Movements and Spawning of Bigheaded Carps in the Upper Wabash River, Indiana, USA: 2013 Update

Alison Coulter[1], Graduate Research Assistant astrandb@purdue.edu
Reuben R. Goforth, Ph.D.[1], Principal Investigator rgoforth@purdue.edu
[1]Department of Forestry and Natural Resources, Purdue University, 195 Marstellar Street, West Lafayette, IN 47907

Introduction

Over 180 aquatic non-indigenous species (NIS) have been introduced into Great Lakes Basin waters to date, and new introductions are expected in the future. The so-called "bigheaded carps" (e.g., silver *Hypophthalmichthys molitrix* and bighead *H. nobilis*) are considerable threats to the Great Lakes given expected trajectories of nutrient flow disruption and food web alterations that will likely accompany their introduction to the Basin. While great effort has been expended to keep these species from entering the Great Lakes Basin via the Illinois River and its connection to the Chicago Sanitary and Ship Canal, an additional pathway for introduction has been identified at Eagle Marsh near Fort Wayne, Indiana. Eagle Marsh may provide a corridor for movement of these species between the Wabash and Maumee River basins during high water periods. The direct connection of the Maumee River with Lake Erie would therefore provide a means for introduction of bigheaded carp to the Great Lakes. Immediate action has been taken to prevent such an introduction through the installation of a physical barrier across Eagle Marsh. However, the potential ranges and rates of movement by silver and bighead carps throughout the Wabash River, and especially into the Little River and Eagle Marsh, are not fully understood.

Understanding the movements of invading species in novel environments is important for predicting potential impacts (DeGrandchamp et al. 2008), knowing where and when they utilize the environment for life history events like reproduction (Williamson and Garvey 2005), and for devising potential control strategies (DeGrandchamp et al. 2008). Bigheaded carp are known to make rapid, large scale movements that are usually associated with spawning (Abdusamadov 1987), and migrations may be triggered by several factors, including temperature (DeGrandchamp et al. 2008) and river stage/flow (Abdusamadov 1987; Peters et al. 2006; DeGrandchamp et al. 2008). For example, silver carp were found to move ≈10 km/day in the Illinois River and range over 250 miles (DeGrandchamp et al. 2008). The specific cues triggering bigheaded carp movements in the Wabash River watershed are as yet unknown, and such information is critical for devising control measures.

The extent and types of habitats used by bigheaded carp in the Wabash River are also unknown. For example, we currently have little knowledge of the use of smaller tributary rivers, like the Little River, by both silver and bighead carp during any stage of their life cycle. While silver carp were found to avoid both main channel and backwater habitats in the Illinois River where they preferred to remain near the river banks (DeGrandchamp et al. 2008), they currently occur in relatively high densities in Borrow Pit 1 (BP1), a backwater habitat, behind the Williamsburg Apartments in West Lafayette (River Mile 310, RM310), and in a main channel area at Logansport (RM351). From tracking conducted in 2011, we know that they occasionally occur in tributaries such as the Tippecanoe River. Determining habitat use by bigheaded carp in the Wabash River can help to devise strategies for control and prediction of invasion patterns in novel river ecosystems.

Previous studies have successfully used telemetry to observe bigheaded carp movements in rivers (e.g., Calkins et al. 2012; DeGrandchamp et al. 2008). As of fall 2012, we have tagged and tracked 163 bigheaded carp in the Wabash River using ultrasonic tags and passive and manual tracking hardware to observe their movements. We have also monitored and recorded the habitat types that these tagged fish are utilizing. Ultimately, we expect these data to yield insight into the range of river and movement rates these fish may cover, as well as a characterization of their potential habitat. We have also conducted spring surveys to detect bigheaded carp spawning events at multiple sites in the upper Wabash River and one of its largest tributaries, the East Fork of the White River in an attempt to better understand the range of spawning activity and ecology in these fishes.

Methods

Tagging

Fish for acoustic tagging were collected using a 6 m electrofishing boat (Model SR16H; Smith-Root Inc., Vancouver, Washington) and a 6 m Polarcraft modified John boat outfitted with an electrofishing control box (Model VI-A; Smith-Root Inc., Vancouver, Washington). In both cases, the electrofishing equipment was powered by a generator, and adjustments were made to achieve a pulsator running at either 3-4 A of direct current at 30 pulses s^{-1} and 20-50% of range pulse width or 7-8 A of direct current at 120 pulses s^{-1}. Fish were also collected using gill nets set for < 30 min. Nets were borrowed from IDNR and had 10.16 cm bar mesh. Bighead carp from Oakdale Dam on the Tippecanoe River were collected using hook-and-line sampling. Hook-and-line collected fish were transported to the nearest Wabash River boat launch using an aerated fish hauler. Surgery was then done as described below.

Candidate fish were anaesthetized using a custom-made mobile electroanesthesia unit (MEU). An AbP-3™ Pulsed-DC electrofishing box (ETS Electrofishing, LLC, Madison, Wisconsin) was used to generate an electrical field for the MEU (120 V, 30 Hz, 25% duty cycle, 7-15 s). The MEU induced loss of reflex almost instantaneously and recovery from anesthesia was relatively quick. Once loss of reflex was induced, each fish was weighed (g) using a HW-60KGL digital balance (±0.005 kg; A&D Co., Ltd., Tokyo, Japan) and measured for total length (cm). Each fish was also externally tagged using a Floy T-bar anchor tag (Model FD-68B; Floy Tag & Mfg. Inc., Seattle, Washington) inserted near the dorsal fin base. Fish were classified as either silver or bighead carp based on appearance but will later be definitely classified using established DNA markers (Mia et al. 2005).

Vemco ultrasonic transmitters (Model V16-4L, 24 g, 16 mm diameter, 68 mm length) tasked for a nominal delay of 60 s were surgically implanted in the coelomic cavity of the carp. A 4-5 cm incision was made in the left side of the fish just dorsal and anterior to the anal fin in an area sterilized with Betadine (Walgreens Co., Deerfield, Illinois) where scales had been removed using a size 10 or 20 scalpel dipped in a 90% ethanol solution between surgeries. Transmitter weights were <2% of the fishes' weights in accordance with the recommended criteria from Vemco. After implantation, the incisions were closed using three absorbable monofilament sutures (PDS II, Ethicon Inc., Cornelia, Georgia). All fish were visually inspected to determine sex, if possible, although the gonads were often not visible during the surgeries. All fish handling was completed within a 2-minute time period. Fish were allowed to initially recover in the MEU. Once swimming ability had returned, fish were placed in an *in situ* pen until fully recovered, then released in the river. Recovery was defined as the return of normal orientation and swimming behavior post-surgery.

<u>Tracking</u>

Passive – Omnidirectional passive receivers (Vemco VR2W) were deployed on the river bottom in the Little River, Salamonie River, Eel River, Tippecanoe River, and Wabash River between Wabash River Miles (RM) 406-165 (Figure 1). The VR2Ws were attached to custom platforms and anchors (Plates 1-2). The size of each platform and anchor system was adjusted based on the water depth where it would be deployed. This combination of platforms and anchors was connected by 2-30 m steel cable for secure placement on the bottom of the river, and attached floats allowed for grappling of the cable to retrieve the VR2Ws for data downloads. Platforms were welded from rebar and anchors were cement-rebar structures deployed upstream of platforms that varied in weight from 26.3 kg to a single cinderblock. Passive receivers were occasionally tested to ensure their detection efficiency using a Vemco-supplied range testing tag, especially in shallow water.

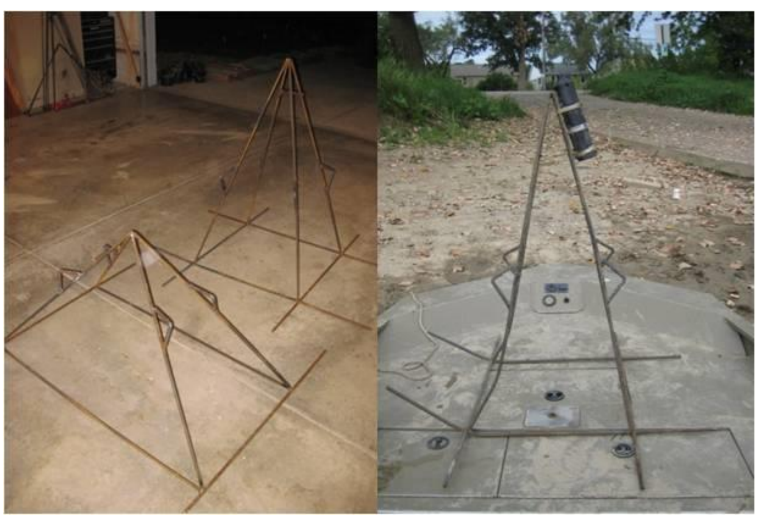

Plate 1. Larger deployment platforms for Vemco VR2W passive receivers (attached to the top of the stand in the picture to the right) deployed in deeper reaches of the Wabash River.

Plate 2. Smaller deployment system used for Vemco VR2W passive receivers in shallow reaches of the Wabash and Little Rivers.

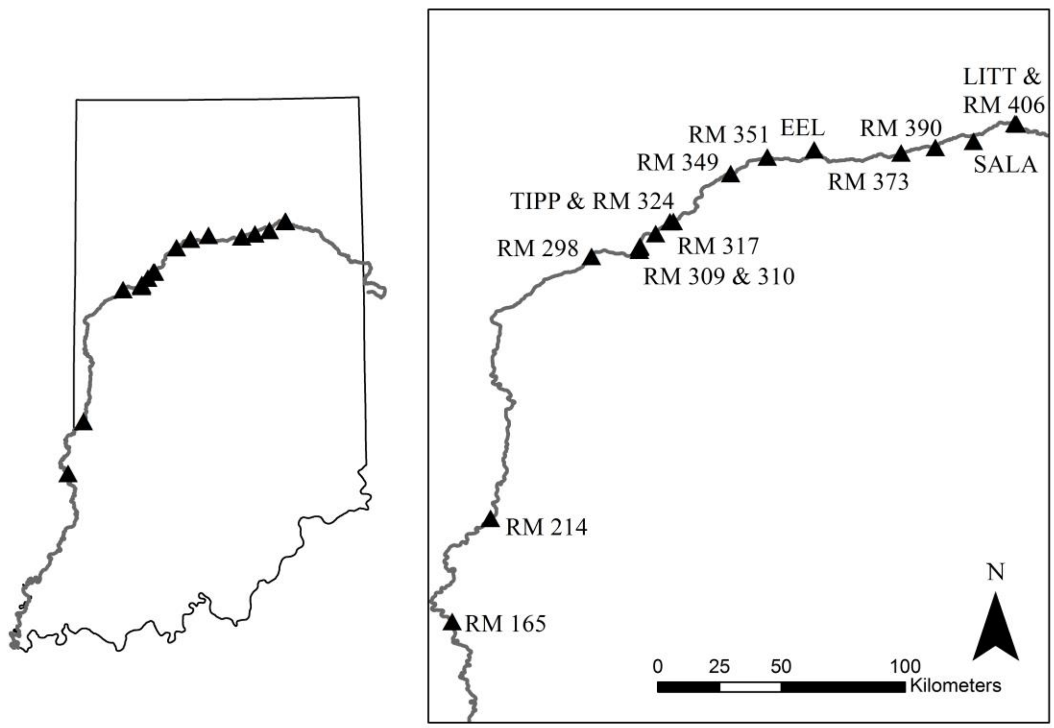

Figure 1. Placement of Vemco VR2W stationary receivers in the Wabash, Little (LITT), Eel (EEL), Salamonie (SALA) and Tippecanoe (TIPP) Rivers. Each triangle indicates the location of a VR2W and all are labeled with Wabash RM and/or the name of the tributary.

Vemco VR2Ws were deployed in the river at smaller increments near tagging locations and at larger increments near the upper and lower boundaries of the study area as well as just upstream in the Tippecanoe and Little Rivers ultimately covering ~200 RM (Figure

1). Placement varied somewhat depending on access points. While this array covered considerably more area than the primary study site in the upper and middle Wabash River, this arrangement was judged sufficient to cover the full potential range of marked bigheaded carp based on maximum movements of silver (267 miles) and bighead (280 miles) carp observed in the Illinois River (DeGrandchamp et al. 2008). Data were downloaded approximately once a month during the summer and every three months the rest of the year. Eastern Illinois University (EIU) has deployed additional VR2W receivers downstream and has engaged in active tracking of their own tagged fish. EIU graduate student Sarah Huck will provide GPS locations for tagged bighead carp that they may locate.

Active – Active tracking was accomplished by deploying hydrophones from boat or canoe depending on river conditions. Active tracking was primarily done between RM354 (Logansport) and RM271 (Covington, IN). A 9 RM portion of the lower Tippecanoe River was also tracked. Sections of river were tracked at least once every two weeks. Lengths of river sections tracked varied depending on the vessel used. Up to 25 RM were tracked per day by boat and up to 16 RM were tracked per day by canoe. An omnidirectional hydrophone (Vemco VH110) connected to one of two manual receivers (Vemco VR100s) was used to locate and identify tagged bigheaded carp. First, the omnidirectional hydrophone was used to detect tagged carp in the vicinity of the tracking boat as it was piloted downriver at <5 mph. Once a reading of >75 db was achieved, the position of the tagged Asian carp was recorded using a handheld GPS (GPSMap 60c or GPS map 62s, Garmin Ltd., Olathe, Kansas).

Habitat measurements were taken when tagged bigheaded carp were detected. Depths (m) were measured using a hand-held depth finder (Model SM-5; Speedtech Instruments, Great Falls, Virginia). Similar to the methods used by Mueller and Pyron (2010), substrate type was determined using a 3 m or 6 m copper pipe to probe the bottom. Substrate type was categorized as one of six types: boulder, cobble, gravel, sand, fines, or hardpan (Wentworth 1922).

Monitoring of the spillways of the three main upstream dams was also conducted in fall 2013. These dams were the Roush, Mississinewa and Salamonie dams. Monitoring was done by dropping the hydrophone, attached to the VR100, into the dam outflow and allowing 10 min. for possible detections to register. This was done from shore and the hydrophone was placed as close to the stilling basin as possible given flow, access and length of the hydrophone cable. The Oakdale dam on the Tippecanoe River was also monitored occasionally throughout the summer.

<u>Spawning Evaluations</u>
We conducted spawning evaluations in the upper Wabash River (RM 310-373). Field crews conducted egg and larval sampling at selected sites on the rivers using paired bongo nets (500μm bucket mesh size) pulled in replicates of three. Bongo nets were towed from the bow of a 5 m John boat in a downstream direction for five minutes while the boat traveled in reverse. At upstream locations, bongo net sampling was conducted by holding the net rather than pulling by boat. The volume of water sampled was

quantified using a flowmeter (G. O. Environmental) attached inside the mouth of the bongo net. Upstream sampling (May 29nd) was conducted in the upper Wabash at RM390, RM373, and RM351.

Ten eggs from each bongo net pull were identified under magnification using a Nikon SMZ1500 microscope (Nikon Instruments, Inc.), frozen, and preserved at -80ºC for later deoxyribonucleic acid (DNA) analysis. Larvae were also preserved at -80ºC for later DNA verification. Bongo net sampling was conducted once water temperatures reached ≥15.6º C and were intensified with rising hydrographs, which have been found to be a trigger for spawning in bigheaded carp (Abdusamadov 1987; Peters et al. 2006; DeGrandchamp et al. 2008). Once eggs were detected, sampling continued on a weekly basis near RM 310 until eggs were not collected for three weeks. Depths (Model SM-5, Speedtech Instruments, Great Falls, Virginia) were taken at the start of each pull. Surface water temperature was also recorded just prior to sampling using a thermometer. Gage height and change in gage height (over 24 hours) were also recorded for each date and will be used in later predictive models.

Statistics

Length and weight regressions were all preformed in R statistical software (2.13.1*).*

Results

Updated length-weight regressions for silver and bighead carp show good fit, with silver carp exhibiting the strongest relationship ($R^2 = 0.9115$; Figure 2). Bighead carp and apparent hybrid silver-bighead carp had slightly weaker relationships ($R^2 = 0.6901$; $R^2 = 0.6911$) but those relationships were similar to each other. Regression for silver carp was significant ($p \leq 0.001$) but was not significant for bighead carp ($p = 0.301$).

By the end of May 2013, 290 bigheaded carp were at large in the Wabash River system. In August, seven bighead carp were captured and tagged bringing the total number of tagged fish to 297 individuals (285 silver, 8 bighead and 4 hybrids). Of these tagged fish, 250 different individuals were detected in 2013. There were 154 active tracking detections collected plus an additional 3 detections provided by EIU (Figure 3). These 157 detections represent a decrease in the number of active tracking detections compared to 299 in 2011 and 347 in 2012. Monitoring of potential upstream dams was done on 10/10/13. While there were no tagged fish present at any of the dams, silver carp were observed jumping at the Mississinewa dam. No tagged fish were detected at the Oakdale dam, although numerous silver carp were observed jumping there as well.

Bighead carp captured at the Oakdale dam with hook-and-line and moved to the Wabash River for release were not detected moving back up the Tippecanoe River. Bighead carp captured from the Wabash River and tagged were detected multiple times after release, mostly moving downstream in the Wabash River main channel.

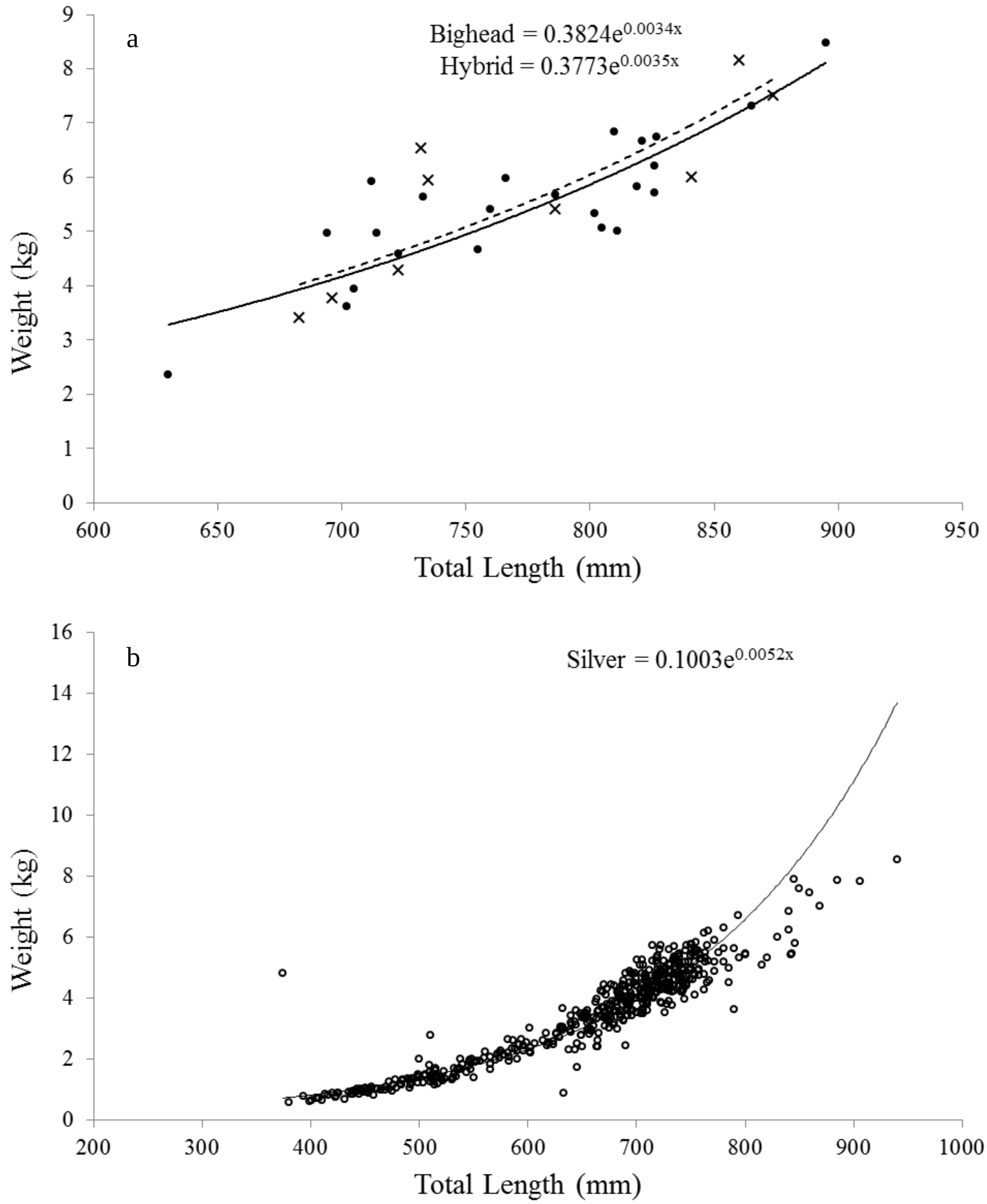

Figure 2. Length (cm) and weight (kg) relationship for a) bighead carp (n = 23) and hybrids (n = 9) and b) silver carp (n = 520) from 2010 to 2013. Bighead carp are closed circles and the solid line. Hybrid silver-bighead carp are represented with an x and a dashed line. Outliers represent some spawning/post-spawning condition fish.

Stationary receiver detections were largely similar to 2011 and 2012, with several notable exceptions (Table 1). The Americus and Tippecanoe River VR2Ws both had increased numbers of overall detections and numbers of individual fishes detected. The number of detections in Borrow 1 declined, but this was likely due to the presence of too many tags in close proximity of the VR2W deployed at that location. The Vemco tags used in this study emit a series of seven pings, one second apart. In order to record the tag ID, the VR2W or VR100 must receive all of these pings. The receiver can only focus on the signal from one tag at a time so the presence of multiple tags causes the receiver to switch from one tag signal to another. The ultimate result of this is that, when many tags are present, the detection probability decreases.

The number of detections on the Forks VR2W also increased. Detections at this receiver have been limited to the spring in the past. However, 2013 detections occurred in the spring as well as June and August. Of the four fish detected at the forks, two fish moved upstream in May and June and returned downstream in October, one went upstream in June and did not return downstream and one went upstream only for a two week period in early June. This final fish was near the Americus and Tippecanoe River VR2Ws in early May, was on the Forks VR2W on June 3rd, and passed the Americus VR2W on June 4th. The Little River VR2W was not lost, as in previous years, and had no detections. However, the presence of tagged fish was detected on the nearby Forks VR2W, so bigheaded carp are near the confluence but not entering the Little River.

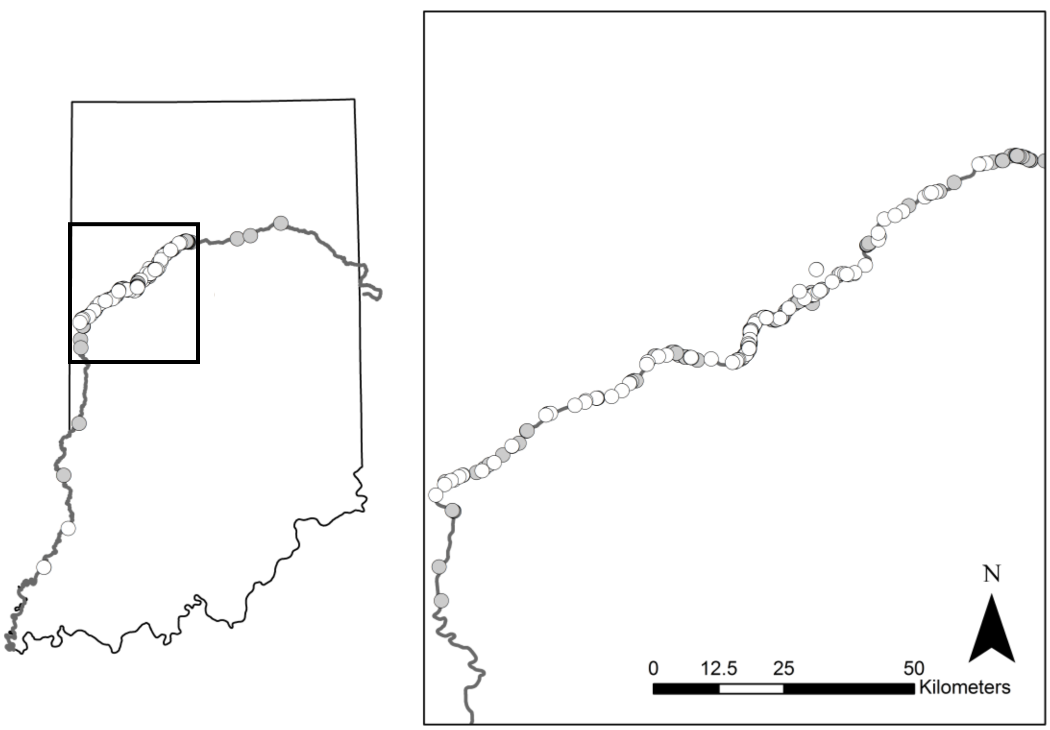

Figure 3. Active tracking detections for 2013 (n = 157). White circles are 2013 detections and gray circles are 2011 and 2012 detections.

Table 1. Summary of VR2W stationary receiver locations and data from 2013. A status of "Current" indicates that the VR2W is still recording detections, based on battery life, and that it or it's buoy have been located recently. Two VR2Ws were lost this year: in the Eel River and the Wabash River at French Post Park. River miles were estimated from Hoggatt 1975.

Receiver Name	River Mile	# Detections	# Fish	Last Download	Status
Little River	2	0	0	9/26/2013	Current
Forks of the Wabash	406	10	4	9/26/2013	Current
Salamonie River	3.3	0	0	9/26/2013	Current
Wabash	390	12	8	10/10/2013	Current
Peru	373	43	19	10/10/2013	Current
Eel River	7.36	-	-		Lost - located snapped cable
Logansport	351	-	-		2 attempts - diver retrieval needed
French Post Park	340	-	-		Lost- 8 attempts to locate
Americus	324	103297	125	10/8/2013	Current
Tippecanoe River	2	3924	55	10/8/2013	Current
I-65	317	11557	114	10/17/2013	Current
Borrow 1 (BP1)	310	245016	176	10/3/2013	Current
Borrow 2 (BP2)	310	30	8	5/10/2013	Current – fall download when water level allows
IN 26	309	-	-		Diver unable to retrieve
Goose Island	298	1476	98	10/17/2013	Current
Terre Haute	214	-	-		Needs fall download
Merom	165	-	-		VR2W missing - replaced 10/6/13

Tagged bigheaded carp appeared to associate with backwaters and bridges. High numbers of detections occurred on the Borrow 1 stationary receiver throughout the year. However, fish do appear to enter and exit this backwater habitat (Figure 4). Fish appeared to enter in the spring and may enter and exit several times over the spawning season. Combined data from stationary receivers indicates mid to late March is the time fish moved upstream with spawning occurring several months later. An association was also observed with tagged fishes and the deeper pools found around bridge supports (Figure 5).

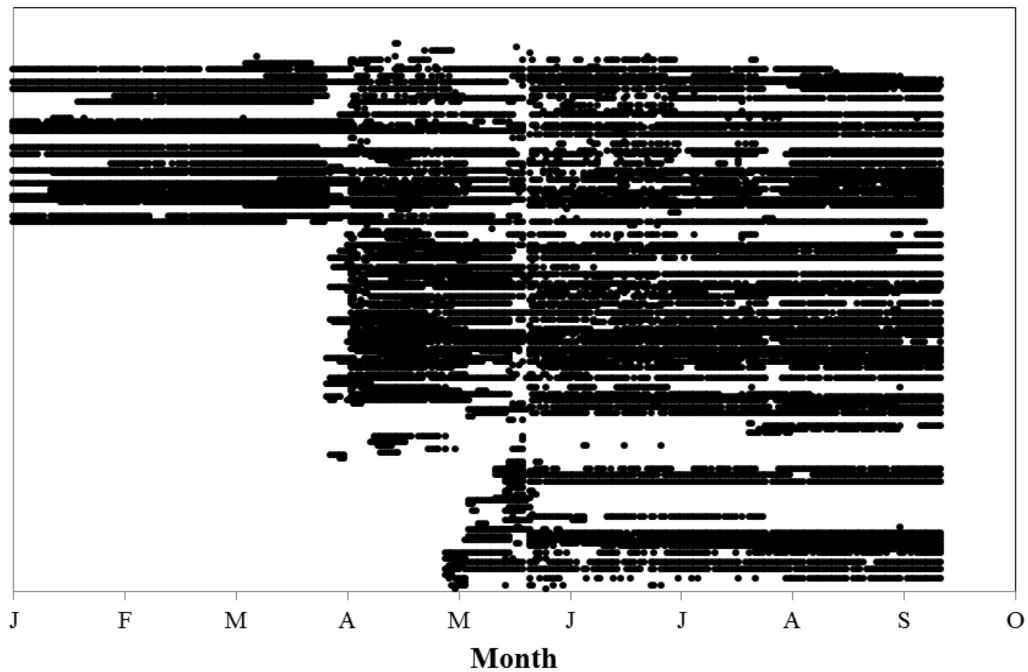

Figure 4. Data from the VR2W stationary reciever located in BP1. Each row of dots represents data for one fish while each individual dot represents the detection of that individual on a certain date. A gap indicates that fish is absent from BP1. Fish tagged earlier in the study are towards the top and newly tagged fish are towards the bottom. 175 tagged fish are represented in this figure.

Monitoring for bigheaded carp spawning activity began on 5/1/2013, with likely bigheaded carp eggs first detected on 5/27/13 (Figure 6). On 6/4/13, there was a large increase in the number of eggs present (~10976 eggs/m^3) which coincided with reports of carp spawning behavior upstream near Lockport. Average egg densities collected varied considerably from month to month: May = 7.1 eggs/m^3, June = 2749.0 eggs/m^3, July = 2.1 eggs/m^3, August = 3.6 eggs/m^3, September = 0.4 eggs/m^3. The last date of egg collection was 9/10/13. Bigheaded carp eggs were not found during upstream sampling. Several larvae were collected at RM390 and RM373 and frozen in the field. These will be tested later to determine if they are bigheaded carp.

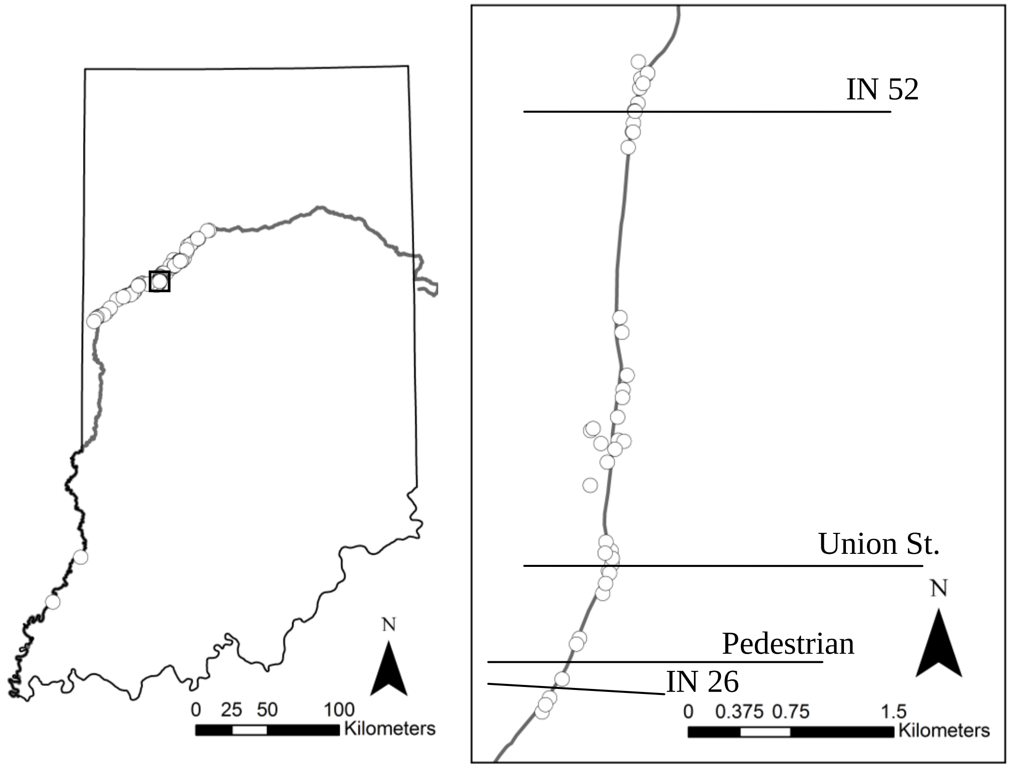

Figure 5. Association of bigheaded carps with bridges and the deep pools around those bridges. White circles represent the locations of tagged bigheaded carps. Bridges are represented by lines and are labeled with the roadway crossing them. The pedestrian bridge connecting West Lafayette and Lafayette is also shown. The cluster of points near the center of the figure are bigheaded carps utilizing the backwater habitats of BP1 and BP2.

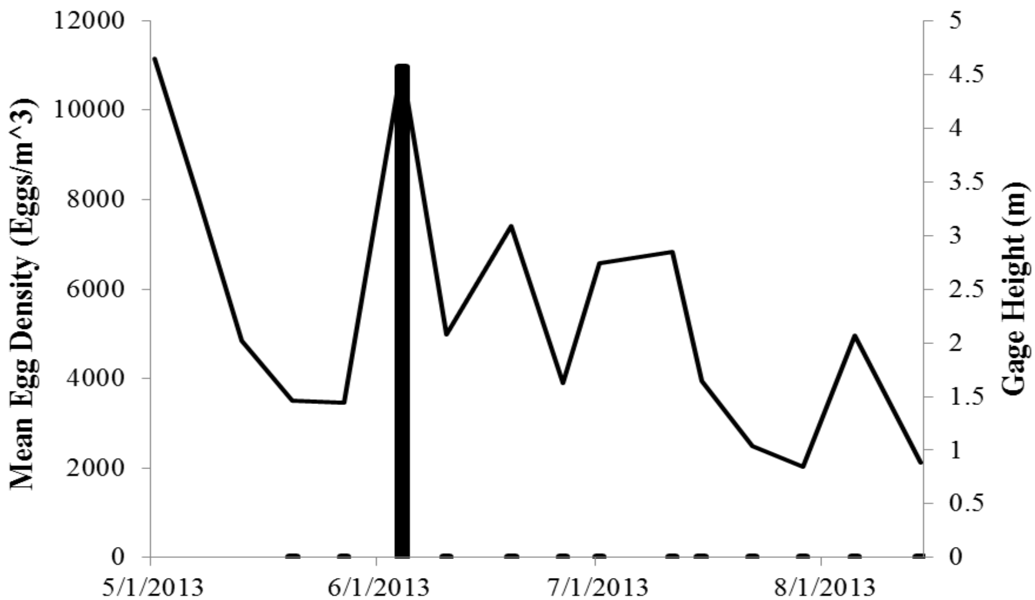

Figure 7. Mean egg density documented at RM 310 shown as bars. Height of USGS Wabash River Gage at Lafayette is shown by the solid line.

Discussion

There was a notable decrease in active tracking detections from 2011 and 2012 to 2013. This occurred despite an increase in the number of tagged fish present in the system. This likely resulted from increased accessibility throughout the Wabash River due to higher water levels. This meant that fish were able to move downstream after spawning more easily than in previous years. Higher water levels would also make more habitat available upstream. This is supported by the slightly increased numbers of fish and detections at the Forks VR2W and in the Tippecanoe River and the decreased numbers of active tracking detections. However, no tagged fish were present in dam spillways which may indicate the presence of an alternative upstream refuge habitat.

Several key differences were documented between 2013 and 2011/2012 detections. For the first time, a tagged fish was located approximately 6 RM up the Tippecanoe River from its confluence with the Wabash River. There were also very few fish located near RM 351 when high abundances had existed there in previous years. The higher water levels seen in 2013 could have helped to facilitate the movement of bigheaded carps into tributaries as exhibited by the Tippecanoe River VR2W. Yet some tributaries may be inhospitable to these fishes demonstrated by the lack of tagged fish detected in the Little or Salamonie Rivers. This is supported by the data showing tagged fish are present near these river confluences but are remaining in the Wabash River.

Again bigheaded carp were found to locate in deeper and lower flow habitats. This supports previous findings from the Illinois and Mississippi Rivers (DeGrandchamp et al. 2008; Kolar et al. 2007) as well as the previous years of this study. Many of these deeper habitats are man-made, such as borrow pits and around bridge abutments. Rivers that are more heavily modified than the Wabash River may therefore increase preferred available habitat for bigheaded carps.

Bigheaded carp spawning began later than in previous years, likely due to lower water temperatures in May. This delay in spawning initiation may have contributed to the major spawning event that occurred around June 4th. As in previous years, spawning continued for several months demonstrating the protracted spawning these bigheaded carp are known to exhibit.

Acknowledgements

This project would not have been possible without the extensive input and help of our State of Indiana collaborators, Goforth Lab graduate students, personnel, and undergraduate technicians. Doug Keller with the Indiana Department of Natural Resources (INDNR) was instrumental in getting this project established and planned. Tom Stefanavage with the INDNR, helped to collect fish for tagging and also assisted with tracking data collection. Goforth Lab graduate students Jay Beugly and Caleb Rennaker helped to capture fish for tagging and also provided active and logistical support in tracking fish. Goforth Lab Coordinator Beth Bailey provided extensive logistical support and field data collection for this project. Undergraduate technicians Allison Lenaerts, Wesley Goldsmith, Courtney Cripe, Tess Thoren, Preston Stipe and Austin Prechtel worked to help collect fish for tagging collected tracking data and helped process bongo net samples. Purdue American Fisheries Society Club also assisted with data collection. We would also like to thank Bryan Pijanowski and the Graduate Assistance in Areas of National Need (GAANN) fellowship. Finally, this project would not have been possible without the generous financial support provided by the Indiana Department of Natural Resources, the US Fish and Wildlife Service, and the USEPA's Great Lakes Restoration Initiative.

Literature Cited

Abdusamadov, A. S. 1987. Biology of white amur, C*tenopharyngodon idella*, silver carp, *Hypophthalmichthys molitrix*, and bighead, *Aristichthys nobilis*, acclimatized in the Terek region of the Caspian Basin. Journal of Ichthyology 26: 41-49.

Calkins, H. A., S. J. Tripp and J. E. Garvey. 2012. Linking silver carp habitat selection to flow and phytoplankton in the Mississippi River. Biological Invasions 14: 949-958.

DeGrandchamp, K. L., J. E. Garvey and R. E. Colombo. 2008. Movement and habitat selection by invasive Asian carps in a large river. Transactions of the American Fisheries Society 137: 45-56.

Hoggatt, R. E. 1975. *Drainage Areas of Indiana Streams*. U.S. Department of the Interior Geological Survey: Water Resources Division.

Jerde, C. L., A.R. Mahon, W.L. Chadderton W. L. and D.M. Lodge. 2011. “Sight-unseen” detection of rare aquatic species using environmental DNA. Conservation Letters 4: 150–157.

Kolar, C. S., D. C. Chapman, W. R. Courtenay, Jr., C. M. Housel, J. D. Williams and D. P. Jennings. 2007. Bigheaded carps: A biological synopsis and environmental risk assessment. American Fisheries Society Special Publication 33, Bethesda, MD.

Mia, M. Y., J. B. Taggart, A. E. Gilmour, A. A. Gheyas, T. K. Das, A. H. M. Kohinoor, M. A. Rahman, M. A. Sattar, M. G. Hussain, M. A. Mazid, D. J. Penman and B. J. McAndrew. 2005. Detection of hybridization between Chinese carp species (*Hypophthalmichthys molitix* and *Aristichthys nobilis*). Aquaculture 247: 267-273.

Mueller, R. Jr. and M. Pyron. 2010. Fish assemblages and substrates in the middle Wabash River, USA. Copeia 2010(1): 47-53.

Peters, L. M., M. A. Pegg and U. G. Reinhardt. 2006. Movements of the adult radio-tagged bighead carp in the Illinois River. Transactions of the American Fisheries Society 135: 1205-1212.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. Journal of Geology 30: 377-392.

Williamson, C. J. and J. E Garvey. 2005. Growth, fecundity, and diets of newly established silver carp in the middle Mississippi River. Transactions of the American Fisheries Society 134: 1423-1430.