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.

<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>Macrohabitat</u> – One of five habitat types used to categorize fixed sites within a pool (e.g. Tributary, Tailwater, Embayment, Island Back-Channel, Main Stem River).
<u>Presence Front</u> – The farthest upstream extent where Asian carp populations occur, but reproduction is not likely.
<u>Targeted Sampling</u> – 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 ($y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \varepsilon$), 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 $\log_{10}[Weight_g] = -5.05 + 3.03 * \log_{10}[Length_{mm}]$ (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 $\log_{10}[Weight_g] = -5.13 + 3.05 * \log_{10}[Length_{mm}]$ (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.

Literature Cited

Beamish, R. J. 1981. Use of Fin-Ray Sections to Age Walleye Pollock, Pacific Cod, and Albacore, and the Importance of this Method. Transactions of the American Fisheries Society 110(2):287–299.

Etnier, D. A., and W. C. Starnes. 2001. The Fishes of Tennessee. University of Tennessee Press, Knoxville.

Foote, K.G., H.P. Knudsen, G. Vestnes, D.N. MacLennan, and E.J. Simmonds. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report 144:1-57.

Gutreuter, S., R. Burkhardt, K. Lubinski. 1995. Long term resource monitoring program procedures: fish monitoring. Report. National Biological Service Environmental Management Technical Center. Onalaska, Wisconsin.

Jelks, H. L., S. J. Walsh, N. M. Burkhead, S. Contreras-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N. E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. J. Schmitter-Soto, E. B. Taylor, and M. L. Warren. 2008. Conservation Status of Imperiled North American Freshwater and Diadromous Fishes. Fisheries 33(8):372–407.

Kolar, C. S., D. C. Chapman, W. R. Courtenay Jr., C. M. Housel, J. D. Williams, and D. P. Jennings. 2005. Asian carps of the genus Hypophthalmichthys (Pisces, Cyprinidae) -- A biological synopsis and environmental risk assessment. Page Report to U.S. Fish and Wildlife Service. Washington, D.C.

Love, R.H. 1971. Measurements of fish target strength: a review. Fisheries Bulletin 69: 703-715.

Lovell, S. J., and S. F. Stone. 2005. The Economic Impacts of Aquatic Invasive Species : A Review of the Literature. Page NCEE Working Paper Series.

MacNamara, R., D. Glover, J. Garvey, W. Bouska, and K. Irons. 2016. Bigheaded carps (Hypophthalmichthys spp.) at the edge of their invaded range: using hydroacoustics to assess population parameters and the efficacy of harvest as a control strategy in a large North American river. Biological Invasions 18: 3293-3307.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52(3 SPEC. ISS.):273–288.

R Core Team. 2016. R: A Language and Environment for Statistical Computing. Vienna, Austria.

Schrank, S. J., and C. S. Guy. 2002. Age, growth, and gonadal characteristics of adult Bighead Carp, Hypophthalmichthys nobilis, in the lower Missouri River. Environmental Biology of Fishes 64:443–450.

Seibert, J. R., and Q. E. Phelps. 2013. Evaluation of Aging Structures for Silver Carp from Midwestern U.S. Rivers. North American Journal of Fisheries Management 33(4):839–844.

Thomas, J. A., E. B. Emery, and F. H. McCormick. 2004. Detection of Temporal Trends in Ohio River Fish Assemblages Based on Lockchamber Surveys.

Williamson, C. J., and J. E. Garvey. 2005. Growth, Fecundity, and Diets of Newly Established Silver Carp in the Middle Mississippi River. Transactions of the American Fisheries Society 134(6):1423–1430.

Figures:

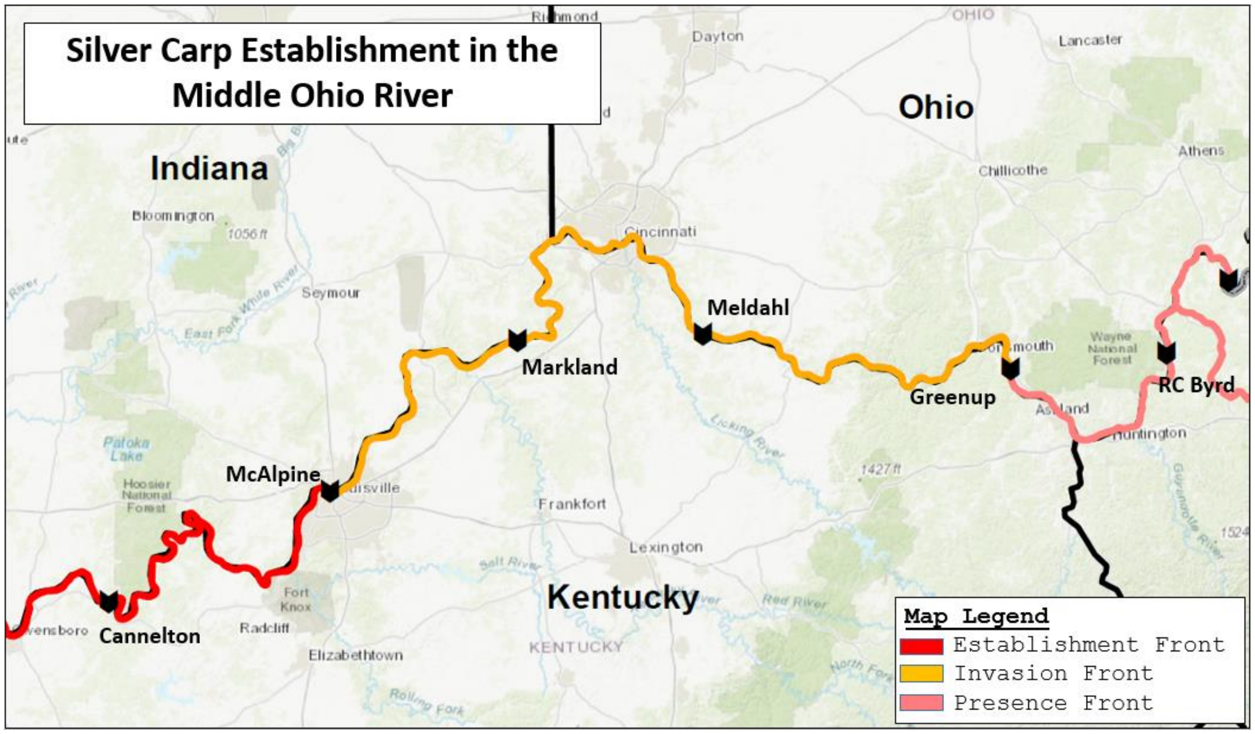

Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

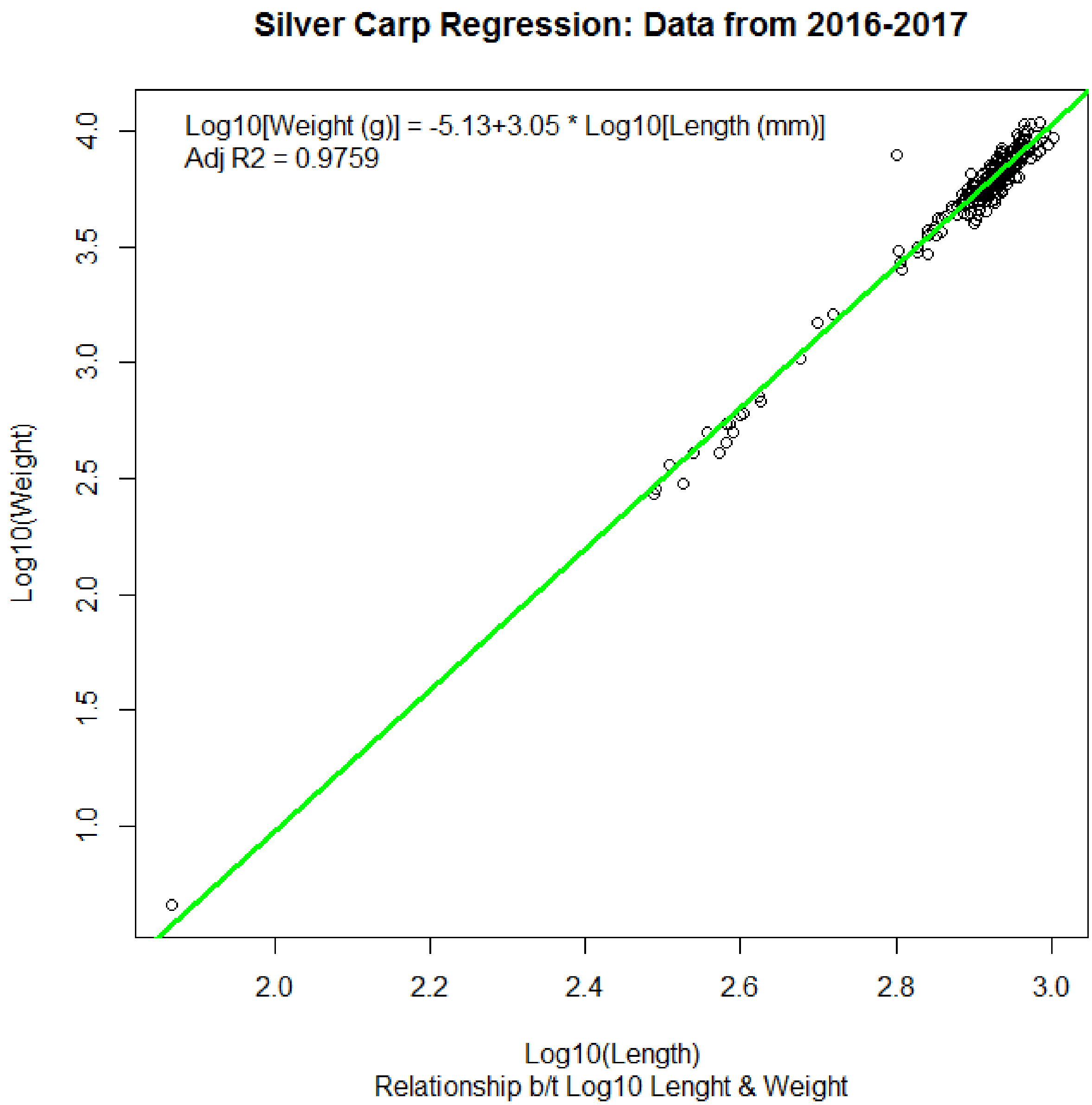

Figure 2. A scatterplot of $\log_{10}$-transformed lengths (mm) and weights (g) from *H. molitrix* captured from August through December in 2016 and 2017 with a regression line describing the relationship between lengths and weights in the ORB (n = 336).

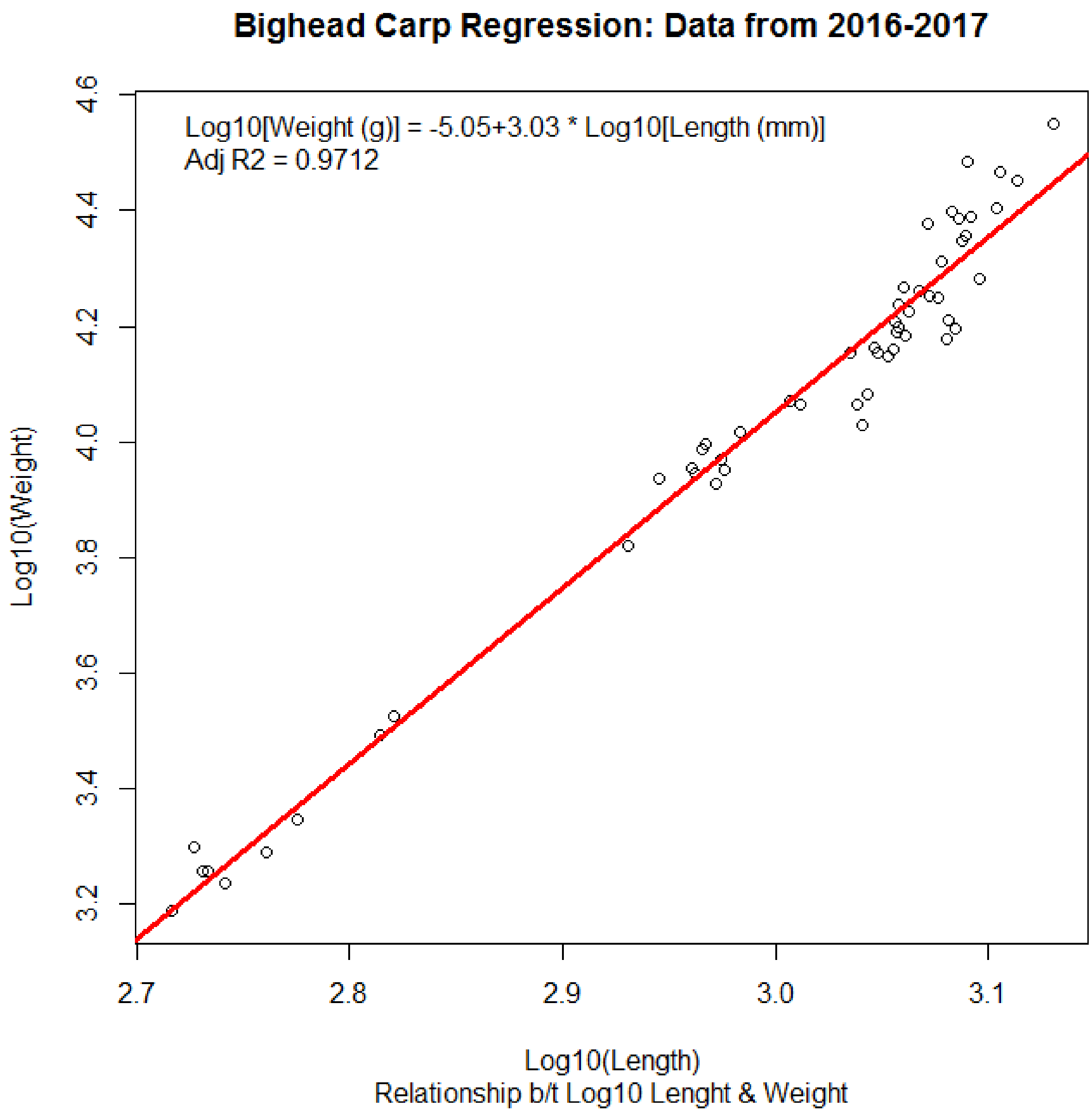

Figure 3. A scatterplot of log_{10}-transformed lengths (mm) and weights (g) from all *H. nobilis* captured from August through December in 2016 and 2017 with a regression line describing the relationship between lengths and weights in the ORB (n = 55).

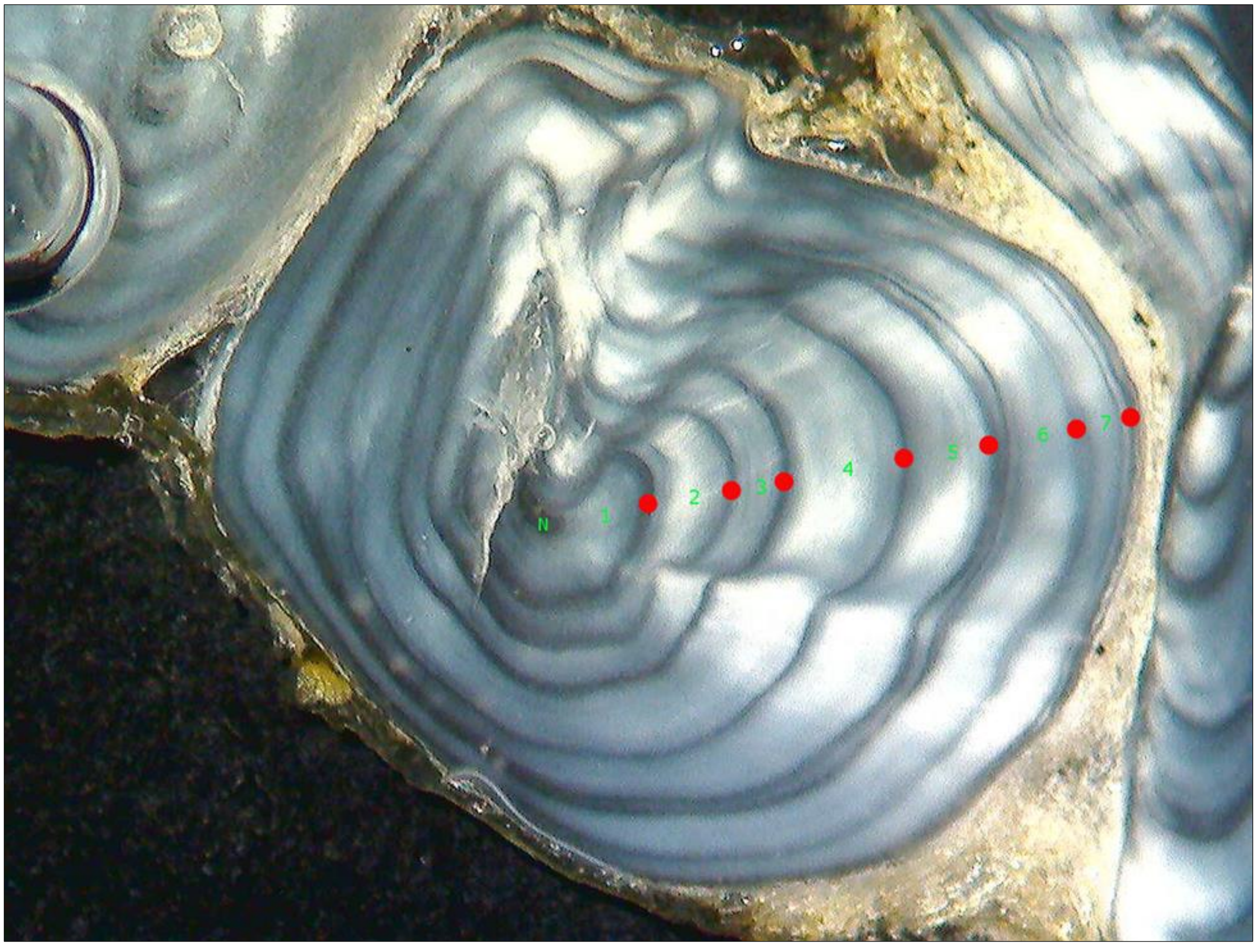

Figure 4. An image of a spine cross-section collected from a 7-year-old silver carp in the Cannelton pool, captured in May 2016.

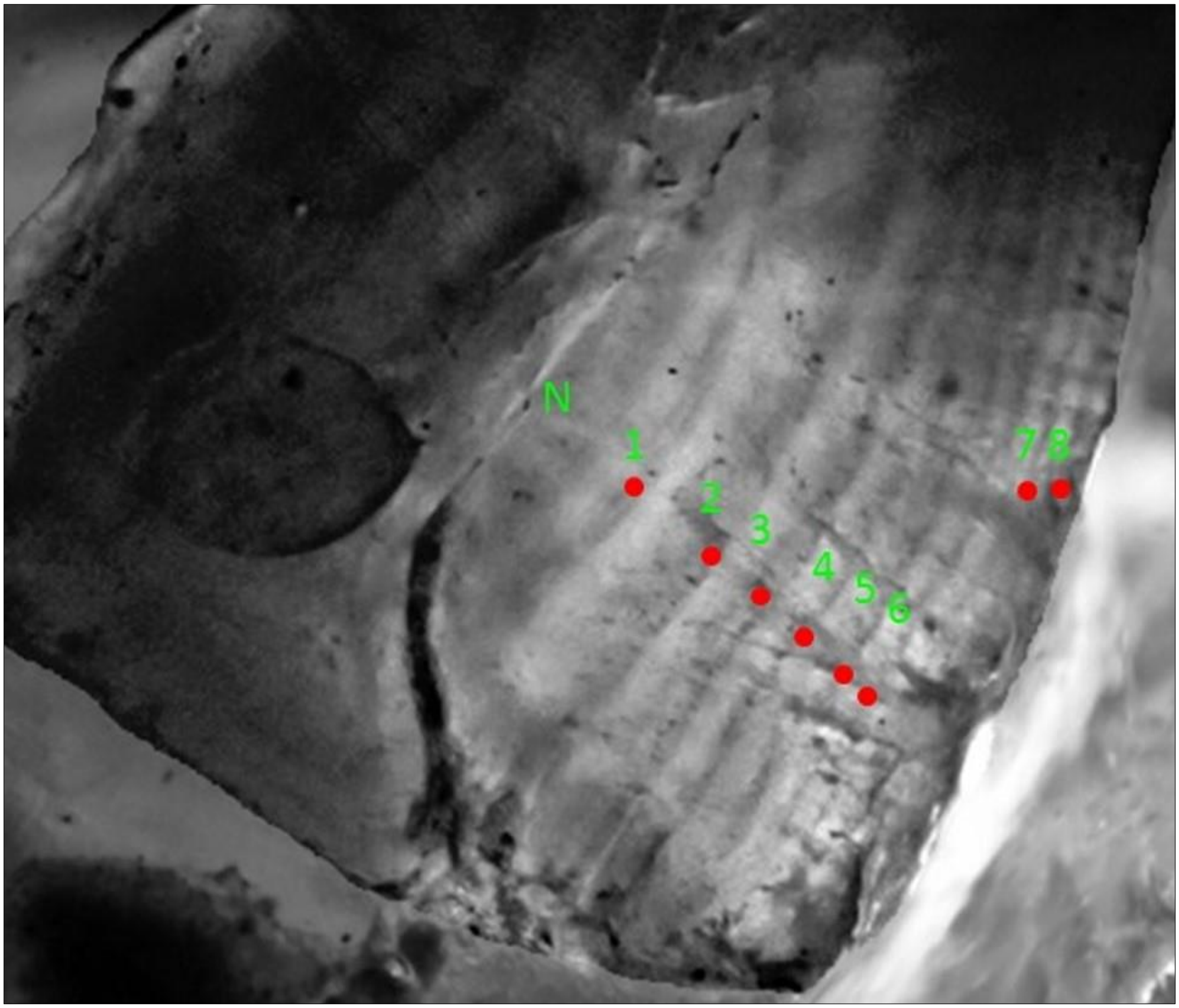

Figure 5. An image of a silver carp otolith collected from an 8-year-old fish, captured in the McAlpine pool in July 2013.

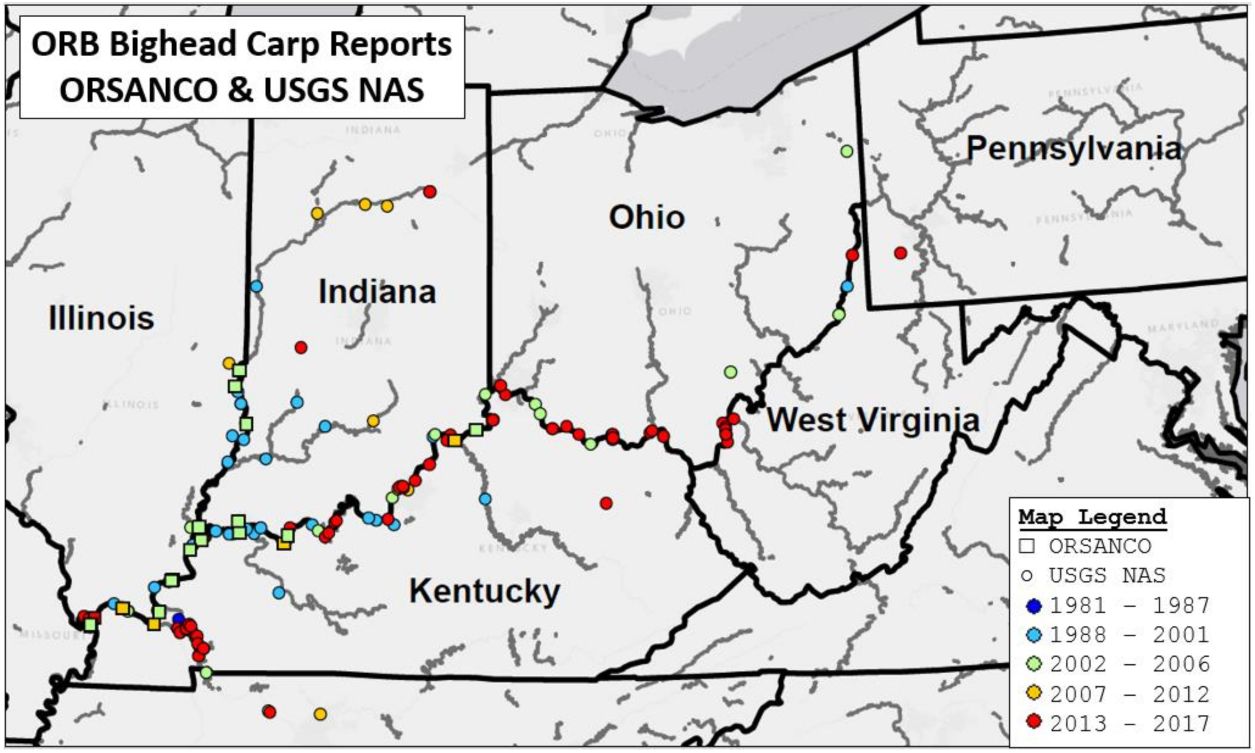

Figure 6. A range map of bighead carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

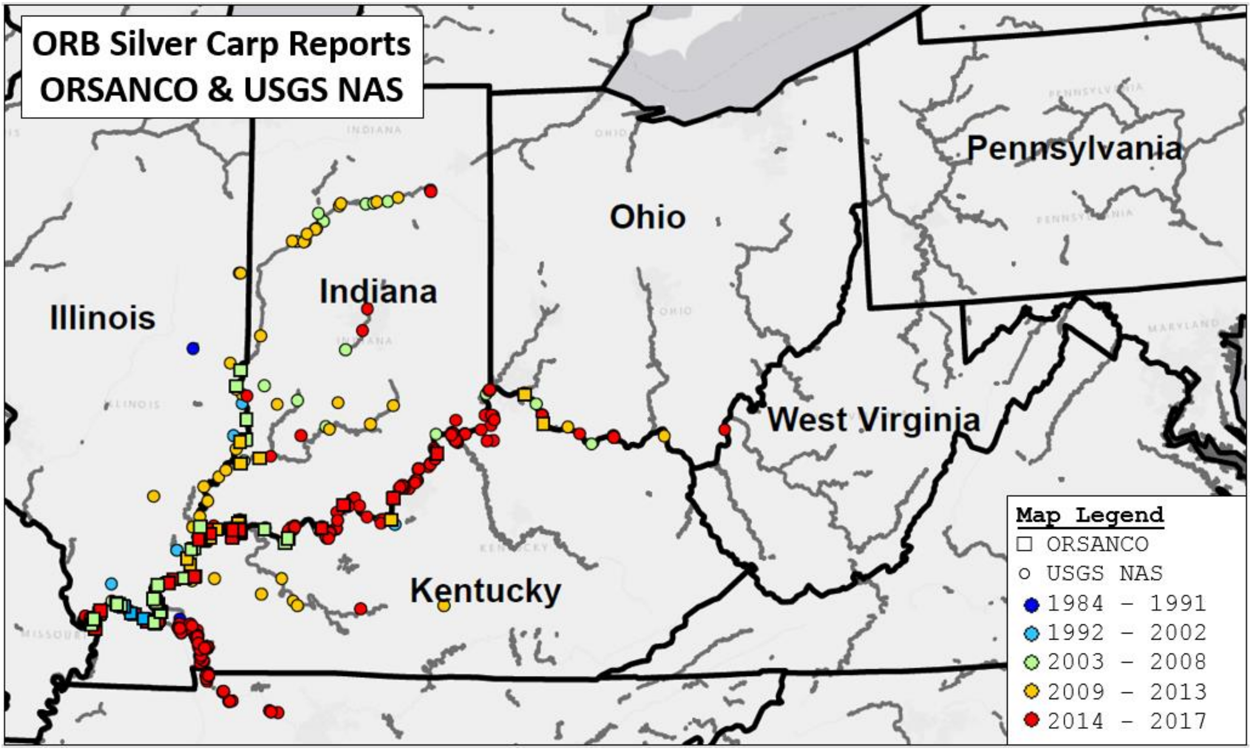

Figure 7. A range map of silver carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

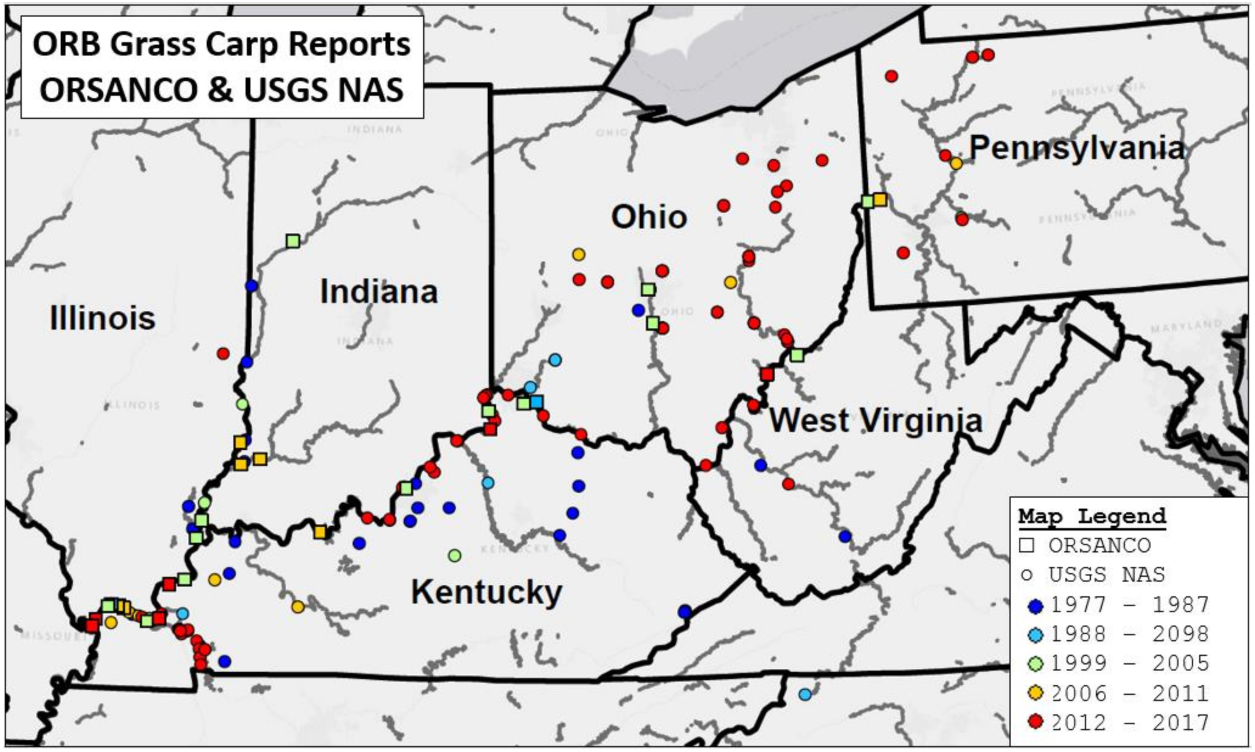

Figure 8. A range map of grass carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

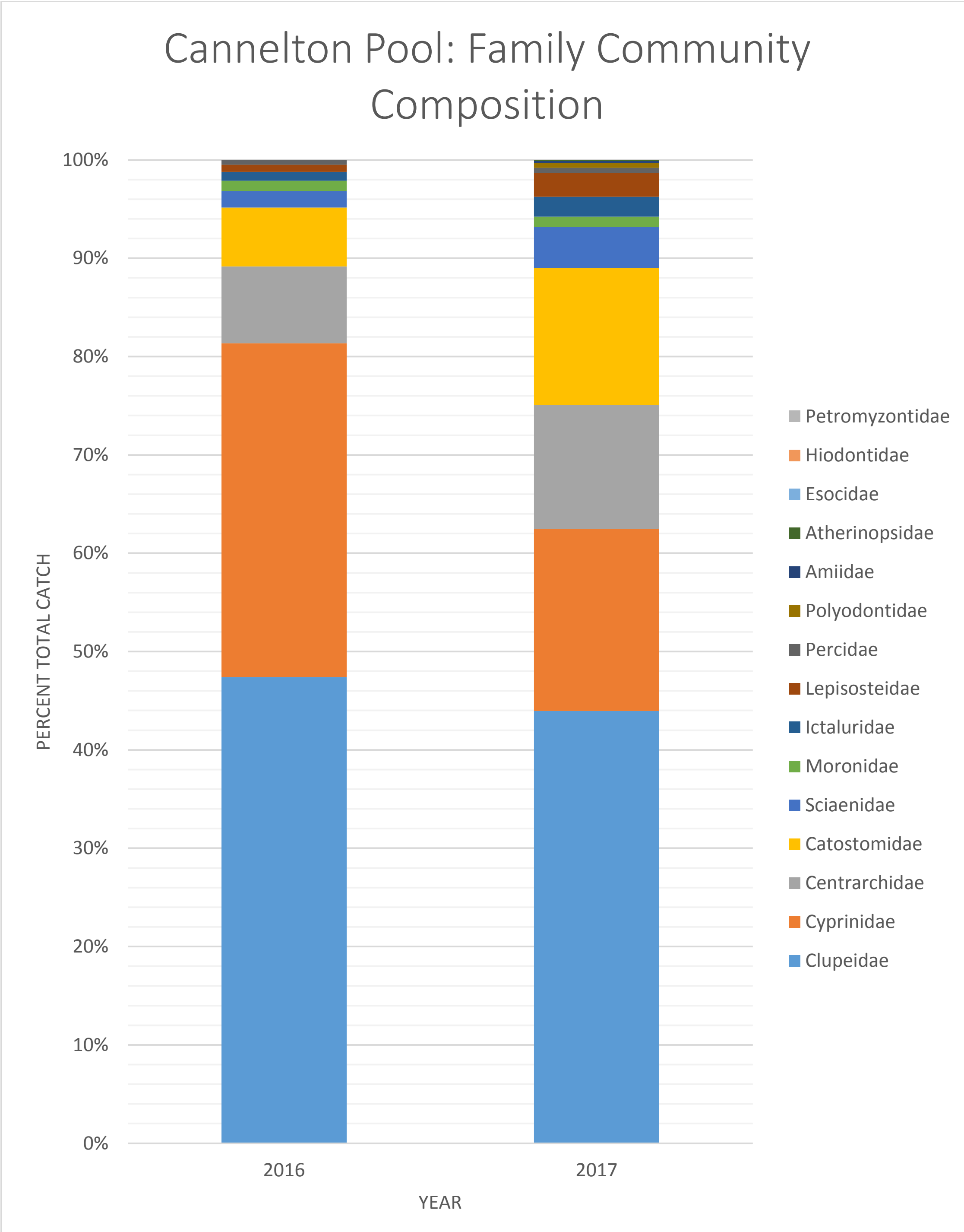

Figure 9. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Cannelton pool.

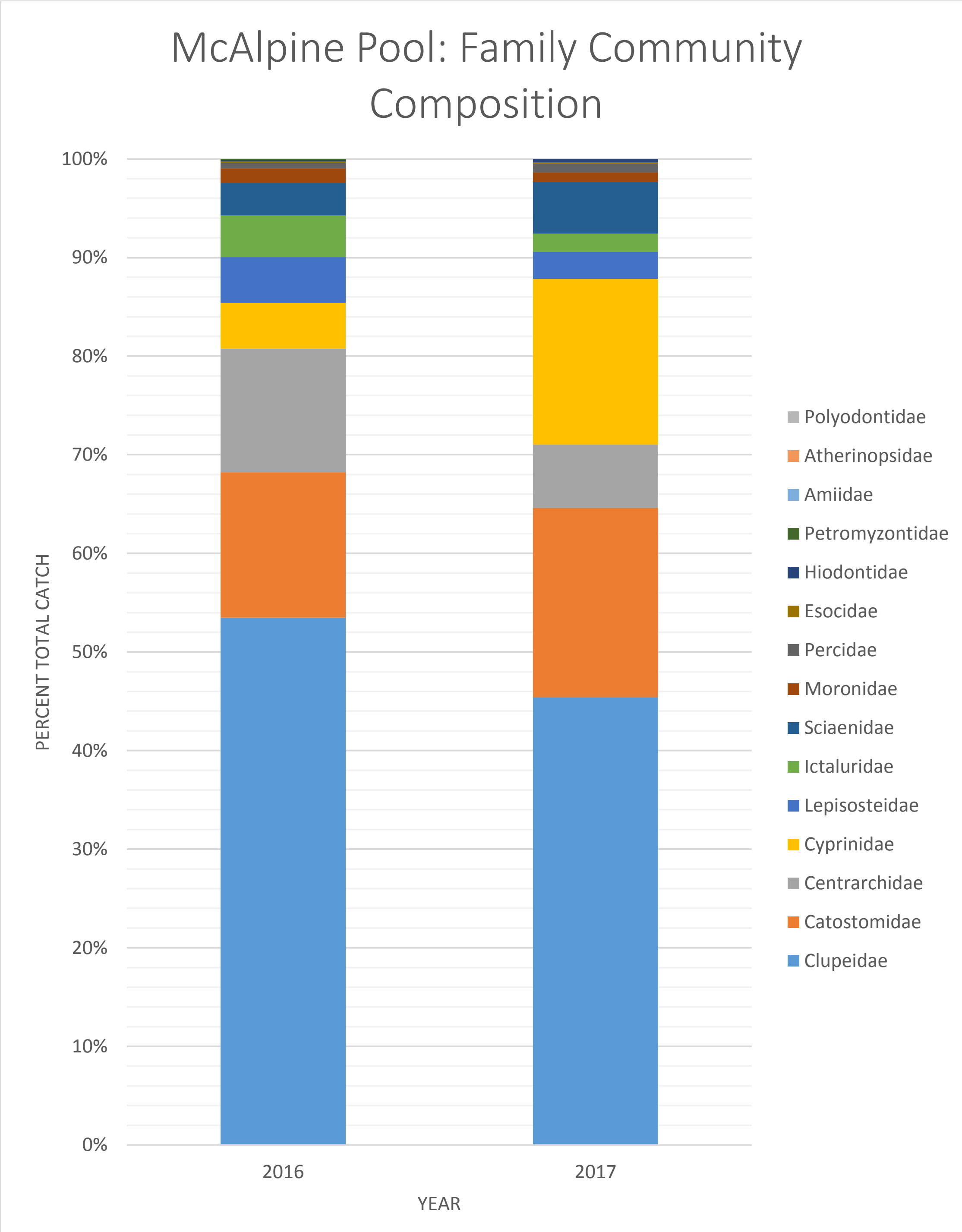

Figure 10. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the McAlpine pool.

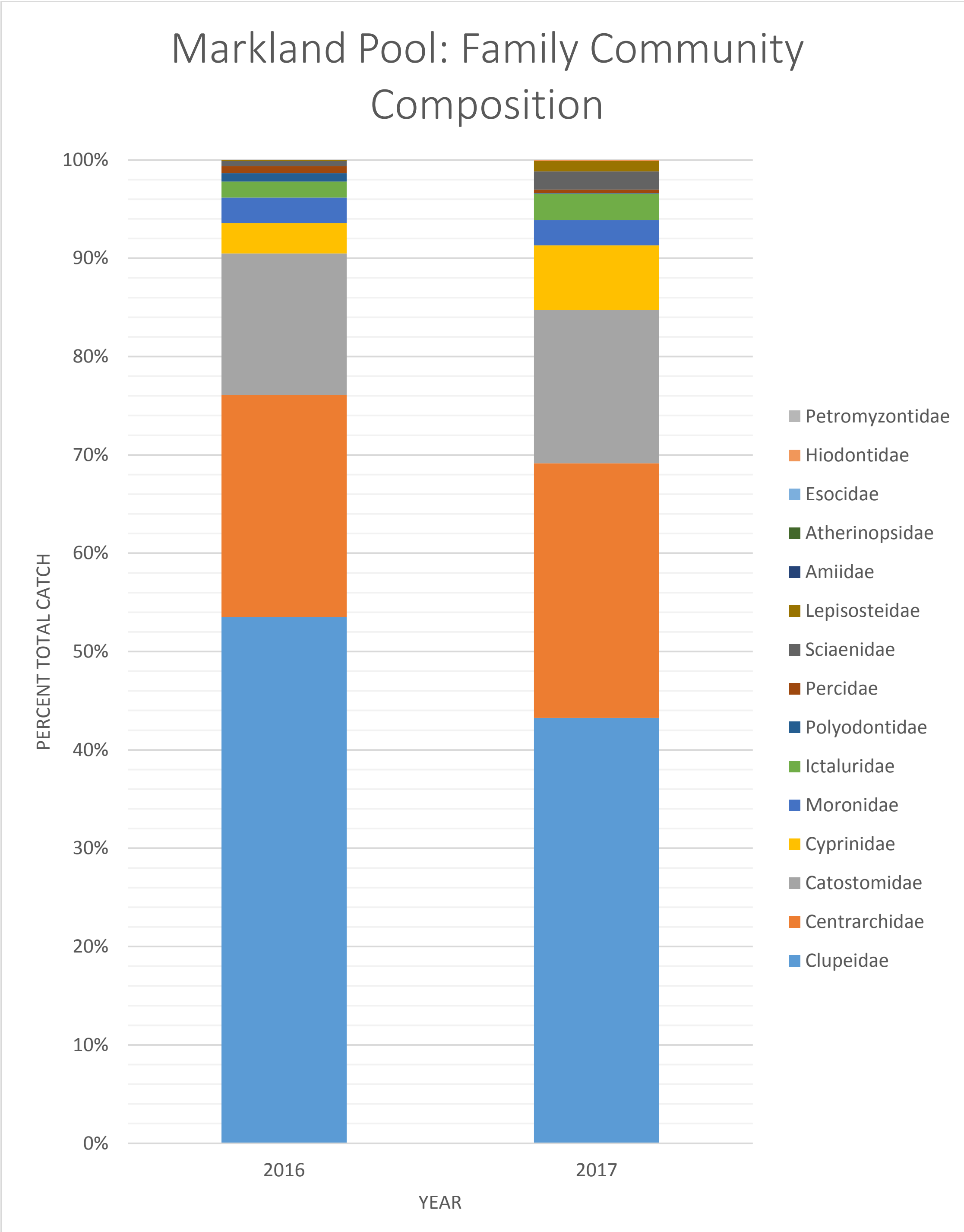

Figure 11. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Markland pool.

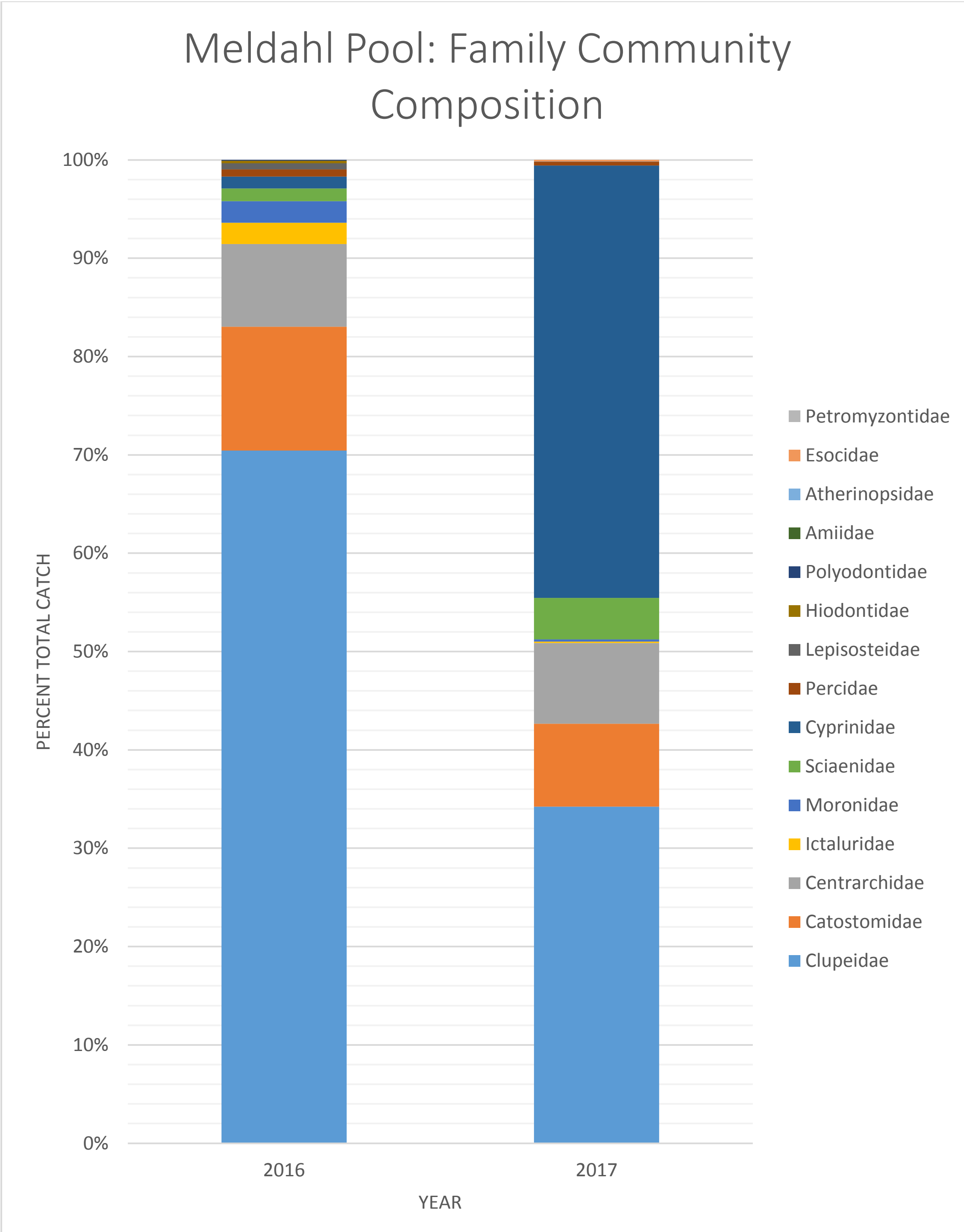

Figure 12. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Meldahl pool.

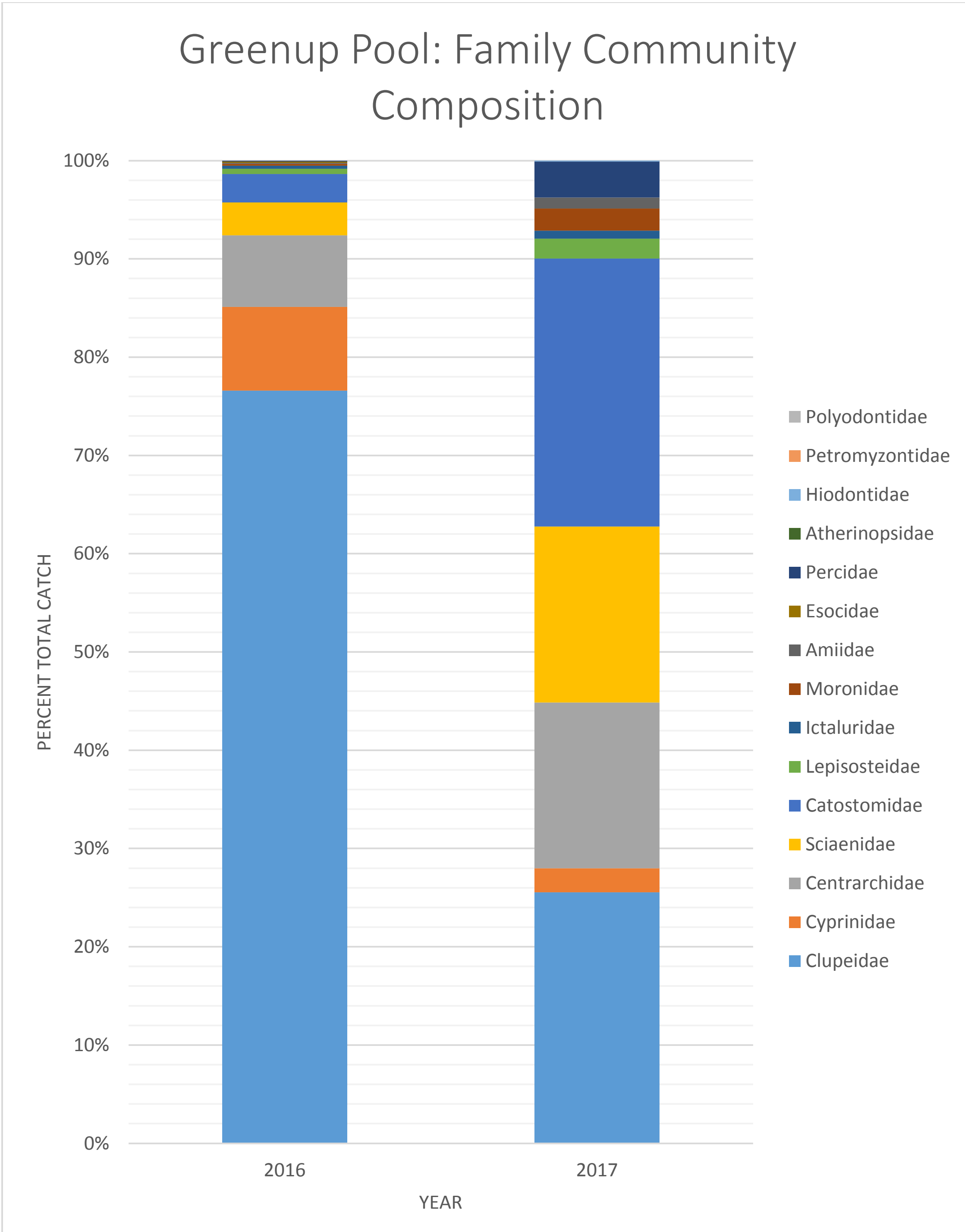

Figure 13. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Greenup pool.

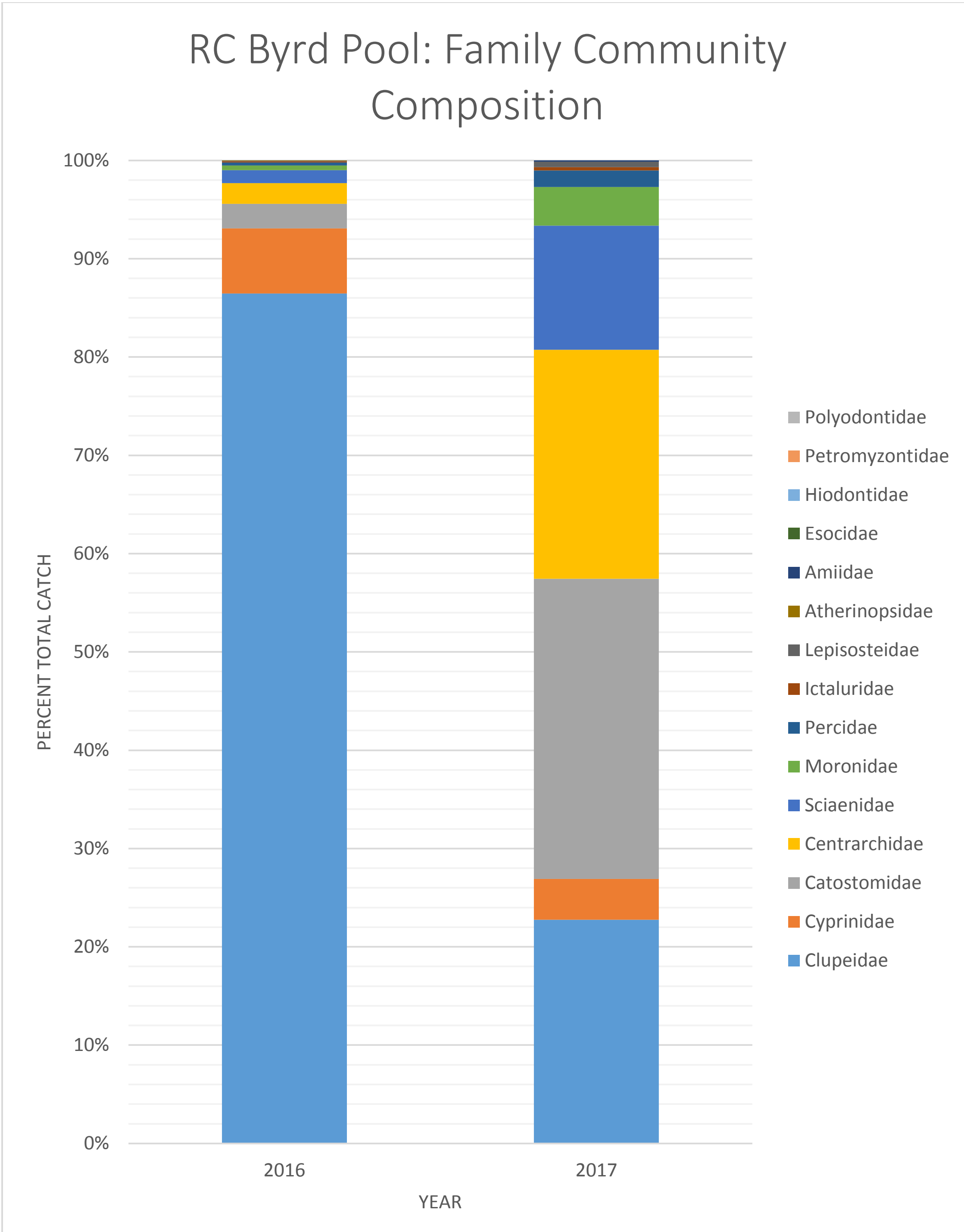

Figure 14. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the RC Byrd pool.

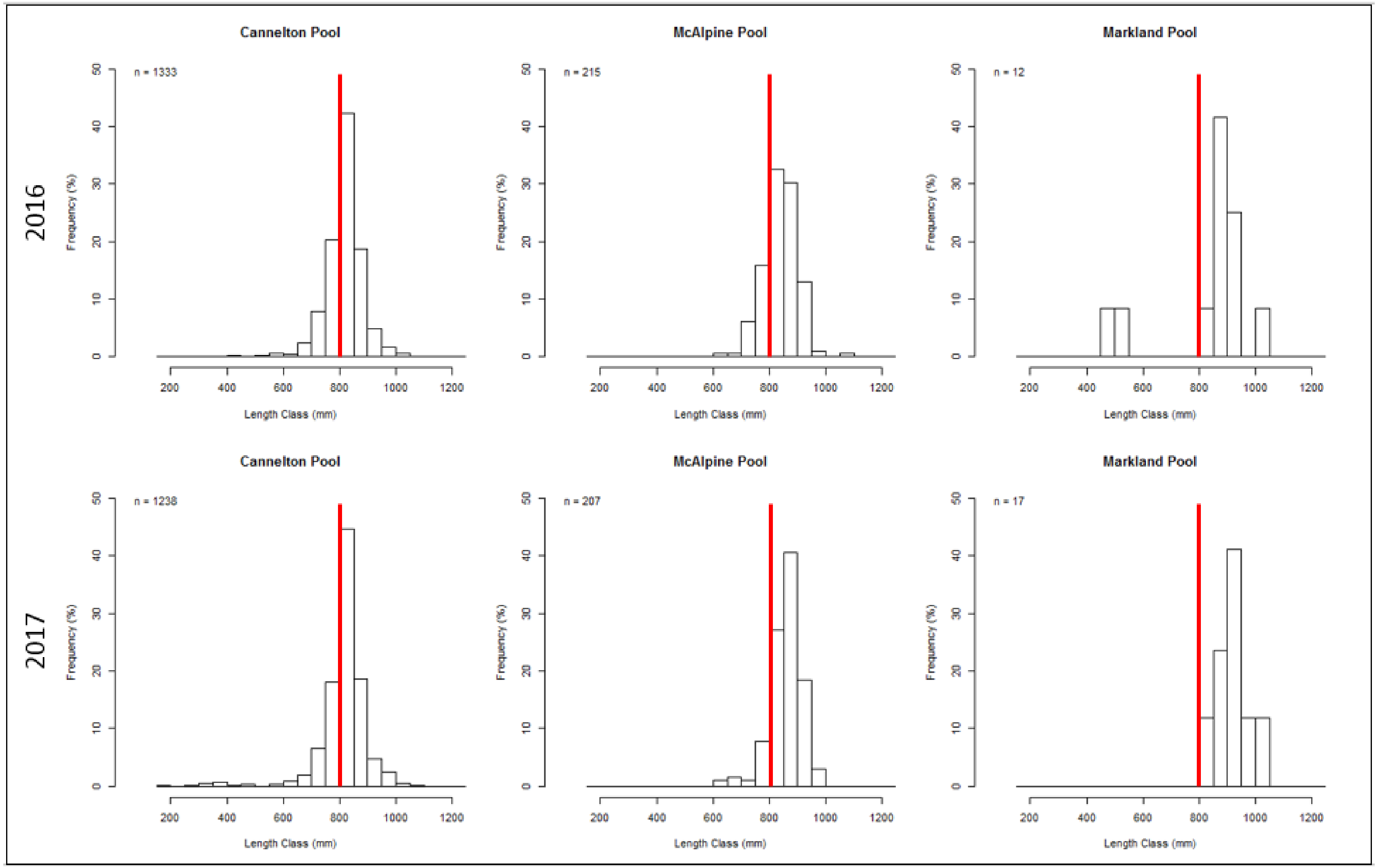

Figure 15. Length frequencies of silver carp captured during sampling efforts in 2016 and 2017. A line at 800mm highlights the change in length-classes from fish captured farther upriver with Cannelton being the farthest pool downstream and Markland the farthest pool upstream.

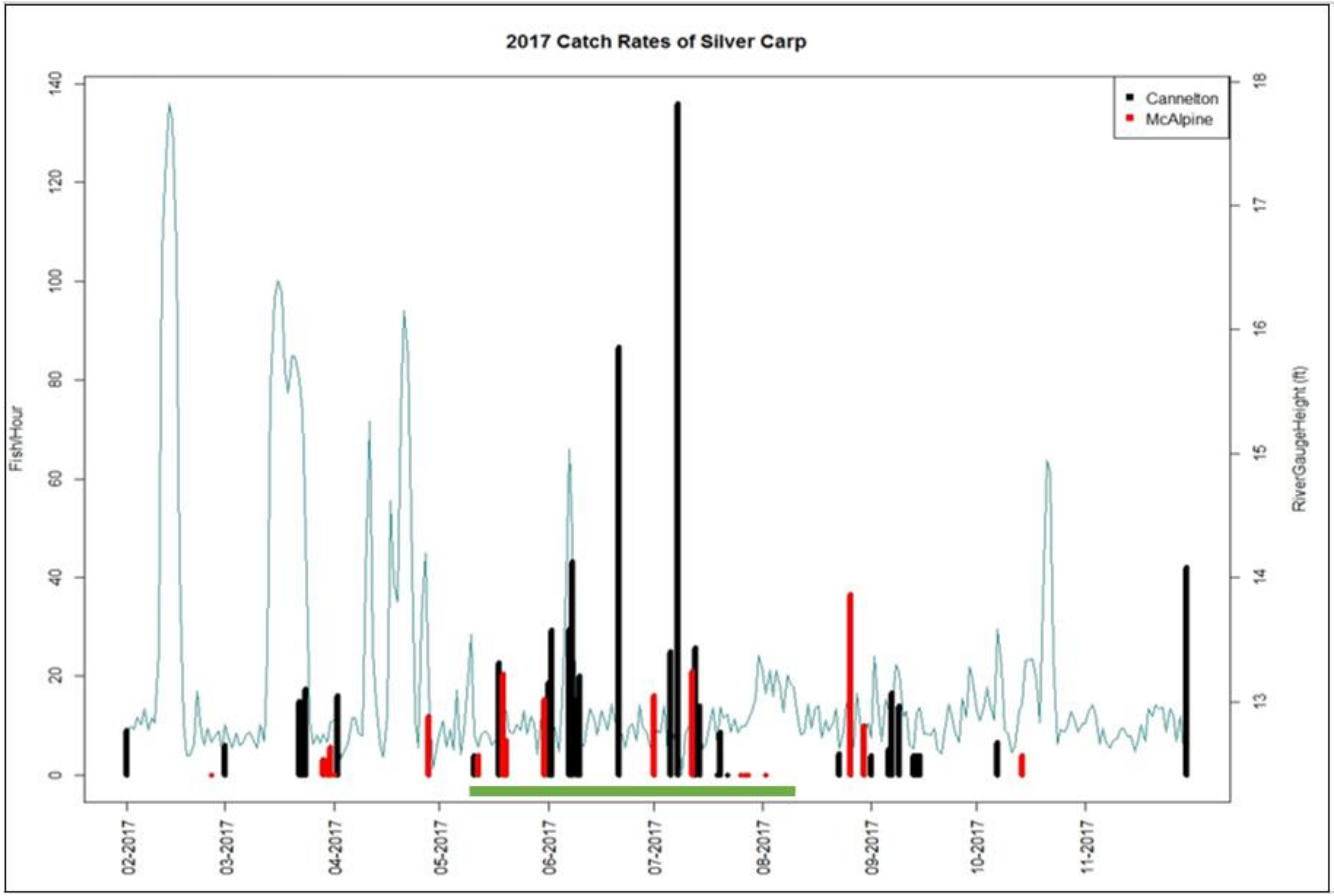

Figure 16. A histogram showing catch rates by month of silver carp captured in Cannelton and McAlpine in 2017 along with the gauge height in feet. The green line between the months of May and August indicate the period where spawning patches appear on females.

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 ($y = \beta0 + \beta1x1 + \beta2x2 + \beta3x1x\ 2 + \mathcal{E}$), 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.

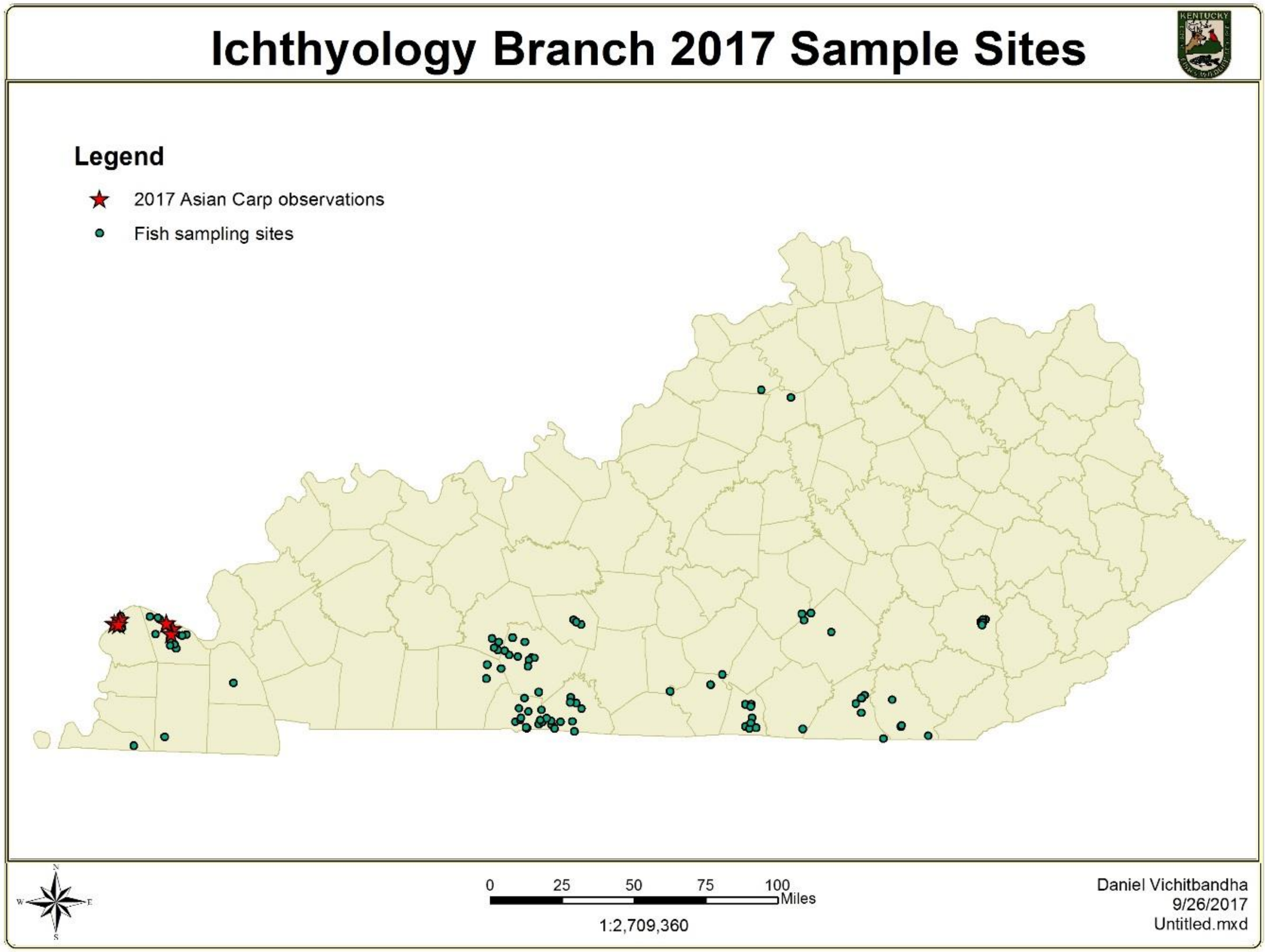

Figure 18. A map of Kentucky showing the sites where the KDFWR ichthyology branch conducted 2017 project sampling with incidental Asian carp observations indicated using red stars.

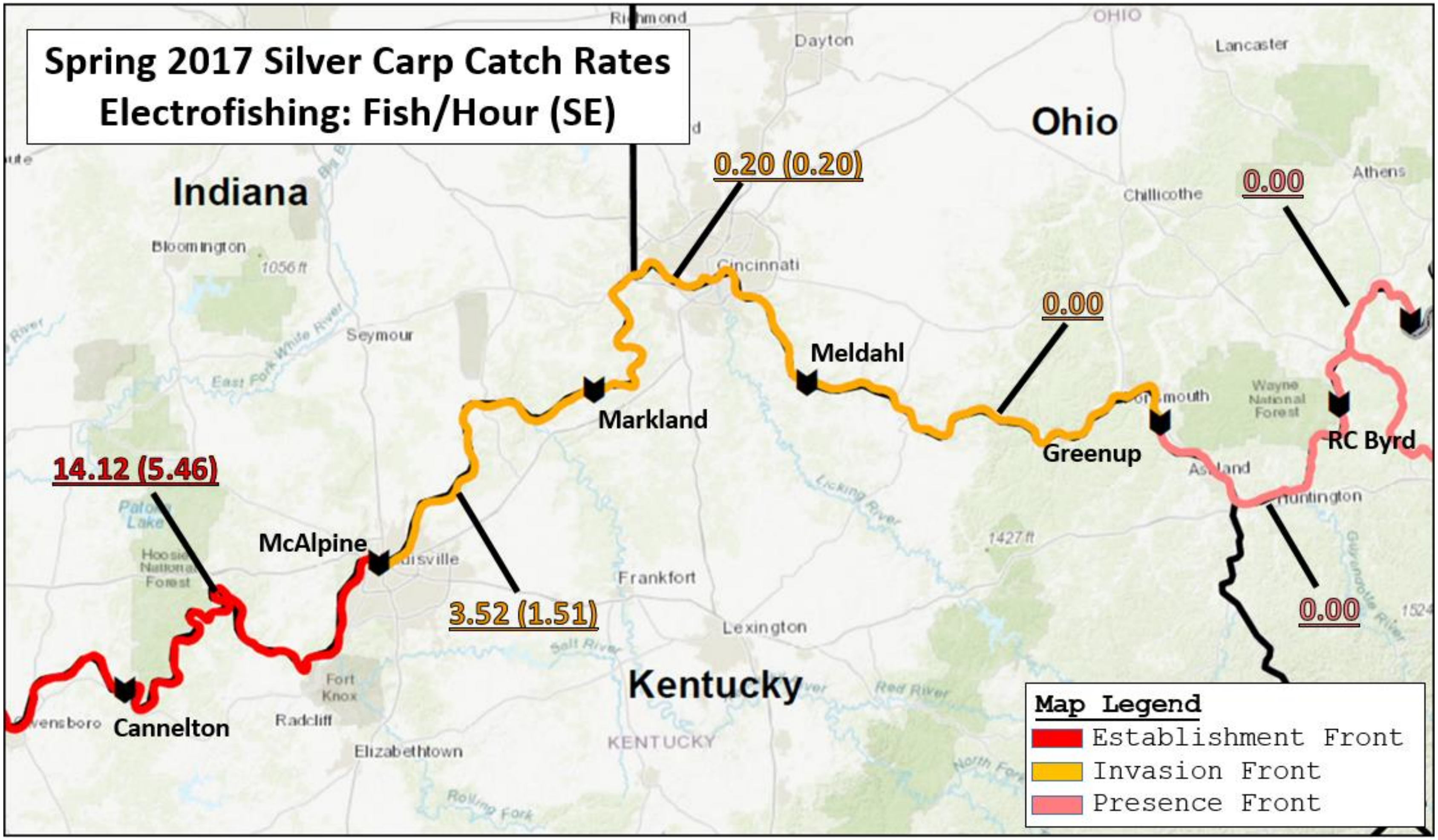

Figure 19. Mean silver carp catch rates by navigation pool using boat electrofishing during targeted sampling in 2017. Standard errors are in parenthesis.

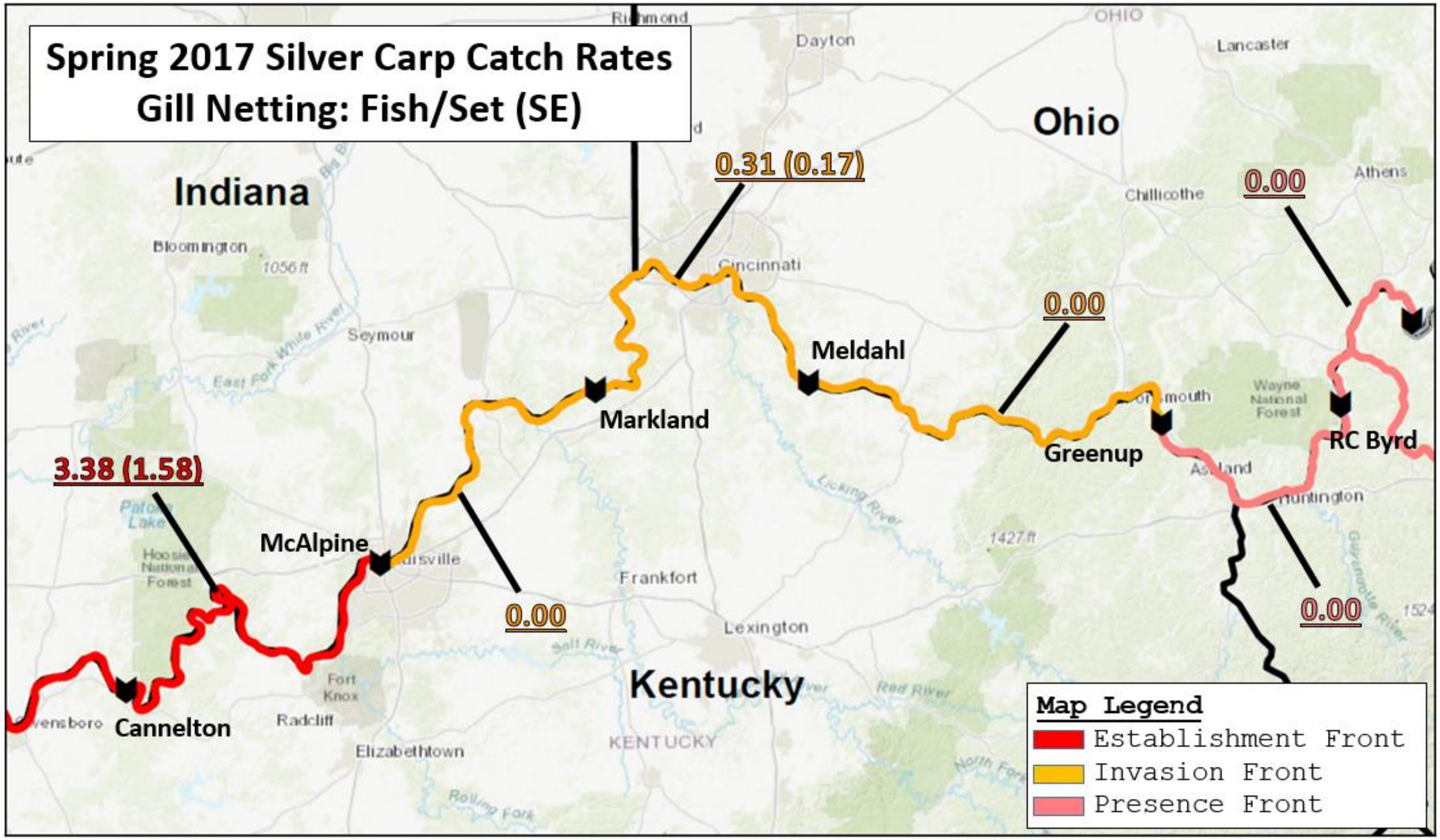

Figure 20. Mean silver carp catch rates by navigation pool using gill netting during targeted sampling efforts in Spring 2017. Standard errors are in parenthesis.

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	