Assessment Of Range, Habitat Use, And Diel Movement Of Flathead Catfish (Pylodictis Olivaris) In The Wabash River Using Ultrasonic Telemetry

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ASSESSMENT OF RANGE, HABITAT USE, AND DIEL MOVEMENT OF FLATHEAD CATFISH (*PYLODICTIS OLIVARIS*) IN THE WABASH RIVER USING ULTRASONIC TELEMETRY

(TITLE)

BY

Sarah Mary Huck

THESIS

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ABSTRACT

Flathead Catfish (*Pylodictis olivaris*) are one of the most targeted species for recreational and commercial fishing within the Mississippi River Basin. With heavy harvest pressure placed on many populations, proper management is crucial; however, the species range, habitat requirements, and diel movement patterns have rarely been investigated in free flowing rivers. Therefore, I used ultrasonic telemetry with active tracking to monitor movement and habitat use of 44 Flathead Catfish from August 2012 to December 2013 in the lower 280 km of the Wabash River. This system is ideal to evaluate broad and fine scale movement of Flathead Catfish because the population is well-established and individuals are able to move without restriction caused by impoundments. Fish were located by reach and diel tracking performed seasonally, and monthly site specific tracking. I found that Flathead Catfish exhibit relatively small movements within a localized annual range (< 12 km). Most often, fish were observed using shoreline habitat, specifically, outside bends and channel borders containing dense woody debris. Although there was no seasonal difference in the range of movement, season was a major driver in daily activity and habitat use. Flathead Catfish showed the most diel movement during summer, utilizing shoreline and main channel habitats, whereas movement decreased dramatically during winter when fish only used shorelines. Results from my research indicate habitat requirements for Flathead Catfish during annual spawning and overwintering are found in outside bends containing logjam structure. I suggest these areas are crucial for the species persistence within lotic systems and should be recognized as such. Managers can use this information to ensure habitat requirements are met and to assist

with development of restoration and conservation strategies if future populations begin to decline.

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GENERAL INTRODUCTION

Freshwater fishes continue to decline despite conservation efforts to recover threatened and endangered species within their native ranges. The lack of successful reestablishment is partially due to focusing on habitats and species that are already degraded (Williams et al. 2011). Therefore, it is crucial to understand habitat requirements of a well-established native population in order to ensure its persistence. To evaluate habitat contributing to the success of a species, biologists monitor movement of individuals. Fishes move to satisfy various fundamental requirements of life, such as food, shelter, and spawning (Lucas & Baras 2000); thus, by monitoring movement of individuals year round, we can assess habitat use during different life history stages (spawning, feeding and growth, and overwintering). Managers can use this information to restore and protect critical habitat and define the geographic extent of management regulations. Within the past few decades, telemetry has been shown to be a valuable tool used to locate individuals in their natural setting (Lucas & Baras 2000).

Telemetry in aquatic systems has become more prevalent in recent years and has dramatically improved our understanding of fish movement and habitat use (Adams et al. 2012). Telemetry involves a transmitter (tag) that is attached or implanted in an animal, and a receiver, which is used to locate and gather information about the location, movement, and environment of the tagged individual. There are two basic categories of telemetry, acoustic and radio. Acoustic telemetry is based on principals of sonar and is favored in deep waters with high conductivity and low turbulence (Winter 1996). Radio telemetry is based on wireless radio communication and is best suited in shallow waters with low conductivity (Adams et al. 2012). With either type, tagged individuals can be relocated overtime and easily monitored using active or passive tracking methods. Due to the popularity of migration research of fish, passive receivers are most often used to collect presence/absence data (Rogers & White 2001). However, active tracking allows for intimate evaluation of the surrounding environment and can provide detailed information about habitat requirements for fish survival (Adams et al. 2012).

Although commercially and recreationally important, our understanding of Flathead Catfish (*Pylodictis olivaris*) movement and habitat use in free flowing rivers is somewhat vague. Flathead Catfish are large (> 50 kg) piscivorous carnivores native to the Mississippi, Mobile, and Rio Grande River drainages (Lee & Terrell 1987), and have been widely introduced throughout much of the United States and Canada (Jackson 1999, Pflieger 1971). In addition to being a valuable game fish, the species also is commercially exploited in many systems (Jackson 1999). Although they are found in both lentic and lotic environments, they are generally considered a riverine species (Lee & Terrell 1987). In the Mississippi River Basin, Flathead Catfish are considered the most important trophy fishery to anglers (Arterburn et al. 2002, Wilde & Ditton 1999). In a 2002 survey, the majority of catfish anglers fished large rivers when pursuing a trophy fish (Arterburn et al 2002). Due to the importance of Flathead Catfish in lotic systems, it is essential managers understand their mobility and are able to identify important habitat for the population's survival and persistence.

Flathead Catfish have long been described as relatively immobile (Funk 1957, Pflieger 1971, Skains & Jackson 1993), but recent literature has shown opposing results (Stauffer et al. 1996, Daugherty & Sutton 2005a, Vokoun & Rabeni 2005a). Research involving mark-recapture methods suggest Flathead Catfish show restrictive movement behavior (Dames et al. 1989, Skains & Jackson 1993, Travnichek 2004); however, with advances in telemetry, biologists have been able to re-evaluate the species and several authors have documented seasonal migrations (> 63.4 km) associated with spawning and overwintering (Stauffer et al. 1996, Daugherty & Sutton 2005a, Vokoun & Rabeni 2005a). These large movements may suggest critical habitats are not present within the river, but to understand this, biologists must evaluate the species in a variety of ecologically diverse aquatic systems. Much of the past research has observed fish movement between tributaries (Skains & Jackson 1993, Vokoun & Rabeni 2005b, Garrett & Rabeni 2011), or within small reaches (less than 50 km) of free flowing rivers (Daugherty & Sutton 2005a, Shroyer 2011). To date, Flathead Catfish have not been observed in large reaches of a moderately sized free flowing river. This is vital because managers must be aware of possible variability in movement behavior depending on the ecology of the river. In order to properly manage Flathead Catfish in free flowing rivers, we must monitor movements and assess habitat use; therefore further research is necessary.

Whereas accurate information regarding the extent of Flathead Catfish movement (broad scale) is important to manage the species within the appropriate geographic boundary, evaluation of fine scale movement can provide a more accurate representation of mobility and habitat use. Flathead Catfish have been described as a species with nocturnal and crepuscular activity based on nighttime feeding patterns (Minckley & Deacon 1959, Quinn 1987). Interestingly, diel movements and habitat use has rarely been investigated (Daugherty & Sutton 2005b, Malindzak 2006, Vokoun & Rabeni 2006) and of this research, none have monitored fish during all seasons. Although studies generally conclude Flathead Catfish exhibit nocturnal activity (Daugherty and Sutton 2005b, Malindzak 2006), increased movement has been reported during other times of the daily cycle (Vokoun & Rabeni 2006, Brewster 2007). Evaluating fine scale movements of Flathead Catfish, year round, allows biologists to observe habitat requirements associated with spawning, growth, and overwintering.

Catfishes (Ictaluridae) are of utmost importance in the Wabash River, particularly in the boundary water between Illinois and Indiana. A survey in 2005 and 2006, found catfish were the most targeted fishes, and estimated recreational and commercial anglers harvested approximately 6,723 Flathead Catfish, weighing 34,747 lbs, from the Wabash River (Clark-Kolaks et al. 2011). Despite heavy harvest pressure, the lower 300 km of the Wabash River is home to a well-established, healthy Flathead Catfish population (Moody 2013), which suggests resources are currently suitable for spawning, feeding and growth, and overwintering. The river runs over 800 km with the lower 661 km free of barriers, making the Wabash River the longest free flowing river east of the Mississippi River (Skibsted 2012). Furthermore, passive receivers have been stationed within the upper 288 km of the free flowing reach due to an ongoing Asian Carp monitoring project (Coulter et al. 2012). Due to the uniqueness of the system and the lack of Flathead Catfish movement data, I chose to monitor the population in the lower 280 km. This reach is essential because understanding Flathead Catfish movement in a large unimpounded system can provide insight to habitat that is important for a sustainable fishery. The information gathered from my study will inform managers of baseline habitat requirements in similar ecosystems, and ensure these areas are available in the Wabash River if future populations begin to show signs of decline.

OBJECTIVES

- Evaluate annual and seasonal broad scale movements and habitat use of Flathead Catfish in the lower Wabash River.
    - Determine the extent of annual range of movement
    - Identify annual and seasonal habitat use and selection
    - Assess seasonal differences in range and habitat use
- Evaluate annual and seasonal diel (fine scale) movement and habitat use of Flathead Catfish in the lower Wabash River.
    - Determine daily movement patterns and habitat use each season
    - Assess annual and seasonal daily movement cycle and habitat use

GENERAL METHODS

Study Sites

The Wabash River is the largest undammed river east of the Mississippi River, with a total land area of 137,269 square km (Skibsted 2012). The river begins in western Ohio and flows over 800 km; it runs west through Indiana, then south along the Illinois/Indiana border until it reaches its confluence with the Ohio River, in southern Illinois. The lower 643 km is completely free flowing (unimpounded), making it ideal for evaluating fish movement without barriers. Recently, population dynamics were evaluated within the lower Wabash River and found that the Flathead Catfish population is healthy and well-established (Moody 2013). I focused on the boundary water between Illinois and Indiana because upstream of river km 288 there is a passive receiver network monitored by Purdue University (Coulter et al. 2012). Since no tagged Flathead Catfish were detected by these receivers, I focused my active tracking efforts on the lower 280 km of the river. I selected four tagging sites based on accessibility of the river throughout the year; Darwin, Illinois (river km 265.54), Hutsonville, Illinois (river km 237.38), St. Francisville, Illinois (river km 147.26), and New Harmony, Indiana (river km 67.59) (Figure 1).

Flathead Catfish Sampling

I collected Flathead Catfish greater than 680 grams (g) using low pulse (15 kHz) direct current (DC) boat electrofishing. The size requirement of the fish was to ensure the transmitter weight, in air, did not exceed 2% of the fish's body weight, thus inhibiting or restricting natural movements (Winter 1996). In June, July, and November 2012, I implanted coded ultrasonic transmitters in the peritoneal cavity of 24 Flathead Catfish; eleven at Darwin, seven at New Harmony, and six at St. Francisville. In June and July 2013, I used DC boat electrofishing with the addition of a chase boat to collect and tag a total of 20 Flathead Catfish; six at Darwin, five at Hutsonville, and nine at New Harmony. In total, 44 Flathead Catfish were tagged with ultrasonic transmitters from June 2012 through July 2013; seventeen at Darwin, five at Hutsonville, six at St. Francisville, and sixteen at New Harmony.

Ultrasonic Transmitters

I surgically implanted 69 kHz coded ultrasonic transmitters (tags) from Sonotronics (model CT-82-2-I; Tucson, Arizona) and Vemco (model V13-1x-69kHz; Nova Scotia, Canada) in the body cavity of Flathead Catfish. Transmitters were cylindrical, 53 mm long and 15.6 mm in diameter (Sonotronics), and 36 mm long and 13 mm in diameter (Vemco), with a battery life of 14 months. Both transmitter types had a maximum detection range of approximately 300 meters (field tested). One month prior to tagging, I secured a 10 mm piece of coffee straw to the flat end of the transmitter with marine two part epoxy. This attachment was used to secure the transmitter to the pectoral girdle during surgery. Including the coffee straw, Sonotronics transmitters weighed approximately 19 g in air and Vemco transmitters weighed approximately 10 g in air; therefore, fish greater than 680 g were implanted with Vemco transmitters and fish greater than 700 g were implanted with Sonotronics transmitters.

Surgery

Prior to surgical implantation of transmitters, I measured Flathead Catfish to the nearest millimeter in total length and weighed them to the nearest gram. In order to easily identify tagged fish externally, I attached a Floy tag, containing an individual identification number and Eastern Illinois University contact information, to the dorsal fin origin of each fish. To begin the surgery, I placed the fish, ventral side up, on a wooden v-frame surgical trough (lined with wetted wash cloths) and covered the body and head with wetted towels. Throughout the duration of the surgery (approximately 7 minutes), an assistant continuously flushed fresh water over the gills of the fish. Prior to use, I cleaned all surgical tools with 200 proof ethyl alcohol. I used a scalpel to cut an incision through the mid-right ventral side body wall (halfway between the pectoral and pelvic fins) and into the peritoneal cavity. The completed opening, approximately 35 mm, was only as large as required to admit the transmitter. To attach the transmitter to the pectoral girdle, I threaded an ethilon non-absorbable suture (with the needle cut off) (Ethicon; Material: Black monofilament; Suture length: 45 cm; Pliabilized) through the coffee straw attachment. Then, I used a covered needle (Siegwarth & Pitlo 1999) to guide the suture through the body cavity and secure it around the pectoral girdle. Once the transmitter was fully inside the body cavity, I closed the incision with three evenly placed ethilon non-absorbable sutures (Ethicon; Material: Black monofilament; Needle type: PS-4; Suture size: 6-0; Needle length: 16 mm; Needle shape: ½ circle; Suture length: 45cm; Pliabilized) using a simple interrupted suture pattern (Wagner et al. 2000). Immediately after surgery I placed the fish in an aerated live-well for 10 minutes. After the recovery period, I released the fish and recorded the time, date, GPS coordinates

(Garmin GPSmap62s), temperature (° C) (YSI-85 multi-meter), conductivity (μS) (YSI-85 multi-meter), and dissolved oxygen (mg/L) (YSI-85 multi-meter).

Active Tracking

To locate tagged Flathead Catfish, I conducted active tracking with a Sonotronics USR-08 Manual Receiver (Sonotronics, Tuscon, Arizona). During all methods of active tracking, I drove the boat between 6 and 11 km per hour downstream, while towing an omnidirectional hydrophone. When the receiver detected a transmitter signal, I maneuvered the boat to determine an approximate location, depending on the omnidirectional signal strength (loudness). When the signal was strongest, I lowered the gain on the receiver (to reduce background noise) and used a submersible directional hydrophone (mounted to the end of a 2 m long polyvinyl chloride (PVC) pipe). Using the directional hydrophone, I was able to determine the fish location, based on the direction from which the transmitter signal was originating and the signal strength. Once the transmitter code was read by the receiver, and the signal was at its loudest, I anchored the boat in that location and recorded; the fish identification number, time, date, GPS location (Garmin GPSmap62s), depth (m) (Lowrance depth finder), secchi (m) (secchi disk), substrate type (petite ponar), temperature (°C) (YSI-85 multi-meter), conductivity (μS) (YSI-85 multi-meter), dissolved oxygen (mg/L) (YSI-85 multi-meter), flow (m/s) (Marsh-McBirney hand held flow meter), habitat, microhabitat, and behavior (active or sedentary) of the fish.

Reach and Site Specific Tracking

Seasonally, I actively tracked the lower 280 km of the Wabash River (termed, 'reach tracking'). I began 15 km upstream of the Darwin (IL) boat ramp and continued down the middle of the river, ending at the confluence of the Ohio River. This method of active tracking was conducted during day light hours only. The end tracking point for one day became the starting point for tracking the following day. Typically, reach tracking was completed in approximately one week.

I supplemented reach tracking with monthly site specific tracking (termed 'site tracking'). This method was also conducted during day light hours. I actively located fish within approximately 12 km of each site, but this varied depending on maneuverability during low water levels. To increase chances of locating all possible tagged fish, I actively tracked both shorelines and the main channel at each site. Site tracking each month was typically completed within two days.

Diel Tracking

Diel active tracking was conducted at least once a season at Darwin or Hutsonville, Illinois. Tracking began between 1500 hours and 1700 hours at the most upstream point of the site. The identification of the first Flathead Catfish marked the start of diel tracking and determined the individual that would be monitored throughout the 24 hour period. After the first fish observation, I continued tracking the surrounding area to determine if other tagged individuals were within close proximity. If other fish were located, and time permitted, each fish was located every hour. In several cases, more than three Flathead Catfish moved in and out of the area during the diel cycle. I monitored movements of two fish in September 2012, October 2012, December 2012, and August 2013, and one fish in May 2013, July 2013, and September 2013.

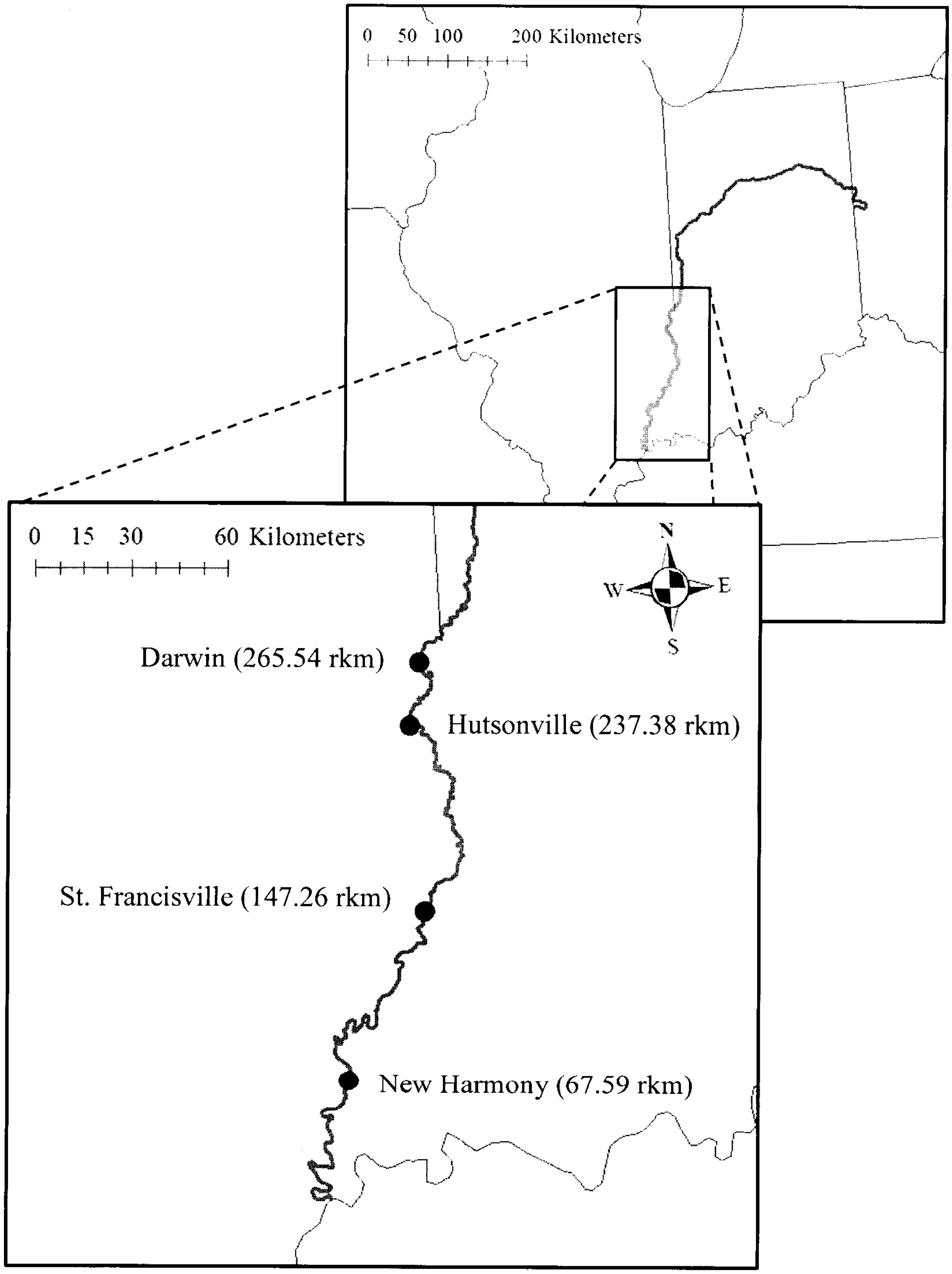

Figure 1. Map of tagging sites within the lower 280 km of the Wabash River.

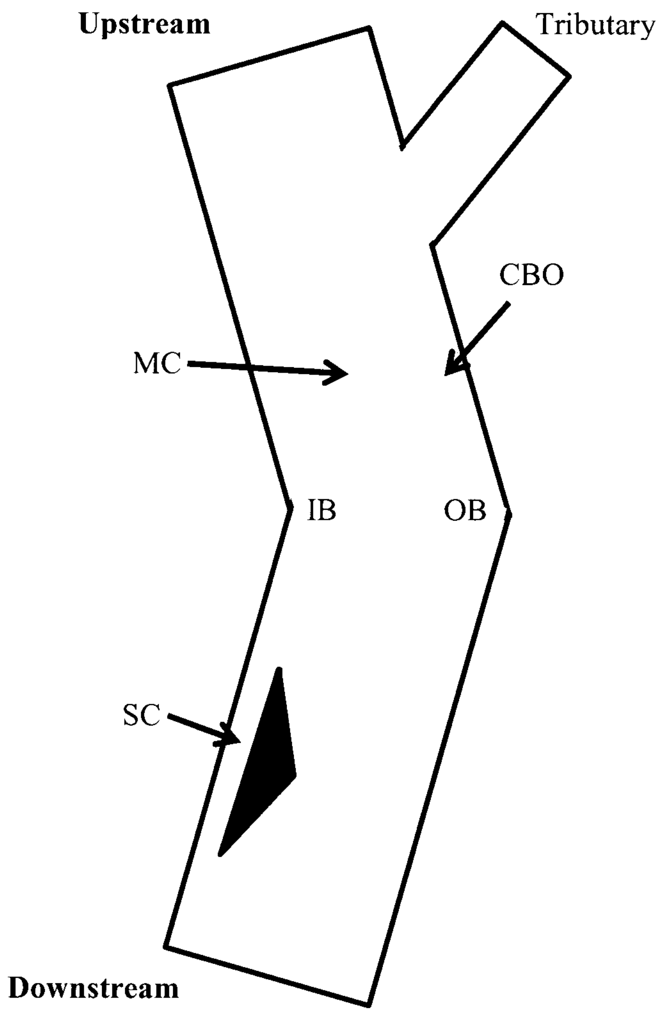

Figure 2. A diagram showing habitat classifications in a river, based off Cobb (1989). Habitat types include; OB (outside bend), CBO (channel border open), IB (inside bend), MC (main channel), and SC (side channel).

Chapter 1: Range and Habitat Use of Flathead Catfish (*Pylodictis olivaris*) in the Lower Wabash River

INTRODUCTION

Flathead Catfish (*Pylodictis olivaris*) are one of the most sought after species within the Mississippi River Basin. Recreational anglers target this large, aggressive, predator for the thrill of a good fight, while commercial fishermen want them for their flavorful meat (Jackson 1999, McCoy 1953). Although Flathead Catfish are an important resource within their native range, only a few studies have examined their movement and habitat use (Dames et al. 1989, Skains & Jackson 1993, Daugherty & Sutton 2005a, Vokoun & Rabeni 2005a & b, Shroyer 2011). This research, however, has provided variable results, with some authors concluding Flathead Catfish exhibit large migrations during the year (Vokoun & Rabeni 2005a & b), and others describing the species as relatively immobile (Skains & Jackson 1993). To allow managers to properly define the geographic extent of regulations and ensure habitat requirements are met, movement research must be implemented in a variety of ecologically different lotic systems. In order to ensure the health and persistence of native Flathead Catfish populations in Midwestern rivers, accurate movement and habitat use information is necessary.

For decades, Flathead Catfish have been considered a species with restricted movement behavior (less than 2 km) (Funk 1957, Dames et al. 1989, Skains & Jackson 1993). Several studies suggest they are generally sedentary, establishing seasonal areas of repeated use (Dobbins et al. 1999, Skains, 1992, Pugh & Schramm 1999, Weller & Winter 2001). Therefore, authors suggest localized management regulations (Skains &

Jackson 1993, Jackson 1999, Travnichek 2004). However, highly mobile individuals have been documented in the Missouri River (313 km) (Dames et al. 1989), Minnesota River (105 km) (Stauffer et al. 1996), and Missouri streams (187 km) (Vokoun & Rabeni 2005a & b). In which case, a watershed scale approach would be suggested. Due to varying results on the range of Flathead Catfish movement in lotic systems, it is clear that further evaluation is needed in order to assign appropriate management strategies.

Flathead Catfish are known to repeatedly use specific areas for spawning and overwintering (Dames et al. 1989, Stauffer et al. 1996, Vokoun & Rabeni 2005b). For example, Skains (1992) found fish in Mississippi River streams had one to three "home sites" which were heavily used and Stauffer et al. (1996) documented site fidelity to summer home ranges and overwinter pools. With evidence showing Flathead Catfish repeatedly use specific locations during some times of the year (Dames et al. 1989, Daugherty & Sutton 2005a, Lee & Terrell 1987, Minckley & Deacon 1959), habitat appears to play a key role contributing to population health. To accurately evaluate these environmental factors, biologists must locate individuals and assess their surroundings, ideally with little disturbance to the fish. Habitat affinities suggest discrete management plans in lotic systems can be established, but defining these strategies may depend on fish movements within a specific river (Skains & Jackson 1993). Therefore, habitat use of Flathead Catfish must be evaluated within the system that management regulations will occur.

To assess movement and habitat use of Flathead Catfish, I chose to examine the population in the lower 280 km of the Wabash River. The Wabash River is a large Ohio River tributary draining 85,340 km^2 (Pyron et al. 2006). The river runs over 800 km before reaching its confluence in southern Illinois and has a mean discharge at its mouth of 1,000 $m^3 s^{-1}$ (Pyron et al. 2006). This reach is ideal to monitor movements of Flathead Catfish because it is free flowing, allowing fish to move without barriers. In addition, the population is currently well-established and healthy (Moody 2013), so movement of individuals will provide insight to habitats contributing to their success. Along with these qualities, Flathead Catfish movement has not been studied in the lower Wabash River, so my research will provide new information about the species in this system. Furthermore, my results will offer baseline habitat requirements for Flathead Catfish in similar rivers.

To maintain the health of Flathead Catfish populations in their native range, it is crucial biologists understand year round habitat requirements and movement. With the use of ultrasonic telemetry, I will provide novel information about Flathead Catfish mobility and habitat use in the free flowing reach of the Wabash River. This information will allow managers to maintain the health of this population in the future, and ensure habitat requirements are met in similar systems. Therefore, the objectives of my study are to evaluate annual and seasonal 1) range of movement, and 2) habitat use and selection of Flathead Catfish in the lower Wabash River.

METHODS

Data Analysis

Data used in statistical analyses were obtained using active tracking methods; which included reach tracking, site tracking, and the first location of an individual during diel tracking (see General Methods). Spring was defined as March-May, summer as June-August, fall as September-November, and winter as December-February. All statistical analyses were conducted using SAS 9.3 (SAS Institute 2011), SigmaPlot Version 11.0 (Systat Software Inc.), and R Version 3.0.3 (R Core Team 2014). Geographic coordinates of locations were mapped in ArcMap 10.0 and distances between successive individual fish locations were calculated as the shortest linear distance in the river. The range of an individual was measured as the linear distance in the river; from the most upstream location, to the most downstream location. Fish that were located at least twice were used in range analyses.

To analyze seasonal variation in movement and range, I used a Kruskal-Wallis one way analysis of variance (ANOVA) followed by a post hoc Dunn's multiple comparisons test. Linear regression analyses were used on natural log transformed ranges to determine the relationship between the size of an individual fish and their annual extent of movement. Averages of movement analyses were reported ± standard error (SE).

In order to analyze habitat use, I differentiated types based on a modification of Cobb (1989), as suggested by Koch et al. (2012) (Figure 2). Shoreline habitats include outside bend (OB), channel border open (CBO), and inside bend (IB). Microhabitat categories were defined as follows; logjam is a shoreline with woody debris/ terrestrial structure in the water, run is a shoreline with swift flowing water and no debris/structures (includes eddy, eroded banks and non-eroded banks), rip rap is a shoreline that contains large boulders, sand bar is a sand or gravel shoreline caused from sediment deposition, and the thalweg is the deepest, fastest flowing part of the river. To determine if habitat and microhabitat of fish locations were randomly distributed annually and within seasons, I used a likelihood ratio chi-squared analysis using the proportion of observations per habitat (and microhabitat) type.

In order to determine if Flathead Catfish were selective in habitat types being used annually (including all sites), annually within each site, and seasonally (including all sites), I calculated habitat selection ratios, suggested by Manly et al. (1993). In order to calculate the proportion of each habitat type, I used ArcMap 10.0 to measure the total area of each site (extent of site was dependent on range of fish locations) and the area of each habitat type (m^2). To determine how fish were distributed among habitat categories, I used a chi-square test on two null hypotheses. The first was that fish locations were uniformly distributed across habitat types, and the second hypothesis was that the proportion of habitat used by individual fish was equal to the proportion of habitat available. In order to test the first hypothesis I used the equation presented by Manly et al. (1993) (Rogers & White 2001):

$$\mathrm{X}_{L1}^2 = 2\sum_{j=1}^{n}\sum_{i=1}^{l} u_{ij} log_e[\frac{u_{ij}}{E(u_{ij})}]$$

Where $E(u_{ij}) = u_{i+}u_{+j}/u_{++}$. In this test, u_{ij} is the amount of habitat type *i* used by fish *j*, u_{i+} is the amount of habitat type *i* used by all fish, u_{+j} is the total amount of habitat units used by fish *j*; and u_{++} is the total number of habitat units used by all fish.

If the value of X^2 is large in comparison with the chi-square distribution with $(I\text{-}1)(n\text{-}1)$ df (I = number of habitat categories and n = number of fish), then fish are not distributed equally across habitats (Manly et al., 1993; Rogers & White, 2001).

For the second hypothesis, I used the same log-likelihood test statistic, but instead, $E(u_{ij}) = \pi_i u_{+j}$, where π_i is the proportion of available habitat units composed of habitat type i. With this test, selection or avoidance is established if X^2 is large with n $(I\text{-}1)$ df. The difference between the two chi squares (I-1 df) describes whether, on average, fish are using habitat types in proportion to their availability, regardless of which ones they are selecting.

In order to determine habitat types being selected for, I calculated a selection ratio ($\hat{W}_i$) for each unit. The selection ratio is a ratio of the proportion of habitat used to the proportion available. Since I wanted to evaluate habitat selection of the population as a whole, I used the Manly et al. (1993) estimation method:

$$\hat{W}_i = u_{i+}/\pi_i u_{++}$$

I calculated a 98% Bonferroni confidence interval (CI) ($\alpha = 0.02$) around each mean selection ratio to determine habitat types that were selected for. Habitat selection ratios with confidence intervals ($\hat{W}_i \pm$ CI) greater than 1 indicates selection, less than 1 indicates avoidance, and including 1 indicates neutrality.

RESULTS

I tagged a total of 44 Flathead Catfish from July 2012 to July 2013 in the lower Wabash River. The average total length of the tagged population was 627.1 ± 24.2 mm (Figure 3) and average weight was 3,775.8 ± 588.2 g. From August 2012 to December 2013, a total of 141 locations were made on 29 Flathead Catfish; 25 of which were located on more than one occasion. I was most successful relocating individuals at the two most upstream sites (Darwin and Hutsonville) (81.8% fish relocated) and least successful at the two most downstream sites (St. Francisville and New Harmony) (45.5% fish relocated) (Figure 4). During my study, 6 fish were harvested by anglers; 4 fish were captured at Darwin, 1 at St. Francisville, and 1 in a small tributary (Sugar Creek) near New Harmony.

Range

I found no seasonal difference in the distance between consecutive locations ($H(3) = 5.751$, $p > 0.05$) or linear range ($H(3) = 1.848$, $p > 0.05$) of Flathead Catfish. The annual range of movement varied among individuals (38.3 - 12,444.9 m), but averaged 1,406.9 ± 519.3 m (Figure 5). The majority of fish (68%) stayed within a 1,000 m range during my study, however, 8 individuals moved over 1,000 m, and 5 exceeded 3,000 m. The largest range I documented (12,444.9 m) was from a fish that moved out of the Wabash River into Sugar Creek, near its tagging site at New Harmony. There was a significant positive regression between Flathead Catfish size (total length) and annual range of movement ($R^2 = 0.180$; $p < 0.05$), but the correlation coefficient indicated a weak relationship (Figure 5). In addition, range could not be calculated for the largest eight

Flathead Catfish (735 mm to 1,220 mm total length), due to their disappearance after tagging.

Habitat Use and Selection

Flathead Catfish in the lower Wabash River used a variety of habitat types. The habitat composition for observations was 44.6 % outside bend, 26.6 % channel border, 23 % main channel, 5 % inside bend, and 0.72 % side channel (Figure 7a). Distribution of locations did not differ between seasons ($X^2 = 12.31$, df = 3, $p > 0.05$), but variation occurred within each season. Annually, fish were not uniformly distributed across habitat types ($X^2_{L1} = 190.013$, df = 112, $p < 0.0001$) and individuals were not selective in the habitats they used ($X^2_{L2} = 125.851$, df = 116, $p = 0.251$). However, Flathead Catfish, on average, did not use habitat units in proportion to their availability (difference between X^2_{L1} and $X^2_{L2} = 64.162$, $p < 0.005$).

The confidence intervals (CIs) around the habitat selection ratios for Flathead Catfish, from August 2012 to December 2013, reflected neutral selection for the main channel, avoidance of inside bend and side channel, and selection for outside bend and channel border habitat (Figure 8). Throughout my study, fish tagged at Darwin and St. Francisville showed selection for outside bend habitat, neutrality to channel border habitat, and avoidance to inside bend and side channel habitat; at Darwin, Flathead Catfish were also neutral to the main channel (Figure 9). At the most downstream site (New Harmony), fish selected channel border habitat, were neutral to outside bend, side channel and inside bend habitat, and avoided the main channel (Figure 9). Interestingly, the only site Flathead Catfish did not show selection for shoreline habitat was

Hutsonville, where selection was for the main channel; individuals were also neutral to outside bend and channel border habitat, and avoided inside bend habitat (Figure 9).

Spring

Spring was the only season Flathead Catfish did not use main channel and inside bend habitats. Flathead Catfish were located in shorelines only, specifically the outside bend (66.7 %) and channel border (33.3 %) (Figure 7b). Despite this, the CIs around the selection ratios indicated Flathead Catfish selected outside bend habitat and were neutral to channel borders. Avoidance was toward inside bend, main channel, and side channel habitat during spring (Figure 10).

Summer

Flathead Catfish locations during summer were not evenly distributed across habitat types (X^2 =20.00, df = 4, $p < 0.0005$). Over 65% of the total locations were in outside bend (40 %) and channel border habitat (26.6 %); however, fish began using main channel (22.2 %), inside bend (8.9 %), and side channel habitat (2.2 %) during summer (Figure 7c). Despite over half of the Flathead Catfish locations being in outside bend and channel border habitat, individuals did not select nor avoid either type; fish were also neutral to main channel and side channel habitat, and avoided inside bend habitat (Figure 10). In fact, summer was the only season Flathead Catfish were not selective in habitats used.

Fall

During fall, the composition of Flathead Catfish locations was 41.7 % outside bend, 30 % channel border, 25 % main channel and 3.3 % inside bend (Figure 7d). Locations were not evenly distributed (X^2 =18.533, df = 3, $p < 0.005$) and over 70 % of the total were in outside bend and channel border habitat; less than 5 % were in inside bend habitat. Not surprisingly, Flathead Catfish showed selection for outside bend habitat, neutrality to channel border and main channel habitat, and avoidance to inside bend and side channel habitat (Figure 10).

Winter

Winter observations on Flathead Catfish were not distributed evenly among habitat types (X^2 =12.60, df = 3, $p < 0.05$) and over 50 % of the total locations were within outside bends (Figure 7e). Interestingly, the main channel accounted for over 25 % of the total fish locations during winter and channel border habitat made up only 16 %. Despite an increase in main channel use, CIs around the selection ratios indicated Flathead Catfish did not select nor avoid this habitat; fish were also neutral to channel border habitat (Figure 10). Similar to spring and fall, individuals selected outside bend habitat and avoided inside bend and main channel habitat during winter (Figure 10).

Microhabitat Use

In the lower 280 km of the Wabash River, microhabitat composition for Flathead Catfish locations year round was 51.5% logjam, 22.3 % thalweg, 16.1 % run, 6.9 % rip rap, and 3.1 % sandbar (Figure 6a). The distribution of observations on Flathead Catfish did not differ between seasons ($X^2 = 15.341$, df = 9, $p > 0.05$); however, locations of fish were not equally distributed among microhabitat types during spring, summer, and fall. During spring, fish were only located in shoreline areas associated with logjam structure (66.7 %) and run (33.3 %) microhabitat (Figure 6b). Similarly, during summer, logjam (56.4 %) and run (23.1 %) microhabitat was used most often; however, fish also utilized thalweg (15.4 %) and sandbar (5.1 %) areas ($X^2 = 23.05$, df = 2, $p > 0.0001$) (Figure 6c). During fall, the majority of locations on Flathead Catfish were also in logjams (51.7 %), but fish began using the thalweg (29.3 %) and rip rap structure (10.34 %) (Figure 6d). Locations during winter were distributed equally among microhabitat types ($X^2 = 6.24$, df = 3, $p < 0.05$); fish used logjam (37.5 %), thalweg (25 %), run (20.83 %), rip rap (12.5 %), and sandbar (4.17 %) areas (Figure 6e). Throughout my study, Flathead Catfish most often used shorelines associated logjams and showed unequal distribution between microhabitats in all seasons, except winter.

DISCUSSION

The movement of Flathead Catfish in the Wabash River coincides with studies that have documented relatively sedentary individuals that remain within a small established home range (Dobbins et al. 1999, Skains & Jackson 1993, Pugh & Schramm 1999, Weller & Winter 2001, Daugherty & Sutton 2005a). Research conducted in the Lower Mississippi River determined Flathead Catfish were relatively non-mobile and had a maximum range of 6 km (Pugh & Schramm 1999). This range, however, is only half of what I observed in the lower Wabash River, indicating fish are not as sedentary in this system compared to a larger river. Similar results were found for an introduced Flathead Catfish population in the Deep River, North Carolina, in that fish exhibited an average annual linear range of 16.2 km (Malindzak 2006). Although Flathead Catfish in my study did not migrate large distances compared to Missouri (188km) (Vokoun & Rabeni 2005b) and Minnesota (100km) (Stauffer et al. 1996) populations, I found evidence that larger individuals may move more. This trend has also been shown in the Missouri River (Travnichek 2004) and Tallahatchie River (Skains & Jackson 1993). I suggest large movements were not necessary for Flathead Catfish in the lower Wabash River because spawning, foraging, and protective habitats were readily available throughout the year.

Flathead Catfish movement is driven by specific habitat requirements during life history stages (Vokoun & Rabeni 2005a, Gelwicks & Simmons 2011, Stauffer et al. 1996). During my study, fish selected outside bend and channel border habitat; however this varied between sites, possibly because availability and quality differed slightly between them. Although Flathead Catfish in the Wabash River did not show seasonal differences in habitat use, they showed seasonal variation in habitat selection. During spring, fall, and winter, Flathead Catfish actively selected outside bend habitat that most often contained logjams; similarly, fish in the Minnesota River utilized outside bends with woody debris most heavily during the year (Shroyer 2011). Many studies have also found logjam structure to be an important microhabitat feature for Flathead Catfish (Dames et al. 1989, Daugherty & Sutton 2005a, Lee & Terrell 1987, Minckley & Deacon 1959). In addition, outside bends in sinuous lotic systems most often contain washed out terrestrial structure and moderately deep water next to eroded banks, which provide protective structures and feeding grounds for many fishes (Pflieger 1975, Shroyer 2011).

Spawning temperatures for Flathead Catfish are between 20 - 25°C (Lee & Terrell 1987), so spawning most likely occurred in late spring/early summer in the lower Wabash River. I found Flathead Catfish select outside bend habitat during spring and became neutral during the summer. This suggests outside bends are used for spawning and neutrality to these areas during summer was caused by behavioral differences between sexes; however, this idea requires further research. Male Flathead Catfish are thought to establish territories for spawning, while females move at random (Pflieger 1975, Lee & Terrell 1987). The species is known as a cavity spawner (Jackson 1999, Turner & Summerfelt 1970), that construct nests in stream banks, cavities near large submerged objects (Pflieger 1975), crevices in natural rock outcroppings, or areas with dense submerged trees (Turner & Summerfelt 1970). Female Flathead Catfish may move more than males during the spawning period (Lee & Terrell 1987); therefore causing telemetry equipment to favor these fish because the sonic signal (from the transmitter) would not be interrupted by structure (spawning cavities).

During fall, fish selected for outside bends, most likely because they were feeding and beginning to locate available overwinter habitat. In Missouri Watersheds, Flathead Catfish exhibited a fall migration to overwintering areas (Vokoun & Rabeni 2005b), thus selection for outside bend habitat during fall may indicate these locations contain features ideal for winter survival. Overwinter habitat may be most specific, in that fish require areas that will minimize energy expenditure and provide protection (e.g. low-velocity, deep, structural cover) (Cunjak 1996). As expected, Flathead Catfish in the Wabash River, selected outside bends during winter; most often these areas are deep and contain dense woody debris. My research corresponds to previous literature that found that outside bends with dense logjams provide important spawning, feeding, and overwintering habitat for Flathead Catfish throughout the year (Minckley & Deacon 1959, Lee & Terrell 1987, Dames et al. 1989, Daugherty & Sutton 2005a, Shroyer 2011).

Flathead Catfish are an important component to Midwestern river fisheries. To ensure native populations remain healthy and sustainable we must understand their range of movement and habitat use throughout the year. My results show that Flathead Catfish in the lower Wabash River exhibit small movements within a restricted range, but larger fish may move farther during the year; however, further research examining individuals greater than 750 mm is necessary. Outside bend habitat is most important for Flathead Catfish because it offers protective structure, feeding grounds, and spawning cavities. With these results, I suggest fish did not have move far distances in the river because suitable habitat was available within a small range throughout the year. In the lower Wabash River, localized management may suitable, as long as the system continues to naturally meander in order to provide necessary outside bend habitat for the health and persistence of the Flathead Catfish population.

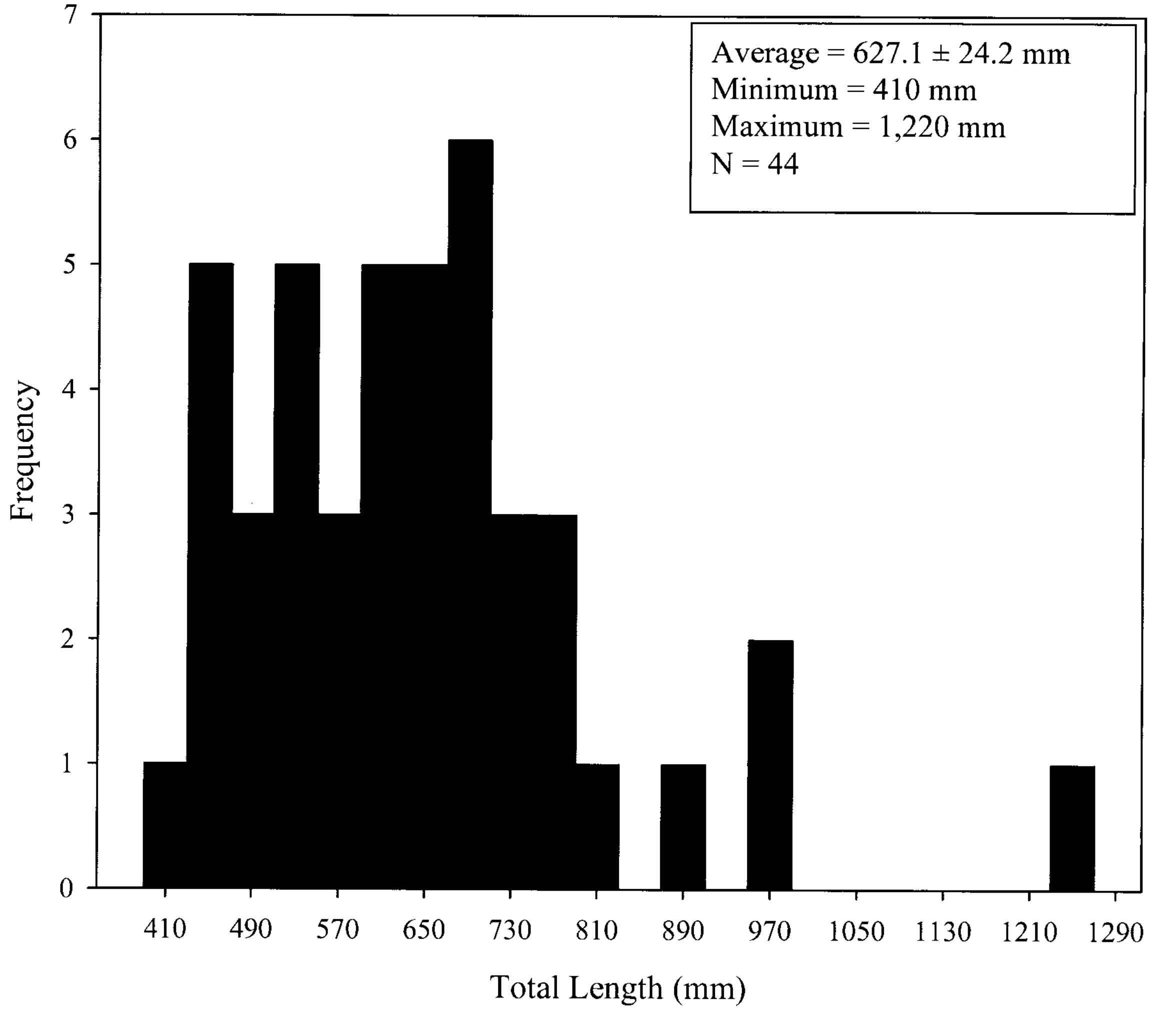

Figure 3. Length frequency distribution of Flathead Catfish tagged with ultrasonic transmitters in the lower Wabash River from July 2012 to July 2013.

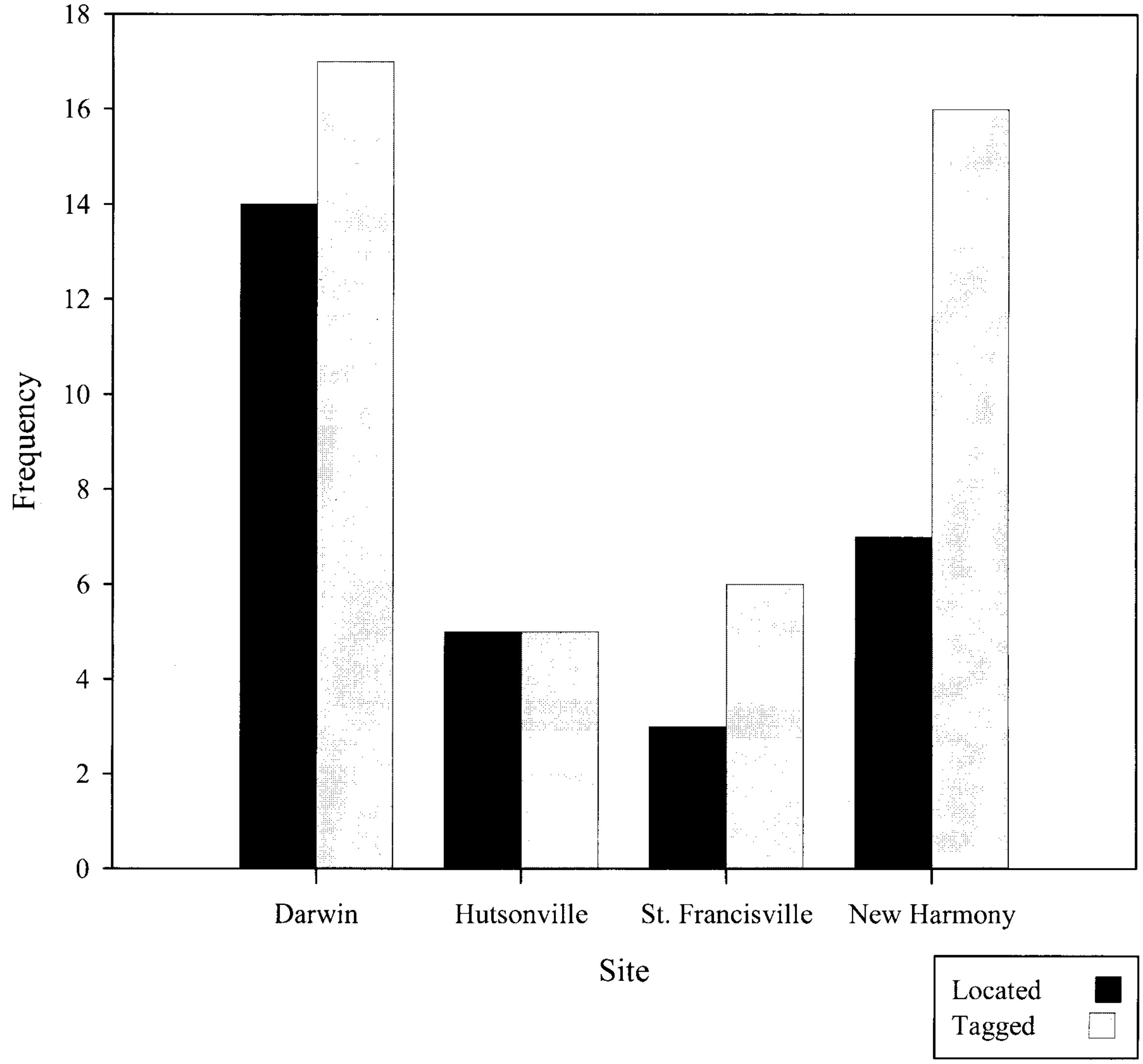

Figure 4. The total number of tagged (N=44) and located (n=29) Flathead Catfish from 2012 to 2013, at four tagging sites (Darwin, Hutsonville, St. Francisville, and New Harmony) within the lower 280 km of the Wabash River.

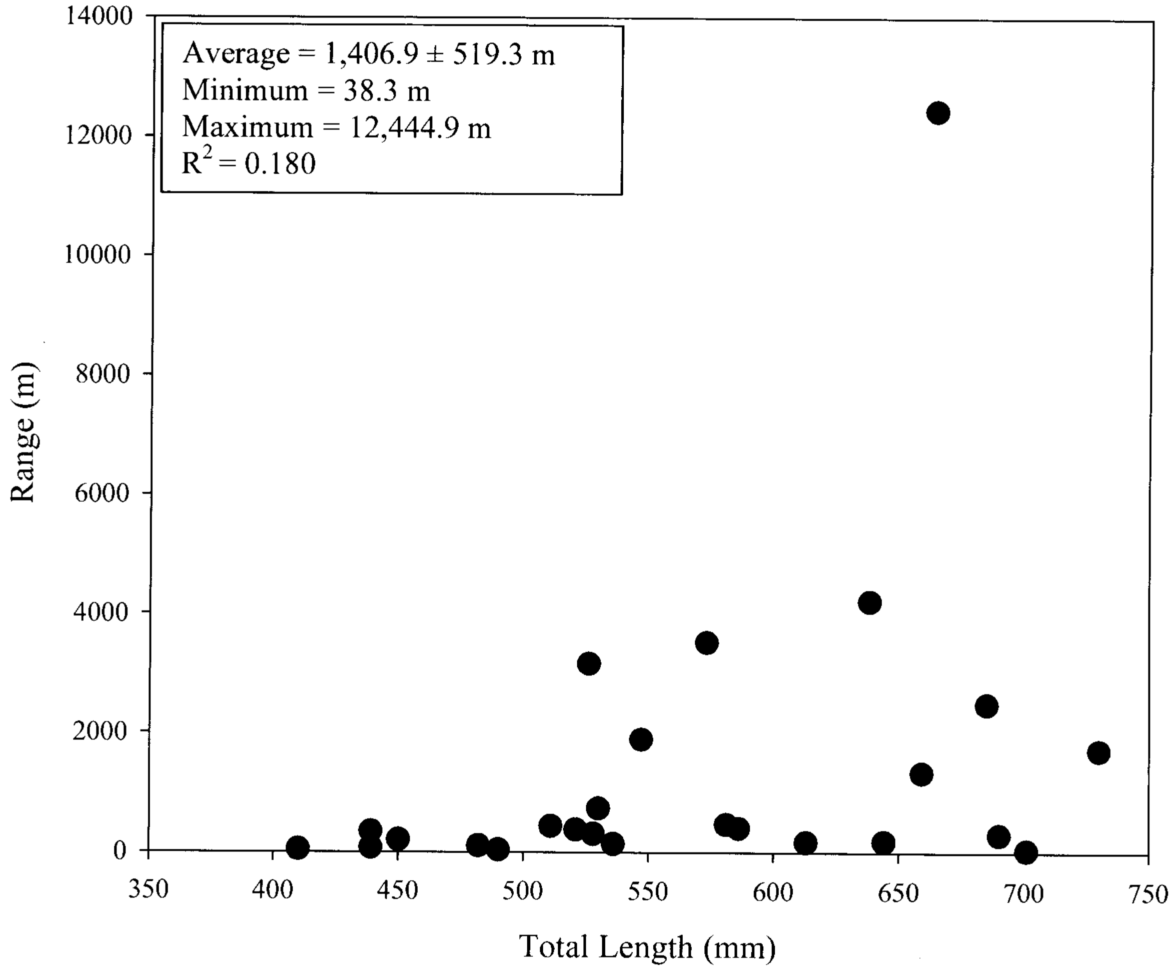

Figure 5. The total linear range and size (total length) of Flathead Catfish (N = 25) located in the lower Wabash River from August 2012 to December 2013. Each point represents one individual.

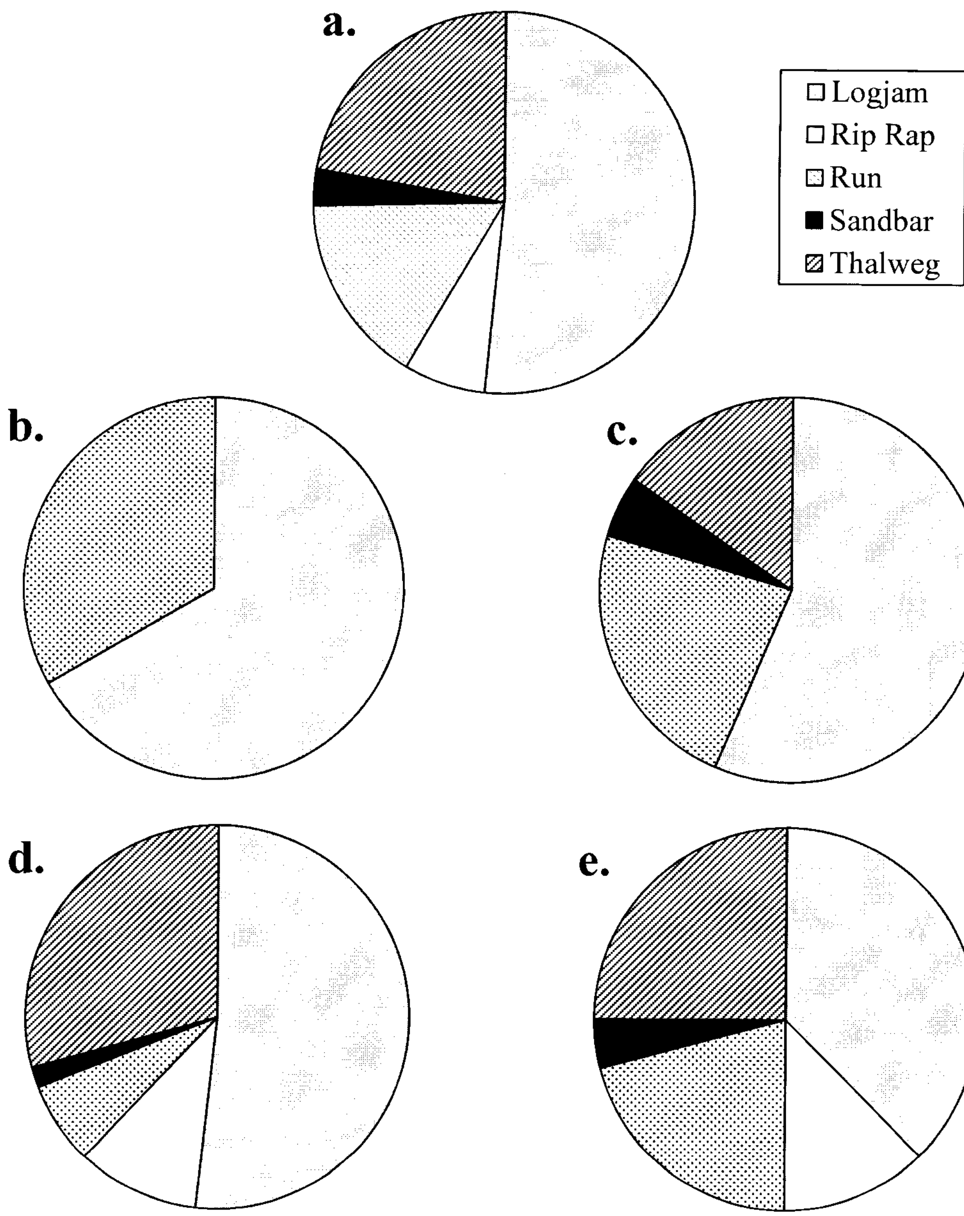

Figure 6. Annual (a) and seasonal (spring (b), summer (c), fall (d), winter (e)) percent of observations of Flathead Catfish in each microhabitat type in the lower Wabash River from August 2012 to December 2013.

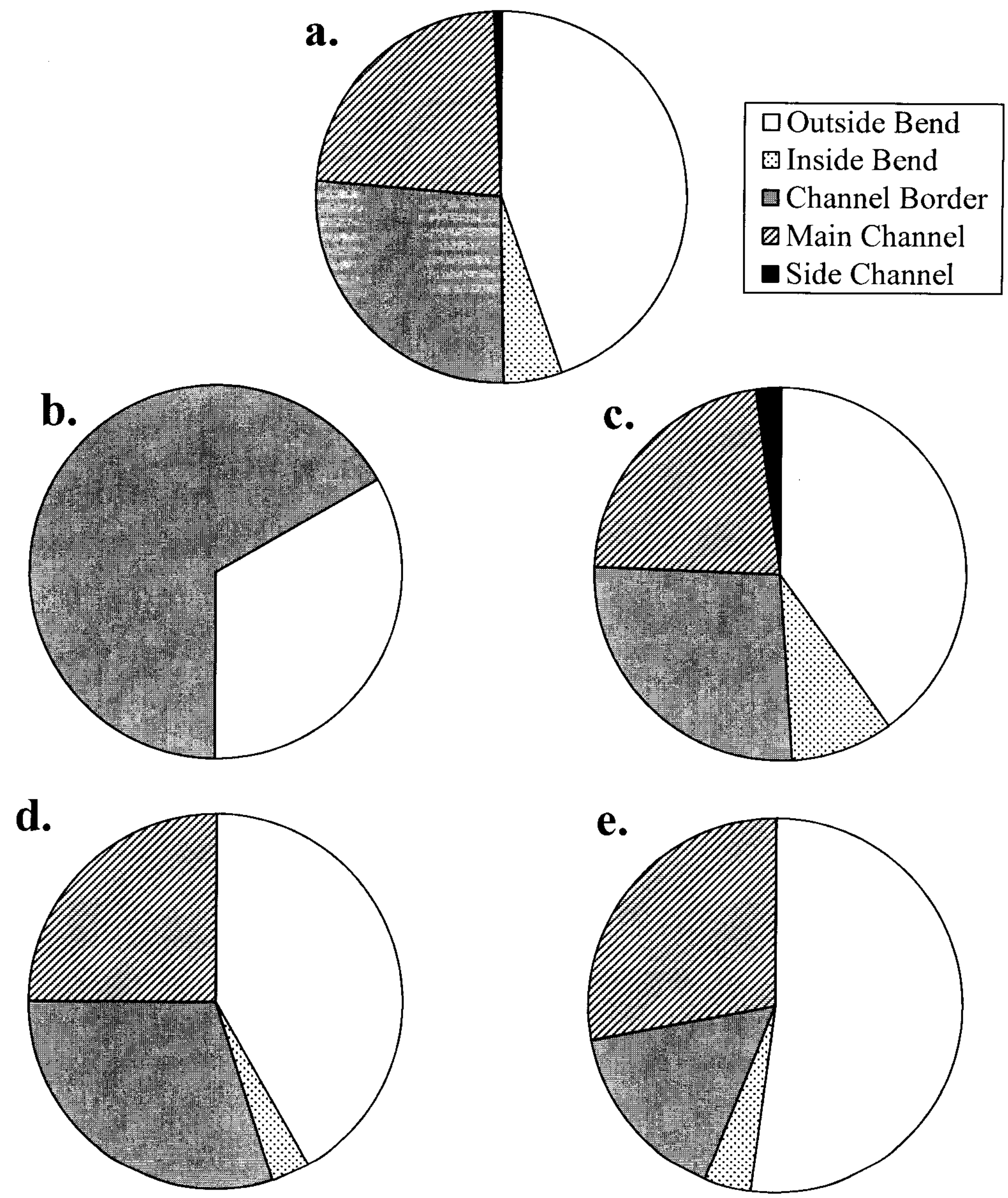

Figure 7. Annual (a) and seasonal (spring (b), summer (c), fall (d), winter (e)) percent of habitat observations on Flathead Catfish in the lower Wabash River from August 2012 through December 2013.

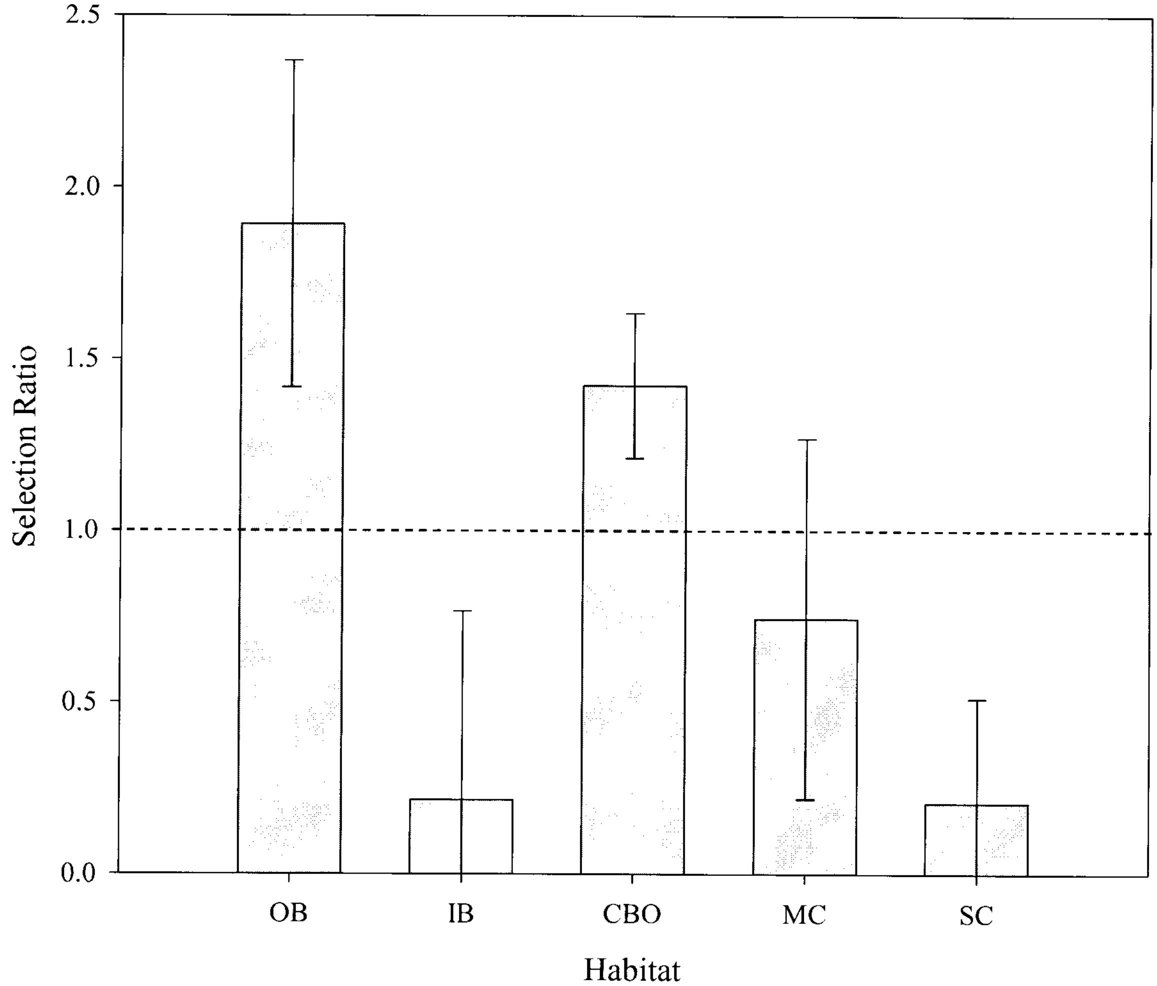

Figure 8. Selection ratios ($\hat{W}_i$) for habitat types used by Flathead Catfish in the lower Wabash River from 2012 to 2013; $\hat{W}_i \pm$ CI greater than 1 indicates preference, less than 1 indicates avoidance, and including 1 indicates neutrality. Habitat types include; OB (outside bend), CBO (channel border open), IB (inside bend), MC (main channel), and SC (side channel).

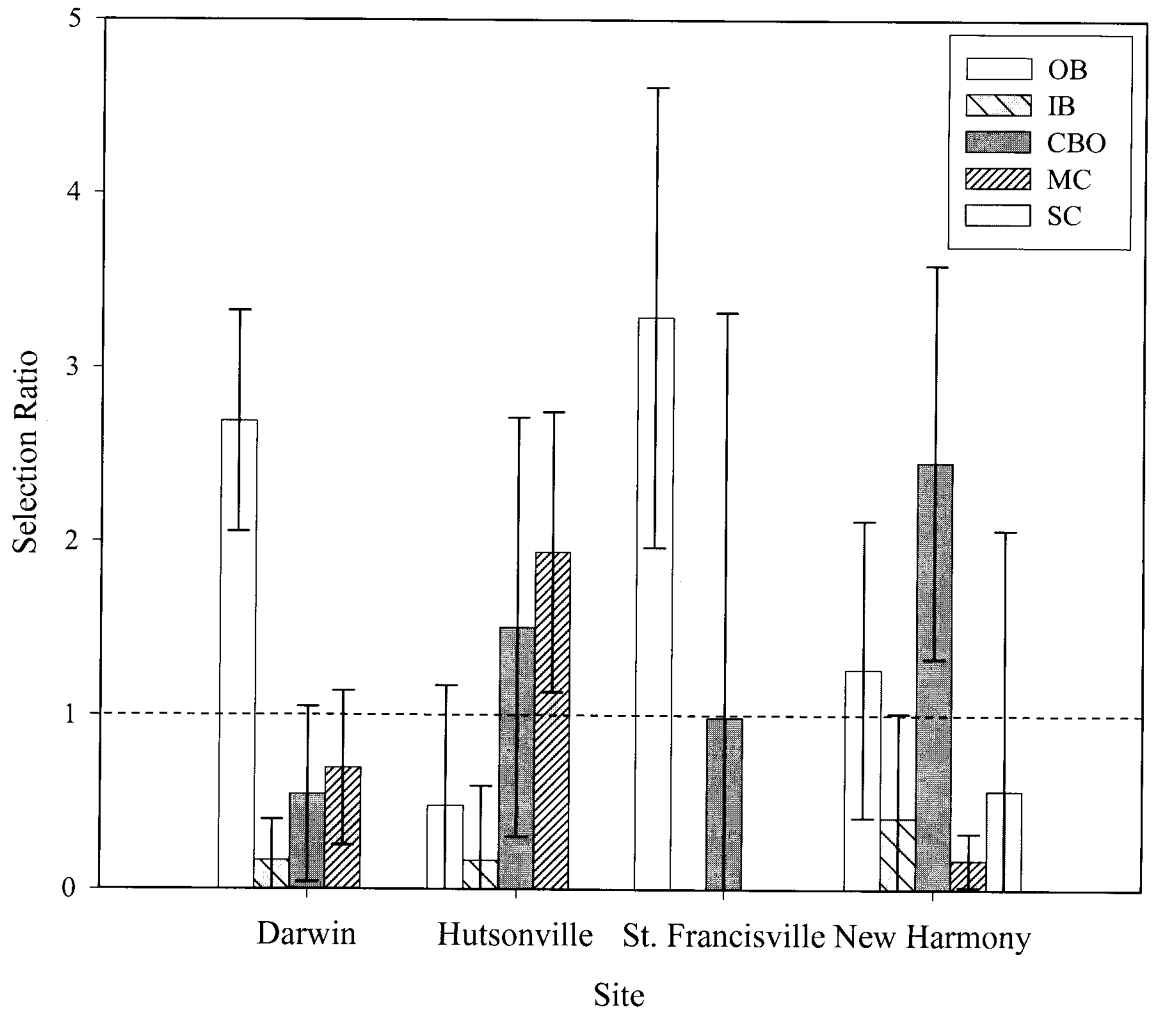

Figure 9. Selection ratios ($\hat{W}_i$) for habitat types used by Flathead Catfish at each tagging site in the lower Wabash River from 2012 to 2013; $\hat{W}_i \pm$ CI greater than 1 indicates preference, less than 1 indicates avoidance, and including 1 indicates neutrality. Habitat types include; OB (outside bend), CBO (channel border open), IB (inside bend), MC (main channel), and SC (side channel).

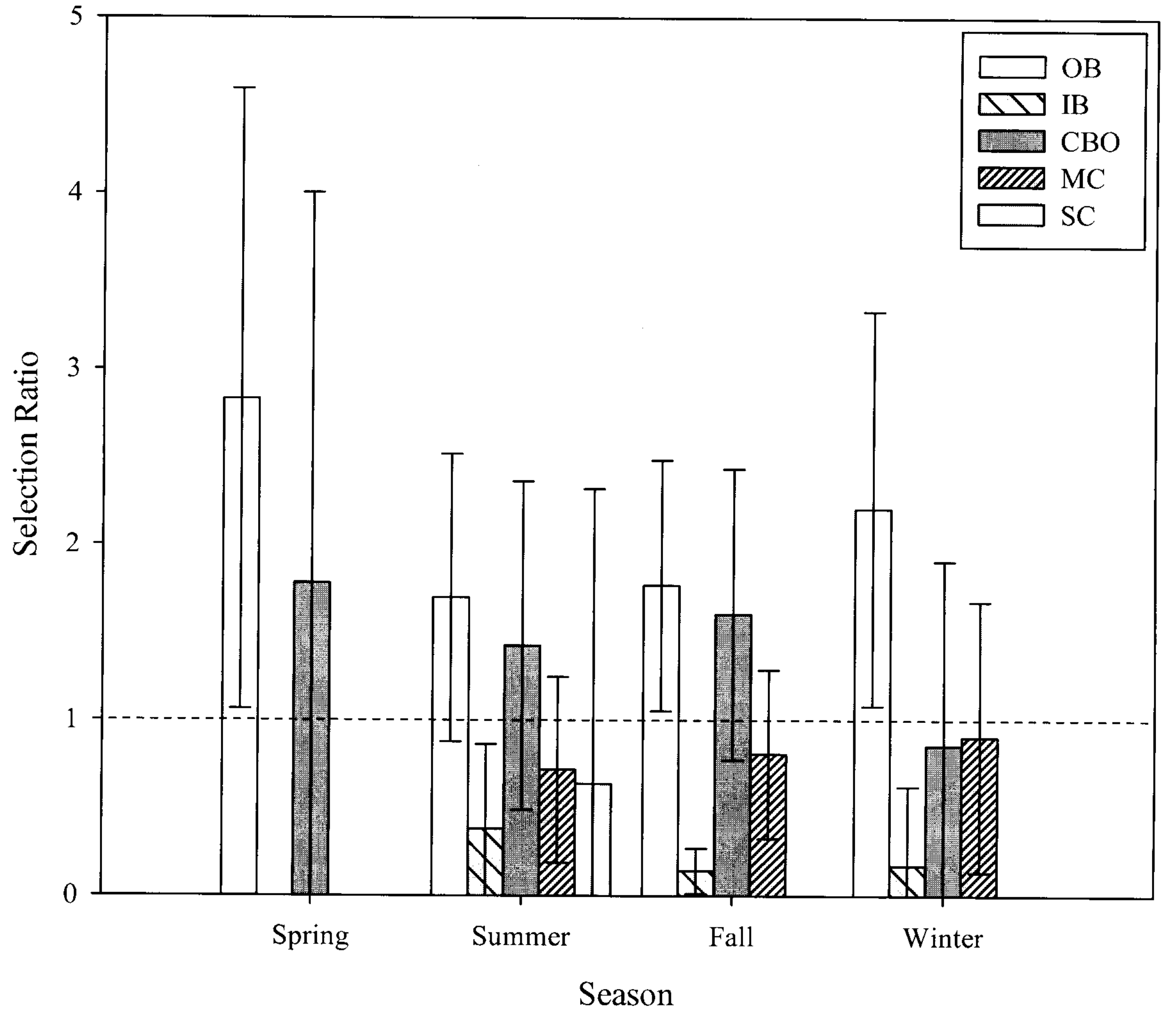

Figure 10. Selection ratios ($\hat{W}_i$) for habitat used by Flathead Catfish each season in the lower Wabash River from 2012 to 2013; $\hat{W}_i \pm$ CI greater than 1 indicates preference, less than 1 indicates avoidance, and including 1 indicates neutrality. Habitat types include; OB (outside bend), CBO (channel border open), IB (inside bend), MC (main channel), and SC (side channel).

Chapter Two: Diel Habitat Use and Movement of Flathead Catfish (*Pylodictis olivaris*) in the Lower Wabash River

INTRODUCTION

Broad scale movement of fishes is commonly evaluated to define the geographic extent of management strategies in lotic systems (Skains & Jackson 1993, Daugherty & Sutton 2005a, Vokoun & Rabeni 2005a & b, Shroyer 2011). However, point – in – time locations alone cannot define important habitat requirements within a system. To accurately identify crucial habitat use for a species, biologists can monitor fine scale movement throughout the daily cycle, year round. Flathead Catfish (*Pylodictis olivaris*) vary habitat use throughout the diel cycle (Daugherty & Sutton 2005b, Malindzak 2006) and this has been most often attributed to daily feeding patterns (Trautman 1981, Pflieger 1997). Minckley and Deacon (1959) conducted an analysis of daily feeding of Flathead Catfish and found most intensive feeding occurred at night and early morning. A study evaluating diel feeding habitat of Channel Catfish (*Ictalurus punctatus*) concluded fish used habitat with cover during low feeding times and more diverse habitat during high feeding times (Kwak et al. 1992). Monitoring fine scale movement of individual fish can allow biologists to evaluate seasonal habitat use and diel movement patterns to define suitable habitat requirements contributing to successful spawning, growth and feeding, and overwintering.

Flathead Catfish are a well-known aggressive predator, native to the Mississippi, Mobile, and Rio Grande River drainages (Pflieger 1971, Lee & Terrell 1987, Jackson 1999); although the species inhabit lotic and lentic systems, they are more commonly considered a riverine fish (Lee & Terrell 1987). Flathead Catfish are sought after for commercial harvest, but more frequently captured for recreational purposes due to their potential to reach size in excess of 50 kg (Mccoy 1953, Layher & Boles 1979, Lee & Terrell 1987). Because of their economic importance, much attention should be focused on identifying critical habitat requirements that contributes to the persistence and health of populations in their native rivers. Broad scale movement research has shown variable results on Flathead Catfish movement depending on the system being assessed (Skains & Jackson 1993, Vokoun & Rabeni 2005b, Malindzak 2006). Therefore, it is important that biologists monitor movement prior to implementing management regulations. Similarly, diel behavior needs to be well understood in order to determine specific habitat requirements to meet the needs of all life history stages (spawning, feeding and growth, and overwintering). Based on a few studies, Flathead Catfish are thought to use different habitat types between day and nighttime hours (Daugherty & Sutton 2005b, Minckley & Deacon 1959, Malindzak 2006). Despite these results, monitoring has not been implemented in a native river during all seasons; therefore, further research is necessary to evaluate critical habitat use throughout the entire year.

Flathead Catfish movements vary widely across systems. Several authors have reported highly mobile individuals that exhibit large migrations during specific times of the year (Stauffer et al. 1996; Daugherty & Sutton 2005a, Vokoun & Rabeni 2005b). For example, Flathead Catfish in tributaries in Missouri showed an annual movement cycle consisting of three main periods of restricted movement, related to life history events (overwintering, spawning, post-spawn), punctuated by brief, but relatively large migrations (Vokoun & Rabeni 2005b). However, when monitoring individuals for 24 hours during summer months (presumed to be a time of low mobility), Flathead Catfish were relatively mobile and made discrete movements associated with physical habitat, suggesting the species may not be as sedentary as assumed (Vokoun & Rabeni 2006). Therefore, it appears necessary to monitor fine scale movements over 24 hours in each season to provide accurate information on movement patterns and habitat use. With this, managers will be able to identify crucial habitat requirements for Flathead Catfish and ensure these areas are available within the system year round.

Previous research reports that Flathead Catfish exhibit increased movement at night (Minckley & Deacon 1959, Daugherty & Sutton 2005b, Malindzak 2006, Vokoun & Rabeni 2006). Minckley and Deacon (1959) reported higher catch rates (using AC electrofishing) of Flathead Catfish during night hours and assumed this was due to higher nighttime mobility. Similarly, fish in a Michigan river showed higher movement rates during dusk, night, and dawn (Daugherty & Sutton 2005b). Although, there is considerable evidence that Flathead Catfish exhibit crepuscular and nocturnal activity (Minckley & Deacon 1959, Skains & Jackson 1993, Daugherty & Sutton 2005b, Malindzak 2006, Vokoun & Rabeni 2006), some authors report increased mobility at other times of the diel cycle (Turner & Summerfelt 1970, Layher & Boles 1980, Baumann & Kwak 2011). Three periods of increased activity (early afternoon, sunset to midnight, and midnight to sunrise) were shown by Flathead Catfish in Missouri streams (Vokoun & Rabeni 2006). As previous research has been conducted during summer and fall only, it is not known whether these patterns are consistent throughout the year. Due to the lack of diel monitoring year round and possible variation in movement patterns between systems, further evaluation is necessary.

The Flathead Catfish population in the lower Wabash River is well-established and healthy (Moody 2013), and exhibit restrictive movement throughout the year (less than 12 km) (Chapter 1). Although fish do not show seasonal migrations, I aim to evaluate movement in finer detail to determine diel habitat use and movement patterns. In addition, diel monitoring of Flathead Catfish has not been examined year round in an unimpounded Midwestern river. Therefore, I will use ultrasonic telemetry to monitor diel movement and habitat use of Flathead Catfish. My objectives are to 1) determine diel movement patterns and habitat use within each season and 2) assess potential seasonal differences in diel movement and habitat use. With this, my study will provide novel information about fine scale activity patterns of Flathead Catfish in native lotic systems throughout the year.

METHODS

Data analysis

For all statistical analyses, spring was defined as March-May, summer as June-August, fall as September-November, and winter as December-February. Statistical tests were conducted using SAS 9.3 (SAS Institute 2011) and SigmaPlot Version 11.0 (Systat Software Inc.). Geographic coordinates of fish locations were mapped in ArcMap 10.0 and distances between successive individual fish locations were measured as the shortest linear distance in the river. The area of diel movements per individual fish was measured in ArcMap 10.0 using minimum convex polygons. Individuals included in movement analyses were located at least twice during each time period, and fish included in habitat analyses were located at least once during the 24 hours. Time periods were defined as 1) midnight to sunrise, 2) sunrise to sunset, and 3) sunset to midnight. Habitat was categorized as shoreline or main channel, based off Cobb (1989); shorelines include outside bend (OB), inside bend (IB), and channel border opens (CBO) (Figure 2). To determine if habitat use differed among time periods, regardless of season, and within seasons, I calculated two separate likelihood ratio chi-squared analysis.

To standardize movement between consecutive locations, I transformed distances into minimum distance moved per hour (m/hr). I calculated the rate of movement (m/hr) for a given individual by dividing the distance between consecutive locations by the minutes between locations, and then multiplied this by 60 minutes. To discern differences in movement between time period and season, I used a two-way analysis of variance (ANOVA) with season, time period and season*time period as main effects. Normality and homogeneity of variances was assessed using Shipro-Wilk and Brown-

Forsythe test at 0.05. Assumptions were not met so data were normalized with a natural log transformation. When ANOVA found a difference, I ran a Tukey's honestly significant difference (HSD) post hoc test. To evaluate seasonal differences in the area of river used by each fish during the diel cycle, I used a Kruskal-Wallis one way analysis of variance, with a post hoc Dunn's multiple comparisons test.

RESULTS

Flathead Catfish monitored during 24 hour tracking had an average total length of 569.3 ± 23.1 mm (439 to 685 mm) and averaged 2,252.2 ± 308.3 g in weight. From September 2012 to September 2013, I made a total of 199 observations on eleven Flathead Catfish from seven 24-hour tracking occasions; six fish were continuously monitored at Darwin and one at Hutsonville. Additionally, I was able to monitor diel activities of one individual at Darwin every season.

Movement

Season had a significant effect on the diel rate of movement (ANOVA, $F_{(3,166)} = 26.743$, $p < 0.0001$, $R^2 = 0.387$); Flathead Catfish had the highest rate of movement during summer (average = 142.0 ± 31.3 m/hr) and the lowest during winter (average = 5.7 ± 1.6 m/hr) (Table 1). Time period did not have a significant effect on Flathead Catfish movement (ANOVA, $F_{(2,166)} = 2.807$, $p > 0.05$); however, the interaction of season and time period impacted movement rates (ANOVA, $F_{(6,166)} = 2.936$, $p < 0.05$). Diel movement patterns of Flathead Catfish in the Wabash River varied seasonally; fish showed increased activity from midnight to dawn during spring and summer, but not fall and winter. Fish movement reduced dramatically in fall and winter and individuals did not show any periods of increased activity throughout the 24 hour cycle (Figure 11).

Spring

During spring, Flathead Catfish exhibited movements between 2.1 and 132.1 m/hr (average = 29.9 ± 6.9 m/hr) (Table 1) within a 7,127.3 m^2 area during the daily cycle

(Table 2). Diel movement during spring was similar to fall ($p > 0.05$), but different than summer ($p < 0.05$) and winter. Flathead Catfish showed significantly larger movements from midnight to sunrise, compared to daylight hours (sunrise to sunset) (ANOVA, $F_{(2,21)} = 5.14$, $p < 0.05$) (Figure 12a).

Summer

Flathead Catfish exhibited the largest rate of movement during the diel cycle during summer (average = 142.0 m/hr) (Table 1); movement was significantly greater than all other seasons ($p < 0.05$). Movements during summer were contained within the largest area (12,284.7 ± 2,772.1 m^2) compared to fall (ANOVA, $p < 0.05$) and winter (ANOVA, $p < 0.05$) (Table 2). Similar to spring, Flathead Catfish moved significantly more from midnight to sunrise compared to daylight hours (sunrise to sunset) (ANOVA, $F_{(2,73)} = 6.88$, $p < 0.01$) (Figure 12b).

Fall

Movement during fall was similar to spring ($p > 0.05$) and Flathead Catfish made movements between 0.5 and 140.3 m/hr (average = 17.9 ± 3.0) throughout the diel cycle (Table 1). The area of movement was significantly smaller than summer (ANOVA, $p < 0.05$), but similar to spring (ANOVA, $p > 0.05$) and winter (ANOVA, $p > 0.05$) (Table 2). Although movement rates were similar to spring, Flathead Catfish did not exhibit the same movement pattern; movement did not differ between time periods in fall (ANOVA, $F_{(2,54)} = 1.21$, $p > 0.05$) (Figure 12c).

Winter

Flathead Catfish movement during winter was minimal (average = 5.70 ± 1.56 m/hr) compared to all other seasons ($p < 0.05$) (Table 1). In addition, the area of activity (357.21 ± 66.91 m^2) was significantly smaller than spring (ANOVA, $p < 0.05$) and summer (ANOVA, $p < 0.05$) (Table 2). Although Flathead Catfish activity was significantly less than fall, fish showed similar movement patterns during winter, as movement rate did not differ between time periods (ANOVA, $F_{(2,18)} = 0.280$, $p > 0.05$) (Figure 12d).

Habitat Use

Flathead Catfish habitat use did not differ between time periods of the daily cycle (regardless of season) ($X^2 = 2.340$, df = 2, $p > 0.05$); however, variation between time periods occurred within spring ($X^2 = 15.012$, df = 2, $p < 0.001$) and summer ($X^2 = 11.058$, df = 2, $p < 0.05$) (Figure 13 a & b). Additionally, during fall and winter, fish used habitat types similarly throughout the 24 hour time period (Figure 13 c & d). Despite variability in diel habitat use during some seasons, the majority of Flathead Catfish locations within the daily cycle each season were in shoreline habitat.

Spring

During spring, fish used shorelines throughout the daily cycle and only used the main channel during nighttime hours (midnight to sunrise and sunset to midnight) ($X^2 = 15.012$, df = 2, $p < 0.001$) (Figure 13a). From midnight to dawn over 80% of the total spring locations were in shoreline habitat and 20% were in the main channel; however, from sunset to midnight, fish were more frequently located in the main channel (80 %) than shoreline (20 %) (Figure 13a).

Summer

Habitat use differed between time periods during summer ($X^2 = 11.058$, df = 2, $p < 0.005$); fish used shoreline habitat throughout the entire 24 hours and used the main channel from midnight to dawn and during daylight hours (sunrise to sunset) (Figure 13b). When fish movement was highest during the diel cycle (midnight to sunrise), 20 % of the total locations were in shoreline habitat and 10 % in the main channel. Fish also utilized both habitats during daylight hours, but 37 % of the locations were in shoreline habitat and 14 % were in the main channel. From dusk until midnight, fish remained within shoreline habitat and then began using the main channel after midnight (Figure 13b).

Fall

In all seasons, except fall, individuals behaved similarly throughout diel tracking. Two fish, at Darwin, used shoreline habitat throughout the 24 hours. The third fish (at Hutsonville) used shoreline and main channel habitat during the daily cycle. Despite variation from individual fish, habitat types were used in similar proportion between time periods (Figure 13c).

Winter

Winter was the only season I did not observe Flathead Catfish using main channel habitat (Figure 13d). All fish used shoreline habitat during the 24 hour diel cycle (Figure 13d). This was not surprising due to the extreme reduction in movement by individuals during cold months. Although Flathead Catfish did not remain completely sedentary throughout 24 hour tracking, all movements (less than 30 m/hr) were within shoreline habitat (Figure 13d).

DISCUSSION

Daily movements of Flathead Catfish in the lower Wabash River differed seasonally. Individuals became sedentary during winter, and had the highest rate of movement during summer. I was not surprised by the sedentary nature of Flathead Catfish during winter because many studies conclude fish are immobile during this time (Cunjak 1996, Stauffer et al.1996, Garrett & Rabeni 2011, Malindzak 2006, Weller & Robbins 1999). Of the few studies that have monitored daily movements of Flathead Catfish (Daugherty & Sutton 2005b, Malindzak 2006, Vokoun & Rabeni 2006), almost all were conducted during summer and fall months; when Flathead Catfish are thought to exhibit restricted movement (Daugherty & Sutton 2005b, Vokoun & Rabeni 2006). Consequently, scientists have not evaluated seasonal differences in daily cycle movements in lotic systems within the species native range. Malindzak (2006) reported the greatest average diel movement during spawning season; however, spawning season, in North Carolina rivers, included March (early spawn) and May through June (late spawn), whereas I classified seasons based on the Julian calendar (March-May is spring, June-August is summer, September-November is fall, December-February is winter). Therefore, my findings are similar to the behavior exhibited by Flathead Catfish outside their native range (Malindzak 2006). There is limited research on year round diel movement of Flathead Catfish in native lotic systems; thus giving importance to the novel nature of my findings.

Movement of Flathead Catfish was not directly affected by the time of day, regardless of season. Due to the nocturnal nature of Flathead Catfish (Pflieger 1997, Skains & Jackson 1993), I expected increased mobility during nighttime hours during all seasons, similar to Malindzak (2006). However, during spring and summer, fish showed higher movement rates from midnight to dawn, compared to daylight hours. During summer months, Flathead Catfish in Missouri streams (Vokoun & Rabeni 2006) and the lower St. Joseph River, Michigan, (Daugherty & Sutton 2005b) showed greater movement rates at night. Many other fish species increase activity at night, including, Channel Catfish (Kwak et al. 1992), freshwater eels (*Anguilla* spp.) (Jellyman & Sykes 2003), Brook Trout (*Salvelinus fontinalis*), and Lake Chub (*Couesius plumbeus*) (Toobaie et al. 2013). However, Northern Pike (*Esox Lucius*) are more active during daylight compared to night (Baktoft et al. 2012) and Smallmouth Bass (*Micropterus dolomieu*) display a crepuscular diel pattern (Kwak et al. 1992). Flathead Catfish in the Wabash River did not exhibit nocturnal activity during fall and winter months. This was not surprising, as several authors report immobility during these seasons due to the extreme reduction in water temperature during colder months (overwintering) (Funk 1957, Lee & Terrell 1987, Malindzak 2006). My results show that Flathead Catfish movement is not strictly affected by the time of day, but by the season as well, and fish exhibit nocturnal movements during spring and summer only.

Flathead Catfish differed in daily habitat use during spring and summer. During spring, fish used shoreline and main channel habitat during night hours and stayed along the shoreline between dawn and dusk. However, during summer fish used both habitats from midnight to dawn and during daylight, and then remained along shoreline habitat from dusk to midnight. During fall, individuals varied in habitat use; two fish (Darwin) only used shoreline habitat and one fish (Hutsonville) used the main channel and shoreline throughout the daily cycle. In my first study (Chapter 1), I found that Flathead

Catfish at Hutsonville select for main channel habitat throughout the year, so this finding was not surprising. The 12 km stretch of the Hutsonville site is somewhat narrow in comparison to the other three tagging sites (Darwin, St. Francisville, New Harmony), possibly explaining why fish frequently use the main channel in this area; however, further research is needed to be conclusive. Fish utilized habitats similarly throughout the daily cycle during fall and winter, but strictly stayed in the shoreline during winter. Similarly, Flathead Catfish in the Deep River generally occupied different habitats between day and nighttime hours, except during winter, when movements were limited and habitat use did not vary (Malindzak 2006). Daugherty and Sutton (2005b) reported Flathead Catfish in the St. Joseph River, Michigan used open water more at night than day, during summer. Movement to specific habitats during the diel cycle has been related to foraging activities (Trautman 1981, Pflieger 1997), as it is well documented that diel variation in habitat use can be related to feeding patterns in other fishes (Collins & Hinch 1993, Kwak et al. 1992). My data may also indicate seasonal variation in daily feeding patters of Flathead Catfish. Due to these diel differences in movement patterns and habitat use, I suggest Flathead Catfish are exhibiting different feeding patterns each season, but without further evaluation this remains unknown.

My study illustrates the importance of monitoring year round diel movement and habitat use of Flathead Catfish. Individuals in the lower Wabash River did not exhibit movements strictly based on the time of day, but on the interaction of season and time period. Additionally, diel movement varied seasonally and Flathead Catfish did not show peak activity at night during every season. Daily habitat use varied during those seasons when fish exhibited diel movement differences as well (spring and summer); suggesting further evaluation is needed to determine the reason behind this. My study provides novel information about seasonal variability of diel movement and habitat use of Flathead Catfish in a free flowing river. With my findings, I suggest at least one year of diel monitoring in order to properly define habitat requirements necessary for the health and persistence of Flathead Catfish populations within a lotic system.

Table 1. Descriptive statistics (minimum, maximum and average rate of movement (meters per hour) (± SE)) of Flathead Catfish movement during the daily cycle, from 2012 to 2013.

Season	Time Period	Minimum	Maximum	Average (± SE)
Spring	Midnight-Sunrise	10.47	65.86	44.83 (10.43)
	Sunrise-Sunset	2.07	44.40	13.53 (3.57)
	Sunset-Midnight	3.27	132.07	60.98 (24.54)
	All	2.07	132.07	29.94 (6.89)
Summer	Midnight-Sunrise	3.75	866.50	205.96 (56.32)
	Sunrise-Sunset	3.89	734.20	48.43 (19.90)
	Sunset-Midnight	3.87	1297.22	156.13 (84.24)
	All	3.75	1297.22	142.02 (31.30)
Fall	Midnight-Sunrise	1.90	140.25	17.99 (6.28)
	Sunrise-Sunset	0.52	64.63	23.56 (4.40)
	Sunset-Midnight	1.54	25.48	10.55 (2.35)
	All	0.52	140.25	17.89 (3.02)
Winter	Midnight-Sunrise	0.63	7.90	3.69 (0.91)
	Sunrise-Sunset	0.88	12.70	4.74 (1.50)
	Sunset-Midnight	1.22	31.77	9.35 (4.99)
	All	0.63	31.77	5.70 (1.56)

Table 2. The average area encompassed by diel movements (m^2) (± SE) of Flathead Catfish, per season, from 2012 to 2013 in the lower Wabash River.

Season	Average (SE)
Spring	7127.33 (N/A)
Summer	12284.65 (2772.05)
Fall	2127.20 (1621.58)
Winter	357.21 (66.91)

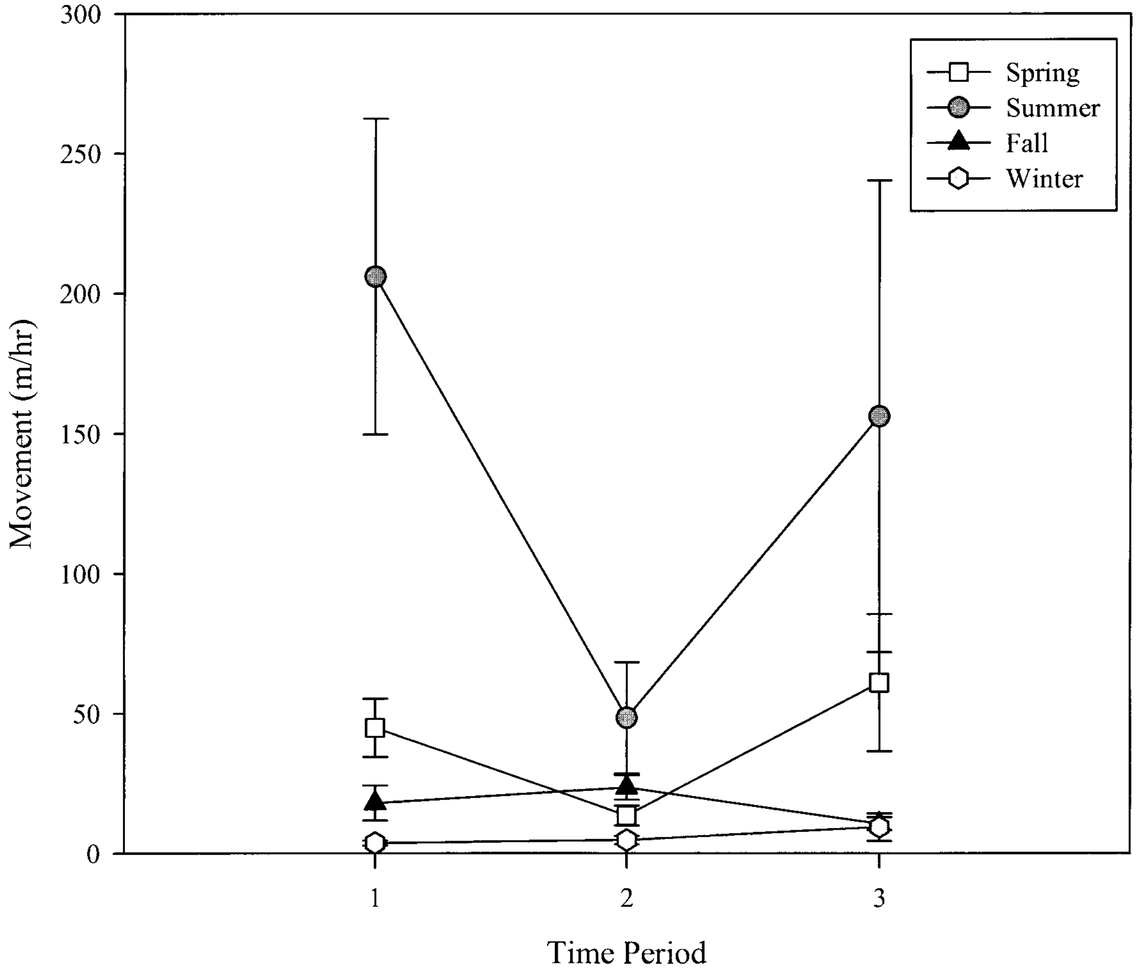

Figure 11. The average rate of movement (± SE) exhibited by Flathead Catfish during each time period (1 is midnight to sunrise, 2 is sunrise to sunset, and 3 is sunset to midnight) within the daily cycle, per season from 2012 to 2013 in the lower Wabash River.

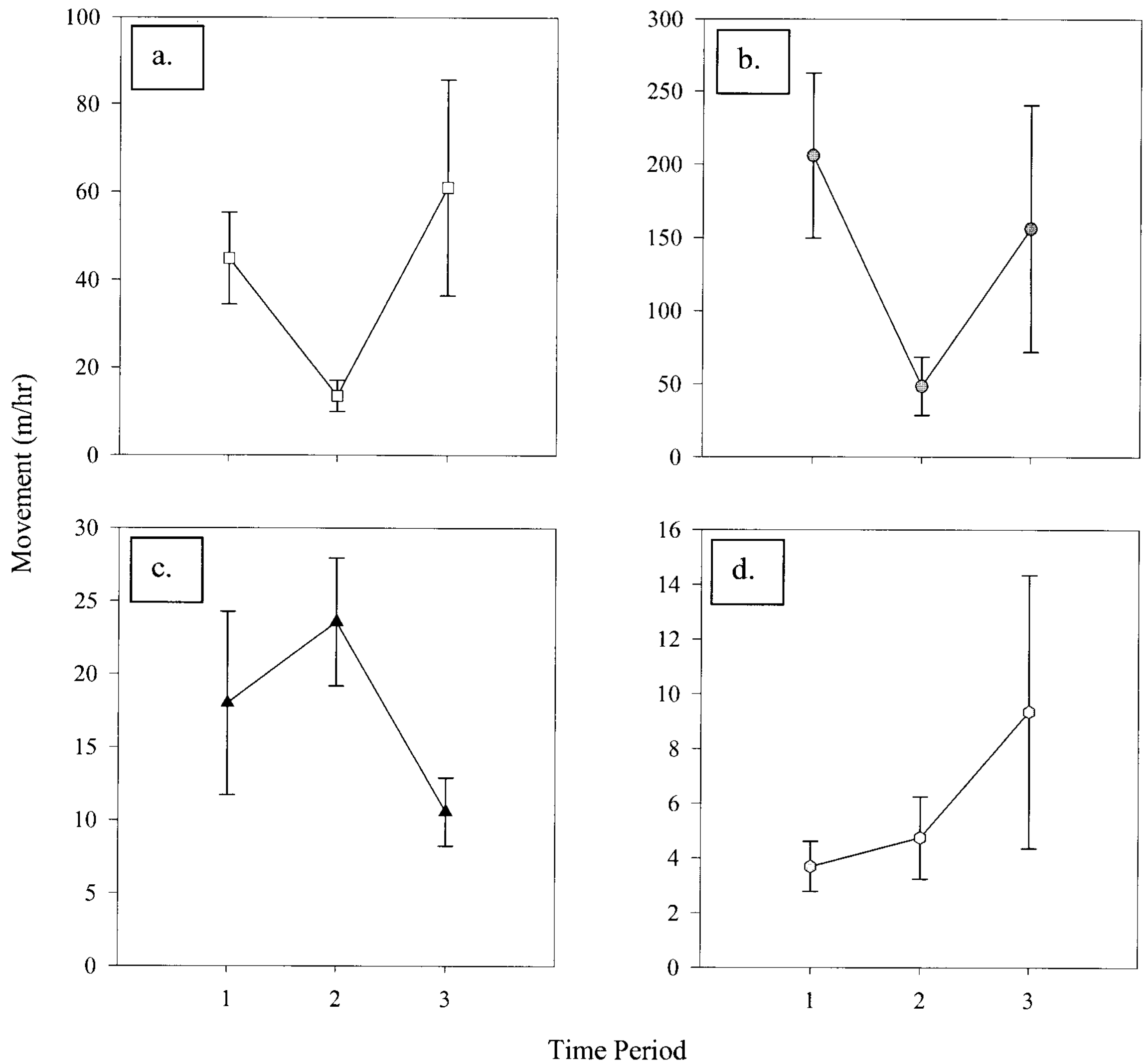

Figure 12. Flathead Catfish average rate of movement (± SE) per time period (1 is midnight to sunrise, 2 is sunrise to sunset, and 3 is sunset to midnight) for spring (a), summer (b), fall (c), and winter (d).*y-axis scale varies per season.

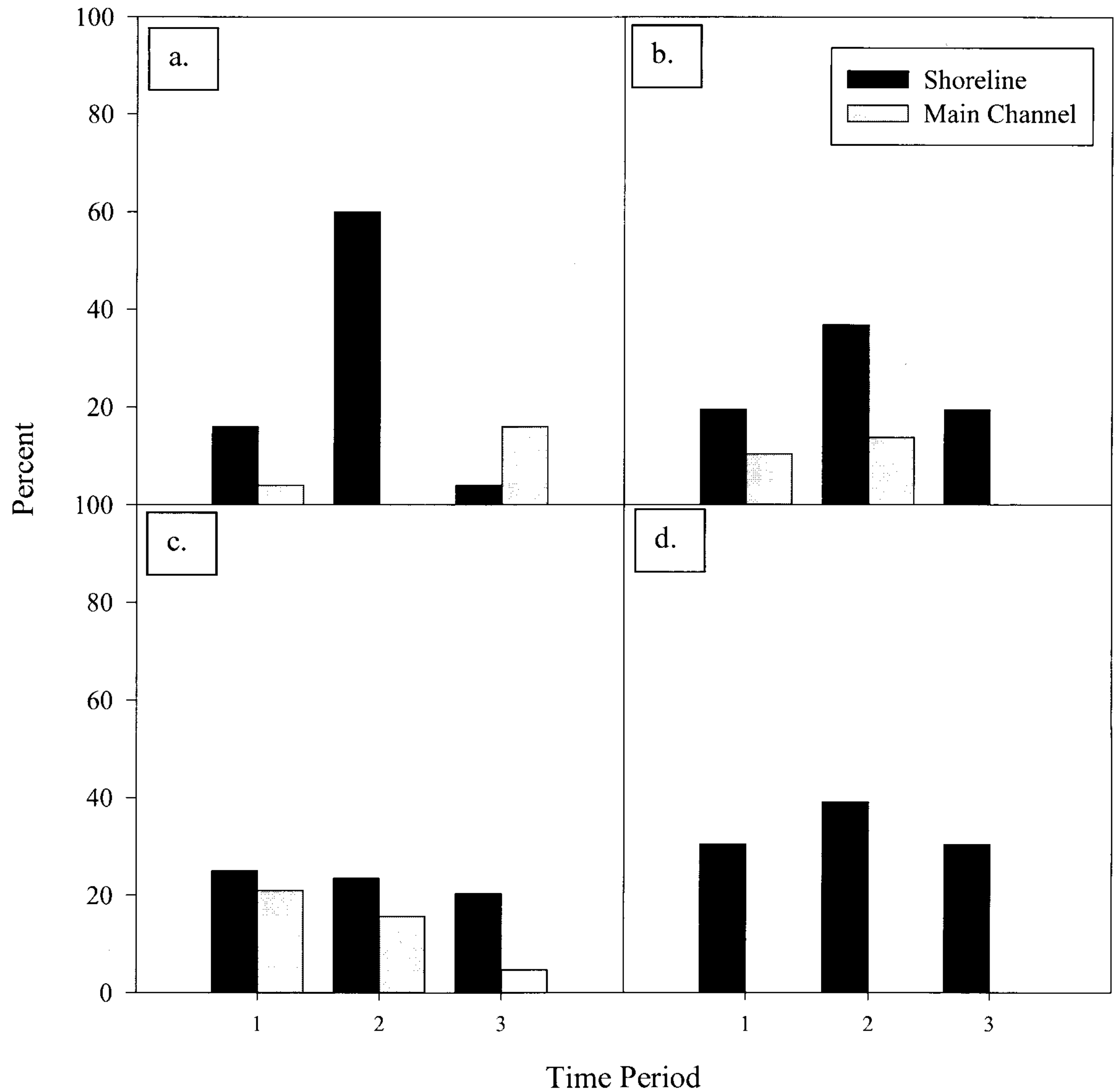

Figure 13. The percent of observations on Flathead Catfish located in main channel and shoreline habitat during each time period (1 is midnight to sunrise, 2 is sunrise to sunset, and 3 is sunset to midnight) during spring (a), summer (b), fall (c), and winter (d) from 2012 to 2013.

GENERAL CONCLUSION

Due to the increasing popularity of Flathead Catfish for commercial and recreational purposes in Midwestern lotic systems, it is vital biologists know the species range of movement and habitat requirements during all seasons. This information is necessary in order to define the geographic extent of management strategies and ensure important habitats are available within a system. I used ultrasonic telemetry with active tracking to monitor broad and fine scale movements of Flathead Catfish in the lower Wabash River, during all seasons. With telemetry, I was able to easily relocate individuals and assess habitat use and selection. Year-round monitoring was extremely beneficial because Flathead Catfish exhibited seasonal differences in diel movement patterns and habitat use. Strictly observing fish during parts of the year (or day) and basing management strategies from this is not adequate to guarantee proper regulations are being implemented and the population will persist. Together, my research shows the importance of evaluating broad and fine scale movements, year round, in order to accurately evaluate movement patterns and identify habitat requirements in a lotic system.

Flathead Catfish in the lower Wabash River did not show seasonal variation in broad scale movements, and generally remained within a relatively small range throughout my study (< 12 km) (Chapter 1). However, individuals were relatively mobile within a defined area throughout the daily cycle during spring and summer months (Chapter 2). Broad scale monitoring provided information about the range of movement within the river, which is useful to determine management extent (for example, watershed or localized). On the other hand, diel observations allowed for a detailed look into Flathead Catfish movement patterns, and gave further evidence to the importance of shoreline habitat. Fish made variable movements throughout the daily cycle each season; the greatest rate of movement occurred during summer and decreased dramatically during winter. Fine scale assessment was valuable because it discerned seasonal differences in Flathead Catfish behavior. Without this aspect of my research, conclusions would have described little seasonality. I was able to determine seasonal differences in Flathead Catfish movement because I observed broad and fine scale activities; these differences would not have been apparent using one method only.

Flathead Catfish remained within a small range in the lower Wabash River from 2012 to 2013. This is most likely because the river contains suitable habitat requirements, within close proximity, for successful spawning, foraging, and protection. In order to assess habitat use, it is necessary to observe fish during day and nighttime hours. By doing so, I was able to confidently determine that fish utilize main channel and shoreline habitat during different times of the diel cycle (depending on the season), but most often use shoreline habitat, in particular, outside bends containing dense woody debris. In addition, habitat use was dependent on the movement of individuals during specific times of the year. I observed the highest diel movement rates during summer months, when fish used the main channel and shoreline, and the least movement during winter, when fish were more restrictive in habitat usage. With the support from both studies, I suggest outside bend habitat is a contributing factor to the health and establishment of the lower Wabash River Flathead Catfish population.

My research is important for the proper management of Flathead Catfish in free flowing lotic systems in their native range. Due to restrictive movement of Flathead

Catfish and selection for outside bends, I suggest these key habitats are currently sufficient and available in the lower Wabash River. If individuals had shown large movements, then I would suggest habitat availability may be low within the river. With this, my results show that the lower free flowing 280 km of the Wabash River is currently ideal for the persistence of Flathead Catfish. In order for this population to remain healthy and sustainable, managers must ensure the lower Wabash River remains undammed; the natural flow causes the river to meander, which in turn, provides outside bends (typically deep) with structural habitat (washed in by annual floods). These features create ideal spawning cavities, foraging grounds, and protection for Flathead Catfish; therefore managers can use this information as baseline habitat requirements in similar river systems. Overall, year round broad and fine scale movement of Flathead Catfish in the lower Wabash River demonstrated the importance of shoreline habitat containing woody structure, giving evidence that these areas are crucial for the health and persistence of the species in lotic systems.

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APPENDIX: FLATHEAD CATFISH DATA

2012-2013

Guidelines for Appendix Tables		
	ID	Fish Identification Number
Season		
	SP	Spring
	SU	Summer
	FA	Fall
	WI	Winter
Site		
	1	Darwin
	2	Hutsonville
	3	St. Francisville
	4	New Harmony
	Tag	Transmitter Number
	TL	Total Length (mm)
	WT	Weight (g)
	Time	Military Time
	Lat.	Latitude
	Lon.	Longitude
	D.O.	Dissolved Oxygen (mg/L)
	Cond.	Conductivity (μS)
	Temp.	Water Temperature (°C)
	Flow	m/s
	Secchi	cm
	Depth	m
Hab.		Habitat
	IB	Inside Bend
	OB	Outside Bend
	CBO	Channel Border Open
	MC	Main Channel
	SC	Side Channel
	T	Tributary
Micro.		Microhabitat
	E	Eddy
	L	Logjam
	R	Run
	RR	Rip Rap

Guidelines for Appendix Tables		
	T	Thalweg
	S	Sandbar
Sub.		Substrate
	G	Gravel
	GH	Gravel/Hardpan
	H	Hardpan
	HIS	Hardpan/Silt
	M	Muck
	MG	Muck/Gravel
	B	Boulder
	SD	Sand
	SDC	Sand/Clay
	SDD	Sand/Detritus
	SDG	Sand/Gravel
	SDH	Sand/Hardpan
	SDM	Sand/Muck
	SDSI	Sand/Silt
	SI	Silt
	WL	Water Level at Mt. Carmel (m)

APPENDIX A: TAGGED FLATHEAD CATFISH IN THE WABASH RIVER

2012-2013

ID	Tag	Site	Date	TL	WT	Lat.	Lon.	D.O.	Cond.	Temp.
1	1526-250	1	6/25/12	581	2200	N 39°17.482	W 87°36.134	6.25	671	28.5
2	1522-254	1	7/2/12	439	900	N 39°17.051	W 87°36.522	6.8	631	32.9
6	1512-264	1	7/2/12	490	1160	N 39°16.788	W 87°36.600	6.8	631	32.9
3	1518-258	1	7/2/12	638	3560	N 39°15.881	W 87°36.235	6.8	631	32.9
4	1520-256	1	7/2/12	678	4450	N 39°15.878	W 87°36.233	6.8	631	32.9
5	1524-252	1	7/2/12	735	4700	N 39°15.878	W 87°36.233	6.8	631	32.9
7	1514-262	4	7/6/12	467	1250	N 38°07.277	W 87°56.799	4.34	622	30.8
10	40031-1101615	4	7/6/12	701	6000	N 38°07.327	W 87°56.794	4.34	622	30.8
13	40030-1101614	4	7/6/12	664	4250	N 38°07.324	W 87°56.797	4.34	622	30.8
9	40036-1101620	4	7/6/12	644	3250	N 38°07.276	W 87°56.800	4.34	622	30.8
12	40035-1101619	4	7/6/12	526	1500	N 38°07.324	W 87°56.797	4.34	622	30.8
8	1516-260	4	7/6/12	955	11500	N 38°07.276	W 87°56.799	4.34	622	30.8
11	40029-1101613	4	7/6/12	632	2950	N 38°07.325	W 87°56.797	4.34	622	30.8
14	40033-1101617	3	7/9/12	573	1880	N 38°34.230	W 87°38.884	3.43	625	29.9
17	40028-1101612	3	7/9/12	410	680	N 38°35.498	W 87°38.298	3.43	625	29.9
15	40034-1101618	3	7/9/12	416	700	N 38°34.200	W 87°38.900	3.43	625	29.9
16	40032-1101616	3	7/9/12	650	2850	N 38°35.498	W 87°38.297	3.43	625	29.9
18	38981-1096207	1	7/26/12	610	2370	N 39°16.603	W 87°36.493	-	-	-
21	38979-1096205	3	7/26/12	549	1760	N 38°34.227	W 87°38.830	-	-	-
19	40027-1101611	1	7/26/12	685	3890	N 39°16.604	W 87°36.493	-	-	-
20	38980-1096206	3	7/26/12	735	4300	N 38°34.228	W 87°38.830	-	-	-
23	1478-298	1	11/10/12	730	5200	N 39°17.857	W 87°35.837	3.34	590	12.3
22	1480-296	1	11/10/12	528	1448	N 39°17.864	W 87°35.841	3.34	590	12.3
24	1494-282	1	11/10/12	530	1604	N 39°17.858	W 87°35.836	3.34	590	12.3
30	1482-294	4	6/20/13	939	12200	N 38°06.907	W 87°56.780	1.9	433.9	26.1

ID	Tag	Site	Date	TL	WT	Lat.	Lon.	D.O.	Cond.	Temp.
33	1492-284	4	6/20/13	547	1795	N 38°06.907	W 87°56.780	1.9	433.9	26.1
25	1476-300	4	6/20/13	1220	21600	N 38°06.907	W 87°56.780	1.9	433.9	26.1
26	1496-280	4	6/20/13	580	2410	N 38°06.907	W 87°56.780	1.9	433.9	26.1
27	1484-292	4	6/20/13	680	3800	N 38°06.907	W 87°56.780	1.9	433.9	26.1
28	1502-274	4	6/20/13	810	7200	N 38°06.907	W 87°56.780	1.9	433.9	26.1
29	1478-298	4	6/20/13	745	5600	N 38°06.907	W 87°56.780	1.9	433.9	26.1
31	1486-290	4	6/20/13	707	4610	N 38°06.907	W 87°56.780	1.9	433.9	26.1
32	1488-288	4	6/20/13	880	11200	N 38°06.907	W 87°56.780	1.9	433.9	26.1
41	1360-416	1	7/25/13	536	1648	N 39°17.341	W 87°36.311	-	-	-
38	40027-1101611	2	7/25/13	439	842	N 39°06.482	W 87°39.167	-	-	-
40	1368-408	1	7/25/13	613	2415	N 39°17.341	W 87°36.311	-	-	-
44	1498-278	1	7/25/13	482	1070	N 39°17.341	W 87°36.311	-	-	-
37	1364-412	2	7/25/13	690	4508	N 39°06.482	W 87°39.167	-	-	-
39	1490-286	1	7/25/13	586	2652	N 39°17.341	W 87°36.311	-	-	-
34	38977-1096203	2	7/25/13	511	1500	N 39°06.992	W 87°39.005	-	-	-
35	40030-1101614	2	7/25/13	450	883	N 39°06.992	W 87°39.005	-	-	-
43	1366-410	1	7/25/13	521	1669	N 39°17.341	W 87°36.311	-	-	-
36	1500-276	2	7/25/13	659	3366	N 39°06.482	W 87°39.167	-	-	-
42	1362-414	1	7/25/13	432	816	N 39°17.341	W 87°36.311	-	-	-

APPENDIX B: BROAD SCALE LOCATIONS OF FLATHEAD CATFISH IN THE WABASH RIVER

2012 - 2013

ID	Date	Season	Time	Site	Lat.	Lon.	D.O.	Cond.	Temp.	Flow	Secchi	Depth	Hab.	Micro.	Sub.	WL
2	8/26/12	SU	1026	1	N 39°17.556	W 87°36.030	3.01	637	26.6	0.1	34	1.14	IB	L	M	0.69
19	8/26/12	SU	1119	1	N 39°16.524	W 87°36.441	3.15	635	26.8	0.3	35	3	OB	L	SDD	0.69
1	8/26/12	SU	0848	1	N 39°17.831	W 87°35.775	3.08	638	26.7	0.5	35	1.56	OB	L	SDG	0.69
6	8/26/12	SU	1058	1	N 39°16.683	W 87°36.567	3.23	636	26.8	0.3	36	1.5	CBO	L	SDG	0.69
3	8/26/12	SU	1147	1	N 39°16.196	W 87°36.057	3.15	635	26.8	0.2	30	3.3	OB	L	SDG	0.69
14	8/28/12	SU	1212	3	N 38°34.122	W 87°39.145	4.16	576	27.9	0.3	28	2.55	OB	R	-	0.66
7	8/29/12	SU	0852	1	N 38°07.968	W 87°56.478	2.47	615	26.1	0.2	44	2.43	MC	R	HIS	0.63
9	8/29/12	SU	1002	4	N 38°07.794	W 87°56.684	2.43	617	26.8	0.1	69	2.07	CBO	L	SD	0.66
12	8/29/12	SU	1122	4	N 38°06.913	W 87°57.017	2.94	616	27.3	0.3	44	4.8	IB	L	SD	0.63
12	8/29/12	SU	1106	4	N 38°06.941	W 87°57.019	2.94	616	27.3	0.3	44	2.88	OB	L	SDG	0.63
13	8/29/12	SU	1219	4	N 38°07.426	W 87°56.749	2.94	616	27.3	0.2	44	2.19	CBO	L	SDM	0.63
9	8/29/12	SU	0944	4	N 38°07.835	W 87°56.651	2.43	617	26.8	0.1	69	2.07	CBO	L	SDM	0.66
2	9/24/12	FA	1250	1	N 39°17.551	W 87°36.040	3.6	645	19.9	-	33.7	1.77	CBO	L	M	0.75
1	9/24/12	FA	1207	1	N 39°17.813	W 87°35.771	3.22	638	19.7	0.35	29.2	1.5	OB	L	SDD	0.75
13	10/12/12	FA	1057	4	N 38°08.149	W 87°55.988	5.5	549	15.2	0.1	38	1.05	OB	RR	B	1.10
13	10/12/12	FA	1352	4	N 38°08.165	W 87°56.065	5.5	549	15.2	-	38	-	OB	RR	B	1.10
13	10/12/12	FA	1420	4	N 38°08.164	W 87°56.032	5.5	549	15.2	-	38	-	OB	RR	B	1.10
9	10/12/12	FA	1259	4	N 38°07.748	W 87°56.710	5.42	551	16.1	0.1	36	1.29	CBO	L	SD	1.10
12	10/12/12	FA	1151	4	N 38°06.946	W 87°57.020	5.7	547	15.7	0.5	41	4.5	OB	L	SDG	1.10
2	10/13/12	FA	1008	1	N 39°17.536	W 87°36.048	5.33	594	13.9	0.1	40.5	2.46	CBO	L	M	1.13
1	10/13/12	FA	0912	1	N 39°17.811	W 87°35.774	5.45	591	13.7	0.6	42.3	2.82	OB	L	SD	1.13
6	10/13/12	FA	1048	1	N 39°16.695	W 87°36.542	5.72	593	13.8	0.5	41	1.44	MC	T	SDM	1.13
19	10/28/12	FA	1925	1	N 39°17.539	W 87°36.046	-	574	13.4	-	-	-	CBO	-	SD	1.58
2	10/28/12	FA	1634	1	N 39°17.535	W 87°36.046	4.13	565	14.1	-	35.5	2.7	CBO	-	-	1.58
1	10/29/12	FA	1511	1	N 39°17.849	W 87°35.761	5.59	589	13.2	-	31	1.17	OB	L	H	1.58

ID	Date	Season	Time	Site	Lat.	Lon.	D.O.	Cond.	Temp.	Flow	Secchi	Depth	Hab.	Micro.	Sub.	WL
13	11/14/12	FA	1034	4	N 38°08.160	W 87°56.081	3.85	644	9.7	1.6	50	6	OB	RR	B	1.11
12	11/14/12	FA	1305	4	N 38°07.399	W 87°56.777	3.19	656	9.9	0.7	58	3.9	CBO	L	SD	1.11
12	11/14/12	FA	1310	4	N 38°07.445	W 87°56.720	3.19	656	9.9	0.7	58	3.9	CBO	L	SD	1.11
1	11/16/12	FA	0953	1	N 39°17.854	W 87°35.757	2.54	633	8.8	1.47	-	1.59	OB	L	H	1.14
23	11/16/12	FA	1013	1	N 39°17.667	W 87°35.884	2.41	642	8.9	1.97	-	2.43	OB	L	SD	1.14
24	11/16/12	FA	1044	1	N 39°17.622	W 87°35.932	2.41	642	8.9	0.97	-	2.94	OB	L	SDD	1.14
1	12/6/12	WI	1826	1	N 39°17.854	W 87°35.767	5.87	712	10.8	2.367	-	2.01	OB	L	SDG	0.92
22	12/6/12	WI	1616	1	N 39°17.983	W 87°35.803	3.5	712	11	0.53	67	0.6	OB	L	SDM	0.92
1	1/11/13	WI	1110	1	N 39°17.821	W 87°35.770	2.3	678	6	0.83	22	2.85	OB	R	GH	2.55
22	1/11/13	WI	1048	1	N 39°18.009	W 87°35.822	2.3	648	6	1.3	23	1.32	OB	R	HIS	2.55
19	1/11/13	WI	1237	1	N 39°16.523	W 87°36.454	2.11	529	6	1.17	19	2.34	OB	L	SDG	2.55
14	2/18/13	WI	1305	3	N 38°35.594	W 87°38.288	5.81	618	5.5	0.4	26	2.4	OB	L	G	2.92
21	2/18/13	WI	1214	3	N 38°35.535	W 87°36.619	6.46	612	5	2.8	34	-	OB	RR	B	2.92
12	2/25/13	WI	1024	4	N 38°07.649	W 87°56.602	4.17	563	4.7	0.83	33	3.6	CBO	R	G	2.54
13	2/25/13	WI	9444	4	N 38°07.958	W 87°56.542	4.68	558	4.6	2.63	37.5	-	CBO	RR	B	2.54
10	2/25/13	WI	1009	4	N 38°07.757	W 87°56.648	4.17	563	4.7	1.83	33	6	CBO	R	SD	2.54
22	2/26/13	WI	0940	1	N 39°17.949	W 87°35.795	3.27	697	4.3	0.2	42	2.025	OB	L	SD	2.54
18	2/26/13	WI	1041	1	N 39°16.667	W 87°36.558	2.8	624	4	1.57	9	2.975	CBO	L	SDM	2.54
3	2/26/13	WI	1125	1	N 39°16.091	W 87°36.232	2.42	641	4.2	2.63	15.24	5.1	OB	-	-	2.54
3	3/14/13	SP	1057	1	N 39°16.137	W 87°36.235	9.86	570	5.1	0.27	33	3.87	OB	R	M	3.87
1	3/14/13	SP	0937	1	N 39°17.948	W 87°35.785	8.16	567	5	1.7	33	3.39	OB	R	SD	3.87
14	3/18/13	SP	1601	3	N 38°58.194	W 87°64.126	5.54	430.6	5.1	2.87	13	3.3	CBO	L	SDH	4.68
17	3/18/13	SP	1530	3	N 39°59.313	W 87°63.809	5.28	442.1	5	4.3	13	4.65	OB	L	SDM	4.68
10	3/27/13	SP	1532	4	N 38°07.749	W 87°56.547	5.17	461.9	7.6	1.83	35	2.49	CBO	L	SDM	3.38
23	5/13/13	SP	0852	1	N 39°18.273	W 87°36.490	12.29	466.3	15.2	1.27	26	4.35	OB	L	-	5.6

ID	Date	Season	Time	Site	Lat.	Lon.	D.O.	Cond.	Temp.	Flow	Secchi	Depth	Hab.	Micro.	Sub.	WL
17	5/19/13	SP	1030	3	N 38°75.578	W 87°38.316	9.76	513	21.7	2.13	39	3.54	OB	L	SDM	3.84
10	5/21/13	SP	0948	4	N 38°07.748	W 87°56.548	10.42	502	22.7	0.87	16	4.38	CBO	R	SD	3.16
1	5/25/13	SP	1704	1	N 39°17.838	W 87°35.770	19.3	591	19.3	1.43	31	3.72	OB	L	SDH	2.67
23	6/1/13	SU	-	1	-	-	-	-	-	-	-	-	IB	SB	SD	4.2
13	6/9/13	SU	-	4	N 38°06.165	W 88°00.843	-	-	-	-	-	-	T	-	-	4.35
19	6/16/13	SU	1035	1	N 39°17.671	W 87°35.99	-	425.6	23	0.37	11	2.4	IB	R	M	3.15
23	6/16/13	SU	0949	1	N 39°18.011	W 87°35.825	15.1	425.2	23	0.63	12	4.5	OB	R	SDC	3.3
17	6/18/13	SU	1052	3	N 38°35.583	W 87°38.320	1.47	417	25.1	0.67	10	3.3	OB	L	SDSI	3.90
24	7/8/13	SU	0940	1	N 39°17.986	W 87°35.811	-	509	24.4	0.67	24	3	OB	L	G	4.2
1	7/8/13	SU	1005	1	N 39°17.792	W 87°35.777	-	510	24.6	0.3	24	2.4	OB	R	SDM	4.2
12	7/12/13	SU	1224	4	N 38°06.865	W 87°56.815	-	505	26.5	0.57	25	1.5	SC	SB	SD	3.15
30	7/12/13	SU	1130	4	N 38°07.398	W 87°56.759	-	504	26.4	0.43	25	2.46	CBO	R	SDC	3.15
10	7/12/13	SU	1100	4	N 38°07.743	W 87°56.550	-	505	26.5	0.2	25	4.83	CBO	R	SI	3.15
1	7/13/13	SU	1551	1	N 39°17.861	W 87°35.768	6.38	525	26.7	1.3	28	5.22	OB	L	SDG	3.2
22	7/13/13	SU	2327	1	N 39°17.883	W 87°35.761	-	-	25.1	-	-	4.47	OB	-	-	3.2
24	7/14/13	SU	1038	1	N 39°17.979	W 87°35.803	-	-	-	-	-	3.03	OB	-	-	3.2
43	8/7/13	SU	1743	1	N 39°17.860	W 87°35.762	-	-	25.7	-	-	2.85	OB	L	-	1.4
40	8/7/13	SU	1650	1	N 39°17.910	W 87°35.766	3.41	563	25.5	3.44	22	3.09	OB	R	-	1.4
39	8/8/13	SU	1134	1	N 39°17.630	W 87°35.949	-	-	-	-	-	3.15	MC	-	SD	1.4
44	8/8/13	SU	0734	1	N 39°17.720	W 87°35.836	4.94	494	24.6	-	-	5.07	MC	L	SDG	1.4
22	8/8/13	SU	2000	1	N 39°17.961	W 87°35.794	-	-	24.8	-	-	2.84	OB	-	-	1.4
3	8/8/13	SU	1400	1	N 39°17.711	W 87°35.851	3.95	513	24.8	-	-	3.9	OB	-	-	1.4
40	8/12/13	SU	1117	1	N 39°17.741	W 87°35.801	8.58	595	26.4	0.27	35	0.69	OB	L	SD	1.44
39	8/12/13	SU	1150	1	N 39°17.607	W 87°35.986	8.58	595	26.4	0.67	35	3.75	CBO	L	SD	1.44
43	8/12/13	SU	1056	1	N 39°17.807	W 87°35.781	8.58	595	26.5	0.63	35	4.5	MC	L	SD	1.44

ID	Date	Season	Time	Site	Lat.	Lon.	D.O.	Cond.	Temp.	Flow	Secchi	Depth	Hab.	Micro.	Sub.	WL
35	8/12/13	SU	1545	2	N 39°07.168	W 87°38.702	10.01	594	26.6	0.63	47	2.7	MC	T	SD	1.44
36	8/12/13	SU	1520	2	N 39°07.431	W 87°38.546	10.01	594	26.6	0.63	47	4.17	MC	T	SD	1.44
22	8/12/13	SU	1040	1	N 39°18.016	W 87°35.844	8.64	591	26.4	1.13	35	2.52	OB	L	SDG	1.44
38	8/12/13	SU	1621	2	N 39°06.970	W 87°39.115	10.01	594	26.6	0.63	47	4.5	CBO	R	-	1.44
41	8/12/13	SU	1246	2	N 39°17.425	W 87°36.239	8.58	595	26.4	0.73	35	1.89	MC	T	-	1.44
38	8/12/13	SU	1652	2	N 39°06.913	W 87°39.132	-	-	-	-	-	5.25	MC	T	-	1.44
39	8/12/13	SU	1228	1	N 39°17.561	W 87°36.039	8.58	595	26.4	0.67	35	2.4	MC	T	-	1.44
37	8/12/13	SU	1630	2	N 39°06.985	W 87°39.019	10.01	594	26.6	0.63	47	1.05	CBO	-	-	1.44
12	8/15/13	SU	0954	4	N 38°06.794	W 87°56.963	8.05	590	24.1	0.63	36	2.61	MC	T	G	1.32
33	8/15/13	SU	1023	4	N 38°07.567	W 87°56.657	-	-	-	-	-	-	CBO	L	SDG	1.32
10	8/15/13	SU	0750	4	N 39°07.742	W 87°56.553	8.92	588	24.3	0.28	38	3.36	CBO	L	-	1.32
33	8/15/13	SU	0808	4	N 38°07.578	W 87°56.637	8.05	590	24.1	0.083	32	0.81	CBO	L	-	1.32
36	9/19/13	FA	1512	2	N 39°07.435	W 87°38.515	10.52	639	23.5	0.1	23.5	3.27	MC	T	SD	0.78
33	9/22/13	FA	1148	4	N 38°07.777	W 87°56.549	9.27	653	22.5	-	30	4.29	CBO	R	G	0.77
33	9/22/13	FA	1235	4	N 38°07.874	W 87°56.611	9.27	653	22.5	-	30	4.65	CBO	R	H	0.77
12	9/22/13	FA	1319	4	N 38°06.869	W 87°57.003	10.04	648	23.2	-	26	5.43	IB	L	SD	0.77
10	9/22/13	FA	1355	4	N 38°07.736	W 87°56.554	8.73	667	23.1	-	30	2.49	CBO	L	SDC	0.77
22	9/23/13	FA	1347	1	N 39°18.033	W 87°35.853	10.02	622	23.2	-	24	1.74	OB	L	SD	0.83
35	9/23/13	FA	1100	2	N 39°07.223	W 87°38.602	7.01	690	22.1	-	25	2.58	CBO	L	SD	0.83
36	9/23/13	FA	1039	2	N 39°07.429	W 87°38.504	7.32	680	21.8	-	23	2.67	OB	L	SD	0.83
43	9/23/13	FA	1410	1	N 39°17.940	W 87°35.811	10.12	618	22.9	-	24	1.8	MC	T	SD	0.83
41	9/23/13	FA	1501	2	N 3917.445	W 87°36.189	10.11	622	23	-	28	1.14	CBO	L	SDG	0.83
40	9/23/13	FA	1423	1	N 39°17.739	W 87°35.820	10.26	620	22.7	-	27	4.68	OB	L	SDM	0.83
44	9/23/13	FA	1440	1	N 39°17.669	W 87°35.877	9.9	621	22.9	-	25	1.68	MC	L	SDM	0.83
34	9/23/13	FA	1120	2	N 39°07.069	W 87°38.990	8.38	687	22.4	-	29	4.38	MC	R	-	0.83

ID	Date	Season	Time	Site	Lat.	Lon.	D.O.	Cond.	Temp.	Flow	Secchi	Depth	Hab.	Micro.	Sub.	WL
38	9/23/13	FA	1205	2	N 39°06.897	W 87°39.140	8.38	687	22.4	-	29	4.26	MC	T	-	0.83
33	10/28/13	FA	0941	4	N 38°08.158	W 87°56.427	12.5	454	10.8	0.08	26	3.6	OB	T	B	0.96
33	10/28/13	FA	0919	4	N 38°08.206	W 87°56.158	12.45	451	10.4	0.03	26	1.35	OB	SB	SD	0.96
12	10/28/13	FA	1030	4	N 38°06.922	W 87°56.023	13	455.5	11	0.65	26	4.8	IB	L	SDH	0.96
10	10/28/13	FA	1055	4	N 38°07.738	W 87°56.554	12.36	454.5	10.9	0.04	26	3.6	CBO	L	SI	0.96
39	10/29/13	FA	1204	1	N 39°17.691	W 87°35.858	9.22	424.3	11.4	0.56	47	1.8	OB	L	H	0.96
3	10/29/13	FA	-	1	N 39°17.746	W 87°35.812	9.45	424.6	11.4	0.37	47	3.9	OB	L	H	0.96
35	10/29/13	FA	0842	2	N 39°07.165	W 87°38.726	10.08	423.8	10.6	0.57	44	6.3	MC	T	H	0.96
36	10/29/13	FA	-	2	N 39°07.410	W 87°38.521	10.38	424.5	10.6	0.42	38	5.1	MC	T	H	0.96
36	10/29/13	FA	-	2	N 39°07.262	W 87°38.592	10.38	425.5	10.6	0.42	38	2.55	MC	T	H	0.96
41	10/29/13	FA	1230	2	N 39°17.447	W 87°36.230	9.41	425	11.5	0.69	45	2.19	MC	T	SD	0.96
22	10/29/13	FA	1127	1	N 39°18.021	W 87°35.854	9.45	424.6	11.4	0.8	47	1.65	MC	T	SD	0.96
3	10/29/13	FA	1218	1	N 39°17.662	W 87°35.922	9.22	424.3	11.4	0.56	47	2.7	MC	T	SD	0.96
43	10/29/13	FA	1136	1	N 39°17.952	W 87°35.817	9.72	424.6	11.4	1.04	47	1.38	MC	T	SD	0.96
3	11/11/13	FA	1004	1	N 39°16.758	W 87°36.596	9.8	425.5	10.5	0.31	31	3	OB	L	G	1.37
34	11/11/13	FA	1254	2	N 39°07.039	W 87°38.960	9.43	429	10.6	0.46	31	2.4	MC	L	SD	1.37
22	11/11/13	FA	0739	1	N 39°18.024	W 87°35.847	9.22	426.2	10.4	0.38	31	2.1	OB	L	SD	1.37
41	11/11/13	FA	0930	2	N 39°17.483	W 87°36.198	9.63	425	10.4	0.59	31	1.8	CBO	T	SD	1.37
38	11/11/13	FA	1345	2	N 39°06.819	W 87°39.242	9.49	429.6	10.6	0.02	34	5.1	CBO	T	SD	1.37
44	11/11/13	FA	0850	1	N 39°17.685	W 87°35.899	9.58	425.2	10.4	0.56	31	2.4	MC	T	SDG	1.37
39	11/11/13	FA	0837	1	N 39°17.708	W 87°35.832	9.22	425.7	10.4	0.11	31	2.4	OB	L	SDSI	1.37
43	11/11/13	FA	0756	1	N 39°17.931	W 87°35.778	9.3	426	10.4	0.2	31	2.1	OB	L	SDSI	1.37
36	11/11/13	FA	1224	2	N 39°07.298	W 87°38.526	9.32	429.6	10.6	0.22	31	4.55	OB	L	SDSI	1.37
37	11/11/13	FA	1311	2	N 39°06.977	W 87°39.096	9.58	429.6	10.6	0.17	34	4.8	CBO	T	SDSI	1.37
37	11/11/13	FA	1328	2	N 39°06.884	W 87°39.175	-	-	-	-	-	-	CBO	T	-	1.37

ID	Date	Season	Time	Site	Lat.	Lon.	D.O.	Cond.	Temp.	Flow	Secchi	Depth	Hab.	Micro.	Sub.	WL
10	11/12/13	FA	0908	4	N 38°07.738	W 87°56.553	9.44	417.6	9.9	-	31	5.1	CBO	R	G	1.31
33	11/12/13	FA	0745	4	N 38°08.177	W 87°55.884	9.4	418.4	9.9	-	31	6	OB	RR	B	1.31
12	11/12/13	FA	0752	4	N 38°08.165	W 87°56.090	9.55	417.9	9.9	-	31	5.4	OB	RR	B	1.31
22	12/4/13	WI	0800	1	N 39°17.999	W 87°35.834	9.68	474.4	7.3	0.81	62	1.59	OB	L	G	1.2
43	12/4/13	WI	0817	1	N 39°17.939	W 87°35.803	9.92	474.7	7.3	0.86	62	1.86	OB	L	MG	1.2
35	12/4/13	WI	1300	2	N 39°07.215	W 87°38.629	9.79	-	7.4	0.62	51	2.61	OB	L	SD	1.2
35	12/4/13	WI	1314	2	N 39°07.191	W 87°38.727	9.79	-	7.4	0.62	51	0.81	IB	SB	SD	1.2
3	12/4/13	WI	0933	1	N 39°16.950	W 87°36.610	9.67	473.6	7.4	0.15	64	2.37	MC	R	SDG	1.2
41	12/4/13	WI	0850	2	N 39°17.479	W 87°36.168	9.79	474.9	7.3	0.49	64	1.62	MC	T	SDG	1.2
38	12/4/13	WI	1353	2	N 39°06.966	W 87°39.093	10.49	468	7.5	0.43	57	5.7	MC	T	-	1.2
34	12/4/13	WI	1343	2	N 39°07.191	W 87°38.727	9.72	468	7.4	0.38	54	5.37	MC	T	-	1.2
36	12/4/13	WI	1351	2	N 39°06.966	W 87°39.093	10.49	468	7.5	0.43	57	5.7	MC	T	-	1.2
33	12/5/13	WI	0854	4	N 38°08.163	W 87°55.992	10.35	444.6	7.5	-	54	10.5	OB	RR	B	1.16
12	12/5/13	WI	0924	4	N 38°08.097	W 87°56.447	10.1	444.5	7.5	-	52	9	MC	T	-	1.16

APPENDIX C: FINE SCALE LOCATIONS OF FLATHEAD CATFISH IN THE WABASH RIVER

2012 - 2013

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
1	9/24/12	FA	1207	N 39°17.813	W 87°35.771	3.22	572	19.7	1.5	OB	L	0.75
2	9/24/12	FA	1250	N 39°17.551	W 87°36.040	3.6	582	19.9	1.77	CBO	L	0.75
19	9/24/12	FA	1503	N 39°16.521	W 87°36.426	3.07	588	20.8	3.18	OB	L	0.75
1	9/24/12	FA	1624	N 39°17.814	W 87°35.769	-	-	-	2.04	OB	L	0.75
2	9/24/12	FA	1703	N 39°17.535	W 87°36.051	-	-	-	1.74	CBO	L	0.75
1	9/24/12	FA	1907	N 39°17.817	W 87°35.767	-	-	-	1.89	OB	L	0.75
1	9/24/12	FA	1929	N 39°17.812	W 87°35.772	-	-	-	2.25	OB	L	0.75
2	9/24/12	FA	1958	N 39°17.548	W 87°36.054	-	-	-	1.74	CBO	L	0.75
2	9/24/12	FA	2119	N 39°17.542	W 87°36.047	3.02	582	19.1	1.44	CBO	L	0.756
2	9/24/12	FA	2229	N 39°17.538	W 87°36.047	-	-	19	1.47	CBO	L	0.756
1	9/24/12	FA	2245	N 39°17.799	W 87°35.777	-	-	19	3	OB	L	0.756
2	9/24/12	FA	2316	N 39°17.535	W 87°36.060	3.44	591	18.9	1.2	CBO	T	0.756
1	9/24/12	FA	2343	N 39°17.818	W 87°35.765	-	-	18.8	1.53	OB	L	0.756
2	9/25/12	FA	0020	N 39°17.531	W 87°36.052	-	-	18.8	1.83	CBO	L	0.756
1	9/25/12	FA	0053	N 39°17.817	W 87°35.769	-	-	18.8	1.98	OB	L	0.756
2	9/25/12	FA	0136	N 39°17.538	W 87°36.048	-	-	18.8	1.5	CBO	L	0.756
1	9/25/12	FA	0150	N 39°17.821	W 87°35.778	-	-	18.8	1.14	OB	L	0.756
2	9/25/12	FA	0238	N 39°17.539	W 87°36.045	-	-	18.7	1.98	CBO	L	0.756
1	9/25/12	FA	0247	N 39°17.817	W 87°35.771	-	-	18.7	2.1	OB	L	0.756
2	9/25/12	FA	0331	N 39°17.538	W 87°36.048	-	-	18.7	1.98	CBO	L	0.756
1	9/25/12	FA	0340	N 39°17.823	W 87°35.770	-	-	18.7	0.75	OB	L	0.756
2	9/25/12	FA	0428	N 39°17.537	W 87°36.043	-	-	18.5	1.74	CBO	L	0.756
1	9/25/12	FA	0440	N 39°17.817	W 87°35.766	-	-	18.5	0.93	OB	L	0.756
2	9/25/12	FA	0504	N 39°17.537	W 87°36.045	-	-	18.5	1.8	CBO	L	0.756
1	9/25/12	FA	0514	N 39°17.819	W 87°35.765	-	-	18.4	1.86	OB	L	0.756

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
2	10/28/12	FA	1634	N 39°17.535	W 87°36.046	4.13	448.6	14.1	2.7	CBO	L	1.575
2	10/28/12	FA	1750	N 39°17.536	W 87°36.046	4.5	448.3	14	3.09	CBO	L	1.575
2	10/28/12	FA	1925	N 39°17.539	W 87°36.046	-	448	13.4	-	CBO	L	1.575
19	10/28/12	FA	1925	N 39°17.539	W 87°36.046	-	448	13.4	-	CBO	L	1.575
2	10/28/12	FA	2150	N 39°17.534	W 87°36.049	4.5	450	13.5	3.15	CBO	L	1.575
19	10/28/12	FA	2150	N 39°17.534	W 87°36.049	4.5	450	13.3	3.15	CBO	L	1.575
2	10/28/12	FA	2356	N 39°17.538	W 87°36.042	-	448	12.8	1.8	CBO	L	1.575
2	10/29/12	FA	0015	N 39°17.529	W 87°36.052	4.48	451.9	13.1	1.65	CBO	L	1.575
2	10/29/12	FA	0145	N 39°17.536	W 87°36.047	4.6	448.3	12.9	1.17	CBO	L	1.575
2	10/29/12	FA	0257	N 39°17.530	W 87°36.050	-	-	-	1.17	CBO	L	1.575
2	10/29/12	FA	0334	N 39°17.538	W 87°36.048	-	-	12.6	0.99	CBO	L	1.575
1	10/29/12	FA	1511	N 39°17.849	W 87°35.761	5.59	456	13.2	1.17	OB	L	1.575
1	10/29/12	FA	1615	N 39°17.854	W 87°35.756	-	-	13.1	-	OB	L	1.575
22	12/6/12	WI	1616	N 39°17.983	W 87°35.803	3.5	521	11	0.6	OB	L	0.924
22	12/6/12	WI	1709	N 39°17.981	W 87°35.803	4.03	520	10.8	0.9	OB	L	0.924
22	12/6/12	WI	1805	N 39°17.980	W 87°35.804	4	524	10.8	0.84	OB	L	0.924
1	12/6/12	WI	1826	N 39°17.854	W 87°35.767	5.87	520	10.8	2.01	OB	L	0.924
22	12/6/12	WI	1945	N 39°17.977	W 87°35.798	4.2	523	10.7	1.8	OB	L	0.924
22	12/6/12	WI	2053	N 39°17.976	W 87°35.799	-	-	-	1.74	OB	L	0.924
22	12/6/12	WI	2230	N 39°17.976	W 87°35.799	-	-	-	-	OB	L	0.924
22	12/6/12	WI	2318	N 39°17.983	W 87°35.830	-	-	-	1.95	OB	T	0.924
1	12/7/12	WI	0022	N 39°17.850	W 87°35.770	4.24	523	10.6	1.65	OB	L	0.93
1	12/7/12	WI	0205	N 39°17.850	W 87°35.769	-	-	-	1.65	OB	L	0.93
1	12/7/12	WI	0304	N 39°17.848	W 87°35.770	-	-	-	1.65	OB	L	0.93
1	12/7/12	WI	0327	N 39°17.849	W 87°35.770	-	-	-	1.65	OB	L	0.93

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
1	12/7/12	WI	0418	N 39°17.851	W 87°35.770	4.9	522	10.8	1.92	OB	L	0.93
1	12/7/12	WI	0442	N 39°17.850	W 87°35.771	-	-	-	1.92	OB	L	0.93
1	12/7/12	WI	0630	N 39°17.848	W 87°35.761	-	-	-	-	OB	L	0.93
22	12/7/12	WI	0712	N 39°17.975	W 87°35.799	-	-	-	3.15	OB	-	0.93
22	12/7/12	WI	0848	N 39°17.975	W 87°35.798	-	-	-	-	OB	-	0.93
1	12/7/12	WI	1102	N 39°17.839	W 87°35.771	-	-	-	-	OB	-	0.93
1	12/7/12	WI	1150	N 39°17.840	W 87°35.765	-	-	-	-	OB	-	0.93
1	12/7/12	WI	1236	N 39°17.839	W 87°35.767	-	-	-	-	OB	-	0.93
1	12/7/12	WI	1320	N 39°17.839	W 87°35.766	-	-	-	-	OB	-	0.93
1	12/7/12	WI	1422	N 39°17.839	W 87°35.770	-	-	-	-	OB	-	0.93
1	12/7/12	WI	1512	N 39°17.833	W 87°35.760	-	-	-	-	OB	-	0.93
1	5/25/13	SP	1704	N 39°17.838	W 87°35.770	-	530	19.3	3.72	OB	L	2.67
1	5/25/13	SP	1748	N 39°17.839	W 87°35.767	-	-	19.3	3.72	OB	L	2.67
1	5/25/13	SP	1853	N 39°17.838	W 87°35.766	-	-	19.1	3.72	OB	L	2.67
1	5/25/13	SP	2003	N 39°17.850	W 87°35.761	-	-	19.1	3.51	OB	L	2.67
1	5/25/13	SP	2135	N 39°17.822	W 87°35.793	13.58	523	18.3	4.2	MC	T	2.67
1	5/25/13	SP	2215	N 39°17.819	W 87°35.797	14.07	522	18.3	3.87	MC	T	2.67
1	5/25/13	SP	2315	N 39°17.841	W 87°35.787	14.21	522	18.6	3.69	MC	T	2.67
1	5/25/13	SP	2355	N 39°17.822	W 87°35.815	-	-	-	2.37	MC	T	2.67
1	5/26/13	SP	0015	N 39°17.790	W 87°35.777	-	-	-	5.16	OB	T	2.67
1	5/26/13	SP	0055	N 39°17.787	W 87°35.804	13.63	517	18.2	4.17	MC	T	2.67
1	5/26/13	SP	0145	N 39°17.804	W 87°35.780	-	-	18.2	3.57	OB	T	2.67
1	5/26/13	SP	0240	N 39°17.796	W 87°35.773	-	-	18.1	3.54	OB	R	2.67
1	5/26/13	SP	0341	N 39°17.847	W 87°35.764	-	-	18.2	3.93	OB	L	2.67
1	5/26/13	SP	0502	N 39°17.764	W 87°35.797	-	-	18	4.71	OB	-	2.67

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
1	5/26/13	SP	0550	N 39°17.759	W 87°35.796	-	-	18.1	4.62	OB	-	2.67
1	5/26/13	SP	0650	N 39°17.758	W 87°35.801	-	-	18.1	5.4	OB	-	2.67
1	5/26/13	SP	0748	N 39°17.759	W 87°35.801	-	-	18.1	5.4	OB	-	2.67
1	5/26/13	SP	0930	N 39°17.830	W 87°35.775	11.69	516	18.2	3.51	OB	L	2.67
1	5/26/13	SP	1023	N 39°17.813	W 87°35.777	-	-	18.2	3.54	OB	L	2.67
1	5/26/13	SP	1121	N 39°17.804	W 87°35.777	-	-	18.3	3.42	OB	-	2.67
1	5/26/13	SP	1209	N 39°17.831	W 87°35.771	-	-	18.9	3.72	OB	-	2.67
1	5/26/13	SP	1304	N 39°17.837	W 87°35.766	-	-	18.8	3.78	OB	-	2.67
1	5/26/13	SP	1409	N 39°17.833	W 87°35.770	-	-	18.7	3.18	OB	-	2.67
1	5/26/13	SP	1504	N 39°17.835	W 87°35.768	-	-	18.7	4.14	OB	-	2.67
1	5/26/13	SP	1554	N 39°17.837	W 87°35.769	-	-	18.9	4.2	OB	-	2.67
1	7/13/13	SU	1551	N 39°17.861	W 87°35.768	6.38	537	26.7	5.22	OB	L	3.195
1	7/13/13	SU	1658	N 39°17.893	W 87°35.746	5.56	539	26.3	1.23	OB	-	3.195
1	7/13/13	SU	1746	N 39°17.863	W 87°35.762	-	-	25.9	4.62	OB	L	3.195
1	7/13/13	SU	1848	N 39°17.859	W 87°35.760	-	-	25.9	4.38	OB	-	3.195
1	7/13/13	SU	1930	N 39°17.875	W 87°35.757	-	-	25.8	3.75	OB	-	3.195
1	7/13/13	SU	2030	N 39°17.871	W 87°35.760	-	-	25.4	4.5	OB	-	3.195
1	7/13/13	SU	2130	N 39°17.831	W 87°35.773	-	-	25.3	4.23	OB	L	3.195
1	7/13/13	SU	2249	N 39°17.698	W 87°35.839	-	-	25.2	4.35	OB	L	3.195
22	7/13/13	SU	2327	N 39°17.883	W 87°35.761	-	-	25.1	4.47	OB	-	3.195
1	7/13/13	SU	2343	N 39°17.701	W 87°35.841	-	-	25.1	4.29	OB	-	3.195
1	7/14/13	SU	0048	N 39°17.822	W 87°35.776	-	-	25	4.8	OB	-	3.195
1	7/14/13	SU	0200	N 39°17.791	W 87°35.794	-	-	25	5.76	OB	-	3.195
1	7/14/13	SU	0230	N 39°17.802	W 87°35.771	-	-	24.7	5.07	OB	-	3.195
1	7/14/13	SU	0326	N 39°17.817	W 87°35.811	-	-	25	4.2	MC	-	3.195

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
1	7/14/13	SU	0407	N 39°17.815	W 87°35.811	-	-	25	4.53	MC	-	3.195
1	7/14/13	SU	0426	N 39°17.796	W 87°35.792	-	-	25	6.27	MC	-	3.195
1	7/14/13	SU	0533	N 39°17.889	W 87°35.792	-	-	24.8	4.32	MC	-	3.195
1	7/14/13	SU	0628	N 39°17.881	W 87°35.758	-	-	25	4.17	OB	-	3.195
1	7/14/13	SU	0710	N 39°17.880	W 87°35.754	-	-	25.1	3.87	OB	-	3.195
1	7/14/13	SU	0810	N 39°17.891	W 87°35.762	-	-	25.2	3.78	OB	-	3.195
1	7/14/13	SU	0912	N 39°17.866	W 87°35.755	-	-	25.5	4.35	OB	-	3.195
24	7/14/13	SU	1038	N 39°17.979	W 87°35.803	-	-	-	3.03	OB	-	3.195
1	7/14/13	SU	1051	N 39°17.883	W 87°35.757	-	-	26.6	0.93	OB	-	3.195
1	7/14/13	SU	1126	N 39°17.891	W 87°35.750	-	-	26.2	1.74	OB	-	3.195
1	7/14/13	SU	1222	N 39°17.830	W 87°35.773	-	-	26.3	4.29	OB	-	3.195
1	7/14/13	SU	1301	N 39°17.873	W 87°35.791	-	-	26.1	4.41	MC	-	3.195
1	7/14/13	SU	1425	N 39°17.845	W 87°35.770	-	-	26.4	5.28	OB	-	3.195
1	7/14/13	SU	1501	N 39°17.857	W 87°35.778	-	-	26.3	4.71	MC	-	3.195
1	7/14/13	SU	1549	N 39°17.845	W 87°35.808	-	-	26.3	3.75	IB	-	3.195
40	8/7/13	SU	1650	N 39°17.910	W 87°35.766	3.41	-	25.5	3.09	OB	E	1.398
43	8/7/13	SU	1743	N 39°17.860	W 87°35.762	-	-	25.7	2.85	OB	L	1.398
40	8/7/13	SU	1809	N 39°17.814	W 87°35.772	-	-	25.7	3.51	OB	L	1.398
43	8/7/13	SU	1840	N 39°17.864	W 87°35.760	-	-	25.7	3.3	OB	L	1.398
40	8/7/13	SU	1849	N 39°17.813	W 87°35.767	-	-	25.7	3.15	OB	L	1.398
40	8/7/13	SU	1937	N 39°17.818	W 87°35.766	-	-	25.6	2.88	OB	L	1.398
43	8/7/13	SU	2003	N 39°17.858	W 87°35.771	-	-	25.4	3.75	OB	-	1.398
43	8/7/13	SU	2025	N 39°17.844	W 87°35.767	-	-	25.5	3.84	OB	L	1.398
43	8/7/13	SU	2034	N 39°17.835	W 87°35.779	-	-	25.5	3.84	OB	T	1.398
40	8/7/13	SU	2037	N 39°17.807	W 87°35.767	-	-	25.1	3.15	OB	-	1.398

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
43	8/7/13	SU	2144	N 39°17.791	W 87°35.775	-	-	25.3	3.48	OB	-	1.398
43	8/7/13	SU	2151	N 39°17.872	W 87°35.763	-	-	25.3	-	OB	-	1.398
43	8/7/13	SU	2156	N 39°17.846	W 87°35.766	-	-	-	3.78	OB	-	1.398
40	8/7/13	SU	2202	N 39°17.762	W 87°35.800	-	-	24.8	5.4	OB	-	1.398
43	8/7/13	SU	2245	N 39°17.867	W 87°35.763	-	-	-	3	OB	-	1.398
40	8/7/13	SU	2300	N 39°17.760	W 87°35.794	-	-	-	4.77	OB	-	1.398
43	8/7/13	SU	2352	N 39°17.891	W 87°35.761	-	-	25	3.39	OB	-	1.398
43	8/8/13	SU	0004	N 39°17.784	W 87°35.793	-	-	-	4.65	MC	-	1.398
3	8/8/13	SU	0014	N 39°17.711	W 87°35.851	3.95	-	24.8	3.9	OB	-	1.398
22	8/8/13	SU	0020	N 39°17.961	W 87°35.794	-	-	24.8	2.844	OB	-	1.398
43	8/8/13	SU	0027	N 39°17.881	W 87°35.762	-	-	25.2	3.129	OB	-	1.398
40	8/8/13	SU	0051	N 39°17.774	W 87°35.785	-	-	25	3.51	OB	-	1.398
43	8/8/13	SU	0143	N 39°17.876	W 87°35.760	-	-	25	3.03	OB	-	1.398
43	8/8/13	SU	0154	N 39°17.791	W 87°35.778	-	-	25	4.62	OB	-	1.398
40	8/8/13	SU	0207	N 39°17.745	W 87°35.808	-	-	25.1	5.61	OB	-	1.398
3	8/8/13	SU	0207	N 39°17.745	W 87°35.808	-	-	25.1	5.61	OB	-	1.398
43	8/8/13	SU	0234	N 39°17.878	W 87°35.765	-	-	-	3.36	OB	-	1.398
43	8/8/13	SU	0245	N 39°17.806	W 87°35.887	-	-	-	2.88	OB	-	1.398
40	8/8/13	SU	0259	N 39°17.747	W 87°35.808	-	-	24.7	5.13	OB	-	1.398
43	8/8/13	SU	0259	N 39°17.747	W 87°35.808	-	-	24.7	5.13	OB	-	1.398
43	8/8/13	SU	0334	N 39°17.844	W 87°35.773	-	-	24.8	4.05	OB	-	1.398
40	8/8/13	SU	0401	N 39°17.777	W 87°35.809	-	-	25	3.6	MC	-	1.398
43	8/8/13	SU	0411	N 39°17.849	W 87°35.770	-	-	-	3.93	OB	-	1.398
43	8/8/13	SU	0417	N 39°17.796	W 87°35.789	-	-	-	4.74	MC	-	1.398
40	8/8/13	SU	0426	N 39°17.751	W 87°35.820	-	-	-	3.99	MC	-	1.398

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
43	8/8/13	SU	0426	N 39°17.751	W 87°35.820	-	-	-	3.99	MC	-	1.398
44	8/8/13	SU	0734	N 39°17.720	W 87°35.836	4.94	490	24.6	5.07	MC	L	1.398
43	8/8/13	SU	0756	N 39°17.799	W 87°35.781	-	-	24.7	4.53	OB	-	1.398
40	8/8/13	SU	0808	N 39°17.738	W 87°35.826	-	-	24.7	4.08	MC	-	1.398
43	8/8/13	SU	0927	N 39°17.797	W 87°35.792	-	-	25.1	4.68	MC	-	1.398
44	8/8/13	SU	0936	N 39°17.711	W 87°35.837	-	-	24.7	4.62	MC	-	1.398
40	8/8/13	SU	0948	N 39°17.758	W 87°35.847	-	-	24.7	1.08	IB	-	1.398
40	8/8/13	SU	1013	N 39°17.750	W 87°35.816	-	-	24.7	4.05	MC	-	1.398
43	8/8/13	SU	1020	N 39°17.763	W 87°35.799	-	-	24.7	5.01	OB	-	1.398
43	8/8/13	SU	1117	N 39°17.896	W 87°35.768	-	-	26	2.25	OB	-	1.398
43	8/8/13	SU	1124	N 39°17.775	W 87°35.793	-	-	26	4.98	OB	-	1.398
40	8/8/13	SU	1127	N 39°17.739	W 87°35.821	-	-	-	4.38	MC	-	1.398
39	8/8/13	SU	1134	N 39°17.630	W 87°35.949	-	-	-	3.15	MC	-	1.398
3	8/8/13	SU	1151	N 39°17.546	W 87°36.051	5.7	489	25.4	2.79	CBO	L	1.398
43	8/8/13	SU	1209	N 39°17.822	W 87°35.788	-	-	-	3.54	MC	-	1.398
40	8/8/13	SU	1215	N 39°17.746	W 87°35.813	5.3	-	26.1	4.74	MC	-	1.398
43	8/8/13	SU	1259	N 39°17.830	W 87°35.771	-	-	26.4	2.88	OB	-	1.398
40	8/8/13	SU	1304	N 39°17.786	W 87°35.782	-	-	26.4	4.29	OB	-	1.398
43	8/8/13	SU	1415	N 39°17.823	W 87°35.770	-	-	26.5	2.85	OB	-	1.398
40	8/8/13	SU	1423	N 39°17.738	W 87°35.806	-	-	26.4	5.07	OB	-	1.398
39	8/8/13	SU	1444	N 39°17.626	W 87°35.940	-	-	-	3.51	CBO	-	1.398
43	8/8/13	SU	1510	N 39°17.806	W 87°35.876	-	-	26.1	4.35	MC	-	1.398
40	8/8/13	SU	1515	N 39°17.742	W 87°35.805	-	-	26	4.95	OB	-	1.398
36	9/19/13	FA	1512	N 39°07.435	W 87°38.515	10.52	639	23.5	3.27	MC	T	0.78
36	9/19/13	FA	1604	N 39°07.421	W 87°38.543	10.35	641	23.6	1.8	MC	T	0.78

ID	Date	Season	Time	Lat.	Lon.	D.O.	Cond.	Temp.	Depth	Hab.	Micro.	WL
36	9/19/13	FA	1638	N 39°07.413	W 87°38.520	10.38	642	23.7	4.65	MC	L	0.78
36	9/19/13	FA	1752	N 39°07.446	W 87°38.535	10.69	645	23.9	2.76	MC	-	0.78
36	9/19/13	FA	1827	N 39°07.450	W 87°38.540	10.56	646	24	2.37	MC	T	0.78
36	9/19/13	FA	1921	N 39°07.451	W 87°38.517	10.51	647	24.1	3.27	MC	L	0.78
36	9/19/13	FA	2022	N 39°07.472	W 87°38.518	9.6	647	24.1	2.52	MC	-	0.78
36	9/19/13	FA	2112	N 39°07.469	W 87°38.510	10.92	648	24.1	3.72	OB	L	0.78
36	9/19/13	FA	2149	N 39°07.462	W 87°38.503	10.4	648	24.1	4.26	OB	L	0.78
36	9/19/13	FA	2258	N 39°07.478	W 87°38.527	10.61	647	24.1	1.44	MC	S	0.78
36	9/19/13	FA	2349	N 39°07.474	W 87°38.521	9.86	647	24.1	3	MC	T	0.78
36	9/20/13	FA	0058	N 39°07.469	W 87°38.524	9.89	647	24	2.85	MC	T	0.78
36	9/20/13	FA	0135	N 39°07.472	W 87°38.535	9.64	647	24	1.62	MC	S	0.78
36	9/20/13	FA	0240	N 39°07.454	W 87°38.534	8.95	646	24	3.15	MC	T	0.78
36	9/20/13	FA	0331	N 39°07.442	W 87°38.539	9.13	646	23.9	2.73	MC	T	0.78
36	9/20/13	FA	0425	N 39°07.468	W 87°38.533	8.72	645	23.8	2.1	MC	S	0.78
36	9/20/13	FA	0444	N 39°07.445	W 87°38.538	8.61	645	23.8	2.37	MC	S	0.78
36	9/20/13	FA	0553	N 39°07.463	W 87°38.522	8.08	645	23.7	2.22	MC	S	0.78
36	9/20/13	FA	0653	N 39°07.453	W 87°38.543	7.71	645	23.6	2.07	MC	-	0.78
36	9/20/13	FA	0757	N 39°07.482	W 87°38.509	7.58	645	23.5	2.37	OB	L	0.78
36	9/20/13	FA	0920	N 39°07.456	W 87°38.528	7.52	644	23.5	3.06	MC	T	0.78
36	9/20/13	FA	0953	N 39°07.447	W 87°38.550	7.71	643	23.5	1.56	IB	S	0.78
36	9/20/13	FA	1100	N 39°07.457	W 87°38.524	8.21	640	23.5	3.12	MC	T	0.78
36	9/20/13	FA	1231	N 39°07.469	W 87°38.505	7.82	-	23.6	3.06	OB	L	0.78
36	9/20/13	FA	1338	N 39°07.458	W 87°38.522	7.87	640	23.7	1.56	IB	S	0.78
36	9/20/13	FA	1415	N 39°07.450	W 87°38.535	7.5	640	23.7	2.76	MC	T	0.78