Asian Carp Annual Interim Reports for the Mississippi River Basin

2017

Ohio River Asian Carp Partnership

Upper Mississippi River Asian Carp Partnership

Preface

The Ohio River Basin and Upper Mississippi River Basin Asian carp partnerships collaboratively identified Asian Carp Control Strategy Framework priority needs, determined cooperating agencies and funding needs for projects in 2017. Project work plans were published in the 2017 Monitoring and Response Plan for Asian Carp in the Upper Mississippi River. The following reports are the product of work proposed and implemented in calendar year 2017 funded (in full or in part) by USFWS FY2017 base funding to address the highest priority prevention and control needs for Asian carp in the ORB and UMRB as identified by the respective sub-basin planning teams. Complimentary Asian carp projects funded by USFWS and other sources that contribute to implementation of the ORB and UMRB Frameworks are included.

Monitoring and Response to Asian Carp in the Ohio River

Geographic Location: Ohio River basin, extending from the Cannelton pool (RM 720.7) to the Racine pool (RM 237.5) along with the Montgomery Island (RM 31.7) and New Cumberland (RM 54.4) pools of the Ohio River in addition to the Allegheny and Monongahela rivers.

Participating Agencies: Indiana Department of Natural Resources (INDNR), Kentucky Department of Fish and Wildlife Resources (KDFWR), Pennsylvania Fish and Boat Commission (PFBC), Unites States Fish and Wildlife Service (USFWS), West Virginia Division of Natural Resources (WVDNR)

Statement of Need:
Invasive species are responsible for undesirable economic and environmental impacts across the nation (Lovell and Stone 2005, Pimentel et al. 2005, Jelks et al. 2008). Considerable effort towards the management and monitoring of Asian carp has been implemented since their introduction in the early 1980's (Kolar et al. 2005). However, because of their tolerance for a wide range of environmental conditions, carp have successfully expanded their range into the Ohio River basin (ORB).

This project provides an ongoing, coordinated approach to monitor Asian carp and fish communities in the ORB (Table 1). Assembling information on distribution and habitat use of Asian carp provides an assessment tool that informs Asian carp prevention, removal, and response efforts. In addition, this information aids in determining impacts of carp on native fish assemblages and provides incremental snapshots on which to assess the effectiveness of removal efforts.

Objectives:
1. Conduct targeted sampling for the purpose of surveillance, early detection, distribution, and relative population characteristics of Asian carp in the Ohio River.
2. Conduct community surveys in order to monitor fish populations in the Ohio River.
3. Compile and incorporate additional data from other state and federal entities on Asian carp and fish communities in the Ohio River.

Methods:
Clarification of Terminology Referenced in This Document
With the current rate of Asian carp expansion and the massive effort to study and adaptively manage carp impacts across several Mississippi River sub-basins, it is important to clarify terminology used in technical documentation and annual reports. Currently, there may not be consistent terminology used across the basins when talking about basin-specific distribution and abundance of Asian carp. With this in mind, below are a list of terms used in this report.

Bigheaded Carps – a term used to reference all species of the bigheaded carps (*Hypophthalmichthys molitrix* and *Hypophthalmichthys nobilis*) and their hybrids, found in the Ohio River basin.
Establishment Front – the farthest upriver range expansion of Asian carp populations that demonstrates the presence of natural recruitment.
Invasion Front – the farthest upriver extent where reproduction has been observed (eggs, embryos, or larvae), but recruitment to young-of-year fish has not been observed.
Macrohabitat – One of five habitat types used to categorize fixed sites within a pool (e.g. Tributary, Tailwater, Embayment, Island Back-Channel, Main Stem River).
Presence Front – The farthest upstream extent where Asian carp populations occur, but reproduction is not likely.
Targeted Sampling – sampling that uses gear and/or techniques intended to specifically target one species (i.e. Silver Carp and Bighead Carp) and exclude others (i.e. native species).

Spring Targeted Sampling (Cannelton – R.C. Byrd)

Asian carp targeted sampling was introduced in 2017 to take the place of spring community monitoring, conducted in 2016. This adjustment was made in an effort to better reflect the annual change in relative carp abundance and provide a baseline assessment to direct future removal efforts. The sampling period was from 10 April – 23 May, along six pools (Cannelton – R.C. Byrd pools) in the middle Ohio River. This geographic range is significant because it currently represents the upper end of the establishment front through the lower end of the presence front for Silver Carp in the ORB (Figure 1). All sites were selected from a stratified random design using GIS map study from sampling efforts in 2015. Pools were segmented into four sections (upper, upper-middle, lower-middle, and lower) with six fixed electrofishing sites and two fixed gill netting sites per section (~24 electrofishing runs and 8 gill net sets per pool). The intent of this standardized design, with fixed sampling locations, was to sample five major macrohabitat types in each pool in order to compare trends within pools through time. Macrohabitat types included main-stem locations, island back-channels, embayments, dam tailwaters, and tributaries in each pool.

Electrofishing transects were standardized at 900 seconds with one dipper. An output power between ~4000 - 5000 (Watts) at 40% duty-cycle and 80 pulses per second (pulsed DC) was targeted using a MLES Infinity Box or a Smith-Root system at ~7amps and 60 pulses per second. Transects were conducted in a downstream direction in order to minimize fish escapement due to flow. Asian carp were specifically targeted using increased driving speeds and allowed pursuit of individual carp upon sightings. During more aggressive boat maneuvering, all other fish species were ignored. All small, shad-like species were collected and examined thoroughly before release to avoid misidentication of juvenile Asian carps.

Gill nets used in targeted sampling were typically 45 – 90 m (150 - 300 ft) in length, 3 m (10 ft) in depth, and constructed of large mesh (either 10cm or 12.5cm bar mesh) and foam core float line to keep them suspended at top water. Sites sampled consisted of at least two net sets, fished for two hours while creating noise and water disturbance every 30 minutes within 90 – 100 meters of the set. Regular disturbance was intended to target and persuade the movements of bigheaded carps into the gear.

Upon capture, all bigheaded carps were examined for the presence of external and/or internal tags (jaw tags and sonic implants attached in 2013-2016 through the Ohio River Asian Carp Telemetry Project), identified, geo-located, weighed, and measured. In most cases, bigheaded carps were euthanized and the left, pectoral fin ray and/or otoliths were collected for aging following established protocols (Beamish 1981, Schrank and Guy 2002, Williamson and Garvey 2005, Seibert and Phelps 2013). Grass Carp (*Ctenopharyngodon idella*) presence was also recorded and fish were euthanized upon capture. Any *Hypophthalmichthys spp*. that were not euthanized were tagged with a distinct jaw tag and a 95mm VEMCO 69 kHz – V16 acoustic-coded transmitter. Tagged fish were released at point of capture to contribute to the Ohio River Asian Carp Telemetry project.

Fall Standardized Community Monitoring (Cannelton – R.C. Byrd)

From 02 October – 28 November, fish community surveys were repeated along the same six pools in the middle Ohio River (Cannelton, McAlpine, Markland, Meldahl, Greenup, and R.C. Byrd) using sampling sites selected in 2015 (see above) (Figure 1). Pool divisions (upper, upper-middle, lower-middle, and lower reaches) remained the same with six fixed electrofishing sites and two fixed gill netting sites per section (~24 electrofishing sites and 8 gill netting sites per pool). These sites are also intended to remain constant throughout consecutive years of monitoring in order to compare trends within and among pools through time.

Electrofishing transects were standardized at 900 seconds with one dipper. An output power ranging between 3000 – 4000 (Watts) was targeted at 25% duty-cycle and 60 pulses per second (pulsed DC) using a MLES Infinity Box (Gutreuter et. al. 1995) or a Smith-Root system at ~7amps and 60 pulses per second. Transects were conducted in a downstream direction in order to minimize fish escapement due to flow. All fish encountered during a 15-minute transect were collected and placed into a live well until the end of a run. All small, shad-like species were examined thoroughly to avoid misidentifying young Asian carps. In areas where large schools of Clupeid or Cyprinid species were encountered, as many fish as possible were collected while maintaining a consistent, straight-line speed.

Gill nets used in community monitoring were typically 45 – 90 meters in length, 3 m (10 ft) in depth, and constructed of large mesh (either 10cm or 12.5cm bar mesh) and foam core float line to keep them suspended at top water. Sites sampled consisted of at least two net sets, fished for two hours while creating noise and water disturbance every 30 minutes within 90 – 100 meters of the set. Regular disturbance was intended to target and persuade the movements of bigheaded carps into the gear.

Fish were identified to the lowest taxonomic level possible, enumerated, weighed, and measured. After all data had been recorded, fish were released in the same location as their capture (excluding Asian carps). Invasive carps were euthanized or tagged after data collection using the same procedure as described above from the targeted sampling in the spring.

Monitoring Asian Carps Ahead of the Invasion Front (New Cumberland, Montgomery Island pools)
Targeted sampling for Asian Carp was conducted in December 2017 in the Montgomery Slough portion of the Ohio River (Montgomery Island Pool, RM 949.78 to 950.11) in proximity to the location of positive eDNA detections for Bighead Carp (2017 and historically), as well as in a backwater area of the Allegheny River in Pool 7 near Tarrtown, PA (RM 48.33). Gill nets used in sampling were 90 meters in length, ~4 meters (12 ft) in depth, and constructed of 8 cm, 10 cm, or 13 cm bar mesh. Gill nets were fished for approximately 24 hours.

Incidental sampling for Asian Carp was conducted using baited tandem hoop nets, beach seining, and boat electrofishing. Baited tandem hoop nets (1 meter diameter, 4 cm bar mesh, 3 nets in tandem) were set in the New Cumberland, Montgomery Island, Dashields, and Emsworth pools of the Ohio River in August and September 2017 and were fished for three consecutive nights. All species were identified and enumerated before being released except for Channel and Flathead Catfish, which were retained for aging using otoliths.

Beach seining was conducted in August at six fixed locations in the Montgomery Island Pool of the Ohio River using a 30 meter seine with 1 cm mesh. One seine haul was conducted at each of the six locations. Species readily identifiable in the field were enumerated and released; all other species were retained for identification and enumeration in the laboratory.

Daytime boat electrofishing was conducted in July and August on four fixed sites in the Montgomery Island Pool of the Ohio River, four fixed sites on the Charleroi Pool of the Monongahela River, and six fixed sites on Pool 4 of the Allegheny River. Electrofishing was conducted using an ETS MBS electrofishing system operated at 25% duty cycle and 60 pulses per second (pulsed DC) at variable voltages and amperages depending on river conditions. Transects were fixed length (100 – 300 m) and were sampled from 6 to 13 minutes. Black bass were measured and enumerated, and presence/absence of other species was recorded.

Nighttime boat electrofishing was conducted in September in the New Cumberland Pool of the Ohio River and Pool 4 of the Allegheny River. Electrofishing was conducted using an ETS MBS electrofishing system operated at 25% duty cycle and 60 pulses per second (pulsed DC) at variable voltages and amperages depending on river conditions. Three 15 minute transects were sampled in the New Cumberland Pool in the tailwater portion of the Montgomery Dam on each bank. All black bass and true bass were collected, and presence/absence of other species was recorded. On the Allegheny River, four fixed sites were sampled. Black bass and Sander species were collected, and presence/absence of other species was recorded.

Assessing Asian Carp Population Demographics

The lengths and weights of Silver carp, H. molitrix, captured from August through December in 2016 and 2017 were compiled and log_{10} transformed for regression analysis and annual comparisons. A single regression line was derived to describe the relationship between Silver Carp total length and weight and compared to regressions from additional basins (Figure 2, Table 2). In addition, ANCOVA analysis was applied to a multiple linear regression model ($y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \mathcal{E}$), with weight (g) being determined by total length (mm) and year used as a categorical predictor variable for fish captured after spawning activity. Predicted weights at each length along the regression were used to determine if there was a statistically significant difference in growth of fish from the previous year. This analysis may serve as one benchmark to determine the effects of harvest as removal efforts increase in the future.

A single linear regression was derived using data compiled from 2016 and 2017 for Bighead carp, H. nobilis, and used to describe the relationship between total length (mm) and weight (g) (Figure 3, Table 3). However, due to low capture rates between the two years, ANCOVA analysis was not applied to determine if conditional growth had changed between the two sampling seasons.

Throughout all ORB projects, a subsample of individual carp lengths (mm), weights (g), otoliths, and pectoral spines were taken to aid in assessing population characteristics of carp along the invasion front. Pectoral spines were collected and sectioned on a low speed saw for aging (Beamish 1981, Schrank and Guy 2002, Williamson and Garvey 2005, Seibert and Phelps 2013). Cross sections are currently being processed and will be photographed while submerged in water against a dark background and aged with reflected light under a dissecting microscope (Figure 4). In addition, all otoliths collected will be adhered to a glass slide using thermoplastic cement, ground to the nucleus, and imaged using reflected light under a microscope (Figure 5). Each fish will be aged by two independent readers. Spines and otoliths will be crosschecked to age each fish. Where ages between each reader differ too widely (> 2 years), otoliths will be excluded from analyses. Ages which differ to a lesser degree (≤ 2 years) will be recounted and an agreed upon age by each reader will be assigned to that fish. Age data will be used to calculate the mean length (range, 95% confidence interval) at each age for carp captured in the ORB. It is expected that this information will be included with the next annual report (October, 2018).

Hydroacoustic Analysis

USFWS conducted mobile hydroacoustic surveys to estimate relative abundance, size distribution, spatial distribution, and density of Asian carp in each pool of the Ohio River from Cannelton to R.C. Byrd. A total of 20 sampling locations were surveyed in October and November of 2017 using methods similar to that described in MacNamara et al. (2016). Briefly, surveys were conducted using two 200 kHz split-beam transducers (BioSonics, Inc.) pointed toward the shoreline and oriented just below the surface of the water. Each transducer had an effective acoustic beam (i.e., -3 dB angle) of 6.4° and was offset in angle to minimize interference from the surface and maximize water column coverage (i.e., 3.2° and 9.6° below the surface of the water). Angles were adjusted and maintained throughout surveys using a dual-axis rotator. Occasionally transducer angles were adjusted farther down to reduce surface interference from inclement weather. Data were collected at 5 pings/s with a pulse width of 0.4 ms. Temperature was recorded at the time of each survey to compensate for its influence on absorption and the speed of sound in water. An on-axis calibration was conducted after each survey following Foote et al. (1987).
Each hydroacoustics survey was conducted parallel to the shoreline on both banks of the Ohio River for 4 miles and up to 2 miles into tributaries. Survey locations were chosen to encompass clusters of sites that were sampled by KDFWR with electrofishing and gill nets (see monitoring section for additional details on fish community sampling). Data from fish community sampling were used to separate species-specific information as detailed below.

Data are in the process of being analyzed using Echoview 8.0 following MacNamara et al. (2016). After background noise removal, the split-beam single target detection (method 2) algorithm was used to detect fish echoes. Multiple targets from a single fish were grouped into a fish track using EchoView's fish tracking algorithm to reduce the potential of overcounting fish targets. Size of fish targets (total length; cm) were estimated from a relationship between maximum side-aspect acoustic target strength (dB) and fish size (Love 1971). This function is wavelength- and temperature-dependent and was therefore scaled appropriately for 200 kHz transducers and temperature recorded during the survey. To estimate density of fish (e.g., number/m^3), the volume of water ensonified was estimated using the wedge volume approach. Individual fish detections cannot reliably be assigned to a particular species using single-frequency hydroacoustics data. Rather, the proportion of fish at each length class determined from community data is applied to the size distribution and frequency of fish echoes. Fish community data from each pool will be apportioned among 3 fish categories (i.e., Silver carp, Bighead carp, and other fish species) for each length class. Finally, pool specific length-weight regressions will be used to estimate length-specific biomass for each species of interest. Density (numeric and mass) will be estimated following MacNamara et al. (2016).

Compilation and Incorporation of Other ORB Data Sources

Regional and national georeferenced databases are ideal for compiling both historical and current Asian carp range data from ORB states and participating basin groups. The Nonindigenous Aquatic Species (NAS) database, currently maintained by United States Geological Survey, was accessed in February 2018 and used to inform the range of Asian carp species captured and reported throughout the ORB. The NAS database provides a single point of reference where confirmed sightings from all partners can be submitted and will be considered when discussing the range and expansion of Asian carps in the ORB and its tributaries. In addition, data from Ohio River Valley Water Sanitation Commission (ORSANCO) were downloaded and compiled to determine the additional occurrences of Asian carps from community sampling data taken between 1957 – 2017. Data were sorted and mapped in order to supplement project records and additional upstream detections of bigheaded carps in the Ohio River (Figures 6 - 8). Some tributaries of the Ohio River are also included in this search, but are only referenced using their associated pools. Internal reports from other agency and partner projects are also included to expand carp sightings and our knowledge of invasion status within basin states. KDFWR's ichthyology branch has provided additional counties where Asian carp have been documented in internal state streams, connected to the larger Ohio River system.

Results:

Spring Targeted Sampling (Cannelton – R.C. Byrd)

Spring community electrofishing in 2016 produced no Bighead Carp captures and an overall CPUE of 0.70 fish/hour (n = 22, SE = 0.32) for Silver Carp and 0.16 fish/hour (n = 5, SE = 0.10) for Grass Carp (Table 4). All Silver Carp were captured within the Cannelton, McAlpine, and Markland pools. In 2017, targeted electrofishing produced one Bighead Carp for an overall CPUE of 0.05 fish/hour (n = 1, SE = 0.05) and 74 Silver Carp for an overall CPUE of 3.71 fish/hour (n = 74, SE = 1.31). No Grass Carp were observed or captured during targeted electrofishing efforts in 2017. The detection range where Silver Carp were captured remained Cannelton through Markland, as in 2016. However, captures of Silver Carp in 2017 were a 236% increase over captures in 2016 using targeted methods.

Spring gill netting in 2016 (Cannelton through Greenup) produced an overall CPUE of 0.02 fish/set (n = 1, SE = 0.02) for Bighead Carp, 0.35 fish/set (n = 22, SE = 0.16) for Silver Carp, and 0.03 fish/set (n = 2, SE = 0.02) for Grass Carp (Table 5). Sixty-two sets made up 18,590ft of net, yielding a total catch of 165 fish and 13 unique taxa. No Asian carps were caught with gill nets above Meldahl Locks and Dam. Smallmouth buffalo and Silver Carp made up over 50% of the total catch by number. In contrast, spring gill netting in 2017 produced an overall CPUE of 0.10 fish/set (n = 10, SE = 0.06) for Bighead Carp, 0.70 fish/set (n = 31, SE = 0.34) for Silver Carp, and 0.19 fish/set (n = 17, SE = 0.10) for Grass Carp (Table 5).

Eighty-five sets made up 19,100ft (5,800m) of net, yielding a total catch of 197 fish and 11 unique taxa. No Silver Carp were captured above Meldahl Locks and Dam, but one Bighead Carp was captured in the R.C. Byrd pool. Once again, smallmouth buffalo and Silver Carp made up over 50% of the total catch by number; however, Bighead Carp made up ~5% of the total catch in contrast to the <1% seen in 2016.

Fall Standardized Community Monitoring (Cannelton – R.C. Byrd)

Fall sampling in 2017 produced no Bighead Carp or Grass Carp captures and an overall CPUE of 0.18 fish/hour (n = 5, SE = 0.07) for Silver Carp. This was a decrease in catch for both Silver carp and Grass carp from efforts in 2016 with no bighead carp captured during the fall of either year (Table 6). A total of 130 transects were completed to yield a catch of 6,536 fish comprising 52 unique taxa. All Silver Carp were captured in the Cannelton and McAlpine pools, as seen previously in 2016. Gizzard shad were also the most commonly encountered species in 2017 sampling, but only comprised 37% of the total catch by number throughout the sampling period (Table 8). Reductions in the proportional catch of gizzard shad occurred in the Cannelton and R.C. Byrd pools with moderate increases in catches in the McAlpine, Markland, and Meldahl pools between 2016 and 2017.

Fall gill netting in 2017 produced an overall CPUE of 0.10 fish/set (n = 9, SE = 0.53) for Bighead Carp, 0.28 fish/set (n = 26, SE = 1.40) for Silver Carp, and 0.01 fish/set (n = 1, SE = 0.01) for Grass Carp (Table 7). In contrast to 2016, two Silver Carp were captured with nets above Meldahl Locks and Dam during 2017 sampling. Ninety four sets made up 18,220ft (5,550m), yielding a total catch of 111 fish and 13 unique taxa. Smallmouth buffalo and Silver Carp alone made up over 50% of the total catch with Bighead Carp and common carp making up an additional 16% (Table 9).

In 2016, clupeids made up the vast majority of species documented across the lower three pools (Cannelton – Markland) sampled in the middle Ohio River. This was typically followed by those species found within the cyprinid, centrarchid, and catostomid families (Figures 9 – 11). Altogether, this reflected more than 85% of the total family diversity in each of the lower three pools during fall sampling. In 2017, this within-pool representation appeared consistent with the previous year's sampling and family representation over both seasons appears to be similar. In 2016, the Meldahl pool had less cyprinid representation than in lower pools and ictalurids, moronids, and sciaenids were more frequent in addition to clupeids, centrarchids and catostomids (Figure 12). This distribution shifted in 2017 with a much lower proportional catch of clupeids and a 43% percentage-point increase in cyprinid representation (mostly comprised of large groups of emerald shiners at sampling locations), making the minnows the most common group of fishes in Meldahl during fall 2017, followed closely by the herrings (primarily comprised of gizzard shad). Both Greenup and R.C. Byrd had dominant family representations distributed across Clupeidae, Cyprinidae, Centrarchidae, Sciaenidae, and Catostomidae both in 2016 and 2017 (Figures 13 – 14). However, in 2017, clupeid numbers decreased drastically within both pools and catostomids, sciaenids, and centrarchid numbers increased.

Trophic guilds were assigned to each fish using the classifications from Simon and Emery (1995) and Emery et al. (2002) as reported in Thomas et al. (2004) or The Fishes of Tennessee (2001) text (Etnier and Starnes 2001, Thomas et al. 2004). The proportional representation of trophic guilds within each pool varies greatly between 2016 and 2017 depending on catch. Guilds identified in the Cannelton, McAlpine, and Markland pools look similar across years with herbivores making up the majority of the population. In 2016, Meldahl, Greenup, and R.C. Byrd communities were comprised mostly of herbivores, but in 2017 the dominant guilds shifted, likely in response to the large change in major taxa groups represented in those pools. Particularly, Meldahl samples displayed a majority of planktivores while Greenup and R.C. Byrd shifted to primarily invertivores, detritivores, and piscivores.

Assessing Asian Carp Population Demographics

In total, the number of Bighead Carp captures across all projects in 2017 was 46 fish. However, this was a >100% increase in total bighead captures when compared to 2016's twenty-one Bighead carp removed from the ORB. Of those two years, males were more common and immature fish were only captured during 2017 sampling. The four immature fish were caught in the Cannelton pool and ranged in total length from 520 – 596mm. The mean total length of bighead across both years was similar, with 2016 average TL = ~1011mm (n = 21, SE = 60.9) and 2017 average TL = ~1020mm (n = 46, SE = 31.0). Using records from both seasons, a weight-length regression using $\log_{10}$ transformed data produced the curve $\log_{10}[\text{Weight}_g] = -5.05 + 3.03 * \log_{10}[\text{Length}_{mm}]$ (Adj $R^2 = 0.971$, Figure 3). Regressions were achieved utilizing the general linear model function (lm()) in base R (R Core Team 2016).

In 2017, 1,661 Silver Carp were removed from the Ohio River during projects being conducted by all partners within the basin. This was an increase in total number of Silver Carp captured in reference to 2016 efforts. The mean total length of Silver Carp captured in 2016 was around 820mm (n = 1578, SE = 1.77) while the mean total length of Silver Carp in 2017 was 796mm (n = 1661, SE = 4.15). Smaller length-classes of Silver Carp were seen with more frequency in 2017 when compared to 2016 due to several occasions where juvenile fish < 400mm were captured in the Cannelton pool. Across both seasons, the relative frequency of larger length-classes in each pool increased with a progression upriver (Figure 15).

The presence of spawning patches on female fish was also tracked throughout 2016 and 2017, which we took as evidence of recent spawning activity. A spawning patch was noted if it was actively hemorrhaging or the flesh was raw, with scales missing along the ventral surface of the body, and there was little to no visible signs of healing. Females captured in all pools exhibited fresh spawning patches from May – August. Within the Cannelton and McAlpine pools, this time period was associated with increases in CPUE for all gears, but most notably electrofishing (Figure 16). This pattern was also seen in 2016 and was likewise associated with increases in Silver Carp catch rates.

Using records from both seasons, a weight-length regression using LOG_{10}-transformed data for Silver Carp was produced for each year (Figure 17) using fish records collected after August to remove the influence of spawning activity on weight. All calculations were conducted in base R (R Core Team 2016). A factorial ANCOVA was used to determine that there was no significant difference between years for LOG_{10}-transformed weights (g) at length (mm) of Silver Carp captured after annual spawning activity, $F(1, 260) = 3.168$, $p = 0.076$ (Figure 17). All records from the fish captured outside of the spawning activity across both years were combined to produce the curve $\log_{10}[\text{Weight}_g] = -5.13 + 3.05 * \log_{10}[\text{Length}_{mm}]$ (Adj $R^2 = 0.976$, Figure 2) in base R (R Core Team 2016).

In total, 131 pectoral spines were taken from Silver Carp captured in the ORB in 2017 have been sectioned and are in the process of being photographed. Otoliths were also taken from a sub-sample of both species of bigheaded carp and are in the process of being ground to the nucleus and imaged before being read. A subsample from each length-class of all aging structures collected will be used to determine the average length at age for Silver Carp within the ORB.

Hydroacoustic Analysis
Hydroacoustic analyses are ongoing; results are anticipated by June 2018.

Monitoring Asian Carps Ahead of the Invasion Front
Targeted gill net sampling for Asian Carp in the Montgomery Slough of the Ohio River and the backwater portion of Pool 7 of the Allegheny River yielded no Asian Carp species. Common Carp and

River Carpsucker comprised 56% and 24% of the total catch on the Ohio River and Smallmouth Buffalo and Muskellunge comprised 52% and 43% of the total catch on the Allegheny River.

Twenty-three baited tandem hoop nets were fished for 69 net nights and captured no Asian Carp species. Sixteen species were captured, and Channel Catfish and Smallmouth Buffalo comprised 39% and 31% of the total catch.

Beach seining on the Montgomery Island Pool collected no Asian Carp species. Total numbers of individuals and species have yet to be determined as laboratory identification is ongoing.

Daytime boat electrofishing on the Ohio River Montgomery Island Pool, Monongahela River Charleroi Pool, and Allegheny River Pool 4 was conducted for 2.1 hrs of effort and no Asian Carp were captured. Similarly, night boat electrofishing on the Ohio River in the New Cumberland Pool at the Montgomery Dam tailwater for 1.5 hrs of effort and in Pool 4 of the Allegheny River for 1.91 hrs of effort captured no Asian Carp.

Compilation and Incorporation of Other ORB Data Sources
Data taken from ORSANCO records since 1957 show a similar pattern in presence/absence of Asian carps as seen during standard monitoring sampling and removal efforts conducted between 2015-2017. The farthest up-river accounts of Asian carps by ORSANCO were in the Markland Pool in 2012 and McAlpine Pool in 2014 (Figures 6 – 8). The USGS NAS database expands the range of carp sightings depending on the species. The farthest upriver detection of Silver Carp was a capture in Raccoon Creek, a tributary of the R.C. Byrd Pool, in 2016 while a Bighead Carp was captured as far up as a tributary of the Pike Island Pool 2016 (Figures 6 – 7). Data records for Grass Carp are sporadic throughout the basin and likely are indicative of establishment throughout the ORB (Figure 8). During routine sampling, the KDFWR ichthyology branch reported Silver Carp sightings at six locations between August and October in McCracken and Ballard counties (Figure 18). Two of six sites (Massac Creek and Clanton Creek wetland) contained juvenile Silver Carp. Seven voucher specimens were obtained from Clanton Creek in October that were YOY species ranging in size from 69 – 85mm. Both of these inland drainages contact the Ohio River below Lock 52 and carp located at each site were within close proximity to the river.

Discussion:
The 2017 Monitoring and Response project built on the design and efforts of monitoring in 2015 – 2016. The original four pools (McAlpine through Greenup) sampled in 2015 were expanded to include one additional down-river pool (Cannelton) and one additional up-river pool (R.C. Byrd) in 2016. Community sampling during 2016 provided the first spring community data obtained during this project, but was modified to target Asian Carp in 2017 to better understand relative carp numbers by pool. This targeted removal not only addresses the goal of tracking relative abundance through time, but also has the added benefit of allowing crews to focus on catching only invasive carp species and therefore increases the number of total fish removed from the system during this period. This benefit was demonstrated in 2017 with the total number of Silver Carp captures during targeted sampling exceeding a 200% increase in catch when compared to the previous year. Increases in capture numbers between 2016 and 2017, specifically with gill nets is a likely indication of a better understanding of how to target these species and when to utilize these gears rather than an increase in relative abundances. However, with the geographic range of detection being similar to that seen during community monitoring in 2016, it is likely that, at present, a higher amount of effort per pool would be necessary to reach any level of detection for carp in lower abundance pools (Meldahl – R.C. Byrd).

Relative catch rates (CPUE) of Silver Carp over both years continue to support increases in relative abundances of Silver Carp from upriver to downriver pools (Figures 19 – 20). This trend among Silver

Carp abundance is also apparent during removal efforts and additional observations during projects further up the Ohio River. No gear types currently used seem to be effective at targeting Bighead Carp; however, reports from fishermen on catches that match or exceed state and federal sampling records in the R.C. Byrd may indicate that the pool has higher numbers of Bighead Carp than previously thought (WVDNR personal communication, 2016). In light of this evidence and relatively little information about Bighead Carp in each pool, it is difficult to determine if they follow a similar geographic pattern of decreasing relative abundance in pools where targeted monitoring was conducted.

Fall community monitoring in 2017 produced catches of four unique taxa when compared to sampling conducted in 2016, but did not contain the presence of seven other taxa, which were sampled the previous year. Across both years, gizzard shad were the most commonly encountered species in electrofishing efforts while smallmouth buffalo were the most commonly encountered species during gill netting. Asian carp were captured from the Cannelton pool through Markland pool, as in 2016, but the number of bigheaded carps captured in the Cannelton pool greatly exceeded the previous year's catch. The majority of carp encountered during monitoring were captured in tributaries. It is unclear if this can be attributed to habitat preference or increased sampling effectiveness in shallower habitats. In 2017, community monitoring began around the same time as 2016 in the lower pools (Cannelton – Markland) with similar temperatures to the previous year; however, sampling the upper pools (Meldahl and R.C. Byrd specifically) extended to almost the end of November with water temperatures getting cooler (~ 14°F difference) when compared to previous years' average temperatures. With upriver pools in 2017 having been sampled later in the season, most of the community assemblage and trophic level shifts seen in those pools may be partly explained by the extension in sampling activities and cooler water temperatures. This reinforces the need to spread effort across resource agencies and partner groups and focus on maintaining a discrete sampling period for community monitoring efforts in the future.

Regressions for growth of both Silver Carp and Bighead Carp were comparable to other basins, suggesting that growth and condition of fish in the Ohio River is similar to that found elsewhere (Tables 1 – 2). Increased frequency of larger length-classes of Silver Carp in upriver pools, in addition to more narrow ranges of total lengths overall, suggests that fish captured upriver are more indicative of migrants rather than successfully reproducing populations. This is further reinforced by reported data from additional sources such as the NAS database records, which have few recent records of Silver Carp extending past the R.C. Byrd pool. However, increases in the frequency of smaller length classes of silvers in Cannelton indicate that fish within that pool may have had a successful spawn and juveniles are now recruiting to gears being used. Tributaries where these younger individuals were observed in 2017 are potentially important to spawning success (primarily Clover Creek/Tug Fork and Oil Creek, among others).

With CPUE highly correlated with spawning activities in 2017, it is important to note that carp are likely more susceptible to the gears and techniques currently being used by project collaborators during the months of May – August (Figure 16). Catch rates have tended to decrease as water temperatures drop toward the fall season. However, recent pursuits between USFWS and KDFWR utilizing hydroacoustics and removal effort in the Cannelton pool during the cooler months suggest that large groups of riverine fish can likely be targeted using side-scan and split-beam technologies and may aid in pinpointing areas where removal efforts can focus during cooler months.

Recommendations:
It is recommend that both targeted sampling and community monitoring continue in 2018 using the consistent and repeatable design now established for this project. Although the monitoring range is geographically extensive, more care to ensure a discrete (~ 3 week) sampling period within a water temperature range of 60° – 70° F (average being ~65°F) will benefit efforts to identify community trends in future monitoring assessments. Control and containment efforts would likely benefit from using

spawning periods as an advantage for removal. The majority of effort placed into carp removal should likely be conducted in the Cannelton and McAlpine pools between April and September to maximize efficiency. Other gears and techniques should be used in an attempt to increase catch of carp outside of this period and hydroacoustic technologies would likely aid in pinpointing focal areas for removal efforts.

Project Highlights:

- The 2017 Monitoring and Response to Asian Carp in the Ohio River project built on the design and efforts of monitoring in 2015 – 2016.
- Work conducted in 2016 was an increase in effort and geographic range when compared to previous efforts conducted since the "Leading Edge" projects were established in 2015.
- A total of ~52 electrofishing hours during monitoring efforts yielded a catch of more than 7,000 fish comprising 52 taxa in 2017. One Bighead Carp and 80 Silver Carp were obtained and removed from several pools in the ORB
- A total of 37,300 ft (11,369 m) of net was deployed, yielding a catch of 308 fish comprised of 13 species in 2017. Nineteen Bighead Carp, 37 Silver Carp, and 18 feral Grass Carp were captured and removed from the ORB.
- A total of 257 km (160 miles) of main channel habitat was surveyed with hydroacoustics during October-November 2017 along the Ohio River across 20 sites that were chosen to encompass clusters of monitoring sites. Any navigable tributary associated with these sites were also surveyed up to 3.2 km (2 miles).
- Continual incorporation of data sources and additional monitoring ahead of the current invasion front should continue in order to inform managers of significant expansions of Asian carp up-river.
- An additional 1,707 silver and Bighead Carp were removed from the ORB in 2017. This adds to the various sampling efforts since 2015 and adds to the > 60,000 lbs of invasive carps removed over the last three years in the middle Ohio River.
- Capture numbers again appear to reflect that Cannelton and McAlpine have much higher densities of invasive bigheaded carp than the pools above them and relative abundance numbers indicate that the current geographic approximate line for Silver Carp establishment still exists near McAlpine pool.
- With less information from sampling efforts on bighead and Grass Carp, little can be said to the extent of their establishment within the ORB.
- It is recommended that monitoring continue in 2018 with more focus on informing control and containment efforts in the Cannelton and McAlpine pools.

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Figures:

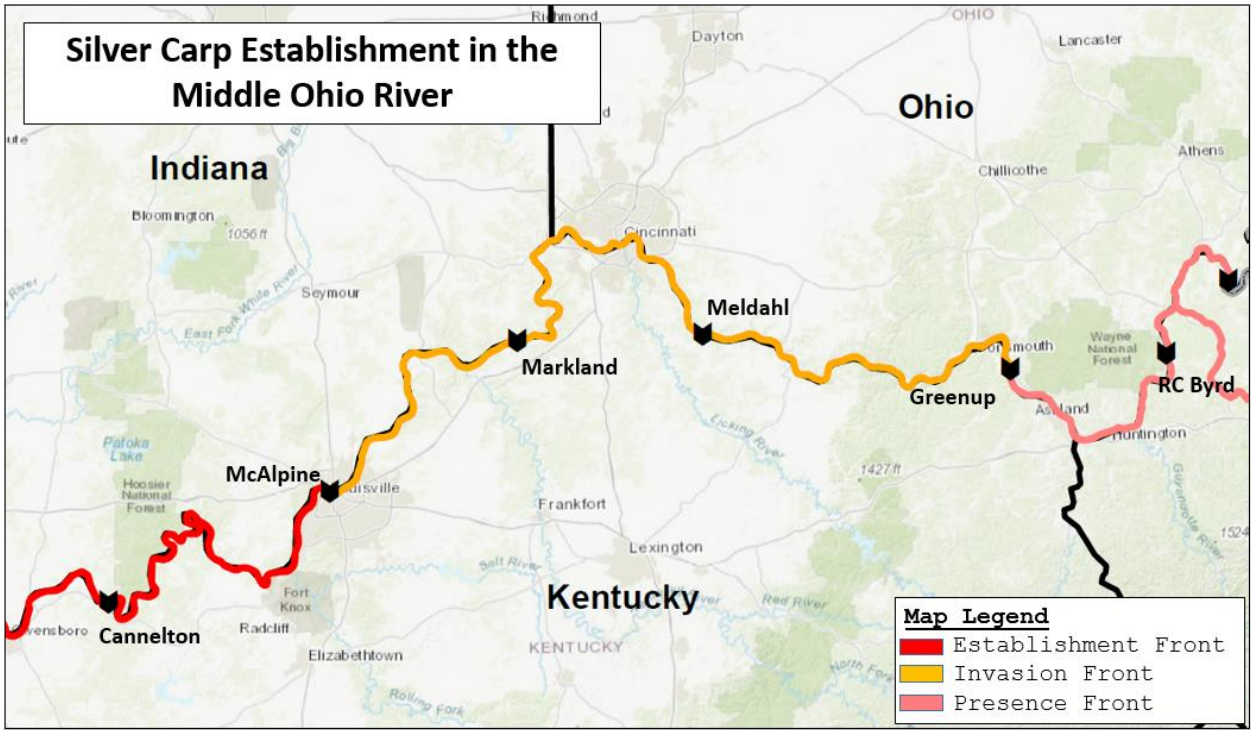

Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

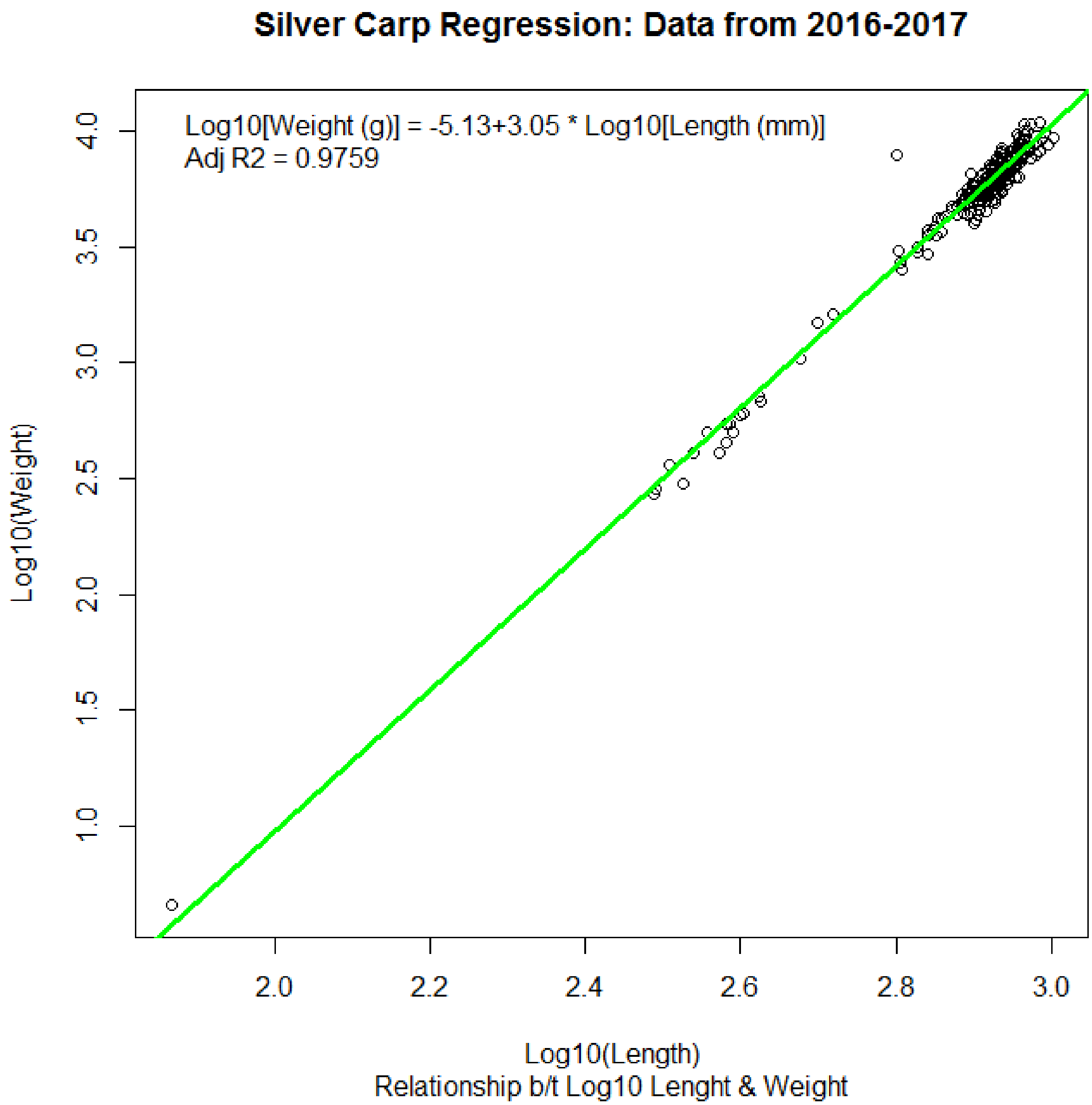

Figure 2. A scatterplot of log_{10}-transformed lengths (mm) and weights (g) from *H. molitrix* captured from August through December in 2016 and 2017 with a regression line describing the relationship between lengths and weights in the ORB (n = 336).

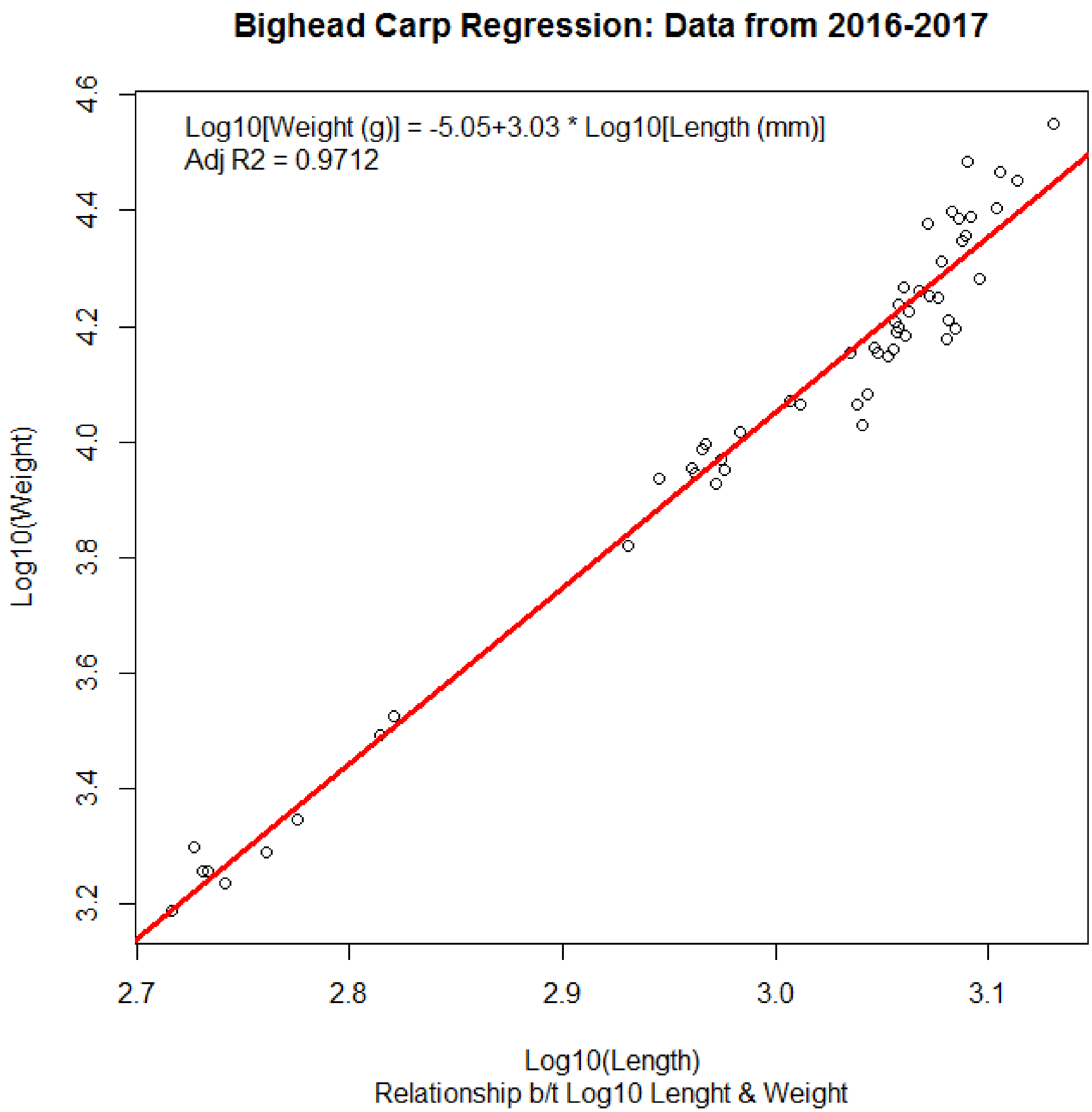

Figure 3. A scatterplot of log_{10}-transformed lengths (mm) and weights (g) from all *H. nobilis* captured from August through December in 2016 and 2017 with a regression line describing the relationship between lengths and weights in the ORB (n = 55).

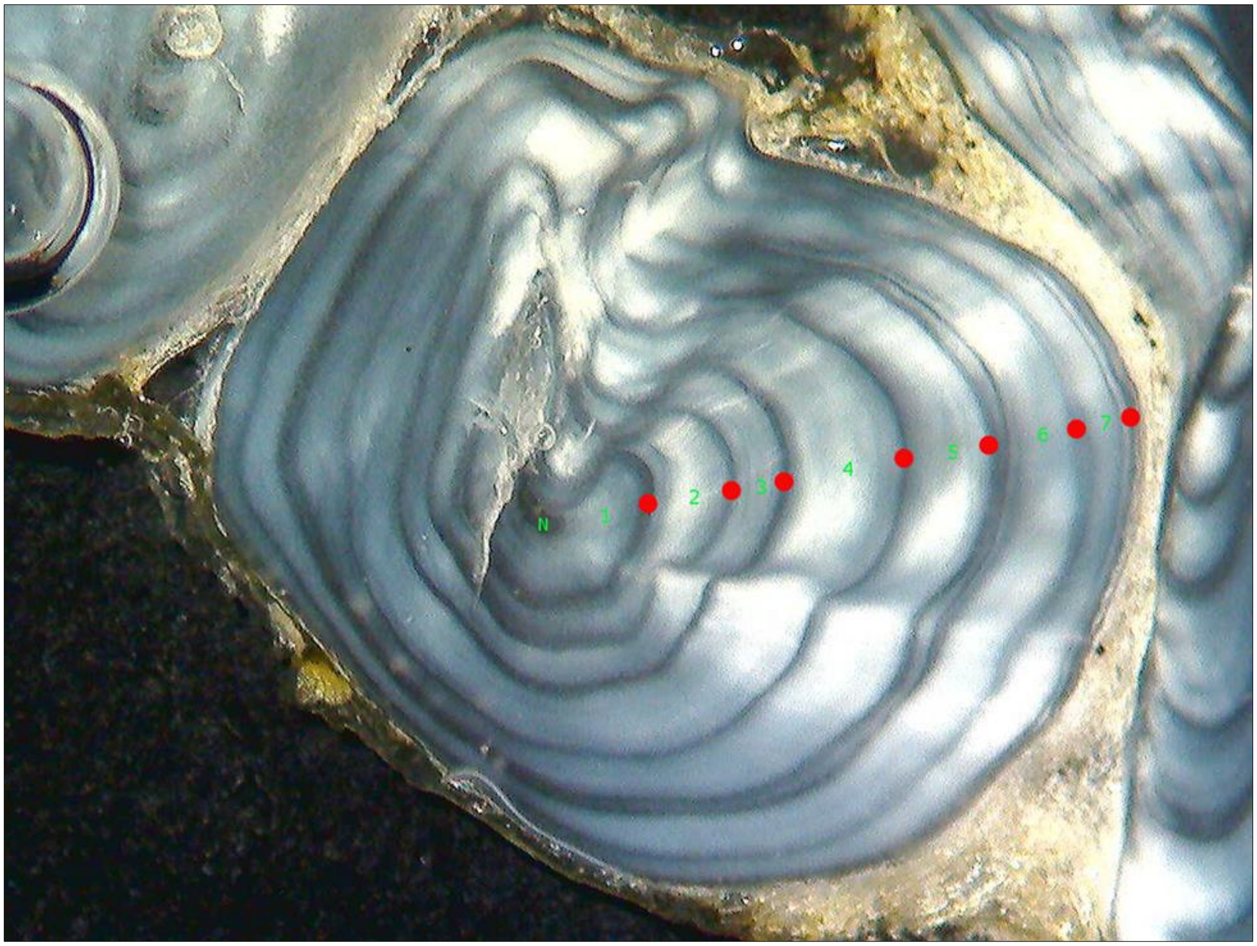

Figure 4. An image of a spine cross-section collected from a 7-year-old silver carp in the Cannelton pool, captured in May 2016.

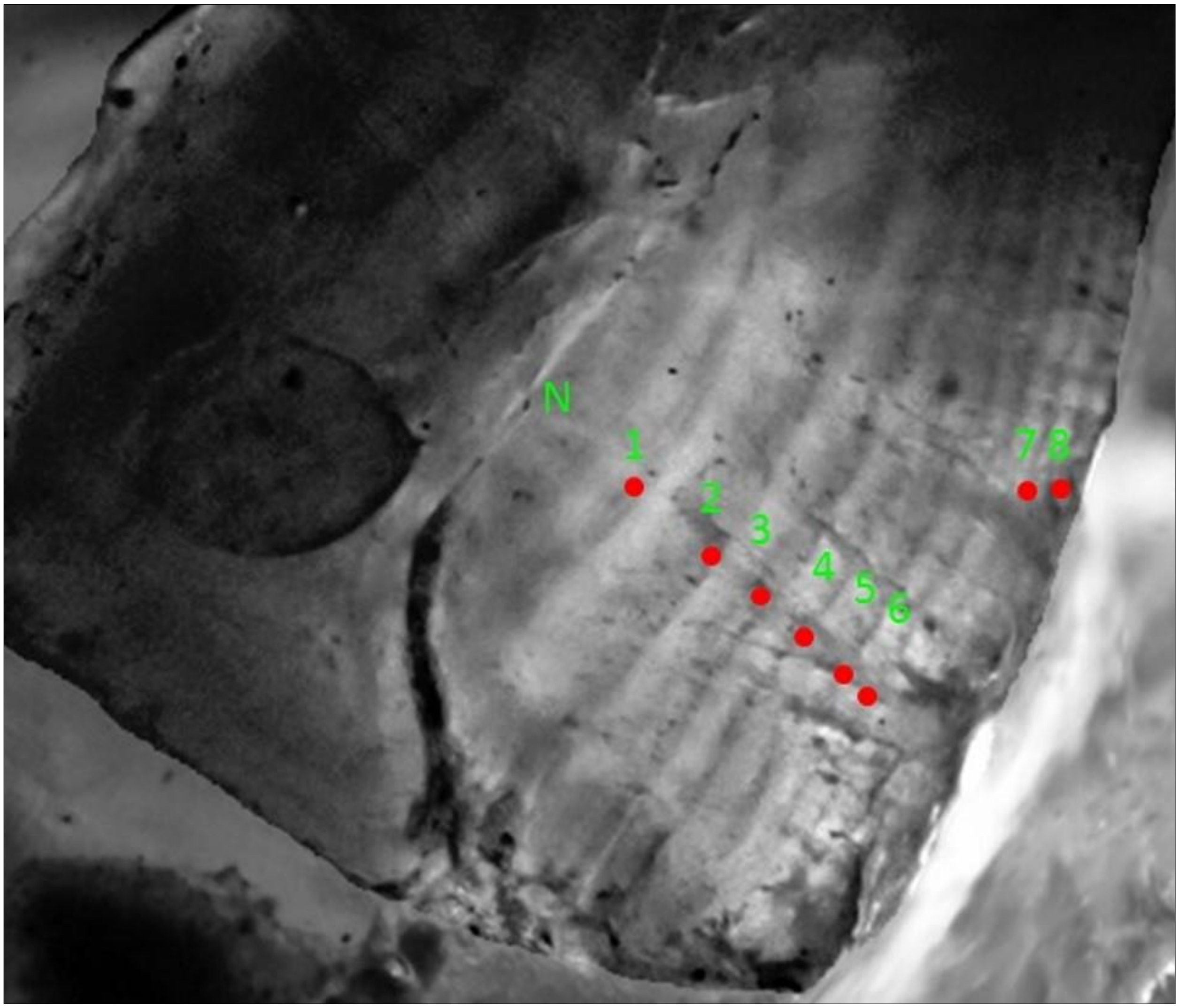

Figure 5. An image of a silver carp otolith collected from an 8-year-old fish, captured in the McAlpine pool in July 2013.

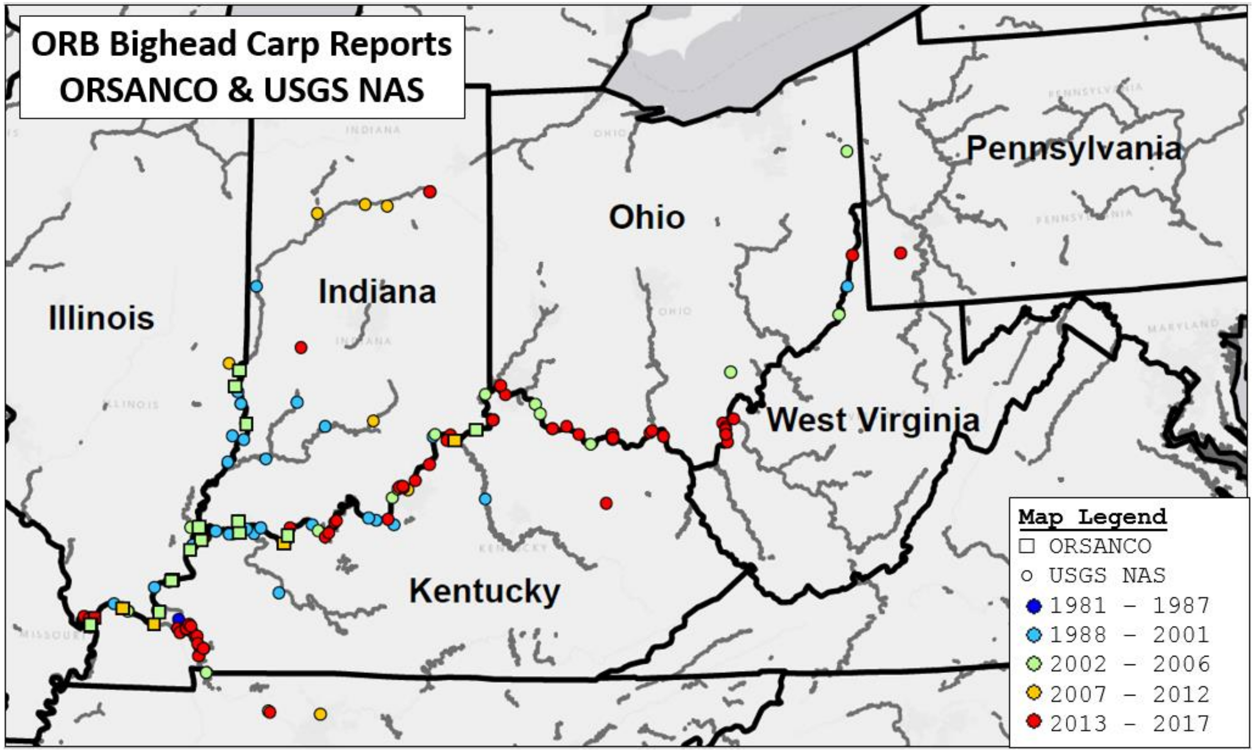

Figure 6. A range map of bighead carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

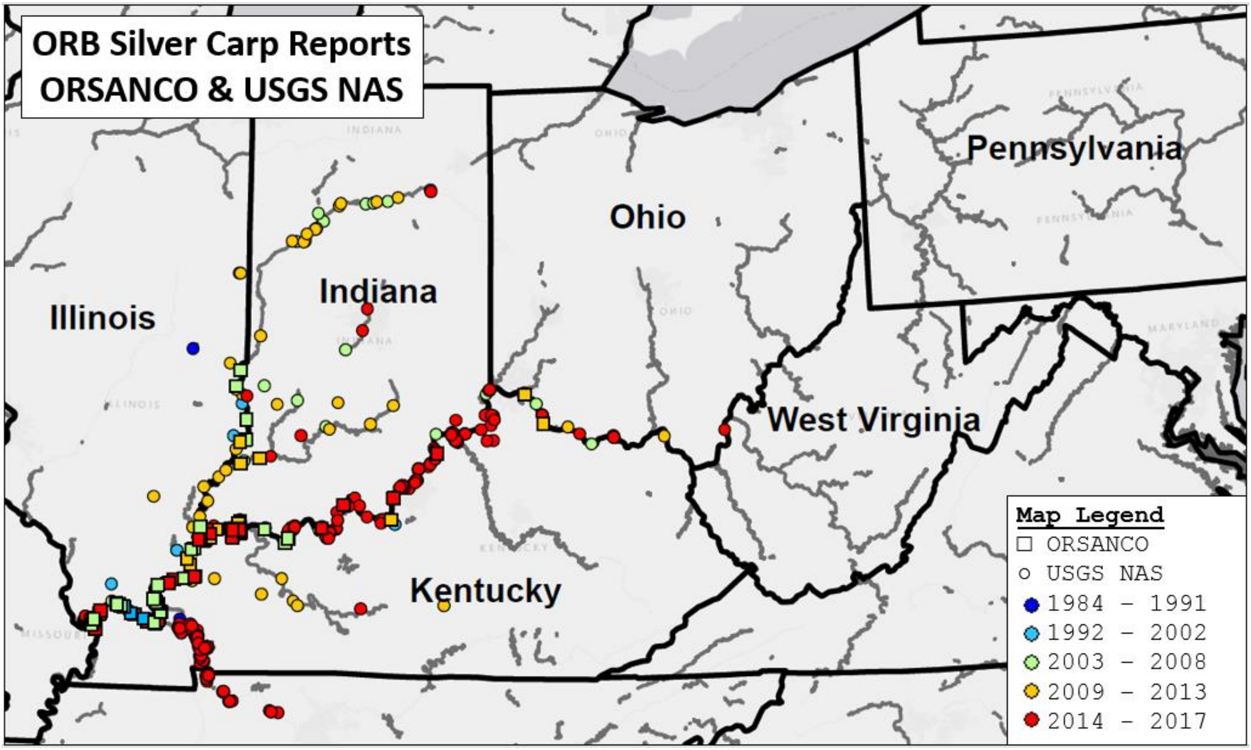

Figure 7. A range map of silver carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

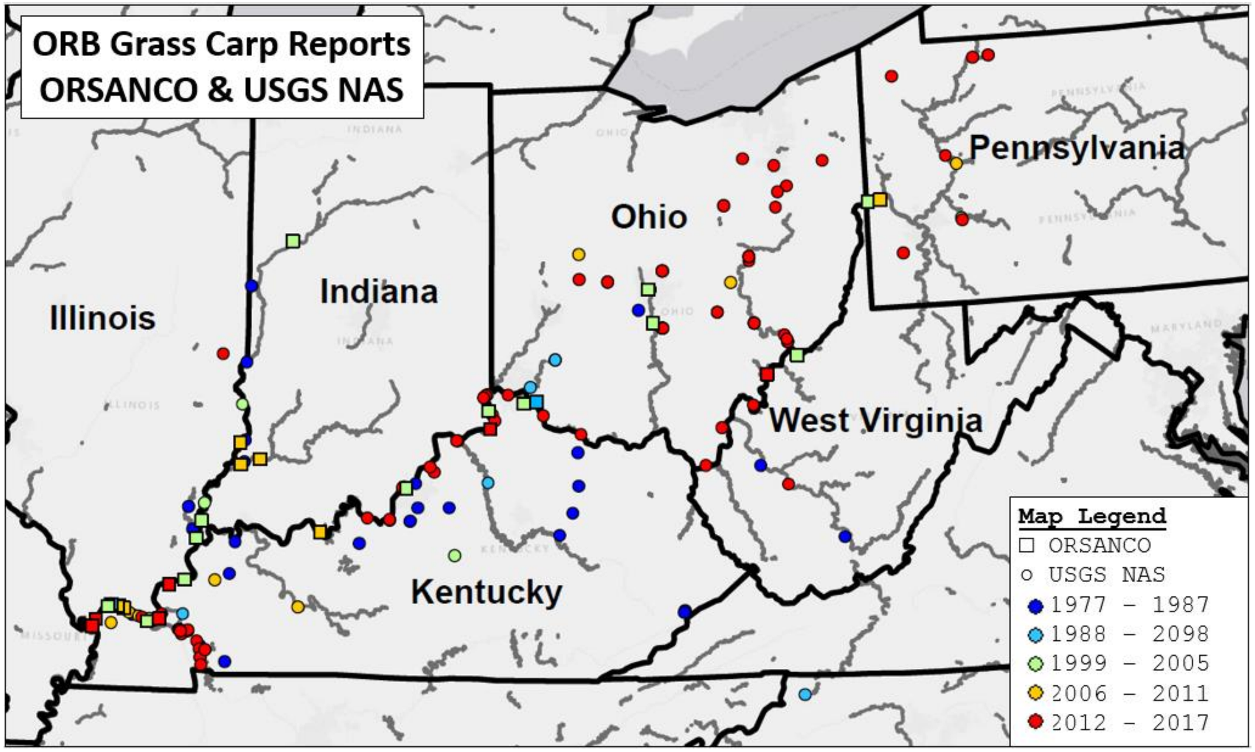

Figure 8. A range map of grass carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

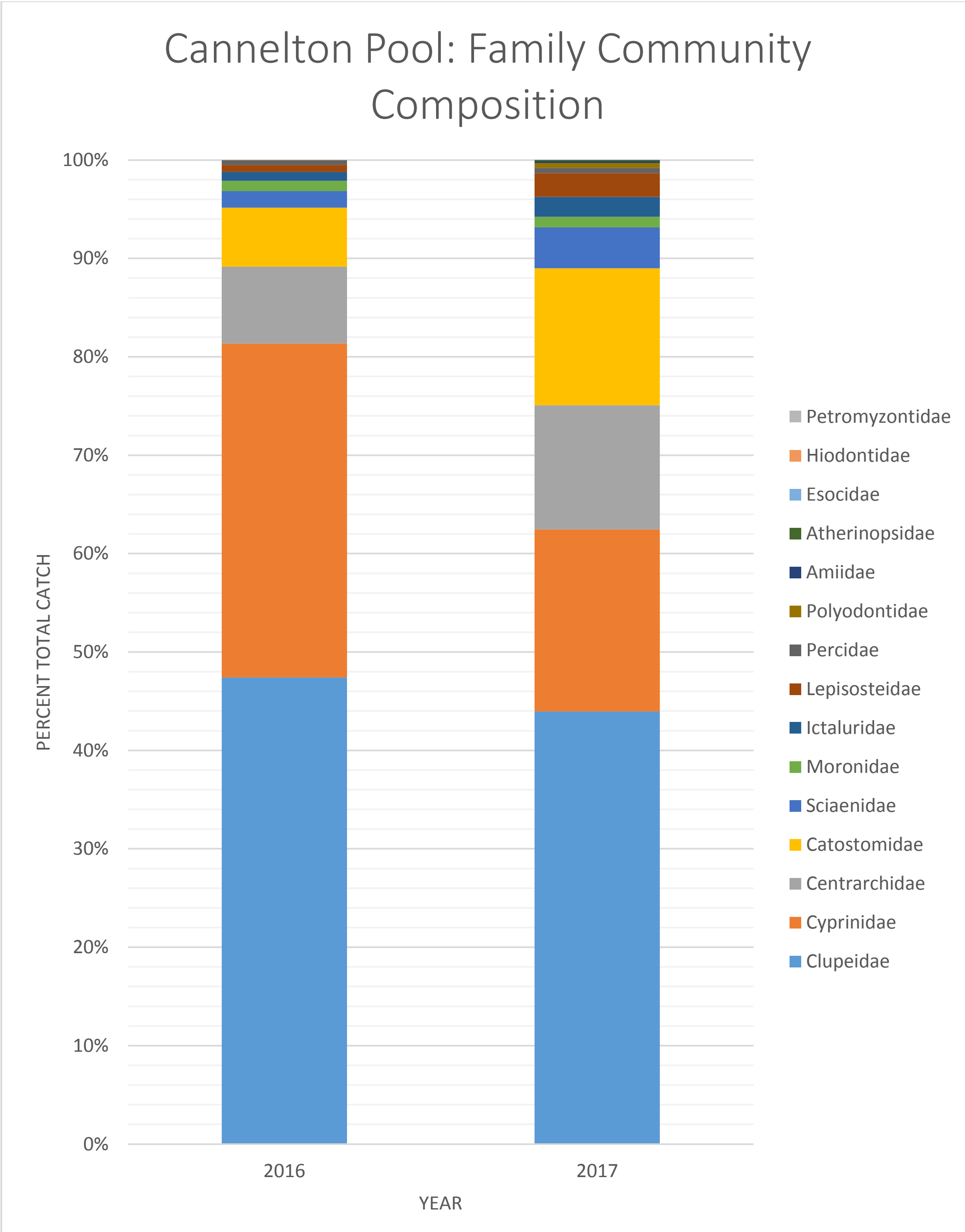

Figure 9. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Cannelton pool.

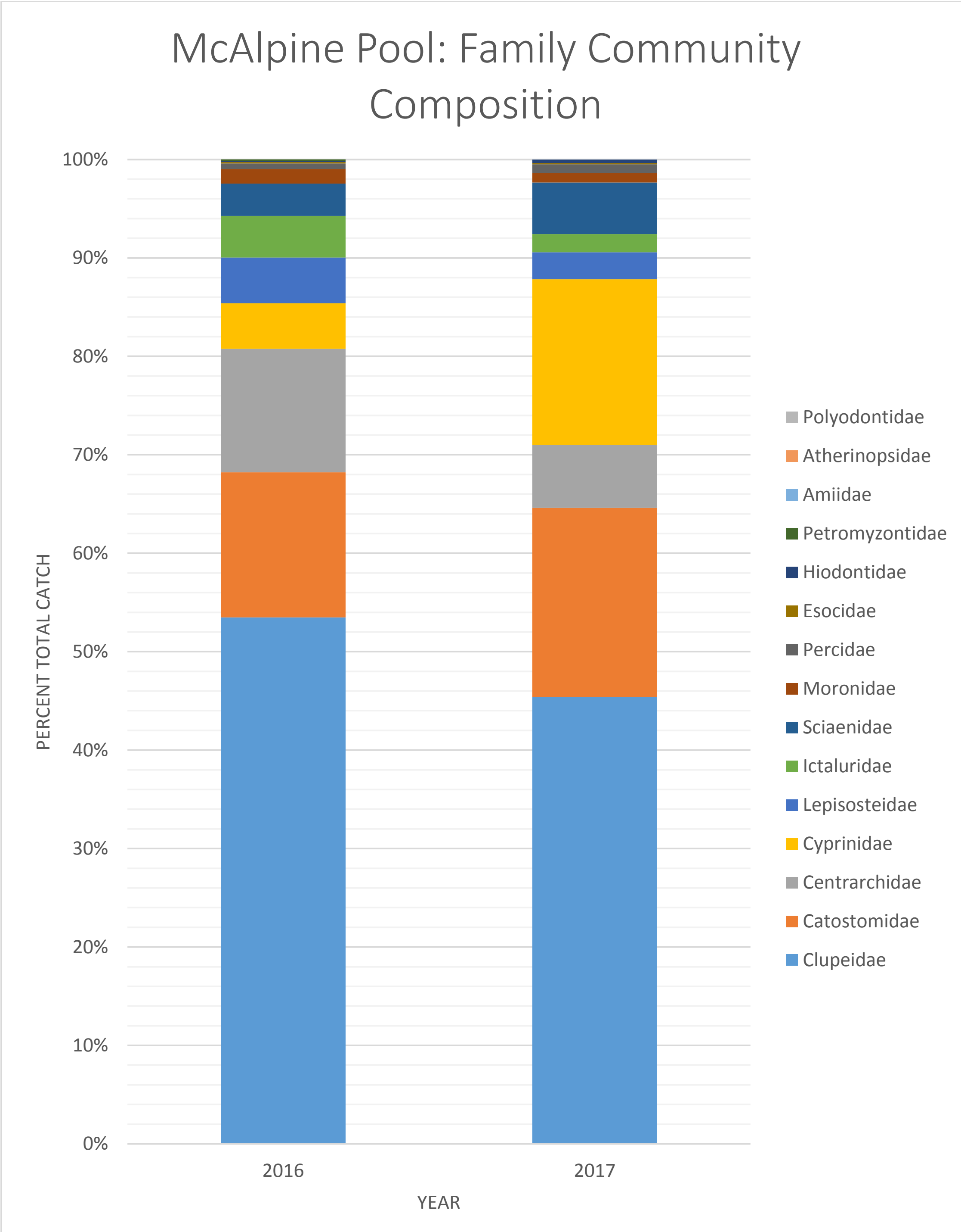

Figure 10. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the McAlpine pool.

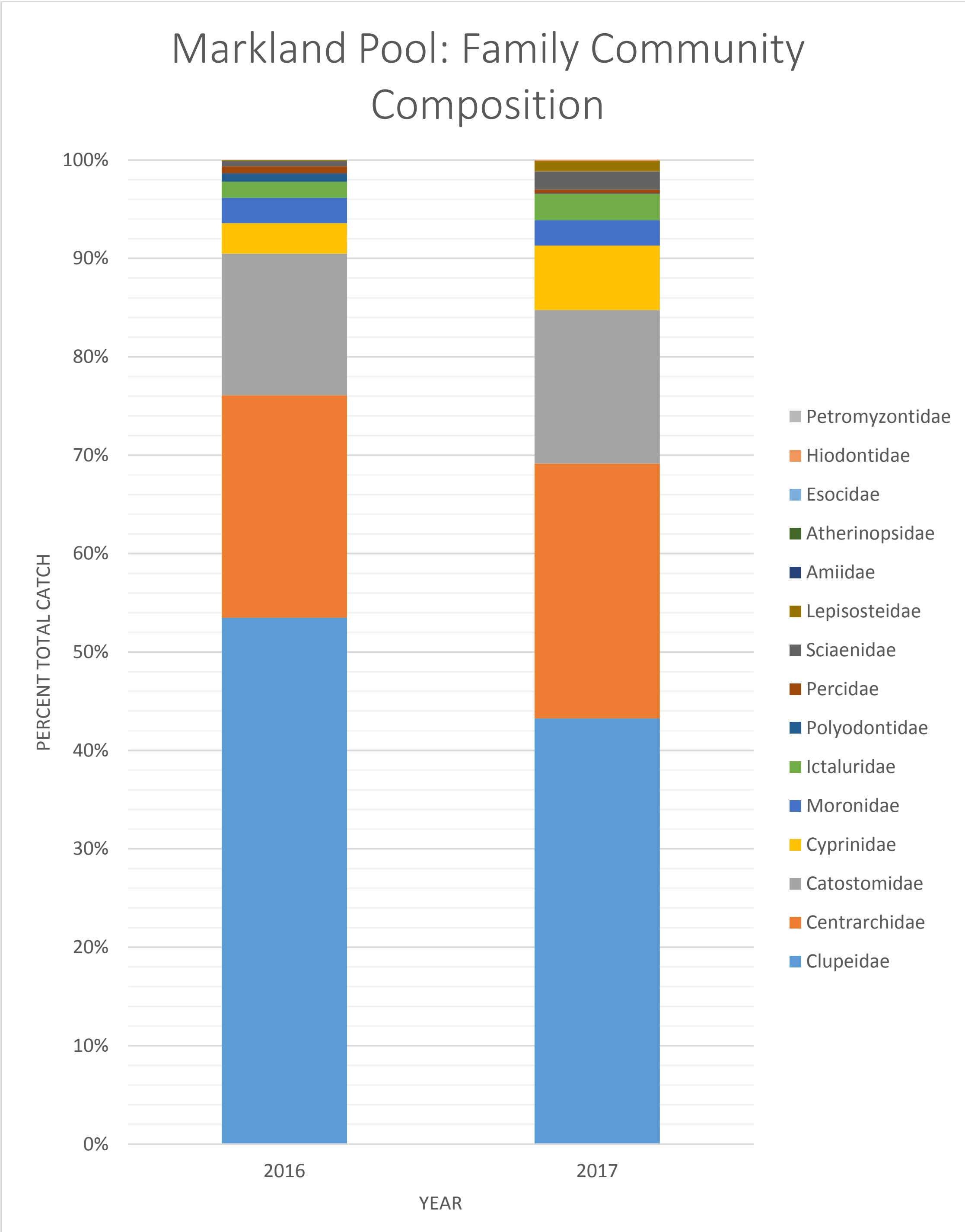

Figure 11. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Markland pool.

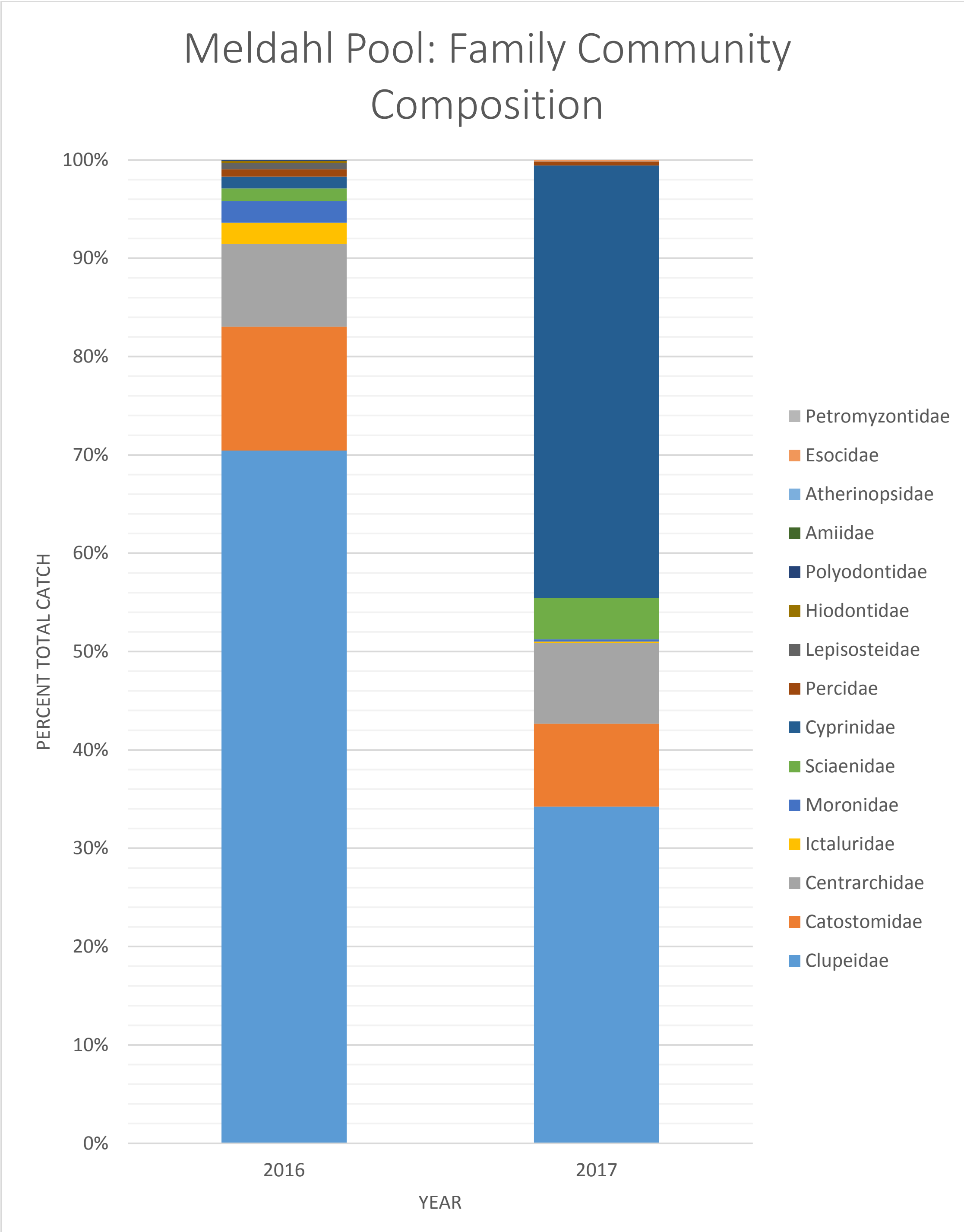

Figure 12. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Meldahl pool.

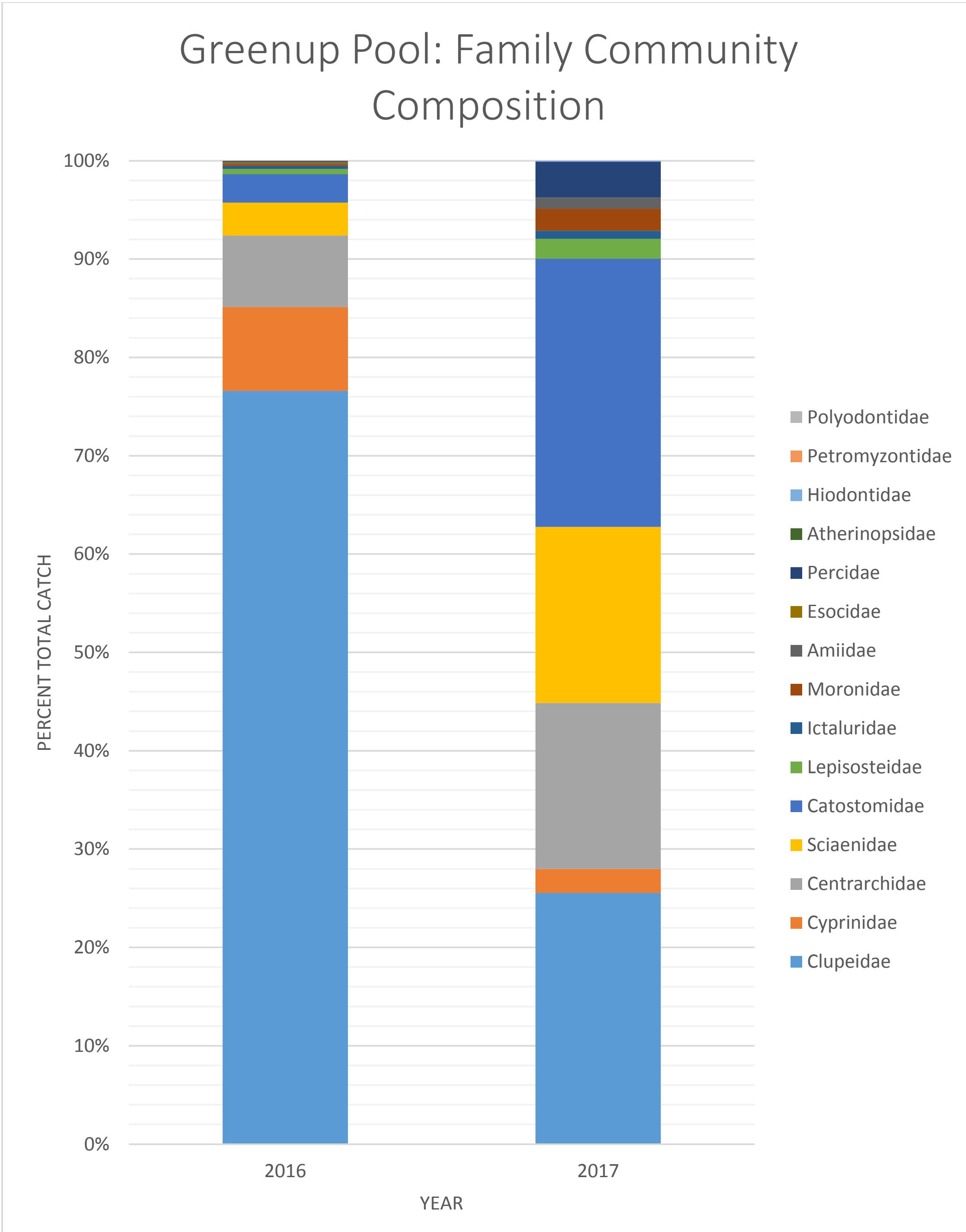

Figure 13. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Greenup pool.

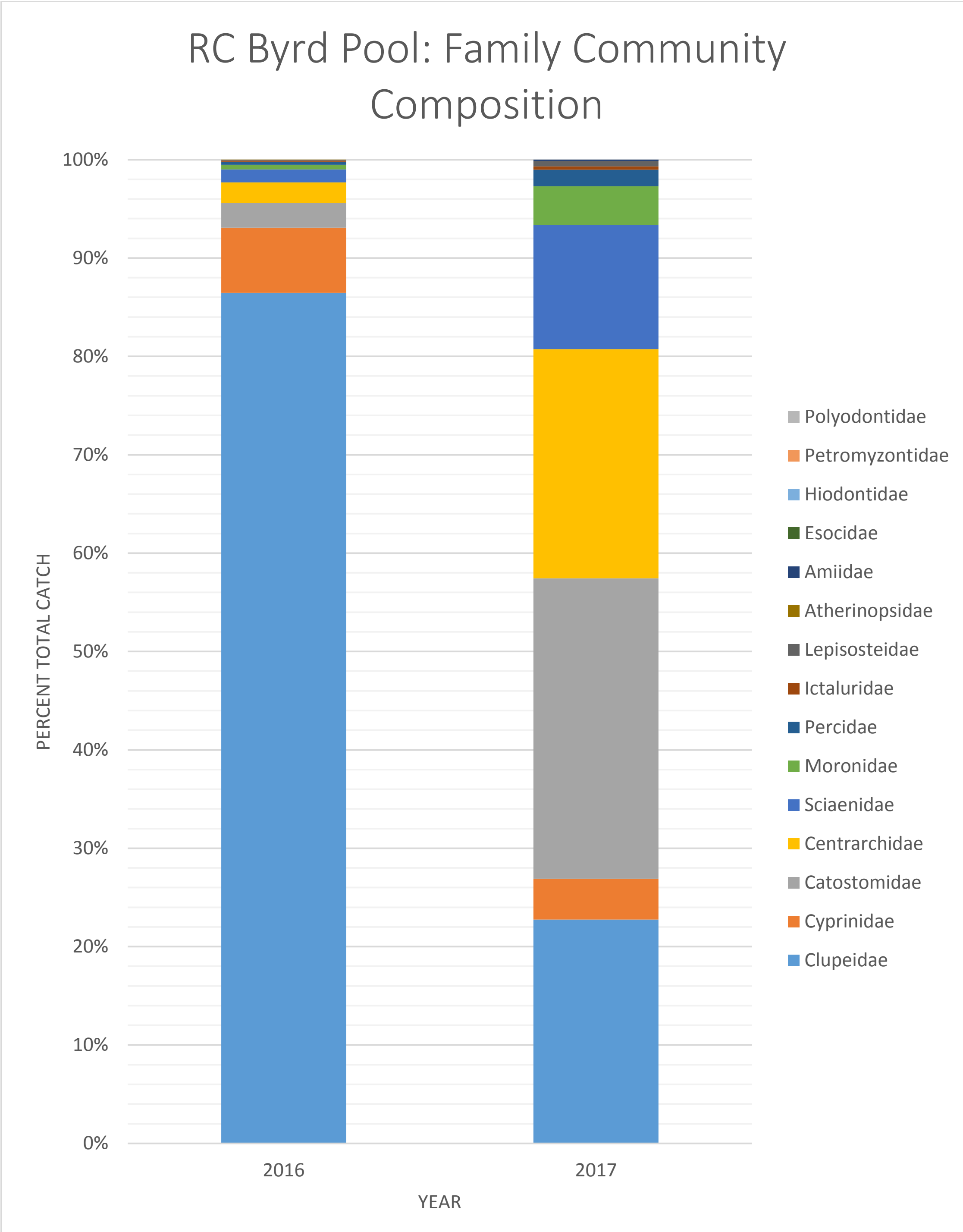

Figure 14. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the RC Byrd pool.

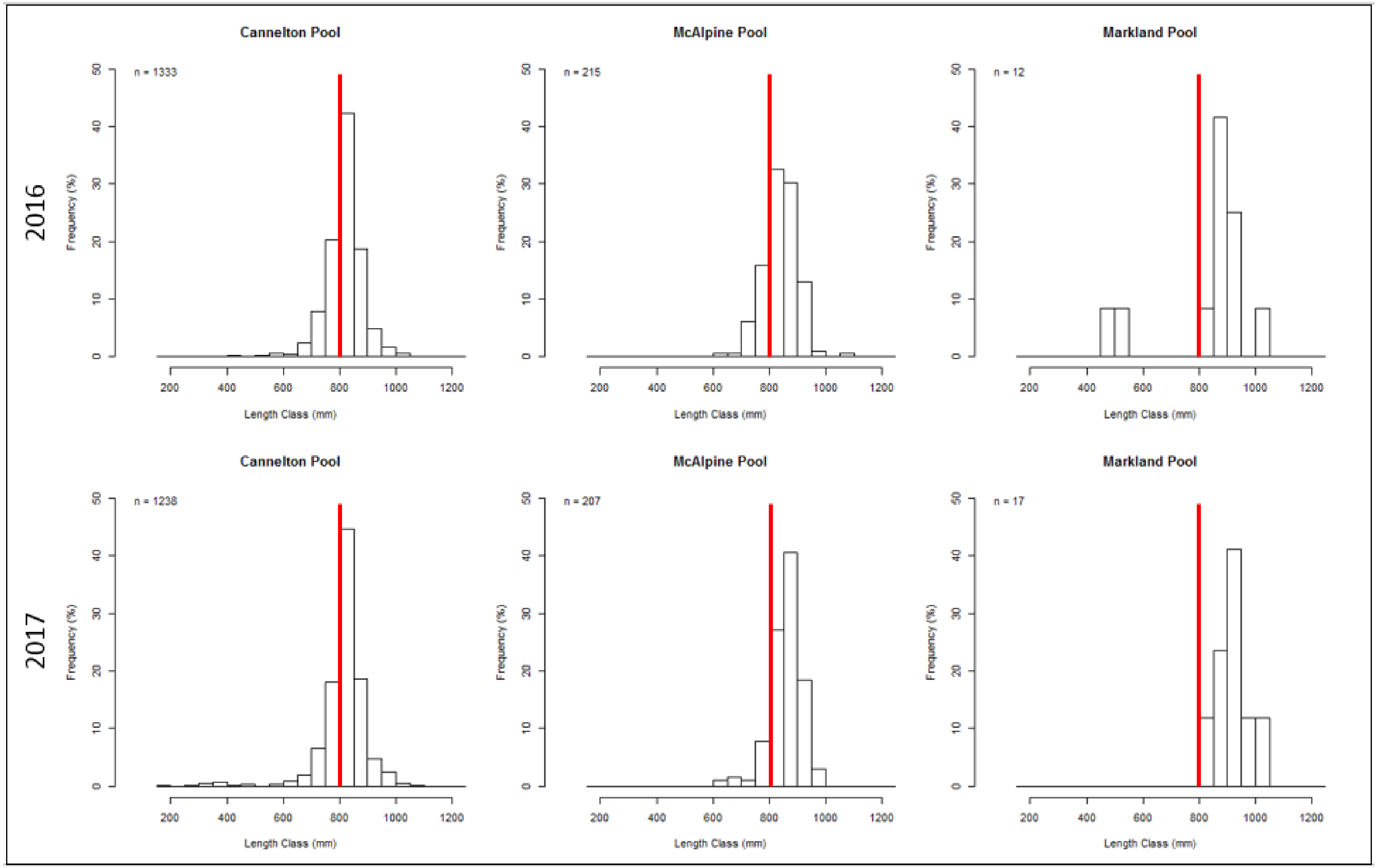

Figure 15. Length frequencies of silver carp captured during sampling efforts in 2016 and 2017. A line at 800mm highlights the change in length-classes from fish captured farther upriver with Cannelton being the farthest pool downstream and Markland the farthest pool upstream.

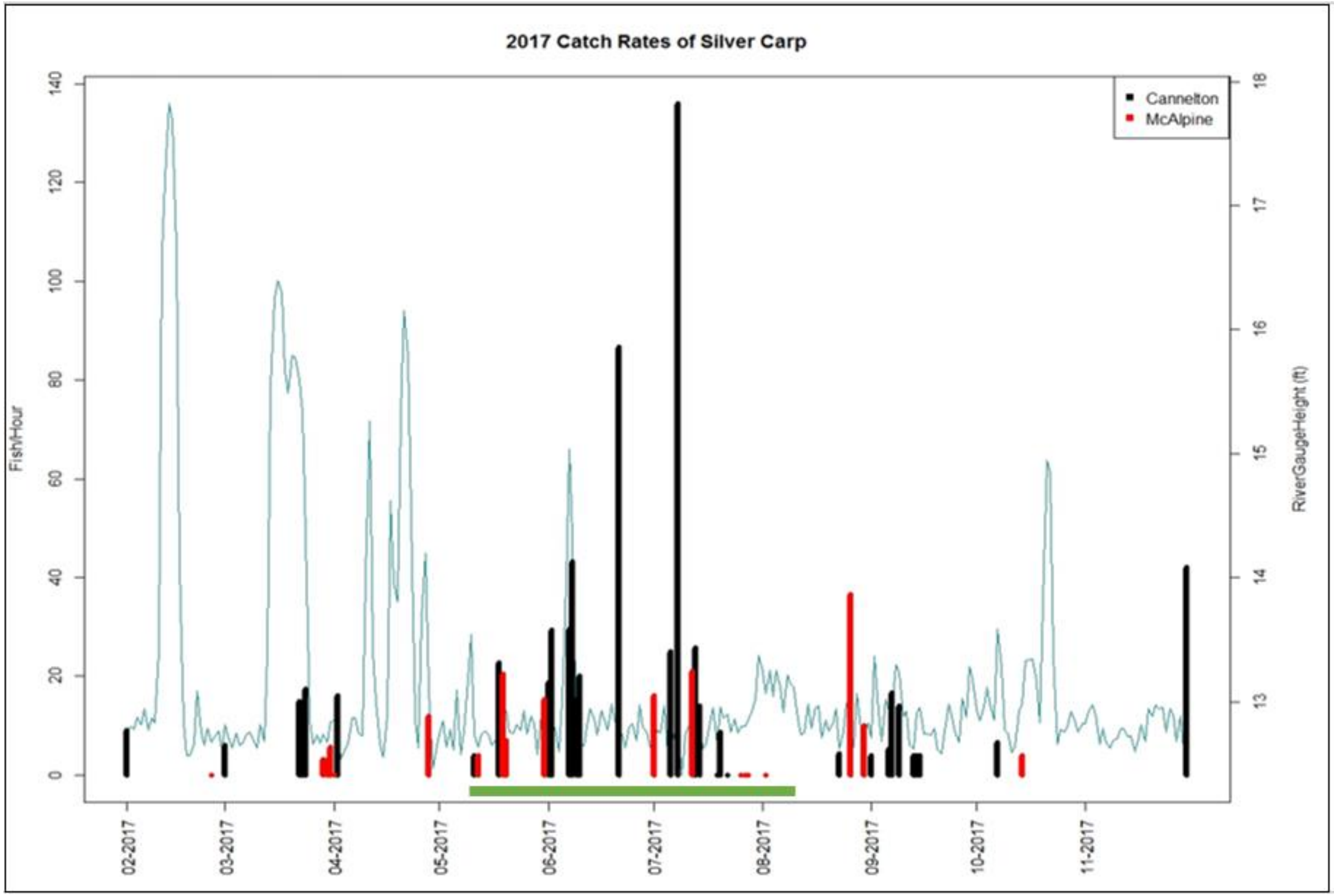

Figure 16. A histogram showing catch rates by month of silver carp captured in Cannelton and McAlpine in 2017 along with the gauge height in feet. The green line between the months of May and August indicate the period where spawning patches appear on females.

Year	Intercept	Slope
2016	-4.938	2.991
2017	-5.250	3.092

	Df	Sum Sq	F value	Pr(>F)
(Intercept)	1	9.539	3386.703	< 2e-16
Log10[Length]	1	28.556	10138.649	< 2e-16
Year	1	0.009	3.168	0.076
Log10[Length]:Year	1	0.008	2.758	0.098
Residuals	260	0.732		

Figure 17. (Top) A table with individual intercepts and slopes for regressions of silver carp log-transformed lengths (mm) and weights(g) in 2016 and 2017. (Bottom) An ANOVA table showing the results of the ANCOVA analysis for the linear regression model (y = β0 + β1x1 + β2x2 + β3x1x 2 + Ɛ), with weight (g) being determined by total length (mm) and year used as a categorical predictor variable for silver carp captured after spawning activity in each sampling year.

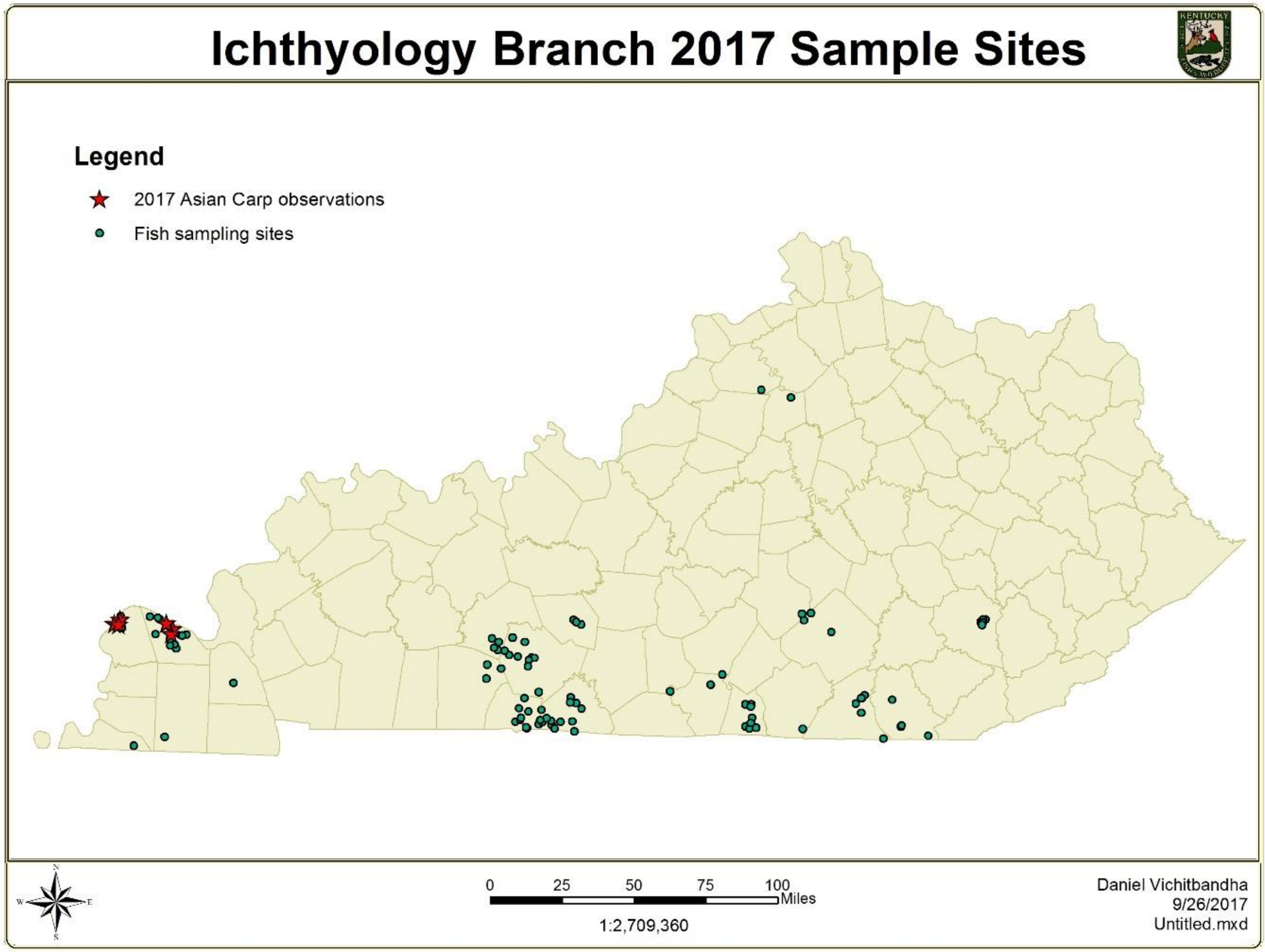

Figure 18. A map of Kentucky showing the sites where the KDFWR ichthyology branch conducted 2017 project sampling with incidental Asian carp observations indicated using red stars.

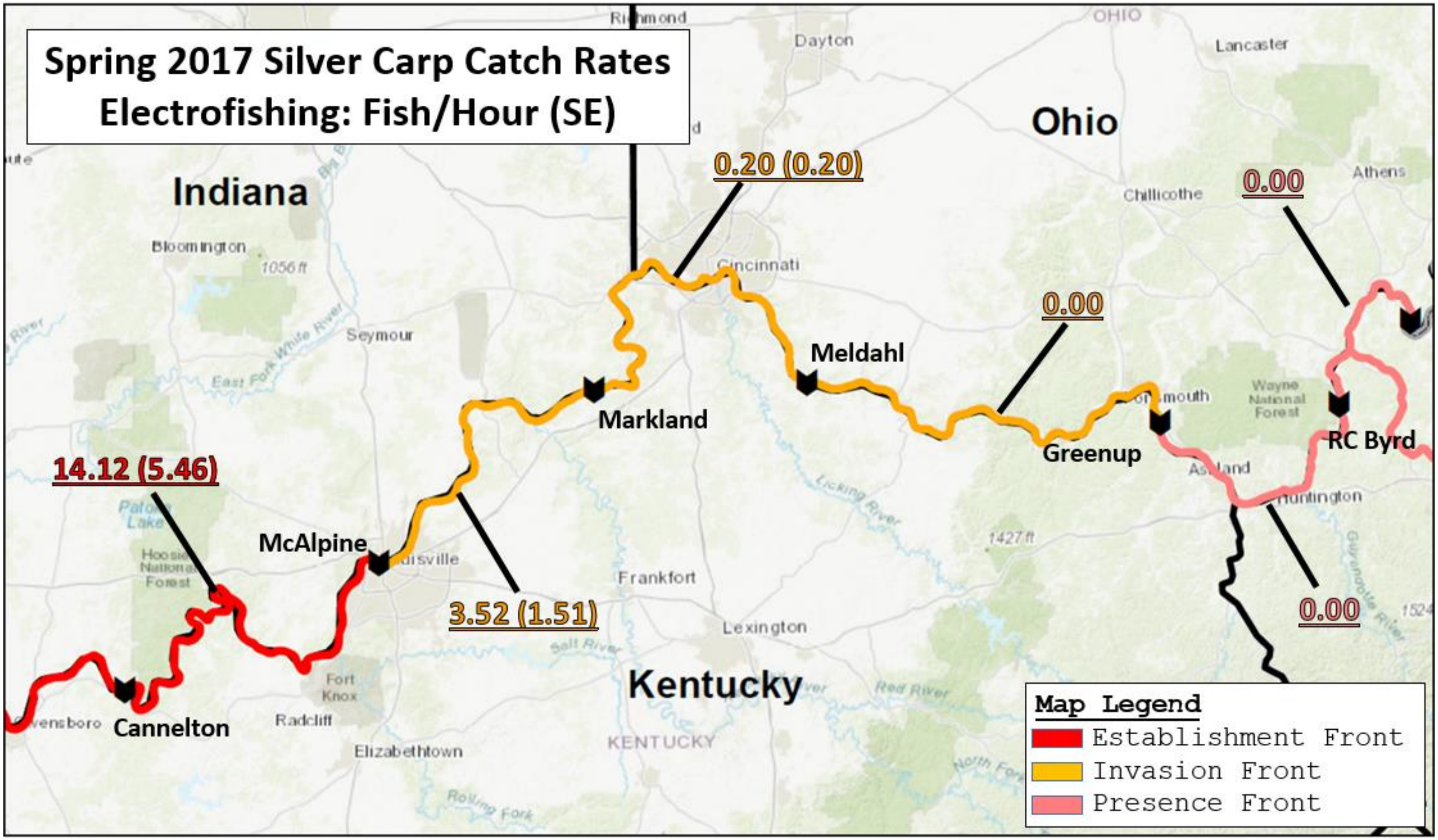

Figure 19. Mean silver carp catch rates by navigation pool using boat electrofishing during targeted sampling in 2017. Standard errors are in parenthesis.

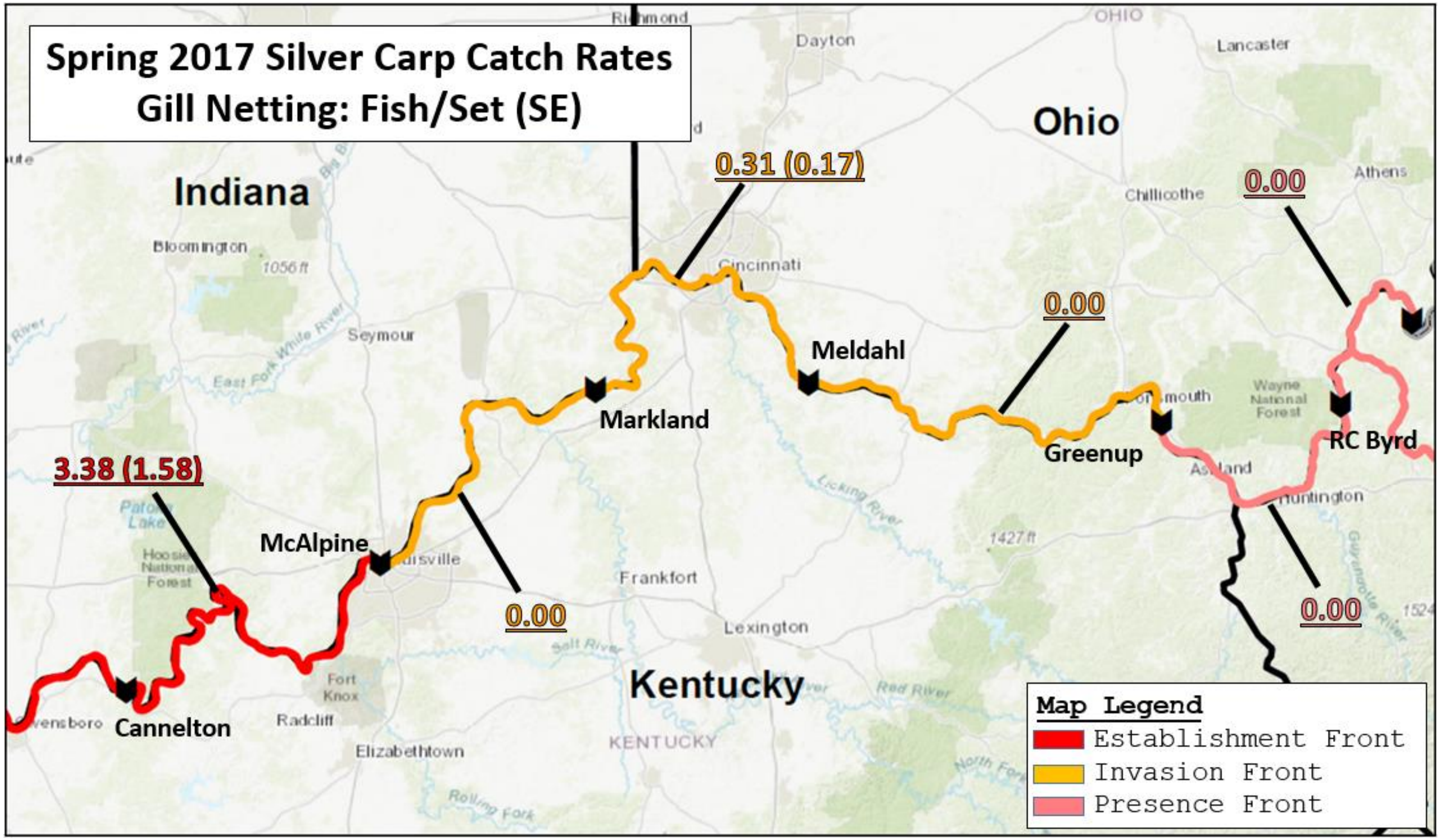

Figure 20. Mean silver carp catch rates by navigation pool using gill netting during targeted sampling efforts in Spring 2017. Standard errors are in parenthesis.

Tables:

Table 1. A summation of sampling efforts by agencies participating in monitoring efforts for 2017.

Partner Group	Electrofishing (hrs)	Gill Netting (ft)	Hoop Netting (Net-nights)	Beach Seine (Events)
INDNR	8.25	4,650	0	0
KDFWR	28.40	17,900	0	0
PFBC	5.50		69	6
USFWS	6.25	2,770	0	0
WVDNR	9.40	12,000	0	0
Total	57.80	37,320	69	6

Table 2. Estimated weights at two lengths for Silver carp from published data collected throughout the Silver carp ranges in the Mississippi River basin. Amended from Hayer et al. 2014.

System: Specific Locale	L-W Regression Equation (metric)	Predicted weight for 450mm (g)	Predicted weight for 800mm (g)	Reference
Ohio River	$\log_{10}$ weight = -5.13 + 3.05($\log_{10}$ length)	917	5302	This Report 2018
Illinois River	$\log_{10}$ weight = -5.29 + 3.12($\log_{10}$ length)	972	5856	Irons et al. 2011
Middle Mississippi River	$\log_{10}$ weight = -5.29 + 3.11($\log_{10}$ length)	915	5477	Williamson and Garvey 2005
Missouri River: Gavins Point	$\log_{10}$ weight = -6.92 + 3.70($\log_{10}$ length)	788	6628	Wanner and Klumb 2009
Missouri River: Interior Highlands	$\log_{10}$ weight = -5.35 + 3.13($\log_{10}$ length)	900	5453	Wanner and Klumb 2009
Missouri River tributary: Big Sioux River	$\log_{10}$ weight = -5.53 + 3.21($\log_{10}$ length)	970	6150	Hayer et al. 2014
Missouri River tributary: James River	$\log_{10}$ weight = -5.26 + 3.11($\log_{10}$ length)	981	5869	Hayer et al. 2014
Missouri River tributary: Vermillion River	$\log_{10}$ weight = -4.82 + 2.90($\log_{10}$ length)	748	3971	Hayer et al. 2014

Table 3. Estimated weights at two lengths for Bighead carp from published data collected throughout the bighead carp range in the Mississippi River basin.

System: Specific Locale	L-W Regression Equation (metric)	Predicted weight for 450mm (g)	Predicted weight for 800mm (g)	Reference
Ohio River	$\log_{10}$ weight = -5.05 + 3.03 ($\log_{10}$ length)	976	5577	This Report 2018
Illinois River: La Grange	$\log_{10}$ weight = -4.84 + 2.95 ($\log_{10}$ length)	970	5298	Irons et al. 2010
Missouri River (Males)	$\log_{10}$ weight = -5.42 + 3.15 ($\log_{10}$ length)	866	5306	Schrank and Guy 2002
Missouri River (Females)	$\log_{10}$ weight = -5.40 + 3.13 ($\log_{10}$ length)	803	4860	Schrank and Guy 2002
Missouri River: Gavins Point	$\log_{10}$ weight = -4.86 + 2.96($\log_{10}$ length)	985	5409	Wanner and Klumb 2009
Missouri River: Interior Highlands	$\log_{10}$ weight = -4.30 + 2.75($\log_{10}$ length)	991	4825	Wanner and Klumb 2009

Table 4. Electrofishing effort and the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per hour) of three species of Asian carp captured in six pools of the Ohio River from spring targeted sampling in 2016 and 2017. Standard errors are in parentheses.

	Spring Boat Electrofishing													
	Ohio River 2016							**Ohio River 2017**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	13 April - 08 June							10 April - 23 May						
Effort (Hours)	5.00	5.00	6.25	5.75	4.55	4.65	31.20	4.25	3.90	5.00	5.00	2.00	0.00	20.15
Sample Transects	20	20	25	23	18	19	125	17	16	20	20	8	0	81
All Fish (N)	1366	1310	2117	2313	2223	2626	11955	61	13	1	0	0	0	75
Species (N)	38	31	36	36	38	34	51	2	1	1	0	0	0	2
Bighead Carp (N)	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Silver Carp (N)	16	5	1	0	0	0	22	60	13	1	0	0	0	74
Grass Carp (N)	0	4	0	0	1	0	5	0	0	0	0	0	0	0
Bighead Carp CPUE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24 (0.24)	0.00	0.00	0.00	0.00	0.00	0.05 (0.05)
Silver Carp CPUE	3.20 (1.85)	0.10 (0.49)	0.16 (0.16)	0.00	0.00	0.00	0.70 (0.32)	14.12 (5.46)	3.52 (1.51)	0.20 (0.20)	0.00	0.00	0.00	3.71 (1.31)
Grass Carp CPUE	0.00	0.80 (0.55)	0.00	0.00	0.22 (0.22)	0.00	0.16 (0.10)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5. Gill netting effort and summaries of the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per set) of three species of Asian carp captured in six pools of the Ohio River from spring tergeted sampling in 2016 and 2017. Standard errors are in parentheses.

	Spring Gill Netting													
	Ohio River 2016							**Ohio River 2017**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	12 April - 06 June							04 April - 23 May						
Effort (ft)	4800	4800	3000	4790	1200	0	18590	2400	1800	3900	3300	3050	4650	19100
Net Sets	16	16	10	16	4	0	62	8	6	13	11	16	31	85
All Fish (N)	74	8	48	34	1	0	165	46	1	70	57	2	21	197
Species (N)	10	4	9	6	1	0	13	6	1	10	8	2	9	11
Bighead Carp (N)	1	0	0	0	0	0	1	6	0	2	1	0	1	10
Silver Carp (N)	19	0	3	0	0	0	22	27	0	4	0	0	0	31
Grass Carp (N)	1	0	1	0	0	0	2	0	1	13	1	1	1	17
Bighead Carp CPUE	0.06 (0.06)	0.00	0.00	0.00	0.00	0.00	0.02 (0.02)	0.75 (0.62)	0.00	0.15 (0.15)	0.00	0.00	0.03 (0.03)	0.10 (0.06)
Silver Carp CPUE	1.18 (0.59)	0.00	0.30 (0.15)	0.00	0.00	0.00	0.35 (0.16)	3.38 (1.58)	0.00	0.31 (0.17)	0.00	0.00	0.00	0.70 (0.34)
Grass Carp CPUE	0.06 (0.06)	0.00	0.10 (0.10)	0.00	0.00	0.00	0.03 (0.02)	0.00	0.17 (0.17)	1.00 (0.62)	0.09 (0.09)	0.06 (0.06)	0.03 (0.03)	0.19 (0.10)

Table 6. Electrofishing effort and the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per hour) of three species of Asian carp captured in six pools of the Ohio River from fall community sampling in 2016 and 2017. Standard errors are in parentheses.

	Fall Electrofishing													
	Ohio River 2016							**Ohio River 2017**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	04 October - 17 November							02 October - 28 November						
Effort (Hours)	5.50	6.00	3.50	5.10	1.50	2.58	24.18	6.00	6.25	6.75	3.75	5.00	4.40	32.15
Sample Transects	22	24	14	21	6	11	98	24	25	27	15	20	19	130
All Fish (N)	2865	713	1075	1222	958	3355	10188	686	1024	1614	1341	983	888	6536
Species (N)	40	34	31	36	30	38	62	37	36	38	30	29	34	56
Bighead Carp (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver Carp (N)	6	6	0	0	0	0	12	5	1	0	0	0	0	6
Grass Carp (N)	0	0	3	0	0	0	3	0	0	0	0	0	0	0
Bighead Carp CPUE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver Carp CPUE	1.09 (0.65)	0.99 (0.50)	0.00	0.00	0.00	0.00	0.49 (0.19)	0.83 (0.34)	0.16 (0.16)	0.00	0.00	0.00	0.00	0.18 (0.07)
Grass Carp CPUE	0.00	0.00	0.86 (0.46)	0.00	0.00	0.00	0.12 (0.07)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Gill netting effort and summaries of the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per set) of three species of Asian carp captured in six pools of the Ohio River from fall community sampling in 2016 and 2017. Standard errors are in parentheses.

	Fall Gill Netting													
	Ohio River 2016							**Ohio River 2017**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	04 October - 19 November							02 October - 28 November						
Effort (ft)	3000	4800	4200	4800	3000	3600	23400	4650	2770	3450	1500	5850	0	18220
Net Sets	10	16	14	16	10	12	78	31	10	23	10	20	0	94
All Fish (N)	7	20	17	16	3	0	63	60	4	7	35	5	0	111
Species (N)	2	7	5	7	2	0	12	11	3	4	4	4	0	12
Bighead Carp (N)	0	1	0	0	0	0	1	9	0	0	0	0	0	9
Silver Carp (N)	5	5	0	0	0	0	10	24	0	2	0	0	0	26
Grass Carp (N)	0	1	2	0	0	0	3	1	0	0	0	0	0	1
Bighead Carp CPUE	0.00	0.06 (0.06)	0.00	0.00	0.00	0.00	0.01 (0.01)	0.29 (0.16)	0.00	0.00	0.00	0.00	0.00	0.10 (0.53)
Silver Carp CPUE	0.50 (0.31)	0.31 (0.25)	0.00	0.00	0.00	0.00	0.13 (0.07)	0.77 (0.43)	0.00	0.09 (0.06)	0.00	0.00	0.00	0.28 (1.40)
Grass Carp CPUE	0.00	0.06 (0.06)	0.14 (0.10)	0.06 (0.06)	0.00	0.00	0.05 (0.03)	0.03 (0.03)	0.00	0.00	0.00	0.00	0.00	0.01 (0.01)

Table 8. The number of fish captured by species and percent of total catch in six pools of the Ohio River with boat electrofishing surveys at fixed monitoring sites in 2016 and 2017. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

	Ohio River Pools in 2016								**Ohio River Pools in 2017**							
Species Captured	Cann	McAlp	Mark	Meld	Green	RC Byrd	Total	Percent	Cann	McAlp	Mark	Meld	Green	RC Byrd	Total	Percent
Bigmouth Buffalo	1	1		2			4	0.039%	3	2	4	1			10	0.153%
Black Buffalo							0	0.000%		1	2				3	0.046%
Black Crappie	4	3	1	2		1	11	0.108%			1	2	5	3	11	0.168%
Black Redhorse						1	1	0.010%					1		1	0.015%
Blue Catfish				1			1	0.010%	3						3	0.046%
Bluegill Sunfish	57	20	103	23	21	29	253	2.483%	34	14	239	45	65	119	516	7.895%
Bluntnose Minnow							0	0.000%		3	1			2	6	0.092%
Bowfin					1		1	0.010%	1				11	1	13	0.199%
Brook Silverside						1	1	0.010%	1						1	0.015%
Bullhead Minnow	8						8	0.079%							0	0.000%
Central Stoneroller							0	0.000%					1		1	0.015%
Channel Catfish	24	30	16	21	1	4	96	0.942%	8	17	40	2	8	3	78	1.193%
Common Carp	9	17	25	8	2	3	64	0.628%	4	1	34	3	23	10	75	1.147%
Emerald Shiner	940	2	2	3	77	215	1239	12.161%	90	146	59	595		19	909	13.908%
Fathead Minnow						2	2	0.020%							0	0.000%
Flathead Catfish	2	1	1	4	2		10	0.098%	2	1	2				5	0.076%
Freshwater Drum	48	24	6	15	32	45	170	1.669%	30	54	30	56	176	112	458	7.007%
Gizzard Shad	1320	374	573	850	736	2898	6751	66.264%	322	442	685	470	251	200	2370	36.261%
Golden Redhorse	44	21	12	17	10	8	112	1.099%	18	62	42	4	24	15	165	2.524%
Goldeye				2			2	0.020%							0	0.000%
Goldfish			1				1	0.010%			3				3	0.046%
Grass Carp			3				3	0.029%							0	0.000%
Green Sunfish		1	5	1	1	3	11	0.108%			2	1	5	14	22	0.337%
Highfin Carpsucker			2			1	3	0.029%		6	2	1	1		10	0.153%
Lampery Family		1					1	0.010%							0	0.000%
Largemouth Bass	40	23	50	26	2	9	150	1.472%	22	10	70	30	38	21	191	2.922%
Logperch					1	2	3	0.029%	1	3	1		1		6	0.092%
Longear Sunfish	16	6	9	3	5	2	41	0.402%	9	5	25	2	2	2	45	0.688%
Longnose Gar	10	32	1	8	5	2	58	0.569%	14	27	18	1	20	5	85	1.300%
Minnow Family	2						2	0.020%		6				4	10	0.153%

Table 8 (cont). The number of fish captured by species and percent of total catch in six pools of the Ohio River with boat electrofishing surveys at fixed monitoring sites in 2016 and 2017. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

Mooneye		1		1			2	0.020%		4	1		1		6	0.092%
Moxostoma Genus	6		1	2			9	0.088%							0	0.000%
Muskellunge		1					1	0.010%		1		2			3	0.046%
Northern Hogsucker		1			6	2	9	0.088%	1	1			1	2	5	0.076%
Orangespotted Sunfish	11				7	4	22	0.216%			2	1		16	19	0.291%
Quillback	1	1		1	1		4	0.039%	2	8	2	4	4	7	27	0.413%
Redear Sunfish	29	1	1	1		1	33	0.324%	11		11	1	4	2	29	0.444%
River Carpsucker	42	12	24	17	2	2	99	0.972%	5	26	53	5	13	17	119	1.821%
River Redhorse	3			3	3	8	17	0.167%			2		2	6	10	0.153%
Rock Bass		1			3		4	0.039%							0	0.000%
Sauger	11	4	8	8		5	36	0.353%	3	6	5	5	34	13	66	1.010%
Saugeye				1		2	3	0.029%							0	0.000%
Sharpnose Darter						1	1	0.010%							0	0.000%
Smallmouth Redhorse	2	9	3	20		1	35	0.344%	6	13	2	1	9	13	44	0.673%
Silver Carp	6	6					12	0.118%	5	1					6	0.092%
Silver Chub	3				3		6	0.059%	1	15	6			1	23	0.352%
Silver Redhorse			1	4	1		6	0.059%				4	4	2	10	0.153%
Skipjack Herring	33	18	11	21		3	86	0.844%	5	25	16			2	48	0.734%
Smallmouth Bass	5	8	1	6	11	11	42	0.412%	4	10	8	1	15	11	49	0.750%
Smallmouth Buffalo	65	51	95	76	2	45	334	3.278%	51	71	130	61	193	189	695	10.633%
Spotfin Shiner						2	2	0.020%	2	1				1	4	0.061%
Spotted Bass	51	26	13	30	16	6	142	1.394%	10	27	25	10	25	15	112	1.714%
Spotted Gar	11						11	0.108%	1						1	0.015%
Spotted Sucker	8	3	15	5	1	16	48	0.471%	4	4	12	9	16	20	65	0.994%
Striped Bass	4	10	21	17			52	0.510%	1	5	18	3			27	0.413%
Sunfish Family						1	1	0.010%							0	0.000%
Sunfish Hybrid	1				3	1	5	0.049%	1				1	1	3	0.046%
Threadfin Shad	9			1			10	0.098%	1			1			2	0.031%
Walleye	2						2	0.020%					1	2	3	0.046%
Warmouth	2		3	2		1	8	0.079%			8	3	1		12	0.184%
Hybrid Striped Bass	18				1	7	26	0.255%	3		4		12	21	40	0.612%
White Bass	7	1	7	10	1	9	35	0.344%	4	5	20		10	14	53	0.811%

Table 8 (cont). The number of fish captured by species and percent of total catch in six pools of the Ohio River with boat electrofishing surveys at fixed monitoring sites in 2016 and 2017. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

White Crappie	9	3	61	10	1	1	85	0.834%	3		29	17	5	3	57	0.872%
White Sucker							0	0.000%		1					1	0.015%
Yellow Bass	1						1	0.010%							0	0.000%
Totals	2865	713	1075	1222	958	3355	10188		686	1024	1614	1341	983	888	6536	

Table 9. The number of fish captured by species and percent of total catch in six pools of the Ohio River with gill netting surveys at fixed monitoring sites in 2016 and 2017. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

	2016 Fall Monitoring Gill Netting								2017 Fall Monitoring Gill Netting							
	River Pool								River Pool							
Species Captured	Cann	McAlp	Mark	Meld	Green	RC Byrd	Total	Percent	Cann	McAlp	Mark	Meld	Green	RC Byrd	Total	Percent
Bighead Carp		1					1	1.587%	9						9	8.108%
Bigmouth Buffalo		1	4	2			7	11.111%	1			1			2	1.802%
Black Buffalo							0	0.000%	2						2	1.802%
Blue Catfish			1				1	1.587%	2	1					3	2.703%
Channel Catfish							0	0.000%					1		1	0.901%
Common Carp		2	1	3			6	9.524%	2			7			9	8.108%
FlatheadCatfish				1			1	1.587%			1		1		2	1.802%
FreshwaterDrum				1			1	1.587%	1			2			3	2.703%
Grass Carp		1	2	1			4	6.349%	1						1	0.901%
Longnose Gar		2					2	3.175%	3	1					4	3.604%
Muskellunge					1		1	1.587%							0	0.000%
Paddlefish	2		9	1			12	19.048%	4		1		1		6	5.405%
Silver Carp	5	5					10	15.873%	24		2				26	23.423%
Smallmouth Buffalo		8		7	2		17	26.984%	11	2	3	25	2		43	38.739%
Totals	7	20	17	16	3	0	63		60	4	7	35	5	0	111	

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).

Asian Carp Containment and Suppression in the Upper Ohio River

Geographic Location: Ohio River basin, extending from the Markland Lock and Dam (RM 531.5) to the Racine Lock and Dam (RM 238) along with some limited removal in the Smithland pool, below Cannelton.

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

Introduction:
Eradication of invasive species after establishment is difficult and often limited by available resources. Since their introduction in the Mississippi River basin, Asian carp (silver carp, bighead carp, and grass carp) have steadily increased their range. Asian carp rapidly and densely colonize river reaches affecting the native food web in large river ecosystems (Irons et al. 2007, Freedman et al. 2012). As a result, funding has been allocated in the basin to limit the impacts of Asian carp where they exist as well as halt their spread into uninhabited waters.

Diverse and consistent removal efforts where Asian carp densities are relatively high may disrupt upriver movement of Asian carp (D. Glover, US Fish and Wildlife Service, personal communication). However, there are few tools available to limit the negative impacts of Asian carp and their spread into new waters. Integrated pest management approaches suggest that inclusion of barrier technologies that prevent movement of the Asian carps into critical areas as well as the targeted removal of Asian carp below barriers are useful for decreasing propagule pressure. Planning and implementation of barriers to Asian carp movement are widely believed to be an important aspect of the control of Asian carp in the Mississippi River basin. However, planning barrier projects can be difficult and require substantial data collection. Urgent efforts to gather distribution and movement data in the Ohio River began in 2015. Currently, the best tool for limiting impacts and further dispersal of Asian carps is the physical removal of fish.

Multi-agency sampling and removal projects have successfully targeted Asian carp along this reach, but the effort required is usually expensive. Removal of Asian carp along this stretch of river reduces the number of Asian carp moving upstream, lessens the likelihood of successful reproduction, and buys managers time to plan and implement potential barriers to Asian carp movement.

Objectives:

- Remove Asian carp from the Ohio River, above Markland dam.
- Attempt to suppress and contain carp below the R.C. Byrd pool.
- Surgically implant transmitters in Asian carp between Markland and Greenup Locks and Dams.
- Explore the development of an Ohio River response protocol.

Methods:
Containment and Suppression efforts in 2017 focused primarily on the pools above Markland Lock and Dam (Figure 1). All other removal effort below Markland Lock and Dam is reported in the 2017 Control and Removal of Asian Carp report. With relatively little information on the best locations to target carp in these pools, effort was blanketed evenly throughout the geographic area in the hope that a select number of fishing grounds could be located for more effective suppression efforts. This strategy made it difficult to focus on sections of river while trying to explore new locations that may be suitable to carp species; however, it provided the basin a way to continue surveillance throughout lower abundance waters while removing some fish.

Clarification of Terminology Referenced in This Document
With the current rate of Asian carp expansion and the massive effort to study and adaptively manage carp impacts across several Mississippi River sub-basins, it is important to clarify terminology used in technical documentation and annual reports. Currently, there may not be consistent terminology used across the basins. With this in mind, below are a list of terms used in this report defined for the specific purpose of this report.

Bigheaded Carps – a term used to reference the collection of the bigheaded carps (*Hypophthalmichthys spp.*) and their hybrids, found in the Ohio River basin.
Establishment Front – the farthest upriver range expansion of Asian carp populations that demonstrates the presence of natural recruitment.
Invasion Front – the farthest upriver extent where reproduction has been observed (eggs, embryos, or larvae) but recruitment to young-of-year fish has not been observed.
Macrohabitat – One of five habitat types used to describe the variety of fixed sites within a pool (e.g. Tributary, Tailwater, Embayment, Island Back-Channel, and Main Stem River).
Presence Front – The farthest upstream extent where Asian carp populations occur, but reproduction is not likely taking place.
Targeted Sampling – sampling that uses gear and/or techniques intended to specifically target one species and exclude others (i.e. silver carp and bighead carp).

Physical Removal of Asian Carps
Containment and suppression efforts typically ended in the euthanization of Asian carps captured through sampling efforts. Electrofishing and gill netting along the invasion and presence fronts in 2017 was conducted for roughly 5 weeks from May – October. Electrofishing was not standardized, but total effort (hours) was recorded. Pulsed DC electricity at 40% duty-cycle and 80 pulses per second was used most often and voltage was adjusted to target a maximum power goal for each run. Large mesh (4.0" – 5.0" square) gill nets were used, with each set consisting of a minimum 180 minutes of soak time, while fish were driven toward nets with boat noise at 30-minute intervals.

Sampling sites focused on tributaries and embayments (mimicking site selection and protocols from lower pools) where densities of Asian carp were likely the highest and fish were easiest to capture. The majority of these locations were selected using monitoring sampling sites from 2015 and 2016. Some effort was expended to investigate additional sites that were either remotely identified through map study, contained features characteristic of typical carp habitat, or where reports were received of carps congregating in the area.

All Asian carps and by-catch were identified to species. All carp were inspected for tags (both jaw and ultrasonic VEMCO tags) before being euthanized for population control or tagged for the Ohio River Telemetry projects. All by-catch was returned to the water. Asian carp species (bighead carp, silver carp, and grass carp) from each sampling location were measured for total length (mm) and weight (g) to provide estimates of the minimum total weight harvested. When possible, supplemental data included a record of sex and a collection of aging structures (spines and otoliths) for each silver or bighead carp captured (Williamson and Garvey 2005, Seibert and Phelps 2013). All fish captured above Greenup Lock and Dam were euthanized in an effort to define a cutoff point for restricting upriver population progression.

Surgical Implantation of Acoustic Transmitters
With Asian Carp populations still purportedly low above Markland Lock and Dam, information on movement, rate of dispersal, and habitat preferences of invasive carps in these pools is vital. This

information is useful for informing more productive removal efforts in these lower abundance pools so that less time is spent seeking out fish. However, with numbers being relatively low in these pools, it has been difficult to capture fish for telemetry efforts. Any fish encountered during containment and suppression activities in the Markland and Meldahl pools was considered for surgical implantation of an acoustic VEMCO tag. Often carp were in too poor of a condition to tag along the invasion front or were captured in periods where water temperatures were too high to effectively tag fish. Manual tracking was conducted in the Racine pool in 2015 and 2016 to locate a bighead carp traveling farther upriver than all other tagged fish; however, manual tracking was not conducted in 2017. All fish captured above the Meldahl pool and below the Racine pool were removed for containment efforts.

Exploration of ORB Response Protocol
In 2017, the WVDNR and KDFWR performed research into the structure and development of an Ohio River contingency plan. The intent was to look at structured contingency plans and gather information and notes considering similar implementation in the ORB. Emails and notes were shared between WVDNR and KDFWR on the topic and the Upper Illinois Waterway Contingency Response Plan from the Mississippi River Basin 2017 Asian Carp Monitoring and Response Plan was picked as a discussion model. The major facets of that plan were identified and are listed here with some notes and input from discussions between West Virginia and Kentucky State agencies.

Results:
Surgical Implantation of Acoustic Transmitters
Due to the time of year, tagging procedures during this project were often suspended dependent on temperature, weather constraints, and fish condition. In 2016, six fish were tagged with an acoustic VEMCO transmitter during removal efforts in pools above McAlpine. In 2017, only three fish were caught in good enough condition to tag above Markland lock and dam. Several fish were captured in the RC Byrd pool in 2017; however, in an effort to define a cutoff for upriver population progression, all fish caught in the Greenup and RC Byrd pools were euthanized upon capture.

Physical Removal of Asian Carps
A total of 26 hours were spent electrofishing in the four Ohio River pools and tributaries from Markland up through RC Byrd pool (Table 1). Six carp totaling ~54 kg (118 lbs) were removed along the upper pools within the invasion and presence fronts. The largest amount of electrofishing effort was expended in the Markland pool where all six silver carp made up the entirety of fish removed via boat electrofishing for this project. Three of those fish were tagged for the Telemetry of Asian Carp in the Ohio River project.

A total of 4,500 ft of gill net was set to capture three bighead carp, four silver carp and one grass carp in the four pools along the invasion and presence fronts (Table 2). The majority of effort was placed in Markland pool, where all four silver carp were captured. Outside of project activities, two additional bighead carp were recreationally snagged out of the old lock chambers on the RC Byrd Lock and Dam. This event caused partners to focus suppression efforts within the lower portion of the RC Byrd pool. Three bighead carp were captured near Raccoon Creek using gill nets in the RC Byrd pool after receiving these reports just upriver of the lock and dam. Additionally, two bighead were captured using snagging techniques by the WVDNR hatchery staff after being sighted in the old lock chambers at the RC Byrd lock and dam complex.

Exploration of ORB Response Protocol
A list of notes and information was compiled from reading the Upper Illinois Waterway Contingency Response Plan (Asian Carp Regional Coordinating Committee 2017). Below is a review of that process.

- Responses are specified depending on observed changes in the Asian carp populations within five pools of the Illinois Waterway (IWW) through annual interim reports and monitoring or removal activities.
    - ORB activities currently fulfill this action and should be continued to track changes in Asian carp population status.
- The plan recognizes a chain of command within the federal government, each member state, and participating agencies. An expert panel was created by the Monitoring and Response Work Group (MRWG) to evaluate the population status, waterway conditions, and outline various scenarios in order to provide a process for initiating response actions that utilize available tools and authorities.
    - This is currently not identified in the ORB. A working group is likely necessary to begin to compile a list of authorities, scenarios, and response actions that are realistic for the ORB.
- The plan defines and recognizes 2015 as a benchmark to aid in evaluation of Asian carp statuses from future years and describes the current state of invasion by pool.
    - A benchmark in the ORB would have to be agreed upon using data available; work started in 2015. Since then, project objectives have been altered to better accomplish project goals.
- The plan defines a navigation pool as the "best and most appropriate scale" for contingency planning purposes.
    - Because dams have the ability to partially restrict fish movements, pools are currently being used to reference relative abundances. They are likely the best unit of measurement for response planning in the ORB.
- The plan defines an "Incident Action Plan" "(IAP) that uses "SMART" objectives (Specific, Measureable, Achievable, Realistic, and Task-oriented), which highlight unique responses by agency and location at varying degrees of significance (Significant Change, Moderate Change, and No Change).
    - This is well structured and would likely require substantial time and effort to develop for the Ohio River.
    - Responses are only effective with good coordination and participation in the plan.
    - Life stage, type of capture, and location from the Great Lakes are also taken into consideration when prescribing actions.
    - Some potential actions included increased sampling effort, barrier operations, complex noise, contracted fishing, hydroacoustics, and block netting and temporary flow control.

Discussion:
Total captures of invasive bigheaded carps across all activities in the upper pools of the invasion and lower presence fronts were low. The increased effort required to catch fish in this section of water reflects the difference in abundances of these fish when compared to the Cannelton and McAlpine pools. One issue that frequently makes the capture of these fish difficult is the amount of river that is being covered by relatively few crews; this project covers ~ 480 km of main stem river with the narrowest portions typically exceeding 300 meters in width and many large tributaries throughout. Focusing on preferred habitats where carp seem to consistently reside is the best approach to catching fish in these pools, but any chance of blanketing surveillance efforts throughout the pools or investigating additional areas would have to be limited. A couple of potential sampling sites have been identified for 2018 removal efforts. Those sites are suggested in Table 3.

Overall, electrofishing seems slightly more effective for locating silver carp in the low-density pools. When population densities are low, electrofishing may be a better gear to utilize when seeking out groups of silver carp simply because it allows for greater coverage when surveying for the presence of these fish.

Netting is often limited by the number of nets that can be deployed over a stretch of river and the man-hours required to run and maintain them. However, boat electrofishing rarely yields bighead carp captures and nets remain the better choice when targeting this species. Reports of greater success when targeting *Hypophthalmichthys spp*. at night and in cooler months suggests that some gears may be more successful if deployed during fall and winter months. In 2017, 20 overnight sets were utilized to target bighead carp along the main stem river. In the R.C. Byrd pool, one instance resulted in the capture of three bighead carp over one net-night; however, paddlefish bycatch made up 35% of the total catch. Using overnight sets in 2017 produced 0.20 bighead/set while the shorter, daily sets from 2016 and 2017 produced 0.18 bighead/set. Although this was only a small increase in catch, the total number of man-hours necessary to work overnight sets decreases while soak time is maximized. Nevertheless, gill netting during the warmer months can be stressful on paddlefish and other non-target species entangled in gears for long periods of time. Balancing efforts by targeting areas where bighead carp are frequently found and focusing netting effort in cooler water temperatures will likely result in higher yields during future removal efforts.

With reports of Asian carp being seen above RC Byrd Locks and Dam, removal effort in the RC Byrd pool is likely to increase. The bighead carp caught in RC Byrd were euthanized because they had exceeded the exclusion point for tolerable upriver expansion. A better understanding of the rate of dam passage continues to be a primary objective of the telemetry project and will likely inform response activities and removal efforts in future removal and containment projects in lower abundance pools. Information gained from telemetry efforts in these pools will be incorporated into the containment and suppression project in the ORB due to its similarities and overlap with that work.

With discussions and focus around long-term planning within the ORB, future effort needs to be placed into developing a contingency plan similar to the one being used in the IWW. The IWW plan provides the framework for a knowledgeable panel to review information on an annual basis and provide recommendations to combat population expansion and dispersal. With an ORB specific plan, information from all basin projects can be used to implement unified responses to Asian carp populations and keep the basin focused on integrated pest management.

Recommendations:
It is recommended that an ORB panel be created in order to develop a contingency plan that defines pool-specific goals for halting upriver expansion of carp populations. Regular removal is suggested to continue as a tool for surveillance and suppression efforts, but it is also recommended that the goals and objectives of this project be combined with the removal project due to a large overlap in project goals. This will also allow crews to focus on only visiting a few sites in lower density pools throughout the season without having to spread resources over a vast geographic length of river. Sites should be limited to tributaries where carp captures are relatively frequent (e.g. Eagle Creek, Ohio Brush Creek, Raccoon Creek) and a couple of locations along the main stem river where contract anglers have captured fish in the past (e.g. River Miles 348 – 350 and 342 – 344). The absorption of this project within removal efforts will also make reporting more efficient and incorporate more partners within one project throughout the basin, focused on population control.

Project Highlights:

- In 2017, an upper boundary defining the exclusion point for tolerable upriver expansion was established by basin partners. Currently, Asian carps above RC Byrd Lock and Dam are considered too far up the system and are targeted for removal.
- A total of 26 hours were spent boat electrofishing along with 4,500 ft of gill net worked to remove 160 kg (~352 lbs) of Asian carps from the pools between Markland and RC Byrd Locks and Dams.

- Efforts to tag three fish during removal efforts contributed to the total number of individuals surgically implanted with transmitters along the lower density pools of the ORB.
- Due to the lower numbers of invasive carps in these pools, electrofishing may be better utilized when seeking out groups of silver carp. Nets in combination with electrofishing may be useful once groups of fish are located.
- Gill netting remains the more effective gear to use when targeting bighead carp, but can involve large amounts of bycatch.
- In the future, this project will be combined with containment efforts due to project overlap and reporting efficiency.

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Figures:

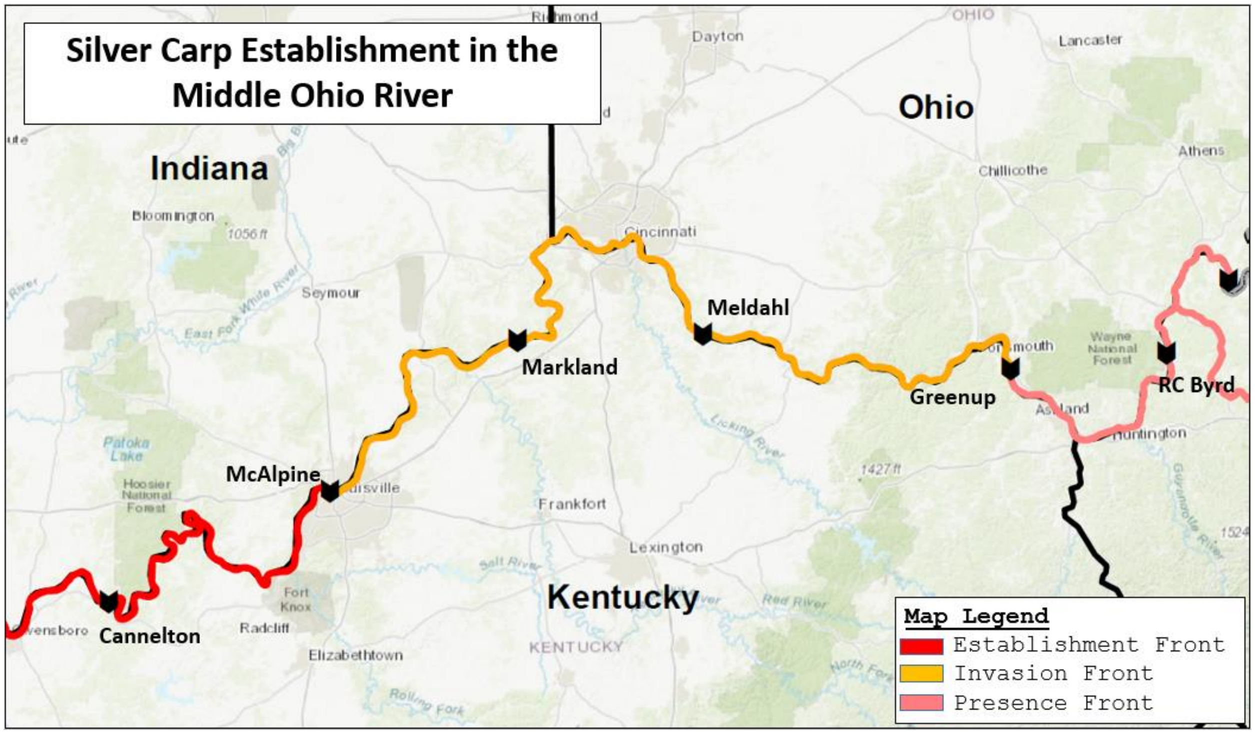

Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

Tables:

Table 1. Electrofishing effort (hours) and resulting catch of three species of Asian carp (number and weight) for four pools of the Ohio River during Asian carp containment efforts in 2017.

Pool	Electro Hours (hr)	Bighead Carp (N)	Silver Carp (N)	Grass Carp (N)	Total (N)	Bighead Carp (kg)	Silver Carp (kg)	Grass Carp (kg)	Total (kg)
Markland	11.00	0	6	0	6	0.00	53.79	0.00	53.79
Meldahl	7.50	0	0	0	0	0.00	0.00	0.00	0.00
Greenup	5.00	0	0	0	0	0.00	0.00	0.00	0.00
RC Byrd	2.50	0	0	0	0	0.00	0.00	0.00	0.00
Total	26.00	0	6	0	6	0.00	53.79	0.00	53.79

Table 2. Gill netting effort (feet) and resulting catch of three species of Asian carp (number and weight) for five pools of the Ohio River during Asian carp removal efforts in 2017.

Pool	Total Net Length (ft)	Bighead Carp (N)	Silver Carp (N)	Grass Carp (N)	Total (N)	Bighead Carp (kg)	Silver Carp (kg)	Grass Carp (kg)	Total (kg)
Markland	1800	0	4	0	4	0.00	32.57	0.00	32.57
Meldahl	900	0	0	0	0	0.00	0.00	0.00	0.00
Greenup	1050	0	0	0	0	0.00	0.00	0.00	0.00
RC Byrd	750	3	0	1	4	67.04	0.00	6.41	73.45
Total	4500	3	4	1	8	67.04	32.57	6.41	106.02

Table 3. Suggested locations for focusing removal efforts in upper pools of the sampling range based off of sampling efforts since 2015.

Pool	Site	Type	Presence Documented
Markland	Belterra Embayment	Embayment	Yes
	Craig's Creek	Embayment	Yes
	Great Miami River	Embayment	Yes
	Big Bone South Fork	Tributary	Yes
	Little Miami River	Tributary	Yes
	Big Indian Creek	Tributary	Yes
Meldahl	Eagle Creek	Tributary	Yes
	Ohio Brush Creek	Tributary	Yes
	RM 340 - 350	Main Stem	Yes
	RM 342 - 344	Main Stem Tailwater	Yes
RC Byrd	Old Lock Chambers	Man-made Structure	Yes
	Raccoon Creek	Tributary	Yes

Control and Removal of Asian carp in the Ohio River

Geographic Location: Ohio River basin, extending from the Cannelton Lock and Dam (RM 720.7) to the Markland Lock and Dam (RM 531.5) along with some limited removal in the Smithland pool, below Cannelton.

Participating Agencies: Kentucky Department of Fish and Wildlife Resources (KDFWR), Indiana Department of Natural Resources (INDNR), US Fish and Wildlife Service (USFWS), US Army Corps of Engineers (USACE)

Introduction:
Eradication of invasive species after establishment is difficult and often limited by available resources. Since their introduction in the Mississippi River basin, Asian carp (silver carp, bighead carp, and grass carp) have steadily increased their range (Kolar et al. 2005) and may densely colonize river reaches, affecting the native food webs in large river ecosystems (Irons et al. 2007, Freedman et al. 2012). Prevention and rapid response are the best tools for limiting establishment of costly invasive species and physical removal of Asian carp in the Ohio River basin may be one tool that can slow their upriver expansion.

Recent studies on Asian carp harvest programs in the Illinois River show that the collapse of silver and bighead carp populations are possible if all fish sizes are targeted (Tsehaye et al. 2013). Diverse and consistent removal efforts in portions of the Ohio River where Asian carp are established may disrupt upriver movement of Asian carp, decrease pressure on existing barriers, and reduce numbers of Asian carp in sensitive areas to protect species of conservation need or important sport fisheries. Removal efforts also provide an opportunity to collect data on the populations of Asian carp in higher density pools of the Ohio River Basin (ORB). This data will provide assessment tools with information that may guide monitoring, barrier defense, and population control efforts in future years.

Objectives:
1. Target and remove all size classes of Asian carp below Markland Locks and Dam.
2. Explore novel sampling techniques, and gear types that increase carp capture.
3. Identify a use for removed fish and support the creation of Asian carp markets.

Methods:
Removal efforts in 2017 were confined to Ohio River pools below Markland Lock and Dam (Figure 1). This region was defined in 2016 in order to focus removal efforts in higher density pools where the largest removal impact could be made. Removal efforts conducted in pools above Markland Lock and Dam are reported in the Control and Suppression project for the 2017 sampling season.

Clarification of Terminology Referenced in This Document
With the current rate of Asian carp expansion and the massive effort to study and adaptively manage carp populations across several Mississippi River sub-basins, it is important to clarify terminology used in technical documentation and annual reports. Currently, there may not be consistent terminology used across the basins when talking about basin-specific invasions. With this in mind, below are a list of terms used in this report that are solely for internal reference.

Bigheaded Carps – a term used to reference the collection of the bigheaded carps (*Hypophthalmichthys spp.*) and their hybrids, found in the Ohio River basin.
Establishment Front – the farthest upriver range expansion of Asian carp populations that demonstrates the presence of natural recruitment.

Invasion Front – the farthest upriver extent where reproduction has been observed (eggs, embryos, or larvae) but recruitment to young-of-year fish has is not been observed.
Macrohabitat – One of five habitat types used to describe the variety of fixed sites within a pool (e.g. Tributary, Tailwater, Embayment, Island Back-Channel, Main Stem River).
Presence Front – The farthest upstream extent where Asian carp populations occur, but reproduction is not likely taking place.
Targeted Sampling – sampling that uses gear and/or techniques intended to specifically target one species and exclude others (i.e. silver carp and bighead carp).

Targeting and Removal of Asian Carps
Electrofishing and gill netting for removal in 2017 were conducted over approximately 15 weeks from May through September. Because removal is the primary objective, electrofishing was not rigorously standardized, but total effort (hours) was recorded. Pulsed DC electricity at 40% duty-cycle and 80 pulses per second was used most often and voltage was adjusted to target a maximum power goal for each run. Large mesh (4.0” – 5.0” square) gill nets were used with each set consisting of a minimum 180 minutes of soak time with fish being driven toward the nets with boat noise at 30-minute intervals. Nets were occasionally set overnight in areas where they did not create hazards to navigation.

Sampling efforts focused on tributaries and embayments where densities of Asian carp are highest and fish are easiest to capture. The majority of these locations were derived from monitoring sampling sites in 2016. Additional sites that were either remotely identified using map study, recommended by agency biologists, or areas that contained characteristics of typical carp habitat were also targeted. However, the majority of effort was spent in known, high-density locations where carp were consistently captured.

All Asian carps and by-catch were identified to species. Asian carp were inspected for tags (both jaw and ultrasonic VEMCO tags) before being euthanized for population control or tagged for the Ohio River Telemetry projects. All by-catch was immediately returned to the water upon recovery. Asian carp species (bighead carp, silver carp, and grass carp) from each sampling location were measured for total length (mm) and weight (g) to provide estimates of the minimum total weight harvested. When possible, supplemental data including sex, fin spines, and otoliths were collected for each silver or bighead carp captured (Williamson and Garvey 2005, Seibert and Phelps 2013).

Exploration of Novel Sampling Techniques and Gears
A limited number of novel removal techniques were explored in 2017. These efforts were intended to identify new methods to more effectively target carp. However, because the primary goal of this project was to remove carp and reduce propagule pressure to move upriver, limited effort was expended testing the effectiveness of new techniques.

In 2016 and 2017, winged hoop nets were used to target Asian carp at known high-density locations. This gear was appealing due to their reported success in other systems and because they can be left, unmonitored for days at a time. Hoop nets were typically fished over a 36-hour period and were often placed where falling water levels and wings might corral fish into the gear. Some nets were set below the surface in flow, near woody debris, with throats facing downstream. On other occasions, throats were placed into flow, where pooled water was actively dropping after a rise in river conditions.

Over-night gill net sets were used with more frequency in 2017 due to electrofishing difficulties in dim lighting during night sampling. Gill nets were set three feet underwater in main-stem river locations and deeper tributaries or tributary mouths. Nets were large mesh (4.0” to 5.0” square) and often set perpendicular to the shoreline.

The use of boat electrofishing as a herding tool, in combination with gill nets, was also employed as a removal technique. Large mesh, gill nets were set in areas where fish could be pushed into the gear. Because of the large amount of variation between net locations, there was no effort to maintain consistency in the design or implementation of this technique. Catch between either gears was recorded together.

Collaborative work between KDFWR and USFWS was conducted using hydroacoustic equipment in an effort to identify schools of carp that could be targeted and herded into entanglement gears. Gill nets were strategically placed in sections of a tributary (Clover Creek, KY) and on the main-stem Ohio River where large schools of riverine fishes were located using a hydroacoustic, split-beam sonar array. Electrofishing boats were used in an attempt to move fish into nets after they were dropped around schools of fish.

Support Creation of Asian Carp Markets
The Kentucky Department of Fish and Wildlife Resources executive leadership is currently working with private business and commercial anglers to aid in furthering the development of an Asian carp fishing industry in Kentucky. Several barriers for a successful industry start-up have been identified and multiple strategies are being developed to address some of the logistical hurdles for market growth. In Kentucky, the Asian carp Harvest Program has been developed to further incentivize commercial anglers to target bigheaded carps specifically.

Results:
Physical Removal of Asian Carps
A total of 61 hours were spent electrofishing in three pools of the Ohio River and its tributaries between Smithland and Markland Lock and Dam (Table 1). One thousand four hundred and sixty-six carp were removed using boat electrofishing over these four pools in 2017. The highest level of effort was expended in the Cannelton pool where a total number of 1,077 carps, weighing approximately 6,077 kg (13,400 lbs), were removed. Total effort and capture numbers accounted for in this report include some time and effort placed into the Abundance and Distribution of Early Life Stages project. However, this report does not contain all effort in the pools where juvenile sampling took place. For more detail on effort and removal conducted during juvenile sampling in 2017, please refer to that report.

A total of 8,850 ft of large mesh (4” and 5” square) gill nets were used in capturing 93 invasive carps in the Cannelton and McAlpine pools (Table 2). This amounted to 777 kg (~1,712 lbs) of bighead and silver and grass carp combined. The largest amount of effort was expended in the Cannelton pool with 6,450 ft of gill net fished to remove 90 fish, weighing approximately 634 kg (~1,400 lbs).

Pursuit of Novel Capture Techniques
No carp within the Cannelton and McAlpine pools have been captured using the hoop nets, and by-catch is typically high. Hoop nets are the only gear that has consistently captured sportfish species as by-catch, with the majority consisting of crappie species. Nets have been deliberately set at sites where electrofishing and gill netting have consistently caught Asian carp in the past. Plans to utilize and target strategic flood zones with hoop nets are planned for 2018. Future target sites include Clover Creek, Flint Island, Oil Creek, and McAlpine Lock and Dam tail-waters in the Cannelton.

The use of boat electrofishing in combination with gill netting appeared to increase carp catches in 2016. In 2017, gill netting while herding carp with boat electrofishing appeared to match or increase yields when compared to gill net catches without electrofishing assistance. Although three bighead carp were captured using these methods in 2016, not a single bighead was captured in 2017. Overnight gill net sets were fished with more frequency in 2017 and have resulted in more captures of bighead carp.

Support Creation of Asian Carp Markets
In 2015, over 1 million pounds of Asian carp were harvested from Kentucky waters and sold to processors within various domestic and exported markets. In 2016, commercial fisherman participating in the Asian Carp Harvest Program in Kentucky waters yielded ~1.4 million pounds of carp which were also sold to various markets. An additional 1.4 million pounds of Asian carp was reported from commercial anglers in 2017 with ~765,000 pounds being harvest through the Asian Carp Harvest Program. In addition, executive leadership in the KDFWR agency has gained an understanding of how commercial fishers and processors operate from inquiries conducted over several years and have identified and worked to lower hurdles for the growing industry. Currently, three Kentucky processers are receiving Asian carp species from commercial anglers and several restaurants in and around Kentucky are serving the fish on their menus.

Removal in Other Projects
While removal was not listed as a primary objective in other ORB projects, Asian carp captured during any sampling on the Ohio River were euthanized unless they were tagged for tracking purposes. Accounts of an additional 1,353 kg (~2,983 lbs) of fish were captured during monitoring efforts and 160 kg (~353 lbs) during containment efforts outside of this project were removed from the river. Details on these additional fish captured during non-targeted sampling are not detailed here, but are included in other ORB reports.

Discussion:
Dams along the Ohio River are likely formidable barriers to dispersal for silver carp migrating up river. Data acquired from sampling efforts in 2017 show that the average sizes of silver carp increase (Figure 2) as you move up river, while catch rates decrease (Figure 3 and Figure 4). This has been a consistent pattern in data gathered since 2015 and is an indication that fish further up river are not only lesser in number, but likely older fish that have had more time to disperse from an established front. With Cannelton being the furthest upriver pool where fish < 400 mm have been observed, it must be prioritized as a major target in terms of population control. Numbers of fish are high enough to suggest that regular fishing pressure is needed, and with the presence of newly recruited fish, it is likely the main source-population contributing to upriver population expansion. Focus on the higher density pools like Cannelton that may be important reservoirs for propagules can alleviate pressure for upriver expansion and decrease efforts expended upriver, where low densities make it difficult to catch and suppress carp populations.

Currently, electrofishing has produced the most success in capturing silver carp due to their transient nature and explosive reaction to electricity. Silver carp can be sought out quickly with boat electrofishing techniques and schools can easily be targeted when found. More aggressive movements and sinuous patterns are often used to pin fish against the bank when targeting silver carp and can be effective at getting fish to surface. However, because they are difficult to catch when airborne, CPUE is often more variable and highly dependent on both the experience of the driver and dipper. In addition, increased catch rates when electrofishing in 2017 correlated with spawning activity and increased movement into tributaries during the summer months (Figure 5). Targeting of tributary waters and tributary mouths give removal crews an advantage because gears are typically more effective in these shallower waters. Future sampling efforts should be designed to take advantage of this period to maximize catch. Additional exploratory efforts should be pursued to increase removal success outside of spawning periods (approximately May – August).

Despite lessons learned from previous years, electrofishing conducted within the removal framework in 2017 produced a lower overall total catch when compared to removal conducted in 2016. However, there was roughly a 232% increase in catch of targeted carp using improved gill netting techniques when compared to 2016. This increase is likely due to better site selection and increased experience among removal crews running gill nets. Additionally, longer soak times when targeting bighead carp has also caused an increase in overall carp captures. In the future, nets will range from 3” bar mesh to 6” bar mesh to decrease size selectivity and target a wider range of length-classes.

Due to the biology and habits of Asian carps, recommendations on utilizing herding techniques seemed like an effective way to force fish to move into gears or traps. Previously, efforts in 2016 did appear to show that a combination of boat electrofishing and gill nets produced higher success rates than single gear methods. This strategy was also productive in 2017 and will continue to be refined. In 2017, floating nets were also successful as in previous years when targeting fish at the top of the water column. One fishing technique often reference, drifting gill nets, has yet to be successful when deployed across the removal range, but likely needs to be attempted at night when carp are ram-feeding at the surface to see success.

Commercial or contract angling should be encouraged in the future to place additional pressure on Asian carp populations within these pools. Increased focus on upper pools with established populations and higher densities will likely allow the reduction of density dependent dispersal. Currently, participating agencies have consistently been able to remove around 9,100 kg of Asian carps per year in these relatively lower density pools (Cannelton – RC Byrd). With no indication that relative abundances have decreased, more effort must be placed in the removal fish along the invasion front. Effective target parameters for population control cannot be developed without an indication that population numbers are being lowered, but annual yields exceeding 9,100 kg (~20,000 lbs) should be attempted in the future.

Recommendations:
Future removal effort should focus primarily on the Cannelton pool during the months of June to August when spawning activity is observed and fish begin to congregate below McAlpine Lock and Dam or in the tributaries. During this time period, special consideration should be given to Clover Creek, Oil Creek, and Yellowbank Creek where juvenile fish have been observed. Sinking Creek, Poison Creek and the Salt River, appear to harbor large groups of fish year around and are important targets within the Cannelton pool. Gill netting activity should increase overall with an emphasis on setting gears near top water during evening hours and overnight. Efforts to spur public and commercial interest within the Cannelton pool should continue and will be an important in contributing to the necessary population control efforts for the Ohio River basin.

Project Highlights:

- Prevention and control are currently the best tools for limiting establishment of costly invasive species. Physical removal of Asian carps in the Ohio River basin is one of our few tools to slow their upstream expansion.
- Removal in 2016 was altered from removal conducted in 2015 in order to focus removal efforts in higher density pools were larger impacts could be made. This was continued in 2017 and efforts must be increased in order to slow and stop upriver progression of carp in the ORB.
- Electrofishing conducted in JT Myers though McAlpine pools in 2016 produced about a 100% increase in effort and a 340% increase in catch when compared to work completed in all five pools sampled in 2015. Efforts in 2017 produced slightly lower yields than in 2016, but the overall biomass removed between the two years was similar.
- Gill netting efforts in Cannelton and McAlpine alone were approximately equivalent to all the effort placed into the five pools previously targeted for removal in 2015. Total catch increased in 2016 (over 160%) and then increased again in 2017 (over 230%) as removal crews began to refine gill netting techniques.

- Effective target parameters for population control cannot be developed without an indication that population numbers are being lowered, but annual yields exceeding 9,100 kg (~20,000 lbs) have been consistent for the past two years and should be increased using lessons learned in the future.

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Figures:

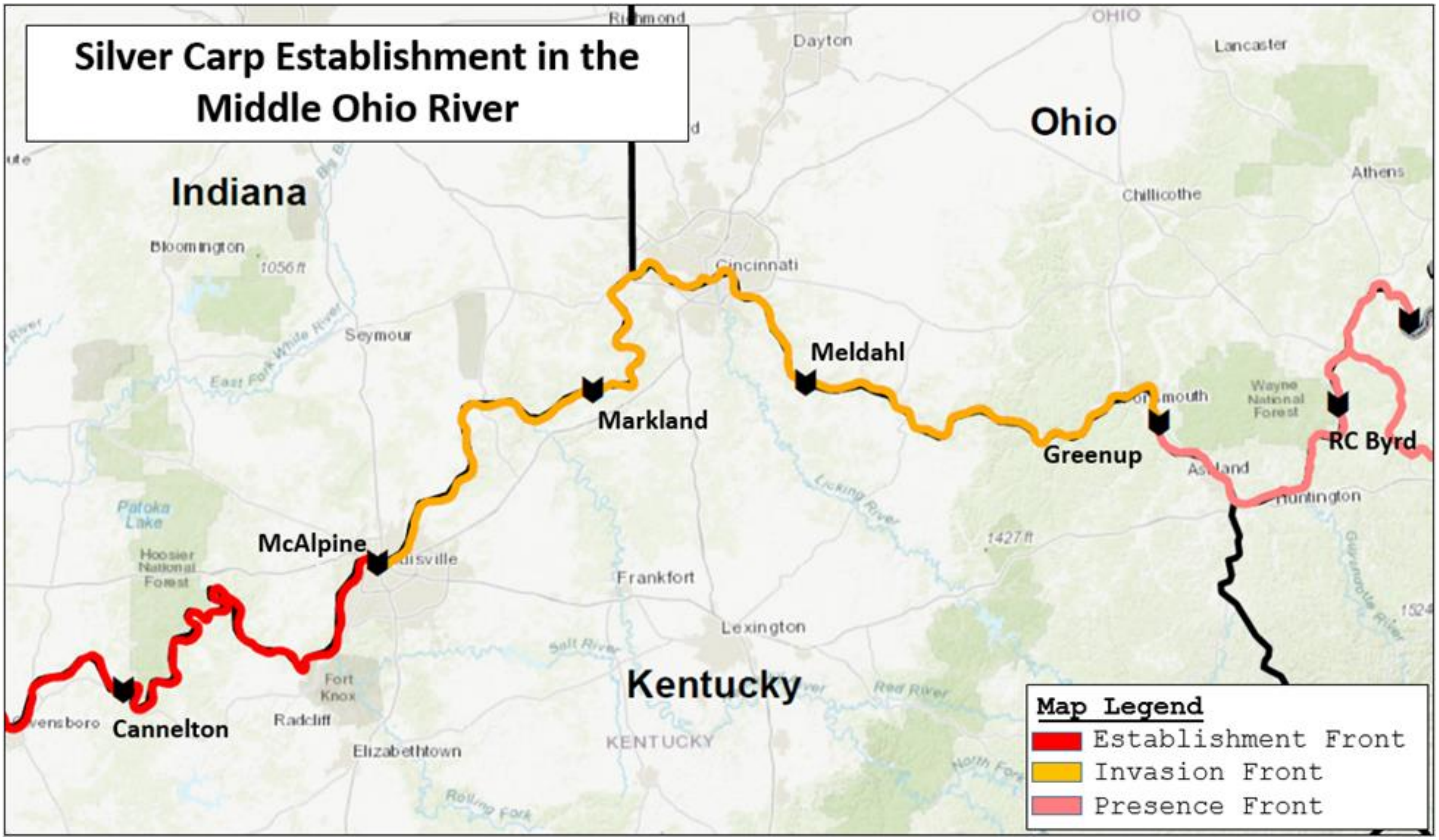

Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

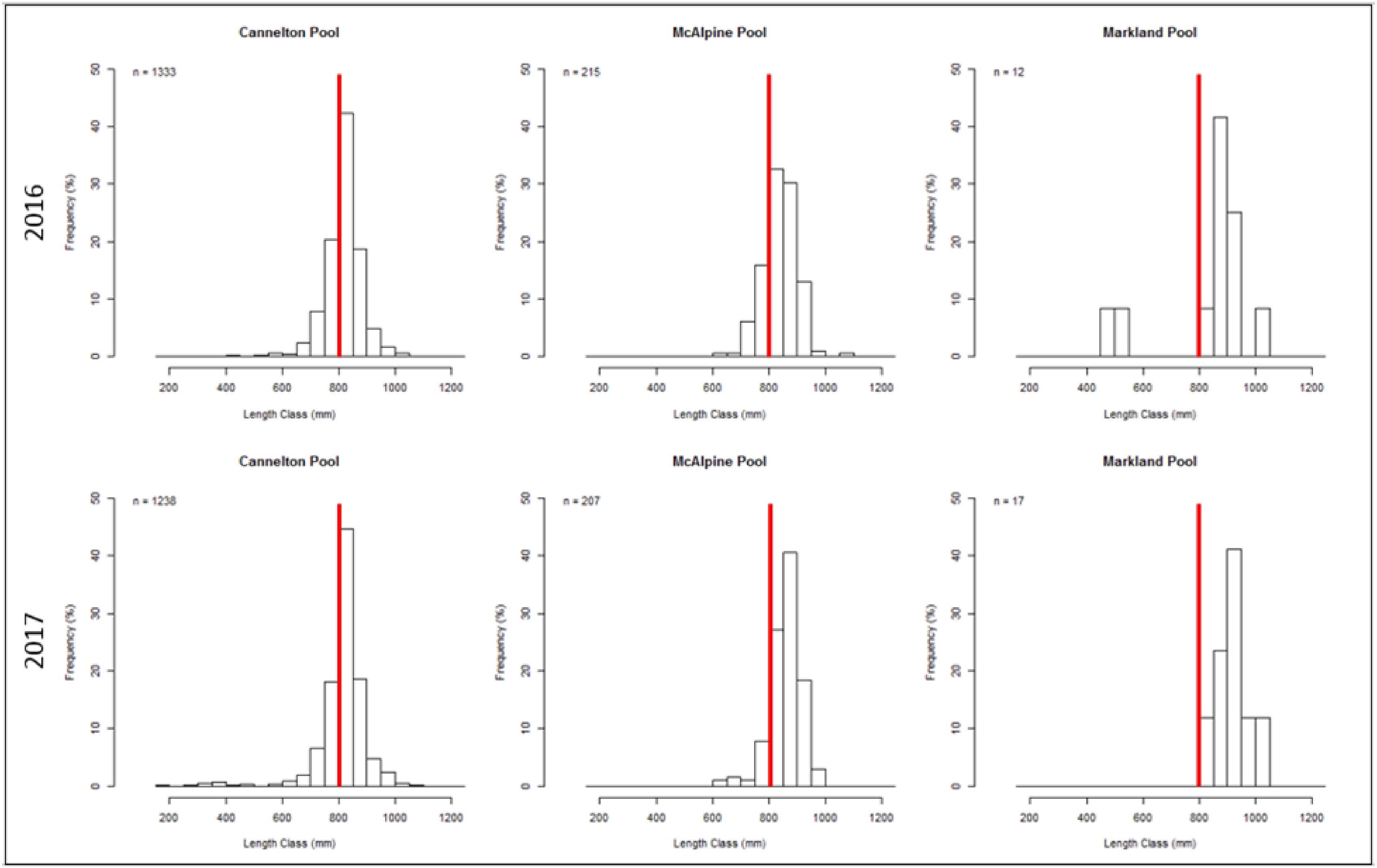

Figure 2. Length frequencies of silver carp captured during sampling efforts in 2016 and 2017. A line at 800mm highlights the change in length-classes from fish captured farther upriver with Cannelton being the farthest pool downstream and Markland the farthest pool upstream.

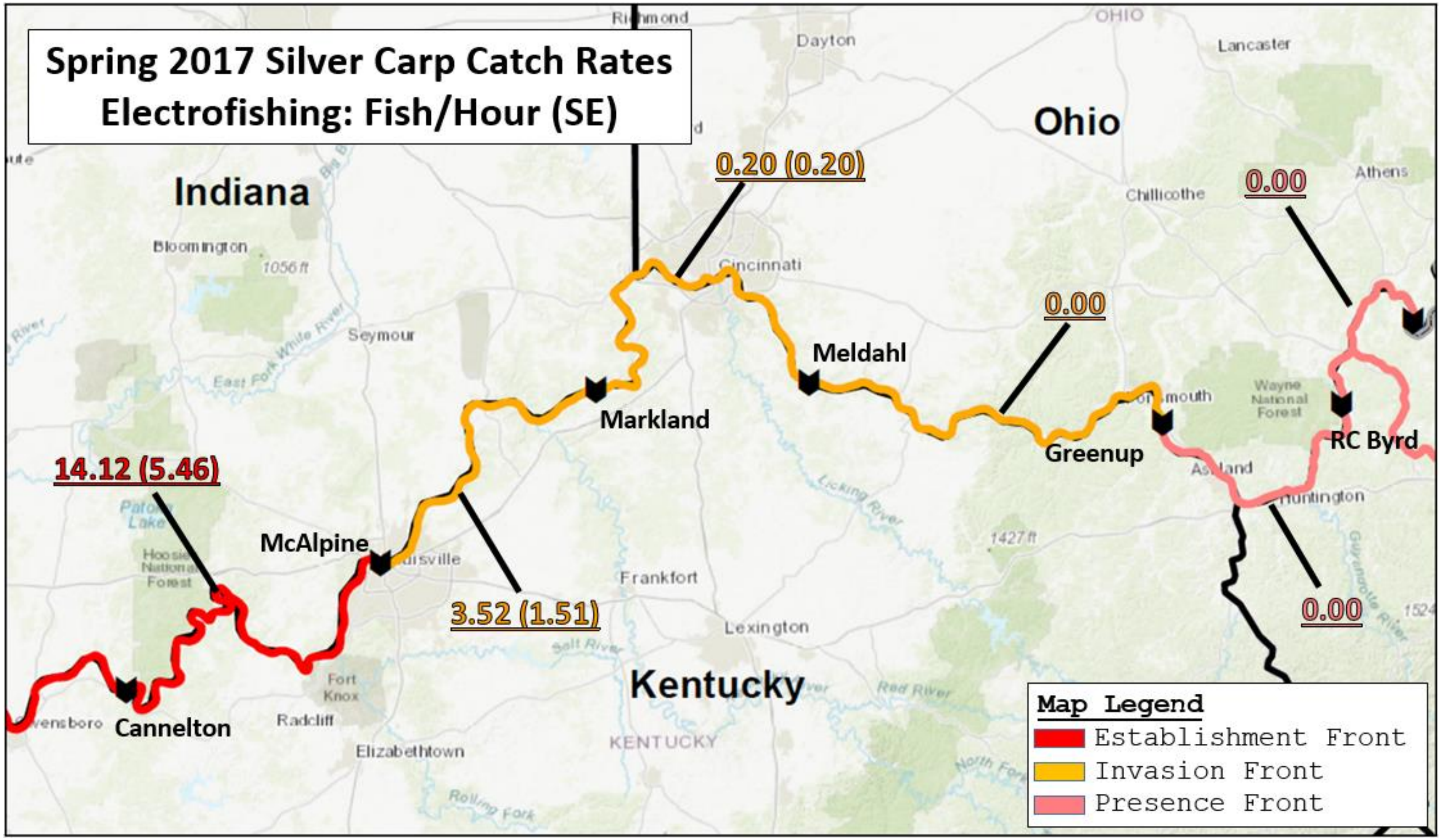

Figure 3. Mean silver carp catch rates by navigation pool using boat electrofishing during targeted sampling in 2017. Standard errors are in parenthesis.

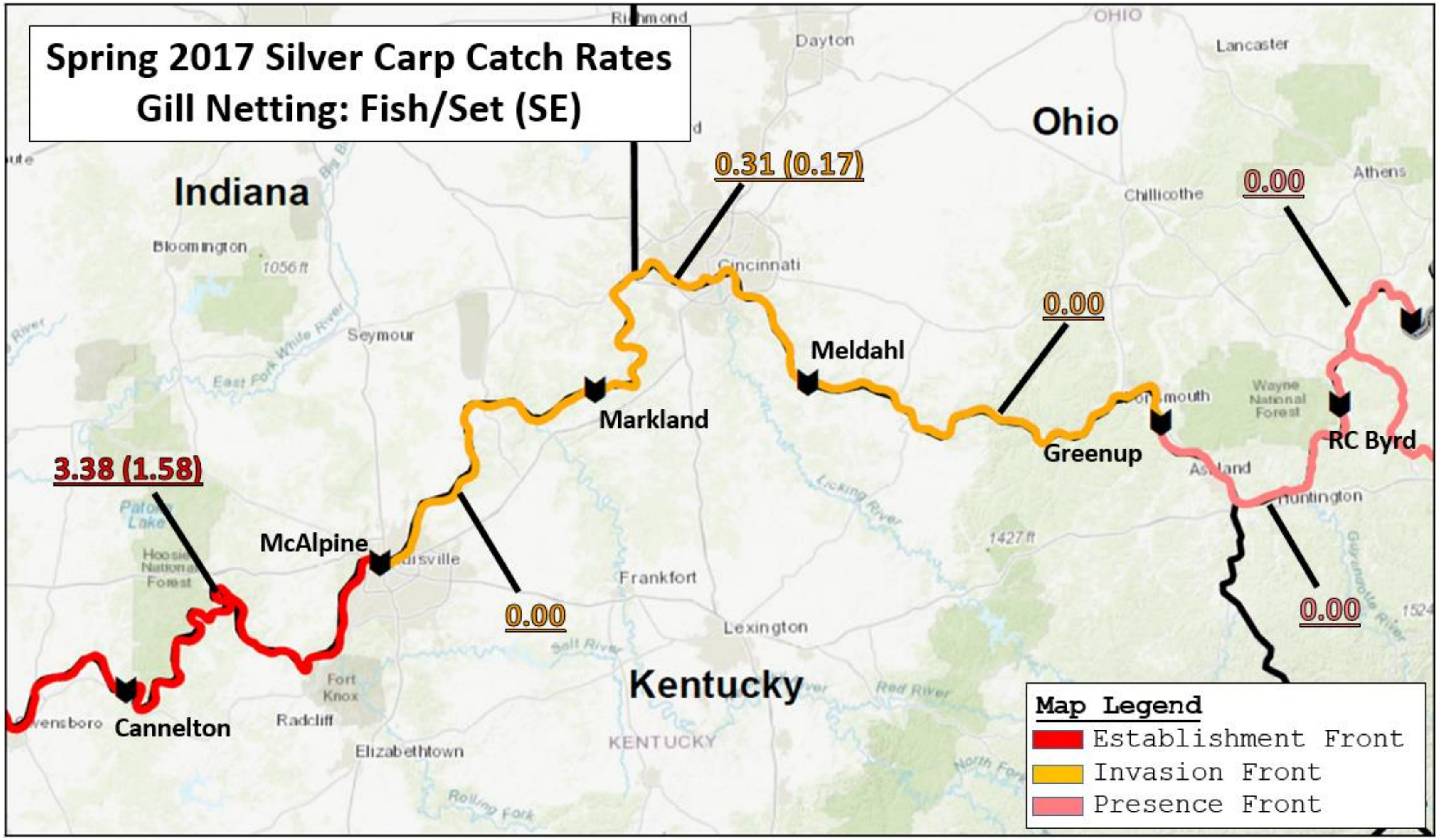

Figure 4. Mean silver carp catch rates by navigation pool using gill netting during targeted sampling efforts in Spring 2017. Standard errors are in parenthesis.

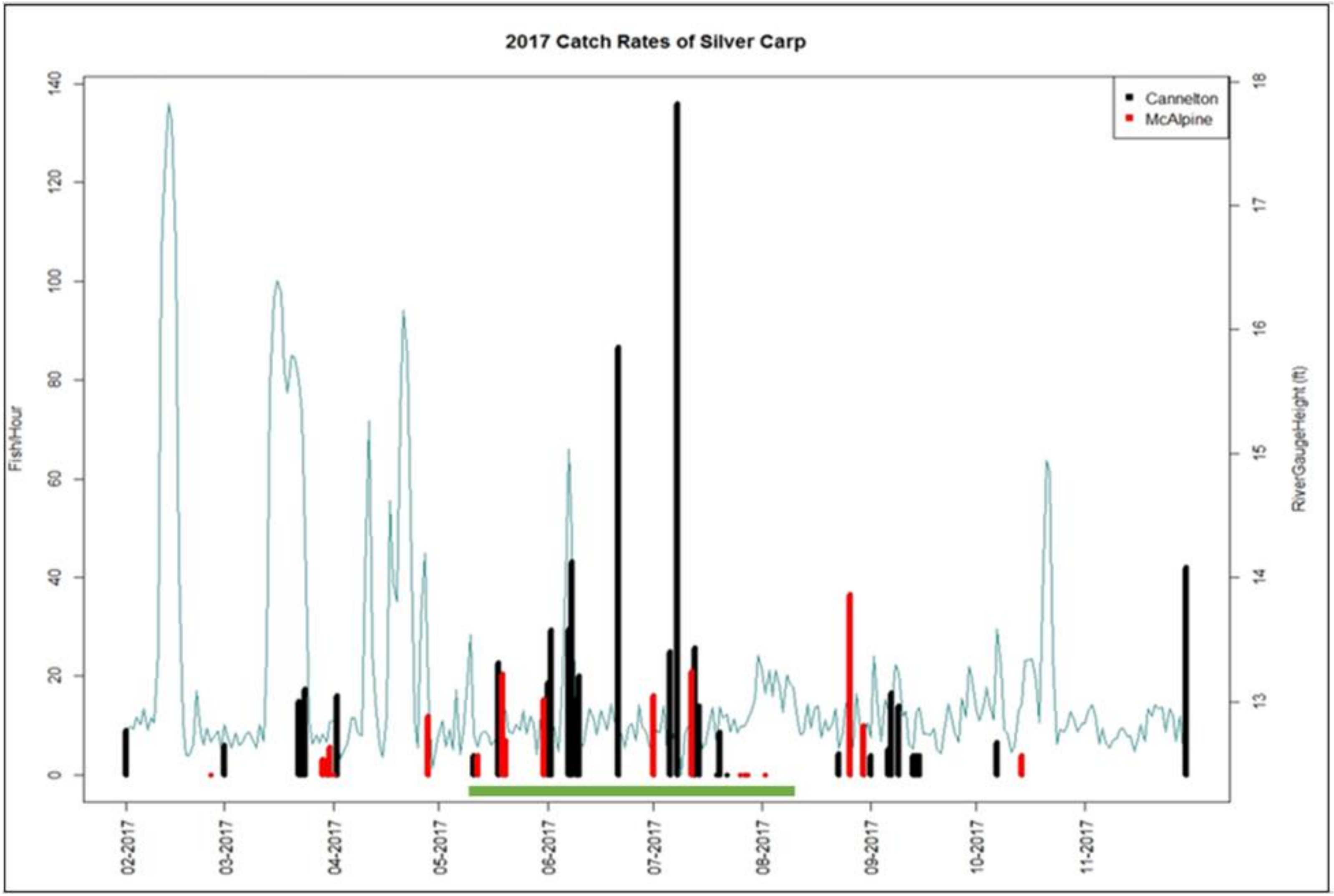

Figure 5. A histogram showing catch rates by month of silver carp captured in Cannelton and McAlpine in 2017 along with the gauge height in feet. The green line between the months of May and August indicate the period where spawning patches appear on females.

Tables:

Table 1. Electrofishing effort (hours) and resulting catch of three species of Asian carp (number and weight) for three pools of the Ohio River during Asian carp removal efforts in 2017.

Pool	Electro Hours (hr)	Bighead Carp (N)	Silver Carp (N)	Grass Carp (N)	Total (N)	Bighead Carp (kg)	Silver Carp (kg)	Grass Carp (kg)	Total (kg)
Smithland	1.00	1	195	1	197	1.85	92.67	15.88	110.40
Cannelton	43.00	10	1050	17	1077	79.61	5924.24	73.27	6077.12
McAlpine	17.00	0	192	0	192	0.00	1314.13	0.00	1314.13
Total	61	11	1437	18	1466	81.46	7331.04	89.15	7501.65

Table 2. Gill netting effort (feet) and resulting catch of three species of Asian carp (number and weight) for two pools of the Ohio River during Asian carp removal efforts in 2017.

Pool	Total Net Length (ft)	Bighead Carp (N)	Silver Carp (N)	Grass Carp (N)	Total (N)	Bighead Carp (kg)	Silver Carp (kg)	Grass Carp (kg)	Total (kg)
Cannelton	6450	11	76	3	90	148.84	456.64	28.44	633.92
McAlpine	2400	1	2	0	3	24.58	118.38	0.00	142.96
Total	8850	12	78	3	93	173.42	575.02	28.44	776.88

Distribution, movement, and lock and dam passage of Asian carp in the Ohio River through acoustic telemetry 2017 Report

Geographic Location: The Ohio River from Cannelton pool near Leavenworth, IN, to just upstream of the Willow Island Lock and Dam near Eureka, WV.

Participating Agencies: US Fish and Wildlife Service (USFWS), Kentucky Department of Fish and Wildlife Resources (KDFWR), Ohio Department of Natural Resources Division of Wildlife (ODNR DOW), West Virginia Division of Natural Resources (WVDNR), Indiana Department of Natural Resources (INDNR)

Statement of Need: The bigheaded carps, herein referred to as Asian carp, include the Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*H. nobilis*) as well as hybrids between these species. Asian carp are highly invasive fishes that have been expanding their range in the U.S. since the early 1980's when they first began to appear in public waters (Freeze and Henderson 1982; Burr et al 1996). Asian carp have been shown to exhibit very high reproductive potentials with high fecundity and the potential for a protracted spawning period (Garvey et al. 2006). Populations of Asian carp have grown exponentially because of their rapid growth rates, short generation times, and dispersal capabilities (DeGrandchamp 2003; Peters et al. 2006; DeGrandchamp et al. 2008). Tsehaye et al. (2013) stated that high reproductive capacity of both species, in particular Silver Carp ensure that attempts to exclude or remove individuals will require a massive undertaking (>70% exploitation) that targets all age classes and sizes. Any information that we can learn about Asian carp distribution, abundance, and/or biology that could facilitate targeting susceptible life stages could therefore limit population expansion.

Populations of Asian carp have become well established in the lower and middle reaches of the Ohio River and successful reproduction is suspected as far upstream as the Falls of the Ohio at Louisville, Kentucky. The upper reaches of the Ohio River as well as many upper basin tributary streams may not currently be inhabited by Asian carp. The need exists to prevent the establishment of these species into the upper portions of the Ohio basin

The Great Lakes and Mississippi River Interbasin Study (GLMRIS) identified six different possible routes for ANS to access the Great Lakes Basin through tributaries of the Ohio River. Because of these potential connections between Ohio River tributaries and Lake Erie, natural resource managers are concerned about the potential for the invasion of Asian carps into the Great Lakes Basin through the upper Ohio River watershed. If Asian carp gain entry into the Great Lakes they could pose a significant threat to established fisheries by competing with economically and recreationally important fishes for limited plankton resources (Sparks et al. 2011). They would also pose a very real danger to recreational boaters. Although predictions of the effects of Asian carp on the Great Lakes ecosystem vary widely, negative impacts on the fishery and recreational use of these resources are expected such that prevention is the preferred management action.

The overall goal of these efforts is to understand the distribution and movement patterns of Asian carp in the middle and upper Ohio River. Understanding these aspects of Asian carp biology in the Ohio River will assist efforts to minimize their further spread in the basin and reduce the size of existing populations.

Project Objectives:

1. Understand use of tributaries as potential sources for recruitment and routes of invasion into adjacent basins.
2. Delineate the upstream population distribution and potential for further upstream dispersal.
3. Help inform contract fishing and agency sampling efforts utilizing telemetry data.
4. Quantify passage of Asian carp at Ohio River locks and dams.

Project Highlights:

- In 2017, the project's extensive array of 158 stationary receivers logged more than 8 million detections from a total of 263 tagged Silver and Bighead carp that were spread across five different pools of the Ohio River.
- Over the course of this study, most of the fish being detected by receivers were found in the same pool where they were originally tagged. Between their first and last detections of 2017, more than 80% of the tagged carp detected last year had moved a net total of five miles or less in either an upstream or a downstream direction.

- Tributary usage by tagged carp in the Cannelton, McAlpine and Markland pools was significantly greater than their use of the mainstem Ohio River, but in the Capt. A Meldahl Pool, tagged carp appeared to occupy the mainstem river more often than any of its tributaries.
- Asian carp have a greater probability (0.18) of moving from the mainstem river into tributaries than moving from tributaries into the mainstem (0.13).
- Preliminary pool-to-pool transition probabilities are still quite small for both Bighead and Silver Carp
- Annual survival of tagged Silver Carp was estimated at nearly 77%, while tagged Bighead Carp survival was more than 85%, but with greater confidence interval margins.

Methods: Ultrasonic telemetry was used to track the movements of Asian carp and evaluate their ability to pass the lock and dam systems upstream of current known populations.

Ultrasonic Transmitter Tagging: Adult Bighead and Silver carp were surgically implanted with ultrasonic transmitters (Vemco, Model V16-6H; 69 kHz) which provide individual identification. These VEMCO V16-6H transmitters encode their unique Tag ID number into an ultrasonic signal that is randomly transmitted every 20 – 60 seconds. Because of this relatively long period between signals, the selection of a high-capacity lithium battery and the lack of extra sensors have all contributed to the transmitter's above-average battery life of 1,825 days, or 5 years. Gill nets and Direct Current (DC) boat electrofishing were used to capture Asian carp for tagging. The efforts were concentrated in habitats that are attractive to Asian carp such as side channels, backwaters, and tributary creeks and rivers. The majority of the 2017 sampling efforts occurred during the spring/summer, and they were concentrated in the Markland and Meldahl pools. The main purpose of these efforts was to replace the tagged Bighead and Silver Carp from 2013-2014, which were originally implanted with transmitters that will start shutting down during summer 2018. Other efforts in 2017 included those in the early fall that were focused on tagging additional fish from the higher density Asian Carp population in the lower Cannelton Pool. After being implanted with a transmitter, the total length, weight and sex of each carp was recorded, and then prior to release, an external aluminum jaw tag was applied to its dentary bone (lower jaw) (National Tag Co. #1242 F9), which allowed for quick identification if the tagged carp was ever recaptured.

Ultrasonic receiver array: A complete array, with both VR2W's and VR2AR's, was established following the redeployment of overwintering receivers to their respective mainstem sites during late March 2017. The project's array consisted of receiver stations that were established across three different site types, which included the mainstem Ohio River, the first two miles of major tributaries and above/below Lock & Dam (L&D) facilities. Most of these efforts in 2017 were focused on establishing new stations to improve the receiver coverage in tributaries that were most likely to contain Asian Carp. Finally, during mid-December 2017, VR2W receivers were once again pulled from stations located in the mainstem Ohio River and kept in overwinter storage to avoid further losses of equipment caused by ice flows.

Mobile Tracking: Active tracking was used in concert with netting and electrofishing to help locate tagged fish and increase the likelihood of capturing additional fish to tag. During each effort, tagged fish were located with a portable hydrophone and receiver (Vemco Model VH110-10M and Vemco Model VR100, respectively).

Collection & Management of Tagged Carp Detections: With the project's array more than doubling since 2013, the participating agencies redistributed the receiver responsibilities in order to improve the efficiency of the monthly efforts to offload new telemetry data from each receiver station. As a result, in 2017, the KDFWR concentrated its efforts on maintaining/offloading the ~40 receiver stations found within the initial 170 miles of the array, while the USFWS and ODOW shared responsibility for the 100+ receivers that were spread throughout the array's upper 330 miles. These efforts to offload new telemetry data were conducted monthly from April to November 2017. Upon completion of their offloading efforts each month, project biologists combined the newest tag detections into a monthly dataset and then shared it with other agencies via a file transfer protocol (FTP) site. As in previous years, the KDFWR resumed efforts to remove all duplicate/erroneous detections from the datasets that all agencies had obtained throughout 2017. All remaining detections were imported into the 2017 telemetry database, which was subsequently reduced to create datasets consisting of hourly/daily detections of tagged carp. Biologists used these datasets to track Asian Carp movements on broader scale (i.e. pool transfers) and/or over longer periods (i.e. weeks & months). An analysis of the entire 2017 telemetry dataset was also completed using R and the VTrack package (v1.11), which consisted of specific tools for analyzing the larger telemetry datasets. All other GIS work for the 2017 Telemetry Project was conducted with ArcMap (v10.5).

Other Statistical Analyses: Pool-to-pool transition probabilities, mainstem river to tributary transition probabilities, annual survival, and detection probabilities were estimated using the "Multi-state with Live Recaptures" analysis in Program MARK (G.C. White, Dept. of Fish, Wildlife, and Cons. Bio., Colorado State University, Fort Collins, CO). Encounter histories were constructed for each individual by determining the pool of last known detection for each month for each year (June 2013 through December 2017). Because individuals were tagged throughout the duration of this study, not all individuals have a complete encounter history (maximum of 55 possible time periods). Encounter histories of tagged carp that had been harvested or whose tag's battery had expired were right censored and removed from the estimation procedures. These encounter histories were then used to construct models to estimate pool transition, survival, and detection probabilities for each species by pool and month. Numerous models were constructed that tested whether data supported more complex models beyond time-invariant parameter estimates (e.g., survival constant across all months vs variable across months) and spatially invariant parameter estimates (e.g., survival is constant across all pools vs variable across pools). The best models for each species were selected based on the Akaike's information criterion corrected for small sample size (AIC_c); a difference in AIC_c values exceeding 2 was taken as evidence that a model outperformed a competing model, with smaller values being better.

Results and Discussion:

Receiver Array Placement: After VR2W's were redeployed to mainstem sites in March 2017, and all of the new receiver stations had been established in tributaries, the project's 500-mile telemetry array in 2017 included at least some portion of nine different pools and contained a total of 158 receiver stations (Figure 1). There were five VR2AR acoustic release receivers that were never recovered from their last deployment sites approximately one mile upstream of the Markland, Capt. A. Meldahl, Greenup, R. C. Byrd, and Belleville dams during April. Additionally, one VR2AR receiver was lost at the mouth of the Kanawha River. Only one of the lost VR2AR receivers was replaced (upstream of the Belleville dam). The VR2AR receivers in Ohio Brush Creek and Big Sandy River were retrieved, data offloaded, and redeployed. In addition, the extensive efforts to improve/establish the telemetry coverage in tributaries located throughout the array had succeeded in creating 33 new receiver stations across 18 different tributaries, which included 15 creeks, streams and small rivers that had never been monitored for tagged carp (Figure 2).

As previously noted, the telemetry array consists of many individual receiver stations that can be grouped according to a site's habitat type and the pool that it's located in. The locations for new stations in 2017 were limited to tributaries and L&D's because the receiver distribution was already skewed towards mainstem sites, which represented nearly 70% of the established receiver stations at the end of 2016. However, by the completion of the 2017 receiver work, the limited site selection helped improve the distribution of the project's telemetry array, which ultimately finished out the year with a combination of 76 mainstem (48%), 54 tributary (34%) and 28 L&D (18%) sites (Table 1).

Fish Tagging Efforts– Over the summer and fall of 2017, the USFWS and KDFWR used a combined 5+ weeks of gill netting and pulsed-DC electrofishing to successfully implant transmitters into a total of 107 Asian Carp, which was composed of 98% Silver Carp (n = 105) and 2% Bigheads (n = 2) (Table 2). After field crews from both agencies tagged only 17 Asian Carp during 4+ weeks of sampling the lower density populations in Markland and Meldahl, the USFWS field crews eventually moved downstream in early October to target higher densities of Asian Carp in the lower Cannelton Pool. They were able to collect/tag an additional 90 Silver Carp in a single week of sampling.

From 2013 through 2017, a total of 508 Asian carp have been surgically implanted with acoustic transmitters from the Cannelton, McAlpine, Markland, Capt. A. Meldahl, and R. C. Byrd pools of the Ohio River (Table 2). Even with tagging efforts occurring in six different pools since 2013, more than 83% of the project's tagged carp were collected from the higher density populations in Cannelton and McAlpine. A length frequency distribution of all 500+ tagged carp indicated that 84% of Silver Carp obtained from "high-density" populations (Cannelton & McAlpine) had total lengths of less than 900 mm, but in contrast, a similar proportion (81%) of the Silver Carp from lower density pools (Markland & Meldahl) actually had total lengths of 900 mm or more (Table 3). A similar evaluation of tagged Bighead Carp showed that 98% had total lengths exceeding 1000 mm, but no notable size differences were found between Bighead Carp sampled from different pools (Table 4).

Fish Detections: In 2017, project biologists completed numerous efforts to error-check and format the telemetry datasets that were offloaded monthly by field crews from the KDFWR, ODOW, USFWS and WVDNR. Upon importing the final datasets into the database, it was determined that between 01 January 2017 and 14 December 2017, eighty-one (51.2%) of the 158 receivers in the array made a combined total of ~8,175,000 detections of tagged Asian Carp (Table 5). Further analysis determined that the database contained at least one detection from 263 (51.8%) of the 508 total carp that have been tagged over the past five years. However, this total also included the 90 Silver Carp that were recently tagged (October 2017) in the lower half of the Cannelton pool, which was up to 50 miles downstream of the closest receiver. This could reduce the detection percentage until additional receivers are placed in this area of the pool or until these recently tagged fish move upstream into the receiver array. The 2017 database was also reduced to create two separate datasets of 346,478 hourly and 35,064 daily detections, which were later used to analyze the large-scale movements.

Although many receivers had similar numbers of tagged carp detections, there were "hot spots" where substantially more detections were recorded (Figure 3). The area containing the largest proportion of detections (82%) was the McAlpine Pool, which was not unexpected from a mid-sized pool (~75 miles) containing 22 active receivers and as many as 237 tagged carp. Overall, the McAlpine receivers made a total of 6.7 million detections of 164 unique carp during 2017. This was more than 10 times higher than the Meldahl Pool receivers credited with making 573,578 tagged carp detections, which is the project's 2nd highest total in 2017 (Table 5).

Fish Movements – During 2017 the majority of tagged fish in this study remained close to the area in which they were initially detected at the start of the year. Over 81% of the tagged fish detected during this study had a net upstream or downstream movement of five miles or less (Figure 4). The mean monthly ranges were also determined for Bighead Carp and Silver Carp that were recorded by a least two receivers during 2017. These ranges were established by first separating all hourly detections by pool and then calculating the distance (in river miles) between the most upstream and most downstream detections for each tagged carp over a specific time period (i.e. month). When the monthly distances were compared for both carp species in the McAlpine, Markland and Meldahl pools, the results indicated that Bighead Carp tend to cover a larger stretch of river during most months, with the exception of April 2017, when Silver Carp in Markland had a mean range that was more than double that of Bighead Carp (Figure 5). Regardless of the pool, both species appeared to be quite active between April and August 2017, but during these 5 months, the Bighead Carp often exhibited greater distances between their most upstream and downstream detections (Figure 6). Even though they had been relatively active, Bighead Carp movements ended abruptly during September. In contrast, the Silver Carp were still active in October and November, but their mean ranges during these fall months were noticeably reduced compared to spring and summer.

Model Selection – The best model selected for Silver Carp provided time and state invariant survival estimates, probability of detection estimates that varied over space and time, and movement estimates that varied for each pool. The closest competing model of the remaining 119 models that were tested had a ΔAIC_c of 75 and included an additional 132 parameters. Of the 104 models run for Bighead Carp, the top model selected provided time invariant survival estimates, probability of detection estimates that varied over space and time (i.e., seasonally), and movement estimates that varied for each pool. The ΔAIC_c of the next closest model was nearly 4.5 and included an additional two parameters. The model selected to determine differences in survival, detection probabilities, and transition probabilities between mainstem river habitats and tributary habitats had time dependent survival, detection probabilities that varied over space and time, and movement estimates that varied between the mainstem and its tributaries. Of the 65 models run, one closely competing model ($\Delta AIC_c < 2$) was not selected due to its greater level of complexity (an addition of 11 parameters) while explaining for less of the variability in the data.

Tributary Use – Tributary use within Cannelton, McAlpine, Markland, and Capt. A. Meldahl pools was analyzed by comparing the number of unique tags detected daily by receivers located either in the mainstem Ohio River or in its tributaries. A paired two-tailed t-test was used to determine whether the number of tagged fish located within tributaries was significantly different than those located by mainstem receivers. Based on unique detections per day, tributary use was higher than the mainstem in Cannelton ($p < 0.0001$), McAlpine ($p < 0.0001$), and Markland pools ($p < 0.0001$), whereas use of the mainstem habitat was higher in the Capt. A. Meldahl pool compared to tributaries ($p < 0.0001$). Detection and transition probabilities between the mainstem Ohio River and its tributaries for 2017 were analyzed using multi-state modeling in Program MARK. Probability of detection was significantly higher in tributaries than in the mainstem river throughout all months, except for December, when detection probabilities were higher in the mainstem river (Figure 7). During any given time period, telemetered fish within the mainstem river had an 18% chance of moving from the mainstem into tributaries, whereas those already in tributaries were 7 times more likely to remain in tributaries that to transition to mainstem habitats. That said, individuals already in mainstem habitats were 4.6 times more likely to remain in the mainstem habitat as opposed to transition to tributaries even when accounting for differences in detection probabilities between these two habitats. This further demonstrates the two dichotomies of individual behaviors in which there are individuals that could be highly mobile and those that are more sedentary.

Dam Passage – Throughout this study, there have been 41 dam passage events by 16 Silver Carp and seven Bighead Carp. Of these 23 fish, three Bighead Carp and four Silver Carp were responsible for 20 (48.78%) of the passage events. Sixteen of the 41 (39%) passage events were in an upstream direction by three Bighead Carp (eight passes), six Silver Carp (seven passes), and one unidentified tagged fish (one pass). Of the tagged Bighead and Silver Carp, 16.28% and 3.46% were found to pass through dam structures, respectively. During 2017, ten Asian Carp (two Bighead Carp, six Silver Carp, two unidentified tagged carp) passed through dams on 15 occasions with six being in an upstream direction *(Table 6)*. Of the 15 passage events, five are thought to be through the use of the lock chambers. Preliminary pool to pool transition probabilities were found to be highest for Silver Carp from McAlpine pool to Markland pool (0.12 ± 0.01) and from Cannelton pool to Markland pool (0.10 ± 0.02) (Table 7). For Bighead Carp, transitions from Markland pool to McAlpine pool (0.28 ± 0.05), Cannelton pool to McAlpine pool (0.27 ± 0.10), and Capt. A. Meldahl pool to McAlpine pool (0.14 ± 0.03) showed the highest probabilities (Table 8). For both Silver Carp and Bighead Carp in any navigation pool along the Ohio River, staying within the same pool accounted for the most likely observation.

The 2017 hourly detection data also contained eight instances where tagged carp initially appeared to transfer pools, but a closer examination of the details surrounding each event raised some doubt as to whether a pool transfer actually occurred (Table 9). There were seven tagged carp (5 Silver Carp, 1 Bighead and an unknown) in 2017 that had made "possible" pool transfers. In each occurrence, the only detection(s) of the tagged carp in the adjacent pool came from a receiver in the upstream/downstream approach that was located on the opposite side of the L&D that each carp supposedly transferred through. It may be possible for an ultrasonic signal to bounce around a lock chamber and be picked up by the receiver on the other side of the gate. All seven tagged carp returned to their original pool soon after the detections were made in the opposite approach, which lends credence to the original hypothesis. Each event will remain a "possible" pool transfer until the tagged carp is detected in the adjacent pool by a receiver that is not directly associated with the L&D. Finally, there was an additional pool transfer involving a Bighead Carp that moved downstream into the McAlpine Pool via the Markland L&D without a single detection, but it was then detected by a receiver in the Kentucky River before returning to the Markland Pool by once again moving undetected through Markland L&D. Because of the high speed required to complete the trip and the need to pass many receivers without detection, it is highly unlikely that this event actually occurred, and as a result, it has been officially marked as an "Invalid Transfer".

Survival – The annual survival estimate of tagged Asian carp was calculated in Program MARK using a multi-state live-capture model. Silver Carp survival was estimated to be 76.98% (95% C.I. = 71.63 – 81.47%) throughout all pools. Bighead Carp were found to have a slightly higher annual survival rate at 85.32% (95% C.I. = 61.46 – 95.17%), however, the 95% confidence interval was less constricted than the Silver Carp estimate due to the lower sample size of Bighead Carp in the study. Given that only one of these fish were known to have been harvested, we believe that this estimate provides a robust estimate of natural mortality (e.g., 95% CI = 18.53% - 28.02% for Silver Carp; 95% CI = 4.83% - 38.54% for Bighead Carp).

Recommendations:

After following recommendations outlined in the project report from last year, data relative to tributary use has greatly increased and is providing a unique insight into overall use, as well as factors influencing use of tributaries versus mainstem habitats. However, continued monitoring of tributaries will provide a more in depth understanding of the importance of this habitat type to Asian carp. Continued monitoring of dam passage and inter-pool movement will not only strengthen current passage estimates, but also increase the accuracy of survival and detection probabilities. Movement estimates will also need to be formatted for incorporation into the spatially explicit population model being developed for the Ohio River. Finally, upstream movement estimates appear to be very low whereas downstream movement below Cannelton pool is not well known. A recent detection of a tagged Asian carp in Lake Barkley originating from Cannelton pool begs the question as to if and how Kentucky Lake or Lake Barkley serve as a population sink for the Ohio River population, thereby reducing upstream range expansion on the Ohio River. With the proposed deterrent technologies at Barkley Lock, one hypothesis that should be considered is whether blocking a potential population sink of the Ohio River population will increase upstream movement rates. Continued evaluation of the movement of Asian carp through Kentucky and Barkley Dams, as well as movement downstream of Cannelton Locks and Dam will help evaluate what effects these barriers will have on the upper pools of the Ohio River. Modeling simulations will help us better understand how management decisions affect the Asian carp population at much larger scales.

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Figures and Tables:

Table 1. Total numbers and distribution (%) of receivers to the three habitat types that were utilized for the project's telemetry array in 2017 (L&D = Lock and Dam, RM = river miles).

Ohio River Pool	Mainstem		L&D		Tributary		Total # of 2017 Sites	% of All 2017 Sites	RM added to Array	RM per Mainstem Receiver
	# of Sites	% Sites in Pool	# of Sites	% Sites in Pool	# of Sites	% Sites in Pool				
Cannelton	7	77.8	0	0.0	2	22.2	9	5.7	54	7.7
McAlpine	9	47.4	0	0.0	10	52.6	19	12.0	75	8.3
Markland	10	34.5	4	13.8	15	51.7	29	18.4	95	9.5
Meldahl	24	63.2	4	10.5	10	26.3	38	24.1	95	4.0
Greenup	9	47.4	4	21.1	6	31.6	19	12.0	62	6.9
RC Byrd	4	36.4	4	36.4	3	27.3	11	7.0	42	10.5
Racine	3	33.3	4	44.4	2	22.2	9	5.7	33	11.0
Belleville	9	47.4	4	21.1	6	31.6	19	12.0	42	4.7
Willow Island	1	20.0	4	80.0	0	0.0	5	3.2	3	3.0
Totals	76	48.1	28	17.7	54	34.2	158	100.0	501	6.6

Table 2. Total numbers of the Bighead Carp and Silver Carp collected from five pools of the Ohio River and then implanted with transmitters for the AC Telemetry Project in 2013 - 2017

Year	Species	Pool					All Pools
		Cannelton	McAlpine	Markland	Meldahl	RC Byrd	
2013	Silver Carp	-	-	-	6	-	6
	Bighead Carp	-	-	-	13	-	13
2014	Silver Carp	-	115	6	10	-	131
	Bighead Carp	-	4	4	0	-	8
2015	Silver Carp	-	22	3	5	-	30
	Bighead Carp	-	1	1	5	-	7
2016	Silver Carp	92	94	6	0	0	192
	Bighead Carp	4	1	4	2	3	14
2017	Silver Carp	90	-	12	3	-	105
	Bighead Carp	0	-	2	0	-	2
2013-2017	Silver Carp	182	231	27	24	0	464
	Bighead Carp	4	6	11	20	3	44
All Years	All Species	**186**	**237**	**38**	**44**	**3**	**508**
	% of Total	36.6	46.7	7.5	8.7	0.6	100.0
Mean TL (mm)	Silver Carp	826.5	859.5	909.2	961.3	-	852.8
	Bighead Carp	1139.8	1169.0	1175.1	1154.5	1210.0	1164.1

Table 5. The total detections (Total Dtxns) and the numbers of unique AC offloaded from receivers in 2017 and then grouped by season, pool and site type.

Table 3. The length frequency distribution of Silver Carp that were tagged in 2013-2017 after being collected from four different pools that are characterized as having a higher (Cannelton & McAlpine) or lower (Markland & Meldahl) density population of Asian Carp.

Species	Pool	2 cm Size Classes																						Total
		66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	
Silver Carp	Cannelton	2	2	2	3	4	11	20	27	29	35	25	7	6	2	3	1	1	2					182
	McAlpine	1	0	1	2	0	3	7	24	29	43	35	34	25	5	5	7	2	2	0	0	0	1	226
	Both Pools	3	2	3	5	4	14	27	51	58	78	60	41	31	7	8	8	3	4	0	0	0	1	408
	Markland										2	4	3	6	4	6	2							27
	Meldahl												1	6	1	4	4	2	2	3	0	1		24
	Both Pools										2	4	4	12	5	10	6	2	2	3	0	1		51
	All Pools	3	2	3	5	4	14	27	51	58	80	64	45	43	12	18	14	5	6	3	0	1	1	459

Table 4. The length frequency distribution of Bighead Carp collected & tagged from five different pools in 2013 - 2017.

Species	Pool	2 cm Size Classes																				Total
		94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	
Bighead Carp	Cannelton	-	-	-	-	-	-	1	0	0	1	0	1	1								4
	McAlpine								1	1	1	0	0	0	1	1	0	1				6
	Markland				1	0	0	0	0	1	0	2	3	1	0	1	0	0	0	1	1	11
	Meldahl	1	0	0	0	0	0	2	2	2	2	0	3	1	1	2	1	1	2			20
	RC Byrd														2	1						3
	Total	1	0	0	1	0	0	3	3	4	4	2	7	3	4	5	1	2	2	1	1	44

Season	Site Type	Cannelton		McAlpine		Markland		Meldahl		Greenup		RC Byrd		Racine		Total	
		Total Dtxns	Unique AC	Total Dtxns	Unique AC	Total Dtxns	Unique AC	Total Dtxns	Unique AC	Total Dtxns	Unique AC	Total Dtxns	Unique AC	Total Dtxns	Unique AC	Total Dtxns	Unique AC
Winter	Main	77	2	30,454	10	0	0	2,553	10	0	0	0	0	0	0	33,084	22
	Trib	0	0	394,288	49	0	0	93,974	10	0	0	0	0	0	0	488,262	59
	L&D	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	All	77	2	424,743	54	0	0	96,527	10	0	0	0	0	0	0	521,347	66
Spring	Main	7	2	73,251	124	758	6	3,934	15	0	0	14	1	8	1	77,972	149
	Trib	0	0	1,686,649	142	116,834	5	18,596	12	0	0	0	0	0	0	1,822,079	159
	L&D	0	0	77	4	0	0	1,101	8	261	6	23,331	2	0	0	24,770	14
	All	7	2	1,759,977	146	117,592	7	23,631	16	261	6	23,345	3	8	1	1,924,821	175
Summer	Main	16,041	25	169,135	128	3,360	9	75,315	17	49	2	0	0	30	1	263,930	178
	Trib	115,300	17	2,089,275	136	107,597	15	88,145	14	0	0	7,466	4	0	0	2,407,783	185
	L&D	0	0	430	3	835	1	2	1	34	2	583	2	96	1	1,980	7
	All	131,341	38	2,258,840	151	111,792	19	163,462	18	83	4	8,049	5	126	1	2,673,693	226
Fall	Main	3,146	7	337,222	99	3	1	131,704	15	64,047	1	0	0	0	0	536,122	123
	Trib	178,424	38	1,715,724	102	186,213	11	104,634	14	0	0	6,632	2	0	0	2,191,627	167
	L&D	0	0	0	0	0	0	0	0	0	0	71	1	0	0	71	1
	All	181,570	39	2,052,946	121	186,216	12	236,338	16	64,047	1	6,703	3	0	0	2,727,820	191
All	Main	19,271	28	669,292	148	4,121	10	245,975	17	96,834	2	14	1	38	1	1,035,545	201
	Trib	311,439	41	6,029,513	151	430,911	16	326,500	15	0	0	14,098	5	0	0	7,112,461	225
	L&D	0	0	508	7	835	1	1,103	8	295	8	23,985	3	96	1	26,822	19
	All	330,710	60	6,699,313	164	435,867	20	573,578	18	97,129	9	38,097	7	134	1	8,174,828	263

Table 6. Pool-to-Pool transfers in 2017 that were validated when the tagged AC were detected by at least one receiver (mainstem and/or tributary) located beyond the initial Lock and Dam (L&D) site that divided the two pools.

Transmitter ID	Species	Sex	Tagging Pool	Tag Year	Pool with... First Detection	Most DS Detection	Most US Detection	Last Detection	Transfer Direction	Notes
A69-1601-23996	SVC	M	McAlpine	2014	McAlpine	Cannelton	McAlpine	Cannelton	DS	Moved from McAlpine into the Cannelton Pool during late June; Remained in Cannelton through the end of 2017.
A69-1601-24009	N/A	na	N/A	na	RC Byrd	Greenup	RC Byrd	Greenup	DS	Used a lock on 7/26 to move from RC Byrd to Greenup; Stayed <5 mi below RC Byrd L&D through the end of 2017.
A69-1601-27347	SVC	M	Markland	2016	Markland*	McAlpine	Markland*	McAlpine	DS	In Markland through 2016 & then moved into McAlpine on 1/13/2017; No contact since a 1/15 detection in KY River.
A69-1601-56475	BHC	F	Markland	2017	Markland	McAlpine	Markland	McAlpine	DS	Moved from Markland to McAlpine on 8/01 via the L&D's 600-ft lock chamber; Still in lower McAlpine at end of 2017
A69-1601-57948	SVC	M	McAlpine	2016	Cannelton	Cannelton	McAlpine	McAlpine	US	Moved from Cannelton up to McAlpine in late June; Still in lower McAlpine when 2017 ended.
A69-1601-57962	SVC	F	McAlpine	2015	McAlpine	Cannelton	McAlpine	McAlpine	Both	Moved from McAlpine to Cannelton in early June 2017, but then returned to the McAlpine Pool in August.
A69-1601-57975	SVC	M	McAlpine	2015	McAlpine	Cannelton	McAlpine	Cannelton	DS	Transferred from McAlpine to the Cannelton Pool in June 2017; Detected in the Salt River by the end of the year.
A69-1601-58058	SVC	F	McAlpine	2016	McAlpine	Cannelton	McAlpine	McAlpine	Both	Moved from McAlpine to Cannelton in May 2017; Returned to McAlpine in June & was still there when 2017 ended.

Table 7. Pool-to-pool transition probabilities of Silver Carp in the Ohio River through acoustic telemetry – 2013 to 2017 based on the best model (preliminary results). The best model ($\Delta AIC_c > 2$) for Silver Carp provided time and state invariant survival estimates, probability of detection estimates that varied over space and time, and movement estimates that varied for each pool. Note that transition probabilities were not estimated above Capt. A. Meldahl pool due to the lack of movement data above this reach of the river.

Departure pool	Destination pool			
	Cannelton	McAlpine	Markland	Meldahl
Cannelton	0.89	0.01	0.10	0.00
McAlpine	0.02	0.86	0.12	0.00
Markland	0.00	0.08	0.92	0.00
Meldahl	0.00	0.00	0.01	0.99

Table 8. Pool-to-pool transition probabilities of Bighead Carp in the Ohio River through acoustic telemetry – 2013 to 2017 based on the best model (preliminary results). The best model ($\Delta AIC_c > 2$) for Bigheaded Carp provided time invariant survival estimates, probability of detection estimates that varied over space and time (i.e., seasonally), and movement estimates that varied for each pool.

	Destination pool						
Departure pool	Cannelton	McAlpine	Markland	Meldahl	Greenup	R. C. Byrd	Racine
Cannelton	0.66	0.27	0.00	0.08	0.00	0.00	0.00
McAlpine	0.00	0.98	0.01	0.01	0.00	0.00	0.00
Markland	0.00	0.28	0.72	0.00	0.00	0.00	0.00
Meldahl	0.00	0.14	0.01	0.84	0.01	0.00	0.00
Greenup	0.00	0.00	0.00	0.00	0.91	0.09	0.00
R. C. Byrd	0.00	0.07	0.00	0.00	0.00	0.89	0.04
Racine	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Table 9. Pool-to-Pool transfers in 2017 that could not be validated. These events have been categorized either as 1) "Possible Transfers" of tagged AC that were only detected by receivers associated with the initial L&D site, or as 2) "Invalid Transfers" that were based solely on what were later identified as False detections.

Transmitter ID	Species	Sex	Tagging Pool	Tag Year	Pool with First Detection	Pool with Most DS Detection	Pool with Most US Detection	Pool with Last Detection	Transfer Direction	Notes
POSSIBLE										
A69-1601-24005	N/A	na	N/A	N/A	RC Byrd	Greenup	RC Byrd	RC Byrd	Both?	Only Greenup detection came from the lower approach of RC Byrd L&D. The other 23,834 detections in 2017 came from receivers in the RC Byrd Pool;
A69-1601-27339	SVC	na	Meldahl	2014	Meldahl	Meldahl	Greenup	Meldahl	Both?	Most of the 6000+ detections in 2017 came from Meldahl, except for the ~20 detections in early May that occurred in the upper approach of Greenup L&D;
A69-1601-27380	SVC	na	Meldahl	2014	Meldahl	Meldahl	Greenup	Meldahl	Both?	Approx. 13,000 detections in 2017 came from VR2's in the Meldahl Pool, which doesn't include the 18 times it was found in the US approach of Greenup L&D;
A69-1601-27381	SVC	na	Meldahl	2014	Meldahl	Meldahl	Greenup	Meldahl	Both?	Detected in Meldahl throughout 2017, except between 5/2 and 5/21 when ~30 detections were made by a VR2 in the US approach of Greenup L&D;
A69-1601-27404	SVC	na	Meldahl	2014	Meldahl	Meldahl	Greenup	Meldahl	Both?	Except for 1 detection made on 4/18 in the US approach Greenup L&D, Tagged AC #27404 spent all of 2017 in the Meldahl Pool.
A69-1601-27414	SVC	na	Meldahl	2014	Meldahl	Meldahl	Greenup	Meldahl	Both?	Aside from 8 detections in May that were made in the US approach of Greenup L&D, Tag #27414 was only detected by Meldahl VR2's during 2017.
A69-1601-56546	BHC	F	Meldahl	2016	Meldahl	Meldahl	Greenup	Meldahl	Both?	Detected only by VR2's from the Meldahl Pool during 2017, with the exception of a single detection made in the US approach of Greenup L&D on 6/21;
INVALID										
A69-1601-57990	BHC	M	Markland	2016	McAlpine	McAlpine	Markland	Markland	US	Identified as a transfer after being falsely detected by a VR2W in the KY River; But Tagged AC #57990 actually spent the entire year in the Markland Pool;

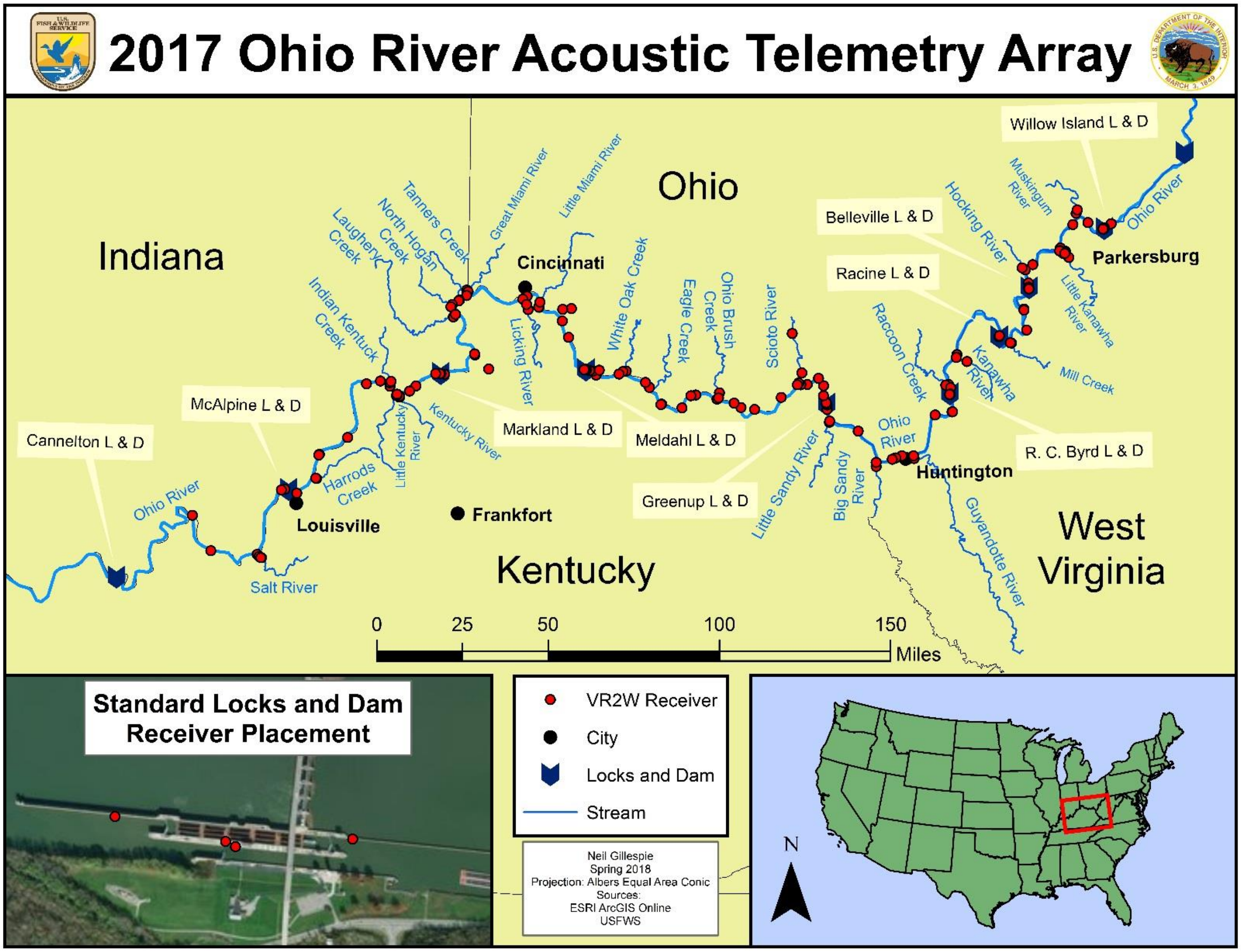

Figure 1. Locations of stationary VR2W and VR2AR receivers in 2017. Individual points may represent more than one receiver at this scale.

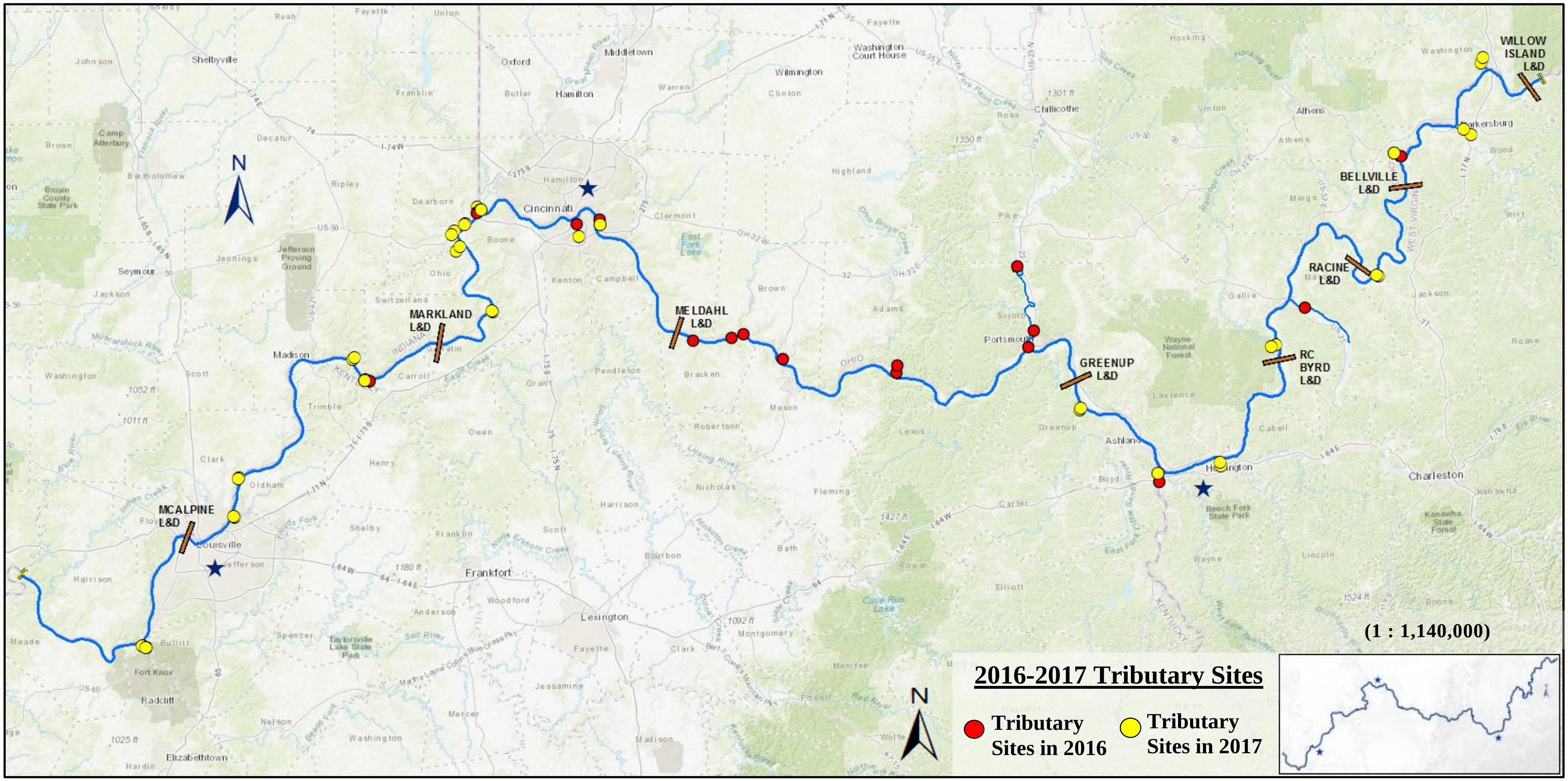

Figure 2. Distribution of the receiver stations that were located in tributaries during 2016 - 2017. The 2017 efforts to extend the project's receiver coverage of tributaries succeeded in establishing as many as two new stations in 15 previously unmonitored streams and small rivers, which was in addition to the 13 tributaries that already contained receiver sites by the end of 2016.

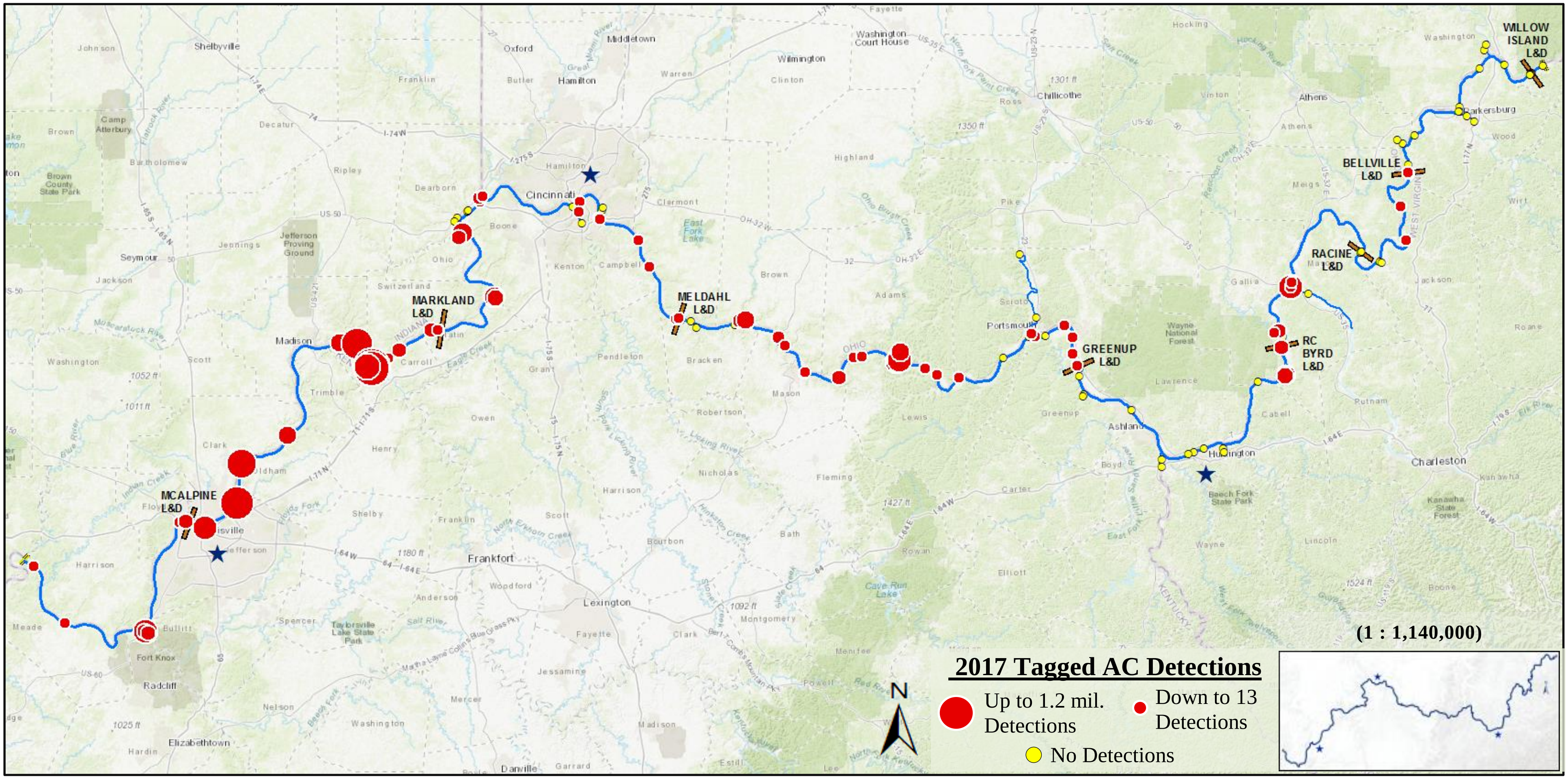

Figure 3. The distribution of the receiver stations that made at least one valid detection of a tagged Asian Carp in 2017. The diameter of each red circle on the map corresponds to the total amount of tagged carp detections that were made by the receiver that had been deployed to that location.

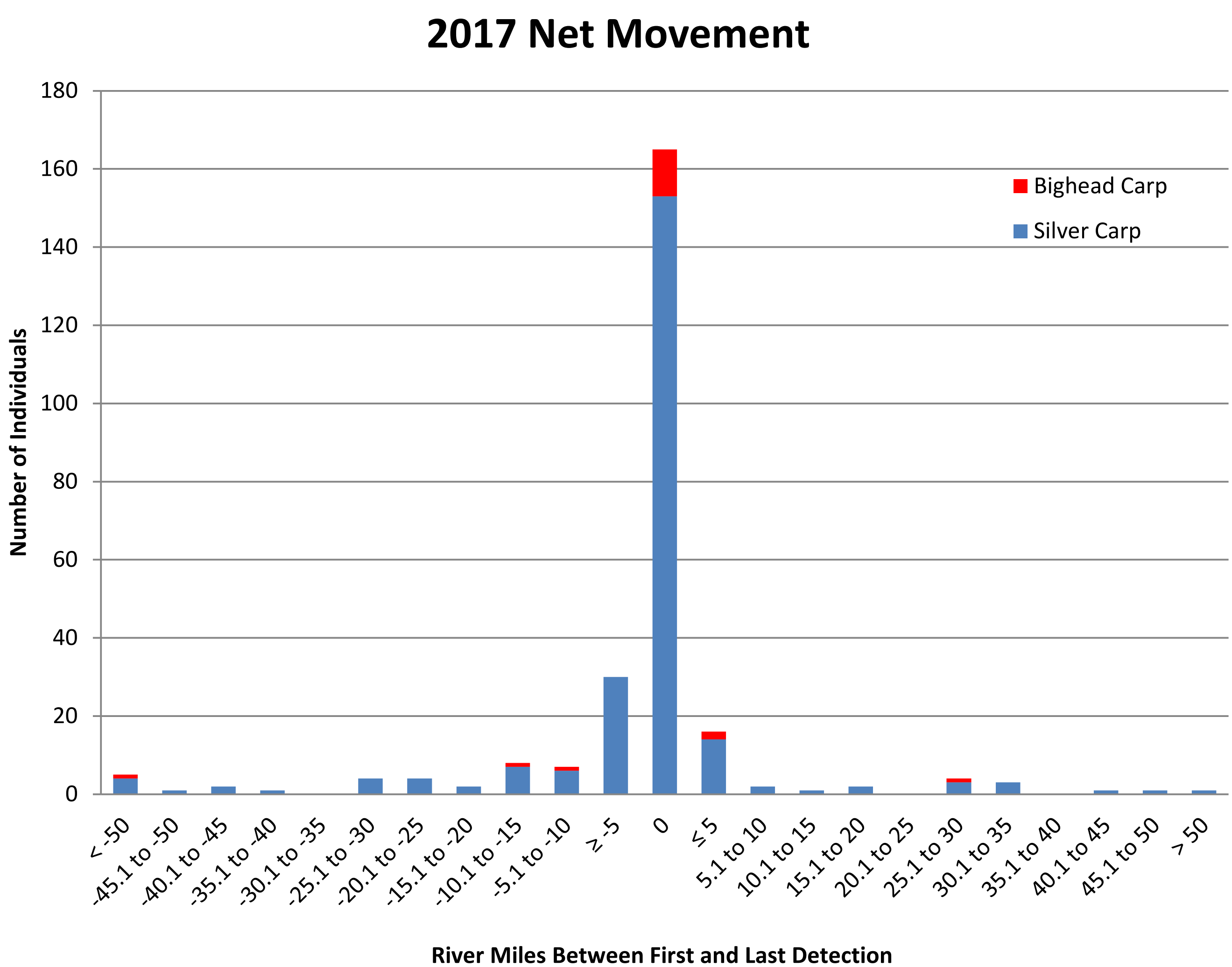

Figure 4. Net upstream and downstream movement of Asian carp in the Ohio River from first to last detection in 2017.

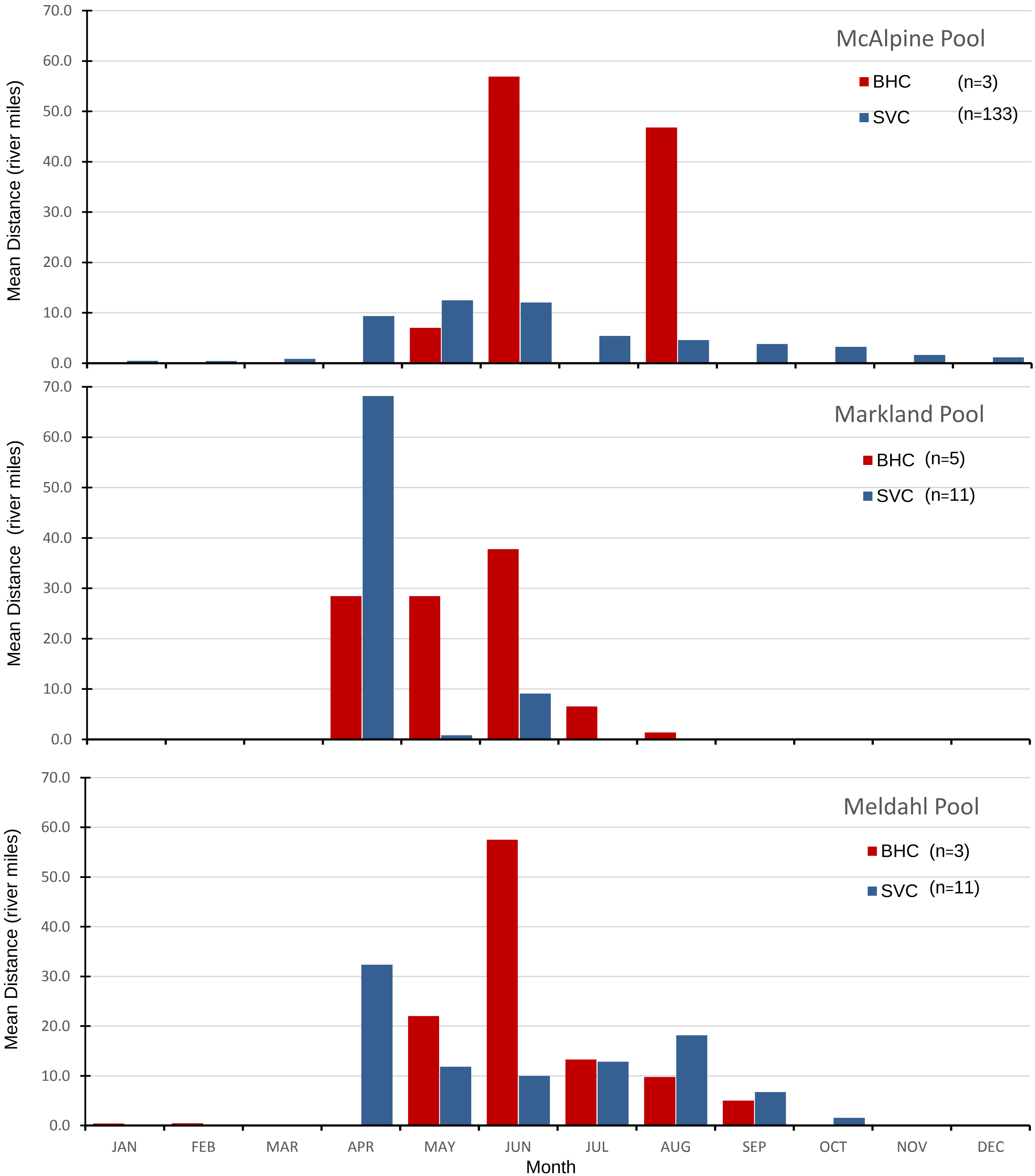

Figure 5. The mean monthly distances (in river miles) between the most upstream and downstream detections for tagged Bighead Carp and Silver Carp in the three most active pools of the telemetry project. Only tagged carp that were detected by 2 or more receivers during 2017 were included in the distance calculations.

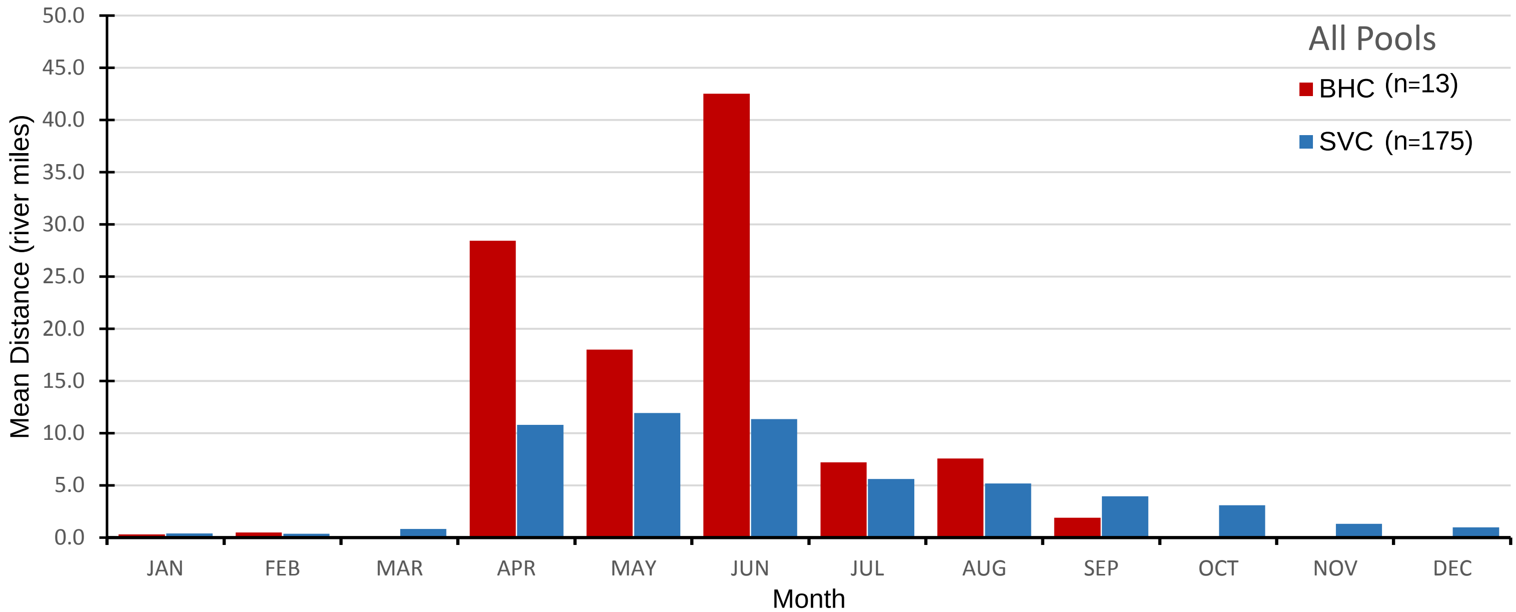

Figure 6. The mean monthly distances (in river miles) between the most upstream and downstream detections for all tagged Bighead Carp and Silver Carp that were detected by 2 or more receivers during 2017

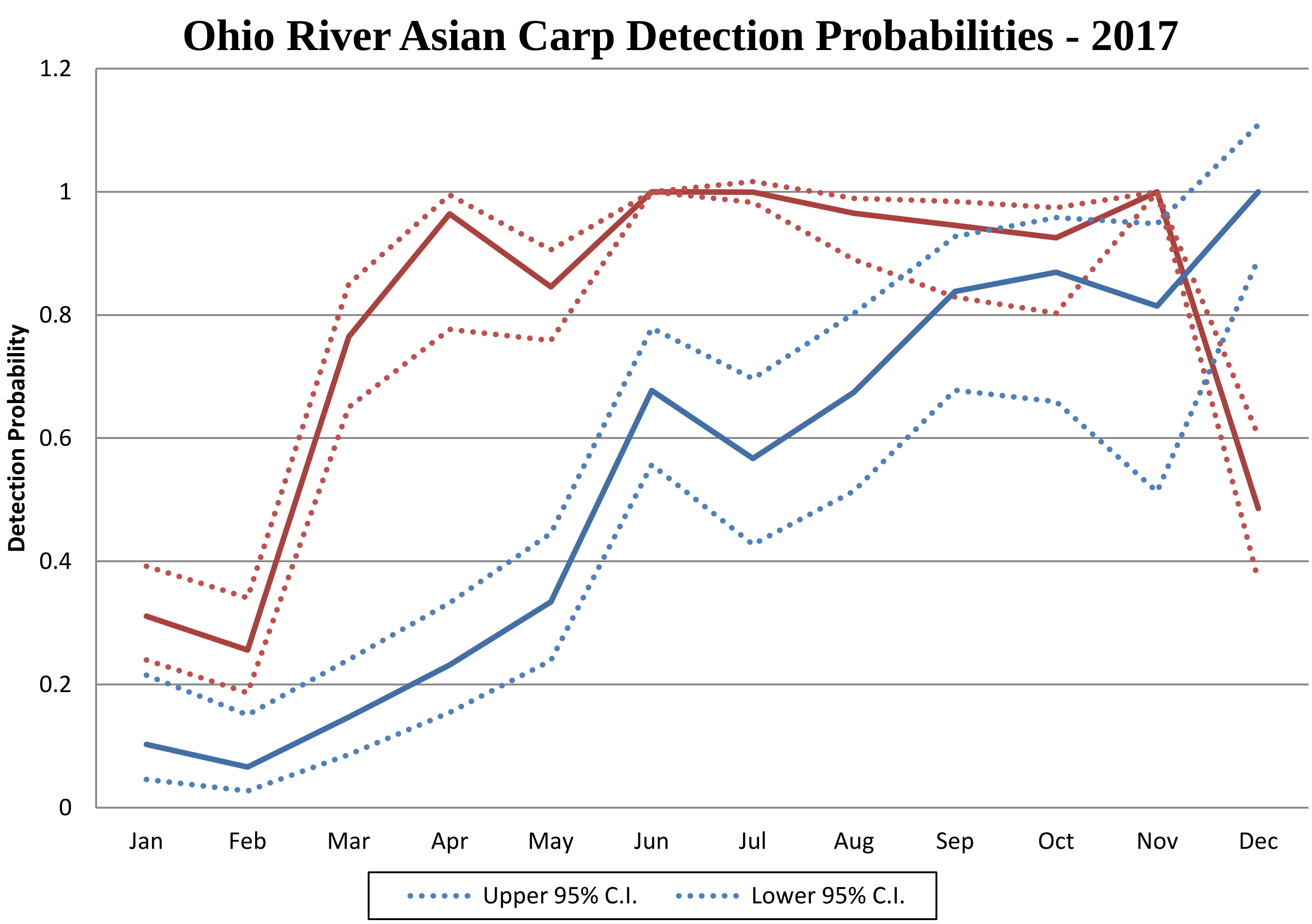

Figure 7. Detection probabilities with upper and lower 95% confidence intervals of telemetered Asian carp within the mainstem Ohio River and its tributaries during 2017.

2017 Annual Interim Report

Project Title: Relative Population Densities, Movements, and Spawning Success of Asian Carp in the Tennessee River and Cumberland Rivers, Tributaries of the Ohio River

Geographic Location: Ohio River Basin; Tennessee and Cumberland rivers

Lead Agency: Tennessee Wildlife Resources Agency

Agency Collaboration: Kentucky Department of Fish and Wildlife Resources (KDFWR), Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), Alabama Department of Conservation and Natural Resources, Murray State University (MSU), Tennessee Technological University (TTU), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS).

Statement of Need: Baseline information on Asian carp populations and invasion movements in the Tennessee and Cumberland rivers.

Project Objectives:

1) Conduct targeted sampling for the purpose of surveillance, early detection, distribution, and relative population characteristics of Asian carp in the Tennessee and Cumberland rivers.
2) Evaluate lock and dam passage of Asian Carp and movements among reservoirs
3) Evaluate reproductive success, established leading edges, and age – 0 abundance of Asian carps in Kentucky and Barkley reservoirs.

Project Highlights:

In 2017, intial Federal funding to support and execute objectives of the Ohio River Basin Asian carp control strategies were implemented in the Tennessee and Cumberland rivers, tributaries to the Ohio River. Primary goals focused on collecting baseline information on population densities and developing a framework to monitor lock and dam passage, using acoustic telemetry technology, to inform upstream invasion. The final goal was to conduct spring and summer sampling for juvenile Asian Carp to help inform the current reproductive capacity and success within Kentucky Lake and Barkley Lake.

Objective 1 Methods TWRA,TTU:

Targeted sampling for adult bighead and silver carp was conducted in Kentucky and Pickwick reservoirs on the Tennessee River and Barkley and Cheatham reservoirs on the Cumberland river. Three reaches were sampled in the downstream reservoirs on both rivers (Figure 1), while two sites were sampled in the upstream reservoirs of each river (Figures 2 and 3). Short gill net sets (approximately 2 hours) and pulsed DC electrofishing were conducted at each site during Summer 2017. Overnight gill net sets were used to sample in Fall 2017 and Spring 2018. Gill net mesh sizes ranged from 3.5" to 5" and nets were constructed of multitwist monofilament. All bigheaded carp captured were measured (TL, mm), weighed (g), and gonad weights (g) were taken for females to help identify spawning seasonality. Lapilli otoliths were removed from the majority of individuals to inform population age structure. Otolith processing and age estimation followed methods of Ridgway and Bettoli (2017). Calculations of catch-per-unit-effort (CPUE) for each gear type will be used to compare relative densities within and among reservoirs and within reaches. Size structure, length-at-age, condition, sex ratios, and gonadosomatic index (GSI) values will be compared to assess differences in population characteristics among reservoirs.

Objective 2 Methods TWRA, TTU:

TTU procured and emplaced acoustic telemetry receivers across the locks and dams within the Tennessee River except for Kentucky Dam that was already monitored by KDFWR and MSU (see below). Receivers were affixed using either bottom set anchors or custom fabricated receiver holders suspended from lock walls. TTU will download data from receivers every few months to keep an updated data set of Asian Carp movements. TTU CRU will continue to work with the states of Mississippi, Kentucky, and Alabama to increase the number of tagged fish and increase efficiency of downloading receivers. Data from the navigation locks of Pickwick, Wilson, and Wheeler Dams were downloaded February 26th and 27th. Data from Duck River, RM 176.5, and the headwater and tail water of Pickwick will be offloaded at a later date in March because of dangerous boating conditions due to high water flows and dam discharges. All data will be shared with collaborators.

Fish intended for transmitter implantation were collected using electrofishing and gillnetting. Fish were held less than five minutes including the surgery procedure. Surgical procedures were similar to KDFWR methods below, however TTU used electro anesthesia to comply with university IACUC requirements and fish were not held in tanks to evaluate recovery. Cooperators developed and shared a “methods matrix” that identified the entire process for capture, handling, surgeries, and release to facilitate commonality and repeatability.

Objective 2 Methods KDFWR:

In Kentucky Lake, Silver Carp to be surgically implanted with acoustic transmitters were captured using a Paupier net. The Paupier net was operated by USFWS staff from Columbia, MO. Paupier net settings varied depending on water conditions and reaction of fishes. Paupier net sampling was conducted in the Sledd Creek and Big Bear embayments of Kentucky Lake for one night in each location in April, July, and October. Silver Carp were not implanted with transmitters in July due to high water temperatures. The fish were captured with the Paupier net and then transferred to a holding tank on a tender boat where surgeries were conducted. Murray State University provided the tender boat used for performing surgeries and assisted with surgeries on each occasion. In December Silver Carp in Lake Barkley Dam tailwaters were captured via targeted electrofishing runs and transferred to surgery stations on the bank. Electrofishing settings varied depending on water conditions and conductivity.

Prior to surgery all tools, tags and sutures were soaked in alcohol. Fish were placed upside down or on their side in cradles, a bilge pump was inserted into their mouths to keep fresh water on the fish’s gills and a wet rag was placed over their head. Using a scalpel, scales were scraped from approximately 1 ½ in x ½ inch area of fish lower abdomen just posterior of the pelvic fin. The area was then cleaned with betadine solution and the incision was made with as few cuts as possible until access to the abdominal cavity was obtained. Forceps were then used to open the incision and insert the tag into abdominal cavity. The incisions were closed with three stitches, tying each stitch with three knots. After the incision was closed, superglue was applied over the stitches. Once the surgery was complete the fish was tagged with an exterior marker of a jaw tag or self-locking loop tag. Jaw tags were applied to the lower jaw and crimped into place with pliers. Loop tags required a needle to be used to pierce the flesh and insert the tag directly posterior of the dorsal fin where the tag extended through the either side of the fish and the ends locked together. After surgery and exterior tagging was complete, fish were released directly back into the water body from which they were captured. If the fish did not swim vigorously from release location, it was held by the tail until equilibrium was achieved and strong muscle contractions became obvious. Fish that did not recover were euthanized and the tags removed. KDFWR conducted manual tracking efforts on Kentucky Lake to locate tagged Silver Carp.

Manual tracking was accomplished by using a VR100 and omnidirectional hydrophone deployed from a boat. The hydrophone was lowered into the water at 1km intervals and monitored for at least two minutes before moving to the next location. It was determined through range testing that the omnidirectional hydrophone could detect transmitters from a distance of 500km. Therefore, stopping at 1km intervals provided sufficient coverage of the lake. Twenty-four-hour manual tracking efforts of individual Silver Carp were also conducted in Kentucky Lake. Four of these studies were attempted in 2017. Tagged Silver Carp were located from a boat using the VR100 and omnidirectional hydrophone. Once located, the directional hydrophone was utilized to hone in on the fish's location. When locations are determined, time, waypoints, water depth, temperature are recorded. The fish is then relocated every hour and the same information recorded.

In 2017 two VR2W stationary receivers were deployed in Lake Barkley on bottom stands. Two receivers were deployed in ladder wells of the Lake Barkley lock chamber with one receiver inside the lock chamber and one receiver outside of the lock chamber on the upstream approach wall. One receiver was deployed in the Lake Barkley Dam tailwaters on a channel marker buoy. Another receiver was deployed on a buoy in the canal between Kentucky Lake and Lake Barkley. Two receivers were deployed in the Kentucky Dam tailwaters on buoys. There are now 23 stationary receivers deployed throughout the northern portion of Kentucky Lake, Lake Barkley, and their tailwaters. Files are downloaded from all stationary receivers at least every other month throughout the year.

Objective 3 Methods TWRA:
Kentucky Lake and Barkley Lake were sampled in 2016 and 2017 to detect larval fish and inform potential in-lake spawning events. Light traps were deployed across the longitudinal gradient of the reservoirs and boat neuston net tows were conducted in the same locations. Samples collected with light traps and net tows were washed down and samples were split evenly into separate jars containing either ethanol or formalin. The justification for using two different preservatives was to ensure 1) that formalin preserved samples would facilitate identification, and 2) that ethanol preserved samples would allow genetic testing if identifications indicated presence of larval Asian Carp. Larval fish identification is being conducted by Dr. Quenton Fontenot at Nicholls State University.

Results and Discussion:

Objective 1 Results, TTU:

Electrofishing, short gill net sets and overnight gill net sets were completed for Summer and Fall 2017 across study lakes (Table 1, Figures 1-3). Approximately 950 person hours were expended during standardized sampling, and 671 bigheaded carp (60 bighead carp, 611 silver carp) were captured across gears. The majority of carp were captured in Lake Barkley (332 individuals), and overnight gill net sets had the greatest success, capturing 498 individuals across the four reservoirs. In addition to individuals captured during standardized sampling, bigheaded carp obtained via boat motor agitation and paupier boat sampling with USFWS were included in the total catch summary, increasing our sample size to 741.

Table 1. Completed and ongoing sampling to delineate relative densities of Asian carp in Kentucky Lake, Barkley Lake, Pickwick Lake, and Cheatham Lake.

Project Activity	**Sampling Location**	**Season**	**Year**
Electrofishing	Kentucky, Barkley, Pickwick, and Cheatham reservoirs	Summer	2017
Short Gill Net Sets	Kentucky, Barkley, Pickwick, and Cheatham reservoirs	Summer	2017
Overnight Gill Net Sets	Kentucky, Barkley, Pickwick, and Cheatham reservoirs	Fall, Spring	2017, 2018 (respectively)

Table 2. Catch summary for bigheaded carp sampling conducted in 2017.

Reservoir	Sample Site	Total # of carp captured
Lake Barkley	Barkley Dam	63
	Little River	207
	Saline Creek	96
Kentucky Lake	Kentucky Dam	80
	Big Sandy	24
	Duck River	84
	Johnson Creek	7
Cheatham Lake	Cheatham Dam	76
	Sycamore Creek	31
Pickwick Lake	Pickwick Dam	4
	Bear Creek	76
Total		**741**

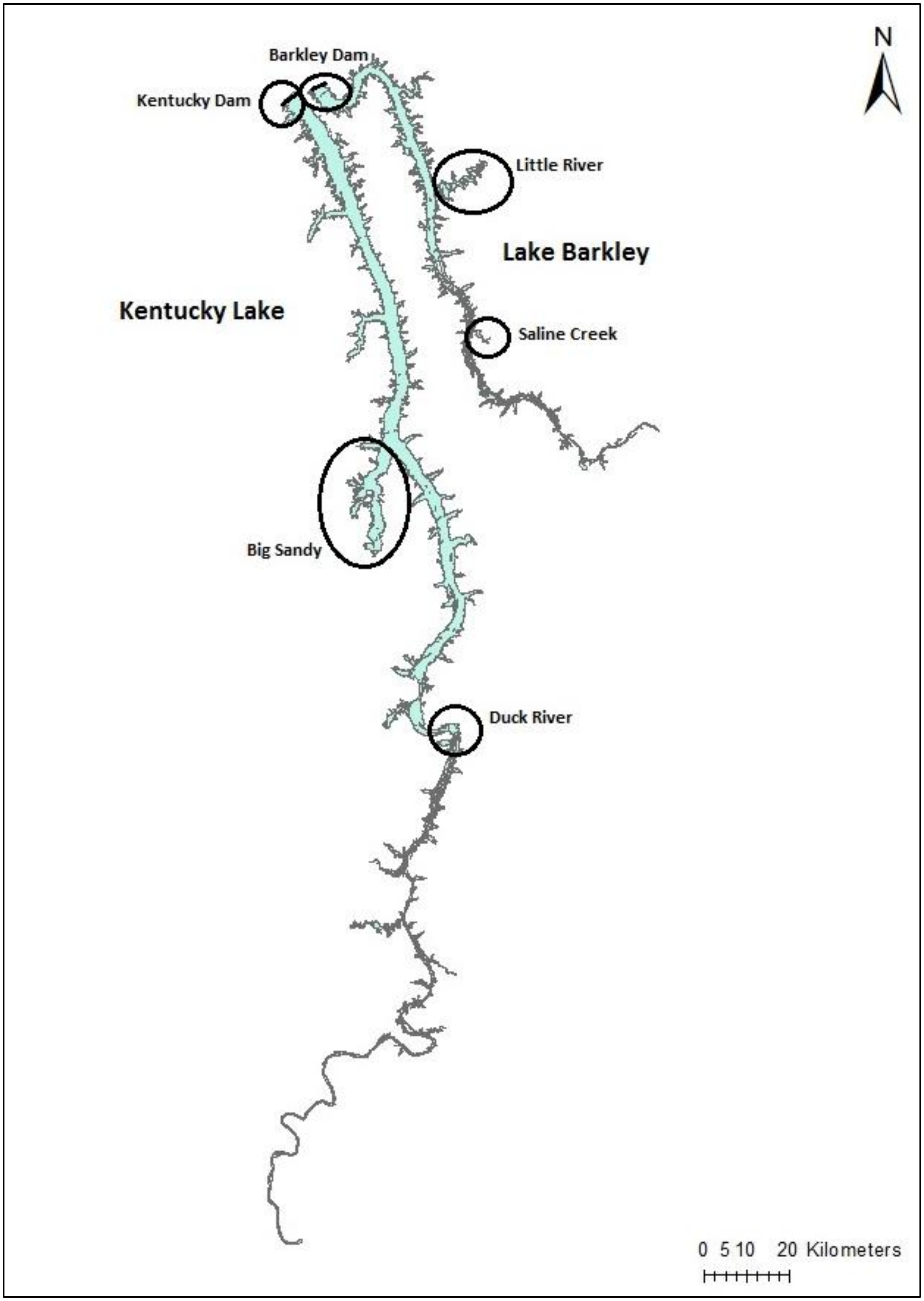

Figure 1. Sampling areas on Kentucky Lake and Lake Barkley.

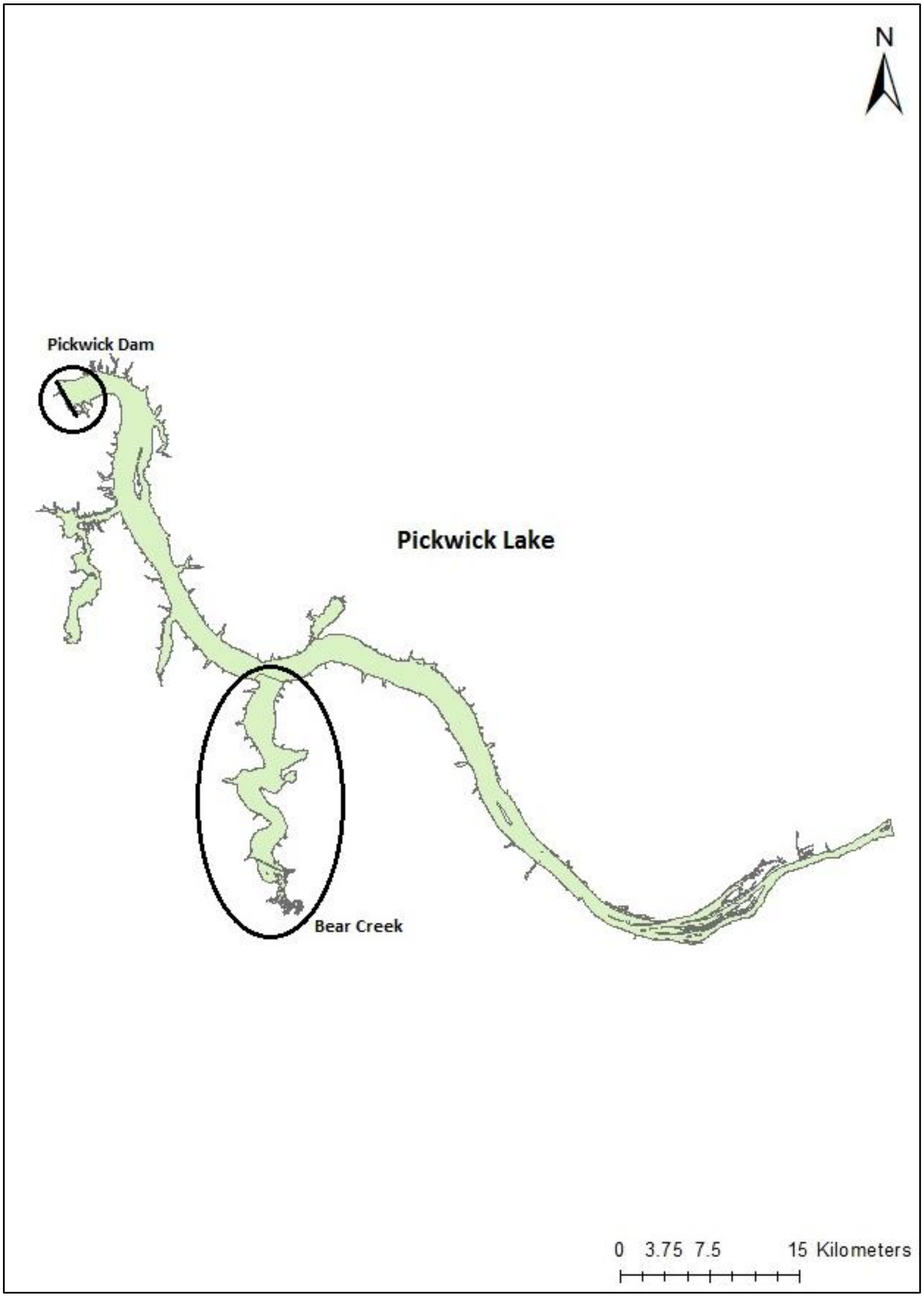

Figure 2. Sampling sites on Pickwick Lake

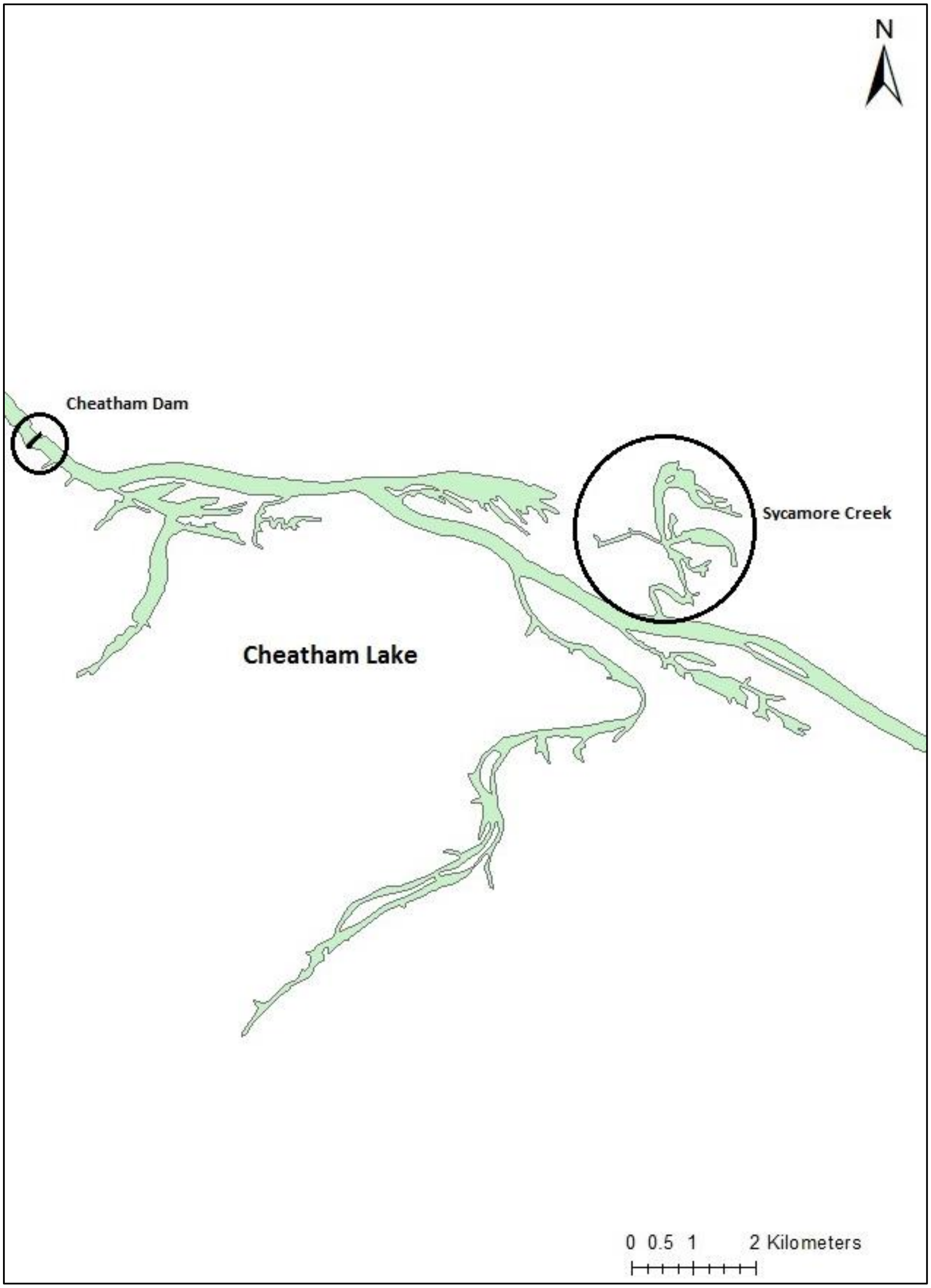

Figure 3. Sampling sites on Cheatham Lake

Objective 2 Results, TTU: TTU placed a total of 11 acoustic telemetry receivers within the Tennessee River system. These locations included one receiver in the lower Duck River, one receiver at RM 176.5, two receivers in the Pickwick Dam tail water, one receiver in the headwater of Pickwick Dam, and two receivers within each of the navigation locks at Pickwick Dam, Wilson Dam, and Wheeler Dam. TTU personnel met with KDFWR personnel in October, 2017 to discuss telemetry database structure, management, and data sharing.

TTU has surgically implanted acoustic telemetry transmitters in 54 Silver Carp in the Tennessee River. Within Kentucky Lake, 44 Silver Carp were implanted with acoustic telemetry tags within Tennessee waters to complement tagging occurring in Kentucky waters (32 individuals at Beech Creek, TN and 12 at Clifton, TN). Within Pickwick Lake, 10 Silver Carp were tagged at Indian Creek, MS. Tagging efforts will continue in Spring 2018 with intentions of continuing tagging in fall pending future funds.

Objective 2 Results, KDWFR and MSU:
In Kentucy Lake, sampling efforts with the Paupier net resulted in 30 Silver Carp tagged in Big Bear and 16 fish tagged in Sledd Creek embayments. This brings the total of tagged Silver Carp in the northern portion of Kentucly Lake to 115. Of the 46 total fish tagged in 2017, 10 are presumed to be deceased due to inactivity for extended periods of time. In the Lake Barkley Dam tailwaters, 20 Silver Carp were surgically implated with transmitters. By increasing the number of tagged Silver Carp in Tennessee and Cumberland river systems we can better quantify movement of these fish between resevoirs through lock and dam structures. These two river systems are connected directly through a canal between Kentucky Lake and Lake Barkley and several tagged Silver Carp have been detected passing through this canal by stationary receivers. Therefore, it is logical to monitor movement of Silver Carp in these two river systems in conjunction.

KDFWR completed 35 manual tracking trips on Kentucky Lake. --- Silver Carp were detected through manual tracking efforts. Three 24-hour tracking studies of individual Silver Carp were also completed.

Stationary receivers (Figure 4) had detections of Silver Carp. Other fish detected included paddlefish that had been tagged by Missouri Department of Conservation (MDOC). To date, only one Silver Carp has been detected passing through Kentucky lock. This fish was tagged in Kentucky Lake, was detected passing through the canal into Lake Barkley and then detected again several weeks later by stationary receivers in Kentucky lock, and on the upstream receiver on the lock approach. These detections took place prior to the receivers being deployed in the Lake Barkley lock. Therefore, it is assumed that this fish swam through the canal into Lake Barkley, downstream through Barkley lock, down the Cumberland River to the Ohio River, and back upstream through the Tennessee River to the Kentucky lock, where it passed back into

Kentucky Lake via the lock chamber. Two paddlefish tagged by MDOC have also been detected using the Kentucky lock chamber to access Kentucky Lake.

Figure 1. *Locations of current VR2W receivers deployed by MSU and KDFWR in Kentucky Lake, Lake Barkley and the lower Tennessee and Cumberland rivers.*

Objective 3 Results, TWRA:
In 2016, 80 light trap samples were collected and 25 contained larval fish. No Asian carp larvae were detected. In 2017, sampling was conducted from May 15 to August 11 and sampling included four days per week. In total, 140 light trap samples were collected at Kentucky Lake with 80 complimentary larval tows, whereas at Barkley Lake there were 130 light trap samples collected with 70 larval fish tows. Currently, over 25% of the samples have been sorted and identified with no detection of Asian Carp larvae. Most common species in samples have included members of the Centrarchidae, Clupeidae, and Atherinopsidae families. Sample sorting and identification will continue through spring 2018.

Discussion and Recommendation:
The distribution and abundances of bigheaded carps in the Tennessee and Cumberland rivers is still uncertain, which creates questions about control intensity, effort requirements, and leading edge to inhibit invasion. These uncertainties are a potential hindrance to implementing efficient controls. For example, TTU had multiple trips to Pickwick Lake with zero catches of Asian Carp, and yet, had one trip where they caught 74 in one night. The schooling nature of Asian Carp, movement rate, and gear avoidance make informing density data challenging after only one full sampling season. We recommend further sampling and gear evaluations for establishing density indices in these large reservoirs.

Passage of tagged Silver Carp through locks with remote receivers should be detected given the minimal passage opportunities through locks and with large dams. However, at Kentucky and Barkley locks, where the most effort has been, very few detections have been made. Therefore, we suggest increasing the number of tagged Silver Carp both below and above these lock structures across the Tennessee River. Increased numbers of fish tagged near Pickwick dam would also help as the detection infrastructure has greatly increased. This will allow us to better evaluate both upstream and downstream movements of Silver Carp through these structures. Additionally, we suggest increasing the number of stationary receivers deployed in Lake Barkley and in the lower Tennessee and Cumberland rivers. Lake Barkeley has received increased focus as a potential test barrier location, and thus, increased telemetry activity in that are would be beneficial. This action will expand coverage in these water bodies which will improve detection probabilities of tagged Silver Carp using these areas. Other studies have examined movement of Silver Carp in river systems extensively. However, there is still some lack of information regarding small scale movements of Silver carp in large resevoirs. At a higher level, there is a knowledge gap regarding usable habitat for these native riverine species in large reservoirs. In order to meet this need we recommend increasing the number of 24-hour manual tracking studies conducted in Kentucky Lake and Lake Barkley. These studies will aid in determining more precise information about Silver Carp movement and habitat usage in large reseviors.

Doubt regarding within-reservoir reproduction can only be improved through continued sampling at life stages that would not be expected to immigrate from the the Ohio River, and thus, light trapping and neuston netting to detect in-lake reproduction are necessary within the the Tennessee and Cumberland rivers with funding availability. Kentucky and Tennessee cooperators are providing samples for otolith michrochemistty to help inform the likelihood of reproduction within the Tennessee and Cumberland rivers systems.

UPPER MISSISSIPPI RIVER MONITORING PROGRAM 2017 ANNUAL INTERIM REPORT

The following projects represent individual reports by multiple agencies as part of a collaborative project covering a broad geographic scale for Asian Carp monitoring in the Upper Mississippi River.

DETECTION, CAPTURE RESPONSE, AND MONITORING OF INVASIVE CARP IN THE UNESTABLISHED ZONE: MISSISSIPPI RIVER POOLS 1-8, LOWER ST. CROIX RIVER, AND MINNESOTA RIVER

Submitted By: John Waters, Ben Larson, Joel Stiras, TJ DeBates, and Nick Frohnauer; Minnesota Department of Natural Resources

Geographic Location: Mississippi River Pool 8 through Pool 1; St. Croix and Minnesota rivers in Minnesota

Lead Agency: MN DNR

Statement of Need:

Bighead Carp *Hypophthalmichthys nobilis*, Silver Carp *H. molitrix*, Grass Carp *Ctenopharyngodon idella*, and Black Carp *Mylopharyngodon piceus* (hereafter collectively referred to as Invasive Carps) are invasive species currently found in the United States. These species were introduced into the United States during the early 1970's as aids in fish aquaculture operations (Henderson 1976). Subsequently, large flood events allowed these species to escape into the Mississippi River drainage, where they began reproducing and spreading (Freeze and Henderson 1982). Invasive Carps have migrated up the Mississippi River, and adjoining tributaries, quickly establishing populations in newly invaded areas. In Minnesota, Bighead and Grass carp have been collected in the Mississippi, Minnesota, and St. Croix rivers while Silver Carp have only been captured in the Mississippi and St. Croix rivers (Figure 1). Black Carp have never been collected in Minnesota or Wisconsin waters. Currently, there is no evidence of Invasive Carp reproduction in Minnesota waters.

Invasive Carps have the potential to devastate local ecosystems by competing with native planktivores and overcrowding other native species. With high fecundity and the ability to populate new areas quickly, Invasive Carps can reach high abundances, sometimes comprising most of the fish biomass in certain systems (MICRA 2002). Invasive Carps have a voracious appetite, and coupled with their large size (>70 pounds), have the ability to consume large amounts of food by filtering zooplankton, phytoplankton, and organic particles out of the water column (Jennings 1988; Smith 1989; Voros 1997). If Invasive Carp populations establish in Minnesota, native planktivores such as Paddlefish *Polyodon spathula*, Bigmouth Buffalo

Ictiobus cyprinellus, Gizzard Shad *Dorosoma cepedianum*, and the larval stages of many other native fishes may be in direct competition with Invasive Carps for food resources. Evidence from the Illinois River suggests that competition with Invasive Carps resulted in reduced condition factors for Bigmouth Buffalo and Gizzard Shad (Irons et al. 2007). Worldwide, introductions of Invasive Carps have led to declines in fish species diversity and abundances of commercially desirable species (Spatura and Gophen 1985; Petr 2002).

In fiscal year 2017, UMR partners continued development and implementation of a comprehensive and complementary early detection, monitoring, and population assessment program for Bighead, Silver, Grass, and Black carps in the UMRB. This fundamental information informed all aspects of prevention and control such as where to target early detection monitoring, where to consider containment measures such as deterrent barriers, where to target management actions to disrupt spawning and recruitment, and where to target control activities. Additionally, this effort will help evaluate the effects of proposed management actions (e.g., adult harvest, barrier at Lock and Dam 19). Sampling will use a diverse array of traditional and novel gears to sample all potential life stages in targeted areas.

The monitoring program is one segment of the UMR invasive carp effort. The findings help guide and evaluate other segments of the collaborative effort including the development of deterrents and implementing an effective harvest program. Results from 2015 and 2016 were used to develop distribution maps for each of the species. The information was combined with deterrent technology knowledge, lock and dam data, and control activity options to develop a deterrent strategy.

Project Objectives:

- Detect and monitor all life stages of Invasive Carps in the non-established zone to:
    - Inform management efforts in Minnesota; and
    - Provide information for Upper Mississippi River managers on carp population changes in the presence front.
- Monitor native fish species that may be affected by the establishment of Invasive Carps.

Project Highlights:

- In total, 90 days were spent sampling between January and December 2017.
- Seven invasive carp were acquired through the various methods.
- The MN DNR led a comprehensive response effort to a bighead carp capture in the Minnesota River that included multiple DNR and USFWS crews.
- The MN DNR captured, tagged, released, and tracked its first invasive carp (bighead carp) since being authorized by the Minnesota legislature.
- 757 stable isotope samples were collected from 40 species.

Sampling Sites:

In the Mississippi River, standard Invasive Carp sampling occurred in approximately 89 km of water from St. Anthony Falls Lock and Dam in Minneapolis, MN to Polander Lake in Pool 5A 5 near Winona, MN. In the St. Croix River, standard effort was focused on an 83 km stretch from the dam near Taylors Falls, MN to the confluence with the Mississippi River near Prescott, WI.

Sampling Methods:

Gears, methods, and targeted locations were derived from personal communications with biologists who have been sampling Invasive Carps (V. Santucci, Illinois Department of Natural Resources, personal communication; J. Lamer, Western Illinois University, personal communication) and conducting research on the most efficient gears to sample Invasive Carps (M. Diana, Illinois Natural History Survey, personal communication), literature review of sampling techniques and habitat preferences (Lohmeyer and Garvey 2009; Williamson and Garvey 2005; Dettmers et al. 2001; DeGrandchamp et al. 2007; Kolar et al. 2007; DeGrandchamp et al. 2008; Wanner and Klumb 2009; ACRCC 2012), and experience from prior field seasons. Sampling information for Invasive Carps included in this report took place between January 1, 2017 and December 31, 2017.

Commercial Fishing

Commercial fishermen were contracted to target Invasive Carp with gill nets and seines. Minnesota Department of Natural Resources (MN DNR) personnel accompanied contracted commercial fishermen to direct sampling locations and monitor efforts. The number of fish caught by species was estimated during gill netting operations and total weight harvested was requested from the commercial fishermen for both gill netting and seining operations.

Invasive Carp Acoustic Tagging and Tracking

In Minnesota, Statute 84D.05, Subdivision 1 stated “A person may not possess, import, purchase, sell, propagate, transport, or introduce a prohibited invasive species.” In 2017, the legislature passed and the governor signed an amendment to this statute: *Subd. 1a.* ***Permit for invasive carp.*** *The commissioner may issue a permit to departmental divisions for tagging bighead, black, grass, or silver carp for research or control. Under the permit, the carp may be released into the water body from which the carp was captured. This subdivision expires December 31, 2021.* As part of the permitting process, DNR fisheries developed a protocol to characterize and minimize potential risk while maximizing the amount of information gained (See MN DNR “Permit for DNR Divisions to tag and release invasive carp”). For further information regarding the tagging and tracking procedures, please see the permit issued by the Department of Natural Resource’s Division of Ecological and Water Resources.

Based on the tagging results, MN DNR staff will gain a better understanding of movement patterns and habitat preferences, while posing a very low risk to native fish populations or risk of increasing Invasive Carp populations. Other states have already begun work of this nature in riverine environments and have shown significant results and ability to remove additional fish with this tagging method. This information will be used to inform sampling and removal efforts. The DNR was permitted to tag one or two Invasive Carp at a time with acoustic tags. The DNR utilized both passive telemetry (a stationary receiver array already in place) and active tracking (using a portable receiver) to determine preferred habitats, longitudinal movement patterns, depth preferences, and specific locations for capture efforts.

The state of Minnesota has a total of 88 receivers from above the Coon Rapids Dam to Lock and Dam 5 in the Mississippi River, from the Mississippi River confluence at Prescott, WI to Taylor's Falls in the St. Croix River, and from the Mississippi River confluence to the County Road 6 bridge north of Delhi, MN, in the Minnesota River (river mile 209). 66 receivers are maintained by the East Metro office, eleven are maintained in the Minnesota River by the Hutchinson office (from river mile 18.7 to river mile 209), and eleven are maintained by the Lake City office in the Chippewa River and Pools 4 and 5 of the Mississippi River. In addition, the U.S. Fish and Wildlife Service maintains seven receivers in Minnesota waters and 47 additional receivers that extend downstream to Pool 19 near Keokuk, IA. Additional receivers are maintained by other states and universities that include, but are not limited to, 11 receivers maintained by the Missouri Department of Conservation from Pool 19 to the confluence with the Ohio River.

By tagging one or two Invasive Carp, we hope to capture additional Invasive Carp if they are present. Recapture actions will be taken, including the use of commercial fishermen, when tagged fish are in jeopardy of being un-trackable due to tag life nearing completion, leaving the passive array footprint, or to support removal of other conspecifics. The DNR will take all reasonable measures to ensure all tagged fish are tracked and their locations known through active tracking and an extensive passive tracking network. Comprehensive removal efforts will be employed to remove tagged and un-tagged fish from Minnesota waters.

The impacts of releasing wild-caught Invasive Carp back into the wild have been considered and are believed to be minimal when compared to the potential information gained from this project. As outlined in this report, MN DNR maintains an extensive monitoring and removal program to ensure populations are adequately sampled and document if reproduction is occurring in Minnesota waters to provide accurate information for Upper Mississippi River managers on carp population changes in the presence front. Finally, Minnesota is remaining conservative with only one or two fish permitted to be tagged and released at a time, with all other Invasive Carp euthanized.

Pool 2 Stable Isotope Analysis

With the financial support of the Minnesota Environment and Natural Resources Trust Fund (ENRTF) from the Legislative-Citizens Commission on Minnesota Resources (LCCMR), during the 2017 field season samples were collected from Pool 2 of the Mississippi River for Carbon (C^{13}) and Nitrogen (N^{15}) stable isotope analysis. The purpose of this project is to use stable isotope analysis to examine the aquatic food web within Pool 2 and provide baseline trophic data before Invasive Carp establishment. All Invasive Carp caught were to be euthanized and processed according to state sampling protocols and a pelvic fin clip was taken to determine trophic niche overlap with native fish to better understand the potential for management of native fish to control the spread of Invasive Carp and retain biological diversity.

Our goal was to collect 30 samples per species/species group in lower Pool 2. The sampling area will focus downstream of River Lake and extend to Lock and Dam 2 near Hastings. Samples were dried (using Cabela's Pro Series Dehydrator), stored in vacuum seal bags, and frozen. Samples were originally sent to the University of Minnesota for pre-processing and analysis; however, the mass spectrometer had problems which could not be repaired in a timely fashion. As a result, the contract with the University of Minnesota was nullified and samples were returned to the MN DNR. After completing a competitive bidding process, MN DNR contracted the pre-processing and analysis of these samples with Cornell University and are awaiting results at the time of publication.

Baseline samples were collected from zebra mussels, crayfish, snails, phytoplankton, zooplankton, invertebrates, detritus, leaves, and submerged aquatic vegetation during the summer (May-July). For mussels only zebra mussels were sampled, with 30 samples collected. Crayfish and snails (dominant species of each) were collected from hand picking or grab samples with 30 samples collected. A 63 micrometer plankton tow net and 500 micrometer plankton trawl net were used to collect phytoplankton and zooplankton samples. Zooplankton (Cladocerans and Rotifers) were allowed to evacuate their gut contents in refrigerated water, separated, and dried. The most abundant species of primary consumer invertebrates were dried and analyzed (which will likely include a Scrapper/Shredder (nymph mayfly), a Collector/Gatherer (Chironomid), and a Filter Feeder (nymph caddisfly, Hydropsychid)). In addition, 30 samples were collected for each of the 3 most abundant predatory invertebrate species. Thirty samples of detritus and leaves were collected throughout the sampling season. Submerged aquatic vegetation (curly-leaf pondweed, Eurasian watermilfoil, and Vallisneria) were collected and the samples will be pooled based on the most abundant species per site.
Fish were collected using a variety of gears with length and weight information collected for all sampled individuals. Fish sampling focused primarily during the fall (August-October). Predator fish species included Flathead Catfish, Channel Catfish, Sauger, and Walleye. Prey species included Gizzard Shad [*both large (individuals 1 year old or older, > 280 mm) and small size individuals (young of the year individuals or < 280 mm)], Emerald Shiners, Bluegill [both large (>90 mm) and small size (< 90 mm) individuals], Silver Redhorse, Shorthead Redhorse, and

Freshwater Drum. For Gizzard Shad, age-at-length determinations were based on previous research conducted by East Metro Fisheries staff from Pool 2. Other species analyzed included all Invasive Carp (Silver, Bighead, or Grass Carp) and Paddlefish, as well as 30 Common Carp, Bigmouth Buffalo, and Smallmouth Buffalo. Fish, excluding Invasive Carp, had a fin clip taken, and released alive. For all fish species (except Bluegill, Gizzard Shad, Paddlefish, and Invasive Carp) individuals sampled were tallied using length frequency bins to best achieve a wide range of lengths to determine if differences exist in trophic signature among size classes for each species.

Larval Trawling

Larval trawling was conducted in the Mississippi River Pools 2 and 3 and the St. Croix River to target early life stages of Invasive Carps. Eight standardized sites were sampled in Pool 2 (Figure 2), the St. Croix (Figure 3), and Pool 3 (Figure 4). A bow mounted icthyoplankton net (0.75 m x 3 m) consisting of 500 um mesh was pushed near the surface into the current so that the velocity of the water entering the net is between 1.0 to 1.5 m/s. At sampling locations where no water current exists (e.g. backwaters), sampling occurred towards a random direction that allowed for a complete sample to be taken in a relatively linear path. A mechanical flow meter was placed in the mouth of the net to determine the volume of water sampled. In 2017, water quality measurements were collected for all samples including surface temperature, dissolved oxygen, conductivity, and pH. A total of eight locations were sampled in each standardized system with two, 5-minute pushes conducted at each location. In Pool 2, Pool 3, and the St. Croix River, sampling sites were located in the following macro habitats: 4 main channel, 2 side channel, and 2 backwater locations in each system. For all samples, contents were placed in containers labeled with sample location, name of the water body, and date, and preserved. For preservation, samples were placed into 10% buffered formalin for 24-48 hours and then the formalin was removed and replaced by 90% alcohol. All samples were sifted to remove all excess material, with only eggs and fish kept. Fish and eggs were examined to determine if any Invasive Carp species were collected and to identify specimens to the lowest possible taxonomic level. Samples were also sent to an external researcher for verification and to create a reference collection of the species caught for future reference. Sampling site locations, sampling dates, gear description, effort, habitat type (main channel border, backwater, wing dike, etc.), water depth, and crew details were recorded for each site.

Buffalo Tagging

This study will provide information on population dynamics and movements of Smallmouth Buffalo and Bigmouth Buffalo in Pool 2 of the Mississippi River. From the literature and previous experience, Bigmouth Buffalo are often found with Silver and Bighead Carp. As a result this species is being studied to serve as a surrogate for tagging additional Bighead or Silver Carp.

Beginning in the spring of 2015, Buffalo sampled in the Mississippi River Pool 2 have been collected primarily from large mesh gill net and seine commercial fishing operations, as well as standard large mesh gill nets, trammel nets, and electrofishing have been tagged. Buffalo are tagged externally with a yellow Floy t-bar tag, along with a secondary mark by removing one pelvic fin ray. This allows recaptured Buffalo to be identified for as long as the tags are retained (>4 years) and to assess tag retention. Pelvic fin rays are being used for ageing purposes to determine variation in movement patterns by age as well as validate ageing techniques by re-ageing recaptured fish using the original fin when the fish was tagged and the fin clip when the fish is re-captured in subsequent years. To date, no known studies have validated Buffalo ageing techniques.

As one of the United States' most prolific and valuable freshwater commercial fisheries, it is also imperative that fisheries managers develop management plans and quotas to ensure populations are sustainably harvested and do not become overfished. Further, Buffalo are native to the United States, occupying a distinct ecological niche that may ultimately be filled by Invasive Carp species should Buffalo populations become overfished. Bighead and Silver Carp have adverse effects on all life stages of native fish species because they feed on plankton, the primary food source of several adult fish (Irons et al. 2007), all larval fish (Schrank et al. 2003), as well as all mussel species (Kolar et al. 2007) creating cascading trophic effects throughout the food web. The full impacts of Invasive Carp, should they become established in Minnesota, cannot be well documented without this biological data from commercial fish species.

Electrofishing

Electrofishing occurred in a variety of habitats including backwaters, side channels, main channel borders, and over wing dikes. Sampling locations consisted of 8 standardized sampling locations in Pool 2 (Figure 2) and the St. Croix River (Figure 3), and all other sampling events occurred at non-standardized locations in the aforementioned habitats at the discretion of the sampler. Standardized sampling locations were selected based on habitats Invasive Carps are likely to occupy and are 1/3 mile (500 meters) in length. At these set sampling locations, all observed fish were collected, identified, measured and weights and ageing structures were taken from fish included in the age and growth analysis. If positive identification was not possible, voucher specimens were kept, labeled, and preserved in 90% ethanol for later identification. At non-standardized sampling sites, fish were identified in the water and only fish needed to collect ageing structures and Invasive Carps were collected. This reduced unnecessary processing time and allowed for greater sampling effort. Sampling site locations, sampling dates, gear description, effort, habitat type (main channel border, backwater, wing dike, etc.), water depth, and crew details were recorded for each electrofishing run.

Trap Netting

Trap netting was conducted on Pool 2 of the Mississippi River in 2017 using standard and mini-fyke nets. Trap netting was not conducted in the St. Croix River this field season. The mini-fyke nets consist of a double frame (27 in. x 39 in.), 4 hoops (2 ft.), a single throat, and a 25 ft. lead, with a square mesh size of 0.125 in. throughout. All fish were identified and enumerated in the field.

Seining

A small 35 foot seine was proposed to be used to sample shallow water habitats for young fish from June through September on Pool 2 and the Minnesota River; however no small seine hauls were completed in 2017 due to high waters and high juvenile fish catch in trap nets. The seine measure 35 ft. long and 6 ft. deep with 3 ft. square bag (3 ft. x 3 ft. x 3 ft.) located at the center of the net, consisting of "Ace"-type nylon netting 1/8 in. mesh, with a mudline.

Fish Tagging Efforts

Currently several species of fish in the Mississippi River Pool 2 and the St. Croix River are tagged according to study guidelines as part of ongoing tagging studies when encountered. These species included Flathead Catfish *Pylodictis olivaris*, Channel Catfish *Ictalurus punctatus*, Smallmouth Buffalo *Ictiobus bubalus*, and Bigmouth Buffalo in Pool 2. In the St. Croix River, Lake Sturgeon *Acipenser fulvescens*, Muskellunge *Esox masquinongy*, White Bass *Morone chrysops*, Flathead Catfish, and Channel Catfish are being tagged. In both Pool 2 and the St. Croix River, Paddlefish are also tagged.

Age and Growth Analysis

In 2017, age and growth analyses were limited to Smallmouth Buffalo and Bigmouth Buffalo. Bigmouth Buffalo are native planktivores that may be in direct competition with Bighead and Silver Carp. Smallmouth Buffalo, as well as Bigmouth Buffalo, are commercially important and a better understanding of these species will be useful to determine effects from commercial fishing and/or the presence of Invasive Carp. For the previously mentioned species, lengths, weights, and ageing structures were collected as follows: for fish less than 300 mm, up to 5 individuals in each 10 mm length group and for fish 300 mm and greater up to ten individuals in each 25 mm length group. For Smallmouth and Bigmouth Buffalo, pelvic fin rays were extracted and compared. During the 2015, 2016, and 2017 field seasons, nearly 4,000 Smallmouth and Bigmouth Buffalo (1,882 Smallmouth Buffalo and 2,182 Bigmouth Buffalo) have been tagged with Floy tags and their pelvic fins were removed for ageing and to validate ageing analyses using re-captured fish in the future as part of another study. Fin rays were dried and cut using a low-speed isomet saw. Two independent readers counted each opaque band as an annulus under a dissecting microscope, using both reflected and transmitted light sources. If counts differed between readers, the readers re-examined the structure independently a second time. If readings differed the second time, the readers conferred until a consensus was reached. The results of this study are presented in an annual MN DNR tagging report.

Gill and Trammel Netting

Gill netting and trammel netting occurred during multiple sampling events on each system. Large mesh gill nets of depths from 8 to 24 feet and lengths of 150 to 300 feet with square mesh sizes of 4 to 6 inches were used to target adult Invasive Carps. Trammel nets with outside wall square mesh sizes of 14 inches and inner square mesh sizes of 4 inches were also used to target adult Invasive Carps. Experimental gill nets 250 feet in length and 6 feet deep consisting of 50 feet complements of net with square mesh sizes 0.75, 1, 1.25, 1.5, 2 inches were used to target juvenile Invasive Carps. Nets were set either short-term or overnight, with short-term sets favored when water temperatures were greater than 60º F. All fish caught were identified and measured.

Invasive Carp Blood Hormone Analysis

November 29 through December 1, 2016 Minnesota DNR personnel traveled to Illinois to work with Western Illinois University researcher Dr. Jim Lamer along with commercial fishermen to track acoustically tagged Silver and Bighead Carp in Pools 17 through 20. In addition to gaining experience tracking tagged Invasive Carp, MN DNR staff were able to collect 61 blood samples to determine if hormone levels in blood could be used to determine the sex and maturity of fish without lethal analysis. Ten males and ten female Silver and Bighead Carp were collected and nine male and ten female Grass Carp were collected. Approximately 10 ml of blood was drawn for plasma hormone analysis in the field and placed in a Vacutainer tube with heparin. Surgical incisions were made in the field to validate sex and reproductive status of individuals. Blood samples were immediately put on ice and centrifuged within 12 hours. Plasma was extracted from centrifuged samples and plasma was then placed in a deep freezer until analysis.
Plasma sex steroids, including estradiol, testosterone, and 11-ketotestosterone, regulate spawning behavior and gonad development in many fish species. Concentrations of these sex steroids follow predictable cycles that have been used to accurately determine sex and reproductive status of many fish species. This research will help determine if estradiol, testosterone, and vitellogenin could be used to determine sex and reproductive condition in Silver, Bighead, and Grass Carp. If this proves to be effective, it will also be used to test temporal changes in sex steroid concentrations to identify potential spawning dates.

Analyses of these samples were analyzed by Dr. Joshua Lallaman at St. Mary's University in Winona, MN. Overall differences in mean plasma hormone concentrations between sex and reproductive condition will be tested using a 2-Factor ANOVA and a stepwise-discriminant function analysis will be used to determine if sex and spawning condition could be correctly classified by hormone concentrations. If this research shows potential for determining sex and maturity, Invasive Carp caught in Minnesota will also be sampled in this manner for confirmation of this method.

Results and Discussion:

Sampling Results

In total, 90 days were spent sampling between January and December 2017 on the Mississippi River Pool 1, 2, 3, 4, and 5, and the St. Croix River with gears appropriate for sampling Invasive Carps (Table 1)(Figure 5). A greater amount of effort was focused on Pool 2 and the St. Croix River, because Invasive Carps were found above Lock and Dam 2 on the Mississippi River in 2014 and due to the finding of multiple Bighead Carp at the Allen S. King Plant discharge on the St. Croix in 2015. In 2017 there was also an increase in field sampling off the Minnesota River due to a Bighead Carp captured near Redwood Falls in June 2017 and previous captures.

In 2017, a total of 3 Bighead Carp were caught in Minnesota waters and Wisconsin boundary waters (Table 2). One mature female Bighead Carp was collected near the confluence of Pool 3 and the St. Croix River at Point Douglas by commercial fishermen on March 10, 2017. In addition, the first Silver Carp captured on the St. Croix River was collected in this commercial seine haul at Point Douglas. On March 10, 2017 and April 2, 2017 in two separate seine hauls, two mature male Silver Carp were caught at Point Douglas. Though this is the first capture of Silver Carp on the St. Croix River, these fish were found very close to the confluence with the Mississippi River and Silver Carp have been captured further upstream on the Mississippi River in 2014 when two were caught in Pool 2 in Lower Grey Cloud Slough. On April 11, 2017 in a contracted commercial gill net one mature male and one mature female Grass Carp were caught in Pool 2 in Lower Grey Cloud Slough.

On June 4, 2017 a mature female Bighead Carp was shot by a bowfisherman in a small gravel pit off the Minnesota River near Redwood Falls, MN. This represents the furthest upstream this species has ever been observed in the Minnesota River. The bowfisherman called the MN DNR Invasive Carp reporting phone number and the fish was picked up on June 5th. As a result of this capture, MN DNR staff worked with land owners to prepare a plan to survey the property and subsequently sampled these pits using over 3,000 feet of large mesh gill nets on June 9th.
A larger, collaborative effort took place on June 16th. DNR fisheries crews from East Metro and Hutchinson offices set another 3,000 feet of large mesh gill nets in the pits, electrofished within the pits and nearby sections of the Minnesota River, and set 12 hoop nets in the Minnesota River near Granite Falls, MN. The U.S. Fish and Wildlife Service collected 66 eDNA samples in the pits and electrofished on the river near Granite Falls, MN. No additional Invasive Carp were caught in these efforts and all eDNA samples collected tested negative for Invasive Carp DNA. Otoliths were shipped to Dr. Greg Whitledge at Southern Illinois University of microchemistry analysis. Otolith microchemistry results suggest that this fish was born in an environment inconsistent with the Mississippi, St. Croix, or Minnesota rivers and was most recently also

inhabiting existing areas inconsistent with the Minnesota River. Based on these results, we are still unsure where this fish lived and how long it had been within these gravel pits.
Lastly, on July 28, 2017 a Bighead Carp was caught by MN DNR staff at the Allen S. King plant on the St. Croix River as part of routine monitoring of this area. This was the first Invasive Carp to be tagged with an acoustic transmitter and released in Minnesota. Preliminary results of this tagging can be found below.

Contracted commercial fishermen were hired to use large mesh gillnets and seines to sample in the Mississippi River in Pools 2, 3 near Red Wing, Pool 4 near Lake City, and Pool 5A near Winona, and in the St. Croix River from Lake St. Croix to the confluence with the Mississippi River near Prescott, WI. Contracted commercial fishermen set approximately 57,600 feet of gill nets during eight days of effort and conducted four seine hauls between January and December 2017. Gill nets were set short term (2-3 hours) and fish were chased towards the net with boats, typically in large backwater areas. In 2017, nine regular commercial fishing operations were also monitored for the presence of Invasive Carp.

Larval trawling was conducted for 143 total trawls during 10 days by the Invasive Carp fisheries personnel. All samples were sifted by Invasive Carp fisheries personnel and all samples with fish larvae or eggs are preserved and have been sent to Colorado State University for expert analysis to determine the species caught and their respective number.

Both random and standardized electrofishing sampling was conducted on Pool 2 of the Mississippi and the St. Croix rivers. A total of 2,078 minutes of "on time" over 29 days were spent electrofishing between January and December 2017. In 2017, 5 standardized electrofishing sites were sampled once for a total of 115 minutes. Random electrofishing was used to monitor for Invasive Carp and for collection of individuals for age and growth and stable isotope analyses.

Trap netting was conducted using fyke nets for a total of thirty net nights on Pool 2 of the Mississippi River. All fish were counted and measured in mini fyke nets, except Emerald Shiners *Notropis atherinoides* and Common Carp *Cyprinus carpio* due large numbers captured.
Gill nets and trammel nets set by MN DNR personnel were often used to sample behind wing dikes and in smaller side channel and backwater areas where it wasn't feasible for commercial fishermen to target with their larger operations. In 2017, a total of 33,400 feet of gill and trammel nets were set in Pool 2 and the St. Croix River during 24 days, with most net sets being short-term sets (2-5 hours).

Numerous unique or rare native fishes worth mentioning were encountered during these sampling events. Of note for 2017, four Crystal Darters were collected on the St. Croix River near Taylor's Falls in June in one day, and the first confirmed collections of Brassy Minnow

Hybognathus hankinsoni and Hornyhead Chub *Nocomis biguttatus* on the St. Croix River and Central Mudminnow *Umbra limi* and Silver Chub *Macrhybopsis storeriana* on Pool 2 for the Invasive Carp monitoring program. Also, from past experiences and in conjunction with tracking the tagged Bighead Carp, a large number of Paddlefish were caught and jaw and acoustic tagged as part of other MN DNR studies. A complete species list of species caught and observed on Pool 2 and the St. Croix River from January 2013 through December 2017 has been compiled (Table 3).

Determining if invasive carp seen in Minnesota are pioneering individuals or are indicative of a population is a key question for managers. While it is likely there are additional Invasive Carp present in the Minnesota waters of the monitored rivers, the level of effort invested and resulting capture data support the hypothesis that the carp currently present are individual, wandering adults and not part of a population.

Invasive Carp Acoustic Tagging and Tracking

On July 28, 2017 during routine monitoring at the Allen S. King Plant on the St. Croix River, a Bighead Carp was caught by MN DNR staff in a large mesh gill net. The fish was then tagged using a VEMCO V16TP-6H (Vemco Ltd., Nova Scotia, 69 kHz) continuously transmitting acoustic tag containing sensors to measure pressure (depth) and temperature transmitting every 60 seconds on average (minimum transmission delay of 30 seconds, maximum delay of 90 seconds) and released. This fish was actively tracked using a VEMCO VR100 every day for a week after release, followed by actively locating the fish once a week every week until September 5, 2017. After September 5, 2017 the fish was located routinely until the last day in the field on November 20, 2017. In addition, this fish was routinely identified and data recorded by the passive VR2W receiver array in place, with the last VR2W downloaded on November 20, 2017 and the last detection using active tracking and the VR100 occurring on November 27, 2017. Details of when and where this fish were located can be found in Figure 6. Over this time frame, we received 30,388 data points from the VR2W array up until November 20 (115 days) and 319 data points from active tracking with the VR100 up until November 27 (122 days). This fish was observed to range over an extent of 17.6 river miles from Stillwater, MN to the mouth of the Kinnickinnic River (Figure 6). Over the course of this first field season, several areas of recurring use were observed including near the King Plant during July and August, around Afton State Park in August and September, and Lake St. Croix in October, 2017 through February, 2018.

From the temperature and depth data, it appears this fish comes to the water's surface more often and inhabits a wider range of depths, 0 to 68.6 feet, than commonly believed (Figure 7) and tolerates temperatures ranging from 84 to 35.4 degrees Fahrenheit (Figure 8). On two occasions, the temperature the Bighead Carp was experiencing was colder than the Stillwater USGS gauge data, occurring on September 15 through 18 and again on September 24 through 26. During these times, the fish was inhabiting the area from the Kinnickinnic to Catfish Bar off Afton, MN. This time was associated with deep dives including the deepest dive observed over the study period to 68.6 feet. Before these colder periods, the fish was occupying habitats further upstream including close to Catfish Bar and even Lake St. Croix, inhabiting the area around Afton State Park during this period, and afterward returning back upstream to Catfish Bar and Lake St. Croix.

Recapture efforts occurred in November prior to ice up. Over 2 number days, 7250 feet of gillnet, 1 hour of electrofishing, and 12000 feet of large mesh commercial gill nets were deployed to recapture the fish. The fish was not recaptured. The Bighead Carp was suspended 20-30 feet below the surface which proved difficult to sample when the depth ranged from 50-60 feet deep in the area. Standard gill nets reach less than 25 feet from the surface or bottom and even commercial seines only reach 30-40 feet of water. From this experience, MN DNR has purchased additional 24 feet deep large mesh gill nets to better sample the Lake St. Croix and deeper St. Croix River habitats. The DNR is also exploring the purchase of a commercial sized purse seine. A second recapture effort will take place in spring 2018 after ice out.

From this tagged Invasive Carp, we have learned of additional areas where this fish has resided for prolonged periods of time including a potential overwintering site. Based on information from other areas tracking carp and historic sightings in Minnesota, the hypothesis was that this fish would inhabit the King Plant discharge periodically with forays to Lake St. Croix and overwinter near a point where flow is constricted on the river with the most likely location being at Point Douglas, near Prescott, WI. From the tracking data collected, the fish was never observed within the King Plant discharge again despite continued monitoring within the discharge. From July to October, the fish was observed to inhabit a much wider spatial range but did exhibit some site fidelity, inhabiting several key locations for prolonged periods of time. These locations will be sampled extensively during the 2018 field season to determine if other Invasive Carp also use these areas and if this tagged Bighead Carp can reveal the locations of other Invasive Carp using the “Judas fish” technique. Finally, data from October through the last detection in November indicates this fish overwintered in Lake St. Croix, occupying deeper habitats than originally hypothesized. It is hypothesized that the fish will move to shallower water in the spring.

Based on the findings of 2017, tracking methods will be adjusted accordingly for 2018. MN DNR staff will continue to track tagged fish and analyze the data to increase sampling efficiencies.

Pool 2 Stable Isotope Analysis

During May, June, and July baseline samples were collected in Pool 2 to determine the bottom of the food chain and what important fish species consumed over the course of the summer.

Baseline samples included algae, vegetation, detritus, phytoplankton, zooplankton, micro- and macro-invertebrates, crayfish, snails and mussels. In addition a few opportunistic samples of larval fish, fly larvae, and water scorpions were also collected. Overall, most species were collected as planned with several species absent from collection sites despite intense sampling (Table 4).

During August and September fish were collected and pelvic fin samples were collected to determine higher trophic levels. For all primary species, 30 samples were collected for each site to allow for comparison. Similar to baseline samples, most species were collected as planned with several species absent from collection sites despite intense sampling. As expected Bighead Carp, Silver Carp, Grass Carp, and Paddlefish were rare though several individuals were collected outside the study area (Table 5).

Mass spectrometry was contracted with the University of Minnesota for Carbon (C^{13}) and Nitrogen (N^{15}) stable isotope analysis. Due to problems with the mass spectrometer, the University of Minnesota could not complete analysis and samples were subsequently sent to Cornell University. Results are still pending.

Invasive Carp Blood Hormone Analysis
Overall, a discriminant function analysis was only able to categorize 50% of the samples correctly. This indicates that there was not good separation of genders based on the hormone data. There are some similar patterns in female data (all having high vitellogenin), but variable estradiol levels.

In general, the male data was very different between samples. Mature male Bighead Carp had high vitellogenin levels, whereas mature male Grass Carp had low vitellogenin levels. In Bighead Carp, immature males were the only group that completely separated from the mature males and female Bighead Carp. Gravid female Bighead Carp exhibited the widest range in estradiol values, while mature males showed the widest range in vitellogenin levels. In Grass Carp, mature males were the only group that completely separated from the immature males and female Grass Carp. Gravid female Grass Carp showed the widest range in both estradiol and vitellogenin levels. In Silver Carp, the majority of samples overlapped in hormone levels between mature males and mature females. Male Silver Carp showed the greatest range in vitellogenin levels while females showed the greatest range in estradiol levels (Figure 9).
This project was conducted in the winter of 2016 when presumably hormone levels are low in both male and female Invasive Carp. The technique shows promise to determine sex and maturity from these three species; however, high variability among individuals only allows discrimination at approximately 50%. Based on this data, future prediction of sex and reproductive status from plasma samples alone would be difficult. Due to the timing of this preliminary study, it is likely that hormone levels were suppressed and would show a different

pattern in spring and summer seasons when fish are undergoing physiological changes associated with spawning. Another round of validation samples would be beneficial to see how they would compare to late fall/winter samples collected in this study. It is possible there is be too much variability in hormone concentrations between males and females and this technique would not be effective; however, we believe this warrants another trial. It would of interest to conduct this study again in the summer to determine if sex and maturity can be better discerned during this time of year. In addition, recent research has shown that genetic markers have been developed to discern sex from fin clips from farm raised Silver and Bighead Carp in China (Liu et al 2018). Additional genetics samples will be collected from future caught fish in Minnesota to determine if this technique can be validated and used.

Recommendations:
Continued monitoring and removal of Invasive Carp from Minnesota waters is recommended for the foreseeable future. This project is funded in part by the Minnesota Environment and Natural Resources Trust Fund through June 2020; however, it is recommended this project continue beyond that date to ensure Invasive Carp do not establish populations or if they do, adequately document the effects of Invasive Carp to native fish populations. Further, it is recommended that Invasive Carp acoustic tagging continue and once the technique is proven it is recommend that the project expand the number and duration of tagged fish at liberty in Minnesota waters. At this time, per the permit, only two Invasive Carp will be at liberty at any given time.

Further age and growth analysis as well as population dynamics validation (including fecundity and recruitment) is recommended for commercially valuable Bigmouth and Smallmouth Buffalo, which may be in direct competition for food resources with Invasive Carps. In some states, current Invasive Carp population control efforts include increasing commercial fishing effort to decrease Invasive Carp abundance, although increased commercial effort in Minnesota would potentially negatively affect native species. Resource agencies would benefit from a greater understanding of the population dynamics of our commercially important native fishes. In addition to age and growth analyses, over 4,000 Bigmouth Buffalo and Smallmouth Buffalo have been tagged in Pool 2 during 2015, 2016, and 2017 as part of a study investigating movement, exploitation, age and growth, and other key population dynamics of these commercially important species. It is recommended that this tagging project continue to better understand movement patterns and approximate the numbers of individuals present in the Pool 2 of the Mississippi River via mark-recapture techniques.

Paddlefish are another native planktivore that may compete for food resources with Invasive Carps and therefore may be negatively affected. Currently, Paddlefish are a threatened species in Minnesota and populations across their range have suffered due to commercial navigation projects that impede movement and alter habitats, pollution, and overexploitation (Jennings and Zigler 2000). If Invasive Carps become established in Minnesota rivers, local Paddlefish populations would be further stressed. Being a state threatened species, non-lethal means of studying Paddlefish populations are also recommended including continued tagging of encountered Paddlefish using jaw and acoustic tags. Further effort should also be used to encourage boaters to report any deceased paddlefish for age and growth analysis and other MN DNR offices should collect all deceased Paddlefish for analysis.

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Tables:

Table 1. Invasive Carp sampling summary for the Mississippi River Pools 1, 2, 3, 4, 5 and the St. Croix and Minnesota Rivers for January through December 2017. Number of Invasive Carp Captured represents the number of individuals caught by MN DNR, contracted commercial fishermen, or monitored commercial fishing. One Bighead Carp was also caught by a bowfisherman off the Minnesota River in June 2017.

Invasive Carp Sampling Summary January – December 2017	blank	blank	Days
Random Sampling Effort	blank	blank	blank
Gill/Trammel Netting	33,400	feet	24
Electrofishing	1,963	minutes	25
Trap Netting	30	net/nights	6
Standardized Sampling Effort	blank	blank	blank
Electrofishing	115	minutes	4
Larval trawling	143	trawls	10
Targeted Commercial Fishing Effort	blank	blank	blank
Gill Netting	57,600	feet	8
Seining	4	hauls	4
Monitored Commercial Fishing Effort	blank	blank	blank
Seining	9	hauls	9
	blank	blank	blank
Number of Invasive Carp Captured	6	fish	blank
Total Number of Days Sampled	blank	blank	90

Table 2. Invasive Carp caught from January through December 2017 in Minnesota and Wisconsin boundary waters.

Date	Species	Water Body	Location	River Mile	Length (mm)	Weight (grams)	Sex	Maturity	Capture Method	Age
3/10/17	Bighead Carp	St. Croix River	Point Douglas	812	1161	20000	F	M	Monitored Commercial Seine	10
3/10/17	Silver Carp	St. Croix River	Point Douglas	812	836	6100	M	M	Monitored Commercial Seine	9
4/2/17	Silver Carp	St. Croix River	Point Douglas	812	825	6050	M	M	Monitored Commercial Seine	7
4/11/17	Grass Carp	Pool 2	Lower Grey Cloud Slough	821	987	14000	F	M	Contract Commercial Gill Net	9
4/11/17	Grass Carp	Pool 2	Lower Grey Cloud Slough	821	941	10500	M	M	Contract Commercial Gill Net	9
6/4/17	Bighead Carp	Minnesota River	Near Redwood Falls	844+216	1210	2800	F	M	Bow Fisherman	11
7/28/17	Bighead Carp	St. Croix River	Allen S. King Plant	812+20	1086	1700	NE	NE	Gill Net	Unknown

Table 3. Species list for the Mississippi River Pool 2 and the St. Croix River from January 2013 through December 2017, including 78 native and invasive species.

Common Name	Genus Species	Pool 2	St. Croix River
American Eel	Anguilla rostrata	x	blank
Bighead Carp	Hypophthalmichthys nobilis	x	x
Bigmouth Buffalo	Ictiobus cyprinellus	x	x
Black Bullhead	Ameiurus melas	blank	x
Black Crappie	Pomoxis nigromaculatus	x	x
Blackside Darter	Percina maculata	x	x
Blue Sucker	Cycleptus elongatus	x	x
Bluegill	Lepomis macrochirus	x	x
Bluntnose Minnow	Pimephales notatus	x	x
Bowfin	Amia calva	x	x
Brassy Minnow	Hybognathus hankinsoni	blank	x
Brook Silverside	Labidesthes sicculus	x	blank
Brook Stickleback	Culaea inconstans	x	blank
Brown Trout	Salmo trutta	blank	x
Bullhead Minnow	Pimephales vigilax	x	blank
Burbot	Lota lota	blank	x
Central Mudminnow	Umbra limi	x	blank
Channel Catfish	Ictalurus punctatus	x	x
Common Carp	Cyprinus carpio	x	x
Channel Shiner	Notropis wickliffi	x	blank
Crystal Darter	Crystallaria asprella	blank	x
Emerald Shiner	Notropis atherinoides	x	x
Fathead Minnow	Pimephales promelas	x	blank
Flathead Catfish	Pylodictis olivaris	x	x
Freshwater Drum	Aplodinotus grunniens	x	x
Gilt Darter	Percina evides	blank	x
Gizzard Shad	Dorosoma cepedianum	x	x

Goldeye	Hiodon alosoides	x	
Golden Redhorse	Moxostoma erythrurum	x	x
Golden Shiner	Notemigonus crysoleucas	x	blank
Grass Carp	Ctenopharyngodon idella	x	blank
Greater Redhorse	Moxostoma valenciennesi	x	x
Green Sunfish	Lepomis cyanellus	x	x
Hornyhead Chub	Nocomis biguttatus	x	x
Hybrid Sunfish	Lepomis microlophus x L. cyanellus	x	x
Iowa Darter	Etheostoma exile	Blank	x
Johnny Darter	Etheostoma nigrum	Blank	x
Lake Sturgeon	Acipenser fulvescens	Blank	x
Largemouth Bass	Micropterus salmoides	X	x
Logperch	Percina caprodes	X	x
Longnose Gar	Lepisosteus osseus	X	x
Mimic Shiner	Notropis volucellus	X	x
Mooneye	Hiodon tergisus	X	x
Muskellunge	Esox masquinongy	X	x
Northern Hogsucker	Hypentelium nigricans	Blank	x
Northern Pike	Esox lucius	X	x
Orangespotted Sunfish	Lepomis humilis	X	x
Paddlefish	Polyodon spathula	X	x
Pumpkinseed	Lepomis gibbosus	X	x
Quillback	Carpiodes cyprinus	X	x
Rainbow Darter	Etheostoma caeruleum	blank	x
River Carpsucker	Carpiodes carpio	x	x
River Darter	Percina shumardi	x	x
River Redhorse	Moxostoma carinatum	x	x
Rock Bass	Ambloplites rupestris	x	x
Sand Shiner	Notropis stramineus	x	x

Sauger	Sander canadensis	x	x
Shorthead Redhorse	Moxostoma macrolepidotum	x	x
Shortnose Gar	Lepisosteus platostomus	x	x
Silver Carp	Hypophthalmichthys molitrix	x	Blank
Silver Chub	Macrhybopsis storeriana	x	Blank
Silver Lamprey	Ichthyomyzon unicuspis	x	x
Silver Redhorse	Moxostoma anisurum	x	x
Skipjack Herring	Alosa chrysochloris	x	blank
Slenderhead Darter	Percina phoxocephala	x	x
Smallmouth Bass	Micropterus dolomieu	x	x
Smallmouth Buffalo	Ictiobus bubalus	x	x
Spotfin Shiner	Cyprinella spiloptera	x	x
Spottail Shiner	Notropis hudsonius	x	blank
Spotted Sucker	Minytrema melanops	x	x
Tadpole Madtom	Noturus gyrinus	x	blank
Trout Perch	Percopsis omiscomaycus	blank	x
Walleye	Sander vitreus	x	x
White Bass	Morone chrysops	x	x
White Crappie	Pomoxis annularis	x	x
White Sucker	Catostomus commersonii	x	x
Yellow Bullhead	Ameiurus natalis	x	blank
Yellow Perch	Perca flavescens	x	x

Table 4. Baseline specimens and number of samples collected for the Mississippi River Pool 2 Stable Isotope Analysis.

	3M Channel	Lower Grey Cloud	Nelson Mine	River Lake	Spring Lake	TOTAL
Algae	4	3	4	3	3	17
Bloodworms	3	3	3	3	2	14
Caddisfly	3	2	3	0	4	12
Crayfish	0	2	1	2	3	8
Damselfly	2	2	2	3	2	11
Detritus	3	3	4	3	3	16
Dragonfly	2	2	2	1	2	9
Fly larvae	0	0	0	1	0	1
Hexagenia	2	1	0	2	1	6
Larval fish	1	1	1	0	1	4
Leech	2	3	3	3	2	13
Mayfly	3	2	3	2	3	13
Phytoplankton	3	3	3	4	3	16
Predatory Caddisfly	2	2	2	0	2	8
Scud	3	4	3	3	3	16
Snail	3	3	3	3	3	15
Sow bugs	3	3	2	3	3	14
Stonefly	1	1	2	2	2	8
Vegetation	6	7	6	5	6	30
Water Boatmen	4	2	2	3	3	14
Water Scorpion	0	1	0	1	0	2
Whirlygig Beetles	1	3	1	3	1	9
Zebra Mussels	3	4	1	3	2	13
Zooplankton	2	3	3	3	3	14
TOTAL	56	60	54	56	57	283

Table 5. Fish species and number of samples collected for the Mississippi River Pool 2 Stable Isotope Analysis.

	3M Channel	Lower Grey Cloud	Nelson Mine	River Lake	Spring Lake	Other	TOTAL
Bighead Carp	0	0	0	0	0	2	2
Bigmouth Buffalo	6	6	6	6	6	0	30
Bluegill <90 mm	7	8	6	5	6	0	32
Bluegill >90 mm	6	5	6	7	6	0	30
Common Carp	14	6	6	8	6	0	40
Channel Catfish	6	6	7	6	5	0	30
Flathead Catfish	6	7	5	7	8	0	33
Freshwater Drum	10	7	6	6	6	0	35
Grass Carp	0	2	0	0	0	0	2
Gizzard Shad <280 mm	9	8	10	8	6	0	41
Gizzard Shad >280 mm	6	4	7	6	7	0	30
Paddlefish	0	2	0	0	0	1	3
Smallmouth Buffalo	6	6	6	6	6	0	30
Sauger	3	1	12	18	1	0	35
Silver Carp	0	0	0	0	0	2	2
Shorthead Redhorse	8	5	9	8	8	0	38
Silver Redhorse	6	6	7	6	6	0	31
Walleye	6	6	6	6	6	0	30
TOTAL	99	85	99	103	83	5	474

Figures:

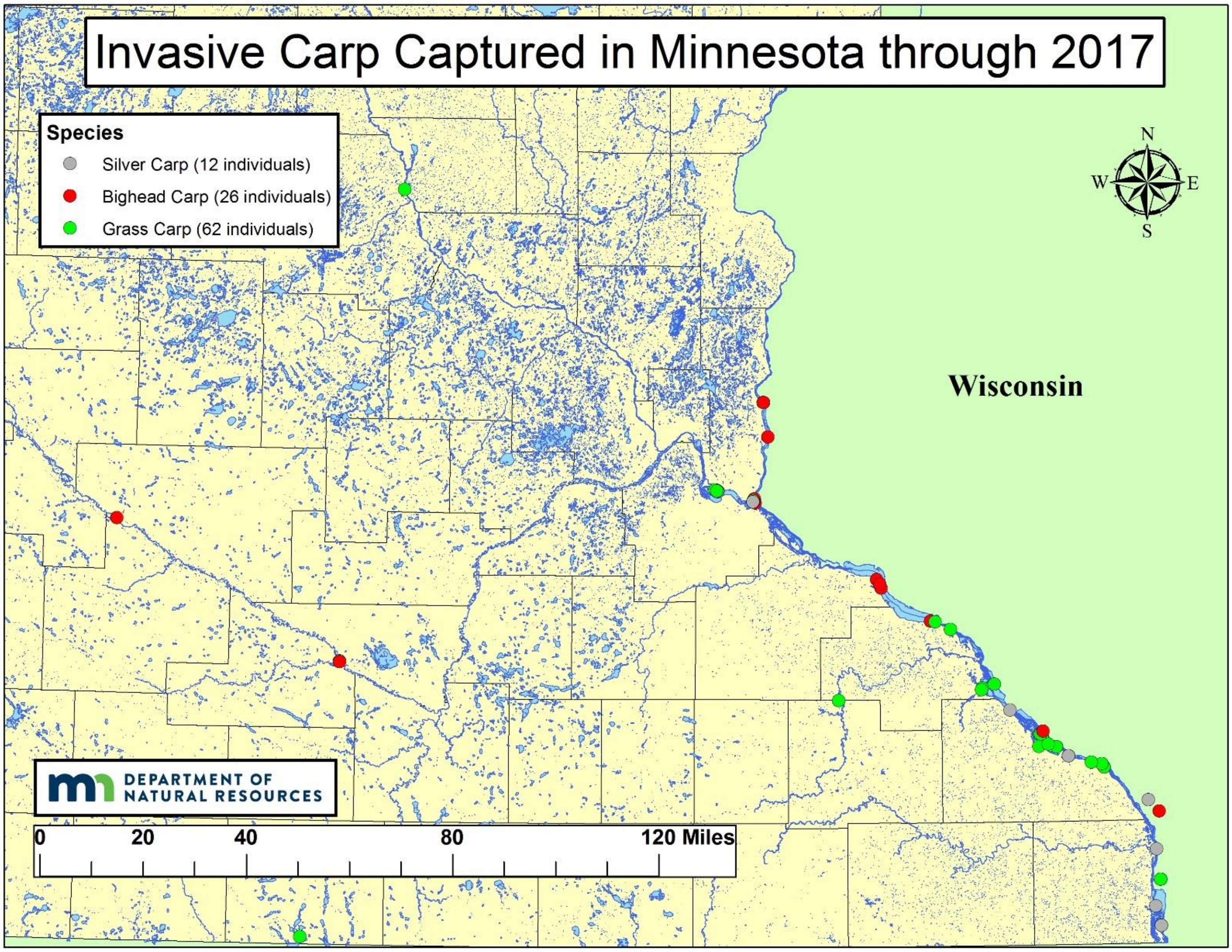

Figure 1. Locations of all known Invasive Carp captured in Minnesota waters through 2017.

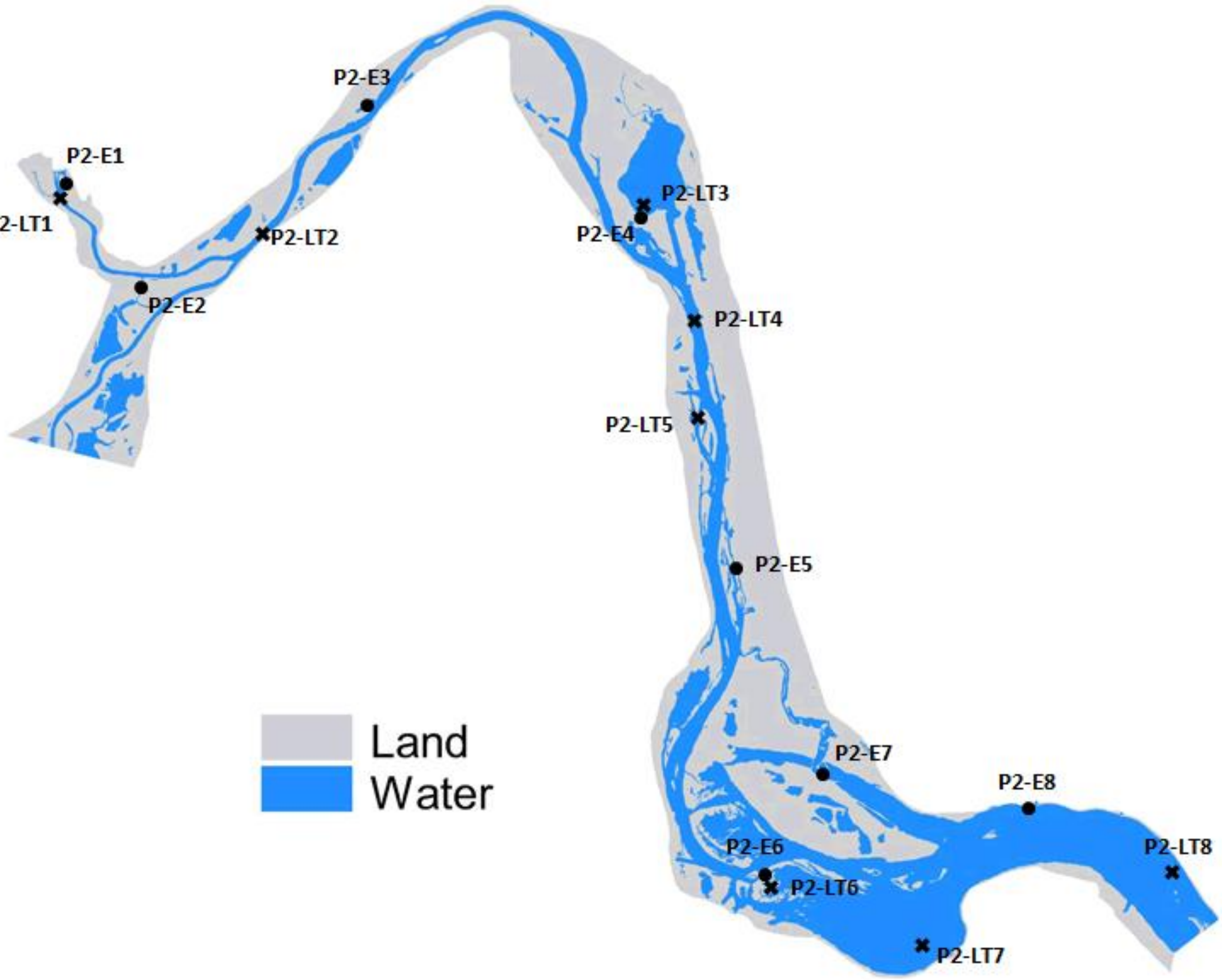

Figure 2. Standardized electrofishing (dark circle, E1 – E8) and larval fish trawling (dark cross, LT1 - LT 8) locations on Pool 2 (P2) of the Mississippi River.

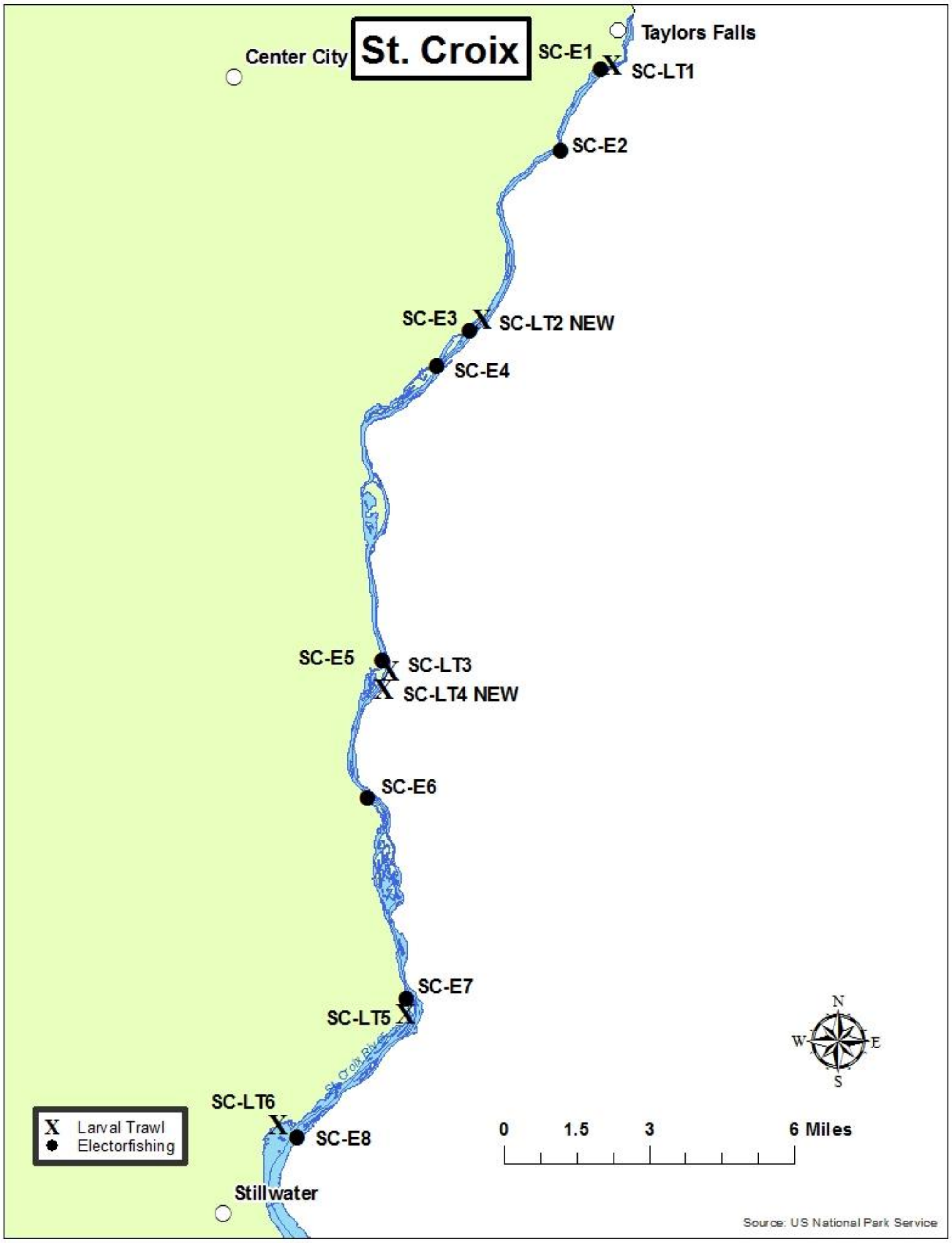

Figure 3. Standardized electrofishing (dark circle, E1 – E8) and larval fish trawling (dark cross, LT1 - LT 6) locations on the St. Croix River (SC). Sites SC-LT2 and SC-LT4 were moved in 2016 due to the site becoming too shallow to trawl.

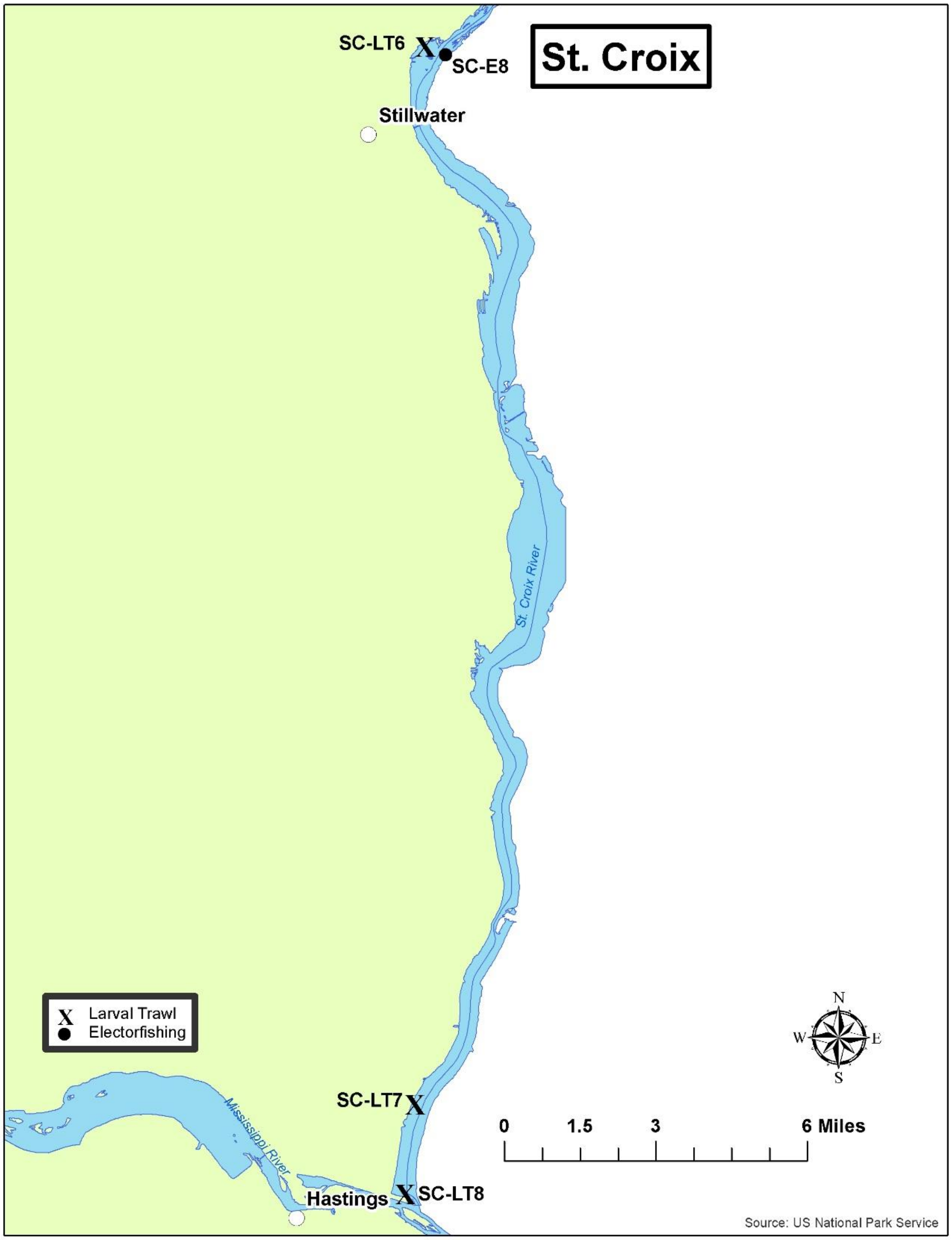

Figure 3 (Continued). Standardized electrofishing (dark circle, E8) and larval fish trawling (dark cross, LT 6 - LT 8) locations on the St. Croix River (SC).

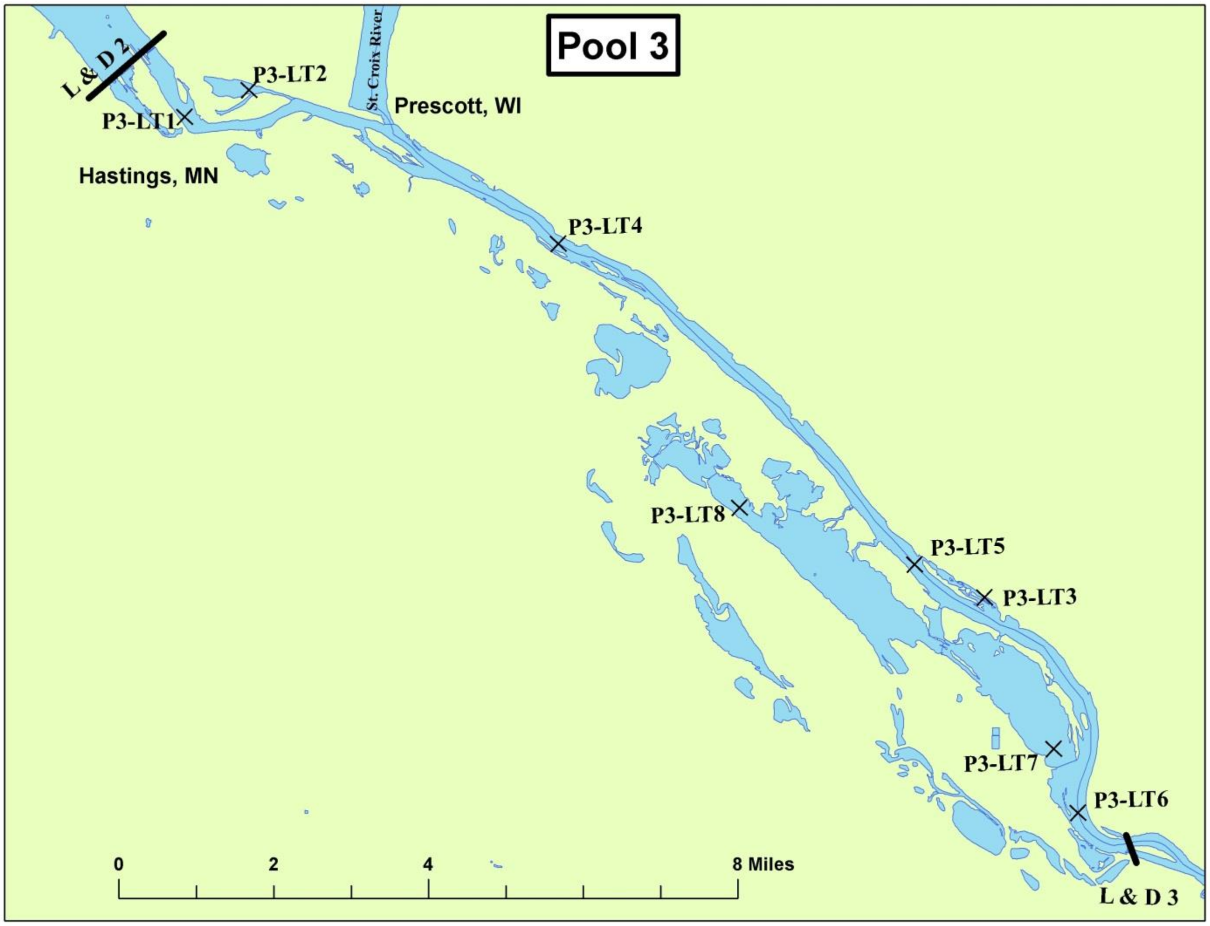

Figure 4. Standardized larval fish trawling (LT1-LT8) locations on Pool 3 (P3). Site P3-LT3 was moved in 2015 due to the site becoming too shallow to trawl.

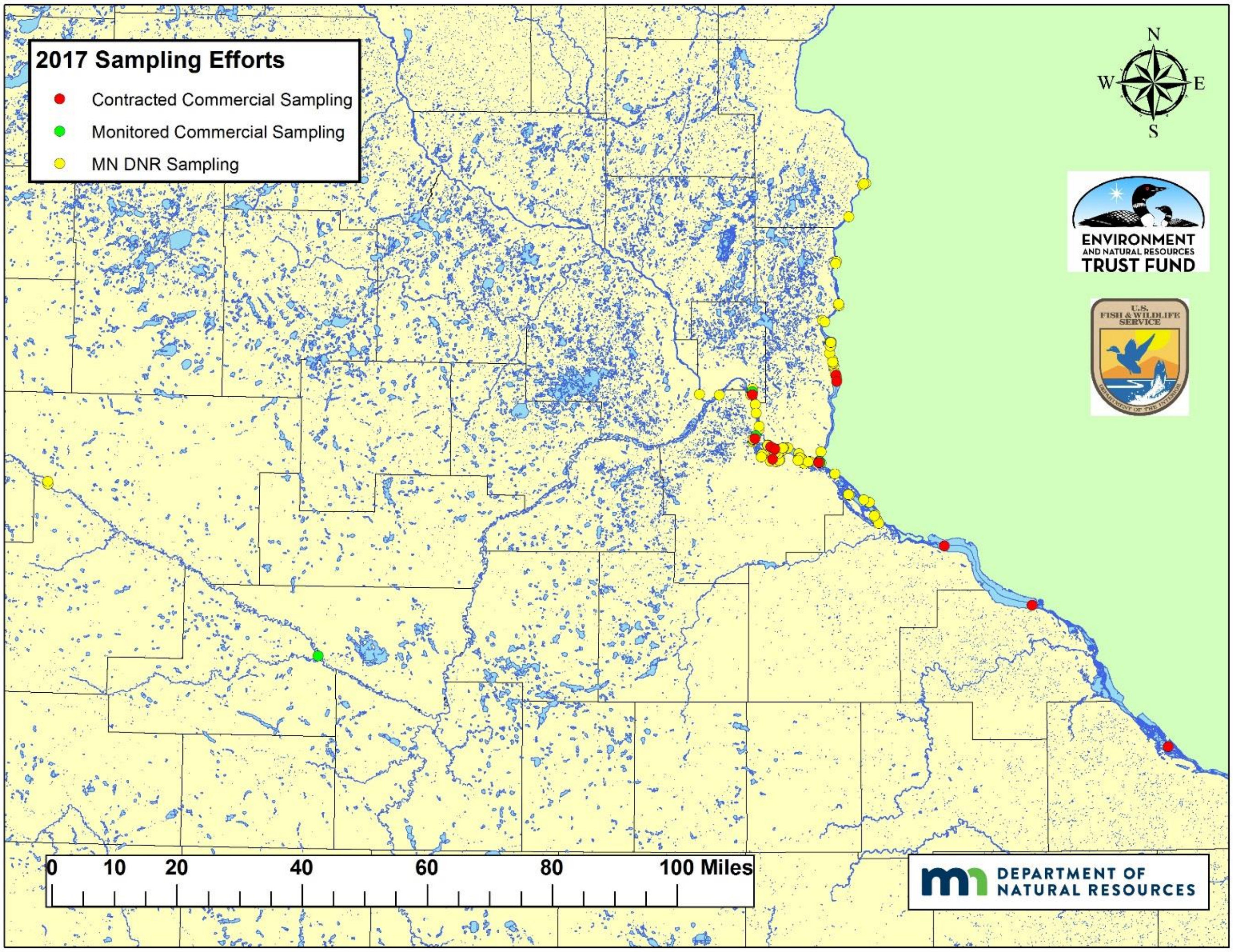

Figure 5. All sampling locations for contracted commercial sampling and MN DNR sampling on the Mississippi, St. Croix, and Minnesota Rivers during 2017.

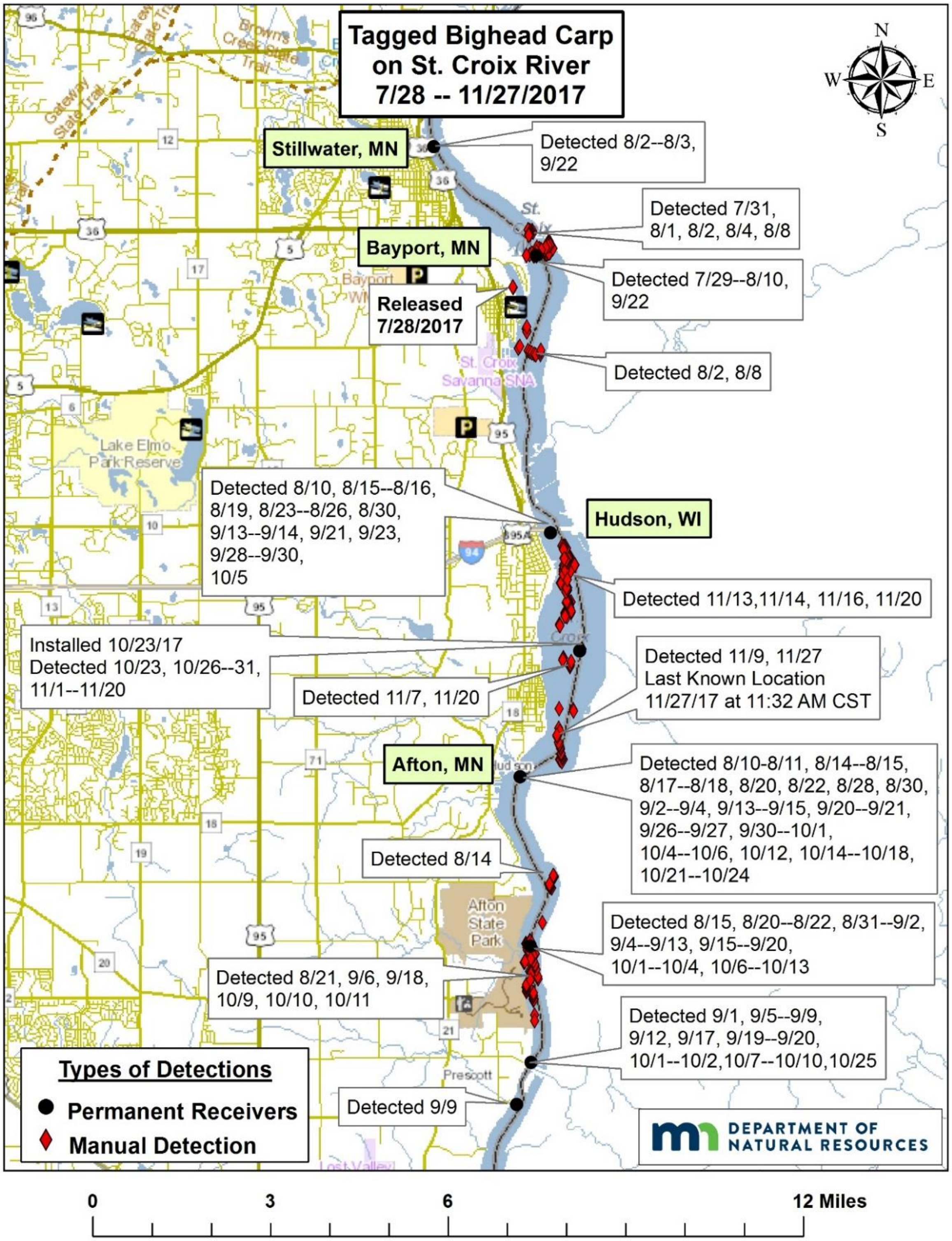

Figure 6. Movement patterns of tagged Bighead Carp from initial release through last manual detection on November 27, 2017.

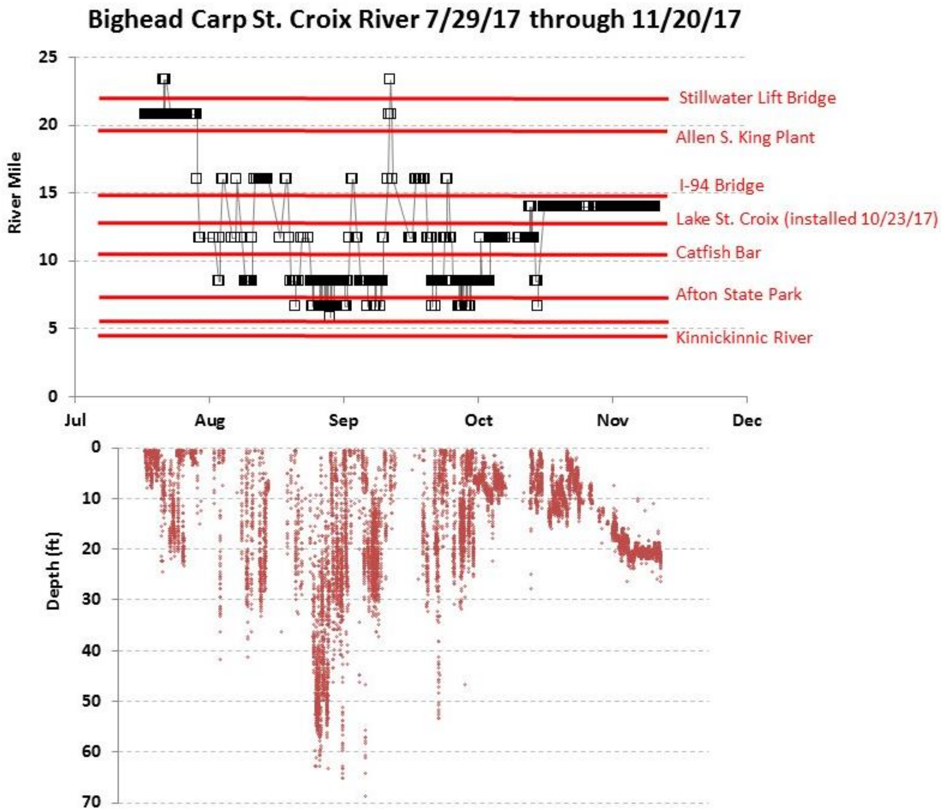

Figure 7. River Mile and Depth patterns of tagged Bighead Carp from initial release through last receiver download for 2017 on November 20, 2017.

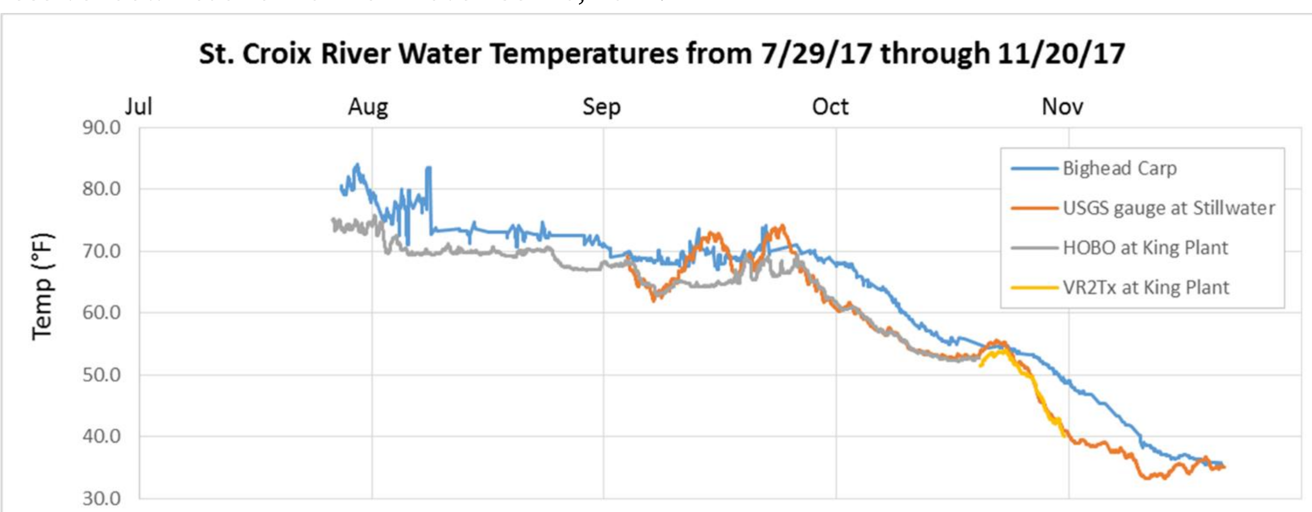

Figure 8. Temperature patterns of tagged Bighead Carp from initial release through last receiver download for 2017 on November 20, 2017. USGS gauge (05341550) data available from September 5 through November 20, 2017.

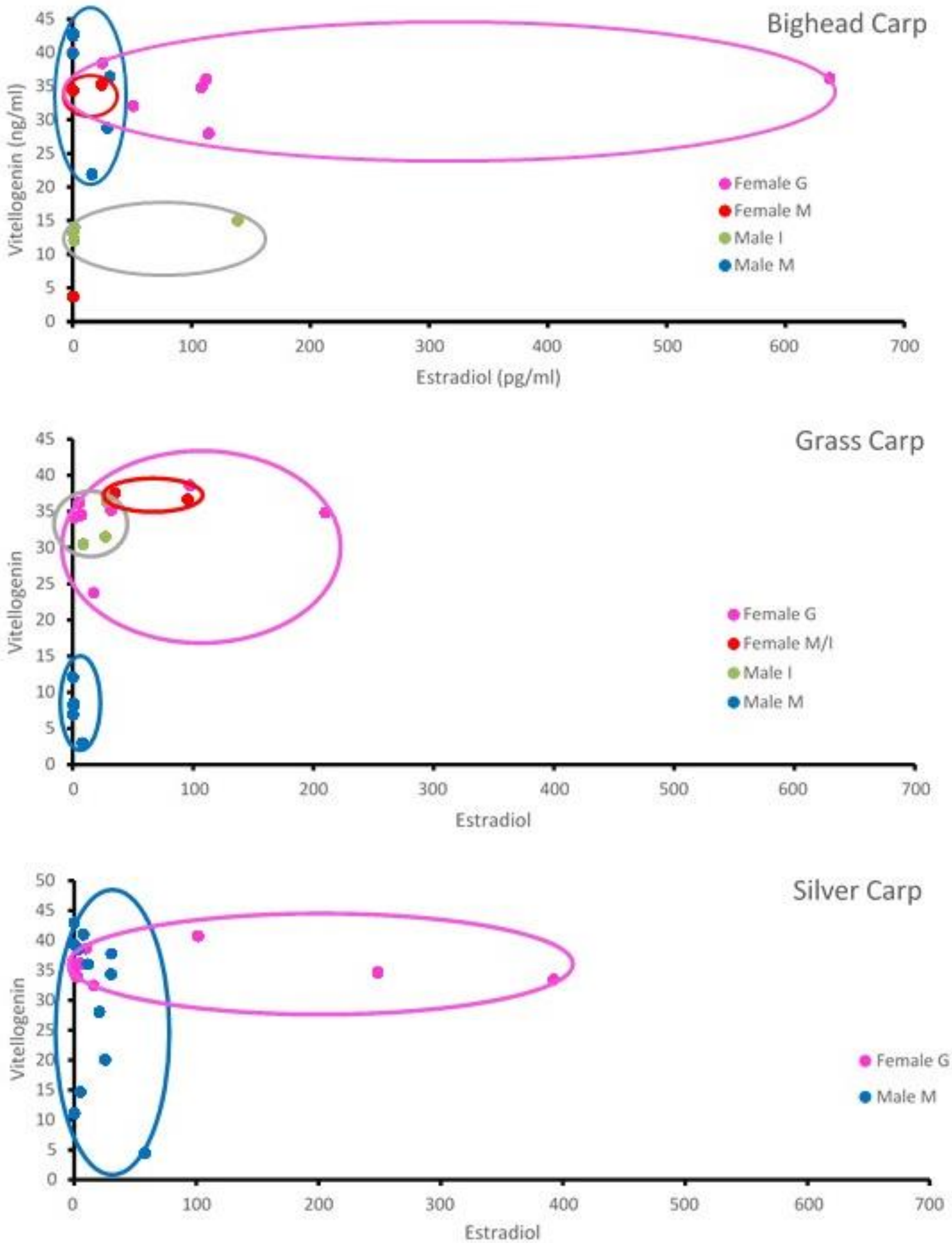

Figure 9. Analysis of vitellogenin and estradiol concentrations in carp plasma samples. Mature females should have both high estradiol & vitellogenin (upper right of graph), while mature males should have low levels of vitellogenin and estradiol (lower left of graph).

DISTRIBUTION AND POPULATION DYNAMICS OF ASIAN CARP IN THE UPPER MISSISSIPPI RIVER

Submitted By: Nathan A. Tillotson, Aaron J. Matthews, Michael J. Weber, and Clay L. Pierce; Department of Natural Resource Ecology and Management, Iowa State University

Geographic Location: The study area of this project is the reach of the Upper Mississippi River along the southeast border of Iowa, USA and its major tributaries (Des Moines, Skunk, Iowa, Rock, and Wapsipinicon Rivers) from Pool 20 at Keokuk, IA to Pool 14 at the confluence of the Wapsipinicon River (Figure 1).

Lead Agency: Iowa DNR and Iowa State University

Statement of Need: Successful expansion and establishment of Asian carp depends on the ability for adults to travel to unestablished areas, and their ability to successfully reproduce in those new areas. Asian carp reproduction requires long stretches of sustained flowing water, and the impounded pools of the Upper Mississippi River (UMR) may limit successful reproduction. However, Asian carp eggs and larvae have been documented in parts of the UMR, and densities of adults are thought to be increasing in their invaded range. The southeast border of Iowa, USA is at the invasion front of Asian carp, and more information is needed on how these fish are expanding and reproducing along this portion of the UMR. Tributaries of the UMR throughout southeast Iowa are thought to be sources of successful reproduction events for Asian carp in the UMR, and evidence of this relationship has been documented in the Des Moines, Skunk, and Iowa Rivers (Camacho 2016). Further evaluation of both adult and egg/larval Asian carp in the UMR is needed in order to determine potential sources and drivers of range expansion and successful recruitment for these species. Detection of Asian carp range expansion and successful spawning events both spatially and temporally throughout the UMR will be important for developing more well-informed management strategies for these invasive species.

Project Objectives:

1) Evaluate Asian carp reproduction in pools 14, 15, 16, 17, 18, 19, 20 and the contribution of the Wapsipinicon, Rock, Iowa, Skunk, and Des Moines rivers to Asian carp reproduction (egg, larval and juvenile densities).
2) Evaluate adult population characteristic (abundance, distribution, size structure, condition) and dynamics (recruitment, growth, mortality) of Asian carp in pools 14, 15, 16, 17, 18, 19, and 20 of the Upper Mississippi River.

Project Highlights:

- Egg densities (all species of fish) across sampling sites peaked during May 30th but a second pulse of eggs was also detected late in the year on July 25th. Larval densities (all species of fish) were highest on June 16th and 27th, shortly after the initial peak in egg densities. The mouths of the Rock and Des Moines rivers tended to have higher egg densities whereas the Mississippi River sites downstream of these tributaries had higher densities of larval fish. Egg densities tended to be higher in thalweg and channel border habitats, and larval densities were generally higher within the backwater and channel border habitats.

- Adult Asian carp caught in 2017 consisted only of Silver Carp and Grass Carp, but Silver Carp were by far the most abundant Asian carp species in the UMR. Relative abundance tend to decrease with increasing latitude, but are much higher below Lock and Dam 19 than above. Average size of Silver Carp was large at 699 mm and 3.99 kg, and average age was 7 years.

Methods:

Egg and Age-0 Fish Sampling

Asian carp eggs and age-0 fish were sampled in 2017 at 18 locations (Figure 1) approximately every 10 days depending upon river conditions from beginning of May until the end of August (12 sessions, with 54 tows per session). Sampling was not conducted when water levels were too high for safe boating or too low for boat access (only the Des Moines River mouth and the Keosauqua site on the final 3 sampling dates). Ichthyoplankton (0.5 m diameter net, 500 µm mesh) tows were conducted at the surface at a constant boat speed relative to the shoreline up to four minutes depending on debris load. A General Oceanics flowmeter (Model 2030R) was mounted in the mouth of the net to estimate volume (m^3) of water filtered during each tow. Three tows were conducted at each site parallel to river flow: the first tow was in the main thalweg for drifting eggs and larvae (<24 hours post fertilization), the second tow occurred near channel borders where water velocity is moving downstream slower than the thalweg, and the third was in an adjacent backwater area for mobile larvae (>24 hours post fertilization). After each tow, ichthyoplankton net contents were rinsed toward the cod end, placed in sample jars, and preserved in 95% ethanol.

In the laboratory, eggs and age-0 fish (larvae and juveniles) were separated from debris. Asian carp larvae are difficult to distinguish among species and are being identified to genus using meristic and morphometric characteristic (Chapman 2006, Chapman and George 2011). Age-0 fishes were first categorized as larval or juveniles based on fin development. Fish recognized as having a full complement of fins are categorized as juvenile fish. All age-0 fish are currently being identified to the lowest possible taxa using morphometric and meristic characteristics described in literature (Auer 1982).

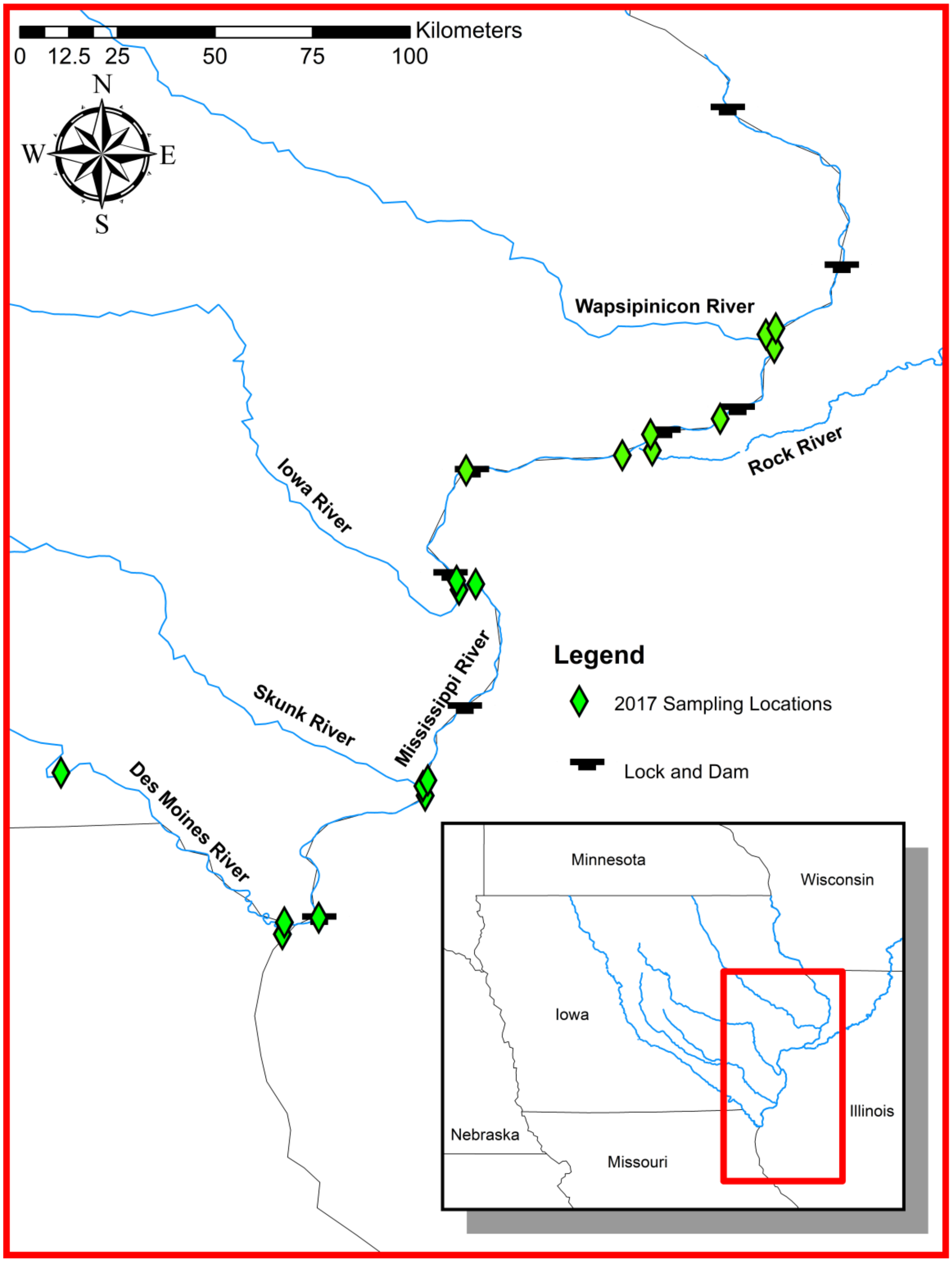

Figure 1. Map of study area on the southeast border of Iowa with the 18 sampling sites of larval fish and adult Bigheaded Carp indicated by green diamonds. Mississippi River lock and dams within our sampling reach in black.

Adult Asian Carp Sampling

Sampling for adult Asian carp took place in October and November of 2017 in Pools 14 – 20 of the UMR, including the mouths of five (Des Moines, Skunk, Iowa, Rock, and Wapsipinicon Rivers) major tributaries (Figure 1). Sites were chosen so that samples were obtained from upstream, downstream, and within the mouths of each of the major tributaries, as well as at least one site in every UMR Pool within our study reach. Daytime boat electrofishing (pulsed DC; amps 4-13, voltage 100-500) was used to target backwater and channel border habitats generally less than 4 meters deep where Asian carp have been shown to typically inhabit. Electrofishing transects (varying effort and transect numbers) are conducted until approximately 150 Silver Carp are captured (Pool 20) or until all available habitat at the electrofishing site is been sampled.

Adult Asian carp were identified as Silver, Bighead, or Silver x Bighead Carp hybrid using meristic and morphometric features, weighed (0.001 kg), measured (total length; 1 mm), and the first pectoral fin spine on each side and lapillus otoliths (up to 150 fish/site) were removed for age and growth analysis. Sex was determined based on visual inspection of gonads (male, female, immature, or unknown).

Lapillus otoliths were air dried at room temperature for at least four weeks following collection before being mounted in epoxy. A 1-mm thick cross section at the nucleus was cut using a Buehler Isomet low-speed saw (Isomet Corporation, Springfield, VA) with the anterior portion of the otolith oriented perpendicular to the blade. Wetted 2,000-grit sandpaper was used to polish each side of the cross section. The section was then placed in immersion oil to improve clarity and annuli viewed under a dissecting microscope with transmitted light. Lapillus otoliths were independently aged by two experienced readers with no knowledge of fish length, estimated age of other structure, or source river. If the readers disagreed, then a common age was decided in unison.

Results and Discussion:

Eggs and Age-0 Fish

In 2017, a total of 627 ichthyoplankton tows were completed. Eggs were collected during every sampling session for a total of 8,619 eggs in 2017. The largest numbers of eggs throughout 2017 were collected during the third sampling event (May 30th - June 1st; 2.26 ± 1.16 SE) with a total of 3,243 eggs (Figure 2). Eggs were found in each river and every site except the backwater habitat of the Wapsipinicon mouth. A total of 429 tows were taken from the Mississippi River for a total of 5,569 eggs. An additional 201 tows were taken within the tributary mouths that captured 3,050 eggs (DSM-KQA = 421 eggs, DSM-MTH = 577 eggs, SKK-MTH = 272 eggs, IAR-MTH = 117 eggs, ROC-MTH = 1,656 eggs, WAP-MTH = 7 eggs). Mean egg density by site was highest within the Rock River (ROC-MTH) and lowest within the Mississippi River upstream of the Des Moines River (Figure 3). Across all habitats and sites, the highest egg density (4.74 ± 4.70 SE) was found within the thalweg of the ROC-MTH (Figure 4), although catches at this site throughout the year were highly variable.

A total of 72,405 age-0 fish (combination of larvae and juveniles) were captured with ichthyoplankton tows throughout 2017. The highest densities of age-0 fish were collected on June 8th (17.54 ± 3.11 SE, 22,888 fish) and 27th (15.58 ± 8.54 SE, 16,079 fish; Figure 2). The two sessions with the highest mean density of age-0 fish were captured within thirty days of the highest eggs density in 2017. The lowest density of age-0 fish throughout all the sessions (0.17 ± 0.03 SE) was captured March 10th.

Age-0 fish were sampled from every river during 2017. The majority of age-0 fish (97%, 70,152 fish) were collected from sites within the Mississippi River downstream of tributaries, whereas only 3% (2,253 individuals) were collected from within tributaries. Mean densities of age-0 fish were higher within the Mississippi River downstream of tributaries than its tributaries (Figure 3). Larval densities were highest within the backwater or channel border throughout 2017. The highest mean density of age-0 fish within the Mississippi River backwaters (60.74 ± 36.97 SE) was collected downstream of the Des Moines River (UMR-DND), followed by (44.2 ± 36.97 SE) downstream of the Rock River (UMR-DNR). The mouth of the Wapsipinicon River (WAP-MTH), had no age-0 fish collected from the backwater habitat throughout 2017. That site also had the lowest density of age-0 fish collected in 2017 within the thalweg (0.005 ± 0.004 SE; Figure 5).

Peak egg densities during the spring of 2017 (May 30th - June 1st) followed by a peak of high larval fish densities (June 16th) was also observed within sampling during 2016. Although eggs collected during 2017 have not been genetically identified, peak mean egg densities in 2016, during May 30th, contained genetically identified Asian carp. This timing coincides with Asian carp spawning, triggered by high levels of discharge and water temperatures above 17°C. Successful Asian carp reproduction within the UMR from the Mississippi River and major tributaries has been observed in previous years (Camacho 2016).

High larval fish densities within backwater and channel border habitats is consistent with life history characteristics of juvenile fish due to their relative abundance of food, refuge from high water currents, and potential predators. Only two sites (UMR-P15 and UMR-UPR) found a higher density of larval fish within the thalweg habitat (Figure 5). Larval fish in these thalweg habitat could be due to poor quality and quantity of refuge habitats. Additionally, fluctuations of river discharge can flush larvae out of their preferred habitats in high flow events.

All ichthyoplankton samples from 2017 have been sorted into categories of yolk-sac larvae, larvae, and juveniles. Identification of age-0 fish is currently in progress. Once eggs and larvae collected in 2017 are identified, this data will add to previous research across similar sites, and provide a better understanding of Asian carp reproduction within the UMR. Further sampling of adult and larval fish will provide additional insight into how populations are recruiting within the UMR and further define a more fine-scale location of the Asian carp invasion front in the UMR.

Adult Asian Carp Population Characteristics and Dynamics

A total of 161 Asian carp were collected from the DSM-MTH, IAR-MTH, UMR-P17, and ROC-MTH sites during a total of 7.03 hours of electrofishing across all sites in 2017. The DSM-KQA site was not sampled for adult Asian carp due to hazardous conditions resulting from low flows throughout fall 2017. The DSM-MTH sites accounted for 94% (152 fish) of all Asian carp captures, while the IAR-MTH sites accounted for 4% (6 fish), the ROC-MTH sites accounted for 1% (2 fish), and UMR-P17 accounted for 1% (1 fish). Silver Carp made up 96% (154 individuals) of total Asian carp captures across all sites, and Grass Carp made up 4% (7 individuals). No Bighead Carp or Black Carp were captured across all sites in 2017. Catch per unit effort (CPUE; fish/hr) for both Silver Carp and Grass Carp was highest at the DSM-MTH sites (Table 1). Catches of Grass Carp were low and similar across sites, and did not show any spatial trend. Catches of Silver Carp were very high below Lock and Dam 19 (LD19), and dropped to zero at all sites above LD19 except at the IAR-MTH sites. Of the 154 Silver Carp captured across all sites in 2017, 97% (150 individuals) came from the DSM-MTH sites, while the other 3% (4 individuals) came from the IAR-MTH sites. Although no Silver Carp were captured at the SKK-MTH sites, approximately 30 individuals were seen jumping out of reach of the netters. Additionally, approximately 10 other Silver Carp were observed jumping at the IAR-MTH.

Silver Carp ranged in size from 427 mm to 966 mm (mean = 699 mm), and from 0.836 kg to 10.120 kg (mean = 3.99 kg). Silver Carp size structure was lower at the IAR-MTH sites than the DSM-MTH sites, but low sample size at IAR-MTH (n=4) should be taken into consideration (Figure 6). Mean Grass Carp size structure was relatively similar across sites, but showed a slight increasing trend with latitude (DSM-MTH = 802 mm, IAR-MTH = 837 mm, UMR-P17 = 928 mm, ROC-MTH = 643 mm) except for the ROC-MTH where it was the lowest (Figure 7). Ages of Silver Carp ranged from 1 to 11 years (Figure 8), and mean age of fish at DSM-MTH (mean = 6.9 years old) was much higher than IAR-MTH (1 year old). Interestingly, Grass Carp tended to decrease in mean age at the farther North sites (Figure 9).

Although no Asian carp were caught at the SKK-MTH sites in 2017, observational data and trends from previous years show a decreasing gradient of Asian carp density as we move north from LD19. All four individual Silver Carp collected at the IAR-MTH sites in 2017 were captured at the same time and place, and were of the same age. The size structure of Silver Carp observed at the IAR-MTH sites in our samples is unusual and may not likely a true representation of the population size structure, especially given that this trend contradicts patterns observed in previous years of data.

Silver Carp are by far the most abundant Asian carp species in the UMR. Populations below LD19 are however much higher than those above. Given that LD19 is the only high-head dam in our study reach, it is likely the main deterrent of Silver Carp rapid population growth in the farther north sites. Although populations above LD19 are not as high, concern should be rising for the ecological integrity of these sites as Asian carp densities slowly grow. If the large sizes and densities of Silver Carp below LD19 are a foreshadowing of populations above, sport and commercial fisheries as well as recreational boaters will all be affected.

Recommendation: Tracking reproduction and recruitment is important to gage the long-term success of harvest, identify large reproductive events, identify recruitment sources and habitat, and monitor the reproductive front upstream. Assessing reproduction along the invasion front should continue to identify environmental (e.g., floods) or human (e.g., harvest) factors that may result in large year-classes, subsequently leading to population growth and expansion.

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Chapman, D. C. 2006. Early development of four cyprinids native to the Yangtze River, China:U.S. Geological Survey Data Series 239.

Chapman, D. C., and A. E. George. 2011. Developmental rate and behavior of early life stages of Bighead Carp and Silver Carp: U.S. Geological Survey Scientific Investigations Report 2011–5076.

Table 1. Electrofishing catch per unit effort (CPUE, fish/hr, mean ± 1 SE) of Asian carp in the UMR in 2017. Individual CPUEs were calculated for each transect and averaged. No Bighead Carp were captured in 2017.

Site Code	Transects	Total Effort (hr)	Silver Carp Catch	Silver Carp CPUE ± SE	Grass Carp Catch	Grass Carp CPUE ± SE
WAP-MTH	1	0.570	0	0	0	0
UMR-P15	1	0.661	0	0	0	0
ROC-MTH	3	1.809	0	0	2	0.92 ± 0.92
UMR-P17	3	1.045	0	0	1	0.85 ± 0.85
IAR-MTH	4	0.894	4	3.14 ± 3.14	2	2.11 ± 2.11
SKK-MTH	7	1.299	0	0	0	0
DSM-MTH	3	0.752	150	228.77 ± 117.48	2	2.74 ± 2.74

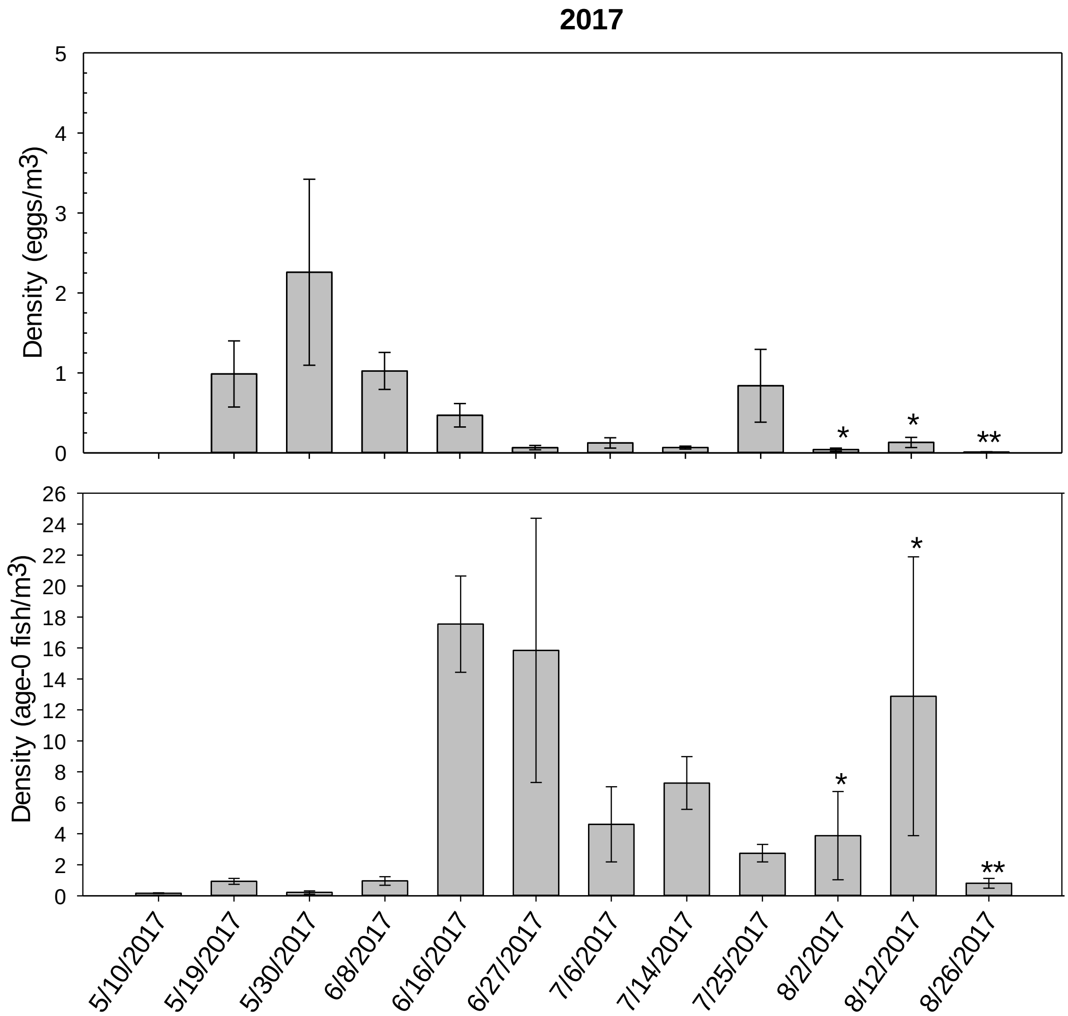


Figure 2. Density (mean ± 1 SE) of eggs (top) and age-0 fish (bottom) collected between April 29 and September 8, 2017.

* DSM-KQA was not sampled during this session due to low flows.

**DSM-KQA, UMR-UPD, and DSM-MTH were not sampled due to unsafe weather conditions.

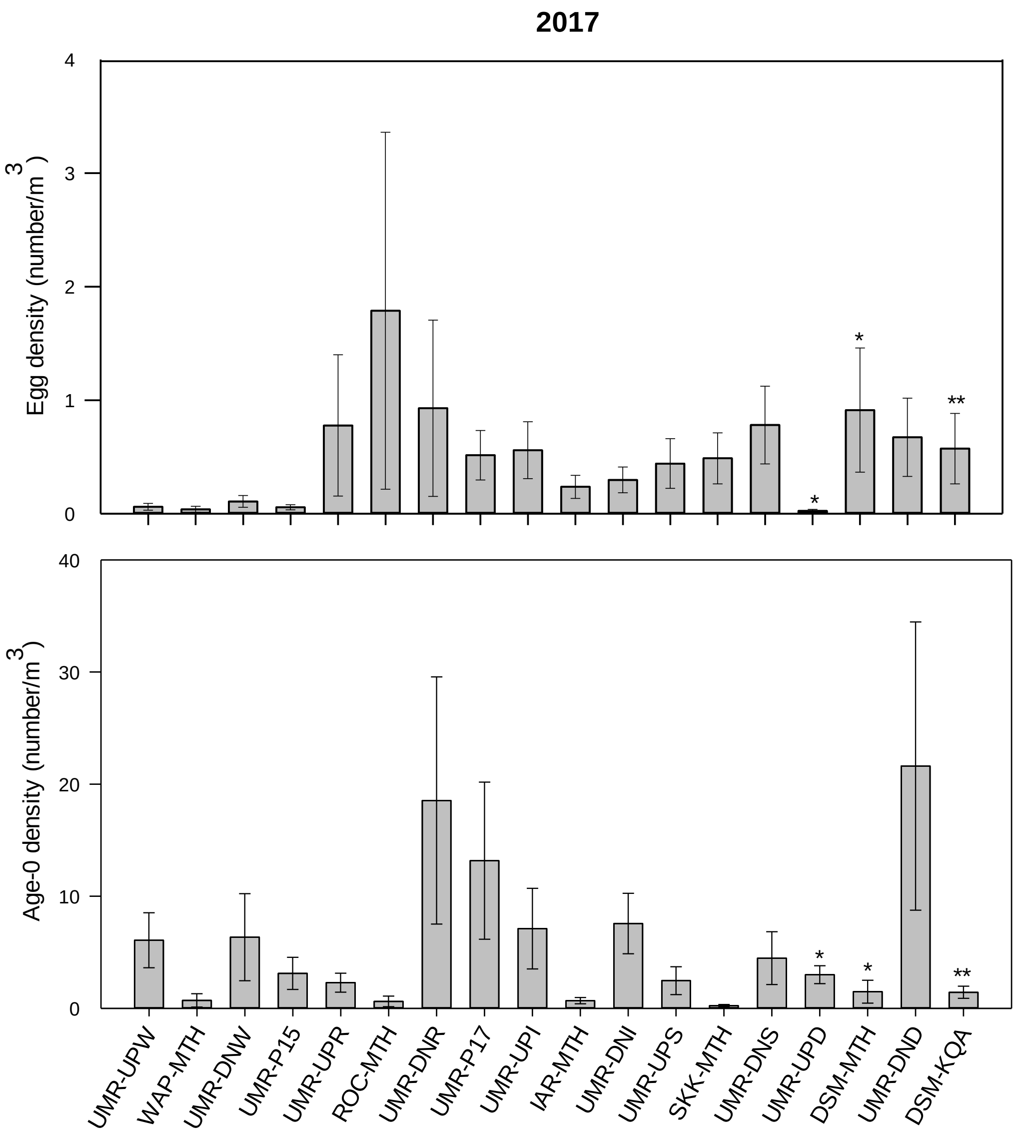


Figure 3. Densities (mean ± 1 SE) of eggs (top) and age-0 fish (bottom) collected from each site during 2017. Site codes are expressed in the first three letters by the river they are sampled within: UMR=Upper Mississippi River: WAP = Wapsipinicon River: ROC=Rock River: IAR = Iowa River: SKK=Skunk River: DSM=Des Moines River. The second set of letter give a more descriptive location of the site. All UMR Sites contain either UP_, or DN_ corresponding to 1 km upstream and downstream 1 km of a major tributary. For example WAP-MTH = the Wapsipinicon River at the mouth river: UMR-UPW = Upper Mississippi River, upstream 1 km of the Wapsipinicon: UMR-DNW = Upper Mississippi River, downstream 1km of the Wapsipinicon River. The only tributary with two sites is the Des Moines River, where the second site above the mouth DSM- KQA is located at the town Keosauqua.

*Site was not sampled on the last sampling session due to inclement weather.

**Site was not sampled during the last three sampling sessions due to low flows.

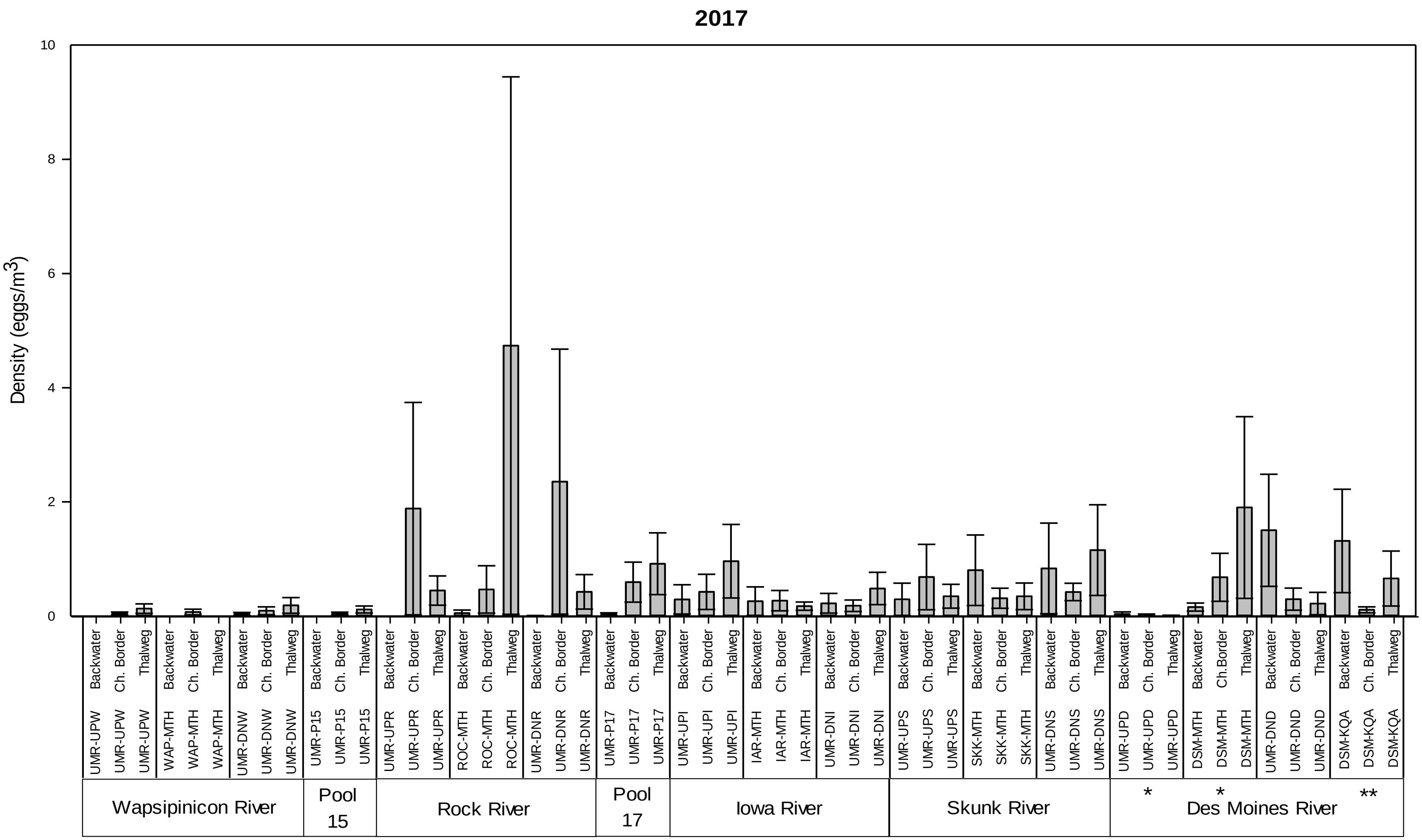


Figure 4. Egg densities (mean ± 1 SE) captured from backwater, channel border, and thalweg habitats in the sites sampled during 2017. Below each habitat is the site code of the site sampled. UMR (Upper Mississippi River), MTH (mouth of the tributary) P15 (Pool 15 of the Mississippi River). See Figure 3 for a more complete site label description.
*Sites were not sampled due to inclement weather during the final session during August 27th.
**Site was not sampled during the last 3 sampling sessions due to low flows.

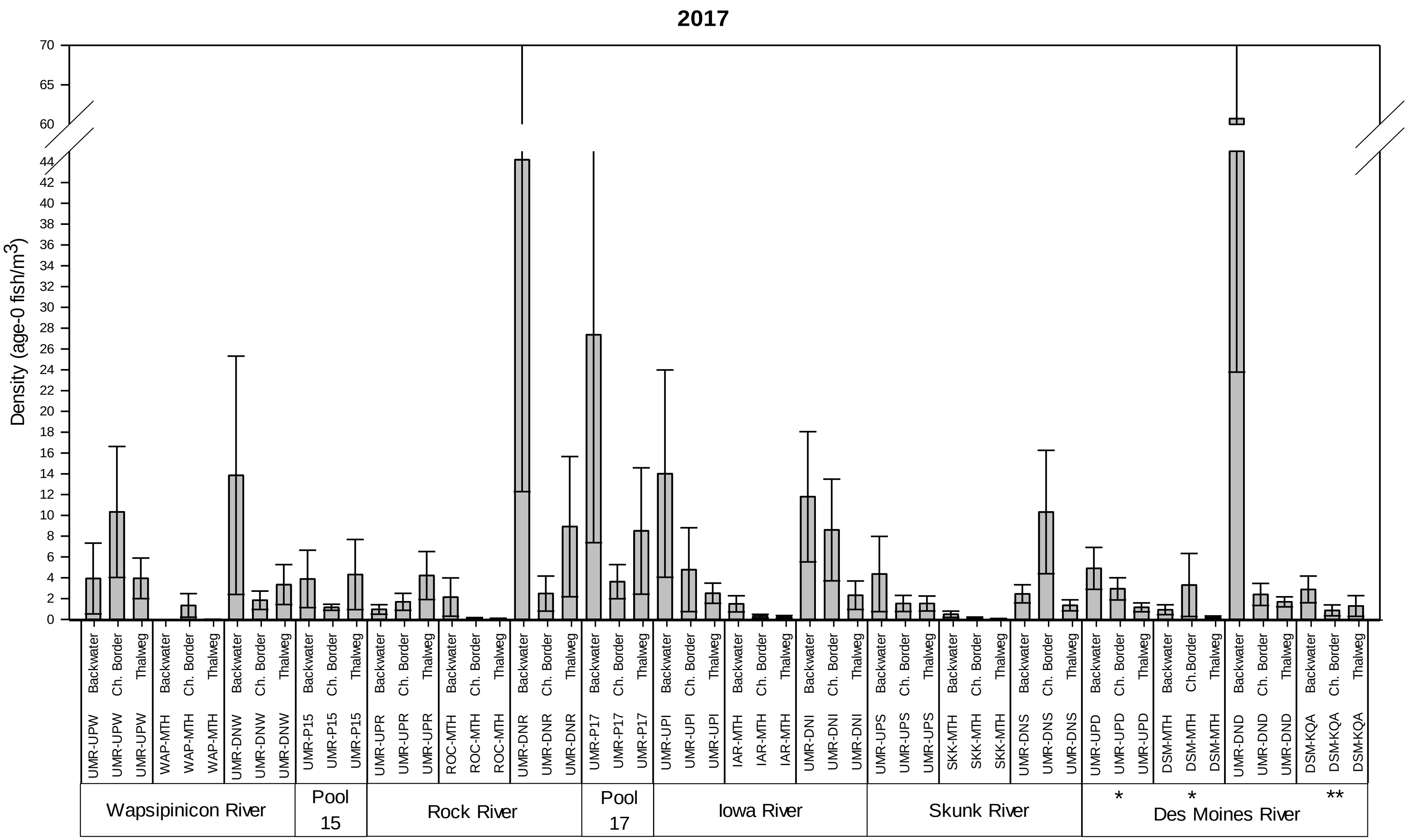


Figure 5. Age-0 fish densities (mean ± 1 SE) captured from backwater, channel border, and thalweg habitats in the sites sampled during 2017. Below each habitat is the site code of the site sampled. UMR (Upper Mississippi River), MTH (mouth of the tributary) P15 (Pool 15 of the Mississippi River). See Figure 3 for a more complete site label description.
*Sites were not sampled due to inclement weather during the final session during August 27th.
**Site was not sampled during the last 3 sampling sessions due to low flows.

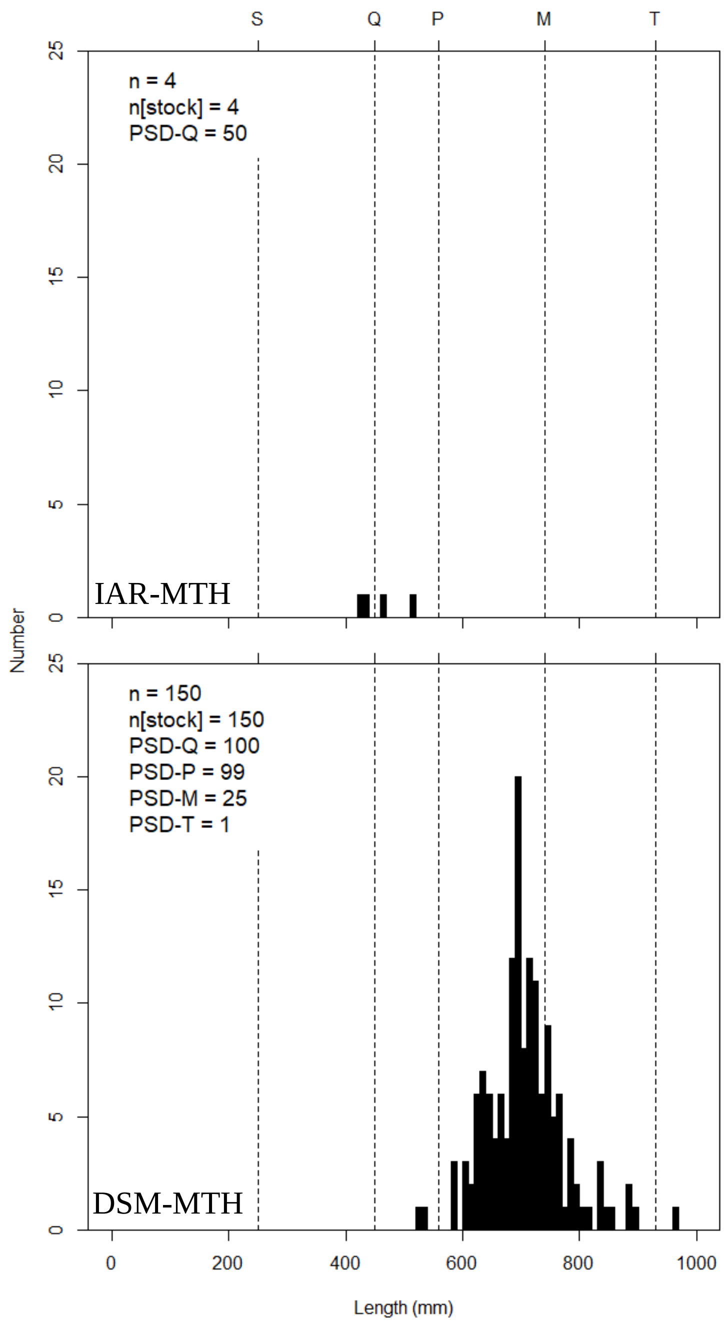


Figure 6. Silver Carp length-frequency histograms and proportional size distribution (PSD; S-Stock, Q-Quality, P-Preferred, M-Memorable, T-Trophy) indices of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH) and the Iowa River (IAR-MTH). No Silver Carp were captured at the mouths of the Skunk, Rock, or Wapsipinicon Rivers, or from Pools 17 or 15 of the Upper Mississippi River.

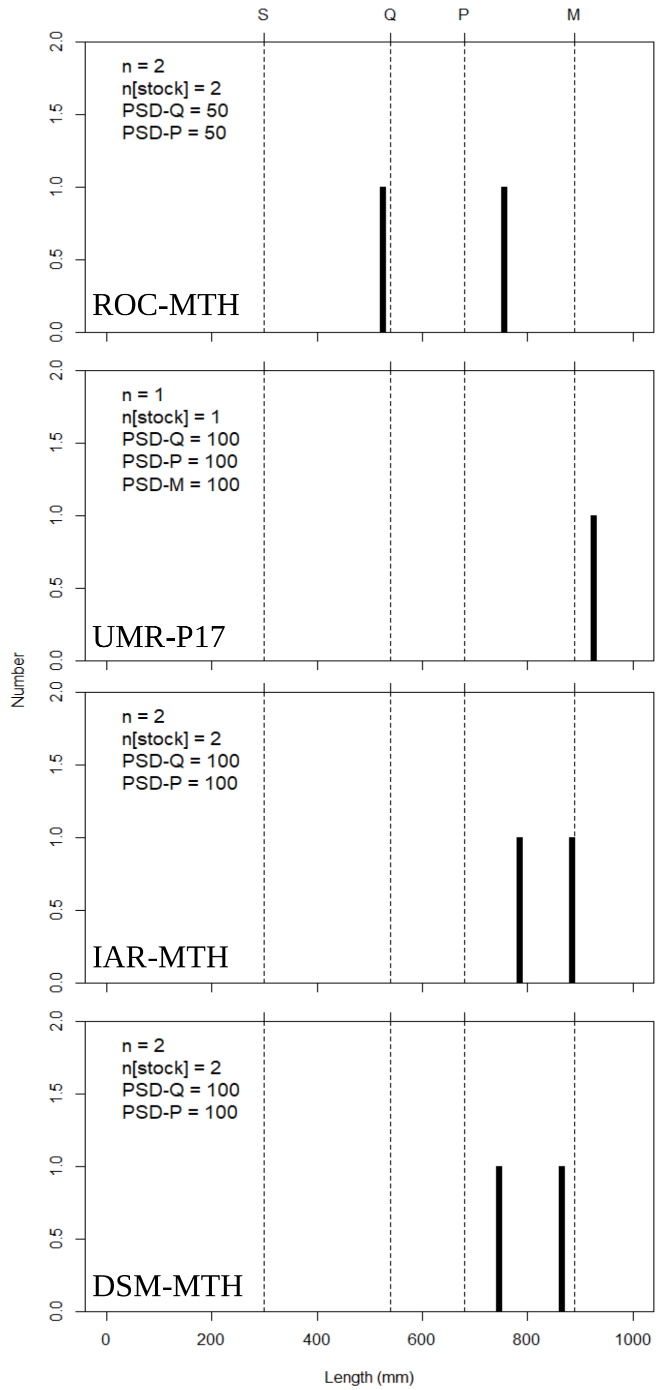


Figure 7. Grass Carp length-frequency histograms and proportional size distribution (PSD; S-Stock, Q-Quality, P-Preferred, M-Memorable, T-Trophy) indices of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH), Iowa River (IAR-MTH), and Rock River (ROC-MTH), as well as Pool 17 of the Upper Mississippi River (UMR-P17). No Grass Carp were captured at the mouths of the Skunk or Wapsipinicon Rivers, or from Pool 15 of the UMR.

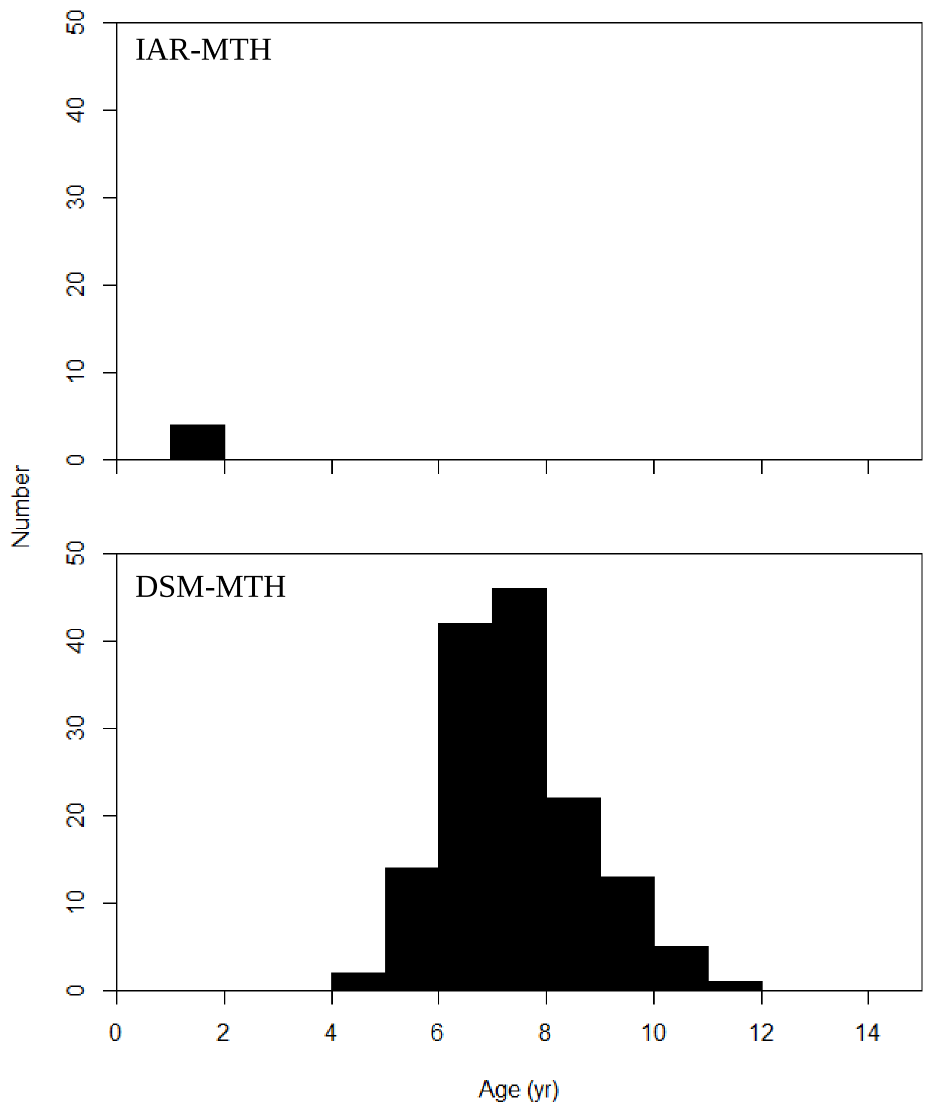


Figure 8. Silver Carp age-frequency histograms of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH) and the Iowa River (IAR-MTH). No Silver Carp were captured at the mouths of the Skunk, Rock, or Wapsipinicon Rivers, or from Pools 17 or 15 of the Upper Mississippi River.

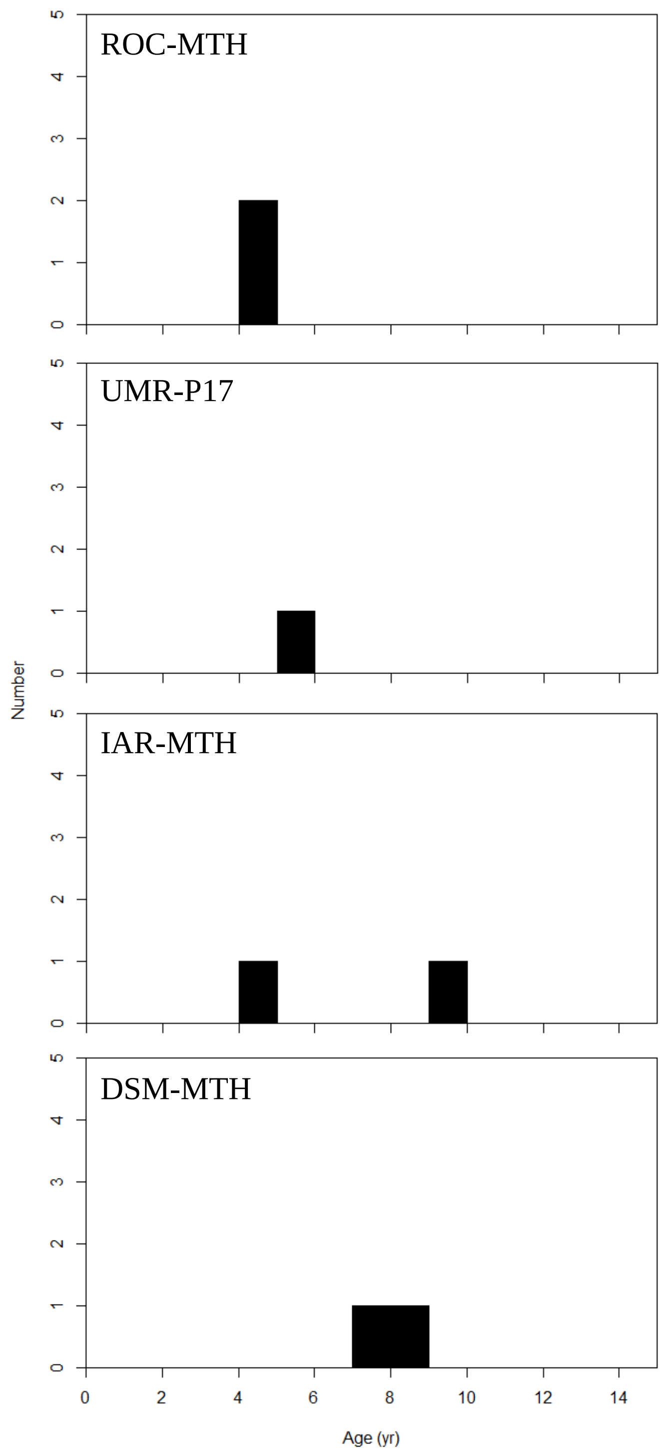


Figure 9. Grass Carp age-frequency histograms of fish collected in 2017 from the mouths of the Des Moines River (DSM-MTH), Iowa River (IAR-MTH), and Rock River (ROC-MTH), as well as Pool 17 of the Upper Mississippi River (UMR-P17). No Grass Carp were captured at the mouths of the Skunk or Wapsipinicon Rivers, or from Pool 15 of the UMR.

Appendix A. Federal Agency Project Reports in Support of the 2017 Monitoring and Response Plan for Asian Carp in the Mississippi River Basin

ASIAN CARP TELEMETRY MONITORING IN POOLS 5A-20 IN THE UPPER MISSISSIPPI RIVER 2017

Geographic Location:
The USFWS/USGS telemetry receivers span from Pool 5a downstream to Pool 20 on the Upper Mississippi River.

Lead Agencies: USFWS LaCrosse Fish and Wildlife Conservation Office and USGS Upper Midwest Environmental Sciences Center

Participating Agencies:
Minnesota Department of Natural Resources
Missouri Department of Conservation
Southern Illinois University
U.S. Army Corps of Engineers
U.S. Coast Guard
U.S. Geological Survey – Upper Midwest Environmental Sciences Center (USGS)
Western Illinois University

Statement of Need:
Populations of Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*H. nobilis*) as well as Hybrids (*H. molitrix x nobilis*) between these species, are advancing in the Upper Mississippi River (UMR) basin (Conover et al. 2007; Chapman and Hoff 2011; O'Connell et al. 2011). Three zones of relative abundance of Asian carp have been identified in the UMR, a robust core population (established) below L&D 19, a transitional zone of moderately dense populations with potential reproduction from L&D19 to L&D 15, and a zone where individual captures of some adults have been recorded above L&D15 (USFWS 2016). This project spans all three management zones to help understand movement and habitat use within and among pools across these zones.

Project Objectives:

1) Utilize real-time mobile tracking and passive receivers to understand Asian carp movement patterns and identify environmental variables that influence those patterns.
2) Increase efficiency of removal efforts by locating congregations of Asian carp and sharing information with removal teams in a timely manner.
3) Understand movement of Asian carp through and around locks and dams to inform development and evaluation of potential deterrents.

Project Highlights:

- 363 Bighead, Silver, and Hybrid Carp have been tagged to date and 313 transmitters were active the entire year in 2017.
- By manual tracking fish tagged in Pool 17, a new congregation site was identified in Pool 16 (the most upstream targeted capture site to date).
    - To date, 82 Asian carp were tagged in Pool 16.
    - Guided by the telemetry data on tagged fish, the largest removal of Asian carp in Pool 16 occurred at this newly identified site in 2017 (80 fish).
- Monthly manual tracking provided 309 pinpointed locations and identified high-use areas in Pools 16 and 19 that aided removal efforts during 2017.
- Asian carp were detected in the Rock (n=49), Cedar (n=7), Iowa, (n=43), and Skunk (n=47) rivers when conditions were favorable for spawning.
- Over 800 passage events have been recorded indicating that Asian carp populations from Pool 10 to Pool 26 intermix at different rates especially during spawning and when main spillway dam gates are open. Greater than 50% of tagged Asian carp used multiple pools with a year.
- Telemetry data resulted in increased efficacy of removal efforts with 150,000 lbs of Asian carp being removed by netting from pools 16-20 in the last two years.
- In 2017, one female Silver Carp, which was tagged in Pool 19, was detected on a stationary receiver in Pool 10 >350 km upstream from where it was tagged. This suggests a small percentage of fish (<1%) move upstream as potential propagules for upstream populations.

Methods:

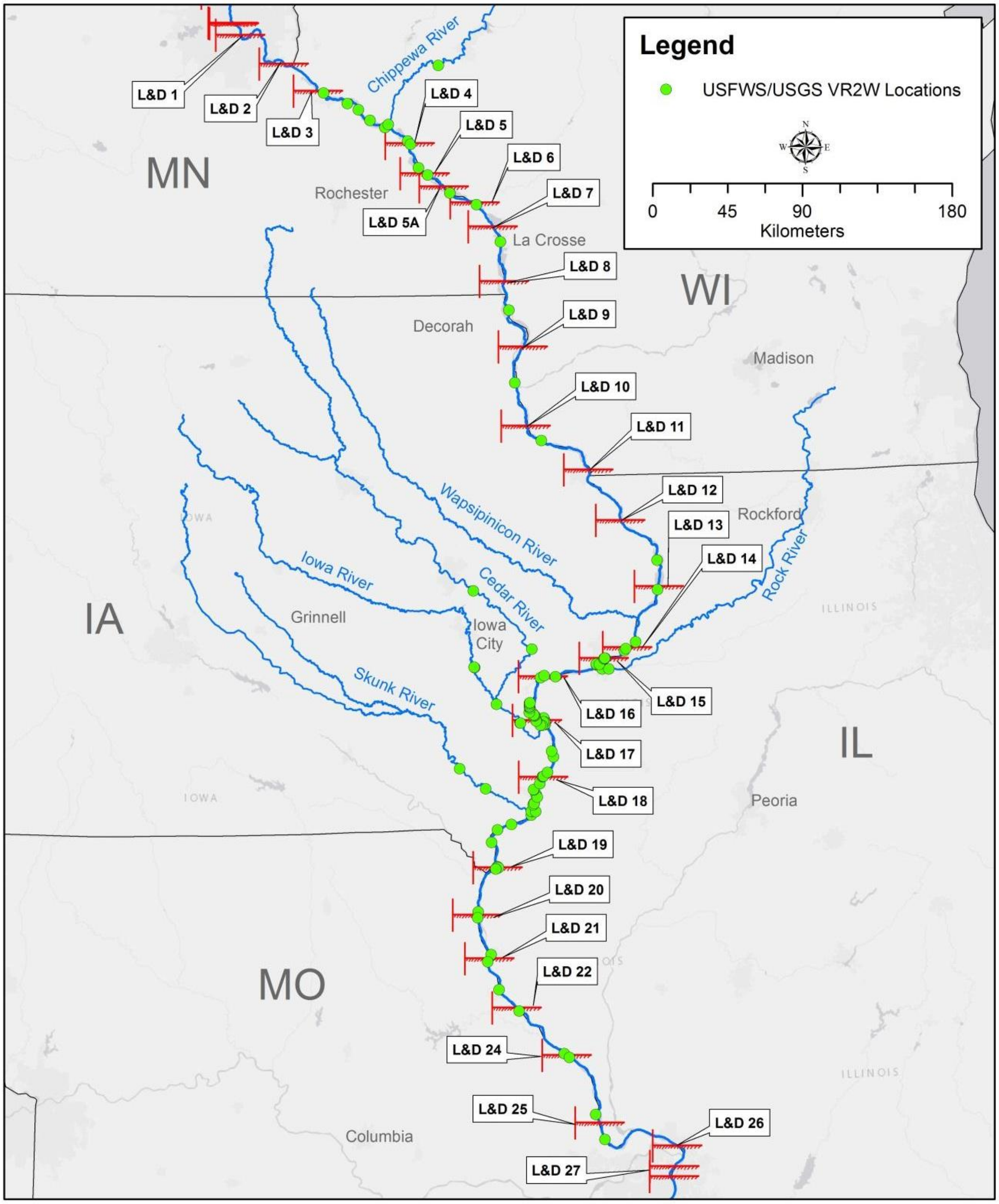
Acoustic Transmitter Tagging: Fish were collected from Pool 16 to Pool 19 using short-term gill net sets. Total length (mm), weight (g), and sex were recorded. Vemco Model V16-6H acoustic transmitters (69 kHz 16mm diameter, 96 mm length, 34g), programmed to transmit on a random delay from 30 to 90 seconds with a battery life of 2,538 days, were tested for recognition with a mobile receiver (VR-100-200) and surgically implanted according to procedures outlined by Summerfelt and Smith (1990). Target tag density was two fish per river mile for each pool. Acoustically tagged Asian carp were also fitted on the jaw with uniquely numbered orange Monel bands printed with contact information. These bands were primarily placed on the upper jaw but a few bands were placed on the lower jaw if necessary for an adequate fit. Post-surgery, each fish was held for observation until the fish recovered enough to maintain equilibrium and swim on its own. Fish were then released in close proximity to the capture location.

Acoustic Receiver Array: An array of stationary receivers (Vemco Model VR2W) was initially installed in the fall of 2013. In 2017, the total number of receivers deployed was increased to about 120, providing coverage from Pool 4 down to Pool 26. Receivers in pools 4 and 5 were maintained by MN DNR. In pool 14 through 19, the transitional population zone and/or the leading edge of the invasion (and where removal efforts are focused), receivers were installed with a higher density to better determine movements and distribution of the population (Figure 1). Receivers were also deployed in several tributaries, including the Rock (Pool 16), Iowa (Pool

18), Cedar (Pool 18), and Skunk (Pool 19) rivers to monitor movements in and out of tributaries and identify possible spawning events. The federal telemetry array bridges a gap between the Minnesota Department of Natural Resources array (Pool 1 to Pool 3) and the Missouri Department of Conservation array (Pool 19 to Caruthersville, MO) resulting in combined telemetry coverage of about 1,600 river kilometers. Data from stationary receivers were downloaded monthly or seasonally which provided information on gross movements, movement patterns, possible spawning events, and habitat use to inform removal and potential deterrent placement.

Two 2-dimensional positioning arrays were placed on the downstream side of each lock approach at Lock 15 and 19 and were operational in 2017 (Figure 2 and 3). Two-dimensional arrays allow latitudinal and longitudinal positioning of fish detected in each lock approach. Receivers (Vemco Model VR2Tx) were placed in ladder recesses, allowing easy access and minimizing interference with lock navigation. Data will be analyzed to establish baseline information to evaluate possible future lock deterrents.

Mobile Tracking: Mobile tracking was used to locate fish within pools and to determine Asian carp movement patterns outside of stationary receiver coverage. In pools where acoustically tagged fish numbers were low, active tracking was used to locate areas where fish were present to increase the probability of capturing new fish to tag and to guide removal efforts. Fish were located with a mobile receiver and hydrophones (Vemco Model VR100-200 and Vemco Model VH110 and VH165). Location, depth, and habitat type were recorded at each site. Tracking in pools 16 and 19 was conducted on a monthly basis from April to October. Standardized point transects (e.g., points along a line), which were spaced 0.53 kilometers apart, were used to provide consistent tracking coverage throughout the sampling season.



Map created by: Jeena Credico
Sources: USFWS, USGS, and Esri
Scale: 1:3,050,000
Projection: NAD 83 UTM Zone 15N

Figure 1. Locations of stationary receivers deployed by the USFWS/USGS (Green) in the Mississippi river basin during 2017.

Figure 2. Locations of stationary receivers deployed by USFWS/USGS (Blue) to form a 2-dimensional positioning array located at Lock and Dam 15.

Figure 3. Locations of stationary receivers deployed by USFWS/USGS (Blue) to form a 2-dimensional positioning array located at Lock and Dam 19.

Results:

Acoustic Transmitter Tagging: An additional 38 Asian carp were acoustically tagged in 2017. This addition and the loss of older transmitters dying out resulted in a maximum of 313 active tags during 2017.

Acoustic Receiver Array: During 2017, 195 fish and 9.6 million detections were recorded on stationary receivers. The number of detections recorded during 2017 doubled the size of the database. Three tagged Asian carp were detected by the array above L&D 15. One male Bighead Carp tagged in Pool 16 in 2016, was detected upstream in Pool 15 during 2016. A female Bighead Carp also tagged in Pool 16 in 2016, was detected as far upstream as Pool 14 during 2017. One female Silver Carp tagged in Pool 19 in 2016, was detected as far upstream as Pool 10 during 2017. This fish was last detected back downstream in Pool 11 near Cassville, WI on June 15th, 2017. Ten fish were detected downstream of L&D 19 from Pool 20 downstream to Pool 25. A total of six Asian carp were detected in the Illinois River during 2017.

*Tributaries of the Mississippi above LD19*__ In 2017, Asian carp were located throughout the season in the Rock (Pool 16, n=49 fish), Skunk (Pool 19, n=47 fish), Iowa (Pool 18, n=43 fish), and Cedar (Pool 18, n=7 fish) rivers. Detections in the tributaries occurred from March to November, but timing did vary for each tributary.

*Key Backwaters*__ Based on manual tracking and stationary receiver information from previous years, a total of ten backwaters were targeted for intense monitoring in Pools 16 through 19 to better understand environmental factors (e.g., flow, temperature, season, food resources, and oxygen) that influence Asian carp movements and aggregations in these areas to inform removal efforts (Figure 4-7). In total, 144 tagged Bighead Carp and Silver Carp were detected in these ten backwaters throughout the year (Figure 8) and nearly half (n=70) of these fish were detected in multiple backwaters.

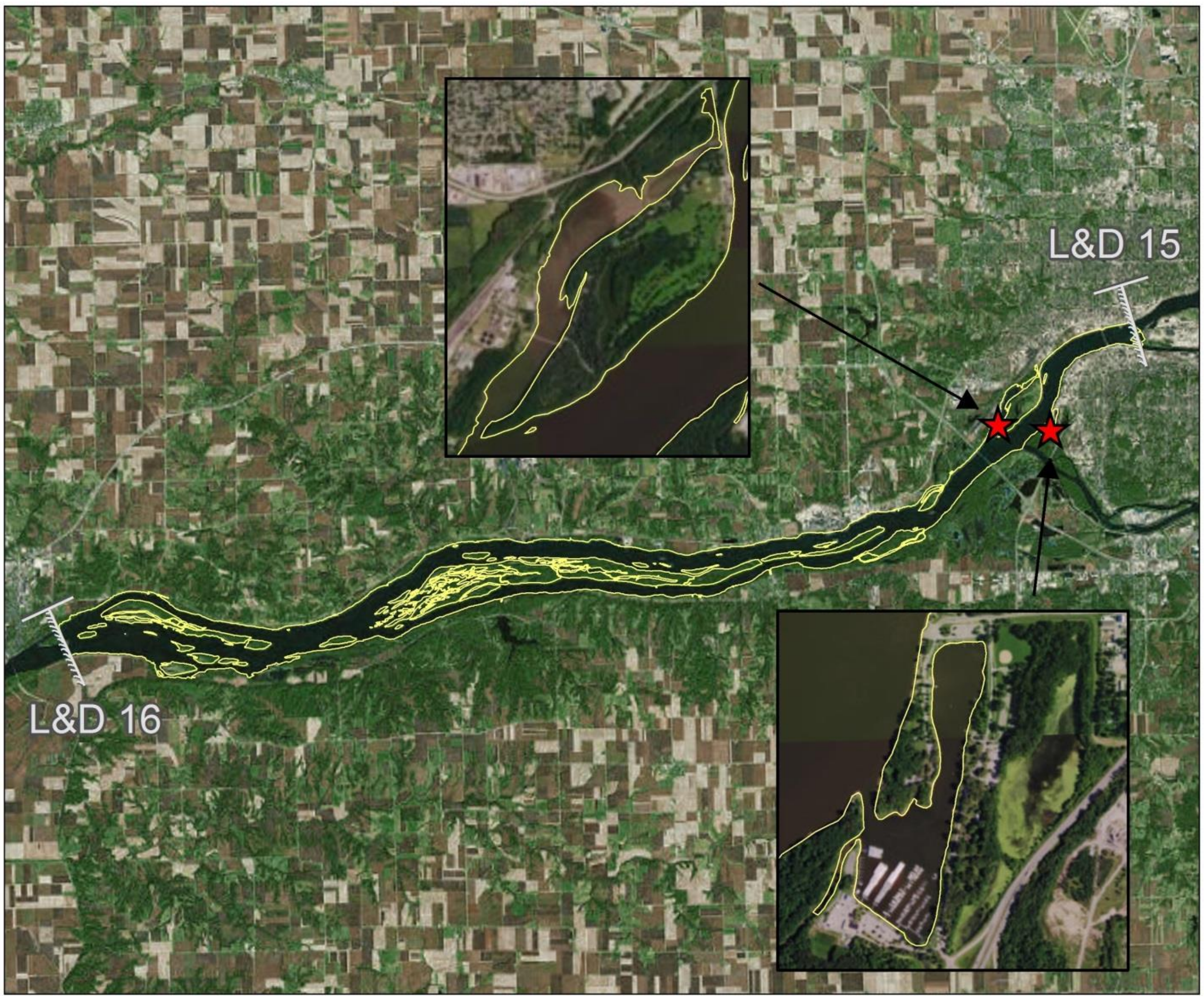


Figure 4. Two backwaters monitored by acoustic receivers in Pools 16 of the Mississippi River.

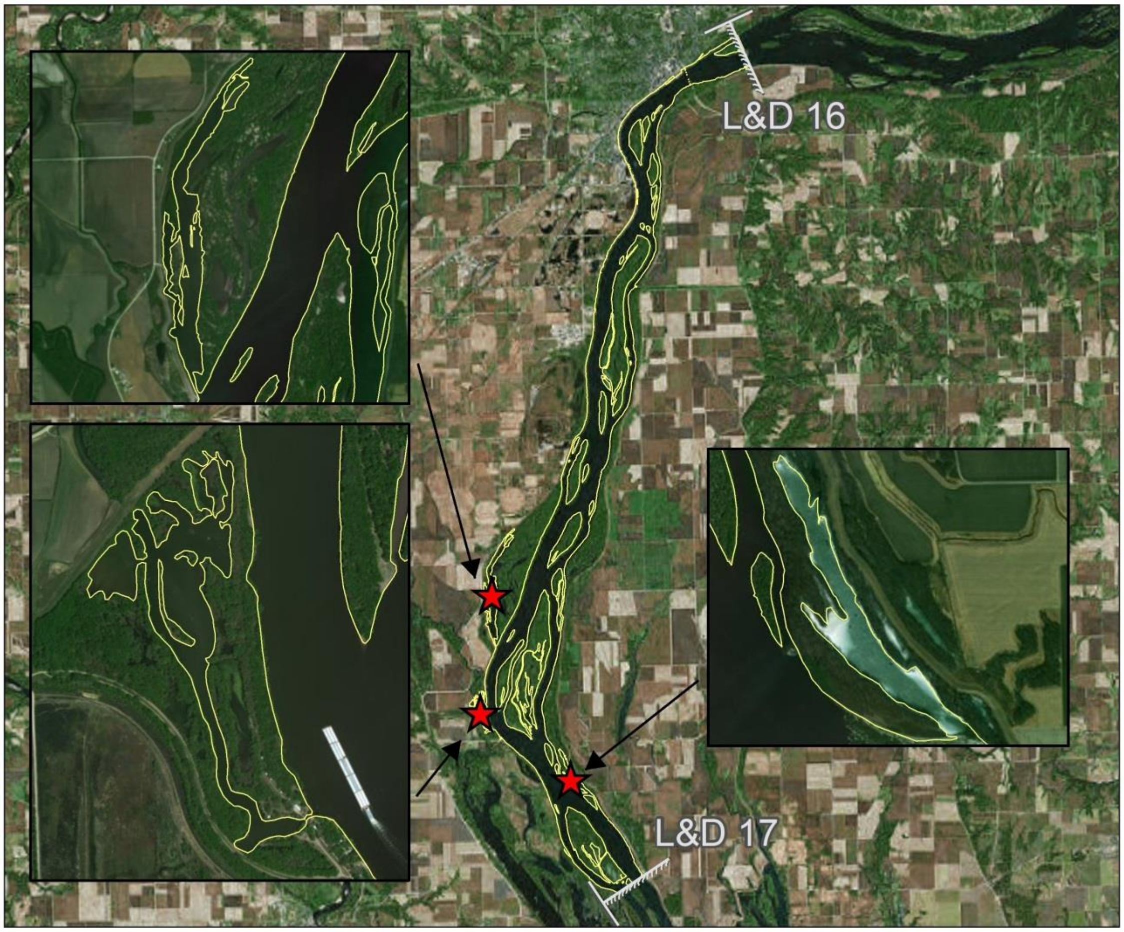


Figure 5. Three backwaters monitored by acoustic receivers in Pools 17 of the Mississippi River.

Figure 6. Two backwaters monitored by acoustic receivers in Pools 18 of the Mississippi River.

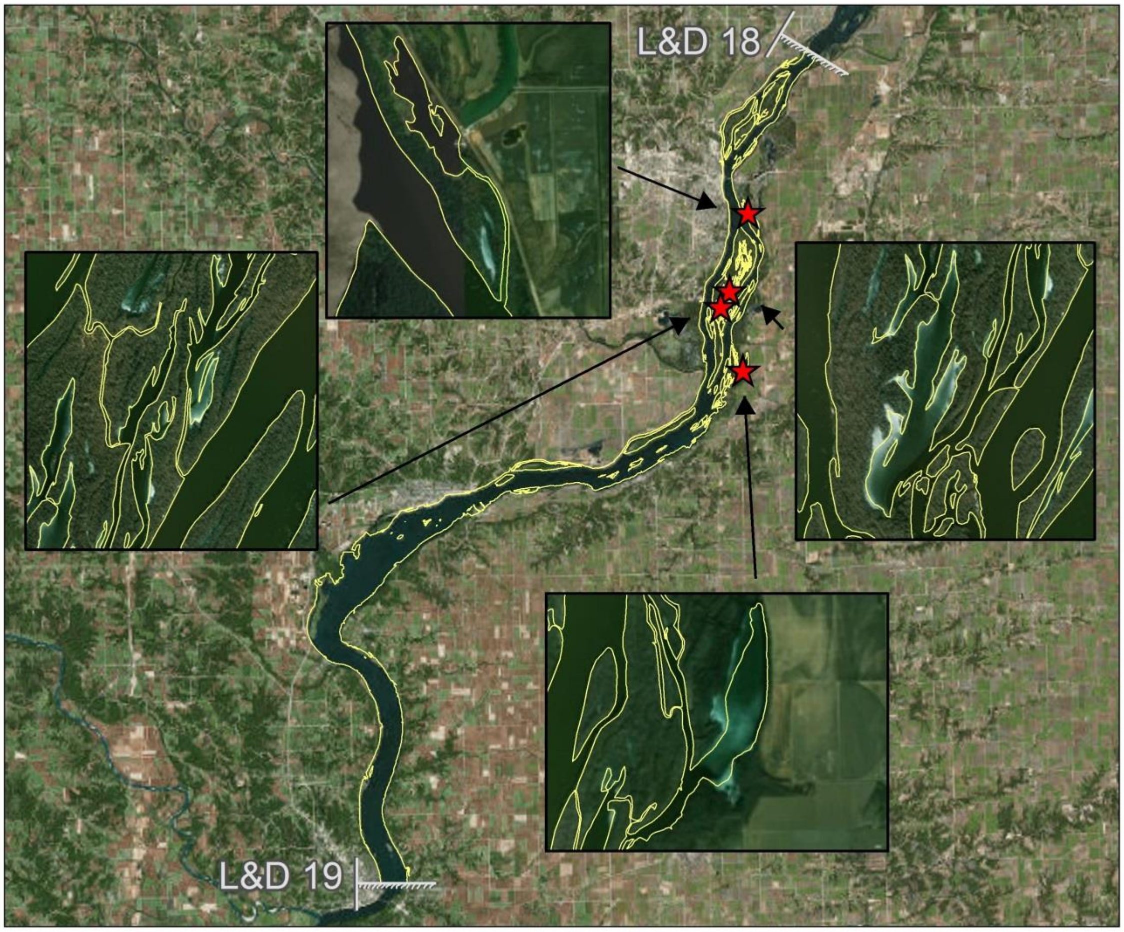


Figure 7. Four backwaters monitored by acoustic receivers in Pools 19 of the Mississippi River.

2-Dimensional Lock Approach Arrays: Lock approach array receivers were deployed from March to December during the 2017 field season. Very few fish were detected at Lock 15 (n=12). Species detected at Lock 15 included Bighead Carp, Silver Carp, and Walleye. However, quite a few fish (n=122 fish) of varying species (n=10) were detected at Lock 19. Two-dimensional positioning data will be analyzed in 2018 to establish baseline data.

Manual Tracking: Monthly manual tracking in pools 16 and 19 resulted in 309 pinpointed Bighead and Silver Carp locations in 2017 and aided in better defining high-use areas. The total number of manual tracking detections for all four pools since inception of the project in 2013 is 1,764. In 2017, 110 Bighead and Silver Carp were located in pools 16 (n=51) and 19 (n=62) and some individual fish were detected in both pools (n=3). Another 13 native fish, which were tagged by Western Illinois University and Missouri Department of Conservation, were located in Pools 16 and 19 by USFWS/USGS tracking efforts. A hotspot analysis will be conducted for all four pools comparing the difference in Bighead and Silver Carp locations for each year. The results of these analyses will be provided in a separate report or manuscript.

Manual tracking and stationary receiver data on Asian carp in 2017 likely contributed to the significant increase in fishing efficacy and efficiency in pools 16-19 as compared to 2016. As well, these data informed contracted fishing that resulted in the largest Asian carp catch in Pool 16, where Asian carp densities are relatively low and capture of Asian carp is more difficult. Specifically, an aggregation of Asian carp was detected using manual tracking and stationary receivers. This information was immediately relayed to Western Illinois University's contracted fishing crews and 100 Bighead and Silver Carp were removed, the largest Pool 16 Asian carp capture and removal to date.

Discussion

Migration Trends and Invasion Front: This study has compiled over 17.2 million detections, and only one Asian carp has been detected making a long (e.g., >350 kilometers) movement upstream into the lowest relative abundance management zone. To date, 0.8% (n=3) of the acoustically tagged fish have been detected above L&D 15. A Silver Carp tagged in Pool 19 has been detected the furthest upstream (Pool 10). Untagged Asian carp have occasionally been collected in upstream pools, mostly by commercial fisherman. This suggests that L&D 14 and 15 may be restricting movements upstream. Conversely, more (2.8%) Asian carp have been detected going downstream to Pool 26 and swimming up the Illinois River. Individual Asian carp used multiple pools (i.e., 16-19) throughout the year, suggesting that the fish in these pools are an intermixed population. Intermixing is particularly notable during the spawning season. The majority of intermixing has occurred between adjacent pools, but some has occurred between four or more pools in this reach. Upstream passage through dams has occurred at all locks and dams from Dam 10 down to Dam 26 with the majority of passages occurring from across dams 16-18. Notably, Bighead Carp and Silver Carp have moved downstream through L&D 19 and five of these fish have been detected moving back upstream through L&D 19.

Importance of Tributaries: Of the three tributaries above LD19 that were monitored and where Asian carp were detected, the Iowa River system has the longest reach (180+ kilometers) without an impassable barrier. Some studies suggest Asian carp require long passable river reaches for successful spawning (Kocovsky et al. 2012), suggesting that the Iowa River may be preferred by Asian carp for spawning over other tributaries that were monitored. Multiple peaks in the frequency-of-occurrence of Asian carp in the tributaries matched up with peaks in flow, and Asian carp egg and larval collections (M. Weber, Iowa State University, unpublished data). These data suggested that the Asian carp populations at this invasion front may spawn as many as five times in a given year if conditions are right. The greatest number of Asian carp detected in the tributaries was during the months of May and June indicating that this may be their primary spawning period. Staging of Asian carp prior to spawning in all three tributaries was primarily observed when water temperatures were >16°C.

The Rock River has the shortest stretch (8 km) of unobstructed river relative to the other tributaries that were utilized by Asian carp. Short river reaches may not provide adequate drift time for egg survival to hatch time (Kocovsky et al. 2012) and therefore the Rock River may provide less favorable spawning conditions than the Iowa and Skunk rivers. However, the Rock River had the highest number of individual fish detected during 2017. Asian carp eggs produced here may survive to hatch if they stay suspended in the Mississippi River after drifting out of the Rock River.

The Skunk River had the second highest number of detected fish in 2017. The Skunk River does have a 60 km reach without a barrier which should provide adequate drift times needed for incubation (Koscovsky et al. 2012). The number of fish detected in the Skunk River in 2017 most likely increased from previous years because the density of tagged fish in the adjacent pool (19) was greatest in 2017. Fish were also detected congregating at the mouth of the Skunk River throughout the year.

Importance of Backwaters: Several seasonal high-use backwater areas were detected in Pool 16, 17, 18, and 19. Asian carp congregated in backwaters during certain times of the year and half of the Asian carp detected in backwaters used more than one backwater during the year. A large number of Asian carp staged in the backwaters during pre and post-spawn time periods. When not migrating or using the tributaries, Asian carp typically inhabited the high-use backwaters during the spring and summer.

Importance of 2-dimensional Lock Approach Arrays: Data were sent to Vemco for 2-dimensional positioning. Once the 2-D positioning is complete, data will be analyzed to understand how fish use the lock approaches in the absence of any deterrent or control methods. If a deterrent does go into place or a control method is implemented, these pre-data will be necessary to identify changes and determine effectiveness of management actions. Only a small number (n=12) of native fish and Asian carp were detected at Lock 15 in 2017. For a meaningful analysis to be completed, more detection data are needed. It is recommended that additional fish be tagged in Pool 16 to increase the probability of tagged fish entering the array at Lock 15. At the Lock 19 approach, a good variety and number of both native fish and Asian carp were detected. Completion of the 2-d positioning will indicate if more fish need to be tagged in Pool 20 to increase fish numbers using the Lock 19 approach area. Tagging fish with depth sensor transmitters would allow 3-dimensional positioning of the fish, providing critical information for deterrent design, placement, and application.

Implications for Management Efforts: Understanding what drives Asian carp to enter and leave these areas of congregation will be crucial to have successful targeted removals throughout the year. Also, understanding what gear and methods are most effective as river conditions and fish abundance change is critical for effective and efficient removal efforts. In the backwaters, targeting Asian carp with gill nets and pound nets when they are moving into and out of each site (e.g., transitional periods) could increase capture and removal efficiency. Large seines may also be very effective, but may be difficult because of submerged trees at some sites. Boston Bay on Pool 18 could be targeted with gill nets or seine hauls in the bay, but only when water levels are such that fish cannot move into the flooded timber. Pound netting may also be particularly effective if fished when Asian carp enter or leave these areas.

A high percentage of tagged Asian carp congregated in the impounded areas above Dam 16, 17, and 18 just prior to and during winter. This provides an extended window to target Asian carp for removal. Each site has flowing water, but is still suitable for gill netting. If the relative use of these sites by tagged Asian carp is representative of the population, then removal efforts could target >50-90% of the population during these peak congregations in backwaters, tributaries, and impounded areas just above the dams. Asian carp removal efforts in these areas should give serious consideration to minimizing by-catch mortality as large numbers of Smallmouth Buffalo, Largemouth Buffalo, and Paddlefish also congregate there, particularly above the dams.

Table 1. Number of Silver, Bighead and Hybrid Carp tagged by individual pool and total number of active tags during 2017 in the Upper Mississippi River. Only 195 tags were detected.

	Pool					
Species	16	17	18	19	Total Tagged in 2017	Total Active
Bighead	6	-	6	-	12	117
Hybrid	2	-	-	-	2	18
Silver	15	-	9	-	24	178
Total	23	-	15	-	38	313

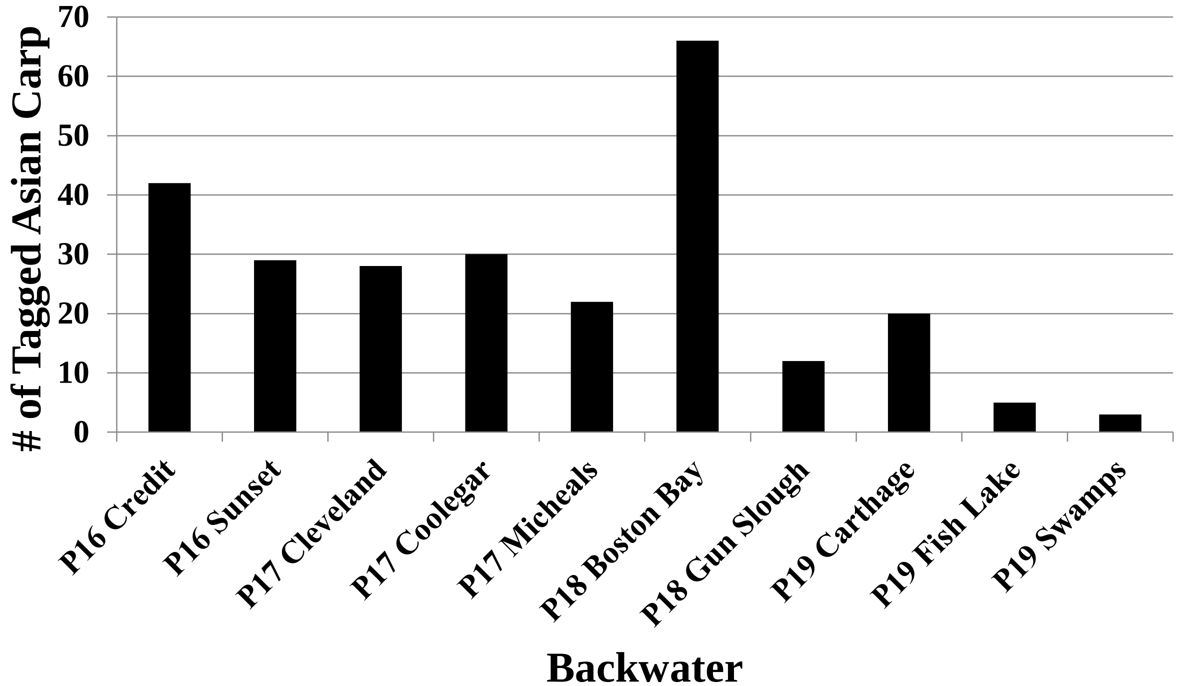


Figure 8. Number of tagged Bighead and Silver Carp (combined) detected in specific backwaters of pools 16 through 19 during 2017. Only 195 tags were detected. Some fish used multiple backwaters.

Recommendations:
Manual tracking data provides further evidence that Asian carp congregate in certain backwaters, above spillways, and in tributaries. These sites are temporally important habitat and can be targeted for Asian carp removal on the Upper Mississippi River. Use of Judas fish techniques (i.e., acoustically tagged Asian carp giving away the locations of many other non-tagged Asian carp) and gaining understanding of habitat selection by Asian carp will play a key role in monitoring and removal of Asian carp in pools where densities are low and where congregation sites are unknown. Two fish were detected by the stationary receiver array above Lock and Dam 15 during 2017 and were not detected moving back downstream of Lock and Dam 15, one as far upstream as Pool 10. A manual tracking effort was conducted in 2017 to locate these fish, but was unsuccessful. An attempt to locate them with stationary receivers and manual tracking will be repeated in early 2018 as they may direct us to new areas that Asian carp congregate in this low abundance zone.

Determining when and why Asian carp select sites is an integral part of effective management. Future work includes model development to predict movements, migrations, and habitat selection. Good models will enable managers to focus removal efforts in time and space and increase capture efficiency. Real-time receivers will also be deployed in 2018 as a primary method to inform removal efforts.

- Continue tagging in all pools to reach and maintain desired tag densities
- Increase density of remote receivers in present array and increase coverage in tributaries
- Place real-time receivers in key areas to further increase efficiency of removal efforts
- Increase density of receivers in pools 10-15 to better detect propagules into these pools
- Maintain 2-dimensional arrays around the lock approach of Locks 15 and 19 to continue collecting pre-deterrent fish use data
- Tag more fish in Pool 16 to increase detections in the lock approach at Lock 15
- Implement use of transmitters with depth sensors to obtain 3-dimensional positioning of fish in the lock approaches and chambers to facilitate the evaluation of deterrents.

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ICHTYOPLANKTON MONITORING FOR EVIDENCE OF ASIAN CARP REPRODUCTION IN POOLS 8-13 OF THE UPPER MISSISSIPPI RIVER

Geographic Location: Upper Mississippi River, Pools 8-13, La Crosse, Wisconsin to Clinton, Iowa
Lead Agency: USFWS- La Crosse Fish and Wildlife Conservation Office

Participating Agencies:
University of Wisconsin- La Crosse
Iowa State University
USGS – Upper Midwest Environmental Services Center
Western Illinois University

Statement of Need:
Ichthyoplankton monitoring for the eggs and larva of Asian carps in the Upper Mississippi River (UMR) is important for timely detection of new spawning events in novel habitats. Researchers have expressed concern that the arrival of Asian carps in the UMR watershed will have cascading effects on local aquatic ecosystems. However, it appears that the success of Asian carps' spawning events may be highly contingent on environmental factors such as sustained, high river discharge during late spring and early summer (Kolar et al 2007; Camacho *et al.* 2016). Understanding why production and recruitment may be limited in some years and in some locations may help managers to recognize bottlenecks in the life history of Asian carps caused by environmental variations and spur the development of new and effective management strategies for limiting their reproduction in unexploited habitats.

Project Objectives:
1) Evaluate Asian carp reproduction (egg, larval, and juvenile densities) in the UMR watershed. The goal of this USFWS-managed program is to establish a monitoring framework on Pools 8-13 of the Mississippi River and its largest tributaries: the Maquoketa, Turkey, and Wisconsin rivers. Researchers at Iowa State University (ISU) maintain a companion monitoring program to accomplish these objectives on Pools 14-20 of the Mississippi River and its tributaries: the Wapsipinicon, Rock, Iowa, Skunk, and Des Moines rivers.
2) Monitor larval fish and egg production of native fishes occurring in the watershed. Yearly monitoring of larval fish and egg drift in the UMR and its tributaries offers opportunities to explore the reproductive habits of fishes aside from Asian carps. These data can help establish a baseline, pre-invasion estimate of native fish production/recruitment in rivers where Asian carps have not yet established robust reproductive populations.

Project Highlights:

- All fishes collected during 2016 sampling were identified during Winter/Spring 2017. No Silver, Bighead, Grass, or Black carps were observed in 240 samples.
- 319 samples were sucessfully collected from the UMR during April-August 2017. These

samples are currently being examined by staff of the La Crosse FWCO and fishes and eggs will be identified as soon as possible.

Methods

Monitoring for Asian carp eggs and larvae using ichthyoplankton tows was conducted at 28 fixed-locations (Figure 1) approximately every 7-10 days from April until August 2017. For the purposes of standardization, every effort was made to sample closest to the original sampling location throughout the summer. Sampling locations had to be relocated in some situations because of the growth of emergent vegetation that fouled the plankton nets. Ichthyoplankton tows using a 0.5 m diameter net with 500 μm mesh were conducted at the surface at a constant boat speed relative to the shoreline for four minutes at each location. A General Oceanics Model (2030R) flowmeter was mounted in the mouth of the net to estimate volume (m3) of water filtered during each tow. The sites were arranged in groups of 2-3 tows to document habitat-specific variations in catch rates. Three tows were conducted at each mainstem Mississippi River sites parallel to river flow. The first tow was conducted in the main thalweg for drifting eggs and larvae, the second tow occurring near channel borders where water velocity is moving downstream slower than the thalweg, and the third in an adjacent backwater area for mobile larvae (>24 hours post fertilization). At each tributary location, one fixed sampling location was established inside the tributary ~1km upstream of the confluence with the Mississippi River and another location was established along the main channel border of the Mississippi River ~1km downstream of the tributary's confluence. After each tow, ichthyoplankton net contents were rinsed toward the cod end, placed in sample jars, and preserved in 95% non-denatured ethanol. The ethanol was replaced in each sample container after the first 24 hours of storage to further preserve samples for later genetic analyses (Kelso et al. 2012).

In the laboratory, eggs and larvae are separated from detritus, counted, and preserved for morphometric and, if necessary, genetic, identification. All larval fishes are identified to the lowest taxonomic family using Auer (1982) as a primary taxonomic key. Asian carp eggs and larvae are identified to genus using keys provided by Chapman (2006) and Chapman and George (2011). All fishes identified as 'possible' Asian carps are immediately submitted to the Whitney Genetics Lab for genetic confirmation of species assignment. The developmental stage of all fishes is differentiated based on fin development. Fish recognized as having a full complement of fins will be categorized as juvenile fish.

Following identification, egg and larval densities (number/m3 of water sampled) will be compared among sites and sample dates within a year. Akaike's Information Criterion (AIC) will be used to evaluate how environmental variables (e.g., temperature, discharge, gage height, rising or declining or stable flow within 24 hour period of sampling event, etc.) are related to egg and larval densities with the most supported model identified by the lowest AIC value.

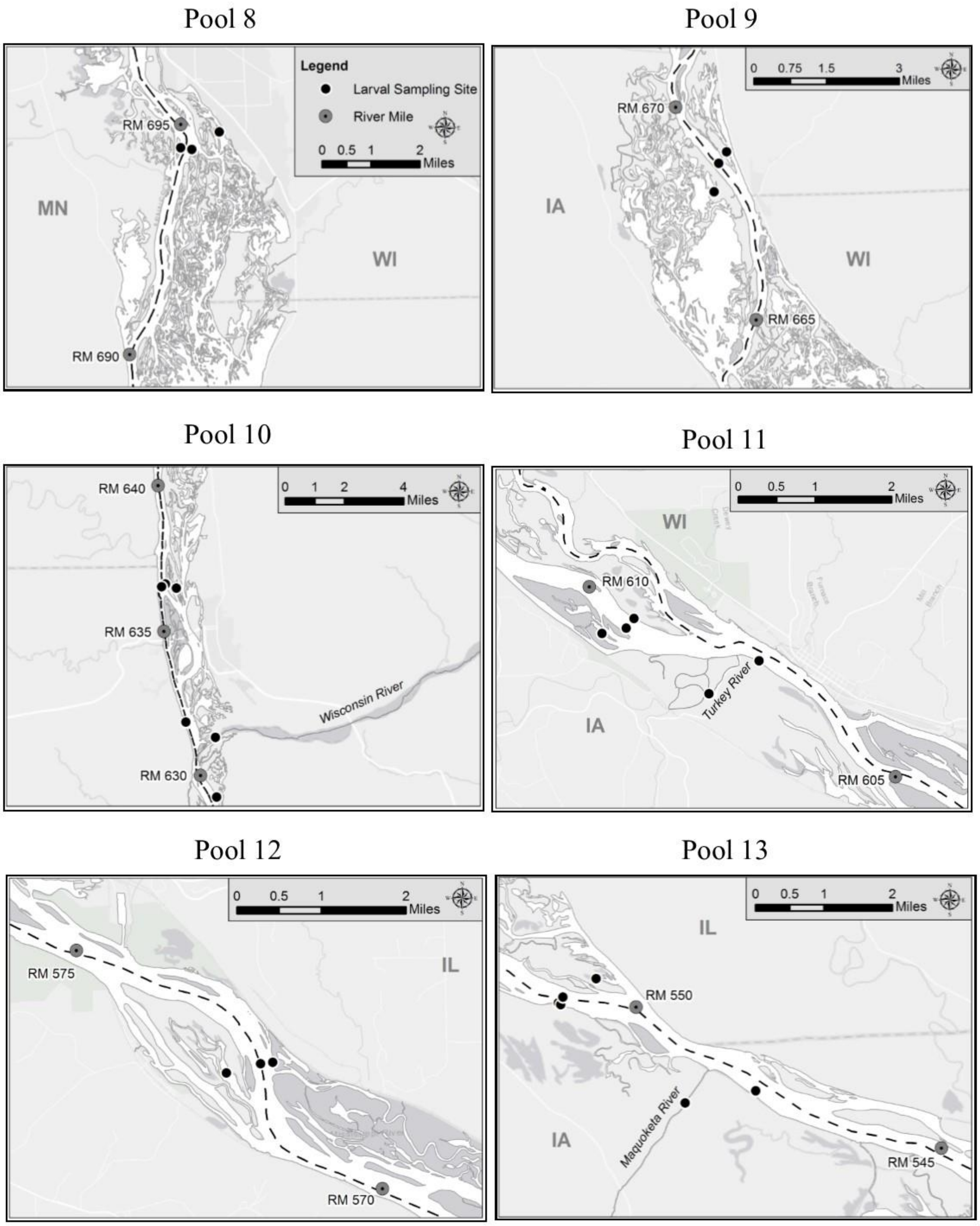

Figure 1. Map of ichthyoplankton netting locations in Navigational Pools 8-13 of the Upper Mississippi River monitored during 2017. Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

Results and Discussion:

2016 Results

5,242 larval and juvenile fish and 3,659 eggs were collected in 240 ichthyoplankton tows conducted between 11 May and 31 August 2016. Initial visual evaluations of larval and juvenile fishes were completed in Winter/Spring 2017 and did not identify any Bighead, Silver, Grass, or Black carps in the samples. Table 1 provides information on the total catch identified to family. A monthly breakdown of catch statistics is provided in Table 2. The relative abundance of eggs peaked in May and decreased throughout June, July, and August. The relative abundance of larval and juvenile fishes peaked during late June and early July.

Table 1. Total catch of fishes from ichthyoplankton monitoring in four tributaries and Pools 8-13 of the Upper Mississippi River during 2016. Specimens were identified to family.

Family	Number Identified
Atherinidae	1
Catostomidae	164
Centrarchidae	160
Clupeidae	272
Cyprinidae*	3934
Hiodontidae	1
Lepisostidae	2
Moronidae	7
Sciaenidae	606

*Family Cyprinidae did not include any Bighead, Silver, Grass, and Black carps

Table 2. Total catch of eggs and larval and juvenile fishes from ichthyoplankton monitoring in six pools of the Upper Mississippi River and four tributaries during 2016.

Mississippi River Pools		**Eggs**	**Fishes**
Pool 8 Totals		552	500
	May	303	8
	June	137	15
	July	112	469
	August	0	8
Pool 9 and Upper Iowa River Confluence Totals		151	121
	May	90	7
	June	37	65
	July	24	38
	August	0	11
Pool 10 and Wisconsin River Confluence Totals		877	533
	May	760	33
	June	69	257
	July	31	173
	August	17	70
Pool 11 and Turkey River Confluence Totals		431	149
	May	275	17
	June	68	80
	July	86	46
	August	2	6
Pool 12 Totals		1167	773
	May	837	98
	June	322	375
	July	4	270
	August	4	30
Pool 13 and Maquoketa River Confluence Totals		322	3163
	May	163	3
	June	18	1530
	July	133	1572
	August	8	58

2017 Results:
319 samples were collected between 20 April and 24 August 2017. All samples were collected during daylight hours between 7.03 a.m. and 6.10 p.m. All sampling was conducted without incident and the samples collected are currently being processed in the laboratory at the La Crosse FWCO. These data will be summarized and analyzed in the 2018 annual report. Specific questions or requests for 2017 data can be directed to Mark Fritts (mark_fritts@fws.gov).

Recommendation:
While the results of our initial survey indicate that Asian carps did not reproduce in Pools 8-13 of the UMR during 2016, we believe that future surveys are necessary given the evidence of sporadic production and recruitment documented in Silver and Bighead carp from the Illinois River (Gibson-Reinemer et al. 2017). That study indicates that Asian carps' recruitment is closely tied to early summer flooding events and that production and recruitment are rarely observed in years when these specific hydrologic conditions are unavailable. We recommend that ichthyoplankton monitoring be conducted in the UMR for, at least, five additional years to incorporate sampling within a spectrum of hydrologic conditions.

We also recommend that these data on Asian carps' production be incorporated into more complex, watershed-scale analyses of Asian carps population dynamics and movement patterns (Rahel and Jackson 2007). If Asian carp eggs or larvae are detected, specialized spacial analyses could help regional managers more precisely determine the times and locations of Asian carp spawning events and the destinations of drifting eggs and larvae (e.g. Hightower et al. 2012 and Garcia et al. 2013). This information, in turn, could be used to direct novel control strategies that both target adult Asian carps and limit successful spawning events or early life-stages growing in nursery habitats.

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JUVENILE ASIAN CARP MONITORING TO DOCUMENT GEOGRAPHIC RANGE OF RECRUITMENT OF ASIAN CARP IN THE UPPER MISSISSIPPI RIVER

Geographic Location: Upper Mississippi River Pools 14-19

Participating Agencies: La Crosse Fish and Wildlife Conservation Office (lead); Western Illinois University and Rock Island Ecological Services Field Office (field support).

Statement of Need:

Adult Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*) were first reported in the Upper Mississippi River basin above Lock and Dam 19 in 1987 and 1999, respectively (http://nas.er.usgs.gov), while Black carp (*Mylopharyngodon piceus*) have not yet been captured above Lock and Dam 22. The first Asian carp populations above LD 19 likely immigrated from source populations downriver. Commercial catch data from Illinois indicate that population densities have increased in recent years (Maher 2016). It is unknown whether reproduction and recruitment or immigration from downstream is driving population growth. In 2014, USGS ichthyoplankton tow samples containing *Hypophthalmichthys* eggs were found in pools 16, 17, 18, and 19 (Larson et al. 2017). Prior to 2016, the only evidence of successful recruitment is a handful of juvenile *Hypophthalmichthys* (<300 mm) reported in lower pool 19 (James Lamer, WIU, personal communication; Cari-Ann Hayer, USGS, unpublished data). In 2016, large numbers of juvenile Silver Carp were collected from pools 18 and 19. Understanding the source of population growth for these species will help direct Asian carp management actions in the UMR.

Project Objectives:

1) Determine the extent of Bighead Carp and Silver Carp recruitment above Lock and Dam 19.
2) Calculate relative abundance of Bighead Carp and Silver Carp in pools 16-19.

Project Highlights:

- In 2017, documented the upstream dispersal of juvenile Silver Carp to pool 16, documented a juvenile Bighead Carp in pool 19, and did not detect recruitment from a 2017 year class.
- In 2016, detected recruitment of Silver Carp as far upstream as pool 18 and Grass Carp in pool 17.

Methods:

Young-of-Year (YOY) sampling was initiated in August and extended through September in pools 14-19. Areas that provided what was suspected to be preferred habitat for juvenile Asian carp were sampled as targeted sites. A dozer trawl and boat electrofishing were used to sample backwaters, marinas, and tributary mouths. In August 2016, YOY Silver Carp captured in Pool 18 were 47 to 166 mm total length ($\bar{x}$=98 mm). The dozer trawl was used at the targeted sites in August of 2017, when it was expected that small Asian carp would be at a size vulnerable to capture via trawl. The rigid frame of the dozer trawl measured 1.83 m wide by 0.91 m tall and the attached net was 35 mm mesh at the opening reducing to 4 mm at the cod end. The trawl was pushed from the front of the boat and the net extended 2.5 m under the boat. Length and duration of trawl was dependent on the site characteristics and available habitat. All fish were identified to species or genus and released.

Pulsed-DC boat electrofishing was used in September to target YOY that were potentially >100 mm. In September 2016 YOY Silver Carp averaged 164.5 mm total length(96-238 mm). The boat electrofisher was as 18 ft flat bottom boat with a Smith Root VVP-15B box set to pulsed-DC current at 60 pulses per second and 30% duty cycle. Temperature and conductivity corrections were made to produce a standard potential transfer of 3000 watts to the water. Electrofishing runs were 15 minutes in length and two netters collected fish. Power was turned off/on intermittently to prevent driving fish away from the effective electrified field. An attempt was made to net all fish that were observed. Non-target species were identified, counted, and released. Asian carp were measured, weighed, and transferred to WIU for collection of aging and microchemistry structures.

Abundance monitoring was conducted using pulsed-DC boat electrofishing with two dip netters in pools 16-18 during spring and fall. Multiple sites in each pool where Asian carp are known or expected to be present were selected as fixed sites. Random and alternate sites were selected for each pool using ArcGIS 10.4 at a minimum density of one site per 1.5 river miles. In the event a random site could not be reached, the nearest accessible alternate site was sampled. The same boat electrofisher that was used for YOY sampling was used for abundance sampling in pools 16-18. The box was set to pulsed-DC current at 60 pulses per second and 25-30% duty cycle. In pools 19-20, the boat electrofisher was a 20 ft flat bottom boat with an ETS box set to pulsed-DC current at 60 pulses per second and 25% duty cycle. Temperature and conductivity corrections were made to produce a standard potential transfer of 3000 watts to the water, per Long Term Resource Monitoring specifications (Gutreuter et al. 1995). Electrofishing runs were 15 minutes in length. Two netters attempted to dip all fish that were observed. All fish were counted and identified. Asian carp were measured and juveniles were tranferred to WIU for collection of aging and microchemistry structures. Fixed site and random site catch per unit effort was averaged across each pool for the year.

Results and Discussion:

Targeted dozer trawling was completed during two weeks in August. Fifty trawling runs took place in pools 14-19 for a total of 13,920 meters trawled. There were 17,771 fish collected representing 23 species, although many smaller specimens were identified only to genus. No YOY Asian carp were observed or collected, although adults and larger juveniles were observed at several locations. A subsample of Gizzard Shad measured to estimate size selectivity of the sampling gear averaged 59.4 mm total length (43-78 mm; n=45).

Targeted electrofishing was completed over two weeks in September. Forty-nine electrofishing runs were completed in pools 14-19 for a total of 12.3 hours of electrofishing. There were 15,609 fish collected representing 50 species and one hybrid. No YOY Asian carp were collected or observed. However, one juvenile Bighead Carp in pool 19 (520 mm), one juvenile Grass Carp in pool 18 (395 mm), and 43 Silver Carp were collected, 37 of which were juveniles (mean= 418.5 mm, range 385-470 mm) (Figure 1). Of the juvenile Silver Carp collected, four were in pool 17 [catch per unit effort (CPUE) = 2.29 juvenile Silver Carp/hour], six were in pool 18 (CPUE = 3.43), and 27 were in pool 19 (CPUE = 17.95) (Table 1).

Sixteen fixed sites and 99 random sites were sampled in April and October of 2017. A total of 13,523 fish representing 53 species and two hybrids were collected in pools 16-18. No Bighead Carp were collected. Four Silver Carp were collected at randomized sites including one juvenile in pool 16 (254 mm) and one juvenile in pool 18 (479 mm) (Table 1). One adult was collected in each of pools 16 and 17. Three juveniles were collected at one pool 18 fixed site and five adults were collected at one pool 17 fixed site (Table 1). Seven adult Grass Carp were collected: one in a pool 16 fixed site, one in a pool 16 random site, and five in pool 18 random sites.

In summary, 46,892 fish were collected at 215 sample sites through all gears combined (Table 2) (Figure 2). There were no YOY Asian carp collected. Fifty-five Silver Carp were collected, 42 of which were juveniles belonging to the 2016 year class. The 2016 year class, detected as far upstream as pool 18 during that year, was detected two pools upstream in pool 16 as a result of this monitoring. A 584 mm Silver Carp collected by Exelon biologists in pool 14 during fall of 2017 now represents the furthest upstream detection reported of a juvenile Silver Carp (James Lamer, WIU, Personal Communication). To our knowledge, the juvenile Bighead Carp collected in pool 19 represents the first and only juvenile of that species documented above Lock and Dam 19.

Recommendation: Continue to target YOY Asian carp during the summer months in backwaters, marinas, and tributary mouths with the dozer trawl and boat electrofishing.

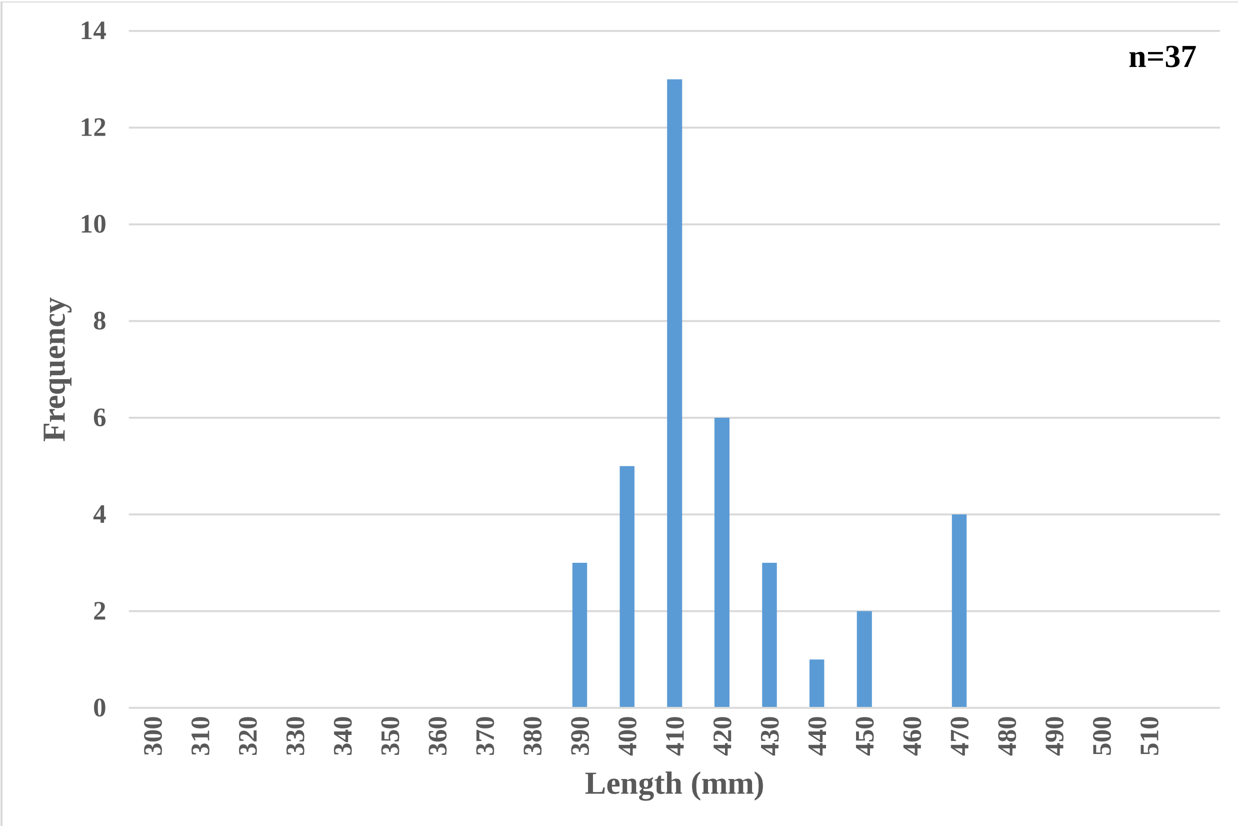

Figure 1. Length-frequency histogram of juvenile Silver Carp collected during targeted electrofishing sampling in pools 17-19.

Table 1. Juvenile Silver Carp collected via electrofishing by pool in 2017. CPUE is calculated as juvenile Silver Carp/hour of electrofishing.

		Targeted Electrofishing		Random Electrofishing		Fixed Electrofishing	
		Age 1 SVCP	CPUE	Age 1 SVCP	CPUE	Age 1 SVCP	CPUE
Pool	14	0	0.00				
	15	0	0.00				
	16	0	0.00	1	0.11	0	0.00
	17	4	2.29	0	0.00	0	0.00
	18	6	3.43	1	0.11	3	2.00
	19	27	17.95				
Total		37	3.02		0.08	3	0.16

Table 1.*Total catch with all gears by pool during 2017 juvenile Asian carp monitoring.*

		Pool						
Common Name	Scientific Name	14	15	16	17	18	19	Total
Gizzard Shad	Dorosoma cepedianum	3,011	2,041	5,223	3,540	5,391	2,255	21,461
Emerald Shiner	Notropis atherinoides	44	159	3,439	2,699	4,808	843	11,992
Unidentified Shiner	Notropis spp.	969	1,296	1,509	1,509	154	1,240	6,677
Freshwater Drum	Aplodinotus grunniens	7	21	497	186	199	5	915
Bluegill	Lepomis macrochirus	92	113	76	153	149	157	740
Largemouth Bass	Micropterus salmoides	152	72	74	132	149	82	661
Common Carp	Cyprinus carpio	39	49	223	92	121	54	578
River Carpsucker	Carpiodes carpio	51	26	149	98	190	4	518
Brook Silverside	Labidesthes sicculus	44	80	27	19	23	96	289
Quillback	Carpiodes cyprinus	26	4	75	46	83	3	237
Bigmouth Buffalo	Ictiobus cyprinellus	4	7	51	61	59	38	220
White Bass	Morone chrysops	10	5	73	51	62	18	219
Unidentified Lepomis	Lepomis spp.			3	118	90		211
Smallmouth buffalo	Ictiobus bubalus	1	4	90	34	68	11	208
Orangespotted Sunfish	Lepomis humilis	7	5	63	11	62	23	171
Shortnose Gar	Lepisosteus platostomus			72	61	27	3	163
Walleye	Sander vitreum	17	1	36	26	33	2	115
White Crappie	Pomoxis annularis	3		22	22	56	9	112
Longnose Gar	Lepisosteus osseus	4	5	54	34	5	1	103
Channel Catfish	Ictalurus punctatus	2		48	23	17	5	95
Mooneye	Hiodon tergisus			67	20	2		89
Golden Shiner	Notemigonus crysoleucas	11	66	1	2	3	2	85
Shorthead Redhorse	Moxostoma macrolepidotum			43	11	31		85
Sauger	Sander canadense	3	4	45	13	18	1	84
Channel Shiner	Notropis wickliffi			3	30	30	20	83
Bowfin	Amia calva	13	3	12	9	16	18	71

Common Name	Scientific Name	Pool 14	15	16	17	18	19	Total
Unidentified Crappie	Pomoxis spp.					66		66
Silver Carp	Hypopthalmichthys molitrix			2	11	10	32	55
Black Crappie	Pomoxis nigromaculatus	4	2	5	8	12	18	49
Highfin Carpsucker	Carpiodes velifer			32	12			44
Sand Shiner	Notropis stramineus	27	9	1	2		1	40
Silver Chub	Macrhybopsis storeriana			24	7	8	1	40
Pumpkinseed	Lepomis gibbosus					40		40
Spotfin Shiner	Cyprinella spiloptera	1		1	4	26	6	38
Yellow Perch	Perca flavescens	8	25	1	2	2		38
Northern Pike	Esox lucius	12	6	8	2	4	5	37
River Shiner	Notropis blennius			7	19	3	3	32
Bullhead Minnow	Pimephales vigilax		1	12	10	5	2	30
Spottail Shiner	Notropis hudsonius	8	4	2	5	5	2	26
Spotted Sucker	Minytrema melanops	7	10	1	2	2	1	23
Yellow Bass	Morone mississippiensis			1	3	15		19
Golden Redhorse	Moxostoma erythrurum	3		7	2	5		17
Flathead Catfish	Pylodictus olivaris			5	4	2	1	12
Silver Redhorse	Moxostoma anisurum	1		9		1		11
Striped Bass x White Bass	Morone saxatilis x M. chrysops	2		5	1	3		11
Smallmouth Bass	Micropterus dolomieu		3	2	3	2		10
White Sucker	Catostomus commersoni				9			9
Grass Carp	Ctenopharyngodon idella			2		6		8
Warmouth	Lepomis gulosus				4	2	1	7
Unidentified Chub	Macrhybopsis spp.	5		1				6
Green Sunfish	Lepomis cyanellus	1			3		1	5
Logperch	Percina caprodes	3	1	1				5
Paddlefish	Polyodon spathula			3	1			4

		Pool						
Common Name	Scientific Name	14	15	16	17	18	19	Total
Longear Sunfish	Lepomis megalotis				4			4
Johnny Darter	Etheostoma nigrum					3		3
Unidentified Redhorse	Moxostoma spp.	1		2				3
Shovelnose Sturgeon	Scaphirhynchus platorynchus			2				2
Goldfish	Carassius auratus			2				2
River Redhorse	Moxostoma carinatum					2		2
Northern Hog Sucker	Hypentelium nigricans					1		1
Black Buffalo	Ictiobus niger	1						1
Redear Sunfish	Lepomis microlophus					1		1
Skipjack Herring	Alosa chrysochloris	1						1
Silver Lamprey	Ichthyomyzon unicuspis						1	1
Brown Bullhead	Ameiurus nebulosus			1				1
Green Sunfish x Bluegill	Lepomis cyanellus x L. macrochirus			1				1
American Eel	Anguilla rostrata			1				1
Unidentified	Unidentified						1	1
Unidentified Sucker	Unidentified Catostomidae			1				1
Mimic Shiner	Notropis volucellus				1			1
Bighead Carp	Hypopthalmichthys nobilis						1	1
Total		4,595	4,022	12,117	9,119	12,073	4,977	46,892

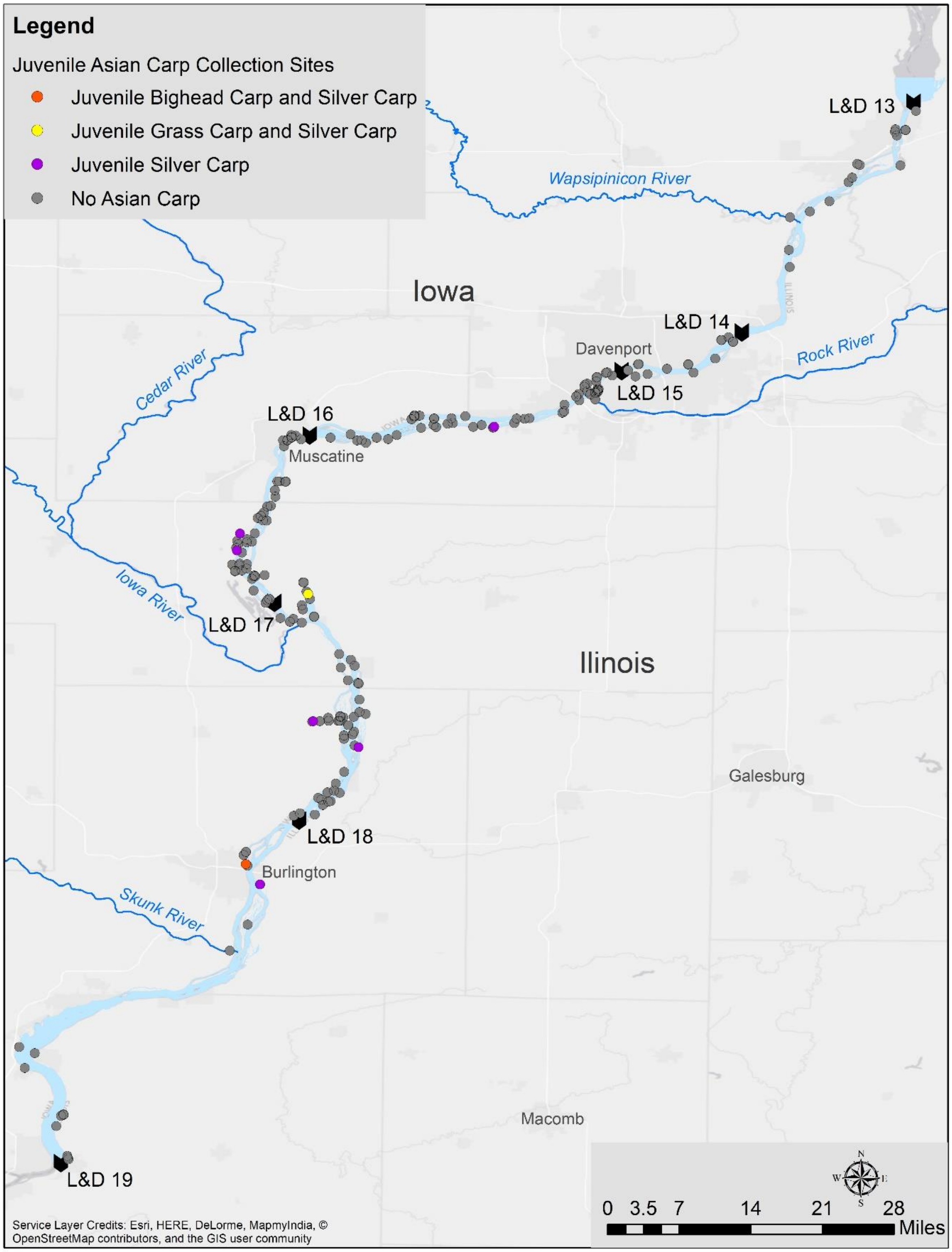

Figure 2. Sample sites for all gears in 2017 and locations where juvenile Asian carp were collected.

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COLLABORATIVE STRATEGY FOR DETERRENT BARRIER RESEARCH, DESIGN, IMPLEMENTATION AND ASSESSMENT TO MINIMIZE THE SPREAD OF ASIAN CARPS IN THE UMR

The following reports represent individual reports from collaborating agencies that are part of a larger project addressing Asian carp deterrence on the UMR.

Lead Agency: USFWS- La Crosse FWCO (USFWS)

Geographic Location: L19 – L14 in the Upper Mississippi River, Illinois and Iowa

Participating Agencies: USGS-Upper Midwest Environmental Services Center (USGS), Western Illinois University (WIU), Missouri Department of Conservation (MDC), US Army Corps of Engineers (USACE) , Minnesota Department of Natural Resources (MNDNR), Illinois Department of Natural Resources (ILDNR), Iowa Department of Natural Resources (IADNR), Wisconsin Department of Natural Resources (WIDNR), Southern Illinois University (SIU), National Park Service (NPS)

Statement of Need:
Invasive carps are established in the upper, middle, and lower Mississippi River and their expansion upstream threatens a variety of aquatic ecosystem services including fishing and recreational boating. The upper Mississippi River contains a series of locks and dams that may already limit upstream movement of invasive carp, and thus their spread, by limiting population growth at the reproductive front and minimizing pioneer fish from moving upstream in the system. If severe enough, passage restrictions might hinder reproductive success of invasive carp at the reproductive front because of their requisite migratory and mass spawning behavior, and drifting egg and larval life stages.

At the time of this writing, a collaborative deterrent strategy for the UMR is in the final stages of review. This document defines an intensive management zone (IMZ) in the Upper Mississippi River that includes an area from Lock and Dam 19 to Lock and Dam 14, bracketing the invasion front of Asian carp in the UMR. In concept, the IMZ would be bracketed by effective barriers to Asian carp passage at the upper and lower ends and intensive efforts to reduce Asian carp abundance in between. The goal of this project is to pursue and expand on the recommendations in the UMR deterrent strategy report including 1) identifying the steps necessary to deploy deterrents, 2) implementing and evaluating the use of promising deterrent technologies 3) evaluating the utility of operational modifications at locks and dams 4) maximizing native fish passage. Important information gaps and research needs regarding fish passage, fish distribution and movement around dams, dam design and hydrology, deterrent design and effectiveness, and gate operations should be filled as preliminary implementation steps begin.

The USFWS received additional funding in FY2017 to be used specifically to test a sound deterrent in the presence of high densities of Asian carp with the goal of identifying a mechanism for preventing upstream passage of Asian carp through lock chambers. One method for assessing the effectiveness of fish deterrents is using acoustic telemetry to assess fish passage rates, and this assessment has begun complimentary to the existing Asian carp acoustic monitoring project. Specifically, the study of Asian carp and native fish passage is ongoing at Lock and Dam 19 and in other locations. As deterrence planning is underway, the UMR Asian carp partnership added an objective to this project to expand and focus telemetry efforts on fish passage rates at key locations in the UMR.

Project Objectives:

1. Evaluate promising technologies and strategic locations, and complete UMR deterrent strategy report
2. Participate in regional workshops and webinars to better understand the state-of-the-science on and steps needed to test and deploy deterrent technologies at locks and dams
3. Support ongoing efforts to better understand the application of deterrents in lock chambers for invasive carp while minimizing effects on natives in the UMR
    a. Support efforts to test CO_2 application at strategic locations in the UMR
    b. Support development of plans to test complex sound applications at strategic locations in the UMR
4. Quantify native and non-native fish passage at lock and dam 19, 15, and 14 as an assessment tool for the future testing of Asian carp deterrents.

Project Highlights:

Objective 1 (evaluate promising technologies)

- University of Minnesota – Twin Cities modeled the effect of gate operations on fish passage at Lock and Dam 5 and continued field evaluation of gate flow modeling at Lock and Dam 2 and acoustic speakers at Lock and Dam 8.
- University of Minnesota – Duluth continued research on complex noise technology

Objective 1 (evaluate strategic locations)

- USFWS - Over 190 minutes of electrofishing conducted and 1700 yards of gill net fished in a two week effort at Lock and Dams 14 and 15
- USFWS and SIU - Nine hours of ARIS imagery collected and one comprehensive hydroacoustic survey completed at Lock and Dams 14 and 15
- USFWS - Over 3,700 fish sampled and 80 floy tags deployed in and around Lock and Dams 14 and 15
- Details of this work are included in this report in the section **USFWS Pilot survey of fish community and behavior at Lock and Dams 14 and 15 using traditional gears, Adaptive Resolution Imaging Sonar (ARIS), and hydroacoustics**

Objective 1 and 2:

- The MN DNR issued an RFP for a feasibility study at Lock and Dam 5 to compile the current state of knowledge of complex noise technology, complete an accounting of all costs associated with construction, operation, and maintenance along with an accounting of all technical problems and equipment failures associated with existing projects; gather pre-engineering data to inform potential design work, provide a synopsis of US Army Corps of Engineers requirements and support and Wisconsin support and provide an assessment and recommendations on the suitability and effectiveness of deterrent technologies at proposed site

Objective 3:

- This objective is currently being addressed at a higher agency level with several agency representatives working with funding under Great Lakes Restoration Initiative and outside of the UMR Asian carp ad-hoc. Coordination in the pursuit of testing CO2 is ongoing at Lock and Dam 14 as is evaluation of sound deterrents at Brandon Road Dam on the Illinois River and Barkley Dam on the Cumberland River. Results of these efforts will be directly relevant and will contribute to any future applications/efforts in the UMR.

Objective 4 USFWS/USGS:

- 363 Bighead, Silver, and Hybrid Carp have been tagged to date and 313 transmitters were active the entire year in 2017.
- Over 800 passage events have been recorded indicating that Asian carp populations from Pool 10 to Pool 26 intermix at different rates especially during spawning and when main spillway dam gates are open. Greater than 50% of tagged Asian carp used multiple pools with a year.
- In 2017, one female Silver Carp, which was tagged in Pool 19, was detected on a stationary receiver in Pool 10 >350 km upstream from where it was tagged. This suggests a small percentage of fish (<1%) move upstream as potential propagules for upstream populations.

Objective 4 MDC:

- Transmitters were implanted into 46 Bighead carp, 48 grass carp, 49 silver carp, 3 hybrid carp, 24 Bigmouth Buffalo, 23 Blue Sucker, 1 Blue Catfish, 20 Channel Catfish, and 25 Flathead Catfish 17 Walleye, 3 Sauger, 2 American Eel, 8 Paddlefish and 50 Lake Sturgeon.
- In the two years of the study (2016-2017), 55 fish were detected in the lock chamber, and 21 of these were detected on the receiver upstream of the chamber
- Of the 27 (49%) of Asian carp that approached the lock chamber, only 2 (4%) passed upstream into Pool 19

- Only Asian carp, Bigmouth Buffalo, Paddlefish, Blue Catfish, and Walleye were detected and assumed to have passed upstream into Pool 19.
- Although 22 of 50 Lake Sturgeon (44%) were detected in or approaching the lock chamber, none were detected moving into Pool 19.
- Detailed information that addresses this objective is included in the Annual UMR Interim Asian Carp Monitoring Report – 2017. This work was completed through interagency cooperation and collaboration that included ILDNR and WIU, MDC, USFWS, and USGS.

Project Activities:

Participant agencies continued to pursue the development and implementation plan for the UMR deterrent strategy. Specifically:

- Final report on a deterrent strategy for the UMR was reviewed and approved by 4/5 state agencies and all federal partners. Because the final report makes management recommendations about locations for the future testing of sound barriers, some agencies may not be able to support the group's recommendation.
- Agency representatives participated in the following meetings and conference calls to continue pursuing planning of deterrent evaluations..

  Meetings:
  One Lock and Dam 14 Asian Carp CO2 Deterrent Project Meeting
  Two Upper Mississippi River Asian Carp Coordination Meetings

  Conference Calls:
  Four Upper Mississippi River Asian Carp Deterrent Strategy Team Conferences
  Five Upper Mississippi River Asian Carp Coordination Conferences
  Six Asian Carp CO2 Deterrent Coordination Team Conferences
  Four Lock and Dam 14 Asian Carp CO2 Deterrent Project Conferences
  Two Asian Carp Acoustic Deterrent Project (Kentucky, LD19) Conferences

  Webinars and Workshops:
  Asian Carp Acoustic Deterrent Workshop Webinar
  Mississippi River Basin Asian Carp Project Updates Webinar
  National Asian Carp Control Strategies Workshop

  State-of-the-science were reviewed at these meetings and the team began identifying authorities and steps needing completion prior to implementing a deterrent evaluation at strategic locks and dams.

- Completed a pilot survey of fish community and behavior at Lock and Dams 14 and 15 to better understand how to deploy deterrents at these strategic locations to deter Invasive carp while minimizing effects to native species.

Recommendations:

Given the ongoing effort to test sound deterrents, there is a need to collect baseline movement data on Asian carp and native fishes that can be used to evaluate a sound deterrent in future years. This project proposes continued collection of movement information and fish passage in the UMR for the purpose of future analysis of sound deterrence.

A better understanding of the 3-dimensional position of native fish and Asian carp in the lock chamber and approach is needed to aid in deterrent design. Additionally, the team should identify key native fish and mussel species that require fish passage to support robust populations. Data are currently being collected by MDC and WIU on the frequency of native fish passage through Lock 19 and funding should continue to support this effort. Studies are needed to better understand the current impacts of LD 19 on native species, how a deterrent may further impact them, how that may be mitigated, and if possible, how to improve passage for natives under current LD 19 operation.

ASIAN CARP INVESTIGATION AT LOCK AND DAM 19 AND IN POOL 20 OF THE UPPER MISSISSIPPI RIVER: PASSAGE AND HABITAT OVERLAP OF NATIVE AND NON-NATIVE FISH

Geographic Location:
The Missouri Department of Conservation maintains and manages the telemetry receivers that span from Pool 20 downstream to Pool 26 on the Upper Mississippi River.

Lead Agency: Missouri Department of Conservation

Participating Agencies:
Southern Illinois University
U.S. Army Corps of Engineers
U.S. Coast Guard
USFWS – La Crosse Fish and Wildlife Conservation Office
USGS – Upper Midwest Environmental Sciences Center
Western Illinois University

Statement of Need:
When certain species are introduced into novel environments, the ecological characteristics may provide favorable environments and lack of natural biological controls. Without evolutionary time to adapt to the presence of the introduced species, they are able to reproduce and expand their range unchecked. Once established, removal and control requires massive resource inputs to have a significant impact. Therefore, the best method of control is prevention. Since the introduction of silver carp (Hypophthalmichthys molitrix), bighead carp (Hypophthalmichthys nobilis), grass carp (Ctenopharyngodon idella), and black carp (Mylopharyngodon piceus), their populations have expanded unconstrained, reaching tremendous densities. The upstream expansion from the Lower Mississippi River (LMR) to the Upper Mississippi River (UMR) reaches has been hindered by the extensive lock and dam network. However, previous acoustic telemetry studies have shown that invasive carps are capable of moving through many of the UMR locks during closed river conditions, with few exceptions. The fish that were able to move past the dams were also able to establish a reproductively successful population. This allowed these fish to not only expand their range, but to reach impressive densities. The current assessment of the invasion shows high densities of invasive carps below Lock and Dam 19, but above the dam exhibits drastically lower densities. It also appears that they have limited reproductive success above this critical point. Further investigation of both invasive carp movement and potential fish deterrents could provide a solution to the upward expansion of invasive Asian carps.

Lock and Dam 19 located in Keokuk, IA, is a major barrier to fish passage due to the perceived inability of fish to pass the gated portion of the dam during closed river conditions unlike other dams in the Upper Mississippi River (Tripp et al. 2013). Therefore, the only avenue of upstream movement is through the navigation lock chamber. With the observed population differences on either side of this barrier, it can be inferred that this barrier holds great importance in the control of these invasive carp species. As the abundance of invasive carp continues to increase in the lower portion of the Upper Mississippi River, it is vital that an evaluation of upstream passage through the lock chamber is conducted so future use of deterrent barriers and operational modifications at lock and dams may be utilized to limit upstream passage of invasive species, while maximizing native fish passage. Because of this the objectives of this study were:

Project Objectives:

1. Quantify native and non-native fish passage at Lock and Dam 19 in the Upper Mississippi River using acoustic telemetry.
2. Evaluate movement and habitat use in Pool 20 of the Upper Mississippi River using acoustic telemetry via manual boat tracking.
3. Determine conditions that show probability of highest passage using environmental variables paired with acoustic telemetry data. Recommend lock operation and deterrent barrier use protocols to minimize passage of non-natives.

Project Highlights:

- Transmitters were implanted into 46 Bighead carp, 48 grass carp, 49 silver carp, 3 hybrid carp, 24 Bigmouth Buffalo, 23 Blue Sucker, 1 Blue Catfish, 20 Channel Catfish, and 25 Flathead Catfish 17 Walleye, 3 Sauger, 2 American Eel, 8 Paddlefish and 50 Lake Sturgeon.
- In the two years of the study (2016-2017), 55 fish were detected in the lock chamber, and 21 of these were detected on the receiver upstream of the chamber
- Of the 27 (49%) of Asian carp that approached the lock chamber, only 2 (4%) passed upstream into Pool 19
- Only Asian carp, Bigmouth Buffalo, Paddlefish, Blue Catfish, and Walleye were detected and assumed to have passed upstream into Pool 19.
- Although 22 of 50 Lake Sturgeon (44%) were detected in or approaching the lock chamber, none were detected moving into Pool 19.

Methods:

In order to monitor fish movement in Pool 20 and potential dam passage, existing acoustic monitoring array of stationary receivers (Vemco VR2W) that were deployed and are maintained collaboratively by state and federal agencies within the Upper Mississippi River was utilized (Figure 1). The receivers within this array were deployed using many different methods such as, navigation buoys, bridge pier attachments, lock chamber wall attachment, bottom set stands, and along with barge-attached units to utilize a method of dynamic tracking by partnering with the commercial navigation industry (e.g., ADM). In order to more closely monitor the movement around Lock and Dam 19, two stationary receivers were placed on navigation buoys below the lock chamber entrance (one unit just outside the chamber and the other approximately one mile downstream of the lock chamber approach). An additional stationary receiver was placed above the lock chamber to work in correspondence with the lock chamber receiver to determine if a fish that enters the lock chamber exits above the dam for a successful passage event (Figure 2). The USFWS also placed a stationary receiver array inside the downstream approach to the lock chamber to further investigate passage (Figure 2). The USFWS array will collect 2-dimensional data and use Vemco Positioning System (VPS; accuracy of position of fish within 5 meters) to pinpoint fish approaching the lock chamber and determine how fish use the lock approach to inform deterrent placement and evaluate a deterrent should one be deployed in the future. Manual boat tracking (Vemco VR100) will also be performed monthly to assess finer scale movement and habitat use within Pool 20.

During the spring of 2016, invasive carp and native fishes were captured using a wide range of gears (e.g., electrofishing, trotlines, experimental gill nets, three and five inch bar mesh gill nets, trammel nets, and hoop nets) that provided a broad size and age distribution to provide a representative sample of each target species. All fish of the target species list were weighed, measured, and sex was determined internally during transmitter implantation. Ultrasonic transmitters (Vemco V16-5H; 69kHz) were allotted for implantation into each of the representative invasive carp groups (silver, bighead, and grass carp), using the methods described in Tripp et al. (2013). Transmitters were implanted into 46 bighead carp, 48 grass carp, 49 silver carp, and 3 hybrid carp. An additional 150 transmitters allotted to be implanted into certain species chosen to represent the native fish community. Transmitter implantation of these species included; 24 bigmouth buffalo, 23 blue sucker, 1 blue catfish, 20 channel catfish, and 25 flathead catfish. A total of 20 walleye and sauger and 2 American eel were implanted with the smaller Vemco V13 transmitters. Opportunistic tagging of 8 paddlefish and 50 lake sturgeon was also completed. Asian carp were also tagged in 2012 in the same location, so detections from these fish were also used in this study (Table 1.) All fish were placed onto a clean surgery board where a low flow bilge pump circulated water over the gills. Incision site and all surgical tools were disinfected at the beginning and end of each surgery. The incision site was located ventral to the lateral line and anterior to the cloacal opening. A scalpel and hemostat was used to carefully make the incision to avoid damaging internal organs. Three or four Ethicon 3-0 monofilament sutures closed the incision site after the transmitter has been inserted into the abdominal cavity. While the incision is open, a quick examination of the gonadal structure for gender determination was be performed and recorded. After disinfection of the suture site the fish were returned gently to the water where they were released upon regaining strength and orientation. The transmitters were all tested prior to implantation with a VR100 unit to ensure they have been activated. Acoustic signals began transmitting upon release of the specimen. The date, time, and location of release were recorded for each specimen.

Stationary receivers will be uploaded seasonally and the detection data will be analyzed to summarize movements and passage of the implanted fish over the four to five year lifespan of the transmitter. This summary will be paired with the manual tracking data to generate finer scale habitat use and movements of fish within Pool 20. In order to investigate the potential overlap of native and invasive species habitat use, daily detections were represented as the GPS location and kernel density estimates were calculated for each group using PROC KDE state with Statistical Analysis System (SAS). This analysis allowed us to visualize location utilization for each of the groups (native and invasive). In order to quantify the overlap of areas used, we developed a grid system using the fishnet analysis in ArcMap and overlaid native and invasive fish detections. From this we determine the number of grids in which both native and invasive fish were utilizing each area. The number and date of passage events will be used to determine river conditions that yield high potential for passage. This summary will be combined with the USFWS 2-D data processed by Vemco to discuss the potential alteration of lock operation during such periods along with the addition of deterrent barriers to minimize upstream movement of invasive carps.

Results:
During the two year period, a total of 55 fish have been detected on the VR2W in the lock chamber. Species detected in the lock chamber were; 1 American Eel, 4 Bighead Carp, 12 Bigmouth Buffalo, 1 Blue Sucker, 2 Channel Catfish, 1 Flathead Catfish, 4 Grass Carp, 16 Lake Sturgeon, 4 Paddlefish, 11 Silver Carp, and 5 Walleye (Table 1). Of these, 21 have been detected on the VR2W above the lock chamber. Species that have passed into pool 19 are as follows; 1 Bighead Carp,10 Bigmouth Buffalo, 3 Walleye, 2 Flathead Catfish, 2 Grass Carp, 2 Paddlefish, and 1 Silver Carp (Table 1). To look at this data another way we determined the percent of individuals within each species that approached the lock chamber and then the percent that successfully passed upstream into Pool 19 (Table 1). This demonstrated that while fewer individuals within each of the native species were implanted with transmitters, the native species (Bigmouth Buffalo, Paddlefish, and Walleye) were more likely to approach the lock chamber, enter, and pass upstream. Despite the invasive species having many more individuals implanted and 27 – 49% approaching the lock chamber, only 2 – 4% of the invasive species actually successfully passed through Lock and Dam 19 into Pool 19 (Table 1). The VR2W array below pool 20 detected 25 fish that have made downstream movements. Native fish species that made downstream movements were Paddlefish, Lake Sturgeon, and Flathead Catfish. All of the invasive species implanted were documented making downstream movements. For the native fish 2 Paddlefish and 4 Lake Sturgeon were documented moving down into Pool 24, and one Paddlefish was documented moving down to Caruthersville, MO which is about 775 kilometers downstream. The invasive fish were also detected making some long range movements downstream, with Bighead, Silver, Grass, and hybrid Carp all being detected in Pool 24 (105 kilometers downstream). Bighead Carp were also detected in the Kaskaskia River (190 kilometers downstream), Cape Girardeau, MO (500 kilometers downstream), and the Ohio River

at Cairo, IL (588 kilometers downstream). A Grass Carp was also detected down at the Ohio River.

When kernel density estimates were developed for the native and invasive species within Pool 20 using the manual tracking detections, it became evident that specific habitats were not being using such as wing dike or channel borders, it was more like the tailwater area or the mouth of the Des Moines River (Figure 3 and Figure 4). While the core use areas are more spread out for native fish, with the natives also using areas below the mouth of the Des Moines River as well as the Mouth of the Des Moines and the tailwater area where invasives congregated (Figrue 3 and 4). When we quantified the overlap of detections within the fishnet grid, 80% of the grids contained both native and invasive fish detections, so 80% of the areas used by native fishes were also being used by invasive carp.

To further investigate the passage events, the number of successful passages was plotted against the river stage based on the gauge for the Mississippi River at Keokuk, IA (Figure 5). Due to the low number of passages statistical analysis were not run of this data, but visual observation of the data show that the majority of the passages occur between June and September when the river was low. When the USFWS approach data is processed we may be able to further investigate the passages and approaches to determine what factors maybe influencing the number of fish that approach and the number that successfully pass.

Discussion:

Asian carp expansion has been slightly slowed by a few of the UMR lock and dams, specifically Lock and Dam 19, 15, and 14 because of the lack of or infrequent open river conditions at this pinch point areas making them the ideal candidate for areas where deterrent systems may be a potential to impede further upstream establishment. With the continued expansion of all Asian carp species including Black Carp, determining the movement and passage rates at areas that may be pinch points will be critical. From this this study we were able to quantify native and invasive fish species entering and passing the lock chamber at Lock and Dam 19; however this data set would benefit from increased sample size and a longer time period to allow more passage events occur so that the environment factors influencing passage and movement can be further investigated.

Since the transmitters used for this study have a battery life of 5 years, they will still provide data for another 3 years. In addition, we have already begun tagging an additional 100 Asian carp and 50 Paddlefish in collaboration with other agencies throughout the UMR which will also be adding both invasive and native fish implanted with transmitters. Additional transmitters and temporal data will also allow the group to investigate seasonal and specific habitat use of native and invasive species and determine the level of overlap occurring. This will provide the UMR Asian Carp Workgroup with the evidence needed to determine the potential impact a deterrence system may have on native and invasive species ability to pass upstream into Pool 19. This pre-deterrent data will inform the partnership of how both native and invasive fish approach the lock chamber in these pinch point areas, the frequency that native fish are able to make successful passage, and identify the abiotic and biotic factors that contribute or hinder successful passage.

As the option of deterrence becomes more likely, understanding how deterrence will be utilized to limit passage of invasive species but maximize native fish passage will be critical. Such additions to the navigational structure and operations of the Upper Mississippi River may be the key to reducing passage of invasive carps and effectively reducing future upstream expansion. The emergence of a reproductively successful population of black carp adds extra stress on the need to prevent the further upstream expansion of invasive carps.

Table 1. Species detected downstream, within, and above Lock and Dam 19 with the percent of each species that approached the lock chamber and the percent that successfully passed through into Pool 19.

Species		# Tagged	# Detected in Downstream Approach L&D 19	# Detected in Lock Chamber	# Detected Above L&D 19	% Approached	% Passed
Native							
	American Eel	2	1	1	0	50	0
	Sauger	3	2	0	0	67	0
	Walleye	17	5	5	3	29	18
	Blue Catfish	1	0	0	0	0	0
	Channel Catfish	20	6	2	0	30	0
	Flathead Catfish	25	2	1	2	8	8
	Bigmouth Buffalo	24	15	12	10	63	42
	Blue Sucker	23	3	1	0	13	0
	Lake Sturgeon	50	22	16	0	44	0
	Paddlefish	8	4	4	2	50	25
Non-Native							
	Bighead Carp	49	24	4	1	49	2
	Grass Carp	48	13	4	2	27	4
	Hybrid Carp	3	1	0	0	33	0
	Silver Carp	58	20	11	1	34	2
		331	112	55	21		

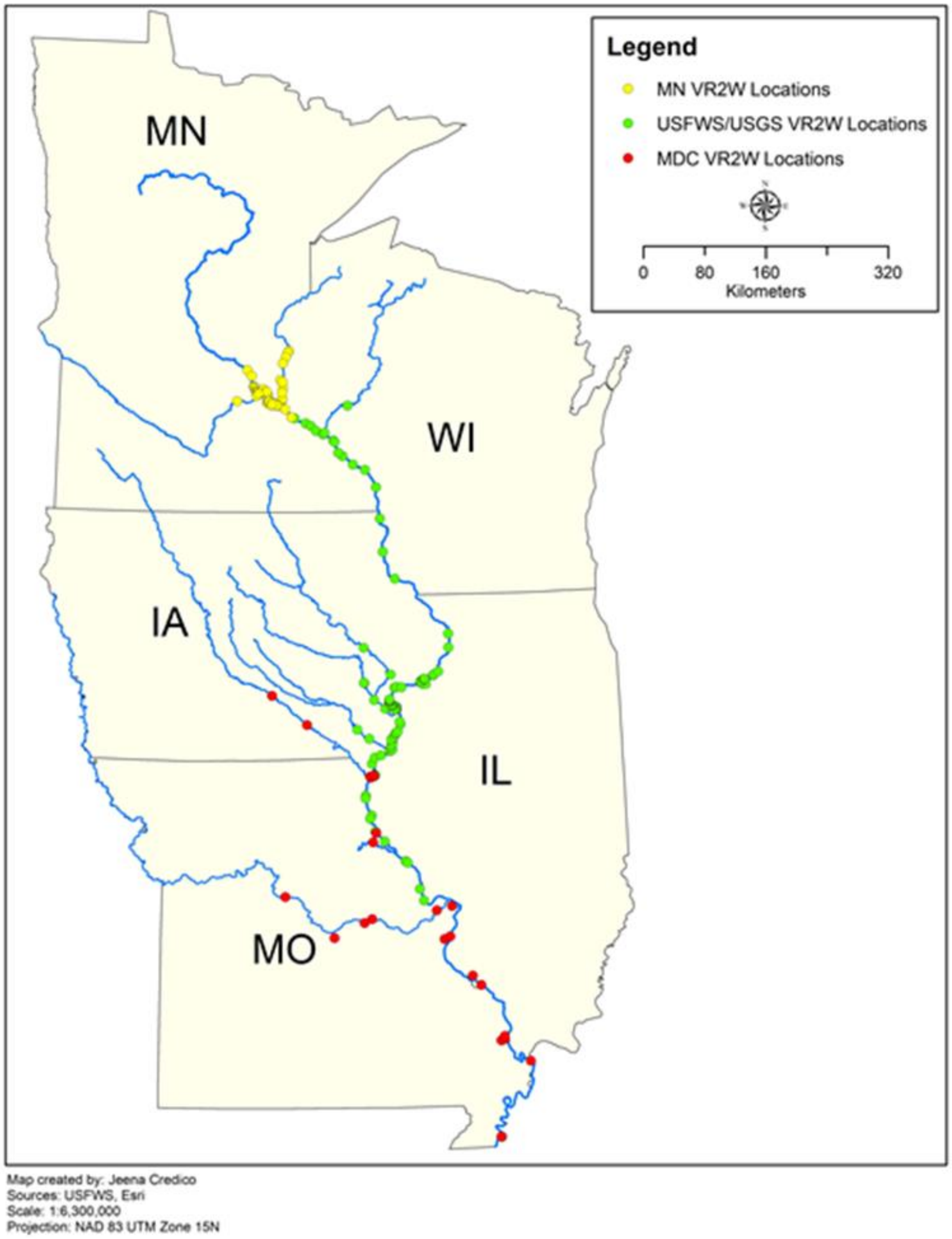

Figure 1. Collaborative stationary receiver array in the Mississippi River and its major tributaries.

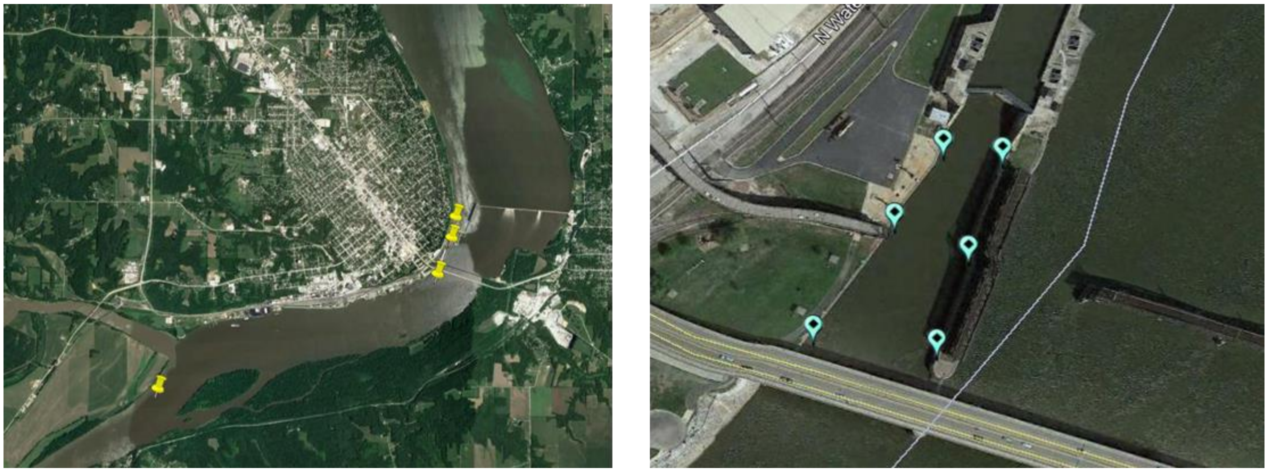

Figure 2. Stationary receiver array around Lock and Dam 19 and the USFWS VPS array in the downstream approach of the lock chamber.

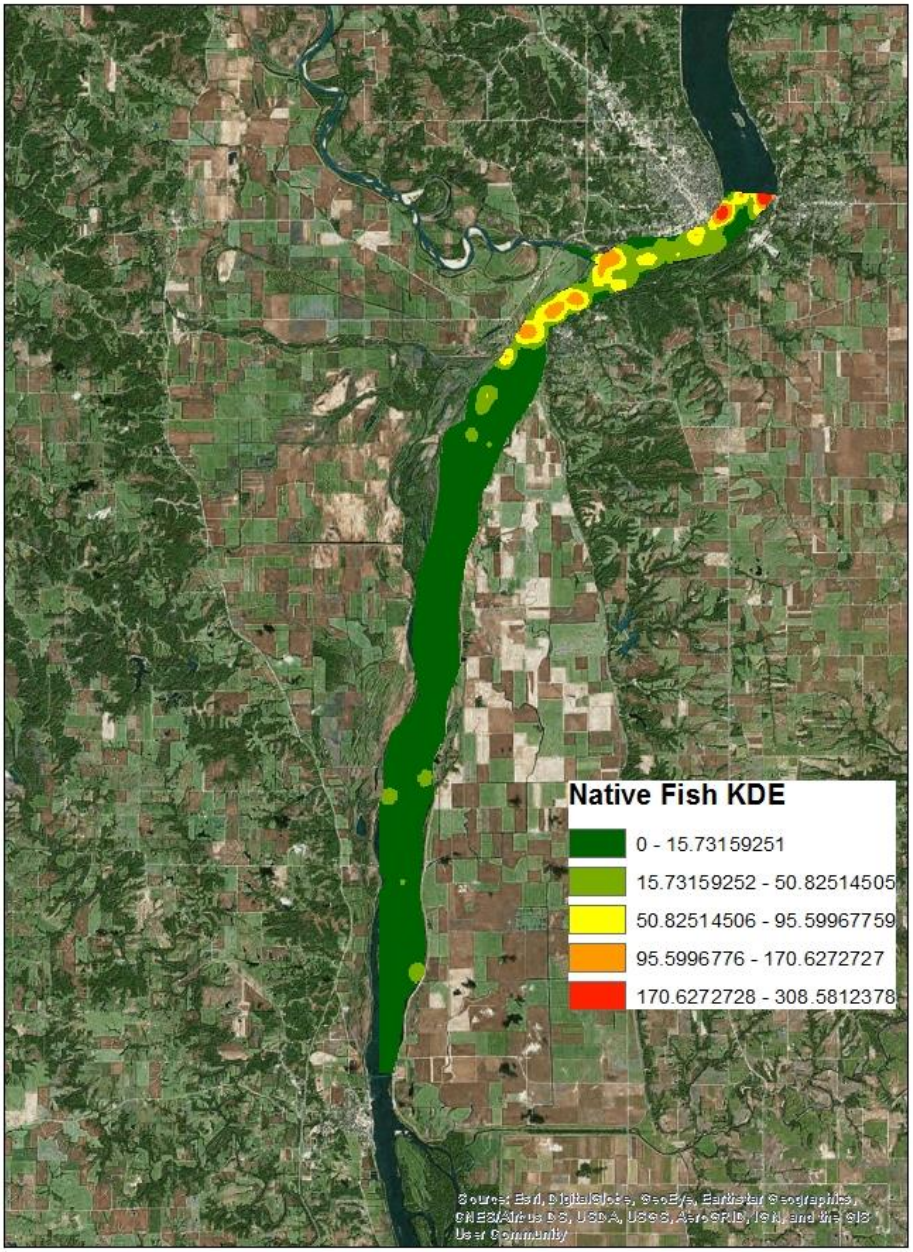

Figure 3. Kernel density estimates for native fish species in Pool 20.

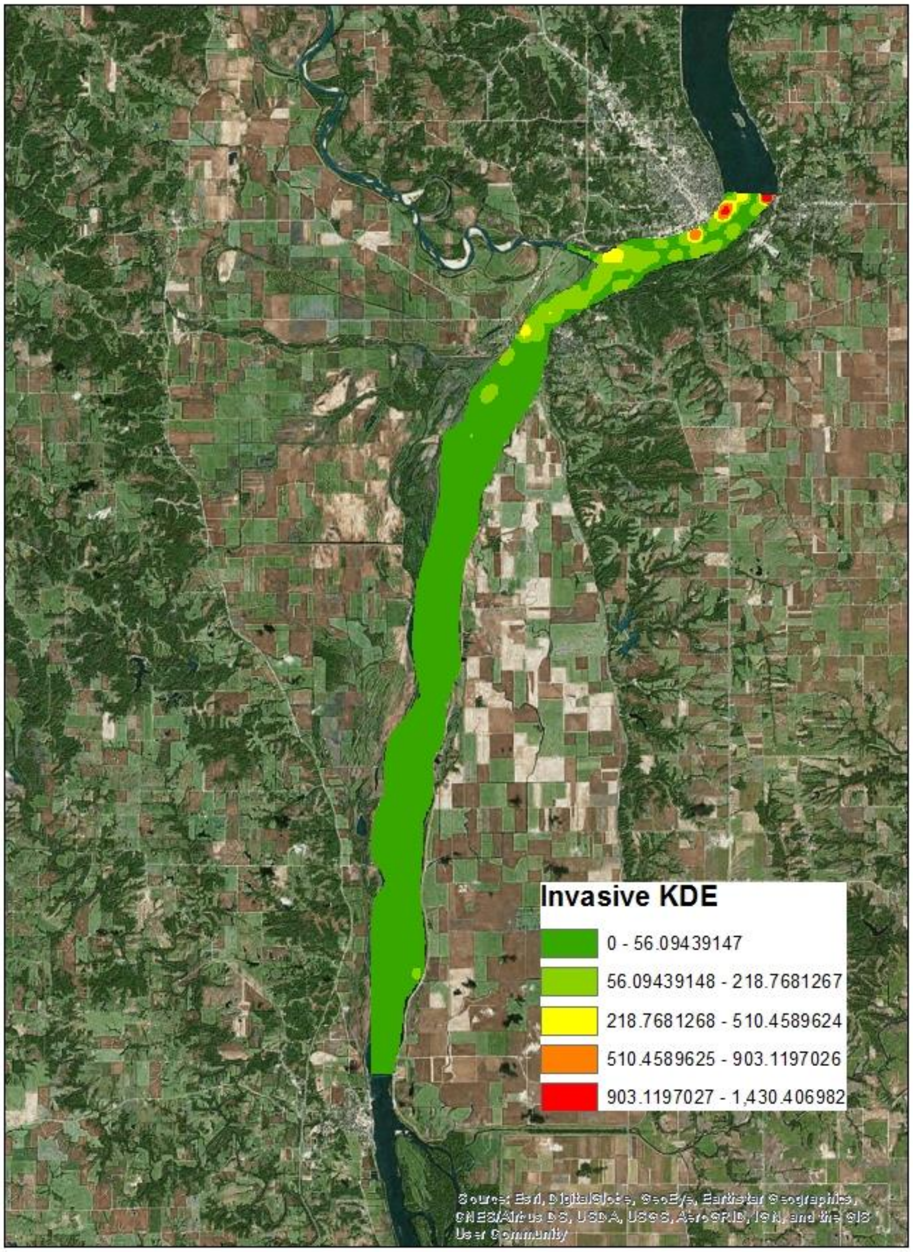

Figure 4. Kernel density estimates for invasive species in Pool 20.

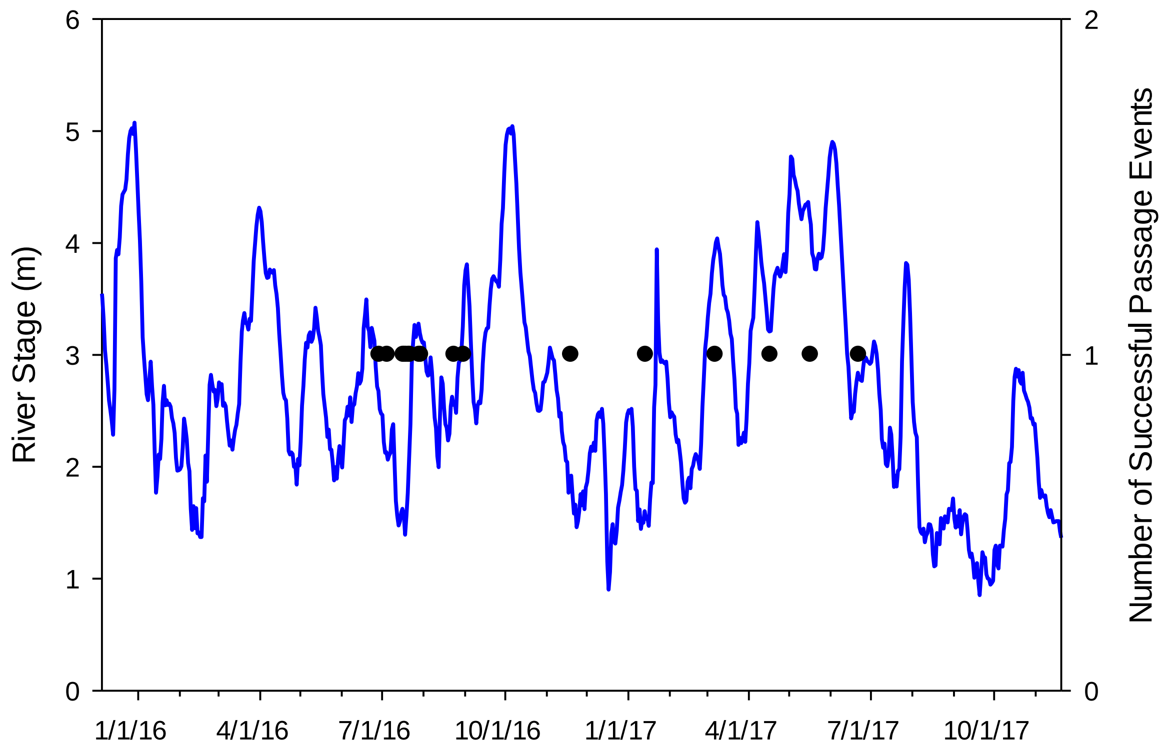

Figure 5. River stage at Keokuk, Iowa gauge associated with the date of successful passage events.

References

Tripp, S., R. Brooks, D. Herzog, and J. Garvey. 2013. Patterns of fish passage in the Upper Mississippi River. River Research and Applications. 30(8):1056-1064

USFWS Pilot survey of fish community and behavior at Lock and Dams 14 and 15 using traditional gears, Adaptive Resolution Imaging Sonar (ARIS), and hydroacoustics

Methods:
All data were collected over the course of one week for the main and auxiliary locks at Lock and Dam 14 and one additional week for the main lock at Lock and Dam 15. The number of replicates in a day/week were dependent on weather and navigational traffic. Due to the operating schedule of the auxiliary lock at 14, survey efforts at this location were reduced to two days.

Fish behavior and movement through the lower and upper miter gates were observed using an ARIS Explorer 3000 (Sound Metrics). The ARIS sonar camera was mounted to a boat to allow for imagery to be captured in multiple locations around the lock system. Imagery was collected at two locations in each lock chamber (Figures 1-2). With the miter gates open, the boat was tied to the open miter gates and the ARIS collected fish passage imagery for up to 30 minutes at a time, viewing across the chamber at the lock entrance, perpendicular to flow. The 30 minute time frame was chosen because it was the estimate, provided by the lock masters, for how long the gates are open at these locations while a barge is entering or exiting.

After collection, fish passage imagery was evaluated by three independent reviewers. Fish counts and movement were analyzed and the average rates of fish movement observed by the three reviewers were calculated for each video and then for each position (e.g. downstream miter gate at Lock 15). These averages included the rate of upstream, downstream, and unknown swim direction observed at a location, as well as total individual fish observed. Individuals in a school of fish were not counted independently because the quality of the videos does not allow for accurate or consistent counting. Rather, the number of fish schools present was counted and the general swim direction of the entire group was noted. Interpretation of these data can be subjective, so a fourth reviewer was utilized in the event that one of the counts from the three reviewers was noticeably different from the others for a particular image file.

The fish community was surveyed in these areas using boat-mounted pulsed DC electrofishing and one dip netter (Figures 3-4). Conductivity and water temperature were measured and the LTRMP standardized electrofishing power settings table was used to ensure that appropriate power goals were met (Gutreuter et al. 1995). Fish were identified to species and counted. Up to 25 individuals of each species were measured for total length (TL) (except sturgeon were measured for fork length (FL) and paddlefish were measured for eye to fork length (EFL)). Fish over 25.4 cm captured downstream of the locks or within the lock chambers were also weighed and floy tagged. All fish over 30 cm TL, captured above or below the lock, were measured and weighed and those data contributed to the hydrocoustic analysis.

The fish communities in the downstream approach channel and inside the lock chamber, were sampled with 3.24-4” bar x 16-24’ gill nets (Figures 5-7). Due to turbulent tailwater flows, nets were not set in the downstream approach of the main chamber of lock 14. Nets were set within 100 yards of the lock chamber doors in the approach channel and in a zig-zag pattern inside the lock chamber. If barge traffic allowed, fish were driven by pounding on the boat or by electricity and then the nets were pulled. Fish were identified, counted, weighed, measured, and tagged (if applicable) in the same manner as those captured by electrofishing. Netting data from this portion of the project contributed to the analysis of the hydroacoustic data that were also collected. Netting and electrofishing efforts were conducted on at least two separate days to see if any tagged fish were recaptured. Catch per unit effort (CPUE) was calculated for each gear and Wilcox et al. (2004) was used to determine if any of the capture species were considered migratory and potentially migratory in the Upper Mississippi River.

Southern Illinois University (SIU) conducted mobile hydroacoustic surveys to identify the spatial and size distributions of fish in the downstream and upstream approach channels of the main and auxiliary locks and inside the lock chambers (Figures 8-9). Surveys were conducted by boat using two horizontally oriented 200 kHz split-beam BioSonics DT-X transducers, which were offset so that one ensonified the upper portion of the water column and the second sampled immediately below the surface transducer beam. A third transducer (70 kHz) was oriented vertically and used to measure water depth. Additional information about equipment and sampling specifications are explained in detail in MacNamara et al. (2016). The vessel surveyed one-mile upstream of each dam to and including the upstream approach channel, then proceeded into the full lock chamber and conducted a survey within the chamber. Additional surveys were conducted from one mile below each dam up to and including the downstream approach channels. Hydroacoustic data were analyzed by SIU. Data from the horizontal transducers were used to estimate fish densities. Electrofishing data from this project contributed to the analysis of the hydroacoustic data. Additional electrofishing was conducted in areas other than those targeted in this survey. Fish, meeting the aforementioned size requirements, captured from this additional effort downstream of the lock structure were floy tagged to increase sample size of tagged fishes below the lock structure. However, those additional electrofishing data were used solely for hydroacoustic analysis and were not used as part of the fish community dataset at the lock locations.

Figure 1. *Locations where stationary ARIS imagery was collected in the main chamber (yellow) and auxiliary chamber (red) of Lock 14 of the UMR.*

Figure 2. *Locations (yellow) where stationary ARIS imagery will be collected in the main chamber of Lock 15 of the UMR.*

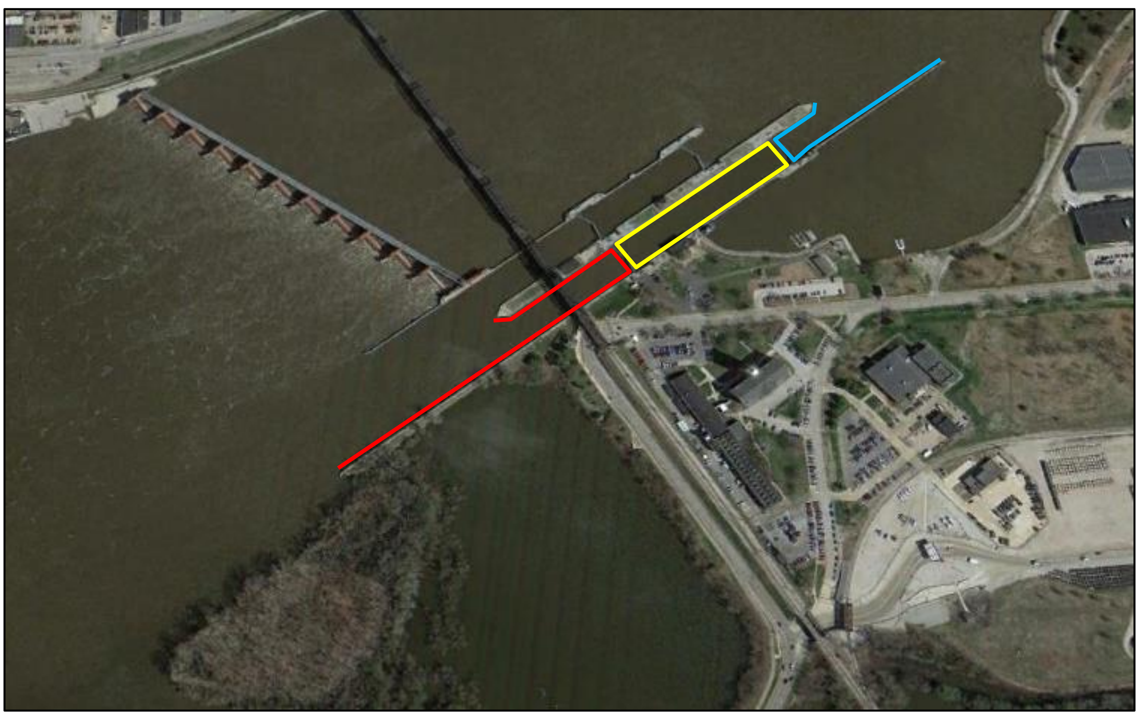

Figure 3. *Areas where pulsed DC electrofishing was conducted in the downstream approach (red), the lock chamber (yellow), and upstream approach (blue) of Lock 14 of the UMR.*

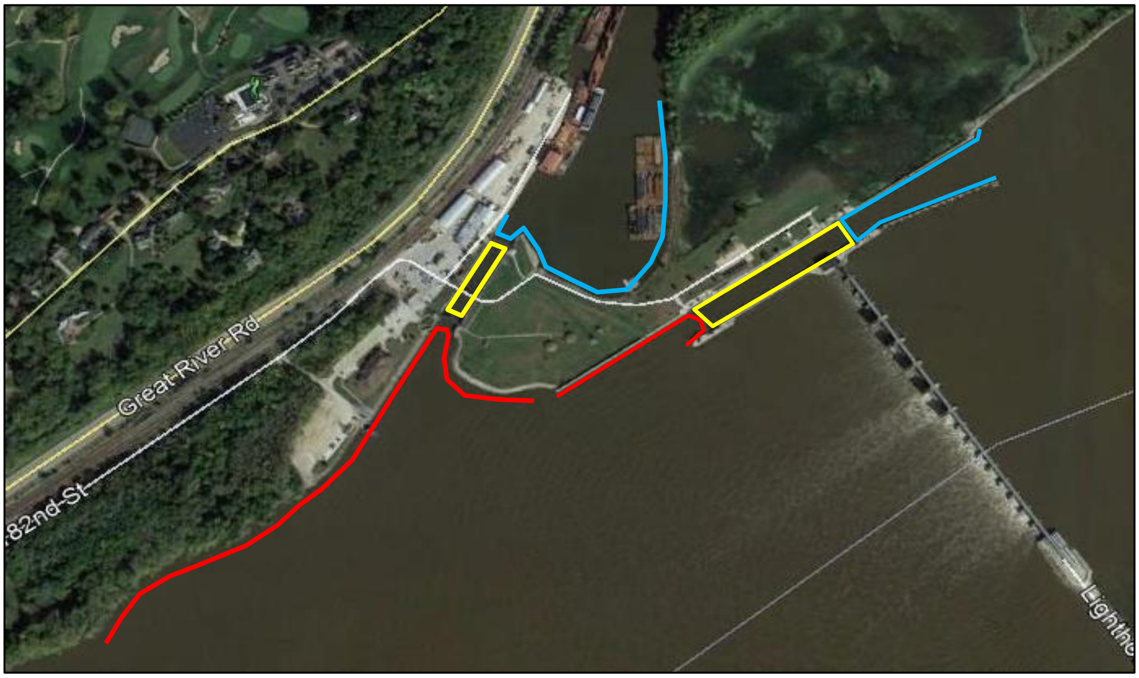

Figure 4. *Areas where pulsed DC electrofishing was conducted in the downstream approaches (red), lock chambers (yellow), and upstream approaches at Lock 14 of the UMR.*

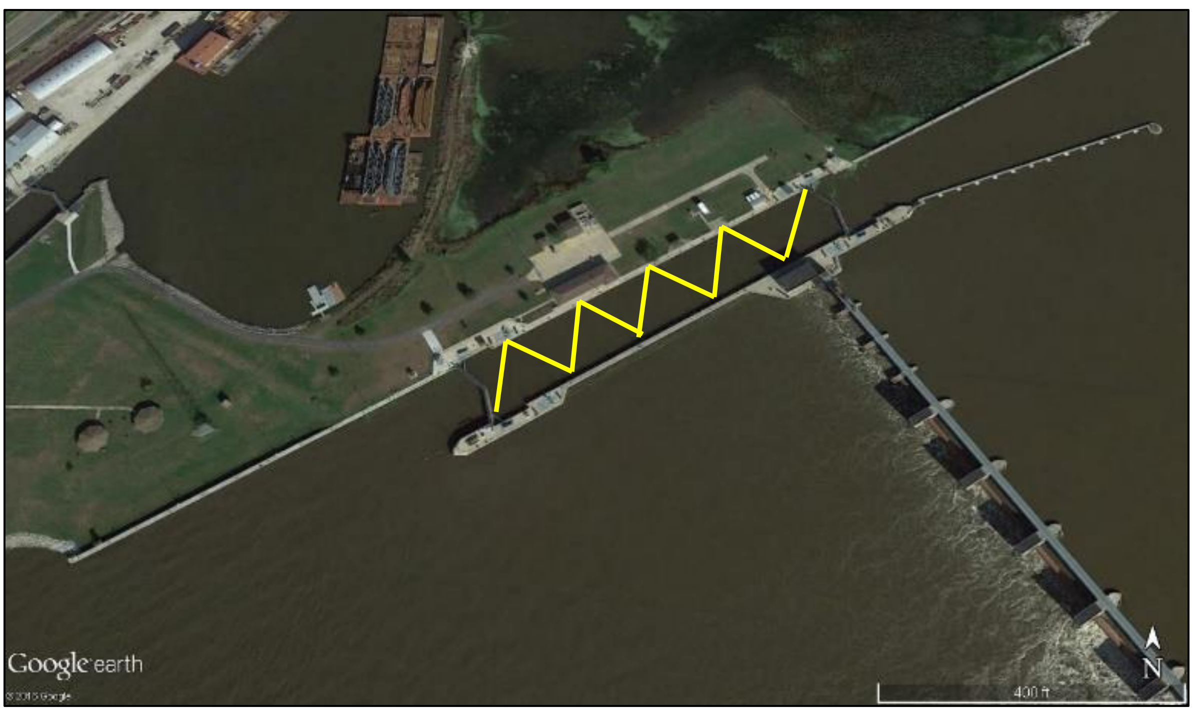

Figure 5. *Areas where gill nets (yellow) were set at the main chamber of Lock 14 the UMR.*

Figure 6. *Areas where pulsed gill nets were set at the lock chamber (yellow) and downstream approach channel (red) of Lock 14 auxiliary of the UMR.*

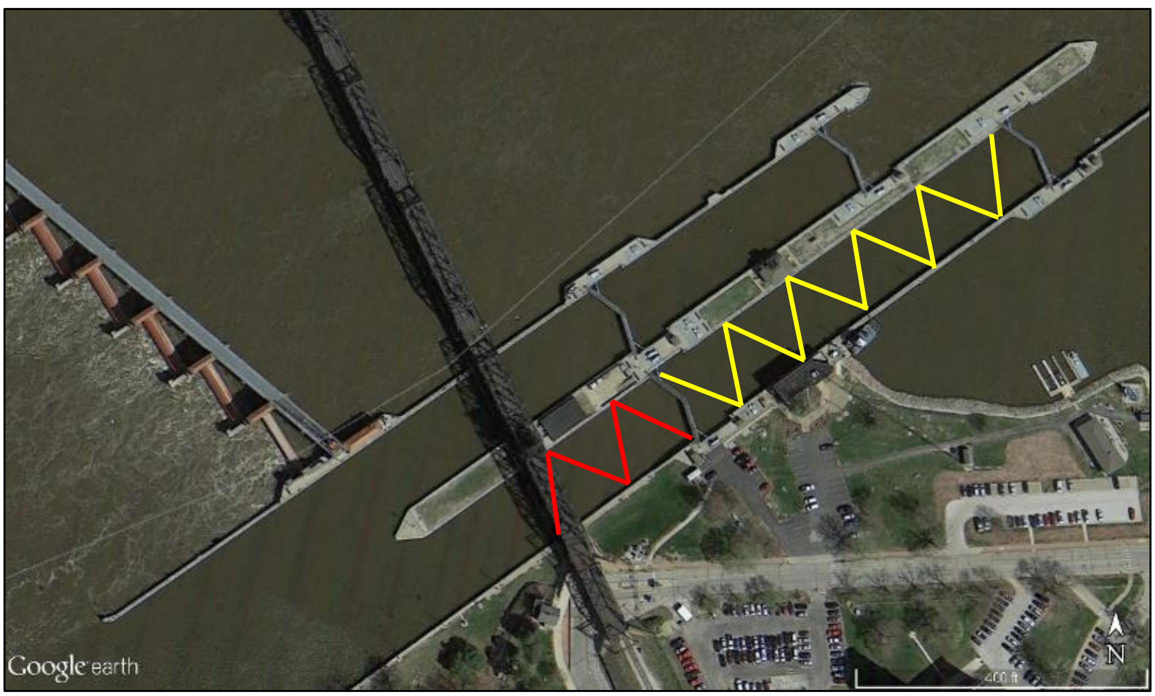

Figure 7. *Areas where gill nets were set in the lock chamber (yellow) and downstream approach channel (red) of Lock 15 of the UMR.*

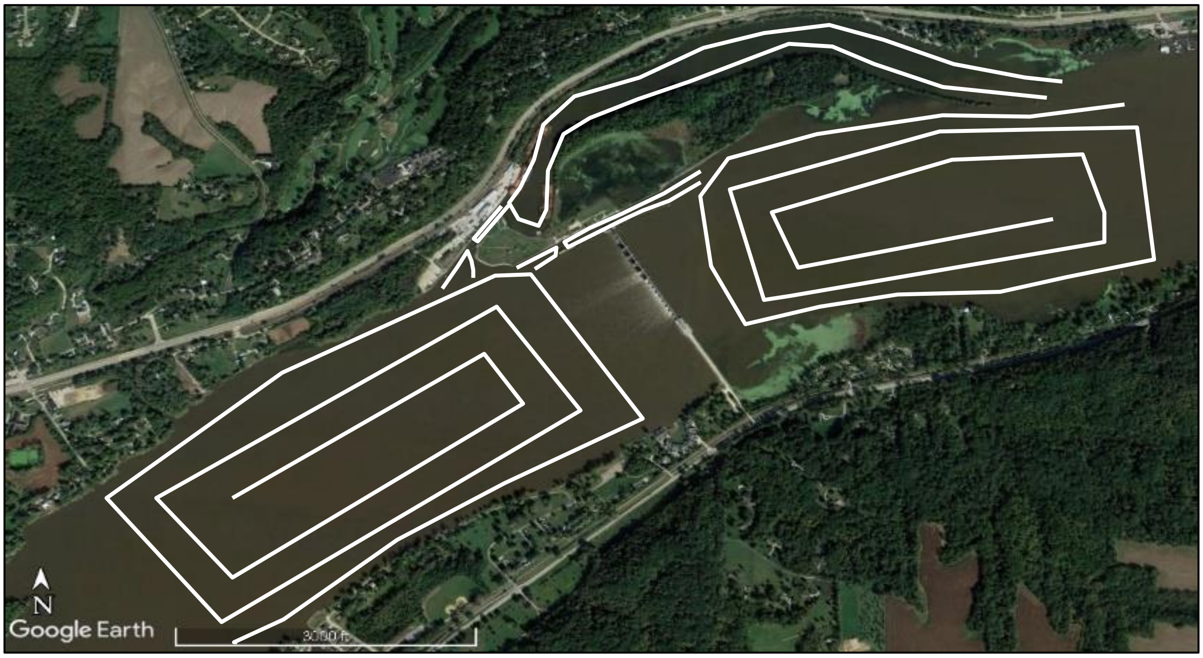

Figure 8. *Generalized paths of hydroacoustic surveys conducted around Lock and Dam 14 of the UMR.*

Figure 9. *Generalized paths of hydroacoustic surveys conducted at Lock and Dam 15 of the UMR.*

Results:
Lock 15
The review of the ARIS imagery proved to be fairly subjective and the interpretation of some of the videos varied widely between reviewers. Some videos required a fourth reviewer due to wide variations in counts. A total of 2.5 hours of ARIS imagery were collected at Lock 15. Due to the constraint of barge traffic, more data were collected at the downstream miter gates than at the upstream gates. When fish were observed at the lower miter gate, more individual and small groups of fish were observed swimming in an upstream direction than downstream (Figure 10). The number of schools counted were highly variable between reviewers, but generally the schools were observed moving in an upstream direction more commonly than downstream (Figure 11). Large numbers of fish moving in various directions close to the camera sometimes made it difficult to distinguish separate schools.

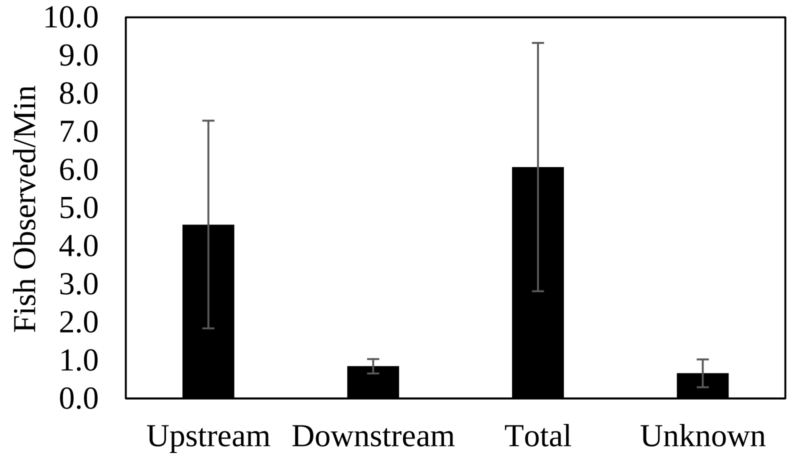

Figure 10. *Average rate (± SD) and swim direction of fish, observed using an ARIS camera, at the open, lower miter gates at Lock 15 of the UMR in August 2017 (n=3).*

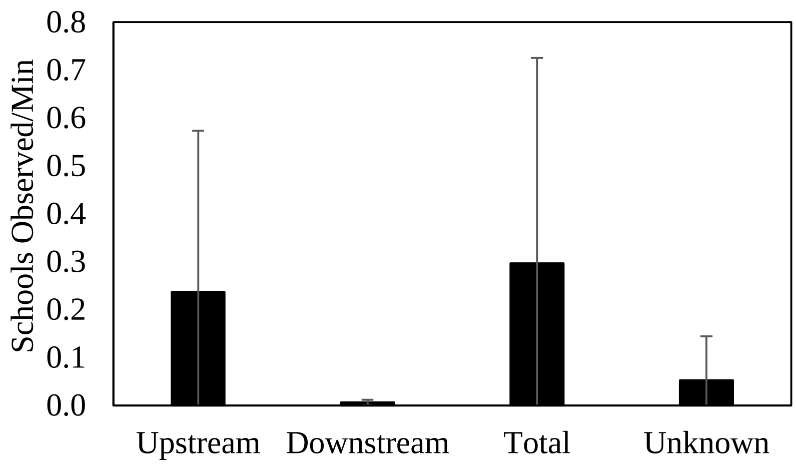

Figure 11. *Average rate (± SD) and swim direction of fish schools, observed using an ARIS camera, at the open, lower miter gates at Lock 15 of the UMR in August 2017 (n=3).*
The effort with traditional gears at Lock 15 was not split evenly among the three target areas surrounding the lock (Figure 3) because of irregular barge traffic. A total of 63 minutes of

electrofishing were conducted and 900 yards of gillnet were set among the three target areas. At all sites, more electrofishing runs were completed than gill net sets because setting nets was time consuming and there was often not adequate time to complete a net set between barge tows. The net sets that were completed captured minimal fish compared to electrofishing, although most of the fish captured by electrofishing were small fish and would not have been captured by gill net anyway (Table 2). Most fish were captured in the downstream approach, however a greater number of species were captured in the lock chamber. In all three areas, Emerald Shiner comprised the majority of the total catch in numbers. Fish captured by this effort that are 1) known to move through UMR dams; and/or 2) migratory in UMR; and/or 3) probably migratory in the UMR included Bigmouth Buffalo, Channel Catfish, Freshwater Drum, Mooneye, Paddlefish, Smallmouth Buffalo, and White Bass (Wilcox et al. 2004).

Table 1. *Total catch and effort using two gears in three areas adjacent to the main chamber of Lock 15 of the UMR in August 2017.*

Site	Gear	Species Count	Total Count	Effort	CPUE
Upstream approach	Electrofishing	1	3	15 min	0.2 fish/min
Chamber	Electrofishing	7	155	32.8 min	4.7 fish/min
	Gill Netting	3	3	700 yd	<0.1 fish/yd
Downstream approach	Electrofishing	5	260	15 min	17.3 fish/min
	Gill Netting	1	1	200 yd	<0.1 fish/yd

Table 2. *Species captured by gear at three sites adjacent to the main lock chamber at Lock and Dam 15 of the UMR in August 2017. Site titles are associated with the colored areas in Figure 3.*

Site	Electrofishing	Gill Netting
LOCK CHAMBER	**155**	**3**
Channel Shiner *Notropis wickliffi*	5	
Common Carp *Cyprinus carpio*		1
Emerald Shiner *Notropis atherinoides*	139	
Freshwater Drum *Aplodinotus grunniens*	1	1
Gizzard Shad *Dorosoma cepedianum*	1	
Mooneye *Hiodon tergisus*	5	
Paddlefish *Polyodon spathula*		1
Smallmouth Buffalo *Ictiobus bubalus*	1	
White Bass *Morone chrysops*	3	
DOWNSTREAM APPROACH	**260**	**1**
Bigmouth Buffalo *Ictiobus cyprinellus*	1	
Channel Catfish *Ictalurus punctatus*		1
Channel Shiner *Notropis wickliffi*	3	
Emerald Shiner *Notropis atherinoides*	250	
Mooneye *Hiodon tergisus*	5	
White Bass *Morone chrysops*	1	
UPSTREAM APPROACH	**3**	
Emerald Shiner *Notropis atherinoides*	3	
TOTAL	**418**	**4**

The hydroacoustic surveys that were completed revealed that the density of fish, with total length ≥30 cm, within one mile of Lock and Dam 15 was greater downstream of the structure than upstream (Figures 12-13). Density hotspots below the dam were along either shoreline, particularly the shoreline just downstream of Sylvan slough, which is the first slough on the left descending bank below the lock. The majority of the fish observed (≥30 cm) both upstream and downstream of the lock and dam were less than 50 cm, which differs from the most common lengths of Silver and Bighead Carp observed the previous year in Pool 19 (Figure 14). There were fish ≥ 30 cm present in the lock chamber and in the upstream and downstream approaches at the time of sampling (Figure 15).

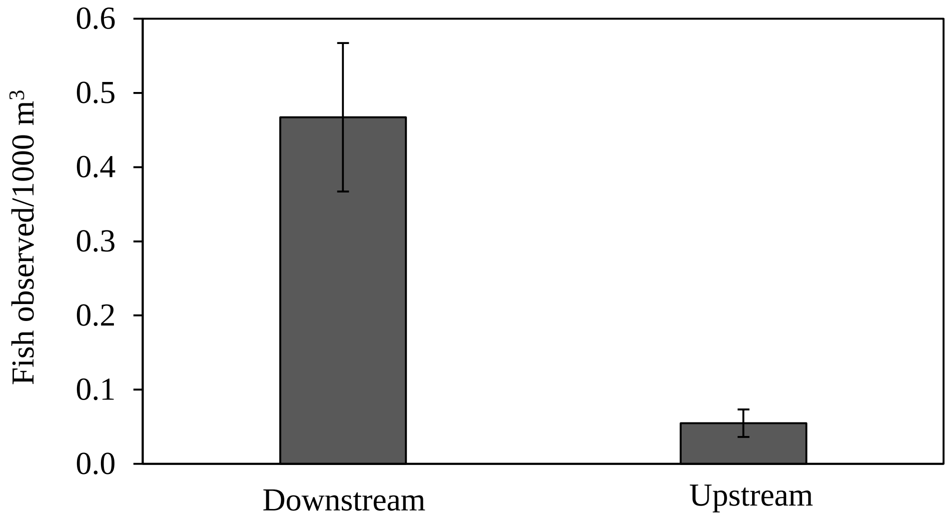

Figure 12. *Mean (SE) densities of fish (individuals ≥ 30 cm total length) observed from mobile hydroacoustic surveys conducted within one mile downstream and upstream of Lock and Dam 15 of the UMR in August 2017.*

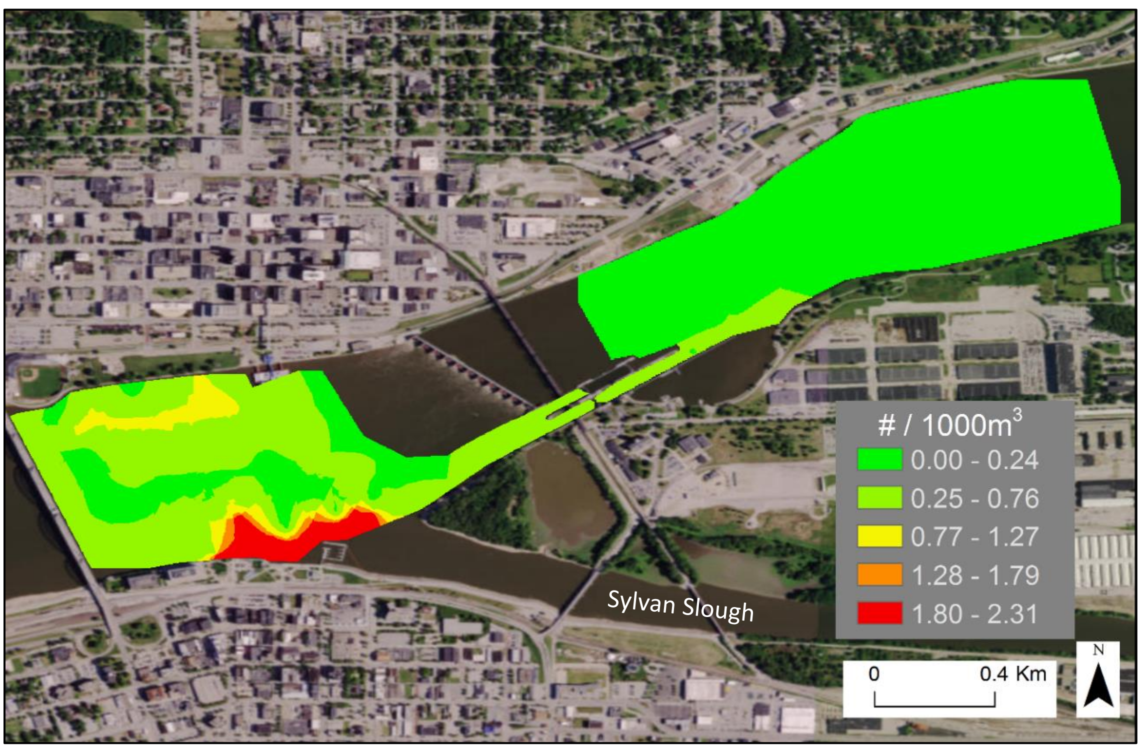

Figure 13. *Densities of all fish ≥ 30 cm total length detected from mobile hydroacoustic surveys upstream and downstream of Lock and Dam 15 of the UMR in August 2017.*

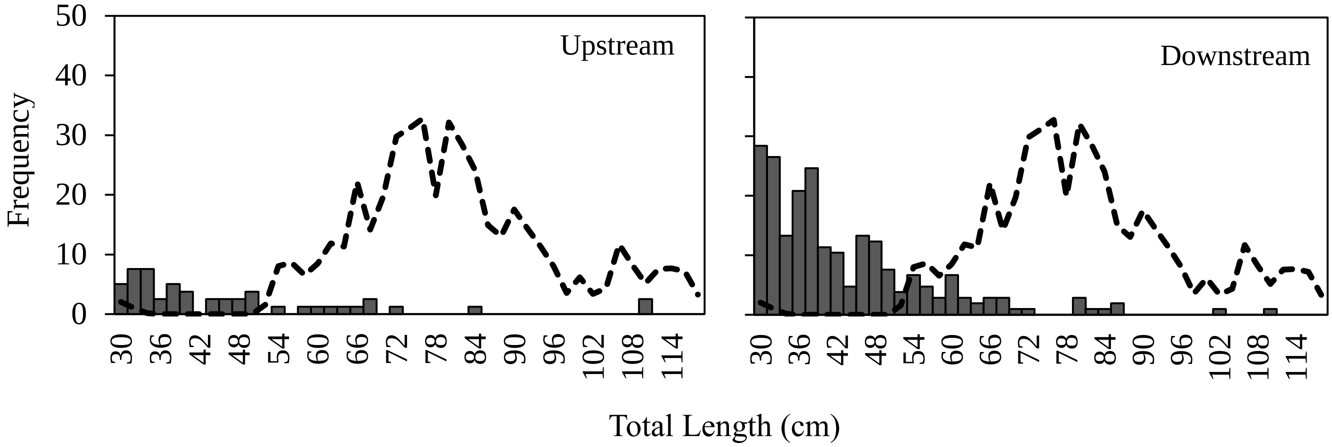

Figure 14. *Size distribution of fishes (gray bars) observed using mobile hydroacoustic surveys within one mile upstream (left) and downstream (right) of Lock and Dam 15 of the UMR in August 2017. Also included for comparison are the combined size distributions of Silver and Bighead Carp (dashed line) observed in Pool 19 by mobile hydroacoustic surveys conducted by Southern Illinois University in December 2016.*

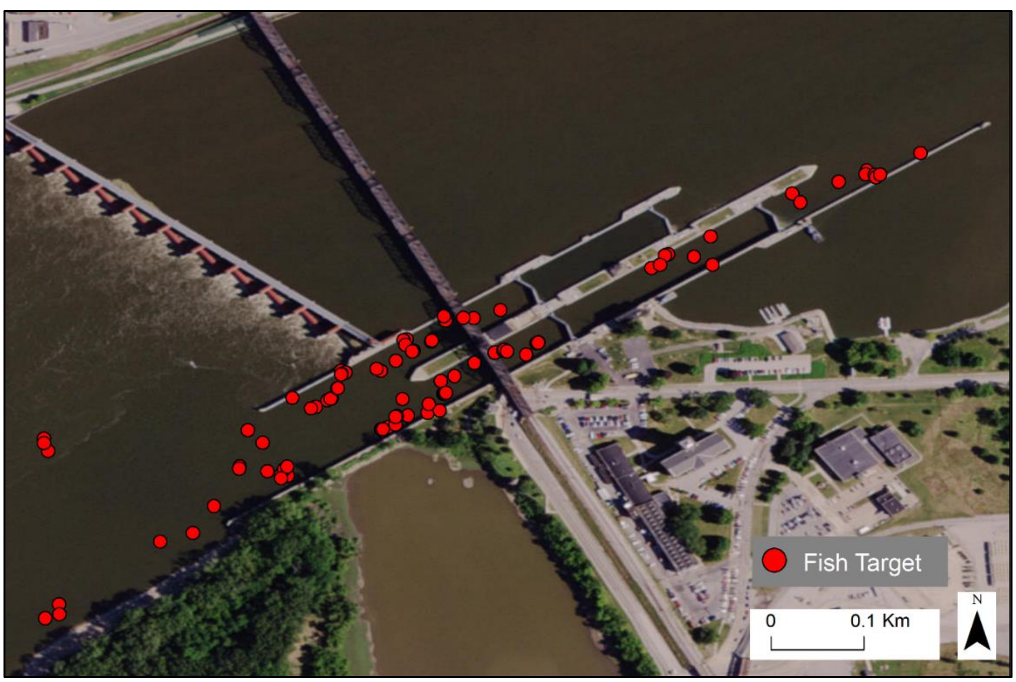

Figure 15. *Locations of all fish ≥ 30 cm in total length detected from mobile hydroacoustic surveys around Lock and Dam 15 in August 2017.*
Lock 14

At Lock 14, both the main and auxiliary chambers were sampled in the same week, however more effort was expended in the areas associated with the auxiliary lock than those associated with the main lock (Figure 4) The auxiliary lock was not open to recreational traffic during the week and could be readily sampled while the main lock was tied up with barge traffic (Table 3).

A total of 2 and 4.5 hours of imagery were collected at the main and auxiliary chambers of Lock 14, respectively. Schools of small fish frequented the imagery and some schools were in view for nearly the entire length of a 30 minute recording. More individual fish were observed at the main lock than at the auxiliary lock, however at both locations, there were more fish swimming in a downstream direction than in an upstream direction (Figure 16). Conversely there were more schools of fish observed at the auxiliary lock than the main lock (Figure 17).

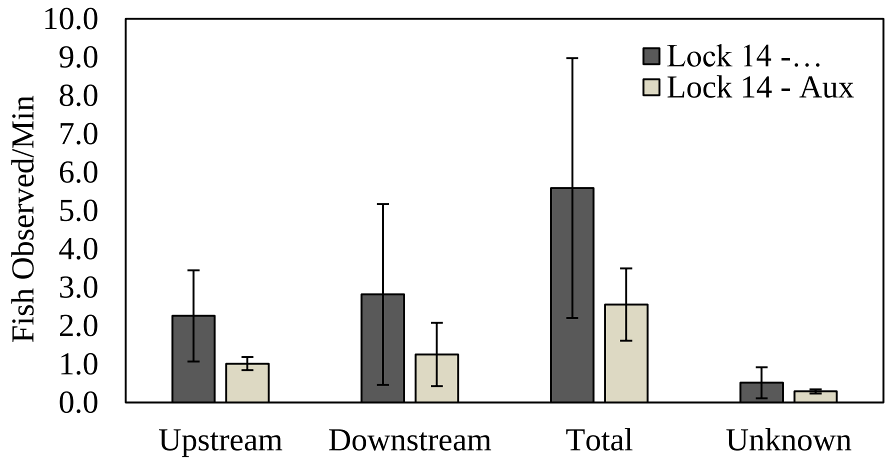

Figure 16. *Average rates (± SD) and swim direction of fish, observed using an ARIS camera, at the open, lower miter gates of the main (n=3) and auxiliary (n=5) chambers of Lock 14 of the UMR in August 2017.*

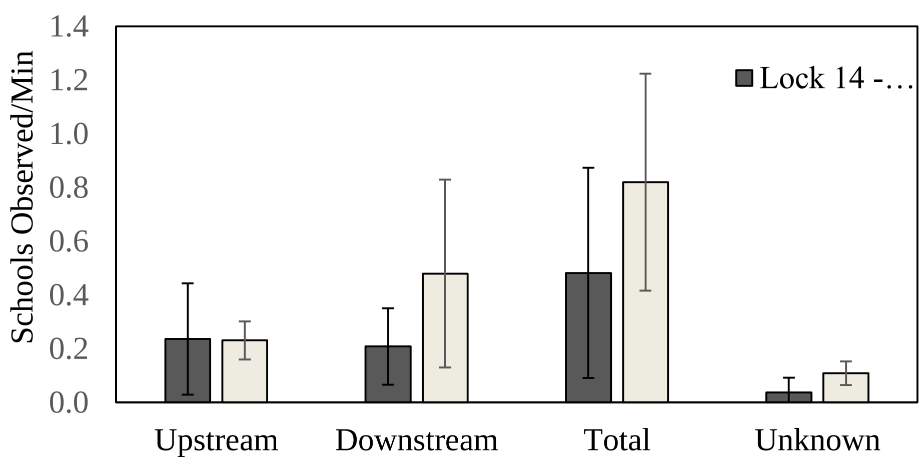

Figure 17. *Average rates (± SD) and swim direction of fish schools, observed using an ARIS camera, at the open, lower miter gates of the main (n=3) and auxiliary (n=5) chambers of Lock 14 of the UMR in August 2017.*

Similar to Lock 15, traditional gears were deployed opportunistically at Lock 14, so total effort with each gear was not equal. Just over 39 minutes and 88 minutes of electrofishing were conducted and 300 yards and 500 yards of gillnet were set in areas associated with the main and auxiliary locks, respectively.

At the main lock, the total catch was similar in the upstream and downstream approaches and these catches were noticeably greater than the total catch inside the chamber (Table 3). Emerald Shiner comprised the majority of the catch for the main lock, followed by gizzard shad, and zero fish were captured by gill netting (Table 4). Fish captured by this effort that are 1) known to move through UMR dams; and/or 2) migratory in UMR; and/or 3) probably migratory in the UMR included Bigmouth Buffalo, Channel Catfish, Largemouth Bass, Mooneye, and White Bass (Wilcox et al. 2004).

Due to the small size of the walled approach channels of the auxiliary lock, electrofishing runs in these areas were extended to included additional shoreline above and below this lock. At the auxiliary lock, the total catch was much higher in the downstream approach channel and lock chamber than in the upstream approach, however efforts in the chamber captured half as many species (Table 3). Emerald Shiner comprised the overwhelming majority of the fish captured in the auxiliary chamber and downstream approach, followed by Gizzard Shad and Largemouth Bass (Table 5). Largemouth Bass, Bluegill, and Common Carp were the most commonly captured species in the upstream approach area. Fish captured by this effort that are 1) known to move through UMR dams; and/or 2) migratory in UMR; and/or 3) probably migratory in the UMR included Bigmouth Buffalo, Bluegill, Channel Catfish, Freshwater Drum, Flathead Catfish, Largemouth Bass, Mooneye, Sauger, Shorthead Redhorse, Smallmouth Buffalo, Spotted Sucker, and White Bass (Wilcox et al. 2004).

Table 3. *Total catch and effort using two gears in three areas adjacent to the main and auxiliary chambers of Lock 14 of the UMR in August 2017.*

Chamber	Site	Gear	Species	Total Catch	Effort	CPUE
Main	Upstream approach	Electrofishing	5	72	15 min	4.8 fish/min
	Chamber	Electrofishing	3	16	11.7 min	1.4 fish/min
		Gill Netting	0	0	300 yd	0 fish/yd
	Downstream approach	Electrofishing	3	68	12.7 min	5.4 fish/min
Auxiliary	Upstream approach	Electrofishing	12, 1 hybrid	131	31.1 min	4.2 fish/min
	Chamber	Electrofishing	6	721	27.5 min	26.2 fish/min
		Gill Netting	0	0	400 yd	0 fish/yd
	Downstream approach	Electrofishing	15	997	30 min	33.2 fish/min
		Gill Netting	1	2	100 yd	<0.1 fish/min

Table 4. *Species captured by electrofishing in three areas adjacent to the main lock chamber at Lock and Dam 14 for the UMR in August 2017. Gill netting was also conducted but captured zero fish. Site titles are associated with the colored areas in Figure 4.*

Site	Count
LOCK CHAMBER	**16**
Emerald Shiner *Notropis atherinoides*	9
Gizzard Shad *Dorosoma cepedianum*	6
Mooneye *Hiodon tergisus*	1
DOWNSTREAM APPROACH	**68**
Bigmouth Buffalo *Ictiobus cyprinellus*	1
Emerald Shiner *Notropis atherinoides*	63
Gizzard Shad *Dorosoma cepedianum*	4
UPSTREAM APPROACH	**72**
Channel Catfish *Ictalurus punctatus*	1
Emerald Shiner *Notropis atherinoides*	35
Gizzard Shad *Dorosoma cepedianum*	32
Largemouth Bass *Micropterus salmoides*	3
White Bass *Morone chrysops*	1
TOTAL	**156**

Table 5. *Species captured by gear at three sites adjacent to the auxiliary lock chamber at Lock and Dam 14 of the UMR in August 2017. Site titles are associated with the colored areas in Figure 4.*

Site	Electrofishing	Gill Netting
CHAMBER	**721**	
Brook Silverside *Labidesthes sicculus*	1	
Channel Shiner *Notropis wickliffi*	1	
Emerald Shiner *Notropis atherinoides*	606	
Gizzard Shad *Dorosoma cepedianum*	81	
Largemouth Bass *Micropterus salmoides*	30	
White Bass *Morone chrysops*	2	
DOWNSTREAM APPROACH	**997**	**2**
Bigmouth Buffalo *Ictiobus cyprinellus*	1	
Bluegill *Lepomis macrochirus*	1	
Channel Catfish *Ictalurus punctatus*	1	
Channel Shiner *Notropis wickliffi*	1	
Common Carp *Cyprinus carpio*	2	2
Emerald Shiner *Notropis atherinoides*	796	
Freshwater Drum *Aplodinotus grunniens*	10	
Gizzard Shad *Dorosoma cepedianum*	142	
Largemouth Bass *Micropterus salmoides*	30	
Logperch *Percina caprodes*	1	
Mooneye *Hiodon tergisus*	1	
River Carpsucker *Carpiodes carpio*	1	
Sauger *Sander canadense*	1	
Spotted Sucker *Minytrema melanops*	1	
White Bass *Morone chrysops*	8	
UPSTREAM APPROACH	**131**	
Bluegill *Lepomis macrochirus*	26	
Brook Silverside *Labidesthes sicculus*	4	
Common Carp *Cyprinus carpio*	17	
Emerald Shiner *Notropis atherinoides*	3	
Flathead Catfish *Pylodictus olivaris*	1	
Freshwater Drum *Aplodinotus grunniens*	3	
Gizzard Shad *Dorosoma cepedianum*	1	
Green Sunfish *Lepomis cyanellus*	4	
Green Sunfish x Bluegill *L. cyanellus x L. macrochirus*	2	
Largemouth Bass *Micropterus salmoides*	62	
Pumpkinseed *Lepomis gibbosus*	1	
Shorthead Redhorse *Moxostoma macrolepidotum*	1	
Smallmouth Buffalo *Ictiobus bubalus*	6	
TOTAL	**1849**	**2**

Mobile hydroacoustic surveys that were completed around Lock and Dam 14 showed that the canal (Le Claire Canal) upstream of the auxiliary chamber had a higher density of fish ≥ 30 cm than the area upstream of the main lock chamber (Figure 18). The downstream area is shared by the main and auxiliary locks (Figure 19), but the density of fish present there was similar to the area upstream of the main chamber. These two areas have similar habitat features which include main channel and main channel border habitat. The canal upstream of the auxiliary lock is separated from the main channel, has minimal flow, and has more shoreline habitat. Density hotspots above the main lock included the upper Iowa shoreline adjacent to the main channel, which is bordered by lotus and lilies. Similarly the upper end of Le Claire Canal is a density hotspot as well as the auxiliary lock chamber itself. The area upstream of the main lock and the downstream areas had fairly similar size frequency distributions, with the majority of the fish detected smaller than 54 cm and therefore smaller than the most common sizes of Bighead and Silver Carp detected the previous year in Pool 19 (Figure 20). While the vast majority of fish detected in Le Claire Canal were also smaller that the majority of the Asian carp detected in Pool 19 in 2016, there were also numerous fish that fell within a similar size range as the Asian carp. There were fish targets (≥ 30 cm) in both lock chambers, however there were more targets detected above and below the auxiliary chamber. Also, fish targets appeared to be clustered into two areas of the main chamber and more scattered in the auxiliary chamber (Figure 21).

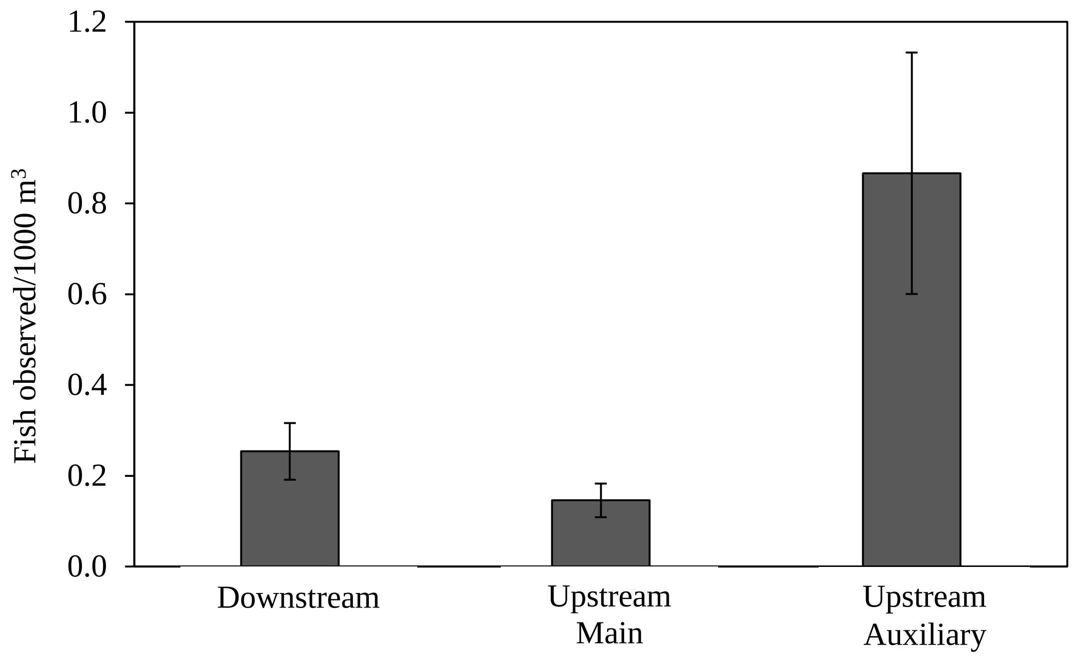

Figure 18. *Mean (SE) densities of fish (individuals ≥ 30 cm total length) observed from mobile hydroacoustic surveys conducted within one mile downstream and upstream of the main and auxiliary locks of Lock and Dam 14 of the UMR in August 2017.*

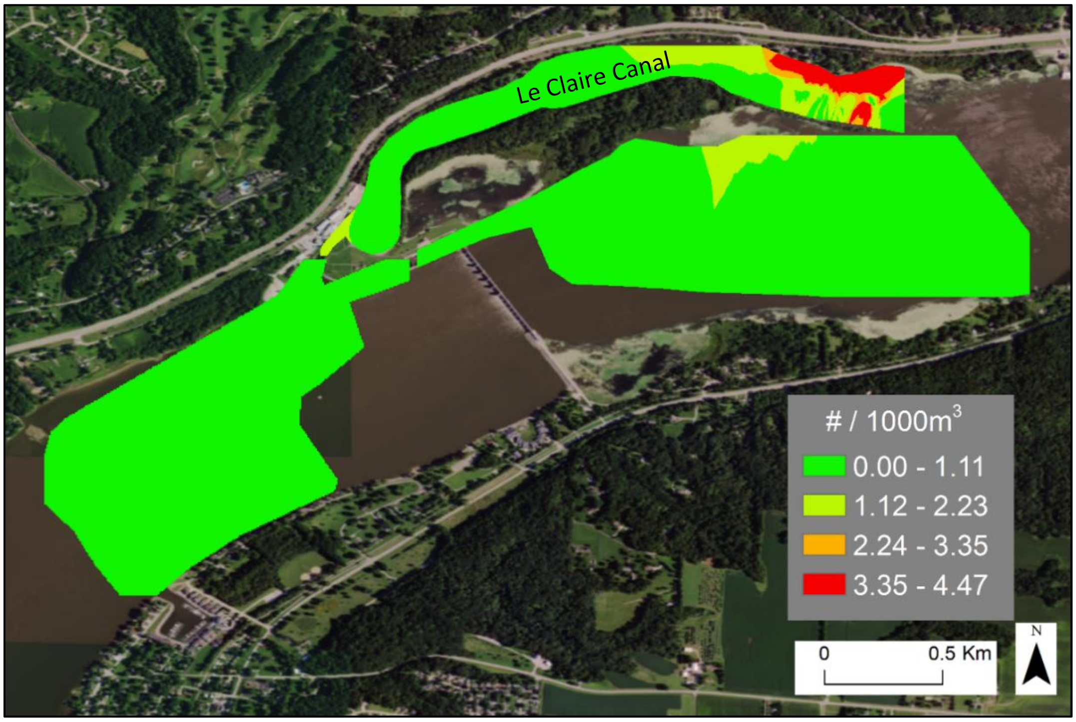

Figure 19. *Densities of all fish ≥ 30 cm total length detected from mobile hydroacoustic surveys upstream and downstream of Lock and Dam 14 of the UMR in August 2017.*

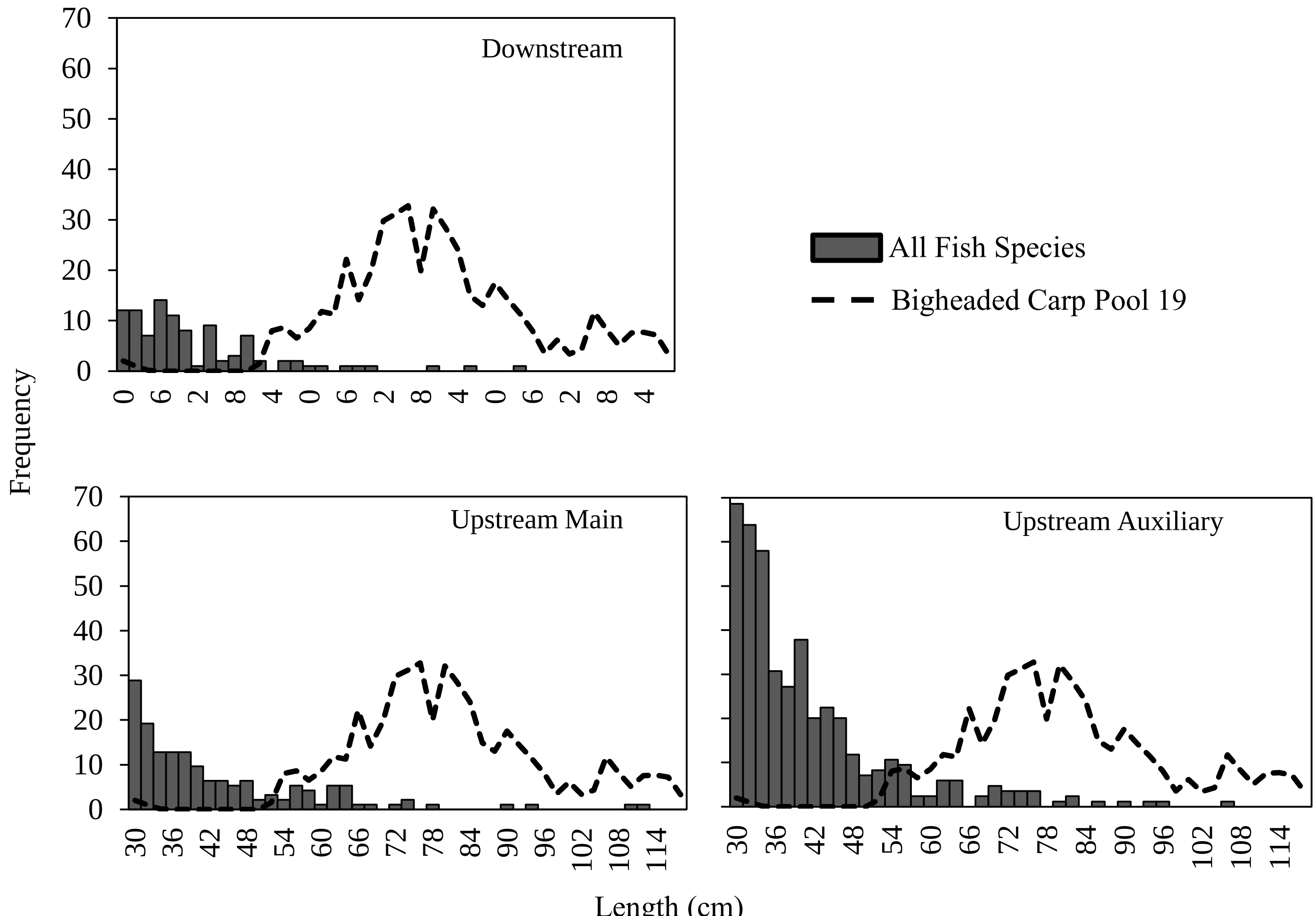

Figure 20. *Size distribution of fishes (gray bars) observed using mobile hydroacoustic surveys within one mile upstream (bottom) and downstream (top) of the main and auxiliary chambers of Lock and Dam 14 of the UMR in August 2017. Also included for comparison are the combined size distributions of Silver and Bighead Carp (dashed line) observed in Pool 19 during December 2016 by mobile hydroacoustic surveys conducted by Southern Illinois University.*

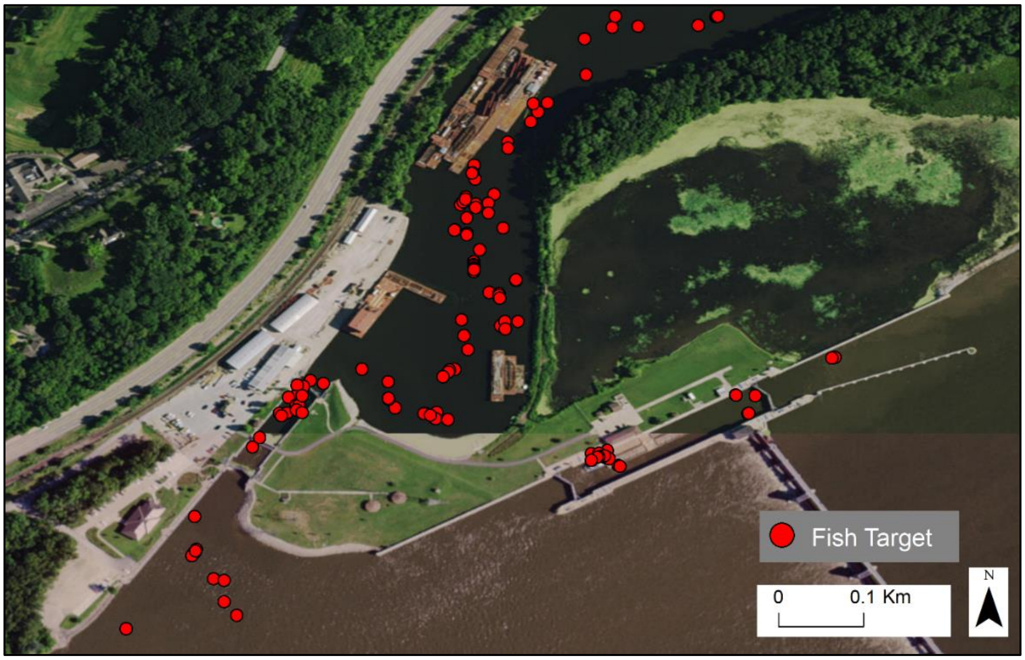

Figure 21. *Locations of all fish ≥ 30 cm in total length detected from mobile hydroacoustic surveys around Lock and Dam 14 in August 2017.*

Discussion:

It was apparent throughout data collection that barge traffic is a huge hindrance to data collection of any kind at both main lock chamber locations sampled in this project. The time spent waiting for barges to clear far exceeded the time spent collecting data at the desired locations. Gill netting proved to be too time consuming to fit into the short windows of time between lockages and therefore few adequate sets were made. When net sets were made in the lock chambers it was often difficult to drive fish to the nets given the short time frames available and confined spaces for maneuvering. The physical aspects of the lock structures also proved to make sampling with traditional gears challenging. At Lock 14, the proximity of the approach channel to the dam tailwaters made it difficult and potentially unsafe to set nets in that area, especially when rushed by approaching barge traffic. Similarly, the depth of the chambers and approaches also made electrofishing fairly inefficient unless fish were closer to the surface. Most of the catch consisted of more pelagic species and we likely did not sample the bottom portion of the water column adequately.

Of the gears used during this project, the mobile hydroacoustic surveys and ARIS camera collected the most data for the time spent deploying them. Both of these technologies could be useful in the future to gather data on changes to the size structure of the fish community, density hotspots, and behavior in response to a deterrent. The ARIS footage was difficult to review at times and moving forward, steps should be taken to reduce the variability among reviewer counts.

Recommendations:

Considering the significant amounts of barge traffic in these areas, it is likely that regular and thorough sampling of these locations with traditional gears would require some type of agreement with the Army Corps of Engineers and commercial navigators so that more time could be spent sampling in the lock. Electrofishing efforts should include deep-water electrofishing equipment so that the full depth of the water column can be sufficiently sampled.

To establish a more robust pre-deterrent data set, sampling should be conducted year around to capture how the size structure and distribution of the fish community fluctuates throughout the year. At a minimum, mobile hydroacoustic surveys could be conducted seasonally for this reason. In order to make better predictions about what species are represented by the fish targets detected in the mobile hydroacoustic surveys, fish species should be sampled using multiple gears in the pools surrounding these locks.

The increased use of telemetry tags in both native and non-native fish species is encouraged to better understand current lock usage and fish behavior in the lock and lock approach. Data collection with this technology would be minimally affected by barge traffic and would provide species-specific passage data.

The data collected during this project should serve as a starting point for pre-deterrent data collection at these locations. A more robust sampling plan will be required to fully evaluate pre- and post-deterrent fish community changes. Hydroacoustics and telemetry would be the technologies best suited for this purpose with the supplemental use of traditional gears only if adequate time can be given for deployment and if equipment is altered to suit deep-water habitats. Moving forward in deterrent research and evaluations, ARIS may be best utilized to evaluate the immediate response of fish to the deterrent stimuli and their ability to penetrate and habituate to said stimuli.

References:

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