Early detection and evaluation of Asian carp removal 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 Dashields (RM 13.3), 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 established invasive populations the Ohio River basin (ORB).

This project provides an ongoing, coordinated approach to monitor Asian carp and fish communities in the ORB. 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. Evaluate management actions using changes in the distribution and relative densities of Asian carp in the Ohio River through targeted sampling.
2. Evaluate indirect influence of Asian carp management actions on native fish communities in the Ohio River.
3. Use relative population characteristics and distribution to devise management strategies that minimize propagule pressure and population expansion of Asian carp.
4. Evaluate Asian carp presence in upstream areas where carp are rarely detected to inform future response and containment efforts.

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 a broad range of 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 sub-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.

<u>Bigheaded Carps</u> – 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.
<u>Establishment Front</u> – the farthest upriver range expansion of Asian carp populations that demonstrates the presence of natural recruitment.
<u>Invasion Front</u> – the farthest upriver extent where reproduction has been observed (eggs, embryos, or larvae), but recruitment to young-of-year fish has not been observed.
<u>Invasive Carp</u> – one of four species (i.e. Silver Carp, Bighead Carp, feral Grass Carp, and Black Carp) of carps originating from the continent of Asia, which are currently classified as aquatic nuisance species.
<u>Macrohabitat</u> – One of four habitat types used to categorize fixed sites within a pool (e.g. Tributary/Embayment, Tailwater, Island Back-Channel, Main Stem River).

Presence Front – The farthest upstream extent where invasive 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, previously conducted in the basin. 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. Targeted sampling was conducted from 16 April – 29 May, 2018, along five 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 fixed sampling sites were selected from a stratified random design in 2015. While randomly selected sites were considered ideal, this study design was found to be prohibitive with many random locations being remote or far from ramp launch sites. Thus, the sampling structure was adjusted in an attempt to offset logistic limitations while maintaining adequate pool coverage. 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 8-12 gill net sets per pool). To ensure coverage of each pool through this fixed sampling design, four major macrohabitat types were identified in each pool in order to compare trends within pools through time. Macrohabitat types included main-stem locations, island back-channels, tributaries/embayments, and dam tailwaters in each pool. In general, tributary or embayment sites comprise the majority of sampling locations (~ 62%). Fish communities tend to accumulate in these locations and tributaries are more frequent in number than islands and dam tailwaters in the Ohio River. The main-stem river is obviously the most frequent habitat available for sampling, but because of span and depth of the river, fisheries gears are limited in their ability to target fish.

Electrofishing transects were conducted during the day (between 0800 – 2100 hours local time) and standardized at 900 seconds in a general downstream direction with one dipper. A power goal aiming at a minimum transfer of 3000 Watts from water to fish was implemented (Gutreuter et al. 1995) with a 40% duty-cycle at 80 pulses per second (pulsed DC) using a MLES Infinity Box or comparable settings on a Smith-Root system at ~7 amps and 60 pulses per second. Asian carp were specifically targeted using increased driving speeds and allowable pursuit of fish upon sightings. During active sampling, all non-target fish species were ignored; however, all small, shad-like species were collected and examined thoroughly before being released to avoid mis-identification of juvenile Asian carps.

Gill nets used in targeted sampling were typically 45m (150ft) in length, 3m (14ft hobbled to 10ft) in depth, and constructed of large mesh (either 10cm or 12.5cm bar mesh) with a foam core float line to keep them suspended at top water. An additional 45m net with 7.6cm mesh (3" bar mesh) was included where conditions allowed in order to broaden the size distribution of invasive carp targeted with netting gear. Appropriate conditions were typically where flow was not so great as to sweep nets or push too much debris into the tighter mesh while being fished in the same manner as the other gears. Gill nets were set perpendicular to the shoreline when possible. Sites sampled consisted of at least two net sets, fished for two hours while creating noise and water disturbance every 30 minutes within 300 meters of the set. Regular disturbance was intended to drive or 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. A subsample of otoliths and spines were collected for aging following established protocols (Beamish 1981, Schrank and Guy 2002, Williamson and Garvey 2005, Seibert and Phelps 2013). Feral 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. All fish tagged during the monitoring project activities are reported in the telemetry project report: Quantifying lock and dam passage, habitat use, and survival rates of Asian carp in the Ohio River.

Fall Standardized Community Monitoring (Cannelton – R.C. Byrd)
From 05 October – 20 November, fish community surveys were repeated along the same pools in the middle Ohio River (Cannelton, McAlpine, Markland, Meldahl, Greenup, and R.C. Byrd) using the same sampling sites as previous years (see above). 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 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 in a downstream direction. An output power aiming for a 3000 Watt transfer from water to fish was targeted at 25% duty-cycle and 60 pulses per second (pulsed DC) using a MLES Infinity Box (Gutreuter et al. 1995) or a comparable setting with a Smith-Root system at ~7amps and 60 pulses per second. 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 (150ft) meters in length, ~3m (10ft) in depth, and constructed of large mesh (either 10cm or 12.5cm bar mesh) with a 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 300 meters of the set. Regular disturbance was intended to target or persuade the movements of bigheaded carps and other species into the gear.

Fish were identified to the lowest taxonomic level possible, enumerated, and measured. A minimum subsample of weights were taken randomly from each species identified. 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.

Boat ramp seining was conducted in November at four locations in the Greenup and R.C. Byrd pools of the Ohio River using a 9 m (30') seine with 0.5 cm (3/16") mesh and a 2 m bag (0.3 cm mesh). One seine haul was conducted at each of the four locations. Species readily identifiable in the field were enumerated, measured and released; all other species were retained for identification and enumerated, measured and weighed in the laboratory (Table 1).

Monitoring Ahead of the Invasion Front
Targeted sampling for Asian Carp was conducted in November 2018 in the Montgomery Slough portion of the Ohio River (Montgomery Island Pool, RM 949.78 to 950.11) near where positive eDNA hits for Bighead Carp were found in 2017 and historically. Gill nets used in sampling were 90 meters (300 feet) in length, ~4 meters (12 feet) in depth, and constructed of 8 cm, 10 cm, or 13 cm (3", 4", or 5", respectively) bar mesh. Three gill nets were fished for approximately 24 hours each.

Fish community monitoring was conducted in May 2018 in the Emsworth tailwater (Dashields pool), Dashields tailwater (Montgomery Island Pool), and Montgomery tailwater (New Cumberland pool) using night boat electrofishing. Five consecutive 10 minute runs were conducted on each bank beginning either downstream of the lock chamber or as close as possible to the dam wall for a total of 100 minutes of shock time. Electrofishing was conducted using an ETS MBS unit operated at 30% duty cycle, 60 pps, and between 250-550 V pulsed DC. All fish species were targeted and enumerated in the field or retained for identification in the laboratory if field identification was not practical. Gamefish species were measured, weighed, and a scale sample was retained for age and growth analysis.

Incidental sampling for Asian Carp was conducted using baited tandem hoop nets, beach seining, and boat electrofishing. Baited tandem hoop nets (3' diameter, 1.5" bar mesh, 3 nets in tandem) were set in the Emsworth, Pool 2, Pool 3, and Pool 4 of the Allegheny River in June 2018 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 m (100') seine with 1 cm (3/8") 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 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 5 to 19 minutes. Black bass were measured and enumerated, and presence/absence of other species was recorded.

Nighttime boat electrofishing was conducted in October in the New Cumberland Pool of the Ohio River and Pool 4 of the Allegheny River and in December in the New Cumberland Pool, the Montgomery Island Pool, and the Dashields pool of the Ohio 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 in October. All black bass and true bass were collected, and presence/absence of other species was recorded. On the Allegheny River in October, four fixed sites were sampled. Black bass and Sander species were collected, and presence/absence of other species was recorded. In the three pools of the Ohio River in December, the same unit and settings were used. Transects consisted of four 10 minute runs in the tailwater portion of each pool. All Sander species were collected and presence/absence of other species were recorded.

Assessing Asian Carp Population Demographics
The lengths and weights of Silver Carp, *H. molitrix*, captured from August through December in 2018 were compiled and $\log_{10}$ transformed for regression analysis and comparison with data from previous years. A single regression line for 2018 was derived to demonstrate the relationship between Silver Carp total length and weight and compared to the regressions reported in 2017 (Figure 2, Table 2). This analysis could serve as a benchmark to determine the effects of harvest as removal efforts increase in the future; however, it is complicated by changes in length distributions of fish from year to year. With no fish below a total length of 575mm captured in 2018, Silver Carp body condition was assessed using the standard weight equation derived by Lamer *et al.* (2015) and compared to fish removed in previous years (Figure 3).

In 2017, a single linear regression was derived using data compiled from Bighead Carp, *H. nobilis*, captured in 2016 and 2017. Again, this was used to contrast the relationship between total length (mm) and weight (g) for fish captured during the 2018 sampling season. Regressions were achieved utilizing the general linear model function (lm()) in base R (R Core Team 2016) and are in the form of $\log_{10}[\text{Weight}_g] = a + b * \log_{10}[\text{Length}_{mm}]$. Bighead Carp captured in 2018 did not span the range of total lengths from the regression generated in 2017 (Figure 4, Table 3). Thus, changes in general body condition were assess using the standard weight equation derived by Lamer *et al.* (2015) and compared to fish removed in previous years (Figure 5). Only enough information was available from the Cannelton pool to show a consistent progression of relative weights by year.

Throughout all ORB projects, a subsample of individual carp lengths (mm), weights (g), and aging structures (specifically otoliths) were taken to aid in assessing population characteristics of carp along the invasion front. Otoliths collected were either adhered to a glass slide using thermoplastic cement, ground to the nucleus, and examined using reflected light under a microscope (Beamish 1981, Schrank and Guy 2002, Williamson and Garvey 2005, Seibert and Phelps 2013) or thin-sectioned using a low speed saw with otolith cross-sections being examined under a microscope using transmitted light (Figure 6). Age data was used to calculate the mean length (range, 95% confidence interval) at each age for carp captured in the ORB. In addition, Silver Carp growth was modeled using the von Bertalanffy growth equation (Figure 7):

$$L_t = L_\infty\ (1\text{-}e^{-K(t\text{-}t0)})$$

Where L_t = the estimated length at time t, L_∞ = the average maximum theoretical length, K = Brody growth coefficient, t = time or age in years, and t_0 = is the time in years when fish length would theoretically be zero. For the equation, L_∞ was set to the largest length captured for age and growth. This fixed L_∞ at the 99th percentile for the total lengths of fish captured within the 2018 field season and is likely a good reflection of the theoretical average maximum length for fish in the pool. The model was fitted in R using non-linear modeling procedures outlined by Derek Ogle (2016). The growth coefficients were then used to obtain two tentative annual mortality estimates for Silver Carp populations in the Cannelton pool. The first method utilized a length-converted catch curve procedure (fish ages four – ten) as outlined in *Analysis and Interpretation of Freshwater Fisheries Data* (Guy and Brown 2007). In addition, the updated $\text{Pauly}_{nls\text{-}T}$ empirical estimator equation (Then et al. 2015) was also used to get an estimate of natural mortality. This equation is often useful in data poor situations and provides a convenient work-around to direct estimation methods with data-rich stocks (Then et al. 2015).

Hydroacoustics Analysis

To estimate relative abundance and size distribution of Asian carp in the Ohio River from the Cannelton Pool to the R.C. Byrd Pool, USFWS conducts annual mobile hydroacoustics surveys in the fall within a similar timeframe that fish community data are collected. Survey locations were established in 2017 to encompass clusters of sites that were sampled by KDFWR with electrofishing and gill nets (Table 4) due to the reliance of hydroacoustics data on fish community data, as described below.

Hydroacoustics surveys were performed using methods similar to those described in MacNamara et al. (2016). Briefly, surveys were conducted parallel to the shoreline on both banks of the Ohio River for 4 miles and up to 2 miles upstream into tributaries. Surveys were conducted using two 200 kHz split-beam transducers (BioSonics, Inc.) aimed in side-looking aspect toward the shoreline on the main channel and away from the shoreline in tributaries and other shallow. The side-looking orientation is important to maximize the volume of water sampled and to reduce the potential of underestimating density of Asian carp that would evade detection of down-looking transducers via behavioral responses to boat disturbance. Transducers had a circular beam pattern of 6.4° and were 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. 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).

Data are in the process of being analyzed using Echoview 9.0 following MacNamara et al. (2016). After background noise removal, the split-beam single target detection (method 2) algorithm was used to detect fish echoes or single targets. 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).

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 2019 and used to inform the range of Asian carp species captured and reported throughout the ORB. The NAS database provides a unified reporting and reference system where confirmed sightings from all basin 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 in sampling data taken from 1957 – 2018. Data were sorted and mapped in order to supplement project records and additional upstream detections of bigheaded carps in the Ohio River (Figures 8-9). In addition, with the increase in Black Carp records over the past several years, a new map was generated using these sources to show the current known distribution of those fish in the ORB (Figure 10). 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 also 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 targeted electrofishing in 2017 produced a single Bighead Carp capture and an overall catch per unit effort (CPUE) of 3.71 fish/hour (n = 74, SE = 1.31) for Silver Carp with no Grass Carp captures in any of the six pools sampled (Table 5). With spring work shifting towards targeted sampling in instead of community monitoring in 2017, Silver Carp yields were higher than previous seasons. However, previous sampling efforts, produced similar captures within the Cannelton, McAlpine, and Markland pools indicating that the yield were likely not an indication of population increases. In 2018, targeted electrofishing yielded zero Bighead Carp and 61 Silver Carp combined from Cannelton, McAlpine and Markland pools. The overall CPUE for all five pools sampled was of 3.05 fish/hour (n = 61, SE = 0.80) (Figure 11). Efforts also yielded an overall catch rate of 0.20 fish/hour (n = 4, SE = 0.12) for Grass Carp, an increase from previous years. Between both years, catch rates for Silver Carp in the Cannelton pool dropped slightly while occurrences increased in the upriver pools of McAlpine and Markland. However, the detection range where Silver Carp were captured remained consistent with targeted effort in 2017.

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 6). Eighty-five sets made up 5,822m (19,100ft) of net, yielding a total catch of 197 fish and 11 unique taxa. Asian carp species were caught throughout the sampling range with feral grass carp landings in all pools, but Silver Carp yield ended below Meldahl Locks and Dam (Figure 12). Bighead Carp were also captured throughout the sampling range in 2017, but only in the Cannelton, Markland, and RC Byrd pools. Smallmouth Buffalo and Silver Carp made up over 50% of the total catch by number. Bighead Carp made up ~5% of the total catch. Similarly, in 2018, Smallmouth Buffalo and Silver Carp made up over 50% of the total catch by number for captures in 2018 and were the most represented groups in term of catch by number (Table 7). Seventy-two net sets (3,292m or 10800ft) yielded a total number of 230 fish sampled in spring 2018 with 13 unique taxa identified. Overall catch rates for Bighead (0.07 fish/set, SE = 0.05), Silver (0.57 fish/set, SE = 0.25) and Grass Carp (0.08 fish/set, SE = 0.03) decreased in the four pools sampled in 2018 (Table 6). Captures in 2018 decreased for all invasives observed in the Cannelton and Markland pools, but increased slightly due to single captures of one each Silver and Grass carp in the McAlpine pool in 2018.

Fall Standardized Community Monitoring (Cannelton – R.C. Byrd)
Fall electrofishing sampling in 2017 produced zero Bighead Carp and Grass Carp captures and an overall CPUE of 0.18 fish/hour (n = 6, SE = 0.07) for Silver Carp. In 2018, no Bighead Carp were captured during fall sampling, but 33 Silver Carp and two grass carp were caught in the Cannelton pool showing an increase in overall catch rates for both species. McAlpine and Markland pools were not sampled and no invasive carp species were captured above Meldahl Locks and Dam (Table 8). A total of 76 transects (18.85 hours) were completed to yield a catch of 5,176 fish comprising 54 unique taxa. Emerald Shiner was the most commonly encountered species in 2018 comprising 34% of the total catch by number throughout the sampling period (Table 9). Reductions in total numbers of Gizzard Shad sampled dropped in from 36% to 26% of the total catch between 2017 and 2018. Reductions in the total catch of Gizzard Shad occurred in the Cannelton and Greenup pools with moderate increases in catches in the Meldahl and RC Byrd pools between 2017 and 2018.

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 10). In 2018, Silver Carp were captured only in the Cannelton Pool while Bighead carp were captured in the Cannelton and RC Byrd pools with nets. Eighty-two sets made up 3,749m (12,300ft), yielding a total catch of 152 fish and 10 unique taxa. Smallmouth Buffalo and Silver Carp alone made up the majority of catch as they did in 2017. Together the two species comprised over 86% of the total catch with Longnose Gar and Paddlefish making up an additional 6% (Table 11).

Body condition indices for Gizzard Shad have varied by pool over the last several years of fall sampling and clear patterns are not evident. In the Cannelton and Markland pools, fish have maintained a relative weight condition around 90 over the past four sampling seasons (Figure 13). However, in the Meldahl and Greenup pools, conditions were in decline until 2017 and have since rebounded in 2018. The McAlpine pool shows a similar decline in condition up until 2017, but no sampling efforts were completed in 2018. Bigmouth Buffalo are generally uncommon in sampling data and provide little information for assessing annual conditions (Figure 14). Meldahl pool is the only section of river that has had consistent annual sampling and appears to show a general increase in fish condition since 2015.

Assessing Asian Carp Population Demographics
In total, the number of Bighead Carp captures across all projects in 2018 was 57 fish, a slight increase compared to the 46 fish caught in 2017. Of those two years, males were only slightly more common than females and immature fish were captured during both years. The mean total length of Bighead Carp across both years was similar, with the 2017 average TL = ~1020mm (n = 46, SE = 31.0) and 2018 average TL = ~1052mm (n = 57, SE = 21.6). The weight-length regression for 2018 produced a more gradual slope and a shallower y-intercept than the ORB regression derived in 2017 (Table 3, Figure 4). Data points from 2018 cluster well, if not only somewhat lower than previous records used to derive the ORB regression, but the range of total lengths for fish taken from that pool in 2018 did not span the full range of total lengths observed in 2016 - 2017. Boxplot comparisons by year for the relative weights (W_r) of Bighead Carp in the Cannelton pool show a slow decline in body condition over the last three sampling seasons (Figure 5).

In 2018, more than 4,000 Silver carp were removed from the Ohio River during projects being conducted by all partners within the basin. This was a 140% increase over Silver Carp harvested in 2017. The mean total length of Silver Carp captured in 2017 was ~796mm (n = 1661, SE = 4.15) while the mean total length of Silver Carp captured in 2018 was slightly larger at ~819mm (n = 3963, SE = 1.12). Smaller length-classes of Silver Carp were seen with more frequency in 2017 when compared to previous years and several juvenile fish (< 400mm) were captured in the Cannelton pool. In 2018, more sampling effort was placed into the Cannelton pool, but no juvenile fish were observed. As in previous years, the relative frequency of larger length-class adults in each pool increases with a progression upriver (Figure 15). Length-class distributions are relatively symmetric in the Cannelton pool while the McAlpine pool annually demonstrates a slight negative skew. Weight-length regression for Silver Carp captured in 2018 also produced a line with a more gradual slope and shallower y-intercept (Figure 2). Data distribution looks very similar to previous records, but only fish >400mm were captured during this sampling season. Relative weight (W_r) comparisons have shown little change in the Cannelton and McAlpine pools since 2015 (Figure 3).

The presence of spawning patches on female fish was also tracked in 2018, which can be viewed as evidence of relatively 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 exhibited fresh spawning patches from May – August. In May, spawning patches showed up by the 15th and 52% of females captured by the end of the month exhibited fresh spawning patches. In June and July, 56% and 41% of females respectively displayed actively bleeding spawning patches. By August, most females captured were either healing or had little sign of damage on their ventral surface with only 8% of females caught showing signs of recent spawning activity. The Cannelton and McAlpine pools during this period of the sampling season typically demonstrate increased CPUE for all gears, but most notably with electrofishing as fish tend to fill tributaries in large numbers and are more accessible to removal crews. This pattern was also seen in 2016 and 2017 and has been used to increase carp capture numbers during population control projects.

In total, otoliths from 68 Silver Carp were examined and used to produce a von Bertalanffy growth curve with a theoretical average maximum length (L_∞) at 986mm. The oldest fish in the sample was 10 years old and the majority of fish were found to be between the ages of four and six. The theoretical average maximum length was fixed using the longest fish in the age and growth sample. This 10 year-old fish was found to be within the 99th percentile of length distributions for fish harvested from the Cannelton pool in 2018. The Brody growth coefficient (K) was calculated at 0.319, which is relatively steep and indicates fish tend to approach L_∞ rapidly; in fact, predicted ages suggest that fish within their second growing season will likely reach a length of approximately 367mm (Table 12). While this model includes some uncertainty due to data limitations, the maximum age and length at age predictions are consistent or similar to growth parameters reported from other basins (Hayer et al. 2014, Seibert et al. 2015).

Fish at length-converted ages of four years or more were used to construct a catch curve with the length distribution of Silver Carp harvested in the Cannelton pool in 2018 (Figure 14). The regression fit was low ($R^2 = 0.84$) due to some smaller (younger) fish being underrepresented in the sample while some longer (older) fish being more frequent than the relative year-classes represented below them. Using 2,617 fish, an instantaneous mortality rate (Z_p) was calculated at 0.85 which would make annual mortality around 57.3% for Silver Carp in Cannelton pool. In addition, the updated $\text{Pauly}_{\text{nls-T}}$ empirical estimator equation was used to obtain an additional estimate of mortality using the Brody growth coefficient $K = 0.319$ and $L_\infty = 98.6$ cm. This gave a natural mortality estimate (M) of 0.38 and an annual mortality estimate for Silver Carp populations in the Cannelton pool around 32.1%.

Hydroacoustic Analysis

USFWS conducted mobile hydroacoustic surveys to estimate relative abundance and size distribution of Asian carp in R.C. Byrd and Greenup pools of the Ohio River. Staff shortages within the USFWS and high water conditions during the fall and winter prevented planned hydroacoustics sampling in the Meldahl, Markland, McAlpine, and Cannelton pools. Staff shortages within the USFWS have also prevented timely analysis of hydroacoustics data to determine pool-specific density and length distribution of Asian carp. As such, hydroacoustics data analyses are ongoing for data collected in both 2017 and 2018.

Monitoring Asian Carps Ahead of the Invasion Front
Targeted gill net sampling for Asian carp in the Montgomery Slough of the Ohio River did not collect any Asian carp species. Common Carp, Smallmouth Buffalo, and River Carpsucker were the only three species captured and comprised 81%, 12%, and 8% of the total catch on the Ohio River, respectively.

Fish community monitoring in the New Cumberland, Montgomery Island, and Dashields pools was conducted in May 2018 and consisted of 1.67 hrs of effort per pool using pulsed DC night electrofishing. No Asian carp species were captured during fish community surveys. Thirty species and 604 individuals, 33 species and 1018 individuals, and 29 species and 890 individuals were captured in the Dashields pool, Montgomery Island pool, and New Cumberland pool, respectively. Common Shiner, Emerald Shiner, and Mimic Shiner comprised approximately 46% of the total catch between all three pools (Table 13). Sixteen baited tandem hoop nets were fished for 48 net nights and captured no Asian carp species. Sixteen species were captured, and Channel Catfish and Smallmouth Buffalo comprised 58% and 25% of the total catch, respectively.

Beach seining on the Montgomery Island Pool in August 2018 collected no Asian carp species. A total of 6,664 individuals of 27 different species were captured. Channel Shiner and Emerald Shiner comprised 41% and 34% of the total catch, respectively. Catch rates were over five times higher in 2018 than in 2017 (Table 14).

Daytime boat electrofishing on the Ohio River Montgomery Island Pool, Monongahela River Charleroi Pool, and Allegheny River Pool 4 was conducted for 2.31 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 1.95 hrs of effort captured no Asian Carp in October. No Asian carp were captured during night electrofishing surveys in December in the New Cumberland, Montgomery Island, or Dashields Pools (1.33 hrs of effort per pool).

Compilation and Incorporation of Other ORB Data Sources
Data taken from ORSANCO records show a similar pattern in presence/absence of Asian carps as seen during standard monitoring sampling and removal efforts conducted between 2015-2018. The farthest up-river accounts of Asian carps by ORSANCO were in the Markland Pool in 2012 and McAlpine Pool in 2014 (Figures 8 – 10). The USGS NAS database expands the range of Silver Carp reports to the farthest upriver detection in Raccoon Creek, a tributary of the R.C. Byrd Pool in 2016 (Figure 9). Recently a Bighead Carp was captured as far up as a tributary of the Pike Island Pool in 2016 and an additional account of a Bighead impinged against the water intake screen at WH Sammis Power Plant in the New Cumberland pool was reported this past season in 2018 (Figure 8). Grass Carp records continue to be sporadic throughout the Ohio River and within all internal waters of the surrounding basin states. This is likely indicative of diploid Grass Carp establishment throughout the ORB. During routine sampling in 2017, the KDFWR ichthyology branch reported Silver Carp sightings at six locations between August and October in McCracken and Ballard counties in 2017. Two of six sites (Massac Creek and Clanton Creek wetland) previously contained juvenile Silver Carp between 69 – 85mm in total length. Both systems are tributaries of the Ohio River close to its confluences with the Mississippi. In 2018, Gar Creek, a tributary below the Tennessee and Cumberland Rivers and above Olmsted Locks and Dam, was sampled in mid-July and found to harbor large numbers of Bighead, Silver, and Grass Carp YOY. Additionally, one young-of-year Black Carp (~ 23mm TL) was discovered while sorting the sample and officially verified by experts at the USGS Research Center and Missouri Department of Conservation. This finding marked the first location where juvenile Black Carp have been observed outside of the Dutchtown ditch near southeast Girardeau, MO. In addition, reports of adult Black Carp

records within the lower part of the Ohio River and surrounding systems have increased in the past few years. In 2018 - 2019 there have been nineteen reports from verified captures in the lower Ohio River and surrounding tributaries, Barkley Lake/Cumberland River, Kentucky Lake/Tennessee River (Figure 10).

Discussion:

The 2017 Monitoring and Response project built on the design and efforts of monitoring in previous years. The original four pools (McAlpine through Greenup) sampled in 2015 were expanded to include Cannelton and R.C. Byrd pools in 2016 to incorporate more resolution between the changes in carp populations by pool. Targeted removal began in 2017 to addresses the goal of tracking relative abundance of Asian carp through time, but also has had the added benefit of allowing crews to focus on catching only invasive carp species and increasing the number of total fish removed from the system during spring sampling months. Increases in capture between 2016 and 2017, specifically with gill nets, were likely an indication of a better understanding of how to target these species and when to utilize these gears rather than an increase in relative abundances. Between 2017 and 2018 sampling seasons, carp capture rates appear to have decreased in most pools. However, capture numbers are very small and variation is high with results likely confounded from a relatively historic high water seasons in 2018. In addition, efforts for targeted monitoring were delayed due to these unfavorable river conditions and sampling in Meldahl pool was abandoned altogether once the water temperatures exceeded the designated sampling range. Bighead Carp catches during targeted efforts remained similar between both years, but is also confounded by the issues described above. With such variation in seasons, it is likely that our ability to rely on catch rates as measures of relative abundance between years is not very robust and we will have to rely on an additional body of evidence in order to track changes in carp populations.

Anecdotal reports from removal crews in the Cannelton and McAlpine pools in 2018 have suggested that Silver Carp populations appear to have increased in size despite monitoring data. Crews beginning in 2015, observed large differences in the relative abundances of fish between Cannelton pool and upriver pools; however, large schools of fish were infrequent and often only small groups were seen on side-scan through 2016. Recently, it has been common place to see the lower mile of larger tributaries in the Cannelton pool contain schools of fish that are so abundant that side-scan units can detect nothing beside Asian carp. Also in 2017, young Silver Carp (> 400 mm in TL) were present in removal data and likely represented a recruited year-class spawned in 2015. This size class of fish was notably absent in 2018, with an increase in frequencies of fish between 400 – 600 mm in TL. This could indicate a gap in recruitment from 2017 considering that a larger amount of removal effort was placed in that pool in 2018 and it is unlikely that fish at this size would not have turned up in removal data. As the 200-400 mm size fish begin recruiting to gill nets, increases in catch rates are expected to reflect this population growth unless there are significant reductions in the adult populations already present within the pool. Future efforts need to be placed into adding/expanding population control measures to the current level of removal being conducted in the Cannelton pool. In addition, it may be useful to revisit our understanding of which annual, environmental factors aid successful reproduction and recruitment.

Relative catch rates (CPUE) of Silver Carp over both years continue to support increases in relative abundances from downriver to upriver pools (Figures 15 – 16). This trend among Silver Carp abundance is also apparent during removal efforts and additional observations during projects further up the Ohio River. Increased frequency of larger length-classes of Silver Carp in upriver pools, in addition to more narrow ranges for total lengths overall, suggests that fish captured upriver are likely migrants rather than successfully reproducing populations (Figure 15). 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 beginning to show up in harvest data. Tributaries where these younger individuals were observed in 2017 are potentially important to recruitment success (primarily Clover Creek/Tug Fork and Oil Creek).

No gear types currently seem to be effective at targeting Bighead Carp; however, as mentioned above, focusing on capture known locations (even in low density pools) have proven useful in removing Bighead Carp from the river. Despite our better understanding of how and where to capture Bighead Carp, successful landings are infrequent and take a substantial amount of effort. This has led to relatively little information on Bighead Carp in each pool and makes it difficult to determine if they follow similar abundance patterns as Silver Carp populations. From our experience, Bighead Carp appear more erratic in their distributions and our current assumptions are that pool densities are less dependent on fish age or population densities. Fall gill netting and regular removal efforts in RC Byrd are beginning to show that Bighead Carp can be consistently caught in the stretch of river between RC Byrd Locks and Dam and Raccoon Creek, while pools below don't appear to produce consistent yields of Bighead, despite historical captures at specific locations. Using agency records and reported sightings, their range upriver appears to greatly exceed the presence front currently suggest for Silver Carp populations. In addition, telemetry data supports the postulation that individual Bighead Carp have a higher propensity to migrate upriver when compared to Silver Carp. However, individual Bighead appear to find their preferred habitat and remain in that area for a majority of time.

The McAlpine pool showed small increases in Silver Carp catch rates despite the high water during monitoring season and fish appeared to be more abundant in some sections of the river when compared to previous sampling seasons. There was also a 52% increase in Silver Carp removed in the McAlpine pool in 2018 with only a 1% increase in total electrofishing effort when compared to fish removed using the same method in 2017. This is concerning as the sampling data, coupled with anecdotal observations, may indicate that the increased flooding in the spring of 2018 facilitated significant upriver movement. With upper pools showing no signs of recruitment, it is likely the majority of carp captured above McAlpine Locks and Dam are immigrants and efforts to identify strategic areas for barrier placement along the river to slow upriver establishment are ongoing. Spring detections in lower density pools still fail to reflect the full range of known carp distribution up river and it is likely that a higher amount of effort per pool would be necessary to reach consistent annual detections that would be robust enough to detect changes in population status. At the current levels of effort, changes in relative abundance using traditional sampling methods are unlikely to detect population changes alone. Hydroacoustic analyses are going to be essential for tying in density increases with additional evidence (i.e. catch rates) in order to recommend management strategies. It is probable that annual records over multiple years that consider length and age distributions, in addition to fish body conditions, and even changes in movement will all have to be used in order to have the level of resolution necessary to describe population trends. In the short term, concerns will likely need to be based on the frequency and location of fish that are < 400 mm in TL and the maximization of population control efforts.

Regressions for both *Hypophthalmichthys spp.* derived in 2017 appear similar to those derived from carp sampled in other watersheds and remain a good estimator for weight at length in the ORB. Previously, an 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) with 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 that there was no statistically significant difference in growth of fish between the two years. However, with the length classes of fish caught between 2017 and 2018 differing in range, appropriate use of this analysis would involve recalculating a regression for 2017 using a truncated dataset containing similar total lengths to fish caught in 2018. With annual regressions being reported, adjusted, and then recalculated each successive year, analyses may become confusing and difficult to track. Thus, regressions for Bighead and Silver Carp were plotted against previous data used in determining condition regressions in 2017 and visually compared. Data for Bighead Carp appeared to cluster slightly lower than data from previous seasons and suggest a small decrease in weight at length for fish caught in 2018. In addition, boxplots showing the range and median relative weights for each year were plotted for comparison. While data ranges showed significant overlap between years, Bighead Carp condition appears to have steadily decreased over the past three removal seasons in the Cannelton pool. Although there is not sufficient evidence to attribute any decline in condition to interspecies competition for resources, this may be part of the body of evidence showing that *Hypophthalmichthys* populations in that section of river are beginning to crowd. Silver Carp regression points clustered similarly with previous data and the 2018 regression slope was likely affected by the lack of smaller size fish in the data range. When looking at Silver Carp relative weights across years in the Cannelton and McAlpine pools, it appears that they have been relatively steady over the last three seasons. Conditions between the two pools do differ slightly and suggest that fish in McAlpine (a lower density pool) have consistently maintained a higher condition than fish in the Cannelton pool (a relatively higher density pool).

Community data is highly variable between years and likely will require longer trend data in order to be useful when considering trophic shifts or changes in represented taxa. Gizzard Shad and Bigmouth Buffalo conditions are considered possible indicators of negative community effects caused by Hypophthalmichthys spp. However, data on Bigmouth Buffalo is difficult to obtain using our current sampling methods and Gizzard Shad conditions seem so variable that there is likely a large year effect represented in the data. Currently, it is unlikely that community monitoring efforts will be useful in detecting annual changes in fish communities. Continuation of community monitoring is necessary however, considering it is an integral addition to the hydroacoustic analyses being conducted.

With increases in CPUE being highly correlated with spawning in 2017 and 2018, 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. In addition, fish appear to move into adjacent tributaries and embayments when river flows spike and are these are good periods to time population control efforts as fish are entering or leaving adjacent waters. Catch rates have tended to decrease as water temperatures drop toward the fall season, but several areas have been identified as overwintering locations for large riverine fish (including invasive carp species). These areas currently include Clover Creek in the Cannelton pool, Sinking Creek in the Cannelton pool, the mouth of Salt River in the Cannelton pool, and the mouth of the Kentucky River in the McAlpine pool. With fish being more susceptible to netting gears in cooler water temperatures it is recommended that regular removal targeting these locations be incorporated annually to boost population control efforts.

Recommendations:
It is recommend that both targeted sampling and community monitoring continue in 2019 using the consistent and repeatable design now established for this project. It is expected that our ability to interpret data trends on an annual basis will be highly influenced by annual, temporal variations between years. With our ability to detect changes between each year being so low, the continuation of sampling and the use of multiple types of trend data are the only tools we have to make sensible management decisions. Unfortunately, this will prolong management decisions between years. However, an increase in our ability to detect population status changes annually would require a substantial increase in efforts and may not be possible or realistic. Because carp are more susceptible to the gears and techniques currently being used by basin partners during the Months of May – August, population control measures should be focused in areas of high densities. The targeting of tributaries should also be a priority since locating schools of fish are more predictable and easier to catch in these areas. Catch rates have tended to decrease as water temperatures drop through the fall season. Several areas have been identified as overwintering locations for large riverine fish (including invasive carp species) and have produced large yields. These areas currently include Clover Creek in the Cannelton pool, Sinking Creek in the Cannelton pool, the mouth of Salt River in the Cannelton pool, and the mouth of the Kentucky River in the McAlpine pool. With fish being more susceptible to netting gears in cooler water temperatures, it is recommended that regular removal targeting these locations be incorporated annually to boost population control efforts. Finally, with results indicating increases in population densities in the Cannelton pool,

larger scale control efforts are a primary objective for future efforts considering that Silver Carp populations may be recruiting in this section of river. With Cannelton pool harboring a potential source of upriver migrant fish, contract fishing is recommended to reach the scale of population control necessary to decrease pressure for upriver progression.

Project Highlights:

- The 2018, Monitoring and Response to Asian Carp in the Ohio River project built on the design and efforts of previous sampling seasons.
- In 2018, targeted electrofishing yielded no Bighead Carp captures, but 61 Silver Carp were removed from Cannelton, McAlpine and Markland all together for an overall CPUE of 3.05 fish/hour (n = 61, SE = 0.80) for the five pools sampled during the spring season.
- Seventy-two net sets (3,292m or 10800ft) yielded a total number of 230 fish sampled in spring 2018 with 13 unique taxa identified. Overall catch rates for Bighead (0.07 fish/set, SE = 0.05), Silver (0.57 fish/set, SE = 0.25) and Grass Carp (0.08 fish/set, SE = 0.03) decreased in the four pools sampled in 2018.
- 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. Currently no invasive *Hypophthalmichthys spp.* have been captured by basin partners targeting areas of previous eDNA positive detections.
- Records for species ranges have remained very similar annually, however there were two significant findings in 2018: 1. The discovery of a young-of-year Black Carp in Gar Creek, Kentucky marks the first record of Black Carp recruitment in the nation outside of the Dutchtown ditch near southeast Girardeau, MO. 2. A Bighead Carp was found impinged against the water intake screen at WH Sammis Power Plant in the New Cumberland pool, the farthest upriver account in the past two years.
- Capture numbers continue 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 some indication that population numbers are increasing in the Cannelton pool, more aggressive control measures are needed to respond to the growth before significant biological pressure begins to force fish to expand upriver at higher rates.
- With less information on Bighead Carp, little can be said to the extent of their establishment within the ORB; however, Bighead are able to be targeted consistently at strategic locations, even in low density pools. Targeting Bighead Carp with nets has the potential to place some pressure on native riverine species, such as paddlefish, and should be monitored with caution.
- It is recommended that monitoring continue in 2019 with more focus on informing control and containment efforts in the Cannelton and McAlpine pools.

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Figures:

Figure 1. The Ohio River from the Cannelton to RC Byrd Pool with corresponding establishment statuses for Silver Carp populations, based on standard sampling and project data from the Ohio River basin.

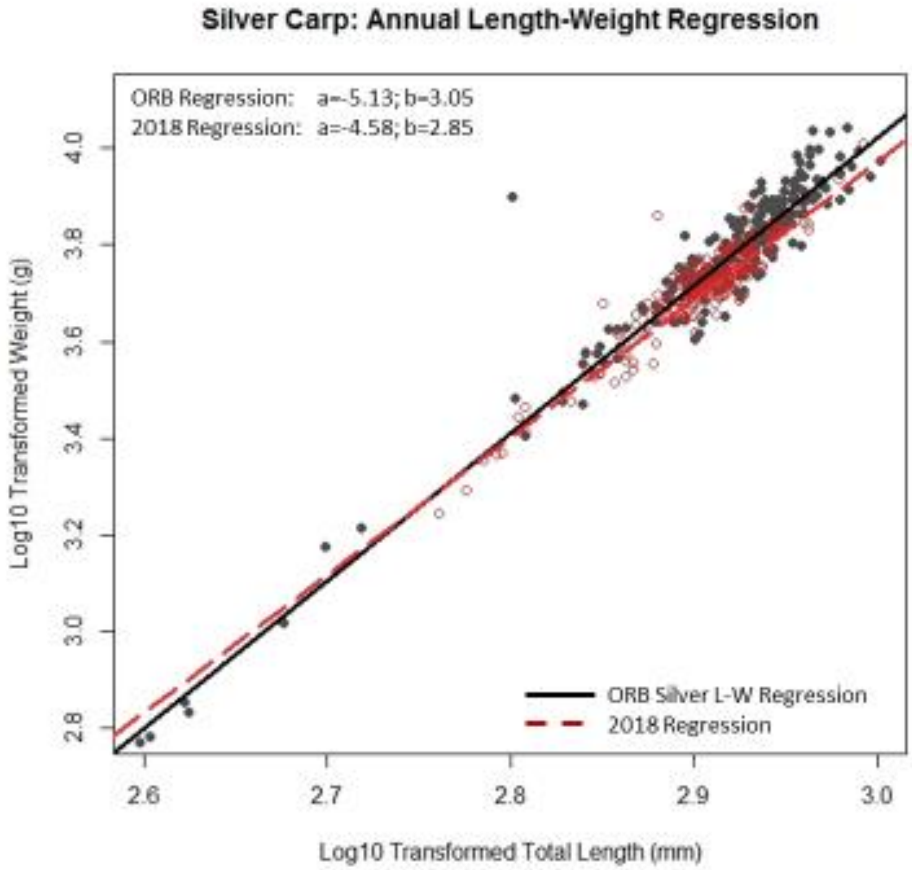

Figure 2. The log-transformed relationship between total length and weight for Silver Carp in the ORB. The black line and data points indicate the cumulative length-weight relationship developed for Silver Carp in the ORB in 2017 (Table 2), while the red line and data points indicate the new 2018 data. There was little change in the overlay of 2018 data points when compared to previous years and differences in the regression are likely an indication of a data gaps from the lack of fish < 400mm in 2018.

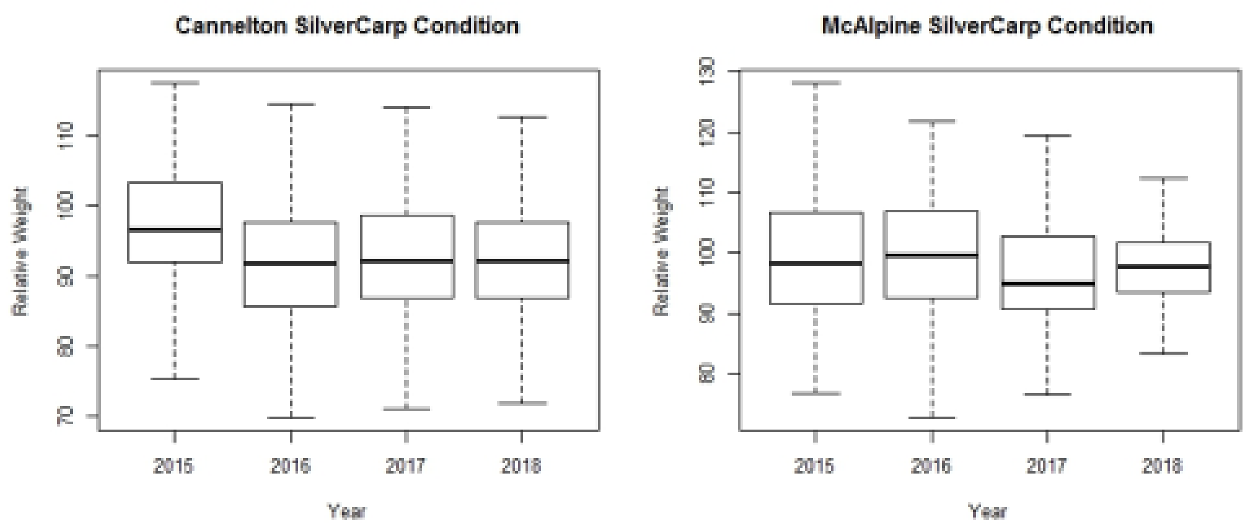

Figure 3. The relative weight (Wr) condition for Silver Carp captured in the Cannelton and McAlpine pools over the past four years. There appears to be little difference in body condition since 2016 across each pool, but fish in McAlpine appear to maintain slightly higher body condition than fish captured in the higher abundance Cannelton pool.

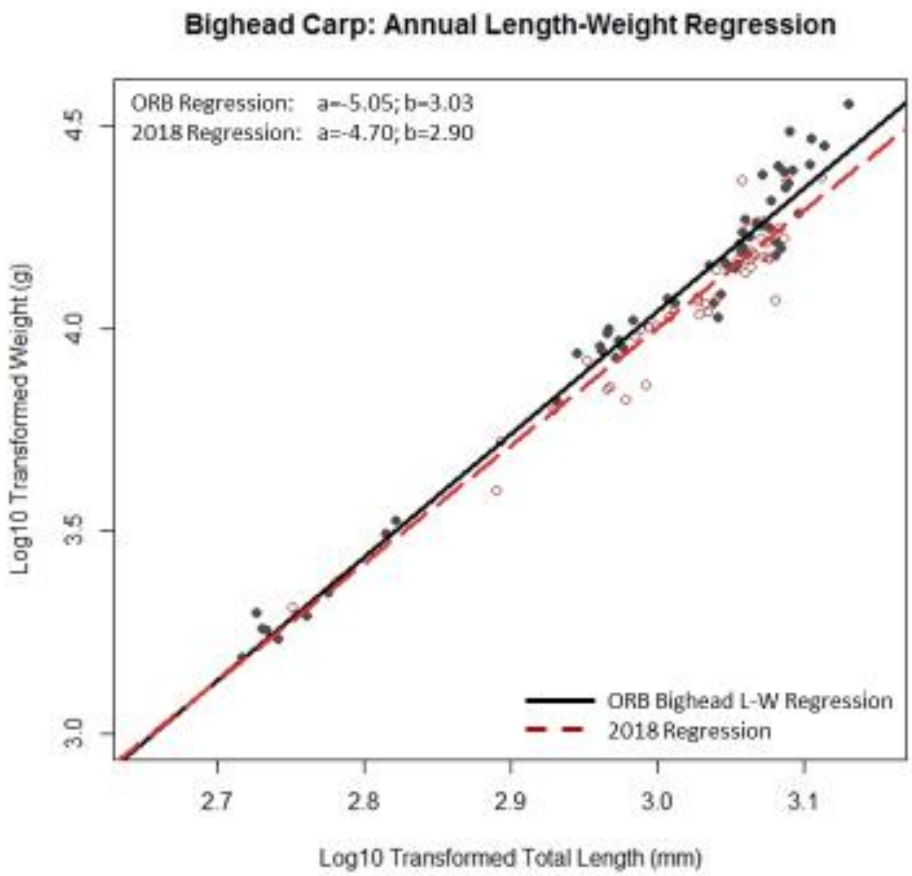

Figure 4. The log-transformed relationship between total length and weight for Bighead Carp in the ORB. The black line and data points indicate the cumulative length-weight relationship developed for Bighead Carp in the ORB in 2017 (Table 3), while the red line and data points indicate the new 2018 data. There was little change in the overlay of 2018 data points when compared to previous years.

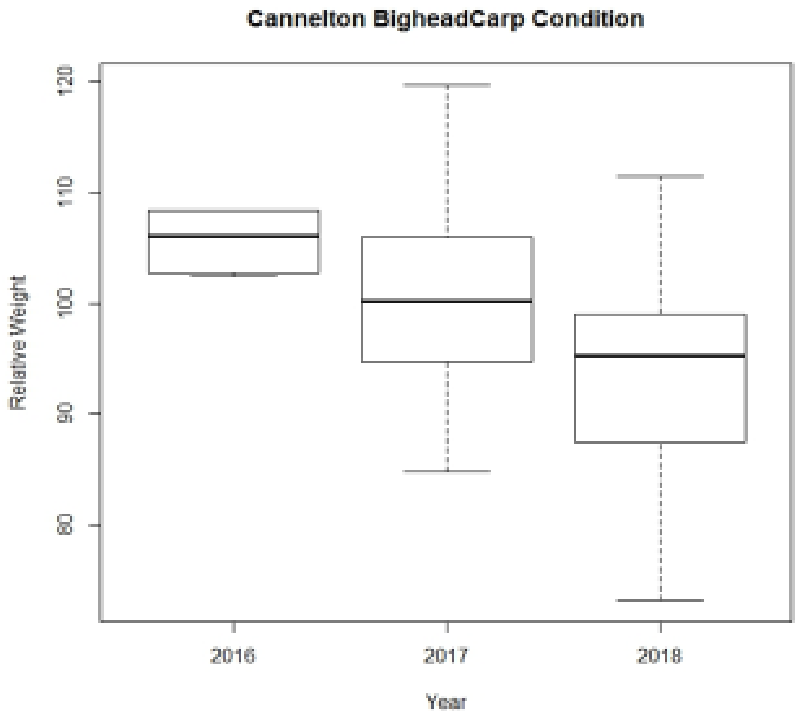

Figure 5. The relative weight (Wr) condition for Bighead Carp captured in the Cannelton pool over the past three years. There appears to be a decline in body condition since 2016.

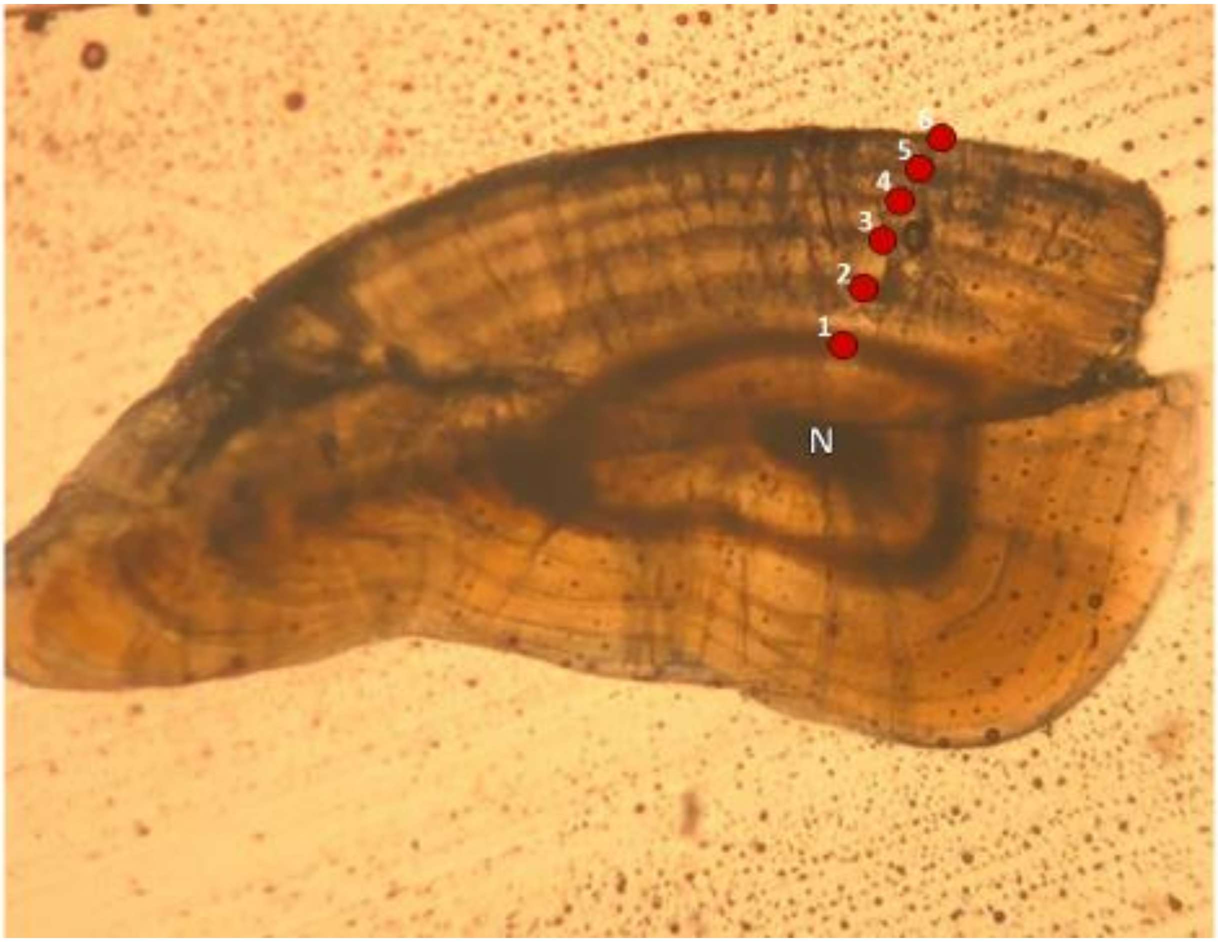

Figure 6. An example of the lapilliar otolith taken from a Silver Carp (age-6) used for age and growth estimation in the Cannelton pool.

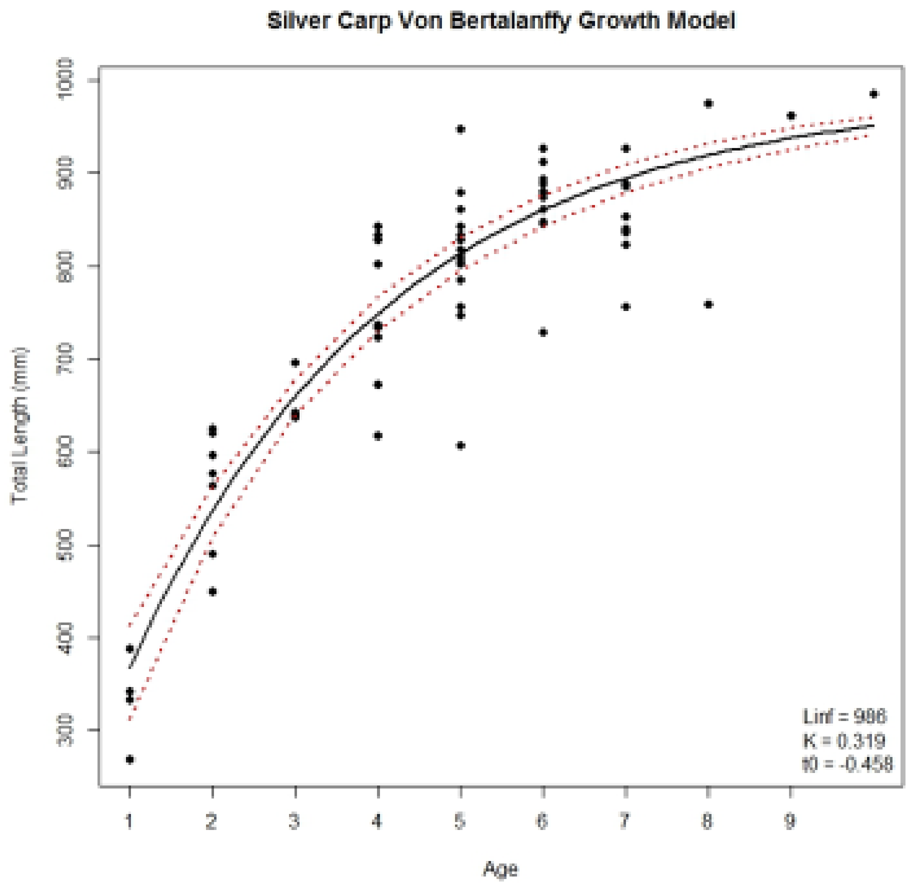

Figure 7. A von Bertalanffy growth curve estimating the age and growth of Silver Carp harvested from the Cannelton Pool in 2018. Age is in years and total length are in millimeters.

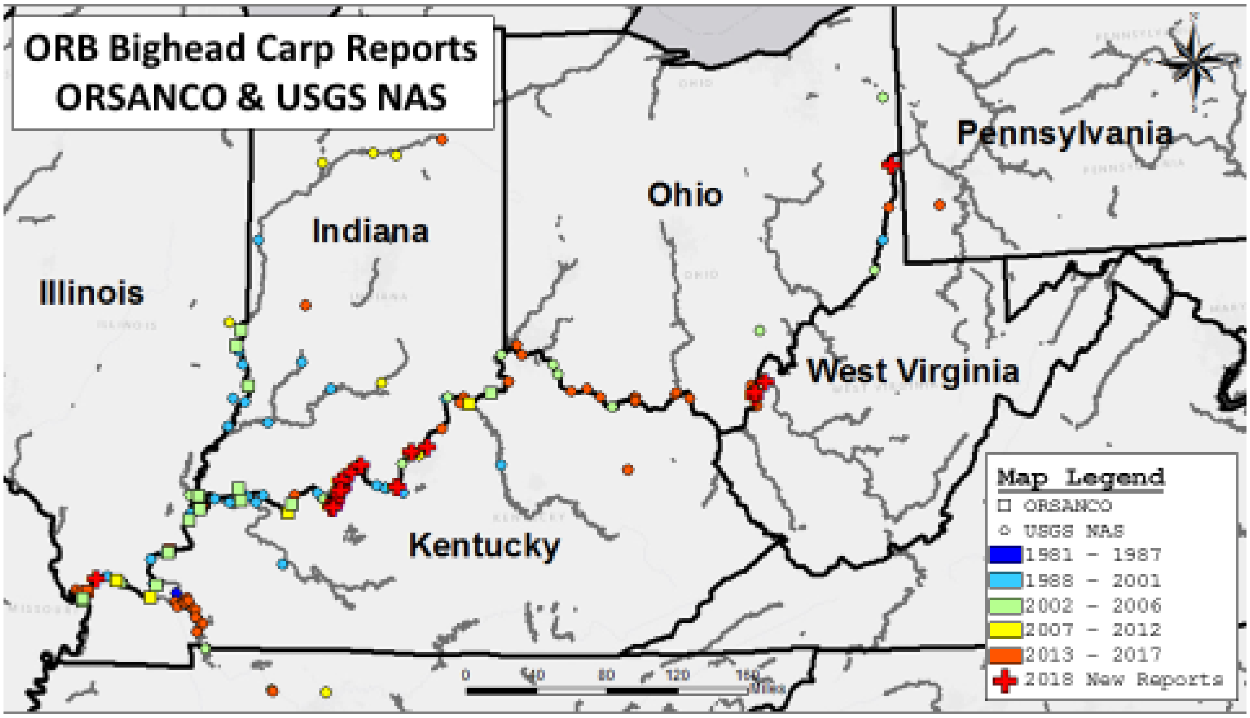

Figure 8. A map depicting the distribution of Bighead Carp throughout the ORB; records were compiled from both ORSANCO and the USGS NAS database and show the range of Bighead, which have been reported by basin states since 1981.

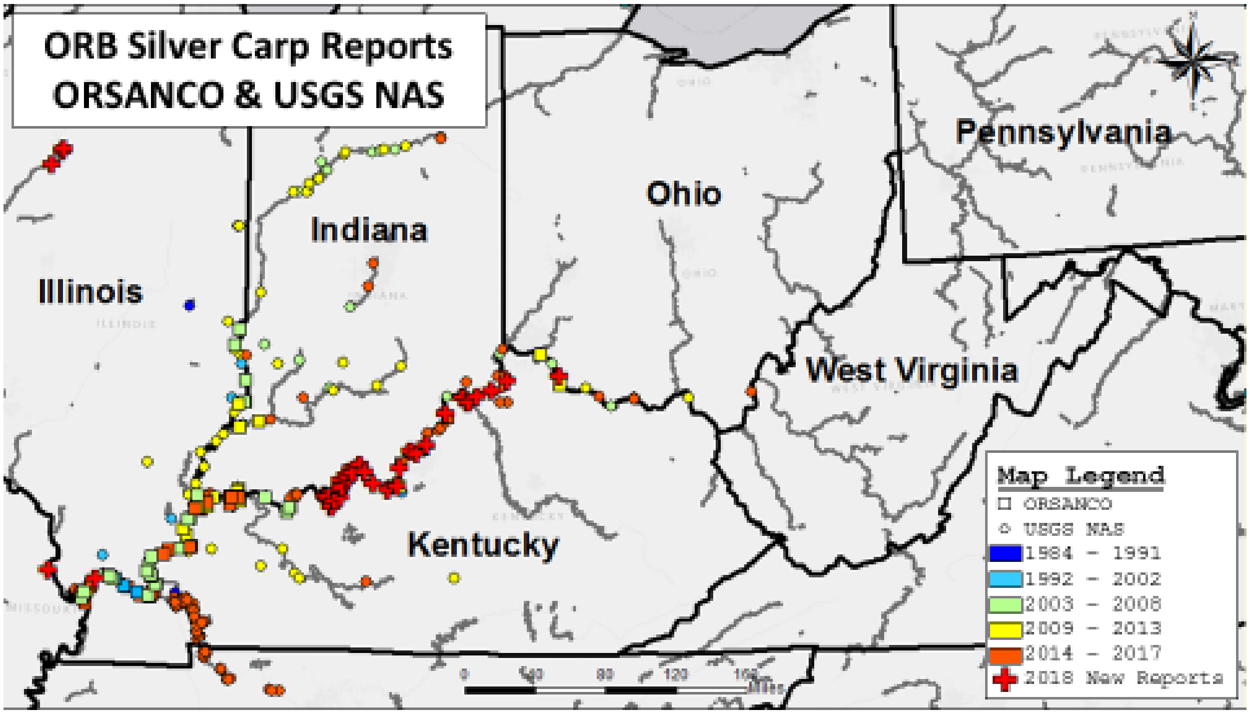

Figure 9. A map depicting the distribution of Silver Carp throughout the ORB; records were compiled from both ORSANCO and the USGS NAS database and show the range of Silver Carp, which have been reported by basin states since 1984.

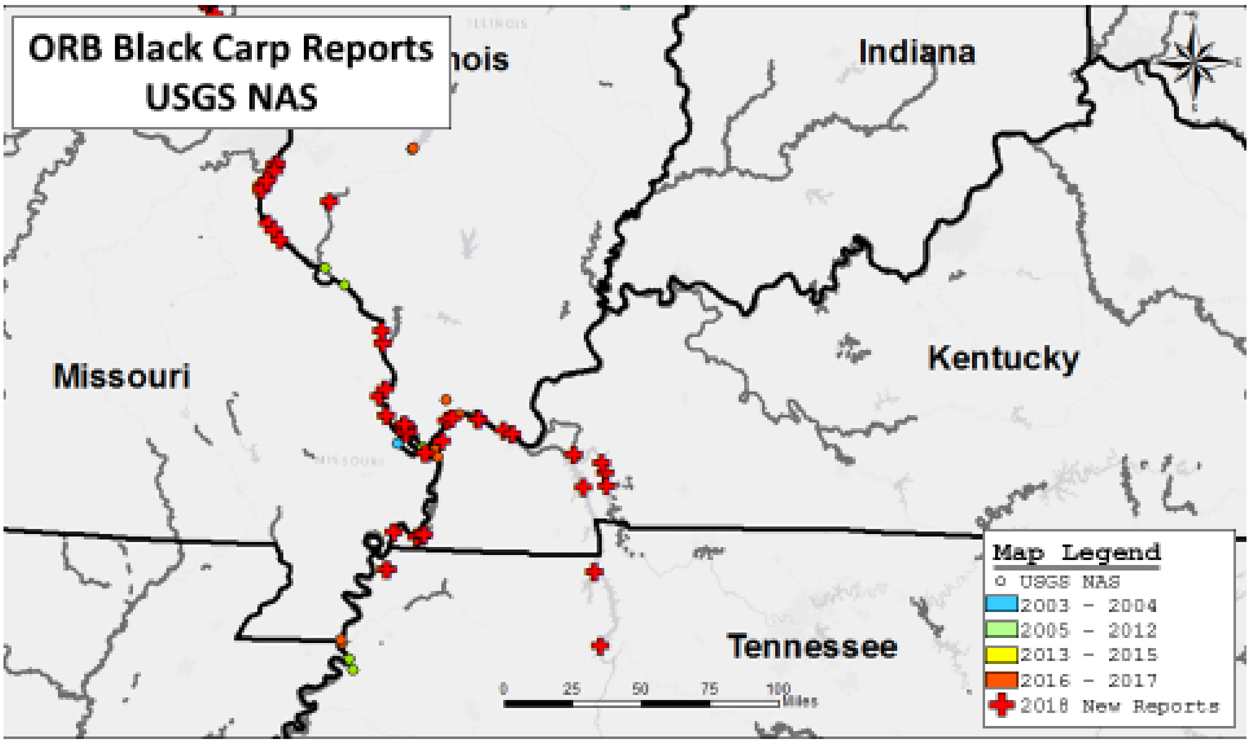

Figure 10. A map depicting the distribution of Black Carp throughout the ORB; records were compiled from both ORSANCO and the USGS NAS database and show the range of Black carp, which have been reported by basin states since 2003.

Figure 11. A map of the Silver Carp establishment ranges between Cannelton and RC Byrd pools and the average catch-rates of Silver Carp per pool during targeted sampling using boat electrofishing.

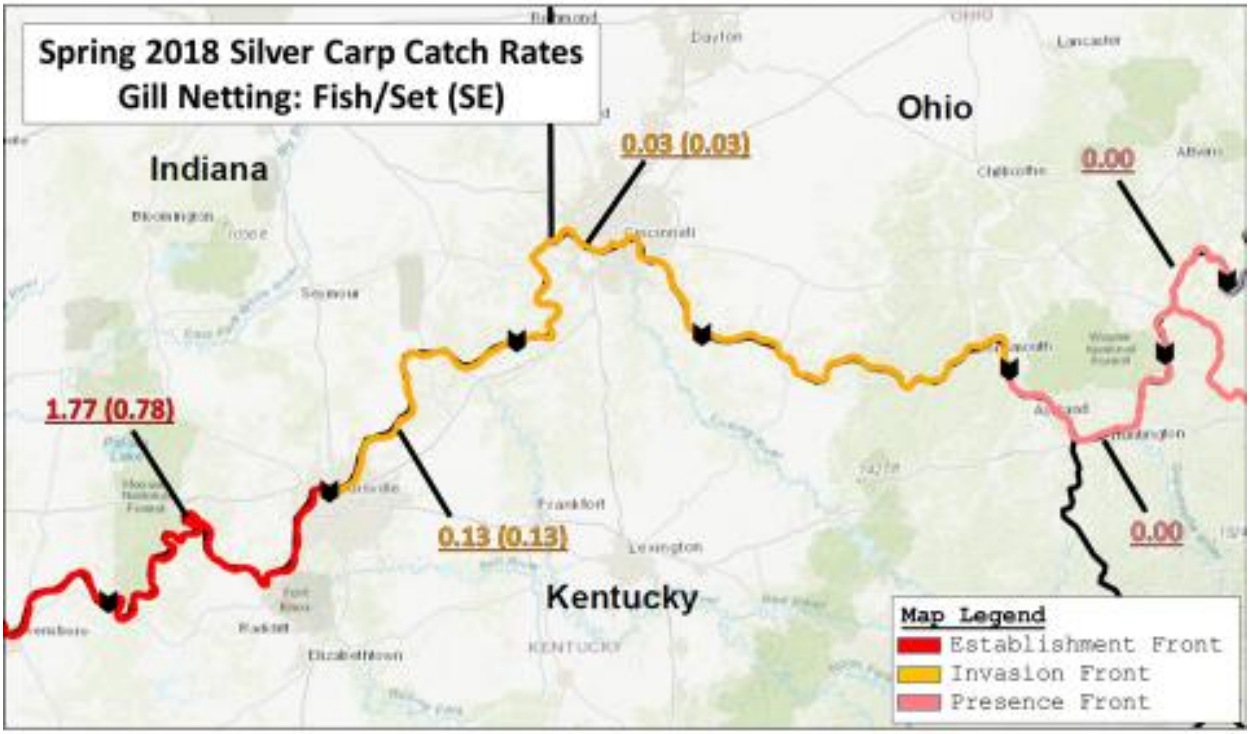

Figure 12. A map of the Silver Carp establishment ranges between Cannelton and RC Byrd pools and the average catch-rates of Silver Carp per pool during targeted sampling using gill netting.

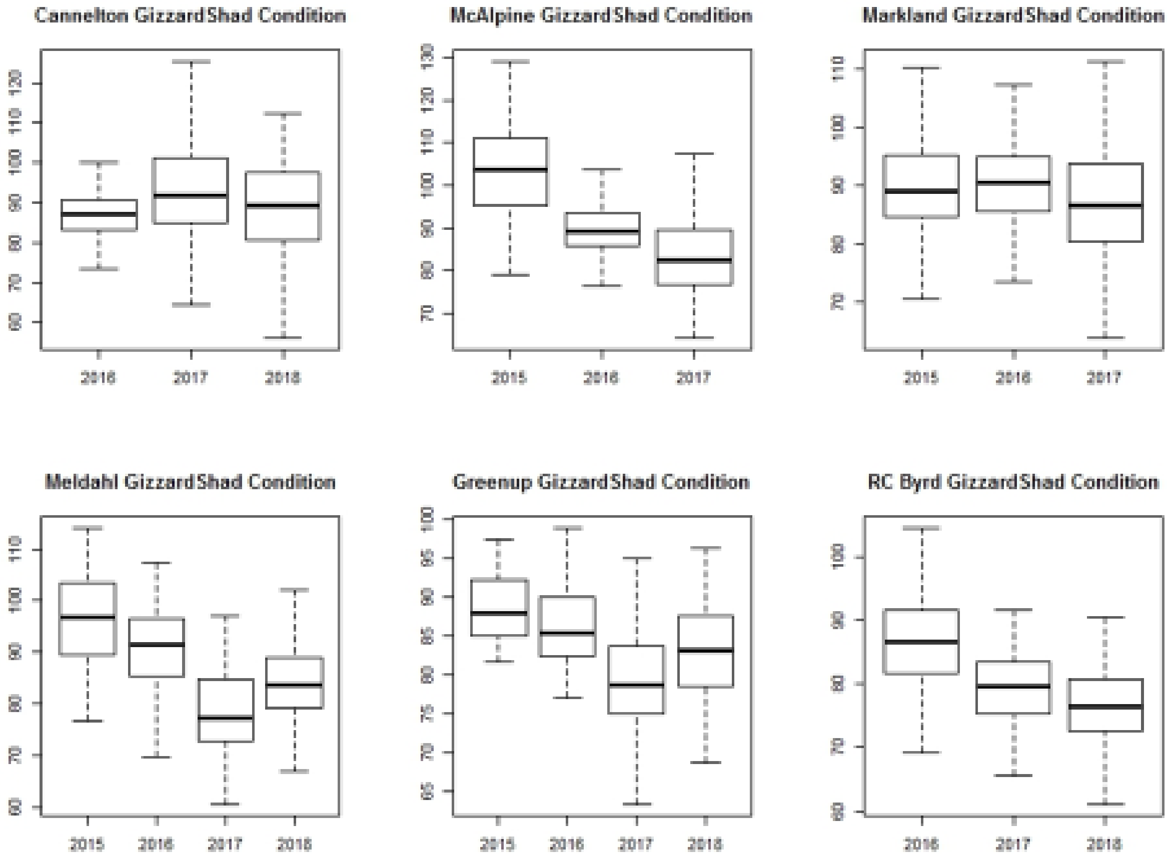

Figure 13. The body condition (Wr) of Gizzard Shad from six of the monitoring pools throughout the Ohio River since 2015.

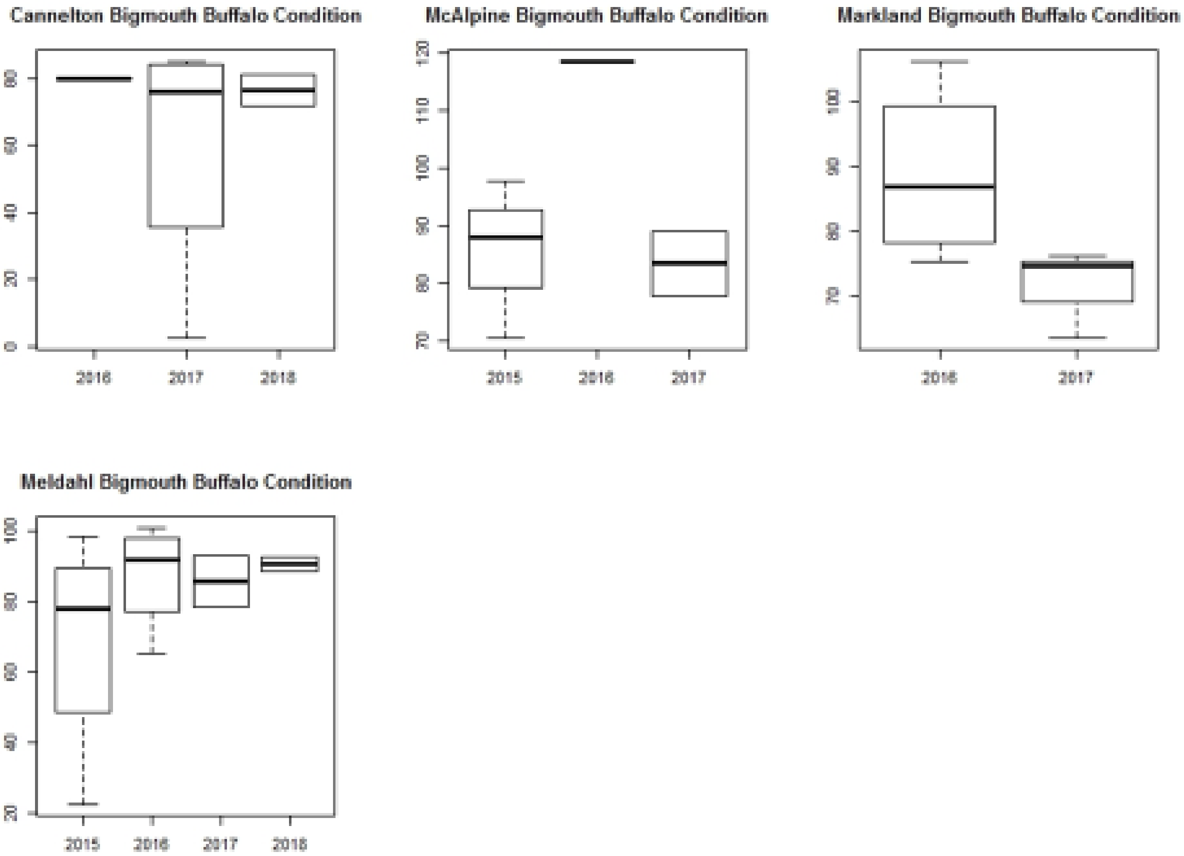

Figure 14. The body condition (Wr) of Bigmouth Buffalo from four of the monitoring pools throughout the Ohio River since 2015. Annually, catches for this species are sporadic and many pools do not have enough occurrences to allow for good trend data.

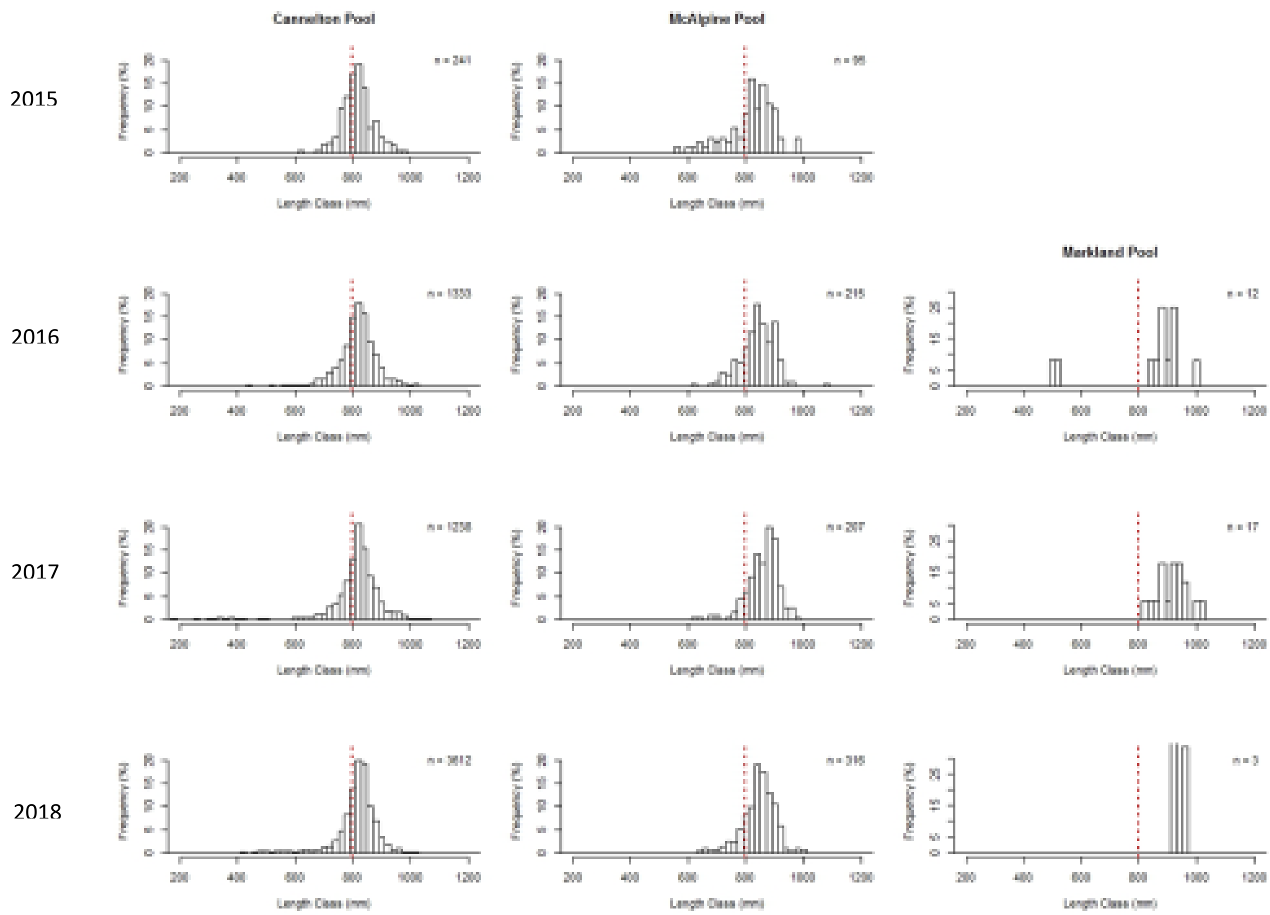

Figure 15. The frequency of total lengths for Silver Carp captured in Cannelton, McAlpine, and Markland pools since 2015. Patterns indicate larger fish occur with higher frequencies and lower numbers as you progress upriver.

Tables:

Table 1. Total number of fish captured and percent of total captured during annual beach seine surveys in the Greenup and RC Byrd pools in 2018.

Species	R.C. Byrd (1 Site)		Greenup (3 Sites)	
	N	% Catch	N	% Catch
Bluegill	70	4.73	272	7.14
Brook Silverside	2	0.14	8	0.21
Bluntnose Minnow	4	0.27	8	0.21
Bullhead Minnow	27	1.82	41	1.08
Channel Shiner	340	22.97	686	18.01
Eastern Mosquitofish	-	-	1	0.03
Emerald Shiner	1022	69.05	2705	71
Ghost Shiner	5	0.34	33	0.87
Johnny Darter	-	-	1	0.03
Largemouth Bass	1	0.07	-	-
Longear Sunfish	1	0.07	8	0.21
Northern Hogsucker	-	-	1	0.03
Orangespotted Sunfish	-	-	2	0.05
Redbreast Sunfish	1	0.07	-	-
River Shiner	-	-	29	0.76
Silver Chub	-	-	5	0.13
Silverjaw Minnow	-	-	1	0.03
Smallmouth Redhorse	-	-	3	0.08
Spotfin Shiner	5	0.34	6	0.16
Steelcolor Shiner	1	0.07	-	-
Warmouth	1	0.07	-	-
Total	1480		3810	

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	ORB Technical Report 2017
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	ORB Technical Report 2017
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. Midpoing latitude and longitude of hydroacoustics survey locations established in 2017 by pool of the Ohio River. The main channel was sampled 2 miles upstream and 2 miles downstream (4 miles total) and up to 2 miles were sampled in tributaries. Only sites listed in R.C. Byrd and Greenup pools were surveyed in 2018.

Pool	Site name	Latitude	Longitude
R.C. Byrd	Raccoon Creek / R.C. Byrd Lock and Dam	38° 42.600'N	82° 10.921'W
Greenup	Guyan Creek	38° 35.282'N	82° 12.936'W
Greenup	Guyandotte River	38° 26.024'N	82° 23.494'W
Greenup	Big Sandy River	38° 24.981'N	82° 35.709'W
Greenup	Little Sandy River	38° 34.887'N	82° 50.385'W
Meldahl	Scioto River	38° 43.822'N	83° 0.782'W
Meldahl	Ohio Brush Creek	38° 40.412'N	83° 27.233'W
Meldahl	Manchester Islands	38° 41.160'N	83° 34.811'W
Meldahl	Eagle Creek	38° 43.181'N	83° 50.435'W
Markland	Big Indian Creek	38° 53.540'N	84° 14.259'W
Markland	Licking River	39° 5.636'N	84° 30.289'W
Markland	Great Miami River	39° 6.419'N	84° 48.907'W
Markland	Craig's Creek	38° 46.414'N	84° 56.299'W
McAlpine	Kentucky River and Little Kentucky River	38° 41.159'N	85° 11.322'W
McAlpine	Patton's Creek and Barrow Pits	38° 31.320'N	85° 25.901'W
McAlpine	Harrod's Creek	38° 19.952'N	85° 38.823'W
Cannelton	McAlpine Tailwaters	38° 16.894'N	85° 48.048'W
Cannelton	Salt River	38° 0.279'N	85° 56.823'W
Cannelton	Clover Creek	37° 50.483'N	86° 37.950'W

Table 5. 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 2017 and 2018. Standard errors are in parentheses.

	Spring Boat Electrofishing													
	Ohio River 2017							**Ohio River 2018**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	10 April - 23 May							16 April - 15 May						
Effort (Hours)	4.25	3.90	5.00	5.00	2.00	0.00	20.15	5.00	3.75	2.50	0.00	4.50	3.85	19.60
Sample Transects	17	16	20	20	8	0	81	20	15	10	0	18	17	80
All Fish (N)	61	13	1	0	0	0	75	40	20	2	0	1	2	65
Species (N)	2	1	1	0	0	0	51	1	1	2	0	1	1	2
Bighead Carp (N)	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Silver Carp (N)	60	13	1	0	0	0	74	40	20	1	0	0	0	61
Grass Carp (N)	0	0	0	0	0	0	0	0	0	1	0	1	2	4
Bighead Carp CPUE	0.24 (0.24)	0.00	0.00	0.00	0.00	0.00	0.05 (0.05)	0.00	0.00	0.00		0.00	0.00	0.00
Silver Carp CPUE	14.12 (5.46)	3.52 (1.51)	0.20 (0.20)	0.00	0.00	0.00	3.71 (1.31)	8.00 (2.34)	5.33 (2.40)	0.40 (0.40)		0.00	0.00	3.05 (0.80)
Grass Carp CPUE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40 (0.40)		0.22 (0.22)	0.47 (0.47)	0.20 (0.12)

Table 6. 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 2017 and 2018. Standard errors are in parentheses.

	Spring Gill Netting													
	Ohio River 2017							**Ohio River 2018**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	04 April - 23 May							18 April - 29 May						
Effort (ft)	2400	1800	3900	3300	3050	4650	19100	3300	1200	4800	0	1500	0	10800
Net Sets	8	6	13	11	16	31	85	22	8	32	0	10	0	72
All Fish (N)	46	1	70	57	2	21	197	144	12	69	0	5	0	230
Species (N)	6	1	10	8	2	9	11	10	7	10	0	3	0	13
Bighead Carp (N)	6	0	2	1	0	1	10	5	0	0	0	0	0	5
Silver Carp (N)	27	0	4	0	0	0	31	39	1	1	0	0	0	41
Grass Carp (N)	0	1	13	1	1	1	17	0	1	5	0	0	0	6
Bighead Carp CPUE	0.75 (0.62)	0.00	0.15 (0.15)	0.00	0.00	0.03 (0.03)	0.10 (0.06)	0.23 (0.15)	0.00	0.00		0.00		0.07 (0.05)
Silver Carp CPUE	3.38 (1.58)	0.00	0.31 (0.17)	0.00	0.00	0.00	0.70 (0.34)	1.77 (0.78)	0.13 (0.13)	0.03 (0.03)		0.00		0.57 (0.25)
Grass Carp CPUE	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)	0.00	0.13 (0.13)	0.16 (0.07)		0.00		0.08 (0.03)

Table 7. A by-catch table showing the catch of non-target species through the use of gill netting during 2018 targeted monitoring. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

Spring Gill Netting					
	Ohio River Pools in 2018				
By-Catch	Cann	McAlp	Mark	Green	Total
Black Buffalo		1	1		2
Blue Catfish	12		2	2	16
Channel Catfish				2	2
Common Carp	1	2	17		20
Flathead Catfish	1		7		8
Freshwater Drum	5	1	1		7
Paddlefish	17		1		18
River Carpsucker	2		2		4
Smallmouth Buffalo	61	6	32		99
Striped Bass	1			1	2

Table 8. 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 2017 and 2018. Standard errors are in parentheses.

	Fall Electrofishing													
	Ohio River 2017							**Ohio River 2018**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	02 October - 28 November							15 October - 06 November						
Effort (Hours)	6.00	6.25	6.75	3.75	5.00	4.40	32.15	6.00	0.00	0.00	6.00	3.75	3.10	18.85
Sample Transects	24	25	27	15	20	19	130	24	0	0	24	15	13	76
All Fish (N)	686	1024	1614	1341	983	888	6536	1223	0	0	1241	1004	1708	5176
Species (N)	37	36	38	30	29	34	62	46	0	0	36	25	32	54
Bighead Carp (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver Carp (N)	5	1	0	0	0	0	6	33	0	0	0	0	0	33
Grass Carp (N)	0	0	0	0	0	0	0	2	0	0	0	0	0	2
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
Silver Carp CPUE	0.83 (0.34)	0.16 (0.16)	0.00	0.00	0.00	0.00	0.18 (0.07)	5.50 (2.39)			0.00	0.00	0.00	1.74 (0.80)
Grass Carp CPUE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33 (0.33)			0.00	0.00	0.00	0.11 (0.11)

Table 9. 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 2017 and 2018. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

	Ohio River Pools in 2017								**Ohio River Pools in 2018**							
Species Captured	Cann	McAlp	Mark	Meld	Green	RC Byrd	Total	Percent	Cann	McAlp	Mark	Meld	Green	RC Byrd	Total	Percent
Banded Sculpin							0	0.000%	2						2	0.039%
Bigmouth Buffalo	3	2	4	1			10	0.153%	2			2		1	5	0.097%
Black Buffalo		1	2				3	0.046%				1			1	0.019%
Black Crappie			1	2	5	3	11	0.168%				3	6	5	14	0.270%
Black Redhorse					1		1	0.015%							0	0.000%
Blue Catfish	3						3	0.046%	1				1		2	0.039%
Bluegill Sunfish	34	14	239	45	65	119	516	7.895%	114			117	34	71	336	6.491%
Bluntnose Minnow		3	1			2	6	0.092%	2						2	0.039%
Bowfin	1				11	1	13	0.199%				1	2		3	0.058%
Brook Silverside	1						1	0.015%	5			13			18	0.348%
Bullhead Minnow							0	0.000%	2						2	0.039%
Central Stoneroller					1		1	0.015%							0	0.000%
Channel Catfish	8	17	40	2	8	3	78	1.193%	41			19	3	3	66	1.275%
Common Carp	4	1	34	3	23	10	75	1.147%	9			20	5	5	39	0.753%
Emerald Shiner	90	146	59	595		19	909	13.908%	307			14	472	952	1745	33.713%
Flathead Catfish	2	1	2				5	0.076%				2			2	0.039%
Freckled Madtom							0		1						1	
Freshwater Drum	30	54	30	56	176	112	458	7.007%	74			24	46	68	212	4.096%
Gizzard Shad	322	442	685	470	251	200	2370	36.261%	253			522	160	408	1343	25.947%
Golden Redhorse	18	62	42	4	24	15	165	2.524%	15			14		6	35	0.676%
Goldfish			3				3	0.046%							0	0.000%
Grass Carp							0	0.000%	2						2	0.039%
Green Sunfish			2	1	5	14	22	0.337%	7			5		5	17	0.328%
Highfin Carpsucker		6	2	1	1		10	0.153%				4		1	5	0.097%
Largemouth Bass	22	10	70	30	38	21	191	2.922%	17			74	15	14	120	2.318%
Logperch	1	3	1		1		6	0.092%							0	0.000%
Longear Sunfish	9	5	25	2	2	2	45	0.688%	32			22	3	6	63	1.217%
Longnose Gar	14	27	18	1	20	5	85	1.300%	16			11	5	5	37	0.715%
Mimic Shiner							0	0.000%	8						8	0.155%
Minnow Family		6				4	10	0.153%							0	0.000%

Table 9 (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		4	1		1		6	0.092%	1				9		10	0.193%
Moxostoma Genus							0	0.000%	1						1	0.019%
Muskellunge		1		2			3	0.046%							0	0.000%
Northern Hogsucker	1	1			1	2	5	0.076%							0	0.000%
Orangespotted Sunfish			2	1		16	19	0.291%	11			1		3	15	0.290%
Quillback	2	8	2	4	4	7	27	0.413%	1			2	3	1	7	0.135%
Redear Sunfish	11		11	1	4	2	29	0.444%	23			2		2	27	0.522%
River Carpsucker	5	26	53	5	13	17	119	1.821%	14			68	6	22	110	2.125%
River Redhorse			2		2	6	10	0.153%	4					2	6	0.116%
River Shiner							0		1						1	
Rock Bass							0	0.000%				3			3	0.058%
Sand Shiner							0		1						1	
Sauger	3	6	5	5	34	13	66	1.010%	15			45	14	14	88	1.700%
Shortnose Gar							0		1						1	
Smallmouth Redhorse	6	13	2	1	9	13	44	0.673%	1			2	7	8	18	0.348%
Silver Carp	5	1					6	0.092%	33						33	0.638%
Silver Chub	1	15	6			1	23	0.352%	4			2			6	0.116%
Silver Redhorse				4	4	2	10	0.153%	2					1	3	0.058%
Skipjack Herring	5	25	16			2	48	0.734%	38			11	2	4	55	1.063%
Smallmouth Bass	4	10	8	1	15	11	49	0.750%	2			3	6	13	24	0.464%
Smallmouth Buffalo	51	71	130	61	193	189	695	10.633%	80			107	179	43	409	7.902%
Spotfin Shiner	2	1				1	4	0.061%							0	0.000%
Spotted Bass	10	27	25	10	25	15	112	1.714%	29			28	9	6	72	1.391%
Spotted Gar	1						1	0.015%	4			5			9	0.174%
Spotted Sucker	4	4	12	9	16	20	65	0.994%	3			9	2	13	27	0.522%
Striped Bass	1	5	18	3			27	0.413%	3			4			7	0.135%
Sunfish Family							0	0.000%							0	0.000%
Sunfish Hybrid	1				1	1	3	0.046%						1	1	0.019%
Threadfin Shad	1			1			2	0.031%							0	0.000%
Walleye					1	2	3	0.046%							0	0.000%
Warmouth			8	3	1		12	0.184%	8			7		1	16	0.309%
Hybrid Striped Bass	3		4		12	21	40	0.612%	19				10	9	38	0.734%

Table 9 (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 Bass	4	5	20		10	14	53	0.811%	1			9	3	11	24	0.464%
White Crappie	3		29	17	5	3	57	0.872%	13			65	2	4	84	1.623%
White Sucker		1					1	0.015%							0	0.000%
Yellow Bass							0	0.000%							0	0.000%
Totals	686	1024	1614	1341	983	888	6536		1223	0	0	1241	1004	1708	5176	

Table 10. 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 2017 and 2018. Standard errors are in parentheses.

	Fall Gill Netting													
	Ohio River 2017							**Ohio River 2018**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	02 October - 28 November							05 October - 20 November						
Effort (ft)	4650	2770	3450	1500	5850	0	18220	4800	0	0	4500	0	3000	12300
Net Sets	31	10	23	10	20	0	94	32	0	0	30	0	20	82
All Fish (N)	60	4	7	35	5	0	111	116	0	0	32	0	4	152
Species (N)	11	3	4	4	4	0	12	8	0	0	4	0	4	10
Bighead Carp (N)	9	0	0	0	0	0	9	1	0	0	0	0	1	2
Silver Carp (N)	24	0	2	0	0	0	26	103	0	0	0	0	0	103
Grass Carp (N)	1	0	0	0	0	0	1	1	0	0	0	0	0	1
Bighead Carp CPUE	0.29 (0.16)	0.00	0.00	0.00	0.00	0.00	0.10 (0.53)	0.03 (0.03)	0.00	0.00	0.00	0.00	0.05 (0.05)	0.02 (0.02)
Silver Carp CPUE	0.77 (0.43)	0.00	0.09 (0.06)	0.00	0.00	0.00	0.28 (1.40)	3.22 (1.45)	0.00	0.00	0.00	0.00	0.00	1.26 (0.59)
Grass Carp CPUE	0.03 (0.03)	0.00	0.00	0.00	0.00	0.00	0.01 (0.01)	0.03 (0.03)	0.00	0.00	0.00	0.00	0.00	0.01 (0.01)

Table 11. 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 2017 and 2018. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

	2017 Fall Monitoring Gill Netting								**2018 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	9						9	8.108%	1					1	2	1.316%
Bigmouth Buffalo	1			1			2	1.802%							0	0.000%
Black Buffalo	2						2	1.802%							0	0.000%
Blue Catfish	2	1					3	2.703%	2					1	3	1.974%
Channel Catfish					1		1	0.901%							0	0.000%
Common Carp	2			7			9	8.108%				2			2	1.316%
FlatheadCatfish			1		1		2	1.802%						1	1	0.658%
FreshwaterDrum	1			2			3	2.703%	1			1			2	1.316%
Grass Carp	1						1	0.901%	1						1	0.658%
Longnose Gar	3	1					4	3.604%	2			4			6	3.947%
Paddlefish	4		1		1		6	5.405%	4						4	2.632%
Silver Carp	24		2				26	23.423%	103						103	67.763%
Smallmouth Buffalo	11	2	3	25	2		43	38.739%	2			25		1	28	18.421%
Totals	60	4	7	35	5	0	111		116	0	0	32	0	4	152	

Table 12. Average length at age for Silver Carp captured in 2017 and 2018 and predicted length at age based on the von Bertalanffy growth model reported herein.

Age	n	Mean Length (mm)	Std Deviation (mm)	Predicted Length* (mm)
1	4	333	+/- 49	367
2	7	560	+/- 66	536
3	4	654	+/- 28	659
4	11	767	+/- 76	748
5	17	814	+/- 72	813
6	12	866	+/- 50	860
7	9	850	+/- 48	895
8	2	867	+/- 153	920
9	1	963		938
10	1	986		950

* Predictions are based on von Bertalanffy growth model derived using data from fish aged in 2017 and 2018.

Table 13. Total number of fish captured per pool and percent of total captured at three pools combined in the Ohio River during spring night electrofishing surveys in 2018.

	Ohio River Pools in 2018				
Species Captured	New Cumb.	Mont. Island	Dashields	Total	Percent
Black Buffalo	0	0	1	1	0.04%
Black Crappie	5	2	1	8	0.32%
Black Redhorse	70	20	4	94	3.74%
Bluegill	11	10	2	23	0.92%
Bluntnose Minnow	0	2	2	4	0.16%
Channel Catfish	8	10	10	28	1.11%
Channel Darter	1	0	0	1	0.04%
Channel Shiner	211	244	56	511	20.34%
Common Carp	3	6	16	25	1.00%
Emerald Shiner	70	45	224	339	13.50%
Flathead Catfish	2	4	1	7	0.28%
Freshwater Drum	21	22	23	66	2.63%
Gizzard Shad	83	18	2	103	4.10%
Golden Redhorse	63	29	6	98	3.90%
Largemouth Bass	6	0	0	6	0.24%
Logperch	9	6	13	28	1.11%
Longhead Darter	0	1	2	3	0.12%
Longnose Gar	61	47	6	114	4.54%
Mimic Shiner	51	228	25	304	12.10%
Mottled Sculpin	0	1	0	1	0.04%
Northern Hog Sucker	1	1	0	2	0.08%
Pumpkinseed	0	1	0	1	0.04%
Quillback	3	3	7	13	0.52%
River Carpsucker	8	9	34	51	2.03%
River Redhorse	5	6	1	12	0.48%
Rock Bass	6	27	14	47	1.87%
Sauger	47	56	14	117	4.66%
Silver Redhorse	21	14	20	55	2.19%
Smallmouth Bass	33	86	30	149	5.93%
Smallmouth Buffalo	41	51	72	164	6.53%
Smallmouth Redhorse	24	13	2	39	1.55%
Spotfin Shiner	3	15	4	22	0.88%
Striped Bass - Hybrid	0	3	0	3	0.12%
Walleye	22	35	7	64	2.55%
White Bass	1	2	4	7	0.28%
White Crappie	0	1	1	2	0.08%
Totals	890	1018	604	2512	

Table 14. Total number of fish captured and percent of total captured during annual beach seine surveys in the Montgomery Island Pool from 2017 and 2018.

Species Captured	2017	Percent Abundance	2018	Percent Abundance
Bigeye Chub	17	1.33%	23	0.35%
Blacknose Dace	0	0.00%	4	0.06%
Blackside Darter	0	0.00%	1	0.02%
Black Redhorse	7	0.55%	0	0.00%
Bluegill	33	2.57%	77	1.16%
Bluntnose Minnow	146	11.39%	633	9.50%
Brook Silverside	28	2.18%	9	0.14%
Central Stoneroller	12	0.94%	16	0.24%
Channel Darter	0	0.00%	2	0.03%
Channel Shiner	44	3.43%	2716	40.76%
Eastern Sand Darter	0	0.00%	1	0.02%
Emerald Shiner	515	40.17%	2288	34.33%
Gizzard Shad	22	1.72%	119	1.79%
Golden Shiner	0	0.00%	1	0.02%
Golden Redhorse	6	0.47%	0	0.00%
Green Sunfish	0	0.00%	1	0.02%
Greenside Darter	0	0.00%	1	0.02%
Johnny Darter	0	0.00%	1	0.02%
Largemouth Bass	1	0.08%	0	0.00%
Logperch	9	0.70%	3	0.05%
Longnose Gar	1	0.08%	0	0.00%
Mimic Shiner	139	10.84%	110	1.65%
Northern Hog Sucker	4	0.31%	27	0.41%
Quillback	1	0.08%	2	0.03%
Rainbow Darter	0	0.00%	8	0.12%
River Carpsucker	0	0.00%	3	0.05%
Rock Bass	5	0.39%	0	0.00%
Sand Shiner	15	1.17%	195	2.93%
Silver Shiner	6	0.47%	88	1.32%
Smallmouth Bass	8	0.62%	4	0.06%
Smallmouth Buffalo	0	0.00%	5	0.08%
Spotfin Shiner	259	20.20%	326	4.89%
Spotted Bass	4	0.31%	0	0.00%
Totals	1282		6664	

Table 15. Total number of fish captured and percent of total captured during annual beach seine surveys in the Greenup and RC Byrd pools in 2018.

Species	R.C. Byrd (1 Site)		Greenup (3 Sites)	
	N	% Catch	N	% Catch
Bluegill	70	4.73	272	7.14
Brook Silverside	2	0.14	8	0.21
Bluntnose Minnow	4	0.27	8	0.21
Bullhead Minnow	27	1.82	41	1.08
Channel Shiner	340	22.97	686	18.01
Eastern Mosquitofish	-	-	1	0.03
Emerald Shiner	1022	69.05	2705	71
Ghost Shiner	5	0.34	33	0.87
Johnny Darter	-	-	1	0.03
Largemouth Bass	1	0.07	-	-
Longear Sunfish	1	0.07	8	0.21
Northern Hogsucker	-	-	1	0.03
Orangespotted Sunfish	-	-	2	0.05
Redbreast Sunfish	1	0.07	-	-
River Shiner	-	-	29	0.76
Silver Chub	-	-	5	0.13
Silverjaw Minnow	-	-	1	0.03
Smallmouth Redhorse	-	-	3	0.08
Spotfin Shiner	5	0.34	6	0.16
Steelcolor Shiner	1	0.07	-	-
Warmouth	1	0.07	-	-
Total	1480		3810	

Table 16. A summation of sampling efforts by agencies participating in monitoring efforts for 2018.

Partner Group	Electrofishing (hrs)	Gill Netting (ft)	Hoop Netting (Net-nights)	Beach Seine (Events)	Hydroacoustic Detection (hrs)
INDNR	9.75	5,400	0	0	0
KDFWR	14.75	13,200	0	0	0
PFBC	14.76	900	48	6	0
USFWS	0.00	0	0	0	
WVDNR	13.75	4,500	0	0	0
Total	53.01	24,000	48	6	0