Abundance and distribution of early life stages of Asian carp in the Ohio River

Geographic Location: Ohio River Basin

Participating Agencies: Indiana Department of Natural Resources (INDNR) Kentucky Department of Fish and Wildlife Resources (KDFWR), West Virginia University (WVU), United States Fish and Wildlife Service (USFWS), West Virginia Division of Natural Resources (WVDNR)

Statement of Need:

The negative effects of Silver (*Hypophthalmichthys molitrix)* and Bighead Carp (*H. Nobilis)*, also known as Asian carp, have been widely documented throughout their introduced range. These effects are numerous and varied in nature, some with direct implications to native biota (Irons et al. 2007, Sampson et al. 2009). Others may be indirect and difficult to quantify, such as economic loss and negative social perception. Research investigating factors that lead to Asian carp range expansion is critical for the control of these invasive fishes, and mitigation of the deleterious effects they can cause.

As of late, extensive research efforts have been directed towards Asian carp reproduction in terms of timing, location, and environmental conditions. Asian carp exhibit a boom and bust pattern of reproduction, with strong year classes usually linked with large sustained flooding and critical temperature ranges (DeGrandchamp et al. 2007). Although some understanding of their reproductive requirements exist, recent evidence suggests that spawning of these species is possible over wider environmental ranges (Coulter et al. 2013), and in more habitats (i.e. tributaries) than previously thought (Kocovsky et al. 2012). In addition, factors leading to successful recruitment of these species are difficult to identify because juveniles are extremely mobile, and effective sampling methods haven't been extensively examined. Identifying factors promoting reproduction and recruitment of these invasive fishes is critical in suppressing their spread into novel environments.

Knowledge of the geospatial ranges for Asian carp in the Ohio River is necessary for evaluating the invasion status of each pool (i.e. the "extent of invasion"). The extent of invasion has three predominant levels (presence front, invasion front, and established front) and is used to guide specific management and control actions in other Mississippi River sub-basins. The "presence front" is the upmost extent of Asian carp capture where densities are low and reproduction has not been documented. The "invasion front" is the location(s) where reproduction (i.e., eggs, embryos, or larvae) has been observed, but recruitment has yet to be documented. Lastly, the "established front" is the location(s) where reproduction and recruitment to the adult life stage is actively occurring. Identifying the specific spatial extents that differentiate the presence, invasion, and established fronts are crucial information that remains unknown for the Ohio River Basin.

Confirmed Asian carp spawning events have been reported in tributaries (i.e. Wabash River) as far upstream as JT Myers Locks and Dam and signs of spawning (i.e. spawning patches) have been observed as far up river as the Markland Pool. Successful reproduction of *Hypophthalmichthys spp.* was detected at river mile 560 (McAlpine Pool) in 2015, and further upstream at river mile 405.7 (Meldahl Pool) in 2016 (EA engineering, personal communication). This defined the leading edge of spawning (invasion front) in the Ohio River (EA Engineering, personal communication). To support Basin Framework objectives (ORFMT 2014) this project was initiated in 2016 in an effort to improve capabilities to detect early stages of invasion and spawning populations of Asian carp (Strategy 2.7) and also monitor upstream range expansion and changes in distribution and abundance (Strategy 2.3). Results of 2016 sampling determined the extent of recruitment (established front) as below Cannelton Lock and Dam, with the majority of YOY and Juvenile detections below Newburgh Lock and Dam in J.T. Myers Pool (Jansen and Stump 2016). In addition to the Basin Framework, this project directly supports the National Plan (Conover et al. 2007) by assisting in the forecast and detection of Asian carp range expansions (Strategy 3.2.4), determining life history characteristics (Strategy 3.3.1), and assembling information about the distribution, biology, life history, and population dynamics of Bighead and Silver Carps (Strategy 3.6.2). Additionally, the results of this project will help managers make informed decisions during future planning efforts regarding resource allocation for Asian carp deterrent and control strategies.

Project objectives:

1. Define the "invasion front" of Asian carp in the Ohio River via sampling for Asian carp eggs, embryos, and larvae.
2. Define the "established front" of Asian carp in the Ohio River via targeted sampling for juvenile Asian carp.
3. Identify characteristics of potential Asian carp nursery areas when juvenile Asian carp are encountered.
4. Identify other sources of fish sampling data in the Ohio River Basin that may inform previous objectives (ORSANCO, EA Engineering, agency biologists, etc.).

Project Highlights:

- As of 2016, Asian carp larvae were collected at river mile 405.7 (Meldahl Pool).
- No Asian carp eggs or larvae were collected during pilot ichthyoplankton study in 2017, number of sampling sites and frequency will be expanded in 2018.
- Sampling in 2017 detected one juvenile Silver Carp in Cannelton Pool.
- Majority of recruitment remains in J.T. Myers Pool, although Cannelton Pool appears to be a new source of recruitment.
- 548 Asian carp were collected for a total of 3,738 pounds of fish removed.

Methods:

For analysis purposes and for the remainder of this report, both "young-of-year" and "immature" are collectively referring to "juvenile" Asian carp; "young-of-year" (YOY) will be defined as fish less than 200 mm, and "immature" will define fish between 200 to 400 mm (likely 1 to 2 years old) which have undeveloped gonads and are not capable of spawning. Adult Asian carp are defined as fish greater than 400 mm with mature, identifiable gonads.

Ichthyoplankton tows:

Ichthyoplankton sampling was incorporated during the 2017 sampling season to provide an updated delineation of the "invasion front" from what EA engineering documented in 2015 and 2016. Ichthyoplankton sampling was conducted at seven tributary sites within J.T. Myers (N=3), Meldahl (N=3), and R.C. Byrd (N=1) Pools. A fine-mesh conical ichthyoplankton net (0.76m, 500 µm mesh) fitted with a General Oceanics Flowmeter to estimate volume of water filtered was used for sampling. One site consisted of three-minute ichthyoplankton tows from the side of the boat, downstream, within, and upstream of each tributary. Samples within tributaries were taken at locations deemed to be outside of main-stem Ohio River hydrologic influence. Sample contents were rinsed into collection jars, preserved in 95% ethanol, and sent to WVU for processing and identification.

Surface trawl:

Experimental surface trawling was conducted at Hovey Lake (J.T. Myers Pool) on June 29 and July 24, 2017. The surface trawl was 7.3 m wide, 1.5 m tall, and 6.1 m deep with 19.1 mm bar mesh. The last eight feet of the purse had an additional layer of 3.2 mm mesh bag attached internally to improve capture of small fishes. Additional foam floats were added to the top line of the trawl to provide extra buoyancy. Otter boards were 38.1 cm tall, 76.2 cm long, and each had three capped and sealed 5.1 cm (inside diameter) by 83.8 cm long PVC pipes attached to the top of the board allowing them to float. The trawl was deployed off of the front of the boat and attached with 24.4 m ropes. The boat was motored in reverse for 5 minutes before retrieving the net. Fish captured were identified to species and all Asian carp were processed as described below in electrofishing methods.

Electrofishing:

Electrofishing was conducted in J.T. Myers, Newburgh, Cannelton and McAlpine Pools of the Ohio River from July 17th to August 31st, 2017. Flooded creek mouths, tributaries, side channels, and other backwater areas large enough for entrance with an electrofishing boat were selected in each pool to be sampled. To account for temporal variability in abundance and environmental conditions, all sites were sampled twice, at least two weeks apart, depending on accessibility.

Electrofishing effort consisted of 15-minute transects at each sampling location, unless otherwise impeded. At the biologist's discretion, more sampling time or multiple runs were conducted at sites where either coverage was limited or juvenile Asian carp were suspected. In some cases, sites were inaccessible or only transects shorter than 15 minutes were possible. Specific electrofishing settings varied by crew because of equipment differences, but all boats adjusted settings based on water conductivity to achieve standard power goals and maximize Asian carp collection when possible. Dippers specifically targeted all fish resembling Asian carp. All Asian carp were then identified to species, measured to total length, weighed, and sexed when possible. When possible and applicable, ovaries of mature females were removed and weighed for gonadosomatic analysis. Lapilli otoliths and fin rays were removed from a subsample of fish for age estimation. Young-of-year Asian carp were frozen whole for potential additional analyses.

Environmental variables:

A suite of habitat variables were collected at each electrofishing site including: water temperature, Secchi disk visibility, conductivity, pH, dissolved oxygen, maximum depth, average depth, tributary width, and presence/absence of woody debris and aquatic vegetation. To increase sample size and statistical power, juvenile occurrences and associated habitat variables were pooled from 2016 and 2017 data. These variables were used to describe the possible habitat preferences of juvenile Asian carp. Using an alpha level of 0.05, two-sample student's t-Tests (assuming unequal variances) were performed individually on each numerical habitat variable to compare mean measurements between locations with juvenile Asian carp present ($N = 20$) to those locations without ($N = 308$). Chi-square test statistic was used to determine whether juvenile Asian carp exhibited a preference for a range of water colors, presence of woody debris, and presence of aquatic vegetation.

Results:

Ichthyoplankton tows:

A total of thirty one, three-minute ichthyoplankton tows were conducted in tributaries and adjacent main channel sites including Highland Creek, Pigeon Creek, Canoe Creek, Ohio Brush Creek, Big Three Mile Creek, Little Three Mile Creek, and Kyger Creek. A total of 137 larval fish (Gizzard Shad, Emerald Shiner, and Channel Catfish) and 50 unidentified eggs were collected. No confirmed Asian carp eggs or larvae were collected throughout the course of sampling.

Surface trawl:

A total of 16 trawl runs were conducted at Hovey Lake, totaling 1.33 hours of sampling effort. Catch included 24 YOY Silver Carp, three adult Silver Carp, and one adult Bighead Carp. Mean trawl CPUE (fish/hour ± SE) in Hovey Lake was 22.2 ± 8.7 for YOY Asian carp, and 2.3 ± 1.2 for adult Asian carp.

Electrofishing:

Electrofishing was conducted at 56 sites; eleven sites were sampled in J.T. Myers Pool, 10 in Newburgh Pool, 18 in Cannelton Pool, and 17 in McAlpine Pool for a total of 6.75, 4.95, 14.83, and 12.56 hours of electrofishing per pool, respectively. A total of 39.6 hours of electrofishing effort were expended. All but eight sites were sampled twice with at least two weeks between sampling dates; 39 sites were large enough for multiple transects (left bank/right bank, upper/lower).

YOY Silver Carp were captured at four sites in the lower portion of J.T. Myers Pool; four were captured in a ditch just above the lock chamber, 19 in the Hovey Lake Drain, three in Hovey Lake, and one in an agricultural ditch near Henderson Kentucky (Figure 1). Mean YOY CPUE (fish/hour ± SE) was highest in Hovey Lake Drain (38.0 ± 30.0), followed by Myers Lock Chamber Ditch (8.0 ± 4.0), Hovey Lake (3.3 ± 1.0), and Field Drain Ditches (3.0 ± 2.0) (Table 1). Immature Silver Carp were captured at four sites in J.T. Myers Pool and one site in Cannelton Pool; one was captured in Lost Creek, six in Hovey Lake Drain, six in Highland Creek, one in Canoe Creek, and one in Clover Creek (Figure 1). Mean Immature CPUE (fish/hour ± SE) was highest in Highland Creek (12.0 ± 4.0) and Hovey Lake Drain (12.0 ± 8.0), followed by Lost Creek (2.0 ± 2.0), and lowest in Canoe and Clover Creeks (1.0 ± 1.0) (Table 1). A total of 506 adult Asian carp were collected (Silver N = 502, Bighead N = 1, Hybrid N = 2, Grass Carp N = 1) with highest CPUE (fish/hour ± SE) in Honey (75.7 ± 40.2) and Little Pigeon Creeks (52.0 ± 25.2) in Newburgh Pool.

Habitat Parameters:

Significant differences in mean habitat parameters existed between sites where juvenile Asian carp were present to those where they were not. Mean water temperature was greater in sites with juvenile Asian carp (83.8°F ± 1.1 SE) than those without (79.5°F ± 0.3 SE); $t(22) = 3.77$, $p < 0.001$. Secchi visibility was significantly lower in sites where Asian carp were captured (14.0 in ± 1.6 SE) than those without (17.5 in ± 0.5 SE); $t(23) = -2.15$, $p = 0.04$). Similarly, conductivity was lower in sites with Asian carp (381.5 ± 29.4 SE) than those without (473.4 ± 12.4 SE), $t(26) = -0.288$, $p = 0.007$). Depths were lower in sites with juvenile Asian carp (max depth: 8.8 ft ± 1.2, avg. depth: 5.2 ft ± 0.6) than sites without (max depth: 13.0 ft ± 0.4, avg. depth: 8.0 ft ± 0.5). Finally, pH, dissolved oxygen, and tributary width were similar between habitats containing juvenile carp and those without. Chi-square tests showed no significant differences in juvenile Asian carp occurrences between water colors $\chi^2(6, N = 325) = 6.04$, $p = 0.417$, presence of woody debris $\chi^2(1, N = 328) = 0.174$, $p = 0.119$, or presence of aquatic vegetation $\chi^2(1, N = 325) = 0.186$, $p = 0.665$.

Discussion:

Results of the second year of the Abundance and Distribution of Asian Carp Early Life Stages in the Ohio River project offer the most up to date information on the extent of Asian carp spawning and recruitment in the Ohio River. Collectively, 162 electrofishing transects were completed, totaling 39.1 hours of effort. This effort resulted in the removal of 548 Asian carp (3,378 lbs.) from the Ohio River and the outcomes directly addressed Basin Framework Strategy 2.7 by improving capabilities to detect early stages of invasion and spawning populations of Asian carp. This project continues to provide data to describe our current understanding of the distribution of Asian carp recruitment for the Water Resources Reform and Development Act (WRRDA) reporting. Moreover, knowledge acquired from this project directly informs planning efforts for future Asian carp deterrent, control, and other management strategies.

In 2015, the most upstream location where verified Asian carp eggs and larvae were detected was river mile 560 in McAlpine Pool, and extended to river mile 405.7 in Meldahl Pool the following year (EA Engineering, personal communication). These eggs and larvae were identified as *Hypophthalmichthys* sp., so it is unclear whether Bighead and/or Silver Carp have spawned in these pools in the past. Spawning of Silver Carp has been confirmed in Cannelton Pool with the collection of yolk-sac larvae at river mile 625.8 by EA Engineering in 2015 and 2016 as well. With the incorporation of ichthyoplankton sampling to this project in 2017, we hoped to provide the most up-to-date delineation of the extent of Asian carp spawning (invasion front) within the Ohio River. We did not detect any Asian carp eggs or larvae during this initial year of sampling, but caution must be taken when drawing conclusions from this result. Our ichthyoplankton effort was spatially and temporally limited this year with only seven sites sampled on few occasions, and the null result is likely due to these limitations. Results of the 2017 sampling did offer important insight to the feasibility and logistics of future ichthyoplankton efforts, which will be more extensive in 2018. With these efforts we hope to better describe the extent of Asian carp spawning to help identify factors and habitats promoting their reproduction in the Ohio River.

Sampling in 2016 detected all but one juvenile Asian carp in J.T. Myers Pool, with the remaining YOY individual captured in a borrow pit in Newburgh Pool. This defined Cannelton Lock and Dam as the most upstream extent of recruitment (established front). As recommended in the 2016 technical report and to address Strategy 2.3 of the basin framework, 2017 sampling was conducted to monitor the recruitment and invasion fronts of Asian carp across years and environmental conditions. Results of 2017 sampling largely support the extent of recruitment we defined in 2016, with the majority of juvenile carp collected in the lower portion of J.T. Myers Pool. This pattern of recruitment in J.T. Myers Pool has been consistent annually, and highlights the need for more-extensive larval sampling to identify timing and location(s) of spawning. The capture of one juvenile Silver Carp in Clover Creek (Cannelton Pool) potentially expands the extent of recruitment to above Cannelton Lock and Dam, further upstream than previously thought. Additionally, the collection of several juvenile Asian carp (269-399mm TL) in Cannelton Pool during other Basin Framework projects (Monitoring, Removal) supports this conclusion. Although recruitment is occurring in both Cannelton and J.T. Myers Pools, it is unclear why it is limited in Newburgh Pool. This is likely a result of Newburgh Pool being relatively small, with few large productive embayments thought to support larval development. The spatial and temporal variation in Asian carp recruitment in the Ohio River emphasizes the need for continued long-term monitoring with this project as well as others within the basin.

Evaluation of abiotic habitat parameters showed juvenile carp were found in habitats with significantly greater water temperature, lower depth, lower secchi visibility, and lower conductivity. This suggests shallow, turbid, and potentially more productive habitats promote survival and recruitment of Asian carp. Additionally, we observed no significant effects of water color, presence of woody debris, or presence of aquatic vegetation. Future sampling may benefit by sampling these variables quantitatively to reduce subjectivity. Although we were limited by a small sample size and suitable analyses for this dataset, this information will be used to help guide future sampling and management efforts.

Efforts in this project provide valuable insight into factors that promote the reproduction and recruitment of Asian carp, and ultimately range expansion. Results support several Basin Framework and National Plan strategies and will be used by biologists to mitigate the spread of these invasive fishes. In addition to this project, INDNR biologists aided KDFWR with the "Monitoring and Response to Asian carp in the Ohio River", and "Control and Removal of Asian carp in the Ohio River" projects.

Recommendation:

While the extent of Asian carp recruitment has been defined, there is still a lack of information of the timing and locations of spawning in the Ohio River. Therefore, we suggest electrofishing efforts should be consolidated to sites where juveniles have been captured or where abiotic factors may promote recruitment. This will allow us to continue to monitor recruitment, and free up extra resources for ichthyoplankton sampling. As our ichthyoplankton sampling was limited in 2017, we recommend and are planning to expand both the number of sites and the frequency in 2018. This will allow for comprehensive coverage of the river where every pool is sampled at multiple locations repeatedly throughout the reproductive season. Other ongoing projects in the Ohio River basin are gathering data on presence of spawning patches on Asian carp; combining these data with information gathered through this project will help managers identify spatiotemporal patterns of Asian carp reproduction in the Ohio River. This information, along with recruitment patterns we have documented previously, can ultimately be used to identify sources of Asian carp population expansion throughout the basin, and help guide other ORFMT efforts such as deterrents and targeted removals.

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	Young-of-Year		***Immature***	
Sample Site	**N**	**CPUE**	**N**	**CPUE**
Lost Creek	0	0	1	2.0 ± 2.0
Lock Chamber Ditch	4	8.0 ± 4.0	0	0
Hovey Lake	1	3.3 ± 1.0	0	0
Hovey Lake Drain	19	38.0 ± 30.0	6	12.0 ± 8.0
Highland Creek	0	0	6	12.0 ± 4.0
Field Drain Ditches	3	3.0 ± 2.0	0	0
Canoe Creek	0	0	1	1.0 ± 1.0
Clover Creek	0	0	1	1.0 ± 1.0

Table 1. Total number and CPUE (fish/hour ± SE) of YOY and immature Asian carp (excluding zeros) collected between electrofishing sampling locations where juvenile Asian carp were present.

Figure 1. Map of electrofishing sites among four pools of the Ohio River (J.T. Myers, Newburgh, Cannelton, McAlpine). Red circles = young-of-year Asian carp collection sites, yellow circles = immature Asian carp collection sites, green circles = adult only Asian carp collection sites. Both young-of-year and immature Asian carp were collected in Hovey Lake Drain (red circle).