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[Article]

Seasonal Movement Patterns, Habitat Use, and Home Range of Flathead Catfish in the Lower St. Joseph River, Michigan

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Abstract.—Few studies have examined the seasonal movement patterns, habitat use, and home range of flathead catfish *Pylodictis olivaris* in lotic systems throughout the northern United States. We used ultrasonic telemetry on 39 flathead catfish (range, 430–1,132 mm total length) in the lower St. Joseph River, Michigan, to increase our understanding of these behaviors in northern populations of flathead catfish and to provide important information for the development of appropriate management strategies in this system. Transmitters were surgically implanted into the peritoneal cavity of selected individuals captured by means of low-voltage AC electrofishing during 2002 and 2003. Habitat use of flathead catfish was dominated by large woody debris and riprap at water depths less than 3 m during all seasons except winter, when fish utilized main-channel pool habitats associated with coarse substrates at water depths greater than 4 m. Flow rates at fish locations were not significantly different among seasons (range, 0.1–0.7 m/s). The mean seasonal movement distance and home range of flathead catfish were greatest during spring (1,045 and 1,513 m, respectively) and fall (1,146 and 1,296 m, respectively), when fish transitioned between summer and winter habitats, while movement distance and home range during summer months averaged 218 and 596 m, respectively. No movement was observed during the winter season. Our study results indicate that seasonal differences exist in the movement patterns, habitat use, and home range of flathead catfish in the lower St. Joseph River and that the availability of structure and main-channel pool habitats are important considerations in the management of this species.

Flathead catfish *Pylodictis olivaris* are an important component of the North American catfish fishery (Jackson 1999). Native to the Mississippi, Mobile, and Rio Grande River drainages, the Laurentian Great Lakes basin, and northeastern portions of Mexico (Hubbs and Lagler 1947; Blair et al. 1968; Lee and Terrell 1987; Jackson 1999), this species supports valuable recreational and commercial fisheries throughout much of its geographic distribution (McCoy 1953; Moss and Tucker 1989; Grussing et al. 2001). Despite the popularity of this species, knowledge of the movement patterns, habitat use, and home range of flathead catfish is limited because little coordinated sampling has been conducted to date. This lack of information is most prevalent in moderate-size rivers, streams, and creeks, where fisheries managers have found assessment of flathead catfish populations difficult because of their solitary nature and low population abundance (Stauffer et al. 1996; Vokoun and Rabeni 1999).

Although a number of studies have examined movement patterns and habitat use of flathead catfish in lotic systems (Robinson 1977; Grace 1985; Sandheinrich and Atchison 1986; Dames et al. 1989; Coon and Dames 1991; Skains and Jackson 1995; Dobbins et al. 1999; Pugh and Schramm 1999; Grussing et al. 2001), most of this research has focused on the Missouri and lower Mississippi River drainages. Results from most tagging and telemetry studies suggest that flathead catfish are generally sedentary and establish seasonal home ranges or areas of repeated use that are limited in size (Skains 1992; Dobbins et al. 1999; Pugh and Schramm 1999; Weller and Winter 2001); however, Dames et al. (1989) documented movements of flathead catfish up to 313 km over a 76-d period in the Missouri waters of the Missouri River. The results of these studies suggest that although flathead catfish remain relatively sedentary in most systems throughout their geographic range, fish in some populations may exhibit greater movement. Previous evaluations of habitat use have identified that flathead catfish exhibit an affinity for areas less than 3 m in depth associated with coarse structure (e.g., woody debris, riprap, etc.) and moderate current (0.1–2.0 m/s; Sandheinrich and Atchison 1986; Lee and Terrell 1987; Coon and Dames 1991; Skains 1992; Lemmons and Schnell 1994; Pflieger 1997; Grussing et al. 2001). Because woody debris and riprap provide important cover, foraging, and spawning structures for flathead cat-

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fish, the availability of these habitat types may be important factors in regulating flathead catfish abundance, growth, and movement.

The movement patterns, habitat use, and home range of flathead catfish are largely unknown in northern systems that support this species. Hawkinson and Grunwald (1979) observed winter congregations of flathead catfish in the upper Mississippi River, Minnesota–Wisconsin, at water depths ranging from 5 to 8 m associated with riprap and sand–cobble substrates. Recaptures of tagged flathead catfish in the Minnesota River, Minnesota, during summer and winter suggested that this species remained relatively sedentary during summer but moved distances in excess of 80 km during fall months to overwinter in pool habitats (Stauffer et al. 1996). However, no studies to date have examined movement patterns and habitat use of flathead catfish in the Upper Midwest and Great Lakes regions during other seasons of the year. The population of flathead catfish in the St. Joseph River, a tributary to Lake Michigan located in southwestern Michigan, has experienced an increase in angler pressure over the past decade (J. Dexter, Michigan Department of Natural Resources, personal communication); however, movement patterns, habitat use characteristics, and home range of flathead catfish in this system are unknown. Therefore, our objective was to describe the seasonal movement patterns, habitat use, and home range of flathead catfish in the St. Joseph River, Michigan. The results of this study will increase our understanding of these behaviors in northern populations of flathead catfish and provide important information for the development of appropriate management strategies.

Study Area

The St. Joseph River is a tributary of Lake Michigan located in southwestern Michigan and north-central Indiana. The free-flowing (hereafter referred to as lower) section of the St. Joseph River is a 37.6-km reach between the Berrien Springs Dam and the mouth of the river at Lake Michigan (Figure 1). Because flathead catfish are not found above the Berrien Springs Dam (J. Dexter, personal communication), the boundaries of this reach served as the upstream and downstream limits of the study area. Mean channel width in the study reach is 130 m (range, 50–250 m) and mean water depth is 1.6 m (range, 0.3–8.2 m), although lateral scour pools with water depths in excess of 7.0 m occur throughout the reach. Stream gradient in the study reach ranged from 0.0 to 0.9 m/km. Midsummer (June–August) water temperatures reach 28°C, mean dissolved oxygen concentration is 9.6 mg/L (range, 6.9–14.1 mg/L), and mean turbidity is 16.5 nephelometric turbidity units (NTU; range, 11–27 NTU). Instream cover is composed of large woody debris and riprap, and few aquatic macrophytes exist in the system. Riparian land cover in the reach is primarily hardwood forest, although urban development dominates the lower quarter of the study reach as the river approaches Lake Michigan.

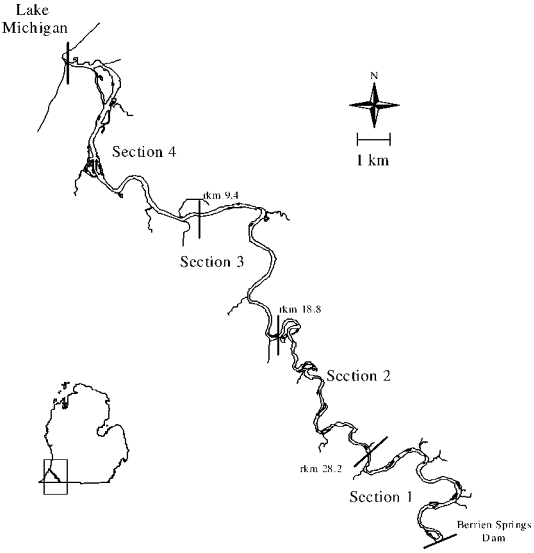

FIGURE 1.—The lower (free-flowing) reach of the St. Joseph River, Michigan. Short bars perpendicular to the river indicate the boundaries of each section.

Methods

Fish collection.—Flathead catfish were collected from June through September 2002 and 2003 by means of 24-V to 38-V AC produced by a 3-bar magnetic motor as described by Morris and Novak (1968). Two 18-gauge insulated wires (each 6.1 m in length) with the distal ends connected to aluminum-bar electrodes (30.5 cm long and 2.5 cm wide) were attached to the motor terminals and powered using a 14.4-V cordless drill connected to the motor driveshaft. At each sampling location, electrodes were deployed approximately 4–5 m upstream and downstream of the boat. Electrical current was applied continuously for 90 s at each sampling location. Gilliland (1988) found that this technique resulted in similar length-frequency distributions of flathead catfish when compared with boats equipped with gasoline-powered, variable-voltage pulsators. All captured individuals were measured for total length (TL) to the nearest 1 mm and wet weight to the nearest 0.1 kg.

Telemetry.—A 14-month ($N = 30$) ultrasonic transmitter (Sonotronics, Tucson, Arizona; Model CT-82–2) and a 7-month ($N = 9$) ultrasonic transmitter (Sonotronics; Model CHP-87-S) were used to monitor the seasonal movement patterns, habitat use, and home range of flathead catfish in the lower St. Joseph River. Fish were selected for transmitter implantation based on TL and capture location in order to obtain a representative sample of the flathead catfish population in the system. Because transmitter weight should not exceed 2% of fish body weight (Winter 1983), only flathead catfish that weighed more than 1.3 kg were considered for the study. Transmitters were surgically implanted into the peritoneal cavity following techniques described by Ziebell (1973) and Hart and Summerfelt (1975) by making a 2.0-cm incision through the ventral body wall approximately 2.0 cm anterior to the pelvic girdle and inserting the transmitter into the peritoneal cavity (Daugherty 2004). After the incision was closed with an absorbable surgical suture, each fish was administered an intraperitoneal injection of oxytetracycline (75 mg/kg fish body weight). Flathead catfish were released at the site of capture after recovering from the procedure.

Flathead catfish fitted with ultrasonic transmitters were relocated once each week between 0900 and 1800 hours from June through October 2002, twice per month from November 2002 to mid-March 2003, and once per week from mid-March through August 2003 using a Sonotronics USR-96 tracking receiver and DH-4 directional hydrophone. Fish were relocated beginning at the upstream end of the study area and continuously searching in a downstream direction. Once an individual was located, the exact location of the fish was determined by decreasing the sensitivity of the receiver and determining the location of greatest signal strength.

Habitat use and availability.—At each fish location, latitude and longitude were recorded using a handheld global positioning system (GPS) and water depth was recorded to the nearest 1 m using a boat-mounted sonar unit. Flow rate was estimated to the nearest 0.1 m/s using a mechanical flowmeter (General Oceanics, Miami, Florida; Model 2030) positioned approximately 0.5 m above the river bottom, and water temperature (°C) was recorded using a Hydrolab Quanta (Hydrolab-Hach Company, Loveland, Colorado). Habitat at each fish location was classified by dominant substrate type in open-water areas (i.e., absence of structure) or by the type of structure present (e.g., large woody debris and riprap). Substrate type was determined using a ponar grab sampler, while the presence of structure was determined visually. Open-water habitats were classified as clay (<0.020 mm), silt (0.020–0.059 mm diameter), sand (0.60–1.99 mm diameter), gravel (2.00–63.00 mm diameter), and cobble (>63.00 mm diameter). Habitats in which structure was present were classified as large woody debris or riprap.

To determine the relative availability of habitats in the lower St. Joseph River, 586 substrate, water depth, and flow rate samples were collected at random from the left-, middle-, and right-channel segments along transects spaced 0.2 km apart throughout the entire study reach. Substrate type, water depth, and flow rate at each sampling location were plotted on a map of the river using ArcView 3.2 (ESRI 1999)), and areas between samples were interpolated in a grid format using the inverse distance-weighted decay function available in the spatial analyst module. Interpolated values for water depth and flow rate variables were then reclassified into eight water depth classes (≤ 1.0, 1.0–1.9, 2.0–2.9, 3.0–3.9, 4.0–4.9, 5.0–5.9, 6.0–6.9, and ≥ 7.0 m) and six flow rate classes (0.00–0.19, 0.20–0.39, 0.40–0.59, 0.60–0.79, 0.80–0.99, and ≥ 1.00 m/s). The relative availability of each substrate type, water depth, and flow rate class was then estimated based on percent grid coverage. For structural habitats, the percent area of large woody debris (>10 cm in diameter and 1.5 m in length; Van Sickle and Gregory 1990) and riprap were determined by recording the total number of each habitat type present in the system during baseline flow conditions. The relative availability of large woody debris habitat was calculated by measuring the length and width of 89 randomly selected large woody debris habitats (31% of the total number of large woody debris habitats inventoried) to determine mean coverage area. The total area of large woody debris habitat was calculated by multiplying the mean coverage area (83.1 ± 7.1 m^2 standard error) by the total number of large woody debris habitats recorded. The length and wetted width of all riprap were measured to calculate the relative availability of this habitat type. Wetted width was measured using a boat-mounted sonar unit to determine the linear distance the habitat extended from the riverbank and water depth. Habitat utilization by each tagged flathead catfish was then estimated as the percentage of fish locations that occurred in each habitat type, water depth, and flow rate class.

Data analyses.—Habitat use and fish movement data were analyzed for temporal trends by defining seasonal categories based on water temperature ranges similar to those defined by Coon and Dames (1991) and Pellett et al. (1998). Spring (March–April) was defined as the period when water temperature increased from 6°C to 18°C, summer (May–October) was defined by water temperatures greater than 18°C, fall (October–November) was defined as the period when water temperature declined to 6°C, and winter (December–March) was defined by water temperatures less than 6°C.

Seasonal habitat, water depth, and flow rate selection by flathead catfish in the lower St. Joseph River were determined using compositional analysis (Aebischer et al. 1993). This multivariate method overcomes problems associated with dependence of proportions of habitat use or availability that sum to one (unit-sum constraint) by transforming proportions to log ratios using one proportion as the denominator (Aebischer et al. 1993; Zigler et al. 2003). Nonrandom utilization was determined by comparing the matrices of log-ratio-transformed use and availability distributions of each habitat variable with a log-likelihood ratio test for each season (Aebischer et al. 1993). Null proportions (i.e., habitat types, water depth, or flow rate classes available but not utilized by flathead catfish) were replaced by a value of 0.01% in the utilization matrices. When seasonal selection of habitat variables was nonrandom, pairwise *t*-tests were used to rank their relative importance and to determine whether selection differed among habitat types, water depth, or flow rate classes (Aebischer et al. 1993).

To describe seasonal movement patterns and home range of flathead catfish, GPS coordinates of weekly relocations of each sonic-tagged fish were plotted on a map of the St. Joseph River using ArcView 3.2 (ESRI 1999). Movements of each fish were recorded by measuring the distance between successive relocations. We considered a fish had exhibited movement if it had moved upstream or downstream between successive relocations. Preliminary tests indicated that the estimated location of submerged transmitters placed in habitats typically utilized by flathead catfish could be located within 3 m of their true location; therefore, movements estimated at less than 3 m were recorded as no movement. The seasonal home range of sonic-tagged fish was calculated as the distance between the most upstream and downstream locations of an individual within a given season (Skains and Jackson 1995). All measurements of fish movement and home range were recorded following the center of the river channel.

Trends in seasonal movement of flathead catfish were analyzed on the basis of the mean movement distance of each fish within a given season. Seasonal home range was analyzed to determine whether flathead catfish utilized similar proportions of the lower St. Joseph River among seasons. In addition, the direction of movement (i.e., upstream or downstream) was examined for seasonal trends in movement direction. Since preliminary examinations of mean seasonal movement distance and home range revealed that the data were not normally distributed, these data were $\log(x) + 0.5$ transformed prior to statistical analysis (Zar 1999). A one-way analysis of variance (ANOVA) was used to determine whether the mean seasonal movement distance and home range of flathead catfish differed among seasons. If significant differences were detected, a Tukey honestly significant difference multiple comparison test was used to separate the means. Trends in directional movement during each season were tested using a binomial goodness-of-fit test to determine whether the directional movement ratio was significantly different from 1:1 (Zar 1999). Assumptions of normality and homoscedasticity of variances of all data were tested prior to statistical analysis using Kolmogorov–Smirnov goodness of fit and Bartlett's tests, respectively (Zar 1999). All statistical analyses were considered significant at an $\alpha = 0.05$ level of confidence.

Results

We recorded 647 locations for 20 flathead catfish implanted with ultrasonic transmitters during 2002 and 19 flathead catfish during 2003. Fish TL ranged from 430 to 1,132 mm and weight ranged from 1,300 to 18,000 g (Table 1). Tag signals from 14 fish fitted with transmitters in 2002 and 4 fish fitted with transmitters in 2003 were lost during the study period. Although tag failure was responsible for the loss of 2 fish during the late fall and winter period of 2002, the cause of the loss of the remaining 16 individuals was unknown. Short-term mortality as a result of capture or surgical procedures may have been responsible for the loss of 8 fish (2002, 4 individuals; 2003, 4 individuals) within two weeks of transmitter implantation. The remaining 8 individuals were lost during the spring and summer periods (spring, 4 individuals; summer, 4 individuals). While the fol-

TABLE 1.—Summary statistics for flathead catfish fitted with ultrasonic transmitters in the lower St. Joseph River, Michigan, during 2002 and 2003. The number of contacts refers to the number of relocations recorded for each sonic-tagged fish; days active refers to the total number of days between transmitter implantation and the last contact.

Fish	Total length (mm)	Weight (g)	Number of contacts	Days active
		2002		
1	750	7,500	37	389
2	710	5,500	3	52
3	1,000	16,000	8	49
4	720	5,000	10	68
5	900	11,000	51	443
6	670	3,500	46	407
7	685	3,250	46	407
8	745	5,500	46	46
9	600	2,250	5	33
10	1,070	13,600	26	274
11	710	4,000	52	443
12	645	2,500	31	306
13	760	4,500	8	49
14	700	5,500	50	447
15	430	1,300	1	1
16	810	9,000	0	0
17	438	1,300	3	11
18	710	4,500	53	78
19	820	7,000	2	8
20	750	5,600	21	225
		2003		
21	928	10,800	3	49
22	772	4,900	9	60
23	790	4,000	10	66
24	740	5,100	10	67
25	820	7,100	0	0
26	551	2,100	10	63
27	945	10,000	11	66
28	1,132	18,000	2	3
29	720	4,100	11	64
30	1,020	13,000	10	67
31	820	5,300	10	67
32	1,005	10,250	2	7
33	863	6,800	11	64
34	684	3,500	11	67
35	686	3,600	1	2
36	934	9,000	10	89
37	780	5,100	10	77
38	1,035	13,400	8	76
39	704	4,000	9	57

TABLE 2.—Compositional analysis ranks of seasonal habitat, water depth, and flow rate selection by flathead catfish in the lower St. Joseph River, Michigan, during 2002 and 2003. For each variable and season, ranks with a common letter were not significantly different.

Sample size and habitat variable	Spring	Summer	Fall	Winter
N	10	28	11	11
Habitat type				
Woody debris	1 z	1 z	1 z	2 y
Riprap	2 y	2 y	2 y	1 z
Clay	3 x	3 x	3 x	3 x
Cobble	4 x	4 x	4 x	4 xw
Silt	5 xw	5 x	5 xw	5 xw
Sand	6 xw	6 x	7 xw	7 xw
Gravel	7 w	7 w	6 w	6 xw
Depth class (m)				
0–0.9	7 y	7 w	7 x	4 y
1.0–1.9	5 y	2 zy	8 x	8 yw
2.0–2.9	4 zy	1 z	5 yx	7 yw
3.0–3.9	1 z	3 y	4 yx	6 yw
4.0–4.9	2 zy	5 w	1 z	1 z
5.0–5.9	8 y	8 w	6 x	5 yw
6.0–6.9	6 y	6 w	3 yx	3 z
7.0–7.9	3 zy	4 w	2 y	2 z
Flow rate class (m/s)				
0–0.19	6 y	6 y	6 z	6 y
0.20–0.39	5 z	5 z	3 z	5 z
0.40–0.59	2 z	3 z	4 z	2 z
0.60–0.79	4 z	4 z	1 z	1 z
0.80–0.99	3 z	2 z	5 z	4 z
≥1.0	1 z	1 z	2 z	3 z

lowing results present data for fish known to have remained in the study area, a substantial proportion (up to 21%) of implanted fish may have left the study area during the spring and summer months. Therefore, the movement and home range information presented here may be incomplete for the entire population of flathead catfish that utilize this system at least some portion of the year. Locations of flathead catfish fitted with transmitters during 2002 were recorded for a mean period of 193 d (range, 0–447 d) and for a mean period of 56 d (range, 0–89 d) in 2003 (Table 1). Flathead catfish were tracked on 10 occasions during spring, on 18 occasions during summer, on 5 occasions during fall, and on 7 occasions during winter. Incomplete seasonal data sets as a result of the loss of tag signals (i.e., partial observations of an individual within a given season) were not included in the analyses of seasonal movement patterns, home range, and habitat use.

Habitat Use

Selection of habitat types by flathead catfish in the lower St. Joseph River was nonrandom during all seasons (all $\Lambda < 0.001$; all df = 6; all $P < 0.0001$). Pairwise comparisons ranked structural habitats (i.e., large woody debris and riprap) significantly higher than open-water habitats during all seasons (Table 2). During spring, summer, and fall, selection of large woody debris habitats was significantly higher than the selection of riprap; a minimum of 70% of the habitat use observations occurred in areas containing large woody debris each season. However, fish utilized riprap significantly more than large woody debris during winter months because as much as 64% of the habitat use observations occurred in areas containing riprap (Figure 2). Although pairwise comparisons resulted in few significant differences in the utilization of open-water habitats by flathead catfish, the use of these areas was limited to gravel substrates and comprised less than 6% of the observations in all seasons except winter. During this period, fish utilized gravel substrates in 18% of the observations (Figure 2).

Water depth selection by flathead catfish was significantly different from random during all seasons (all $\Lambda < 0.001$; all df $= 8$; all $P < 0.0001$). Pairwise comparisons of depth selection rankings indicated that flathead catfish selected water depths ranging from 2.0 to 4.9 m and greater than 7.0 m during spring and shallower water depths (1.0–2.9 m) during summer (Table 2; Figure 3). Water depth selection during fall and winter followed similar patterns; fish selected water depths primarily greater than 4.0 m (Table 2; Figure 3).

Flow rates associated with habitats occupied by flathead catfish were significantly different from random during all seasons (all $\Lambda < 0.328$; all df $= 5$; all $P < 0.0095$). However, pairwise comparisons resulted in few significant differences in seasonal utilization of flow-rate classes (Table 2). Generally, flathead catfish selected habitats associated with flow rates greater than 0.2 m/s during all seasons; however, they limited their selection of areas with flow rates less than 2.0 m/s to spring and summer (Figure 4). No significant differences were detected among selection ranks of flow-rate classes greater than 2.0 m/s for any season, which suggests that the ranked utilization of these strata by flathead catfish was of little importance.

Seasonal Movements and Home Range

Flathead catfish exhibited distinct trends in seasonal movement during 2002 and 2003 (Figure 5). The mean seasonal movement distance exhibited by flathead catfish was significantly different among seasons ($F = 9.883$; df $= 2, 55$; $P < 0.001$). During summer months, flathead catfish moved a mean distance of 218 m (95% confidence interval [CI], 18–418 m; range, 0–1,083 m; Figure 5). We relocated fish at the site of initial capture for 76% of the observations during this season. Movements greater than 1,000 m were confined to early summer (i.e., June) when water temperatures reached 17–24°C. Movements of flathead catfish during the rest of the summer season were generally less than 200 m in length from the initial site of capture (Figure 6).

The mean movement distance of flathead catfish during fall was significantly greater than that in summer as fish transitioned between summer and winter habitats (Figure 5). During this season, flathead catfish remained in summer locations until water temperatures dropped to 10°C. At this temperature, sonic-tagged fish moved a mean distance of 1,146 m (95% CI, 391–1,900 m; range, 0–3,601 m; Figures 5 and 6) to their winter habitats. Upon reaching their winter habitats, no additional movements were observed for the remainder of the season.

Flathead catfish remained inactive in their winter habitats until early spring, when water temperatures increased to 10°C. At this temperature, all fish returned to their original capture locations from the previous summer over a two-week period (Figure 6). The mean movement distance during spring months was similar to that of fall, as fish moved a mean distance of 1,045 m (95% CI, 461–1,629 m; range, 0–2,950 m; Figure 5). Upon returning to their summer habitats, movements during late spring were similar to those observed in early summer (Figure 6). No trends in directional movement were detected during any season of the study period (all $P \geq 0.42$).

Significant differences existed among the seasonal home ranges of flathead catfish ($F = 6.633$; df $= 2, 49$; $P = 0.003$; Figure 5). The mean home range of fish during spring was significantly larger than any other season (1,513 m; 95% CI, 979–2,048 m; range, 214–2,950 m). During summer the mean home range was 596 m (95% CI, 344–847 m; range, 0–2,477 m) and during fall the mean home range was 1,296 m (95% CI, 525–2,068 m; range, 0–3,601 m). Because no movements were observed during winter months, the home range of flathead catfish during this season was considered negligible and omitted from the analysis.

Discussion

Several studies have described flathead catfish as a sedentary species with a highly developed sense of environmental recognition and a tendency to establish areas of repeated use (Funk 1957; Summerfelt and Hart 1972; Hart and Summerfelt 1974; Robinson 1977; Duncan and Meyers 1978; Quinn 1988; Skains 1992; Jackson 1999). However, Weller and Winter (2001) suggested that habitat requirements for flathead catfish change on a seasonal basis. These authors found that fish utilized relatively small home ranges characterized by the presence of woody debris and riprap in shallow water (1–5 m) during all seasons except winter, when flathead catfish utilized deeper water

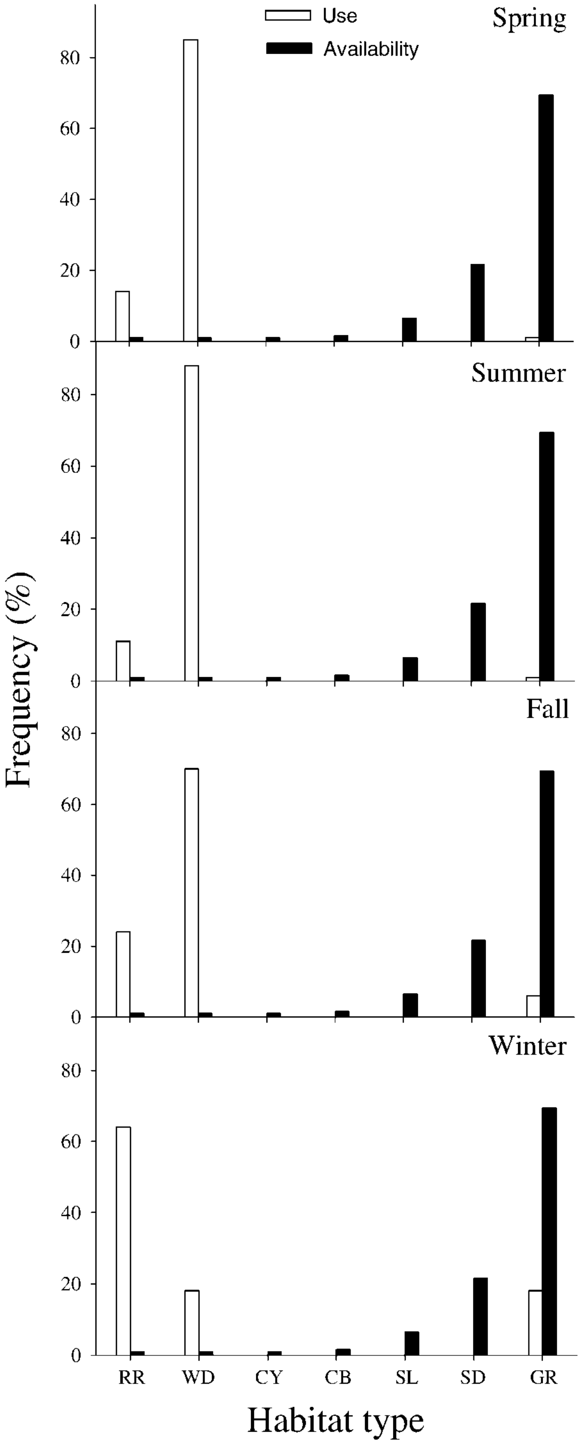

FIGURE 2.—Availability and seasonal use of various habitat types by flathead catfish in the lower St. Joseph River during 2002 and 2003. Habitat types are as follows: riprap (RR), woody debris (WD), open-water clay (CY), cobble (CB), silt (SL), sand (SD), and gravel (GR).

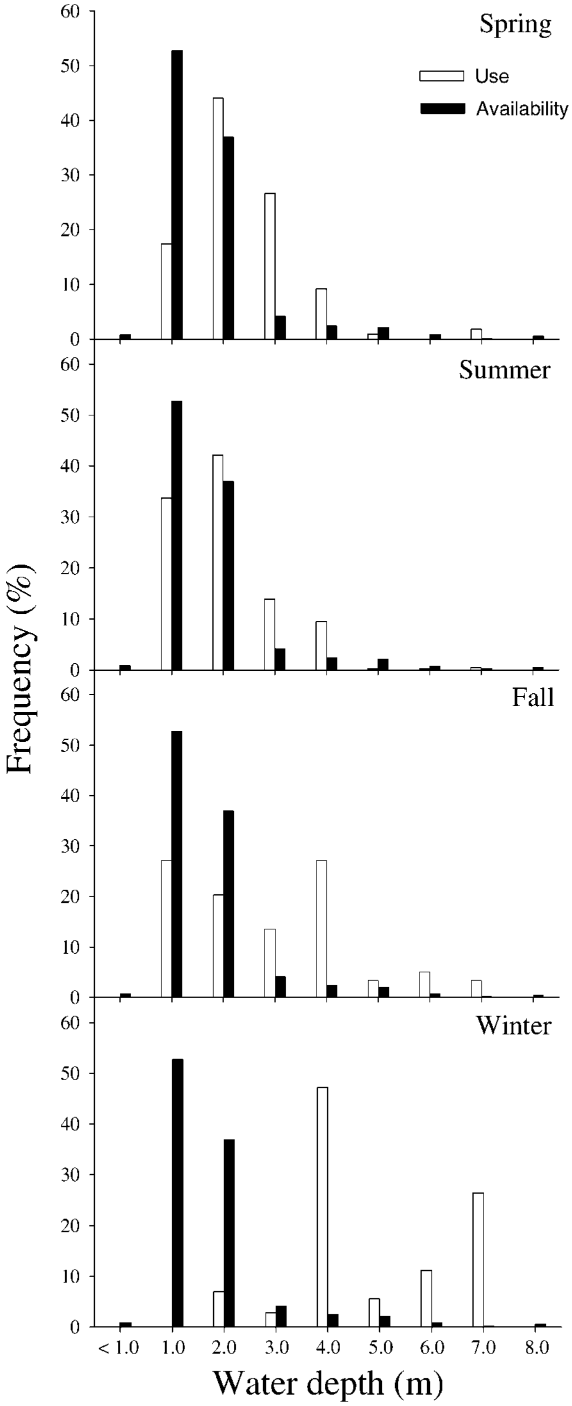

FIGURE 3.—Availability and seasonal use of various water depths by flathead catfish in the lower St. Joseph River during 2002 and 2003. Water depths were grouped into 1-m classes.

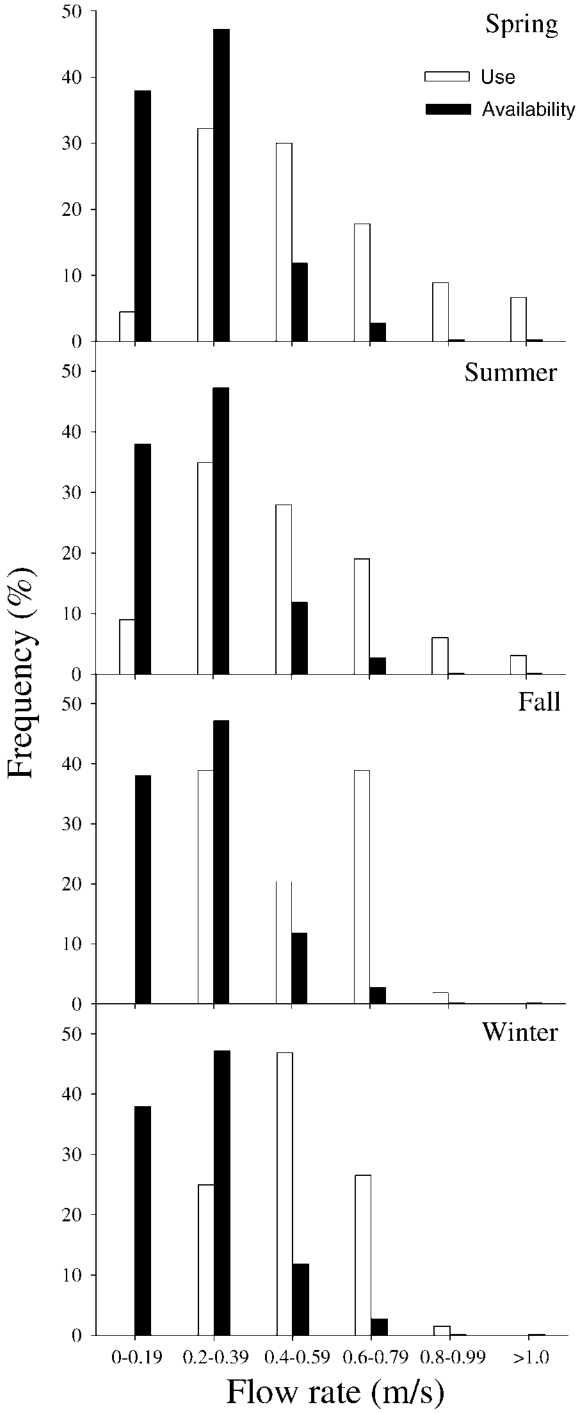

FIGURE 4.—Availability and seasonal use of various flow rates by flathead catfish in the lower St. Joseph River during 2002 and 2003. Flow rates were grouped into 0.2-m/s classes.

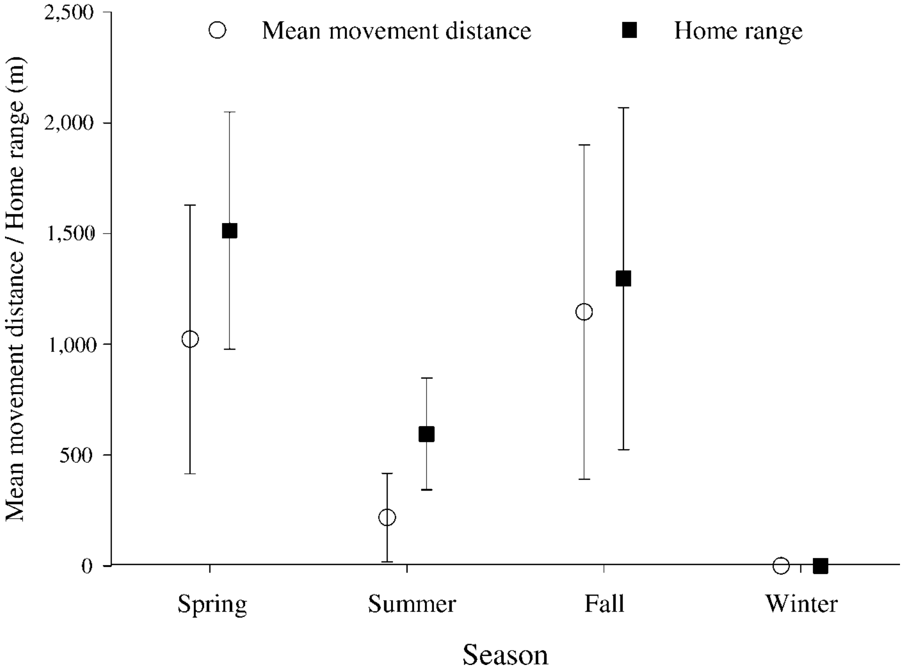

FIGURE 5.—Seasonal movements and home ranges of flathead catfish in the lower St. Joseph River during 2002 and 2003. Means and 95% confidence intervals are shown.

(>5 m) associated with gravel and rock substrates. These studies corroborate our results, indicating that the seasonal movement patterns and home range of flathead catfish in the lower St. Joseph River are related to differences in habitat use among seasons.

During midsummer (July–October), fish utilized relatively small home ranges and occupied structural habitats (primarily large woody debris) at water depths less than 3 m. Fish movements consisted of multiple displacements among structural habitats less than 200 m from their original site of capture and were typically followed by a return near the location of capture in subsequent weeks. Vokoun (2003) reported reduced weekly net movement and home range size of flathead catfish during July through October in the Grand and Cuivre rivers, Missouri. The author suggested that fish movement behavior was related to the development of high-use areas as flathead catfish frequented particular habitat features within their summer home range. Flathead catfish in the Apalachicola River, Florida, were also found to be relatively sedentary, as 96% of the fish tagged in May were collected near their original capture location from June through August (Dobbins et al. 1999). Similarly, Skains (1992) reported that the home range of flathead catfish ranged from 0.5 to 1.1 km in the Big Black River, Mississippi, and 0.8–1.9 km in the Tallahatchie River, Mississippi. Skains (1992) also found that 100% of flathead catfish (N = 20) returned to previously used woody debris cover following nocturnal forays. Although flathead catfish in the lower St. Joseph River moved more frequently during midsummer than during any other season, the limited distance moved by fish may have been related to the utilization of specific habitats within their summer home range.

During November (i.e., fall), the home range of flathead catfish was larger as fish made transitional movements between summer and winter habitats. Stauffer et al. (1996) found that flathead catfish in the Minnesota River traveled a mean distance of 81 km between summer and winter habitats during fall months and moved to deep-water pools for the overwintering period. Similarly, Weller and Winter (2001) reported that flathead catfish left structural habitats at a mean water depth of 3 m and moved to rocky substrates at increasingly greater water depths as water temperatures declined during fall months. These authors attributed these movements to the stable environment and protection provided at greater water depths as flathead catfish became less active. Movements of fish in the lower St. Joseph River during fall months were similar to these studies and suggest that the greater

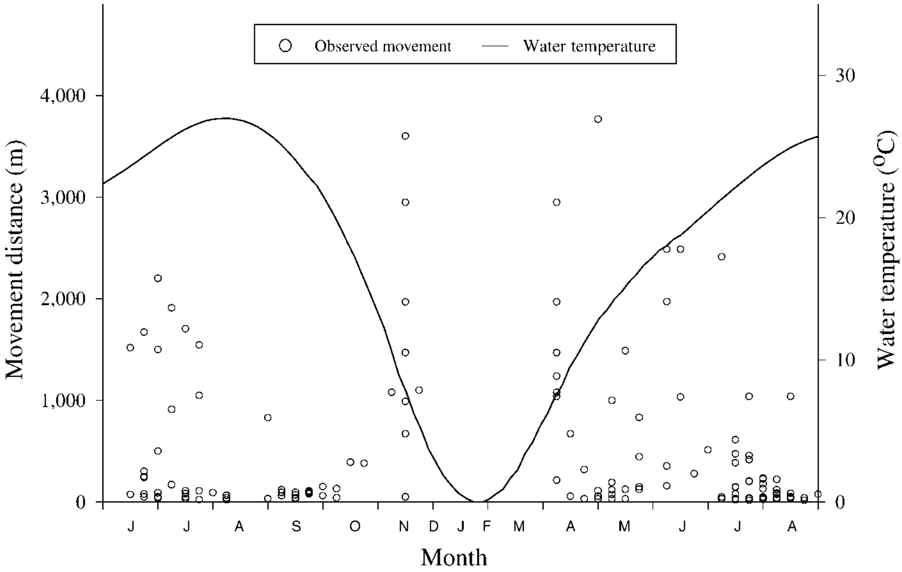

FIGURE 6.—Movements of flathead catfish in the lower St. Joseph River during 2002 and 2003 and corresponding water temperatures. The labels on the *x*-axis refer to months, beginning with June 2002.

water depths and reduced flow rates provided by main-channel pools are important criteria of winter habitat selection for flathead catfish.

Our observation that flathead catfish did not move during winter suggested that fish were highly inactive during this period. Weller and Winter (2001) found flathead catfish to be sedentary during winter. Similarly, Stauffer et al. (1996) reported that flathead catfish collected from pool habitats during December had deposits of sediment on their dorsal surface that suggested these fish remained inactive during winter months. Turner and Summerfelt (1971) studied the seasonal feeding habits of flathead catfish and found that they fed little during this period. The lack of flathead catfish activity observed during winter in these studies may indicate that habitat requirements of flathead catfish during winter may be highly specific because they sought areas that provided a lower probability of disturbance and protected them from river current. Hawkinson and Grunwald (1979) found high densities (230–2,350 fish/ha) of flathead catfish in pool habitats associated with riprap or cobble–sand substrates during winter months. Further, these authors found that the current velocity at all fish locations was 67–75% less than at areas without cobble and riprap substrates. Newcomb (1989) suggested that water depth, flow rate, and the amount of available bottom cover were the most important habitat features that determined the use of pool areas during winter in the Missouri River, Nebraska, by channel catfish *Ictalurus punctatus*. Because multiple tagged flathead catfish occupied the same pool areas during winter, large abundances of fish in the lower St. Joseph River may congregate in specific pool habitats during this season.

The home range of flathead catfish in the lower St. Joseph River during early spring (i.e., April) increased once fish left winter habitats when water temperatures reached 10°C and returned to locations near the site of capture the previous summer. Upon returning to their summer locations, flathead catfish resumed their use of large woody debris habitats in water depths less than 3 m. The utilization of similar summer home ranges by flathead catfish following movements from overwintering sites has been documented in other systems. Stauffer et al. (1996) reported that although flathead catfish moved greater distances during fall between their summer and winter areas, the fish were collected within 6.4 km of their original capture location the following summer. Pugh and Schramm (1999) found that 11 of 12 flathead catfish tagged in summer and early fall 1995 were recaptured within 1 km of their release site during these same seasons in 1996 and 1997. Similarly, Skains (1992) reported that flathead catfish tagged during the summers of 1989 and 1990 were recaptured within 2 km of their original capture location in subsequent years. Although these studies did not determine movements of fish between mark-andrecapture sampling periods, similar movements by flathead catfish in the lower St. Joseph River indicated that they exhibit site fidelity following annual migration events between summer and winter habitats. These results suggest that flathead catfish have the ability to recognize specific structural habitat units within their home range that may provide optimal cover and foraging opportunities.

Movement and habitat use of flathead catfish in the lower St. Joseph River from May through June (i.e., early summer) consisted of individuals moving between large woody debris and riprap habitats at water depths that ranged from 1 to 3 m and at water temperatures that ranged from 17°C to 24°C. Previous studies have suggested that movements and habitat use during this time period were related to fish seeking suitable areas for spawning. For example, Weller and Winter (2001) reported that a majority of spawning flathead catfish in Buffalo Springs Lake, Texas, aggregated at water depths ranging from 2 to 3 m in areas with riprap at water temperatures ranging from 20°C to 25°C. Turner and Summerfelt (1971) found that flathead catfish spawning habitats were associated with rocky substrates or large woody debris at water depths that ranged from 2 to 5 m in Lake Carl Blackwell Reservoir, Oklahoma. Similarly, Layher and Boles (1979) found evidence of flathead catfish spawning activities among riprap during early summer in a Kansas reservoir. Weller and Winter (2001) suggested that the interstitial spaces created during the placement of riprap provided suitable spawning habitat for flathead catfish. Although reproductive maturity of flathead catfish was not examined in our study, 95% of tagged fish were greater than the minimum length at maturity reported for this species (Evermann 1893; Barnickol and Starrett 1951; Minckley and Deacon 1959; Turner and Summerfelt 1971; Perry and Carver 1979; Munger et al. 1994). Our results corroborate these studies, which indicates that the movements of flathead catfish between riprap and woody debris habitats during early summer show that these habitat types may serve as important spawning areas for flathead catfish in the lower St. Joseph River.

Although the results of our study identified the seasonal habitats used by flathead catfish in the lower St. Joseph River, we did not determine the microhabitat characteristics of these habitat types. Our observation that flathead catfish routinely utilized certain structural habitats within their seasonal home ranges while not using equally favorable locations suggests that microhabitat characteristics are an important factor in determining flathead catfish use. Because this information may be important to fisheries managers attempting to increase or enhance flathead catfish habitat availability, future studies should examine these characteristics (e.g., measures of structural complexity, orientation of large woody debris to river current, size of interstitial spaces among riprap, etc.). In addition, the size of transmitters used for tracking purposes prevented us from examining seasonal movement patterns, habitat use, and home ranges of juvenile (<430 mm TL) flathead catfish. Irwin et al. (1999) found that flathead catfish less than 150 mm TL exclusively used riffles with coarse substrates and high flow rates in Alabama systems, demonstrating that habitat requirements for juvenile fish may differ from adults. Future telemetry studies of flathead catfish should include juvenile fish to determine whether the movement patterns, habitat use, and home range of this life stage differ from larger individuals.

Our study results demonstrated that seasonal differences existed in the movement patterns, habitat use, and home ranges of flathead catfish in the lower St. Joseph River. Therefore, efforts to examine these behaviors should incorporate sampling conducted during all seasons of the year to provide conclusive information for the development of adequate management strategies for flathead catfish. The degree of site fidelity exhibited by flathead catfish to large woody debris and riprap habitats during spring, summer, and fall indicated that these habitat types provide important cover the majority of the year, while main-channel pool habitats with coarse substrates provide greater water depth and reduced river flow rates during winter months when fish are inactive. As a result, the availability of these habitat types may be important factors in regulating the abundance, recruitment, growth, and spatial distribution of flathead catfish. Therefore, we recommend that seasonal movement patterns and habitat use be examined to identify structural and main-channel pool habitats utilized by flathead catfish in lotic systems and that these areas be maintained or enhanced to sustain these stocks.

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