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Summer Diel Activity and Movement Paths of Flathead Catfish (Pylodictis olivaris) in Two Missouri Streams

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ABSTRACT.—Within an ongoing round-the-clock radiotracking project, a subset of adult flathead catfish *Pylodictis olivaris* ($n = 6$) was continuously radio-tracked for 24 h to determine detailed diel movement path characteristics and activity in two Missouri streams. The ongoing radiotracking revealed that only a small percentage of point-in-time relocations were recorded as moving, while the majority (greater than 90% for every hour of the day) found fish stationary. The continuously-tracked subset of catfish generally moved by making discrete directed movements from one location to another, with locations corresponding to a physical habitat feature (large woody debris, clay point, undercut bank). All fish revisited locations during the 24-h tracking efforts. Movements were less than 100 m during early afternoon and the first 2 h after sunset, with longer movements undertaken from 2100 through the night to the 0500 hour, ceasing at sunrise. Movement paths had a median distance of 641.16 m with a median activity radius of 66.55 m. Fish spent a median 23.33 h stationary and 0.67 h moving during the diel cycle. The continuous tracking effort resulted in finer resolution and detail than was evident in the larger, typical point-in-time tracking dataset which did not highlight an early afternoon activity period, perhaps due to short, quick movements made at that time.

INTRODUCTION

The movement behavior of flathead catfish *Pylodictis olivaris* has been described as primarily sedentary (Funk, 1957; Quinn, 1988; Jackson, 1999), with movement occurring at night (Skains, 1992). Flathead catfish are believed to have a developed sense of environmental recognition (Jackson, 1999) and have been documented to return to preferred use areas (Hart and Summerfelt, 1974; Skains, 1992). In Mississippi streams, Skains (1992) described flathead catfish as having 1–3 “home sites” that were heavily used. Tagged fish in the Minnesota River displayed fidelity to summer home ranges and wintering pools (Stauffer *et al.*, 1996). Flathead catfish are known to become piscivorous by 300 mm in size (Herndon and Waters, 2002) and are believed to move into shallower water to feed at night (Skains, 1992; Pflieger, 1997). Considered top predators in most systems in which they occur, flathead catfish have been implicated in top-down structuring of fish communities (Thomas, 1995; Herndon and Waters, 2002).

Biologists have pieced together a general picture of diel activity patterns of adult flathead catfish (Pflieger, 1997; Jackson, 1999). However, a formal investigation of diel activity and movement paths of individual fish has not been reported. Young (1999) emphasized the importance of following individual fish vs. indirect point-in-time techniques in which data are compiled across individuals. Indirect techniques lack the ability to link locations through time with a movement path. Movement paths represent fine-scale patterns of movement and are consistent with the biological realism and understanding allowed by

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current technology compared to that gleaned from traditional methods (Kernohan *et al.*, 2001; Pace, 2001). Therefore, within an ongoing point-in-time radiotracking project, we continuously tracked a subset of adult flathead catfish for 24-h noon-to-noon periods to document diel movement paths and associated activity.

METHODS

Field sampling and study area.—Flathead catfish were surgically implanted with radiotransmitters during June and early July in 2001 in the Grand River and during the same time period in 2002 in the Cuivre River. Fish were collected using unbaited hoop nets with front hoop diameters of 60 and 90 cm and bar mesh of 2.54, 3.75 and 5 cm. Fish selection for inclusion in the project was based solely on a minimum size criteria of 51 cm and 1.8 kg that was likely to exclude non-sexually mature juveniles from the study (Skains and Jackson, 1995). Flathead catfish ranged from 55.5 to 121.0 cm and weighed from 1.9 to 20.9 kg. Fish of this size are presumably 5-plus years old (*see* references in Jackson, 1999).

Transmitters were manufactured by Advanced Telemetry Systems, Inc. (Isanti, Minnesota), had a warranty battery life of 400 d and were set to always transmit. Frequencies were between 48.000 and 49.999 Megahertz. Transmitters were implanted in the abdominal cavity through a ventral incision closer to the vent than to the pectoral fins. The incision was closed with five to six interrupted nylon sutures. The trailing whip antenna was exited through a separate puncture made with a large diameter needle in an effort to remove pressure from the incision. Surgeries were conducted on-site and fish were held for a 1 h recovery period in a flow-through pen and then released into the pool from which they were captured.

The ongoing radiotracking of the larger group of fish ($n = 49$; 26 Grand River, 23 Cuivre River) was conducted approximately every 30 h on a staggered schedule (not all fish were relocated at the same time) spanning Monday through Saturday from 15 July to 15 October (2001 Grand River; 2002 Cuivre River), which corresponded to a postspawn summer/fall period before fish made movements towards overwintering habitats. The staggered schedule provided approximately even coverage of the diel clock. During the ongoing tracking fish were recorded as either stationary or moving at the point-in-time of telemetric contact.

Six catfish randomly selected from the larger study group (ranging in length from 64.0–107.2 cm and weighing from 2.7–12.8 kg) were each tracked once for 24 h from noon to noon. These fish were surgically implanted with radiotransmitters from 20 to 403 d prior to the dates of diel tracking. The length of time post-surgery would have ameliorated effects of stress and recuperation associated with capture and implantation (Summerfelt, 1972). Fish were of both sexes, two of each sex and two were undetermined. Three fish each were tracked at each river and contributed data to the ongoing point-in-time dataset excepting the day each was continuously tracked. Continuous tracking was done from a boat, staying at least 40 m from the actual fish location. Multiple bearings were used to initially determine a fish location and then we remained stationary until the fish moved to a new location. Boat movement was kept at a minimum although all fish were part of ongoing research and had been relocated 4–5 times per week at all hours of day and night and had seemingly become indifferent to boat activity. Fish relocations were georeferenced every 15 min through the 24 h tracking period. Relocations were georeferenced by collecting a series of positions (>120) from the global positioning system satellites with a Trimble model Geoexplorer 3 which were stored in a rover file that was later differentially corrected via comparison with base station files. Differentially corrected fish relocations had precisions ranging from 0.68–1.4 m. The 24 h continuous sampling efforts were conducted on 24 and 31 July in the Cuivre River and 7 August and 15 September in the Grand River.

The Cuivre River is a seventh order Mississippi River tributary draining 3199 km^2 and is characterized by a gravel and sand channel with long pools and sporadic well-defined riffles. The Grand River is an eighth order Missouri River tributary draining 20,461 km^2 and is characterized by a sand and silt channel with lateral pools and few well-defined riffles. Both streams are within the dissected till plains ecoregion (Hebrank, 1989). Historic native vegetation was tallgrass prairie interspersed with patchy woodlands and savanna (Schroeder, 1982). Located in the northcentral Missouri the Grand River basin is presently dominated by row-crop agriculture and pasture. Located in eastcentral Missouri the Cuivre River basin is also mostly agricultural but includes a greater portion of small-acreage, low-density housing and suburban development in the lower basin near St. Louis. Large woody debris constitutes the dominant structural habitat feature for large fishes in both streams.

Analysis.—The ongoing radiotracking data from each river was combined and the percent of relocations recorded as moving for each hour of day was calculated to represent diel activity levels. To determine the hourly movement activity of the continuously tracked fish, we calculated a weighted percent of fish moving, defined as the percent of fish moving multiplied by the number of discrete movements that occurred during the given hour. The weighting procedure ameliorated potential over- or under-emphasis of single fish that made multiple movements within a short time span. Associated movement distances are presented as the median and range of distances of discrete movements that occurred during the given hour.

Temporal and spatial locations were identified as places where fish remained stationary during the 24-h tracking period, and do not directly correspond to the 15-min georeferenced relocations that were systematically recorded regardless of the position or activity of the fish. Specifically, multiple relocations occurred at one location if a fish remained stationary for at least 30 min or revisited the same location later during the 24-h period. Relocations were imported into program ArcView® GIS where the Animal Movement Analysis ArcView® Extension (Hooge and Eichenlaub, 2000) was used to generate movement paths and associated statistics. Movement distances between locations were generated using the Polyline from Point Theme option. The sum of these distances was also used to estimate the length of the entire 24-h movement path. The Spider Analysis option was used to calculate an activity radius defined as the mean of the distances from the arithmetic mean of the set of relocation points (used during the 24-h movement path) to each individual point.

A revisitation index was defined as the total number of temporal locations used during the 24-h period divided by the number of unique spatial locations. Thus, if a fish did not revisit locations, the total number of temporal locations equals the number of unique spatial locations and the index equals 1. If revisitation of locations occurred during the 24-h period, the resulting index would be greater than 1. Time stationary was tallied when the fish remained at a location for 0.5 h or more without changing locations. Time moving was tallied when the fish moved from one location to another within 0.5 h of arriving. Therefore, some movements that were quick, and isolated in time did not add to the time moving total. These were most often subtle position changes within the same habitat feature and often took less than 1 min to complete (*i.e.,* one end of a log to the other). Time stationary and moving were rounded to the nearest 0.25 h.

RESULTS

During the ongoing radiotracking 1686 point-in-time relocations were made for the larger group of fish. Only 3.7% (62) of the point-in-time relocations observed individual fish moving. For all hours of day, percent of relocations recorded as moving never exceeded

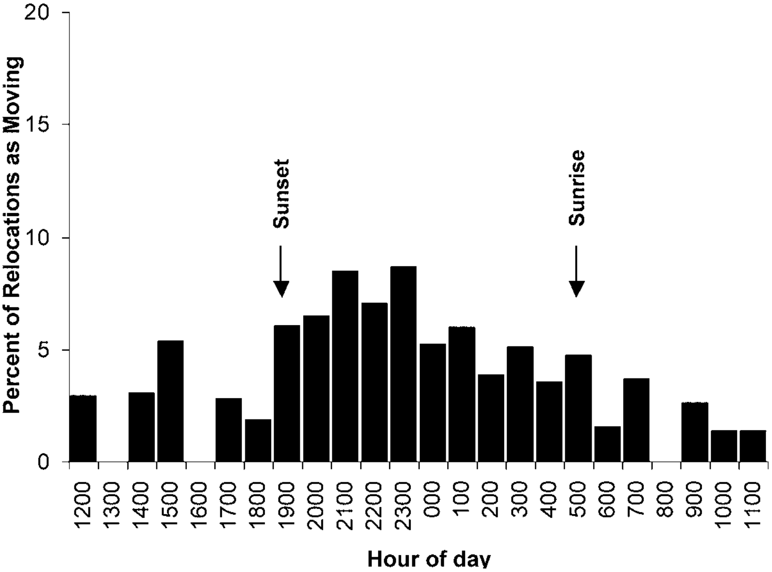

FIG. 1.—The percent of point-in-time relocations recorded as moving by hour of day for adult flathead catfish radiotracked in the Grand River (n = 26) and the Cuivre River (n = 23), both in Missouri, USA

10.0% (Fig. 1). Although inactivity dominated the entire diel cycle, the bulk of movement activity that occurred was in a broad period roughly spanning dusk to dawn. However, many of the daylight hours had percentages equivalent to those at night.

During the 24-h continuous tracking, fish movement behavior consisted of extended periods of inactivity punctuated by quick, discrete movements to distinct physical habitat features such as a log complex, single submerged logs or a clay point. Spatially, the movement behavior resulted in locations that were highly clumped (Fig. 2, panel a). Discrete movements were essentially straight-line, although movements along cut banks arced with the bank. The arrowed segments in panel b of Figure 2 are, therefore, a realistic representation of the 24 h movement path. The length of the movement paths ranged from 145.53–1553.34 m with a median value of 641.16 m (Table 1). The associated activity radii of these movement paths ranged from 18.96–282.04 m with a median value of 66.55 m. Activity radii were calculated from the spider analysis segment lengths that can be displayed in a spider diagram. Spider diagrams of all fish were stretched in the upstream-downstream directions, as in panel c of Figure 2, such that the term activity radius should not be literally interpreted as indicating a circular area of use. The flathead catfish moved a median 13.50 times in the diel cycle and used a median 8.50 unique locations. The revisitation index ranged from 1.11–2.44 with a median value of 1.48. All individuals revisited sites during the diel cycle. None of the six movement paths ended at the same location from which they began.

The 24 h radiotracked flathead catfish had three periods of activity (Fig. 3). One occurred in early afternoon during the 1200, 1300 and 1400 hours. Distances of discrete movements during this period had median values of less than 50 m and did not exceed 100 m. A second period of increased movement activity occurred from the hour containing sunset (1900) through the 2300 hour. Distances moved during this period had similar low median values and ranges for the first two hours after sunset, but then increased during the 2100 hour and

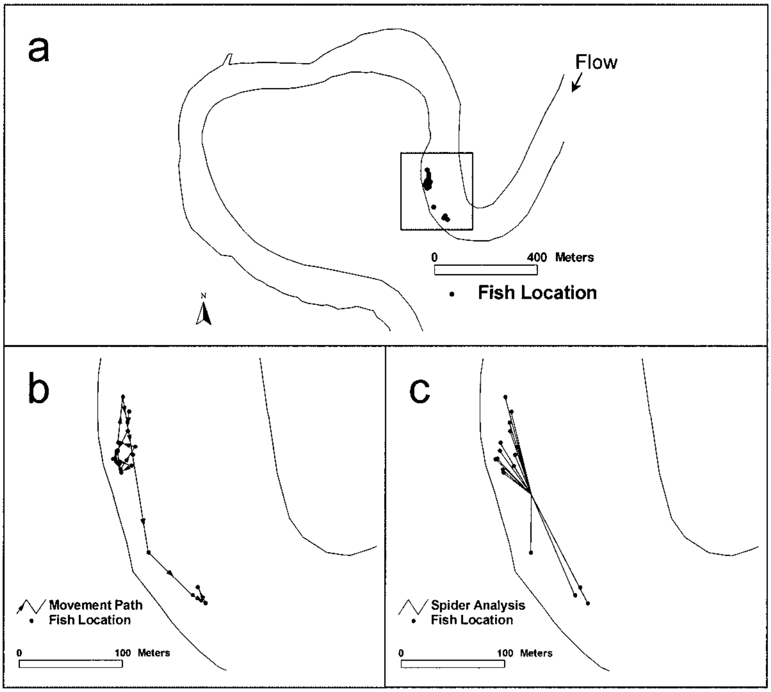

FIG. 2.—a) Position of successive relocations from a 24 h radiotracking effort of an adult flathead catfish, 750 mm total length. Area within box enlarged in bottom panels. b) 24 h movement path viewed with relocations every 15 m. c) Set of lines from the arithmetic mean of the relocation points to each point (termed spider analysis after the shape of the resulting graphics). Mean length of the set of lines is reported as the activity radius in Table 1

some fish made much longer movements (up to 412 m; Fig. 3). During the midnight hour a reduction in movement activity was observed, although the few movements that individual fish did make were greater than 50 m. The third period of increased activity began during the 100 hour and ended at sunrise during the 500 hour. After sunrise reduced activity was

TABLE 1.—Descriptive statistics for 24 h movement paths obtained from 6 radio-tracked flathead catfish from the Grand and Cuivre Rivers, Missouri, USA. Activity radius is the mean distance from the arithmetic mean (of the set of relocations used during the 24 h movement path) to each relocation. Revisitation index is the total number of locations used temporally, divided by the number of unique locations used spatially

	Median	Mean	Min.	Max.
Length of Movement Path (m)	641.16	712.02	145.53	1553.34
Activity Radius (m)	66.55	105.05	18.96	282.04
Number of Discrete Movements	13.50	13.33	6.00	21.00
Number of Unique Locations Used	8.50	8.50	5.00	13.00
Revisitation Index	1.43	1.68	1.11	2.44
Time Stationary (h)	23.33	23.07	22.25	23.50
Time Moving (h)	0.67	0.93	0.50	1.75

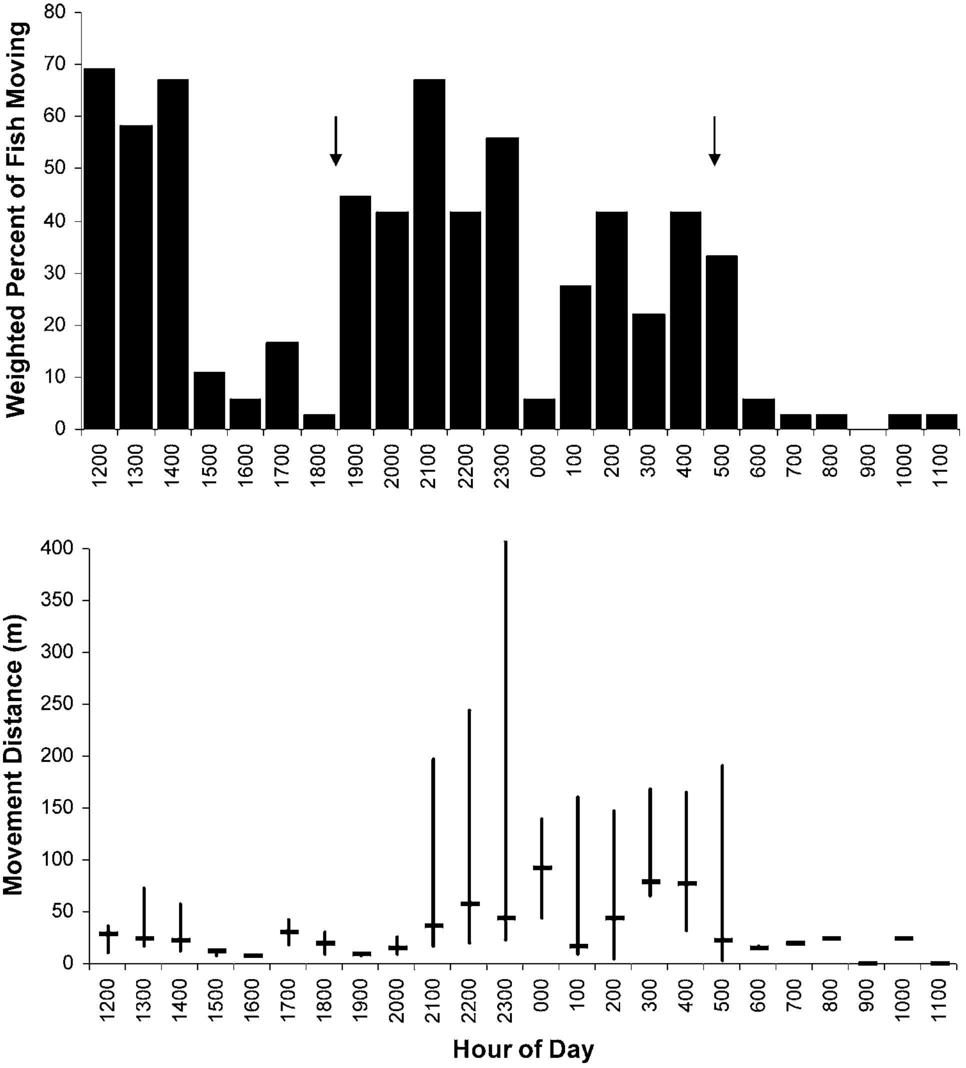

FIG. 3.—The percent of flathead catfish moving weighted by the number of discrete movements made by those fish per hour of day (top panel). The median distance (horizontal dashes) and range (vertical lines) of discrete movements made by the radiotracked fish by hour of day (bottom panel)

apparent through the 1100 hour. Movements made during this morning period of reduced activity were less than 50 m. Summed over the 24 h sampling period the radiotracked fish spent a median 23.33 h stationary and ranged from 22.25–23.50 h. Time spent moving was a median 0.67 h and ranged from 0.50–1.75 h (Table 1).

DISCUSSION

Flathead catfish have long been described as sedentary (Funk, 1957; Robinson, 1977; Dames *et al.*, 1989; Jackson, 1999). Our results generally support that statement for the late summer/early fall postspawn period in north Missouri. We were surprised, however, at the number of short directed movements made by flathead catfish during the diel cycle. Therefore, although individual fish spent little time actually moving, they were in fact relatively mobile. Skains (1992) reported that radiotracked fish had 1–3 'home sites' that they returned to after nighttime movements. Flathead catfish in both the Grand River and Cuivre River had locations at which they spent relatively more time during the diel cycle, and from the ongoing point-in-time tracking, we knew these locations to be frequented. However, the use of many locations during the diel cycle forces a reevaluation of the definition of sedentary usually attributed to the species. Had we not continuously tracked individuals and relied solely on the point-in-time telemetry contacts, the results would have lacked the resolution to make the distinction between mostly stationary behavior at a few locations and the stationary behavior punctuated by many short, discrete movements among several locations that we documented.

That flathead catfish were most active at night was not surprising as all the Ictaluridae are presumed to be nocturnal (Pflieger, 1997). Many other fish species are reportedly more active at night, such as freshwater eels *Anquilla* spp. (Jellyman and Sykes, 2003), lacustrine brook charr *Salvelinus fontinalis* (Bourke *et al.*, 1996) and brown trout *Salmo trutta* (Young, 1999). However, northern pike *Esox lucius* moved during daylight and were inactive at night (Diana, 1980). Smallmouth bass *Micropterus dolomieu* displayed a crepuscular diel pattern in an Ozark stream (Todd and Rabeni, 1989).

Considered top predators in the prairie streams of north Missouri, flathead catfish diel movement patterns are suggestive of a lurking, lie-in-wait ambush predator. Becker (1983) used the term passive predator to describe the flathead catfish. Also an ambush predator, northern pike is reported to be primarily sedentary, but did not have fidelity to sites in an Alberta, Canada lake (Diana, 1980). A similar movement pattern to northern pike was documented for seven radio-tracked black piranha *Serrasalmus rhombeus* in an oxbow lake in Peru (Cohen *et al.*, 1999). Black piranha diel movement was considered discontinuous. This is in apparent contrast to predatory adult brown trout, which were active 9–14 h during diel radiotracking in high-elevation streams (Young, 1999). Brown trout tended to leave diurnal locations after sunset and move throughout the night. However, unlike flathead catfish, brown trout are suspected to spend considerable time feeding on drifting invertebrates by making quick movements into the thalweg from resting locations (Bachman, 1984), but are also known to consume whole fish, frogs and crustaceans (Goldstein and Simon, 1999; Alexander, 1977). Brown trout returned to the same diurnal locations they departed from at sunset the following sunrise (Young, 1999). Seven flathead catfish tracked hourly for 24 h in the St. Joseph River, Michigan, returned to pre-dusk locations the following morning 63% of the time (Daugherty and Sutton, 2005). Our flathead catfish did not appear to make efforts to return to a specific location by sunrise although activity radii were small and fish typically ended up within 150 m of their previous midday location.

There was general agreement between the 24 h continuous tracking results and the point-in-time locations for aspects of the diel cycle. The median and mean time moving during the 24-h tracking when expressed as a percentage of the total 24 h period was 2.79% (median) and 3.88% (mean) and surrounded the 3.68% point-in-time relocations recorded as moving. The diel timing of the bulk of the moving point-in-time relocations also largely occurred within the two nighttime activity periods suggested by the 24 h continuous tracking. The point-in-time relocations considered independently suggest that the second activity period occurring after sunset is when flathead catfish are the most active, as 41% of moving relocations occurred then. This is likely an artifact of the length of movements that occurred during the second activity period, which we suspect from the continuous tracking results. Longer discrete movements would tend towards more opportunity to contact a particular fish while moving. The finer detail of the continuous tracking revealed that the first early afternoon activity period had very similar activity levels in both the number of fish and number of movements which occurred, although the lengths of movements were much shorter decreasing the likelihood that point-in-time tracking would have detected movement activity.

The purpose of the seeming 'short break' in activity near midnight in the continuous tracking data is difficult to explain within documented flathead biology nor has a similar midnight cessation of activity been reported for another species. We found it interesting that angler lore states that flatheads bite from evening until the 1100 hour, with a second bite occurring during the early morning hours to sunrise. The activity period in the early afternoon was unanticipated and also is difficult to explain. One hypothesis is that as the sun passes overhead, the shadowed-side of habitat features changes sides, and that individuals may make movements to a more concealing position to facilitate opportunistic feeding.

Although sample sizes are insufficient for a formal test of the continuous data, there were no indications that size, sex or river affected the length of the movement path or the number of movements made in the diel cycle. The lengths of the movement paths were variable ranging from approximately 150–1500 m. The length of the movement path was not entirely a function of the activity level (number of movements) of the individual, but also varied with the spatial arrangement of habitat features. For example, two fish traveled approximately 800 m during the diel tracking period. One individual made 9 discrete movements in a relatively spread out habitat matrix while the second made 18 discrete movements in a stream pool with more closely spaced habitat features. Habitat structure and availability can affect the movement and activity of predatory fish, potentially altering energetic demands. Largemouth bass *Micropterus salmoides* observed in a channelized river in Florida congregated in high densities in the relatively few structurally complex habitats and spent an elevated amount of time hunting, presumably increasing energetic demands (Annett, 1998). Comparison of the movement paths of flathead catfish under differing habitat conditions warrants future research. Overall, we documented high similarity of the diel pattern among individuals in both rivers. Noteworthy was the synchronous nature of the three movement periods and the small range in the time moving and time stationary values.

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LITERATURE CITED

ALEXANDER, G. R. 1977. Consumption of small trout by large predatory brown trout in the north branch of the Au Sable River, Michigan. Fisheries Research Report 1855. Michigan Department of Natural Resources, Ann Arbor.

ANNETT, C. A. 1998. Hunting behavior of Florida largemouth bass, *Micropterus salmoides floridanus,* in a channelized river. *Env. Biol. Fishes,* **53**:75–87.

BACHMAN, R. A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. *Trans. Am. Fish. Soc.,* **113**:1–32.

BECKER, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1052 p.

BOURKE, P., R. MAGNAN AND M. A. RODRÍGUEZ. 1996. Diel locomotor activity of brook charr, as determined by radiotelemetry. *J. Fish Biol.,* **49**:1174–1185.

COHEN, M. A., W. R. C. BEAUMONT AND N. C. THORPE. 1999. Movement and activity patterns of the black piranha. *Env. Biol. Fishes,* **54**:45–52.

DAMES, H. R., T. G. COON AND J. W. ROBINSON. 1989. Movements of channel and flathead catfish between the Missouri River and a tributary, Perche Creek. *Trans. Am. Fish. Soc.,* **118**:670–679.

DAUGHERTY, D. J. AND T. M. SUTTON. 2005. Diel movement patterns and habitat use of flathead catfish in the lower St. Joseph River, Michigan. *J. Freshw. Ecol.* **20**:1–8.

DIANA, J. S. 1980. Diel activity pattern and swimming speeds of northern pike (*Esox lucius*) in Lac Ste. Anne, Alberta. *Can. J. Fish. Aquat. Sci.,* **37**:1454–1458.

FUNK, J. L. 1957. Movement of stream fishes in Missouri. *Trans. Am. Fish. Soc.,* **85**:39–57.

GOLDSTEIN, R. M. AND T. P. SIMON. 1998. Toward a united definition of guild structure for feeding ecology of North American freshwater fishes, p. 123–202. *In:* T. P. Simon (ed.). Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.

HART, L. G. AND R. C. SUMMERFELT. 1974. Homing behavior of flathead catfish, *Pylodictis olivaris* (Rafinesque), tagged with ultrasonic transmitters. *Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm.,* **27**(1973):520–531.

HEBRANK, A. W. 1989. Geologic natural features classification system for Missouri. *Nat. Areas J.,* **9**: 106–116.

HERNDON, T. M., JR. AND C. T. WATERS. 2002. Flathead catfish diet analysis, stock assessment, and effects of removal on Sutton Lake, North Carolina. *Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm.,* **54**(2000):70–79.

HOOGE, P. N. AND B. EICHENLAUB. 2000. Animal movement extension to Arcview, version 2.0. Alaska Science Center, Biological Science Office, U.S. Geological Survey, Anchorage.

JACKSON, D. C. 1999. Flathead catfish: biology, fisheries, and management, p. 23–35. *In:* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr. and T. Coon (eds.). Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Bethesda, Maryland.

JELLYMAN, D. J. AND J. R. E. SYKES. 2003. Diel and seasonal movements of radio-tagged freshwater eels, *Anguilla* spp., in two New Zealand streams. *Env. Biol. Fishes,* **66**:143–154.

KERNOHAN, B. J., R. A. GITZEN AND J. J. MILLSPAUGH. 2001. Analysis of animal space use and movements, p. 125–166. *In:* J. J. Millspaugh and J. M. Marzluff (eds.). Radio tracking and animal populations. Academic Press, San Diego.

PACE, R. M., III. 2001. Estimating and visualizing movement paths from radio-tracking data, p. 189–206. *In:* J. J. Millspaugh and J. M. Marzluff (eds.). Radio tracking and animal populations. Academic Press, San Diego.

PFLIEGER, W. L. 1997. The fishes of Missouri, revised ed. Jefferson City: Missouri Department of Conservation. 372 p.

QUINN, S. P. 1988. Investigations into the biology of the flathead catfish (*Pylodictis olivaris*) in the lower Flint River, and the promotion of this species as a fisheries resource for Flint River fisherman. Federal Aid Project F-28-15. Georgia Department of Natural Resources, Game and Fish Division, Atlanta. 57 p.

ROBINSON, J. W. 1977. The utilization of dikes by certain fishes in the Missouri River. Federal Aid Project 2. 199R. Missouri Department of Conservation, Jefferson City. 14 p.

SCHROEDER, W. A. 1982. Pre-settlement prairie of Missouri. Natural History Series 2. Missouri Department of Conservation, Jefferson City. 38 p.

SKAINS, J. A. 1992. Linear home range and movements of flathead catfish (*Pylodictis olivaris*) in two Mississippi Streams. M.S. Thesis, Mississippi State University, Mississippi State. 75 p.

——— AND D. C. JACKSON. 1995. Linear ranges of large flathead catfish in two Mississippi streams. *Proc. Ann. Conf. Southeast. Assoc. Fish and Wildl. Agencies,* **47**(1993):539–546.

STAUFFER, K. W., R. C. BINDER, B. C. CHAPMAN AND B. D. KOENEN. 1996. Population characteristics and sampling methods of flathead catfish *Pylodictis olivaris* in the Minnesota River. Study IV, Job 389, Final Report. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries, St. Paul. 60 p.

SUMMERFELT, R. C. 1972. Flathead catfish movements. Completion Report, Oklahoma Project 4-60-R. National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce, Washington, D.C.

THOMAS, M. E. 1995. Monitoring the effects of introduced flathead catfish on sportfish populations in the Altamaha River, Georgia. *Proc. Ann. Conf. Southeast Assoc. Fish and Wildl. Agencies,* **47**(1993):531–538.

TODD, B. L. AND C. F. RABENI. 1989. Movement and habitat use by stream-dwelling smallmouth bass. *Trans. Am. Fish. Soc.,* **118**:229–242.

YOUNG, M. K. 1999. Summer diel activity and movement of adult brown trout in high-elevation streams in Wyoming, U.S.A. *J. Fish Biol.,* **54**:181–189.

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