentation did not occur in half-logs.

Individual LUNKERS were the most expensive structure to construct and install and had a total cost of US$522 per structure. Rootwad enhancement structures were second most costly ($388) and half-logs were the least expensive ($106) and installed without machinery. The cost per unit area of available cover structure produced was $261/$m^2$ for LUNKERS, $227/$m^2$ for rootwad enhancement structures, and $212/$m^2$ for half-logs.

Structure types differed in mean area ($P = 0.05$, $F = 2.36$) and distance to nearest bank ($P < 0.0001$, $F = 9.71$), but not distance to nearest structure ($P = 0.09$, $F= 1.95$) (Table 1). Mean area of structure type varied from 22.2 m^2 for LWD to 0.5 m^2 for half-logs. Mean distance to nearest bank was greatest for half-logs and differed significantly from natural rootwads and undercut banks (Table 1). Mean distance to nearest structure was lowest for LUNKERS and differed significantly from rootwad enhancement structures (Table 1). Half-logs had the highest mean depth (0.84 m) and undercut banks had the lowest (0.56 m); however, structures did not differ significantly ($P = 0.54$, $F = 0.81$; Table 1).

Of the 26 radio-tagged spotted bass, two were never located, four were located less than 20 times, and nine fish did not have enhancement structures in their home range and were excluded from all analyses. Of the remaining 11 fish used in the study, four were tracked in 2001, and seven were tracked in 2002. Mean TL of the adult fish used in the study was 292 mm (SE = 13).

Table 1. Mean (± SE) for velocity (m/s), depth (m), area (m^2), distance to nearest bank (m), and distance to nearest structure (m) for structure types (undercut bank, LUNKERS, natural rootwad, rootwad enhancement structure, large woody debris [LWD], and half-log) in Otter Creek, Kansas. Structure types with different letters indicate significant differences ($P < 0.05$).

Structure type	Velocity (m/s)	Depth (m)	Area (m^2)	Distance to nearest bank (m)	Distance to nearest structure (m)
Undercut bank	0.09 (0.05)	0.56 (0.08)	6.1^{ab} (1.4)	0.06^{b} (0.04)	4.50 (1.41)
LUNKERS	0.03 (0.01)	0.61 (0.09)	8.7^{ab} (0.3)	0.58^{ab} (0.22)	3.17 (1.42)
Natural rootwad	0.02 (0.01)	0.59 (0.10)	5.0^{b} (0.8)	0.49^{b} (0.30)	3.35 (0.77)
Rootwad enhancement structure	0.04 (0.01)	0.59 (0.05)	5.0^{b} (0.7)	1.47^{ab} (0.43)	9.06 (2.94)
LWD	0.05 (0.01)	0.66 (0.04)	22.2^{a} (6.1)	2.74^{a} (0.34)	3.63 (0.72)
Half-log	0.04 (0.01)	0.84 (0.06)	0.5^{b} (0.0)	4.00^{a} (0.82)	6.19 (2.62)

Mean tracking location error was 0.79 m (SE = 0.16 m) and varied from 0.05 m to 1.4 m. Mean home range size was 3,158 m^2 (SE = 705 m^2). Half-logs and rootwad enhancement structures were the least available structures in spotted bass home ranges; however, all fish that had half-logs available in their home range used them at some point during the study. The highest percentage of fish (50%) showed positive selection for half-logs and LUNKERS when they were available compared with other structures (Table 2). In addition, half-logs and LUNKERS were the only structures that were not negatively selected by any fish (Table 2). Rootwad enhancement structures were selected negatively by the highest percentage of fish (63%; Table 2).

Experimental Stream

Juvenile spotted bass mean velocity use throughout the experimental stream was 0.03 m/s; in enhancement structure it was 0.02 m/s. Half-log and rootwad enhancement structure had the lowest mean velocities available and were not

Table 2. Summary of chi-square and selection analyses for structures types (undercut bank, LUNKERS, natural rootwad, rootwad enhancement structure, large woody debris [LWD], and half-log) by individual adult spotted bass tracked in Otter Creek, Kansas. A positive sign (+) indicates positive selection, a negative sign (-) indicates negative selection, and an equal sign (=) indicates neutral selection (i.e., use in equal proportion to availability).

Fish	χ^2	df	P	Undercut bank	LUNKERS	Natural rootwad	Rootwad enhancement structure	LWD	Half-log
1	62.1	2	<0.001	a	a	=	+	–	a
2	56.6	4	<0.001	–	+	+	–	–	a
3	5.5	3	0.137	=	=	=	a	=	a
4	0.8	1	0.361	a	a	a	=	=	a
5	69.3	2	<0.001	+	a	a	–	–	a
6	126.8	4	<0.001	=	a	–	–	=	=
7	606.8	4	<0.001	+	a	–	–	=	+
8	32.7	4	<0.001	=	a	=	=	–	=
9	79.1	4	<0.001	=	a	–	–	+	=
10	227.9	1	<0.001	a	a	a	a	–	+
11	161.2	1	<0.001	a	a	a	a	–	+
Positive selection percentage				29	50	14	12	9	50
Negative selection percentage				14	0	43	63	55	0
Neutral selection percentage				57	50	43	25	36	50

[a]Structure not available in home range

significantly different (Table 3). Open water area had the highest mean velocity and was significantly different than half-log and rootwad enhancement structure (Table 3). No significant differences in velocity were detected between experimental and natural stream LUNKERS (P = 0.97, t = 0.033, df = 9), half-logs (P = 0.19, t = 1.4, df = 9), and rootwad enhancement structures (P = 0.63, t = 0.49, df = 16).

Spotted bass mean light intensity use throughout the experimental stream was 184 lx. Mean light used in enhancement structure was 140 lx and most frequently used light intensity was 48 lx. Mean light intensity available was lowest for half-log and differed significantly from rootwad enhancement structure and open water area (Table 3). Open water area had a significantly higher mean light intensity than all other structures (Table 3).

Half-log was the only structure selected positively by juvenile spotted bass (40%, Table 4). Similar to adults, rootwad enhancement structure was selected negatively by the highest percentage of juveniles in comparison to any structure (20%, Table 4). Open water area was selected negatively by the highest percentage of fish (50%, Table 4).

DISCUSSION

Frequent use of structure by adult spotted bass in our study is corroborated by other studies (Smith et al. 1981, Horton and Guy 2002). Large woody debris, natural rootwads, and undercut banks were used frequently by spotted bass and this substantiates previous results by Horton and Guy (2002) in Otter Creek, Kansas.

Table 3. Mean (± SE) for velocity (m/s) and light intensity (lx) of structure types (open water area, half-log, rootwad enhancement structure, and LUNKERS) in an experimental stream. Structure types with different letters indicate a significant difference (P < 0.05).

Structure type	Mean velocity (m/s)	Mean light intensity (lx)
Open water area	0.04[a]	457[a]
	(0.01)	(27)
Half-log	0.02[b]	46[c]
	(0.00)	(7)
Rootwad enhancement structure	0.02[b]	252[b]
	(0.00)	(45)
LUNKERS	0.03[ab]	151[bc]
	(0.00)	(19)

Table 4. Summary of chi-square and selection analyses for structures types (open water area, LUNKERS, rootwad enhancement structure, and half-log) by individual juvenile spotted bass in an experimental stream. A positive sign (+) indicates positive selection, a negative sign (-) indicates negative selection, and an equal sign (=) indicates neutral selection (i.e., use in equal proportion to availability).

Fish	χ^2	df	P	Open water area	LUNKERS	Rootwad enhancement structure	Half-log
1	10.4	3	0.015	–	=	=	+
2	6.3	3	0.098	–	=	=	=
3	9.3	3	0.025	–	=	–	+
4	2.8	3	0.423	=	=	=	=
5	1.5	3	0.675	=	=	=	=
6	17.2	3	0.001	–	=	–	+
7	1.3	3	0.719	=	=	=	=
8	6.7	3	0.083	–	=	=	+
9	0.4	3	0.934	=	=	=	=
10	4.0	3	0.257	=	=	=	=
Positive selection percentage				0	0	0	40
Negative selection percentage				50	0	20	0
Neutral selection percentage				50	100	80	60

Kansas. Our field study expanded on Horton and Guy (2002) and included enhancement structure types and omitted open water to solely examine structure selection. Therefore, negative selection of natural rootwads and LWD does not imply infrequent use; it does imply negative selection of natural rootwad and LWD relative to installed enhancement structures. Half-logs and LUNKERS were selected positively by the highest percentage of spotted bass in comparison to natural structure types and were the only structures that demonstrated no negative selection. All radio-tagged adult spotted bass in Otter Creek used half-logs during 2002 even though the availability of half-logs was among the lowest of any structure type. However, further study is needed to substantiate adult spotted bass positive selection for these two enhancement structures due to sample size

limitations; especially LUNKERS, which were only available to two fish in 2001. We found that it was difficult to anticipate locations of spotted bass home ranges and install enhancement structures within them.

Juvenile spotted bass used half-log structures most frequently. They were the darkest structures and had a similar mean velocity to rootwad enhancement structures. Cover structure typically is associated with low light intensity and current velocity relative to open water. Light intensity and current velocity are major variables affecting juvenile smallmouth bass (*Micropterus dolomieu*) habitat selection (Sechnick et al. 1986) and likely are used by spotted bass. Light intensity in the natural stream varied with time of day and cloud cover; hence, it was not compared to the experimental stream. However, experimental stream enhancement structure current velocities were similar to those in the natural stream. This similarity substantiated the extrapolation of our experimental stream results to natural streams. Frequent use of half-logs in our study suggested their use in lotic habitat enhancement projects could potentially result in positive selection by juvenile spotted bass in natural streams. In our study juvenile and adult spotted bass positively selected half-logs. Similarly, juvenile and adult cover structure selection has been documented in smallmouth bass (Sechnick et al. 1986). Our results showed that both juvenile and adult spotted bass had similar affinities to cover structure.

Many lowland lotic systems recently have experienced decreased natural LWD recruitment due to de-snagging, deforestation, and maintenance of channels for optimal hydraulic capacity (Bisson et al. 1987, Gippel et al. 1996). Large woody debris might be especially useful in low gradient systems with small substrates by functionally increasing habitat complexity and providing stable substrate for macroinvertebrates (Wallace and Benke 1984, Benke et al. 1985). Strong evidence also exists supporting the positive influence of LWD on abundance of fish in coldwater (Burgess and Bider 1980, Dolloff 1986) and warmwater streams (Hickman 1975, Angermeier and Karr 1984). Enhancement structures, which function similarly to LWD, have been documented to increase abundance and density of lotic fish (Cederholm et al. 1997, Roni and Quinn 2001). However, several authors have suggested changes in rates of immigration and emigration in enhancement reaches are the mechanism behind short-term increases in local abundance (Hunt 1965, Riley and Fausch 1995). Despite this controversy, the installation of enhancement structure might have other positive effects on fish such as increased growth rates through decreased swimming activity, fewer aggressive acts towards conspecifics, and reduction of predation risk (Hartman 1965, Bustard and Narver 1975, Sundbaum and Näslund 1998). Typical Flint Hills stream discharges are highly variable during spring and fall and commonly receive 50% to 60% of their total annual flow during two months of the year (Metzler 1966). Nevertheless, half-logs were not affected by sedimentation in Otter Creek. Further, half-logs were the most cost-effective enhancement structure, used by adult spotted bass regardless of their low

availability, and were the only positively selected structure by juvenile spotted bass in the experimental stream. Therefore, mitigating against the decreased input of LWD with half-log installation likely will have positive effects on spotted bass populations.

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