Commonwealth of Kentucky

Date: June 30, 2018

Period: 01 April 2017
through
31 March 2018

# ANNUAL PERFORMANCE REPORT

for

# Asian Carp Research and Monitoring


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SPORT FISH RESTORATION

**Department of Fish and Wildlife Resources**

**Fisheries Division**

KENTUCKY DEPT. OF FISH & WILDLIFE RESOURCES

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STATE: Kentucky

GRANT NO: F-95-4

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2017 – March 31, 2018

Research and Survey Section

Project 1: Kentucky Lake Tailwater and Lake Barkley Tailwater Sport Fish Assessments

Project Objectives:

1. Investigate species composition and abundance of fish from historical data collected from Lake Barkley Dam tailwater and Kentucky Lake Dam tailwater to identify trends over time.
2. Compare current creel survey angler use and catch statistics to those collected in previous years' surveys conducted in the Kentucky Lake Dam and Lake Barkley Dam tailwaters.
3. Compare current tailwater angler opinions about the impacts of increasing densities of Asian carp on their fishing effort and success.
4. Collect baseline data on the growing bow fishing fishery in each tailwater.

A. ACTIVITY

**Electrofishing**

Kentucky Department of Fish and Wildlife Resources sampled the Kentucky Lake Dam Tailwater and Lake Barkley Dam Tailwater with pulsed DC electrofishing in the spring and fall of 2017 to assess fish species composition and relative abundance. The total number of fish captured was 15,085 (1,259 fish/hr CPUE in Kentucky Tailwater; 1,439 fish/hr CPUE in Barkley Tailwater) comprised of 51 species during 11.42 hours of effort. Spring sampling resulted in the capture of 1,941 total fish comprised of 40 species during 3.92 hours of effort (495.2 fish/hr). Fall sampling resulted in the capture of 13,144 total fish comprised of 45 species over 7.5 hours of effort (1,752.5 fish/hr). In Kentucky Tailwater the most abundant species captured during spring sampling was gizzard shad; and threadfin shad was the most abundant species captured in the fall. In Barkley Tailwater, longear sunfish were the most abundant species captured during spring sampling; and threadfin shad were the most abundant species captured in the fall. The most common sport fishes captured in both tailwaters were bluegill, largemouth bass, yellow bass, and smallmouth bass.

Relative weights (*W*r) were calculated for some species collected during fall sampling to monitor fish condition. Trends in fish condition are important in the current study as any observed declines in condition of individual species may be an indicator of competition for resources and reflective of high Asian carp densities in the tailwaters. In the Kentucky Tailwater, yellow perch (67), white crappie (76), and gizzard shad (83) exhibited low mean relative weights. In the Barkley Tailwater, gizzard shad (80), white bass (86), and black crappie (86) exhibited less than ideal condition. Mean relative weights for silver carp remained low in Kentucky (82) and Barkley

(83) tailwaters in 2017. All other mean *W*r values compiled for species collected during electrofishing in both tailwaters were ≥ 87, which reflects fish in fair condition or above.

Silver carp were captured in both tailwaters during spring and fall sampling efforts. In the Kentucky Tailwater 134 silver carp were captured, and 51 silver carp were captured from the Barkley Tailwater. With more years of data, it will be important to compare species composition and abundance from Kentucky and Barkley Tailwaters to identify any possible impacts of Asian carp on species diversity and fish condition in the tailwater fisheries**.**

**Creel Survey**

A creel survey was not conducted in 2017, therefore, reporting for objectives 2, 3, and 4 is comprised of a brief overview of the creel survey conducted at Kentucky Lake and Lake Barkley tailwaters in 2016.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2018
Work accomplished - 31 March 2018

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

STATE: Kentucky

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PERIOD COVERED: April 1, 2017 – March 31, 2018

Research and Survey Section

Project 2: Impacts of Asian Carp Harvest Program on Sport Fish in Kentucky

Project Objectives:

1. Monitor sport fish bycatch in the Asian Carp Harvest Program through review of commercial fishing harvest reports and ride-alongs with commercial fishermen.
2. Facilitate payment of Asian carp subsidy funds by verifying harvest location of fish, sale of fish to participating fish buyers, and submission of appropriate paperwork to the Kentucky Finance Cabinet.

A. ACTIVITY

Asian Carp Harvest Program

Kentucky Lake and Lake Barkley are two of the largest reservoirs in the United States east of the Mississippi River. These reservoirs represent a 1.2 billion-dollar sport fish and recreational boating industry that is very important to western Kentucky. Asian carp threaten the sport fishery of the lakes by competing with sport fish for food and space. Silver carp also negatively impact recreational boaters as they often jump out of the water when startled by noise and can cause injuries to recreationists. The Asian Carp Harvest Program (ACHP) created by the Kentucky Department of Fish and Wildlife Resources (KDFWR) allows qualified commercial fishermen to fish specifically for Asian carp in waters where commercial fishing was previously restricted. This report focuses primarily on commercial harvest occurring in Kentucky Lake and Lake Barkley as they account for 98% of Asian carp harvested under the ACHP. Since the program's inception in 2013 commercial fishermen in Kentucky have harvested a total of 3,974,195 lbs of Asian carp through the ACHP (3,901,668 lbs silver carp, 72,527 lbs bighead carp).

The number of commercial fishermen using the ACHP grew in the 2016-2017 fishing season and therefore the amount of effort increased as well (346 fishing trips in the 2015-2016 season and 558 fishing trips in the 2016-2017 season). However, the number of commercial fishermen fishing under the ACHP (15) and the amount of effort (347 fishing trips) declined in the 2017-2018 season (April – December 2017). Harvest of Asian carp has followed this trend with commercial fishermen harvesting 775,461 lbs of Asian carp in the 2015-2016 season, 1,406,310 lbs in the 2016-2017 season and 765,721 lbs of Asian carp harvested thus far in the 2017-2018 season. Data suggests that over the next few years' commercial harvest of the 2015-year class will increase, as this cohort recruits into the commercial tackle. It is essential to monitor impacts on sport fish and species of conservation concern as commercial fishing effort increases and types of gears used in the fishery expand. (Project not grant funded)

Ride-alongs

To quantify and refine data of the commercial fishing industry, KDFWR conducted observational ride-alongs with commercial fishers. Observations by KDFWR during ride-alongs were analyzed both aggregately with daily reports turned in by commercial fishermen and as a dataset on its own (i.e. ride-along data). KDFWR conducted 31 ride-alongs with commercial fishermen utilizing the ACHP from January through December 2017. During ride-alongs 32,391 yards of gillnet was fished and 75,499 lbs of Asian carp were harvested. The majority of fishing effort during ride-alongs was in Lake Barkley. There were 295 individuals captured as bycatch, of which 32% were sport fish. For this report sport fish includes all fish listed in section one of 301 KAR1:060 and any catfish species. The survival rate of sport fish in Lake Barkley was 92.4%. The most common species of sport fish caught in commercial nets during ride-alongs were blue catfish (N = 47), flathead catfish (N = 19), and channel catfish (N = 17). In relation to total bycatch, the number of sport fish captured is low (32% during ride-alongs in 2017, 6% from all commercial fishermen reports in April-December 2017). The survival rate of sport fish captured through the ACHP during the 2016-2017 season was 92.1%. The survival rate of fish is defined as fish that swim away after being released; we do not have a measure of post-release mortality at this time. This information shows no indication of negative impacts on the sport fishery resulting from the ACHP.

Asian Carp Subsidy Program

Commercial fishermen who signed up to receive payment of Asian carp subsidy funds were required to provide KDFWR with the date, time, and location desired to fish 48 hours prior to the date requested to fish. KDFWR staff met the fishermen at the predetermined boat ramp to verify harvest location of fish. KDFWR staff followed the fishermen to the participating fish buyers to witness the weight and species of fish sold and provide the fishermen with a voucher copy indicating the amount to be paid to the fishermen by KDFWR. This information was then submitted to the Kentucky Finance Cabinet for the appropriate payment to be made to the fishermen. In July of 2017, KDFWR initiated a reform of the subsidy program. The revised subsidy program allowed Asian carp processors to sign up for the subsidy. Processors that participated in the program were required to pay an additional US $0.05/lb for Asian carp bought from fishermen who requested to use the program upon calling in their fishing location to KDFWR. This reform allowed any commercial fisher utilizing the ACHP in Kentucky Lake, Lake Barkley, or their associated tailwaters to be eligible to receive subsidy funds. In 2017, all fishing trips covered under the subsidy program were conducted on Lake Barkley (53 trips). Pounds of Asian carp harvested totaled 204,222 lbs with $10,211.10 of subsidy funds spent in 2017.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2018

Work accomplished - 31 March 2018

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

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Research and Survey Section

Project 3: Silver Carp Demographics

1. Compare gear types for capturing juvenile Asian carp in Kentucky Lake and Lake Barkley.
2. Estimate hatch date of Asian carp in Kentucky Lake.
3. Investigate Asian carp age and growth, condition, gonadosomatic index, sex ratios, and fecundity for baseline data to be used to assess removal efforts as commercial fisheries grow.

A. ACTIVITY

In the 2017 field season, no young of year or juvenile Asian carp were observed. Therefore, Objectives 1 and 2 were not a priority during this reporting time frame.

Kentucky Lake Silver Carp Population Dynamics

In 2015 KDFWR began a joint project with a graduate student at Murray State University to investigate silver carp (*Hypophthalmichthys molitrix*) demographics in Kentucky Lake. In 2017 KDFWR continued the demographics study of silver carp from Lake Barkley. Demographics of silver carp in Lake Barkley are desirable as this lake has more commercial fishing pressure which could be affecting population structure of silver carp differently than in Kentucky Lake. Silver carp population data was collected from fish captured in Lake Barkley April – December 2017. Silver carp were captured with a variety of capture methods throughout this time frame including KDFWR sampling with gill nets, U.S. Fish and Wildlife Service Paupier net sampling and the commercial fishery. In October 2017 silver carp were sampled in both Kentucky Lake and Lake Barkley with gill nets and the USFWS Paupier net. Lengths and weights were recorded for 1,032 silver carp from Kentucky Lake and 426 silver carp from Lake Barkley. Silver carp captured from Lake Barkley were on average larger than silver carp captured in Kentucky Lake. The size class most prevalent in both lakes (500-599mm in Kentucky Lake; 600-699mm in Lake Barkley) represents silver carp from the 2015-year class when young of year silver carp were documented in the lakes for the first time.

Sixteen trips were made to commercial processing facilities which yielded data from 361 silver carp. The primary size of silver carp was 800-900mm which is similar to the size range of silver carp sampled from Kentucky Lake the previous year. Ages of silver carp collected by commercial fishermen and used for the demographics study ranged from 3-10 years and were dominated by four and five-year-olds. Therefore, it can be inferred that silver carp do not efficiently recruit to these commercial gill nets until 4 years of age. However, Silver carp can become sexually mature at 3 years of age thus the current commercial fishing effort alone cannot be expected to effectively reduce the number of silver carp present in the lakes.

The catch curve regression produced an annual mortality rate of 47.9% for Kentucky Lake in 2016 and 60.6% for Lake Barkley in 2017. Relative weights were calculated for silver carp sampled from the commercial fishery producing a mean *W*r of 101.43 (N=322), indicating fish harvested through the commercial fishery are slightly above average condition. The mean gonadosomatic index (GSI) indicated overlap between months for female silver carp from Kentucky Lake. The highest mean GSI for males and females in 2017 occurred in April, which coincides with high water flows in the lake. Spawning patches were also observed on female silver carp harvested from Lake Barkley on multiple occasions, suggesting that silver carp attempted to spawn in the lake. However, no young of year silver carp were observed in Lake Barkley in 2017.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2018
Work accomplished - 31 March 2018

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

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Research and Survey Section

Project 4: Tracking Silver Carp Movement in Kentucky Lake

Project Objective: Understand movement patterns, habitat use, spawning patterns, and immigration/emigration of Silver Carp in Kentucky Lake.

A. ACTIVITY

Kentucky Department of Fish and Wildlife Resources worked with Murray State University to continue a study tracking silver carp movement in Kentucky Lake. Surgeries were performed on 68 silver carp over five dates in 2017. Boat-mounted hydrophones were used to track tagged silver carp on 38 separate trips during 2017. A series of 19 VR2W passive receivers were deployed throughout Kentucky Lake, Lake Barkley, their locks, and their tailwaters to record long-range movement patterns of tagged silver carp. Fish were detected every week during 2017, so large scale movement rates (in km/day) and fine scale movement rates (in km/hour) were calculated for silver carp. The carp tended to move more as lake elevation levels and water temperatures increased. silver carp movement appeared to increase as surface temperatures reached 12.9 – 19.4$^{o}$C in the spring and movement decreased when temperature fell below this range in the fall. silver carp in Kentucky Lake tended to move upstream in the first half of 2017 but then tended to move downstream in the second half of the year. Several fish moved between Kentucky Lake and Lake Barkley via the canal, including 6 silver carp and 1 Paddlefish. One silver carp and two paddlefish were detected moving into Kentucky Lake through the lock chamber at Kentucky Dam. Several tagged fish from other agencies were detected in 2017, including four Paddlefish from Missouri Department of Conservation, one Bighead carp from Southern Illinois University, and one silver carp from the U.S. Fish and Wildlife Service. In 2018, tagged silver carp will continue to be monitored through manual tracking and the VR2W passive network. Additional effort will also be directed toward 24-hour tracking to collect more fine-scale, diurnal movement data to inform removal efforts. Supplemental VR2W receivers will be deployed in both Kentucky Lake and Lake Barkley, and more fish will be tagged and released into these water bodies.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2018
Work accomplished – 31 March 2018

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

STATE: Kentucky

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GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2017 – March 31, 2018

Research and Survey Section

Project 5: Identifying New Gear Types for Capturing Asian Carp

Project Objective:

Identify and evaluate new gear types for capturing silver and bighead carp in Kentucky Lake and Lake Barkley.

A. ACTIVITY

Asian carp have become a successful invader throughout the Mississippi River basin because they tolerate a wide range of environmental conditions, produce many young, and exhibit fast growth rates (Kolar et al. 2007). Silver and bighead carp (*Hypophthalmicthys molitrix* and *Hypophthalmicthys nobilis*) have been present in Kentucky Lake and Lake Barkley since 2004. The only tool currently available to decrease the number of Asian carp in our waters is manual removal. In Kentucky Lake and Lake Barkley, a significant and expanding commercial fishery for Asian carp has developed in the past five years with harvest totaling over 1.4 million pounds in 2017. This commercial fishery relies almost wholly on gillnets for the gear used to harvest Asian carp. This method has proven effective for capturing adult Asian carp. However, silver carp are often seen jumping over the nets or swimming along the nets without becoming entangled in them. Gillnets are also size selective and most commercial fishermen use 4.25-inch and 5-inch mesh nets which capture adult Asian carp but are not efficient in capturing juvenile Asian carp.

Therefore, in order to effectively reduce Asian carp populations KDFWR assisted in the exploration of other gear types for harvesting Asian carp. KDFWR coordinated with Two Rivers Fisheries to test an experimental gear type in the Honker Bay of Lake Barkley. Use of this gear type was attempted on five occasions with oversight by KDFWR personnel. However, no successful captures of silver carp were observed. KDFWR conducted experimental sampling efforts targeting Asian carp via gill nets, electrofishing, and bottom trawl in the lakes and tailwaters. Gill netting and bottom trawl effort was in response to large numbers of fish suspected to be silver carp reported by anglers in localized areas. The bottom trawl was used on one occasion in Kentucky Lake. However, no Asian carp were captured using this method. Gill nets were fished a total of 4 times on Kentucky Lake with 24 different species caught. Asian carp made up 15.2% of individual fish captured. Gill nets were fished 3 times on Lake Barkley during which 19 species were caught. Asian carp comprised 36.3% of individual fish captured. Targeted sampling with electrofishing was conducted in the tailwaters of Lake Barkley Dam on six occasions. A total of 18,440 lbs of silver carp were captured through 6.83 hrs of electrofishing with a mean CPUE of 274 fish/hour per trip.

In 2017, the USFWS continued sampling efforts with the Paupier net on Kentucky Lake and Lake Barkley. The USFWS crew sampled two embayments on Kentucky Lake; Sledd Creek and Big Bear Creek, and just above the dam on Lake Barkley. Each area was sampled for one night in the months of April, July, and October. Aside from gizzard shad and threadfin shad, silver carp made up the majority of the catch on all sampling occasions with a total of 5,853 silver carp captured throughout all sampling periods. The highest CPUE of silver carp was seen in the Sledd Creek embayment of Kentucky Lake in October (510.5 fish/hour). On average, silver carp captured in Lake Barkley were larger than silver carp captured in Kentucky Lake with the Paupier net. The dominant size class of silver carp apparent in 2017 sampling represents the 2015-year class when young of year silver carp were documented in the lakes for the first time. However, it is notable that very few silver carp captured with the Paupier net were larger than 28 inches in length (3.1%). Silver carp of this size and larger are known to be in the lakes as shown through commercial fishing reports and other sampling efforts. Therefore, it may be a limitation of the Paupier net to capture silver carp in this size class as they are able to out-swim the net in the open waters of Kentucky and Barkley lakes.

KDFWR staff assisted the USFWS (Carterville, IL) conduct sampling efforts on the lower Ohio River and tributaries targeting black carp. No black carp were captured during those sampling efforts. However, one black carp was captured by a commercial fisherman in Lake Barkley in November, 2017. This was the first documented capture of a black carp in the Cumberland River system. One black carp was also collected by a commercial fisherman in Kentucky Lake in January, 2018. This was the first documented capture of a black carp in the Tennessee River system.

B. TARGET DATES FOR ACHEIVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2018
Work accomplished – 31 March 2018

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

E. RECCOMENDATIONS

Continue project as designed

Project 1: Kentucky Lake Tailwater and Lake Barkley Tailwater Sport Fish Assessments

FINDINGS

**Electrofishing**

Kentucky Department of Fish and Wildlife Resources (KDFWR) personnel sampled the lower Tennessee River below the Kentucky Lake Dam (hereafter referred to as Kentucky Tailwater) and the lower Cumberland River below the Lake Barkley Dam (hereafter referred to as Barkley Tailwater). Kentucky Tailwater electrofishing extended from the dam downstream to the Interstate 24 bridge; at Barkley Tailwater electrofishing extended from the dam downstream to the US Hwy 62 bridge (Figure 1). Sampling consisted of 900-second runs using pulsed DC electrofishing in the spring and fall of 2017 to assess species composition and relative abundance. Spring sampling for this project is scheduled to occur in the months of April, May, and June. However, due to high water events in 2017, sampling did not occur in either tailwater in May, and only in Kentucky Tailwater in April. Fall sampling took place as scheduled in September, October, and November. All fish were identified to the lowest taxonomic level and total length (in) was recorded. Weight (lbs) was also recorded in fall sampling. When large numbers of any species were collected, random subsamples were measured for length and weight to decrease processing time. All fish were returned to the water immediately after processing, with the exception of Asian carp, which were euthanized after measurements were recorded.

Spring sampling in the Kentucky Tailwater resulted in the capture of 1,400 total fish comprised of 38 species during 3.0 hours of effort in 2017 (Tables 1 and 5). The number of total fish and species captured was lower than during 2016 sampling (2,167 fish, 47 species). However, this is likely due to the decline in sampling time from 2017 to 2016 (4.65 hours). Gizzard shad were the most abundant species captured with a CPUE of 122.33 fish/hr. Other prominent rough fish species captured during spring sampling at Kentucky Tailwater included emerald shiners (43.33 fish/hr), and longnose gar (41.0 fish/hr). Silver carp CPUE increased notably between 2016 (6.11fish/hr) and 2017 (38.33 fish/hr). This increase is partially due to the 2015-year class of silver carp being affected by a bacterium, *Aeromonas hydrophila*, in April of 2017. The infection from this bacterium resulted in lethargic and erratic behavior of silver carp, sometimes resulting in death. This lethargic behavior made them much more vulnerable to the gear. Silver carp were the only species observed to be affected by the bacterium in 2017. The most prevalent sport fish captured in the Kentucky Tailwater during spring sampling was largemouth bass (76.33 fish/hr), followed distantly by smallmouth bass (13.33 fish/hr). Catch rates for *Morone* sp., sunfish, and catfish species declined in 2017 from 2016. However, catch rates of all black bass species increased (Table 1).

Spring sampling in the Barkley Tailwater resulted in the capture of 541 total fish comprised of 24 species during 0.92 hours of effort in 2017 (Tables 2 and 6). The number of total fish and species captured declined when compared to 2016 sampling (1,242 fish, 42 species). However, similar to Kentucky Tailwaters, this is likely indicative of the decrease in sampling time from 2017 to 2016 (2.75 hours) due to high water levels. Longear sunfish were the most abundant species captured with a CPUE of 183.0 fish/hr. Other prevalent rough fish species caught during spring sampling at Barkley Tailwater were smallmouth buffalo (22.0 fish/hr) and gizzard shad (18.0 fish/hr). Prominent sport fish captured in Barkley Tailwater during spring sampling were largemouth bass (155.0 fish/hr), bluegill (55.0 fish/hr), and redear sunfish (20.0 fish/hr). Similar to Kentucky Tailwaters, CPUE for largemouth bass increased markedly between 2016 and 2017 spring sampling in the Barkley Tailwaters. Catch rates of silver carp in the Barkley Tailwaters decreased between spring of 2016 (24.31 fish/hr) and spring of 2017 (10.0 fish/hr) (Table 2).

Fall sampling in the Kentucky Tailwater resulted in the capture of 8,046 total fish comprised of 43 species in 4.5 hrs of effort in 2017 (Tables 3 and 7). The number of total fish and species captured increased in fall of 2017 when compared to sampling in fall of 2016 (3,876 total fish, 35 species). However, this gain is likely due to the increase in sampling effort in 2017. Similar to previous years, threadfin shad were the most abundant species captured and in the Kentucky Tailwater in 2017 (1,262.89 fish/hr). Other prevalent rough fish species caught in the Kentucky Tailwaters during 2017 fall sampling included gizzard shad (162.89 fish/hr) and longear sunfish (79.78 fish/hr). Prominent sport fish captured in the Kentucky Tailwater during fall sampling were bluegill (127.78 fish/hr), largemouth bass (34.89 fish/hr), and yellow bass (26.0 fish/hr) (Table 3). Catch rates of silver carp during fall sampling at Kentucky Tailwater in 2017 were lower than the previous two years (Table 3).

Fall sampling in the Barkley Tailwater resulted in the capture of 5,098 total fish comprised of 37 species in 3.0 hrs of effort in 2017 (Tables 4 and 8). Although the amount of effort increased in 2017 compared to 2016 (1.99 hrs) the number of fish captured declined markedly from 2016 sampling (11,468 fish). This decrease is largely due to fewer threadfin shad being captured in 2017 sampling. However, threadfin shad were still the most abundant species captured in Barkley Tailwater during fall sampling in 2017 with a CPUE of 1,252.33 fish/hr. Other prevalent rough fish species caught in Barkley Tailwater during 2017 fall sampling were gizzard shad (104.33 fish/hr) and longear sunfish (83.0 fish/hr). Similar to sampling in 2016, abundant sport fish species captured during fall sampling in 2017 included largemouth bass (55.33 fish/hr) and bluegill (55.67 fish/hr). Silver carp CPUE during fall sampling in Barkley Tailwaters increased between 2016 (4.0 fish/hr) and 2017 (13.67 fish/hr) (Table 4).

Length frequency distribution for silver carp captured in Kentucky Tailwater during spring sampling ranged from 11-37 inches (N=115; Table 5). Silver carp lengths from Barkley Tailwater in spring ranged from 19-33 inches (N=10; Table 6). Fall sampling in Kentucky Tailwater captured silver carp with lengths ranging from 12-36 inches (N=19; Table 7). Silver carp lengths from Barkley Tailwater in the fall ranged from 12-34 inches (N=41; Table 8).

Silver carp were captured in both tailwaters during spring and fall sampling efforts, however no bighead carp were captured in either season. These capture rates are not reflective of the relative number of Asian carp in the tailwaters. Silver carp are known to be very sensitive to electrofishing and will often leap out of the water at feeling the slightest current and then dive deep upon re-entering the water. This behavior makes silver carp difficult to immobilize and net relative to their density with electrofishing in the tailwaters. Another method of sampling such as gill netting or purse seining is better suited for quantifying Asian carp populations in the tailwaters but the bycatch could potentially be very high. Electrofishing resulted in the collection of 134 silver carp from Kentucky Tailwater and 51 silver carp from Barkley Tailwater in 2017.

Relative weights (*Wr*) were calculated for selected species collected during fall sampling to monitor fish condition (Table 9 and 10). Trends in fish condition are important in the current study, as any observed declines in condition of individual species may be an indicator of competition for resources and reflective of high Asian carp densities in the tailwaters. Low relative weight is generally characteristic of fish in poor health, whereas high values indicate fish in excellent health (Blackwell et al. 2000). However, ideal target ranges of *W*r values have not been identified for all species and in every habitat type. Therefore, the *W*r values compiled through this study will be used to assess changes in the tailwater fish community over time. In the Kentucky Tailwater, the mean *W*r of gizzard shad increased from previous years (Table 9). Mean relative weight also improved for redear sunfish between 2016 (*W*r = 85) and 2017 (*W*r = 93). However, mean *W*r values decreased notably for white crappie in the Kentucky Tailwater (*W*r = 90 in 2016, *W*r = 76 in 2017). Yellow perch captured in the Kentucky Tailwater also exhibited a low mean relative weight in 2017 (*W*r = 67) (Table 9). Mean relative weight for silver carp captured in the Kentucky Tailwater declined slightly in 2017 (*W*r = 82) from previous years (Table 9). In the Barkley Tailwater, mean relative weight values decreased for white bass, bluegill, and largemouth bass in 2017 (Table 10). However, bluegill (*W*r = 104) and largemouth bass (*W*r = 95) mean relative weight values still indicate fish in healthy condition, and the slight decrease in values may be due to increased sample sizes for the two species. In the Barkley Tailwater, gizzard shad mean relative weight increased between 2016 (*W*r = 70) and 2017 (*W*r = 80), similar to gizzard shad captured in Kentucky Tailwater (Table 10). Black crappie in the Barkley Tailwaters also exhibited a low mean *W*r (86). Mean relative wieights for silver carp in the Barkley Tailwater increased slightly in 2017 (*W*r = 83) when compared to 2016 (*W*r = 81). All other mean *W*r values compiled for species collected during electrofishing in both tailwaters were ≥ 87, which reflects fish in fair condition or above.

Data from Kentucky Tailwater in 2015 and Barkley Tailwater in 2016 marked a baseline on which to measure future trends. With more years of data, it will be important to continue comparison of species composition and abundance from Kentucky and Barkley Tailwaters to identify any possible impacts of Asian carp on species diversity and fish condition in the tailwater fisheries.

**2016 Creel Survey**

A random, non-uniform probability creel survey was conducted in Kentucky Tailwater and at Barkley Tailwater. The survey was conducted from February 15, 2016 through November 15, 2016. The Kentucky Tailwater survey extended from the Kentucky Lake Dam downstream to the Interstate 24 bridge. The Barkley Tailwater survey extended from the Lake Barkley Dam downstream to the US Hwy 62 bridge (Figure 1). The days and time periods to be surveyed each week were randomly selected. The overall temporal sampling scheme was a minimum of 10 days per month in each tailwater, consisting of at least 3 weekend days in each. There were three time periods: morning, afternoon, and late evening. The late evening time period was only utilized for a portion of the survey to collect snagging and bow fishing data. Daily surveys had two parts, angler counts conducted from the bank with binoculars, and angler interviews. All anglers were counted at a randomly chosen time each day in order to calculate a daily average for total effort. An attempt was made to interview all anglers in the tailwater area. This survey was an access point survey and no boat was used. Data recorded during each tailwater creel survey was used to compare current estimated angler use and catch statistics to those collected in previous tailwater surveys. Anglers were also administered an angler attitude survey to gauge angler opinions regarding the impacts of increasing Asian carp densities on their fishing effort and success. The increasing number of Asian carp in the tailwaters over the past decade has sparked an increase in popularity of bow fishing. The 2016 creel survey was the first attempt to collect baseline data on the growing bow fishing fishery in each tailwater.

<u>Kentucky Tailwater</u>

The last creel survey conducted in the Kentucky Tailwater previous to 2016 was in 2007. Therefore, the following is a comparison of results from the 2016 survey to values observed during the 2007 survey.

The number of fish captured increased for most sport fish species including largemouth bass, smallmouth bass, white crappie, white bass, hybrid striped bass, and yellow bass (Figure 2). Hours spent by anglers targeting sportfish generally decreased between the survey periods with the exception of the black bass group (Figure 3). The success rate of anglers targeting sport fish species increased for black bass and Morone spp. but decreased for sauger and crappie (Figure 4). Therefore, anglers targeting black bass are increasing effort and catching more fish; anglers targeting Morone spp. decreased effort but had a higher success rate due largely to increases in capture of white bass. The decrease in success rates of crappie anglers may be related to the decrease in catch of black crappie in the tailwaters.

The number of fish caught by anglers in the Kentucky tailwaters increased for all rough fish species except paddlefish, longear sunfish, and mooneye (Figure 5). There were no grass carp reported caught in 2007. Hours spent by anglers targeting rough fish in 2016 increased for most species groups including catfish, bighead carp, silver carp, buffalo, and skipjack herring (Figure 3). The success rate of anglers targeting rough fish species also increased for all groups except buffalo and paddlefish between survey periods (Figure 4). Asian carp have been found to compete directly with paddlefish and bigmouth buffalo for forage resources (Irons et al. 2007; Schrank et al. 2003). Therefore, the decreasing success rate of anglers for paddlefish and buffalo may be an indication of negative impacts associated with increasing Asian carp numbers. The length and weight of the average paddlefish harvested in the Kentucky Tailwater also decreased between 2007 (34.0 inches, 8.8 pounds) and 2016 (29.4 inches, 3.3 pounds).

Asian carp, specifically silver carp and bighead carp, have increased in density in the Lower Tennessee River and Kentucky Lake since the 2007 creel survey.  This fact is obvious to anglers in the tailwater as Asian carp are often snagged on baits and lures meant for other fish species and can often be seen swimming in large schools just under the water’s surface.  Some anglers reported that they can feel their bait bouncing off the carps as it travels down through the water column. The 2007 creel survey estimated 116 bighead carp and 58 silver carp were caught by anglers in the Kentucky Tailwater.  The number of each species caught increased dramatically in the 2016 creel survey, when total catch was estimated to be 2,718 bighead carp and 22,678 silver carp. During administration of Angler Attitude Surveys, anglers who were dissatisfied with the Kentucky Tailwater fishery cited Asian carp as the number one reason for their dissatisfaction. For more detailed information regarding the 2016 creel survey please reference the KDFWR 2016 Annual Performance Report, Subsection IV: Critical Species Investigations.

Barkley Tailwater

The last creel survey conducted in the Barkley Tailwater previous to 2016 was in 2001. Therefore, the following is a comparison of results from the 2016 survey to values observed during the 2001 survey. The number of fish captured increased for most sport fish species including largemouth bass, black crappie, white bass, hybrid striped bass, yellow bass and redear sunfish (Figure 6). However, the black bass group was the only sport fish group that effort increased for in 2016 (Figure 7). Therefore, the success rates of anglers targeting sport fish increased for all groups except for sauger between survey periods (Figure 8). Similar to the Kentucky Tailwaters, effort expended by anglers towards sauger decreased since the previous survey period, as well as angler effort and success. Although the success rate for anglers targeting Morone spp. increased in 2016 the number of striped bass caught declined dramatically since the survey conducted in 2001; with the difference in the Morone spp. group being made up by increases in catch for white bass and yellow bass in 2016 (Figure 6).

The number of fish caught in the Barkley Tailwaters decreased for all rough fish species except for green sunfish, freshwater drum, bighead carp, silver carp, grass carp, suckers, and shad (Figure 9). No Asian carp species (silver carp, bighead carp, and grass carp) were reported captured in the Barkley Tailwaters during the previous creel survey in 2001. Hours spent by anglers targeting rough fish species decreased for all species on which data for both survey years was recorded (Figure 7). Hours fished for paddlefish in the Barkley Tailwaters was not recorded in 2001, although there were 2,107 paddlefish caught by anglers during the survey period. The number of fish and hours fished for catfish species declined between survey periods, however, the success rate of anglers targeting catfish species was similar between survey periods (Figure 8). Success rates were not calculated for buffalo in 2016, or for paddlefish in 2001. However, the average length and weight of paddlefish harvested from the Barkley Tailwater decreased between the surveys conducted in 2001 (39.0 inches, 9.0 pounds) and 2016 (31.6 inches, 4.2 pounds), which may be indicative of negative impacts of the increasing Asian carp populations in the Barkley Tailwater (Irons et al. 2007; Schrank et al. 2003).

The 2001 creel survey conducted in the Barkley Tailwater did not record any Asian carp captured or harvested. Since then, the density of Asian carp, specifically silver carp and bighead carp, has increased dramatically in the Lower Cumberland River and Lake Barkley reservoir. In the 2016 creel survey it was estimated that 2,853 bighead carp and 21,599 silver carp were caught in the Barkley Tailwater. When Angler Attitude Surveys were conducted, Asian carp were cited as the number two reason for angler dissatisfaction with the Barkley Tailwater fishery (number of fish was number one). For more detailed information regarding the 2016 creel survey please reference the KDFWR 2016 Annual Performance Report, Subsection IV: Critical Species Investigations.

Asian carp have the potential to negatively affect tailwater fisheries in various ways. Asian carp have been shown to change the trophic dynamics of a large river ecosystem by changing the way native fish feed, and the food that is available to them (Freedman et al. 2012). If Asian carp are affecting the food web dynamics of the ecosystem, changes in the fish community over time may be observed. In their highest densities, Asian carp may outcompete other fish species for space, which may be apparent through decreasing species diversity in an area. Additionally, Asian carp may directly compete with native fish for food, causing declines in native fish condition through time (Irons et al. 2007; Schrank et al. 2003). This study strives to monitor these parameters through routine surveys of the fish community. Growing populations of Asian carp may also have a social impact on our sport fisheries. Some anglers may not fish in the tailwaters because they fear silver carp will jump in their boat, creating a mess, or even causing an injury. At their highest densities, schools of Asian carp make fishing for other species difficult, as it may be impossible to drop bait to the bottom of the river without snagging a carp. These issues could lead to decreases in sport fishing effort and success. The higher densities of Asian carp can also positively affect anglers' usage of the tailwater as observed with the rising sport of bow fishing. The number of anglers utilizing the method of snagging has also increased as many anglers now use this method to target Asian carp specifically to either use as bait or for sustenance. KDFWR plans to continue this study as funding is available to monitor the impacts Asian carp have on the tailwater fisheries over time.

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Table 1. Comparison of spring electrofishing CPUE values for all species captured in the Kentucky Lake tailwaters during sampling in 2015 (effort = 2.33 hours), 2016 (effort = 4.65 hours), and 2017 (effort = 3.0 hours). (CPUE=catch per unit effort; S.E.=standard error)

| Species | Kentucky Spring 2015 | | Kentucky Spring 2016 | | Kentucky Spring 2017 | |
|---|---|---|---|---|---|---|
| | CPUE (fish/hr) | S.E. | CPUE (fish/hr) | S.E. | CPUE (fish/hr) | S.E. |
| Paddlefish | | | 0.21 | 0.21 | | |
| Spotted gar | 0.11 | 0.11 | 3.16 | 2.11 | | |
| Longnose gar | 0.11 | 0.11 | 5.61 | 2.02 | 41 | 22.66 |
| Shortnose gar | 2.44 | 1.08 | 6.6 | 3.12 | 11 | 7.27 |
| Bowfin | 0.33 | 0.24 | 0.84 | 0.49 | 1.67 | 0.92 |
| American eel | | | 0.63 | 0.34 | | |
| Skipjack herring | 0.67 | 0.44 | 0.21 | 0.21 | 0.67 | 0.45 |
| Gizzard shad | 23.56 | 4.81 | 52.14 | 14.69 | 122.33 | 83.29 |
| Threadfin shad | | | 7.58 | 4.11 | 3.33 | 1.62 |
| Grass carp | 0.44 | 0.29 | 3.16 | 1.08 | 1.33 | 1.02 |
| Common carp | 0.22 | 0.15 | 0.63 | 0.34 | 1.67 | 1.15 |
| Silver carp | 0.67 | 0.29 | 6.11 | 2.3 | 38.33 | 17.24 |
| Emerald shiner | 0.22 | 0.15 | 21.96 | 9.79 | 43.33 | 34.83 |
| Spottail shiner | | | | | 1.33 | 1.02 |
| Spotfin shiner | | | | | 3.33 | 2.64 |
| Striped shiner | | | 0.21 | 0.21 | | |
| Bullhead minnow | | | | | 0.33 | 0.33 |
| River carpsucker | 0.78 | 0.52 | 2.74 | 1.5 | 1.67 | 0.77 |
| Quillback | 0.11 | 0.11 | | | | |
| Highfin carpsucker | | | 0.21 | 0.21 | | |
| Northern hogsucker | | | 0.42 | 0.29 | 0.67 | 0.45 |
| Smallmouth buffalo | 3 | 0.96 | 27.37 | 6.13 | 12.67 | 3.26 |
| Bigmouth buffalo | 2.11 | 1.02 | 0.63 | 0.34 | 4 | 1.56 |
| Black buffalo | | | 1.68 | 1.12 | 0.67 | 0.45 |
| Spotted sucker | | | | | 1 | 0.72 |
| Shorthead redhorse | | | 5.89 | 1.87 | 0.33 | 0.33 |
| Greater redhorse | | | | | 0.67 | 0.67 |
| Yellow bullhead | | | 0.21 | 0.21 | | |
| Blue catfish | | | 0.42 | 0.29 | | |
| Channel catfish | 0.22 | 0.15 | 1.05 | 0.67 | 0.33 | 0.33 |
| Flathead catfish | | | 18.74 | 5.51 | 4 | 1.3 |
| Inland silverside | | | 0.63 | 0.46 | 1 | 1 |
| White bass | 1 | 0.58 | 7.58 | 2.05 | 1.33 | 0.75 |
| Yellow bass | 0.89 | 0.54 | 30.95 | 12.33 | 2.67 | 1.33 |
| Sunfish family | | | 0.21 | 0.21 | | |
| Flier | | | 0.21 | 0.21 | | |
| Green sunfish | | | 3.58 | 1.46 | 2.33 | 1.34 |
| Warmouth | | | 0.21 | 0.21 | | |
| Orangespotted sunfish | | | 0.21 | 0.21 | 2.67 | 1.66 |
| Bluegill | 1.67 | 0.71 | 91.51 | 16.32 | 30 | 5.62 |
| Longear sunfish | 3.11 | 1.83 | 74.18 | 15.22 | 24.67 | 6.93 |
| Redear sunfish | 0.56 | 0.29 | 2.95 | 1.1 | 2.33 | 1.15 |
| Smallmouth bass | 0.89 | 0.77 | 10.04 | 2.53 | 13.33 | 3.2 |
| Spotted bass | 0.33 | 0.33 | 0.84 | 0.49 | 11 | 4.15 |
| Largemouth bass | 4.89 | 1.6 | 46.25 | 5.24 | 76.33 | 7.93 |
| White crappie | | | 1.47 | 0.93 | 0.33 | 0.33 |
| Black crappie | 0.11 | 0.11 | 0.63 | 0.34 | 0.67 | 0.45 |
| Logperch | | | 2.32 | 1.89 | | |
| Sauger | | | 1.05 | 0.6 | | |
| Freshwater drum | 0.11 | 0.11 | 14.11 | 3.42 | 2 | 0.92 |
| White bass/Striped bass hybrid | | | 1.89 | 0.83 | | |
| Sunfish hybrids | | | 0.21 | 0.21 | | |
| Chestnut lamprey | | | 0.84 | 0.49 | 0.33 | 0.33 |

Table 2. Comparison of spring electrofishing CPUE values for all species captured in the Lake Barkley tailwaters during sampling in 2016 (effort = 2.75 hours) and 2017 (effort = 0.92 hours). (CPUE=catch per unit effort; S.E.=standard error)

| Species | Barkley Spring 2016 | | Barkley Spring 2017 | |
|---|---|---|---|---|
| | CPUE (fish/hr) | S.E. | CPUE (fish/hr) | S.E. |
| Spotted gar | 0.36 | 0.36 | 2 | 2 |
| Longnose gar | 12.67 | 7.57 | 16 | 10.83 |
| Shortnose gar | 15.64 | 6.28 | 16 | 9.66 |
| Bowfin | 0.34 | 0.34 | | |
| Goldeye | 0.36 | 0.36 | | |
| Mooneye | 0.36 | 0.36 | | |
| American eel | 0.73 | 0.49 | 2 | 2 |
| Skipjack herring | | | 4 | 1.63 |
| Gizzard shad | 19.41 | 8.12 | 18 | 14.09 |
| Threadfin shad | 6.49 | 5.01 | | |
| Grass carp | 6.69 | 2.93 | 1 | 1 |
| Common carp | 0.34 | 0.34 | 1 | 1 |
| Silver carp | 24.31 | 9.81 | 10 | 2.58 |
| Emerald shiner | 0.34 | 0.34 | 9 | 7.72 |
| River shiner | 10.46 | 5.48 | 1 | 1 |
| Striped shiner | | | | |
| Spotfin shiner | 0.34 | 0.34 | 1 | 1 |
| Striped shiner | | | | |
| River carpsucker | 2.13 | 1.1 | | |
| Blue sucker | 5.01 | 3.27 | | |
| Smallmouth buffalo | 23.06 | 3.56 | 22 | 3.46 |
| Bigmouth buffalo | 1.06 | 0.55 | 2 | 1.15 |
| Black buffalo | 1.43 | 0.81 | | |
| Spotted sucker | 0.34 | 0.34 | | |
| Golden redhorse | 0.36 | 0.36 | | |
| Shorthead redhorse | 0.73 | 0.73 | | |
| Channel catfish | 1.09 | 0.78 | | |
| Flathead catfish | 16.36 | 5.54 | 6 | 2.58 |
| Inland silverside | 1.09 | 0.78 | | |
| White bass | 7.73 | 3.63 | 6 | 3.46 |
| Yellow bass | 1.79 | 0.98 | 4 | 4 |
| Striped bass | 1.09 | 1.09 | | |
| Green sunfish | 1.45 | 0.81 | 2 | 1.15 |
| Orangespotted sunfish | 0.34 | 0.34 | | |
| Bluegill | 69.35 | 16.1 | 55 | 26.9 |
| Longear sunfish | 110.06 | 23.63 | 183 | 83.58 |
| Redear sunfish | 9.6 | 2.6 | 20 | 5.89 |
| Smallmouth bass | 10.1 | 2.71 | 3 | 3 |
| Spotted bass | 1.09 | 0.56 | | |
| Largemouth bass | 63.57 | 6.16 | 155 | 35.27 |
| White crappie | 0.36 | 0.36 | | |
| Black crappie | 0.73 | 0.73 | | |
| Logperch | 2.55 | 1.89 | | |
| Sauger | 0.36 | 0.36 | | |
| Freshwater drum | 15 | 3.39 | 2 | 2 |

Table 3. Comparison of fall electrofishing CPUE for all species collected in Kentucky Lake tailwaters in 2015 (effort = 1.0 hrs), 2016 (effort = 1.75 hrs), and 2017 (effort = 4.5 hrs). (CPUE=catch per unit effort; S.E.=standard error)

| Species | Kentucky Fall 2015 | | Kentucky Fall 2016 | | Kentucky Fall 2017 | |
|---|---|---|---|---|---|---|
| | CPUE (fish/hr) | S.E. | CPUE (fish/hr) | S.E. | CPUE (fish/hr) | S.E. |
| Spotted gar | | | | | 0.44 | 0.3 |
| Longnose gar | 1 | 1 | 1.14 | 1.14 | 5.78 | 2.61 |
| Shortnose gar | | | 0.57 | 0.57 | 2.44 | 1.68 |
| Bowfin | | | 0.57 | 0.57 | 0.67 | 0.36 |
| American eel | | | 1.14 | 0.74 | 0.67 | 0.67 |
| Skipjack herring | 22 | 8.41 | 0.57 | 0.57 | 18 | 9.45 |
| Gizzard shad | 275 | 58.55 | 184 | 78.01 | 162.89 | 61.06 |
| Threadfin shad | 251 | 176.31 | 1690.29 | 1250.98 | 1262.89 | 636.95 |
| Grass carp | 13 | 1.91 | 5.71 | 2.45 | 1.56 | 0.66 |
| Common carp | 2 | 2 | | | | |
| Silver carp | 6 | 2.58 | 44 | 22.36 | 4.22 | 1.57 |
| Golden shiner | | | 0.57 | 0.57 | 0.22 | 0.22 |
| Emerald shiner | 12 | 9.38 | 14.29 | 13.63 | 0.22 | 0.22 |
| Bluntnose minnow | | | 0.57 | 0.57 | 0.22 | 0.22 |
| River carpsucker | | | | | 0.44 | 0.3 |
| Smallmouth buffalo | 10 | 2.58 | 9.14 | 3.67 | 4.89 | 2.08 |
| Bigmouth buffalo | | | | | 0.67 | 0.36 |
| Black buffalo | 6 | 2 | 2.86 | 1.9 | 0.22 | 0.22 |
| Spotted sucker | | | 0.57 | 0.57 | 0.22 | 0.22 |
| Shorthead redhorse | 2 | 2 | 0.57 | 0.57 | | |
| Blue catfish | | | | | 0.22 | 0.22 |
| Channel catfish | | | 0.57 | 0.57 | 0.89 | 0.89 |
| Flathead catfish | | | 4 | 1.23 | 4.22 | 1.39 |
| Inland silverside | | | 10.86 | 10.86 | 0.89 | 0.61 |
| Silverside family | 1 | 1 | | | | |
| White bass | 8 | 4.32 | 7.43 | 4.04 | 0.44 | 0.3 |
| Yellow bass | 162 | 83.47 | 16.57 | 13.34 | 26 | 4.06 |
| Striped bass | | | | | 1.56 | 0.98 |
| Sunfish family | | | 1.14 | 1.14 | | |
| Green sunfish | | | 2.86 | 1.14 | 2.89 | 0.78 |
| Warmouth | 1 | 1 | | | 0.67 | 0.49 |
| Orangespotted sunfish | | | | | 1.33 | 0.65 |
| Bluegill | 96 | 29.21 | 40.57 | 11.82 | 127.78 | 30.7 |
| Longear sunfish | 14 | 14 | 48 | 12.03 | 79.78 | 25.02 |
| Redear sunfish | 1 | 1 | 6.29 | 2.29 | 6.22 | 1.62 |
| Smallmouth bass | 9 | 2.52 | 20.57 | 5.2 | 10.67 | 3.2 |
| Spotted bass | 1 | 1 | 0.57 | 0.57 | 3.11 | 1.43 |
| Largemouth bass | 62 | 19.77 | 86.29 | 9.44 | 34.89 | 4.31 |
| White crappie | 2 | 2 | 1.14 | 0.74 | 0.67 | 0.36 |
| Black crappie | 2 | 2 | 0.57 | 0.57 | 2.67 | 1.68 |
| Yellow Perch | | | | | 0.44 | 0.3 |
| Logperch | | | 1.14 | 1.14 | 10.44 | 2.59 |
| Sauger | 1 | 1 | | | 0.67 | 0.36 |
| Freshwater drum | 13 | 5.74 | 6.29 | 1.48 | 3.78 | 0.68 |
| White bass/Striped bass hybrid | 1 | 1 | 1.14 | 1.14 | 0.67 | 0.49 |
| White bass/Yellow bass hybrid | | | 1.71 | 1.19 | | |
| Notropis spp | | | | | 0.22 | 0.22 |
| Atlantic needlefish | | | | | 0.22 | 0.22 |

Table 4. Comparison of fall electrofishing CPUE for all species collected in Lake Barkley tailwaters in 2016 (effort = 1.99 hrs) and 2017 (effort = 3.0 hrs). (CPUE=catch per unit effort; S.E.=standard error)

| Species | Barkley Fall 2016 | | Barkley Fall 2017 | |
|---|---|---|---|---|
| | CPUE (fish/hr) | S.E. | CPUE (fish/hr) | S.E. |
| Spotted gar | 1.78 | 0.97 | 1.67 | 0.92 |
| Longnose gar | 0.44 | 0.44 | 8 | 4.59 |
| Shortnose gar | | | 1.33 | 0.57 |
| American eel | 1.33 | 0.94 | 0.33 | 0.33 |
| Skipjack herring | 0.46 | 0.46 | 7.67 | 2.93 |
| Gizzard shad | 208.73 | 52.36 | 104.33 | 18.19 |
| Threadfin shad | 4598.49 | 1818.65 | 1252.33 | 602.06 |
| Grass carp | 4.98 | 2.63 | 0.67 | 0.45 |
| Common carp | 2.28 | 1.55 | 3 | 1.11 |
| Silver carp | 4 | 2 | 13.67 | 7.65 |
| Golden shiner | 1.85 | 1.85 | 0.33 | 0.33 |
| Emerald shiner | 8.44 | 5.43 | 20 | 9.7 |
| Spottail shiner | | | 0.67 | 0.67 |
| Bluntnose minnow | 0.44 | 0.44 | 0.33 | 0.33 |
| River carpsucker | 4.45 | 3.49 | 5.33 | 3.76 |
| Blue sucker | 0.85 | 0.85 | 0.67 | 0.45 |
| Smallmouth buffalo | 14.92 | 7.6 | 9.67 | 2.67 |
| Bigmouth buffalo | 0.89 | 0.89 | 0.33 | 0.33 |
| Black buffalo | | | 0.67 | 0.67 |
| Channel catfish | 0.44 | 0.44 | 0.67 | 0.45 |
| Flathead catfish | 7.63 | 3.64 | 6 | 3.06 |
| Inland silverside | 4.31 | 3.82 | 8.67 | 4.23 |
| White bass | 6.72 | 3.9 | 2.67 | 1.14 |
| Yellow bass | 1.78 | 0.7 | 28 | 15.95 |
| Striped bass | 0.89 | 0.89 | 2 | 1.35 |
| Green sunfish | 4.46 | 2.15 | 0.67 | 0.45 |
| Bluegill | 46.48 | 15.34 | 55.67 | 14.61 |
| Longear sunfish | 101.64 | 25.02 | 83 | 16.75 |
| Redear sunfish | 8.02 | 2.1 | 3 | 1.22 |
| Smallmouth bass | 7.19 | 2.29 | 8.67 | 1.19 |
| Spotted bass | 1.78 | 0.97 | 0.33 | 0.33 |
| Largemouth bass | 48.27 | 8 | 55.33 | 10.27 |
| White crappie | 3.52 | 1.54 | 1 | 0.72 |
| Black crappie | | | 1.67 | 1.34 |
| Freshwater drum | | | 4.67 | 1.54 |
| White bass/ Striped bass hybrid | 0.44 | 0.44 | 3.33 | 2.3 |
| White bass/ Yellow bass hybrid | 1.33 | 1.33 | | |
| Sunfish hybrids | 0.44 | 0.44 | | |
| Notropis ssp. | | | 3 | 3 |

Table 5. Species composition, length frequency and CPUE (fish/hr) of fish collected during 3.0 hours of electrofishing at the Kentucky Tailwater in spring of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Longnose gar | | | | | | | | | | | | 1 | | 1 | 1 | | 4 | 14 | 21 | 21 |
| Shortnose gar | | | | | | | | | | | | | | 1 | 4 | 2 | 5 | 5 | 3 | 3 |
| Bowfin | | | | | | | | | | | | | | | | | | | 1 | |
| Skipjack herring | | 1 | | | | | | | | | 1 | | | | | | | | | |
| Gizzard shad* | | 61 | 62 | 12 | 6 | 3 | 6 | 20 | 19 | 28 | 15 | 6 | 1 | | | 1 | 1 | | | |
| Threadfin shad | 6 | | 3 | 1 | | | | | | | | | | | | | | | | |
| Grass carp | | | | | | | | | | | | | 1 | | | | | | | |
| Common carp | | | | | | | | | | | | | | | | | | 1 | 2 | 1 |
| Silver carp | | | | | | | | | | | 2 | | 2 | 1 | 21 | 36 | 24 | 9 | 4 | |
| Emerald shiner* | 4 | 11 | 34 | 3 | | | | | | | | | | | | | | | | |
| Spottail shiner | | 3 | 1 | | | | | | | | | | | | | | | | | |
| Spotfin shiner | | 4 | 5 | 1 | | | | | | | | | | | | | | | | |
| Bullhead minnow | | 1 | | | | | | | | | | | | | | | | | | |
| River Carpsucker | | | | | | | | | | | | | | 1 | 2 | 1 | | 1 | | |
| Northern hog sucker | | | | | | 1 | | | | 1 | | | | | | | | | | |
| Smallmouth buffalo | | | | | | | | | | | 5 | 3 | 5 | 4 | 6 | 7 | 1 | 4 | 1 | |
| Bigmouth buffalo | | | | | | | | | | | | | 3 | 2 | 3 | 2 | | | 1 | 1 |
| Black buffalo | | | | | | | | | | | | | | | 1 | 1 | | | | |
| Spotted sucker | | | | | 1 | | | | | | | | | 1 | | 1 | | | | |
| Shorthead redhorse | | | | | | | | | | | | | | 1 | | | | | | |
| Greater redhorse | | | | | | | | 1 | 1 | | | | | | | | | | | |
| Channel catfish | | | | | | | | | | | | | | | | 1 | | | | |
| Flathead catfish | | | | | | | | 1 | 1 | 1 | | 1 | 3 | | 2 | | | | | |
| Inland silverside | | | 3 | | | | | | | | | | | | | | | | | |
| White bass | | | | | | | | 2 | | | 1 | | | 1 | | | | | | |
| Yellow bass | | | 1 | | 1 | 2 | 4 | | | | | | | | | | | | | |
| Green sunfish | | 1 | | 1 | 4 | 1 | | | | | | | | | | | | | | |
| Orangespotted sunfish | | 5 | 3 | | | | | | | | | | | | | | | | | |
| Bluegill | | 14 | 16 | 26 | 18 | 10 | 5 | 1 | | | | | | | | | | | | |
| Longear sunfish | | 11 | 25 | 29 | 7 | 2 | | | | | | | | | | | | | | |
| Redear sunfish | | | 3 | 3 | 1 | | | | | | | | | | | | | | | |
| Smallmouth bass | | 4 | 1 | | | 5 | 2 | 4 | 2 | 2 | 2 | 5 | 2 | 3 | 3 | 1 | | 3 | 1 | |
| Spotted bass | 1 | 7 | 3 | 1 | 1 | 6 | 9 | 4 | 1 | | | | | | | | | | | |
| Largemouth bass | 1 | 16 | 10 | | 2 | 7 | 35 | 58 | 38 | 7 | 6 | 4 | 4 | 4 | 10 | 13 | 4 | 8 | 1 | 1 |
| White crappie | | | | | | | 1 | | | | | | | | | | | | | |
| Black crappie | | | | 1 | | 1 | | | | | | | | | | | | | | |
| Freshwater drum | | | | | 1 | | | | | | | | | | 1 | | 1 | 1 | | |
| Chestnut lamprey | | | | | | | | | | | | 1 | | | | | | | | |

* species were randomly subsampled

Table 5 continued. Species composition, length frequency and CPUE (fish/hr) of fish collected during 3.0 hours of electrofishing at the Kentucky Tailwater in spring of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 40 | TOTAL | CPUE | S.E. |
| Longnose gar | 27 | 16 | 5 | 3 | | 2 | 1 | 2 | 1 | | | 1 | | 1 | 1 | | | 123 | 41 | 22.66 |
| Shortnose gar | | 2 | 5 | 1 | | | 1 | 1 | | | | | | | | | | 33 | 11 | 7.27 |
| Bowfin | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | 5 | 1.67 | 0.92 |
| Skipjack herring | | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Gizzard shad* | | | | | | | | | | | | | | | | | | 367 | 122.33 | 83.29 |
| Threadfin shad | | | | | | | | | | | | | | | | | | 10 | 3.33 | 1.62 |
| Grass carp | 1 | | | 1 | | | | | | | | | | | | | 1 | 4 | 1.33 | 1.02 |
| Common carp | 1 | | | | | | | | | | | | | | | | | 5 | 1.67 | 1.15 |
| Silver carp | 1 | 1 | | 2 | 1 | | | 1 | | 1 | 2 | 1 | 1 | 3 | 1 | 1 | | 115 | 38.33 | 17.24 |
| Emerald shiner* | | | | | | | | | | | | | | | | | | 130 | 43.33 | 34.83 |
| Spottail shiner | | | | | | | | | | | | | | | | | | 4 | 1.33 | 1.02 |
| Spotfin shiner | | | | | | | | | | | | | | | | | | 10 | 3.33 | 2.64 |
| Bullhead minnow | | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| River Carpsucker | | | | | | | | | | | | | | | | | | 5 | 1.67 | 0.77 |
| Northern hog sucker | | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Smallmouth buffalo | 1 | 1 | | | | | | | | | | | | | | | | 38 | 12.67 | 3.26 |
| Bigmouth buffalo | | | | | | | | | | | | | | | | | | 12 | 4 | 1.56 |
| Black buffalo | | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Spotted sucker | | | | | | | | | | | | | | | | | | 3 | 1 | 0.72 |
| Shorthead redhorse | | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Greater redhorse | | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.67 |
| Channel catfish | | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Flathead catfish | | 1 | 1 | | | | | | | | | | | 1 | | | | 12 | 4 | 1.3 |
| Inland silverside | | | | | | | | | | | | | | | | | | 3 | 1 | 1 |
| White bass | | | | | | | | | | | | | | | | | | 4 | 1.33 | 0.75 |
| Yellow bass | | | | | | | | | | | | | | | | | | 8 | 2.67 | 1.33 |
| Green sunfish | | | | | | | | | | | | | | | | | | 7 | 2.33 | 1.34 |
| Orangespotted sunfish | | | | | | | | | | | | | | | | | | 8 | 2.67 | 1.66 |
| Bluegill | | | | | | | | | | | | | | | | | | 90 | 30 | 5.62 |
| Longear sunfish | | | | | | | | | | | | | | | | | | 74 | 24.67 | 6.93 |
| Redear sunfish | | | | | | | | | | | | | | | | | | 7 | 2.33 | 1.15 |
| Smallmouth bass | | | | | | | | | | | | | | | | | | 40 | 13.33 | 3.2 |
| Spotted bass | | | | | | | | | | | | | | | | | | 33 | 11 | 4.15 |
| Largemouth bass | | | | | | | | | | | | | | | | | | 229 | 76.33 | 7.93 |
| White crappie | | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Black crappie | | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Freshwater drum | 1 | | | | | | 1 | | | | | | | | | | | 6 | 2 | 0.92 |
| Chestnut lamprey | | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |

* species were randomly subsampled

Table 6. Species composition, length frequency and CPUE (fish/hr) of fish collected during 0.92 hours of electrofishing at the Barkley Tailwater in spring of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Spotted gar | | | | | | | | | | | | | | | 1 | 1 | | | | |
| Longnose gar | | | | | | | | | | | | | 1 | | | | 2 | 3 | 5 | 1 |
| Shortnose gar | | | | | | | | | | | | | | 1 | 3 | 4 | 3 | 1 | | 1 |
| American eel | | | | | | | | | | | | | | | | 1 | 1 | | | |
| Skipjack herring | | 1 | 1 | | | | | | 2 | | | | | | | | | | | |
| Gizzard shad | | | | | 5 | 4 | 3 | 5 | 1 | | | | | | | | | | | |
| Grass carp | | | | | | | | | | | | | | | 1 | | | | | |
| Common carp | | | | | | | | | | | | | | | | | | | | |
| Silver carp | | | | | | | | | | | | | | | | | | | 1 | |
| Emerald shiner | | 2 | 7 | | | | | | | | | | | | | | | | | |
| River shiner | 1 | | | | | | | | | | | | | | | | | | | |
| Spotfin shiner | | 1 | | | | | | | | | | | | | | | | | | |
| Smallmouth buffalo | | | | | | | 2 | | | | | | 2 | | 2 | 8 | 6 | 1 | | 1 |
| Bigmouth buffalo | | | | | | | | | | | 1 | 1 | | | | | | | | |
| Flathead catfish | | | | | | | | 1 | 1 | | 1 | | 2 | | | | | | | |
| White bass | | | | | | | | | 3 | | | | | 2 | 1 | | | | | |
| Yellow bass | | | | | | 4 | | | | | | | | | | | | | | |
| Green sunfish | | | | 1 | 1 | | | | | | | | | | | | | | | |
| Bluegill | | | 5 | 22 | 12 | 12 | 4 | | | | | | | | | | | | | |
| Longear sunfish | 5 | 3 | 60 | 83 | 29 | 3 | | | | | | | | | | | | | | |
| Redear sunfish | | | | | 7 | 3 | 5 | 2 | 1 | 1 | 1 | | | | | | | | | |
| Smallmouth bass | | | | | | 2 | 1 | | | | | | | | | | | | | |
| Largemouth bass | | | | 1 | 2 | 18 | 39 | 26 | 16 | 6 | 1 | 4 | 3 | 6 | 7 | 8 | 7 | 3 | 5 | |
| Freshwater drum | | | | | | | | | | | | | | | | 1 | | 1 | | |

Table 6 continued. Species composition, length frequency and CPUE (fish/hr) of fish collected during 0.92 hours of electrofishing at the Barkley Tailwater in spring of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 25 | 26 | 28 | 29 | 31 | 33 | 35 | TOTAL | CPUE | STE |
| Spotted gar | | | | | | | | | | | 2 | 2 | 2 |
| Longnose gar | | 1 | | | 1 | | | 1 | | 1 | 16 | 16 | 10.83 |
| Shortnose gar | | | | 2 | 1 | | | | | | 16 | 16 | 9.66 |
| American eel | | | | | | | | | | | 2 | 2 | 2 |
| Skipjack herring | | | | | | | | | | | 4 | 4 | 1.63 |
| Gizzard shad | | | | | | | | | | | 18 | 18 | 14.09 |
| Grass carp | | | | | | | | | | | 1 | 1 | 1 |
| Common carp | | | | | | 1 | | | | | 1 | 1 | 1 |
| Silver carp | | 1 | 2 | | | 3 | 1 | 1 | 1 | | 10 | 10 | 2.58 |
| Emerald shiner | | | | | | | | | | | 9 | 9 | 7.72 |
| River shiner | | | | | | | | | | | 1 | 1 | 1 |
| Spotfin shiner | | | | | | | | | | | 1 | 1 | 1 |
| Smallmouth buffalo | | | | | | | | | | | 22 | 22 | 3.46 |
| Bigmouth buffalo | | | | | | | | | | | 2 | 2 | 1.15 |
| Flathead catfish | 1 | | | | | | | | | | 6 | 6 | 2.58 |
| White bass | | | | | | | | | | | 6 | 6 | 3.46 |
| Yellow bass | | | | | | | | | | | 4 | 4 | 4 |
| Green sunfish | | | | | | | | | | | 2 | 2 | 1.15 |
| Bluegill | | | | | | | | | | | 55 | 55 | 26.9 |
| Longear sunfish | | | | | | | | | | | 183 | 183 | 83.58 |
| Redear sunfish | | | | | | | | | | | 20 | 20 | 5.89 |
| Smallmouth bass | | | | | | | | | | | 3 | 3 | 3 |
| Largemouth bass | 3 | | | | | | | | | | 155 | 155 | 35.27 |
| Freshwater drum | | | | | | | | | | | 2 | 2 | 2 |

Table 7. Species composition, length frequency and CPUE (fish/hr) of fish collected during 4.5 hours of electrofishing at the Kentucky Tailwater in fall of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Spotted gar | | | | | | | | | | | | | | | | | | | | |
| Longnose gar | | | | | | | | | | | | | | | | | | | 1 | 2 |
| Shortnose gar | | | | | | | | | | | | | | | 1 | | 1 | | 1 | 1 |
| Bowfin | | | | | | | | | | | | | | | | | | | | |
| American eel | | | | | | | | | | | | | | | | 1 | 1 | 1 | | |
| Skipjack herring* | | | | 18 | 25 | 11 | 8 | | | | | | 1 | | | | | | | |
| Gizzard shad* | | | | | | | 5 | 24 | 39 | 56 | 60 | 20 | 9 | 3 | | | | | | |
| Threadfin shad* | | 43 | 71 | 4 | 5 | 2 | | | | | | | | | | | | | | |
| Grass carp | | | | | | | | | | | | | | | | | 2 | 1 | | 2 |
| Silver carp | | | | | | | | | | | | 2 | | | 2 | | 1 | 2 | | 1 |
| Golden shiner | | | | 1 | | | | | | | | | | | | | | | | |
| Emerald shiner | | 1 | | | | | | | | | | | | | | | | | | |
| Bluntnose minnow | | 1 | | | | | | | | | | | | | | | | | | |
| River carpsucker | | | | | | | | | | | | | | 1 | | | | | | |
| Smallmouth buffalo | | | | | | | | | | | | 1 | 3 | 3 | | 3 | | | 2 | 2 |
| Bigmouth buffalo | | | | | | | | | | | | 2 | | 1 | | | | | | |
| Black buffalo | | | | | | | | | | | | | | | | | | | 1 | |
| Spotted sucker | | | | | | | | | | | 1 | | | | | | | | | |
| Blue catfish | | | | | | | | | | | | | | | | | | | | |
| Channel catfish | | | | | | 1 | 2 | | | | | | 1 | | | | | | | |
| Flathead catfish | | | | | | | | 1 | 2 | 5 | 2 | | 2 | 1 | | 1 | 1 | 1 | 1 | |
| Inland silverside | | | 4 | | | | | | | | | | | | | | | | | |
| White bass | | | | | | | | | | | 1 | | | | | 1 | | | | |
| Yellow bass | | | 16 | 2 | 18 | 22 | 35 | 23 | 1 | | | | | | | | | | | |
| Striped bass | | | 3 | | 3 | 1 | | | | | | | | | | | | | | |
| Green sunfish | | | 2 | 4 | 3 | 3 | 1 | | | | | | | | | | | | | |
| Warmouth | | | | 1 | 1 | | 1 | | | | | | | | | | | | | |
| Orangespotted sunfish | | 3 | 3 | | | | | | | | | | | | | | | | | |
| Bluegill* | | 40 | 46 | 64 | 75 | 25 | 17 | 1 | | | | | | | | | | | | |
| Longear sunfish* | | 11 | 64 | 90 | 41 | 2 | | | | | | | | | | | | | | |
| Redear sunfish | | | | 3 | 8 | 8 | 9 | | | | | | | | | | | | | |
| Smallmouth bass | | 1 | 5 | 11 | 14 | 8 | 4 | 3 | | | 1 | | | | | | | | | 1 |
| Spotted bass | | | | 1 | 4 | 3 | 4 | 1 | | | | | | 1 | | | | | | |
| Largemouth bass | | | 1 | 1 | 10 | 15 | 13 | 6 | 7 | 24 | 26 | 19 | 4 | 1 | 7 | 6 | 3 | 6 | 5 | |
| White crappie | | | | | | | | | 1 | 1 | | | | 1 | | | | | | |
| Black crappie | | | | | | 1 | | 7 | 4 | | | | | | | | | | | |
| Yellow perch | | | | | | | | | 2 | | | | | | | | | | | |
| Logperch | | | 8 | 34 | 5 | | | | | | | | | | | | | | | |
| Sauger | | | | | | | | | 1 | | | | | 1 | | 1 | | | | |
| Freshwater drum | | | | 1 | | | | | | | | | | | 2 | 1 | 1 | 3 | | |
| White bass/Striped bass hybrid | | | | | | 3 | | | | | | | | | | | | | | |
| Notropis spp. | | | | 1 | | | | | | | | | | | | | | | | |
| Atlantic needlefish | | | | | | | | | | | | 1 | | | | | | | | |

* species were randomly subsampled

Table 7 continued. Species composition, length frequency and CPUE (fish/hr) of fish collected during 4.5 hours of electrofishing at the Kentucky Tailwater in fall of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 36 | 37 | 41 | 43 | TOTAL | CPUE | S.E. |
| Spotted gar | | 1 | 1 | | | | | | | | | | | | | 2 | 0.44 | 0.3 |
| Longnose gar | 4 | 2 | 3 | | 1 | 3 | | 4 | 1 | 1 | 1 | 2 | 1 | | | 26 | 5.78 | 2.61 |
| Shortnose gar | | | 1 | | 2 | 2 | 1 | | | | 1 | | | | | 11 | 2.44 | 1.68 |
| Bowfin | | | 1 | 1 | | 1 | | | | | | | | | | 3 | 0.67 | 0.36 |
| American eel | | | | | | | | | | | | | | | | 3 | 0.67 | 0.67 |
| Skipjack herring* | | | | | | | | | | | | | | | | 81 | 18 | 9.45 |
| Gizzard shad* | | | | | | | | | | | | | | | | 733 | 163 | 61.1 |
| Threadfin shad* | | | | | | | | | | | | | | | | 5683 | 1263 | 637 |
| Grass carp | | | | | | | | | | | | | | 1 | 1 | 7 | 1.56 | 0.66 |
| Silver carp | 1 | 2 | 2 | 2 | | 1 | | 1 | 1 | | | 1 | | | | 19 | 4.22 | 1.57 |
| Golden shiner | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |
| Emerald shiner | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |
| Bluntnose minnow | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |
| River carpsucker | | 1 | | | | | | | | | | | | | | 2 | 0.44 | 0.3 |
| Smallmouth buffalo | 3 | 1 | 1 | | 2 | 1 | | | | | | | | | | 22 | 4.89 | 2.08 |
| Bigmouth buffalo | | | | | | | | | | | | | | | | 3 | 0.67 | 0.36 |
| Black buffalo | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |
| Spotted sucker | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |
| Blue catfish | | | | | | | | | | 1 | | | | | | 1 | 0.22 | 0.22 |
| Channel catfish | | | | | | | | | | | | | | | | 4 | 0.89 | 0.89 |
| Flathead catfish | | | | | | | | 2 | | | | | | | | 19 | 4.22 | 1.39 |
| Inland silverside | | | | | | | | | | | | | | | | 4 | 0.89 | 0.61 |
| White bass | | | | | | | | | | | | | | | | 2 | 0.44 | 0.3 |
| Yellow bass | | | | | | | | | | | | | | | | 117 | 26 | 4.06 |
| Striped bass | | | | | | | | | | | | | | | | 7 | 1.56 | 0.98 |
| Green sunfish | | | | | | | | | | | | | | | | 13 | 2.89 | 0.78 |
| Warmouth | | | | | | | | | | | | | | | | 3 | 0.67 | 0.49 |
| Orangespotted sunfish | | | | | | | | | | | | | | | | 6 | 1.33 | 0.65 |
| Bluegill* | | | | | | | | | | | | | | | | 575 | 128 | 30.7 |
| Longear sunfish* | | | | | | | | | | | | | | | | 359 | 79.8 | 25 |
| Redear sunfish | | | | | | | | | | | | | | | | 28 | 6.22 | 1.62 |
| Smallmouth bass | | | | | | | | | | | | | | | | 48 | 10.7 | 3.2 |
| Spotted bass | | | | | | | | | | | | | | | | 14 | 3.11 | 1.43 |
| Largemouth bass | | | | | | | | | | | | | | | | 157 | 34.9 | 4.31 |
| White crappie | | | | | | | | | | | | | | | | 3 | 0.67 | 0.36 |
| Black crappie | | | | | | | | | | | | | | | | 12 | 2.67 | 1.68 |
| Yellow perch | | | | | | | | | | | | | | | | 2 | 0.44 | 0.3 |
| Logperch | | | | | | | | | | | | | | | | 47 | 10.4 | 2.59 |
| Sauger | | | | | | | | | | | | | | | | 3 | 0.67 | 0.36 |
| Freshwater drum | | | | | | | | | | | | | | | | 17 | 3.78 | 0.68 |
| White bass/Striped bass hybrid | | | | | | | | | | | | | | | | 3 | 0.67 | 0.49 |
| Notropis spp. | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |
| Atlantic needlefish | | | | | | | | | | | | | | | | 1 | 0.22 | 0.22 |

Table 8. Species composition, length frequency and CPUE (fish/hr) of fish collected during 3.0 hours of electrofishing at the Barkley Tailwater in fall of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Spotted gar | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Longnose gar | | | | | | | | | | | | | | | | | | 1 | | 2 |
| Shortnose gar | | | | | | | | | | | | | | | | | | | | 1 |
| American eel | | | | | | | | | | | | | | | | | | | | |
| Skipjack herring | | | 1 | 2 | 8 | 4 | 6 | 2 | | | | | | | | | | | | |
| Gizzard shad* | | | | | 13 | 5 | 25 | 67 | 51 | 20 | 15 | 7 | 1 | 2 | | 1 | | | | |
| Threadfin shad* | | 34 | 100 | 43 | 12 | 7 | | | | | | | | | | | | | | |
| Grass carp | | | | | | | | | | | | | | 1 | 1 | | | | | |
| Common carp | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 1 |
| Silver carp | | | | | | | | | | | | 1 | | | 1 | | 2 | 4 | 5 | 2 |
| Golden shiner | | | 1 | | | | | | | | | | | | | | | | | |
| Emerald shiner | | 13 | 42 | 5 | | | | | | | | | | | | | | | | |
| Spottail shiner | | 2 | | | | | | | | | | | | | | | | | | |
| Bluntnose minnow | 1 | | | | | | | | | | | | | | | | | | | |
| River carpsucker | | | | | | | | | | | | | | 1 | 7 | 3 | | 1 | 1 | 1 |
| Blue sucker | | | | | | | | | | | | | | | | | | | | |
| Smallmouth buffalo | | | | | | | | | | | | | 1 | 1 | 2 | 8 | 5 | 3 | 2 | 4 |
| Bigmouth buffalo | | | | | | | | | | | | | | | | | | 1 | | |
| Black buffalo | | | | | | | | | | | | | 1 | | | | | | 1 | |
| Channel catfish | | | | | | | | | | | | | | 1 | | | 1 | | | |
| Flathead catfish | | | 2 | | 2 | | 2 | | 1 | 2 | 6 | 1 | | 1 | | | | | | 1 |
| Inland silverside | | 2 | 22 | 2 | | | | | | | | | | | | | | | | |
| White bass | | | | | | | | | 1 | 3 | 2 | 1 | | 1 | | | | | | |
| Yellow bass* | | | 1 | 1 | 11 | 15 | 32 | 13 | | | | | | | | | | | | |
| Striped bass | | | | 1 | 2 | | | | | | 1 | | | | | 2 | | | | |
| Green sunfish | | | | 1 | 1 | | | | | | | | | | | | | | | |
| Bluegill* | | 23 | 17 | 23 | 48 | 22 | 7 | | | | | | | | | | | | | |
| Longear sunfish* | | 1 | 18 | 88 | 68 | 5 | | | | | | | | | | | | | | |
| Redear sunfish | | | | | | 3 | | | 1 | 3 | 2 | | | | | | | | | |
| Smallmouth bass | | | | 2 | 8 | 5 | 3 | 3 | 1 | 1 | 1 | 2 | | | | | | | | |
| Spotted bass | | | | | | 1 | | | | | | | | | | | | | | |
| Largemouth bass | | | | 5 | 9 | 21 | 11 | 12 | 33 | 24 | 11 | 4 | 5 | 5 | 4 | 9 | 5 | 1 | 6 | 1 |
| White crappie | | | | | 1 | | | | | | | 1 | | 1 | | | | | | |
| Black crappie | | | | | | | 1 | | 2 | 1 | 1 | | | | | | | | | |
| Freshwater drum | | | | | | | | | | | | | | 1 | 1 | 4 | 2 | 2 | 2 | 1 |
| White bass/Striped bass hybrid | | | | | | | 1 | | | | 2 | 2 | 3 | 1 | 1 | | | | | |
| Notropis spp. | | 2 | 7 | | | | | | | | | | | | | | | | | |

* species were randomly subsampled

Table 8 continued. Species composition, length frequency and CPUE (fish/hr) of fish collected during 3.0 hours of electrofishing at the Barkley Tailwater in fall of 2017. (CPUE = catch per unit effort; S.E. = standard error)

| Species | Inch Class | | | | | | | | | | | | | | | | TOTAL | CPUE | STE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | | | |
| Spotted gar | | 1 | | | 1 | 1 | | | | | | | | | | | 5 | 1.67 | 0.92 |
| Longnose gar | 1 | | 1 | 3 | 1 | 1 | | 4 | 3 | 3 | 1 | | 1 | | 1 | 1 | 24 | 8 | 4.59 |
| Shortnose gar | | | | 3 | | | | | | | | | | | | | 4 | 1.33 | 0.57 |
| American eel | | | | | | 1 | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Skipjack herring | | | | | | | | | | | | | | | | | 23 | 7.67 | 2.93 |
| Gizzard shad* | | | | | | | | | | | | | | | | | 313 | 104.33 | 18.19 |
| Threadfin shad* | | | | | | | | | | | | | | | | | 3757 | 1252.3 | 602.1 |
| Grass carp | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Common carp | | | | 1 | | 1 | | | | | | | | | | | 9 | 3 | 1.11 |
| Silver carp | 2 | 3 | 1 | | | 2 | 4 | | 6 | 3 | 2 | 2 | | 1 | | | 41 | 13.67 | 7.65 |
| Golden shiner | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Emerald shiner | | | | | | | | | | | | | | | | | 60 | 20 | 9.7 |
| Spottail shiner | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.67 |
| Bluntnose minnow | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| River carpsucker | 2 | | | | | | | | | | | | | | | | 16 | 5.33 | 3.76 |
| Blue sucker | | | | 1 | | | 1 | | | | | | | | | | 2 | 0.67 | 0.45 |
| Smallmouth buffalo | 2 | | | | | 1 | | | | | | | | | | | 29 | 9.67 | 2.67 |
| Bigmouth buffalo | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Black buffalo | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.67 |
| Channel catfish | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Flathead catfish | | | | | | | | | | | | | | | | | 18 | 6 | 3.06 |
| Inland silverside | | | | | | | | | | | | | | | | | 26 | 8.67 | 4.23 |
| White bass | | | | | | | | | | | | | | | | | 8 | 2.67 | 1.14 |
| Yellow bass* | | | | | | | | | | | | | | | | | 84 | 28 | 15.95 |
| Striped bass | | | | | | | | | | | | | | | | | 6 | 2 | 1.35 |
| Green sunfish | | | | | | | | | | | | | | | | | 2 | 0.67 | 0.45 |
| Bluegill* | | | | | | | | | | | | | | | | | 167 | 55.67 | 14.61 |
| Longear sunfish* | | | | | | | | | | | | | | | | | 249 | 83 | 16.75 |
| Redear sunfish | | | | | | | | | | | | | | | | | 9 | 3 | 1.22 |
| Smallmouth bass | | | | | | | | | | | | | | | | | 26 | 8.67 | 1.19 |
| Spotted bass | | | | | | | | | | | | | | | | | 1 | 0.33 | 0.33 |
| Largemouth bass | | | | | | | | | | | | | | | | | 166 | 55.33 | 10.27 |
| White crappie | | | | | | | | | | | | | | | | | 3 | 1 | 0.72 |
| Black crappie | | | | | | | | | | | | | | | | | 5 | 1.67 | 1.34 |
| Freshwater drum | | 1 | | | | | | | | | | | | | | | 14 | 4.67 | 1.54 |
| White bass/Striped bass hybrid | | | | | | | | | | | | | | | | | 10 | 3.33 | 2.3 |
| Notropis spp. | | | | | | | | | | | | | | | | | 9 | 3 | 3 |

Table 9. Relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2015-2017. (S.E. = standard error)

| Species | Kentucky Lake TW 2015 | | | Kentucky Lake TW 2016 | | | Kentucky Lake TW 2017 | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean *Wr* | S.E. | N | Mean *Wr* | S.E. | N | Mean *Wr* | S.E. |
| Gizzard shad | 19 | 76 | 2.5 | 45 | 72 | 1.6 | 215 | 83 | 0.7 |
| Blue catfish | | | | | | | 1 | 108 | |
| Channel catfish | | | | 1 | 102 | | 1 | 105 | |
| White bass | 7 | 92 | 4.1 | 13 | 99 | 2.6 | 2 | 97 | 20.4 |
| White bass/Striped bass hybrid | | | | 2 | 81 | 7.5 | | | |
| Bluegill | 69 | 88 | 1.7 | 49 | 103 | 3.7 | 220 | 93 | 2.2 |
| Redear sunfish | 1 | 98 | 0.0 | 10 | 85 | 6.9 | 28 | 93 | 3.3 |
| Smallmouth bass | 6 | 93 | 3.1 | 13 | 91 | 2.0 | 9 | 92 | 3.4 |
| Spotted bass | 1 | 103 | 0.0 | 1 | 123 | | 6 | 109 | 3.1 |
| Largemouth bass | 42 | 102 | 3.2 | 89 | 102 | 1.7 | 117 | 97 | 1.9 |
| White crappie | 2 | 79 | 0.9 | 2 | 90 | 8.7 | 3 | 76 | 7.3 |
| Black crappie | 1 | 91 | 0.0 | | | | 12 | 90 | 2.7 |
| Yellow perch | | | | | | | 2 | 67 | 4.9 |
| Sauger | 1 | 87 | 0.0 | | | | 3 | 97 | 21.8 |
| Freshwater drum | 12 | 91 | 5.4 | 11 | 100 | 2.7 | 17 | 92 | 3.3 |
| Silver carp | 6 | 84 | 2.3 | 75 | 89 | 1.6 | 19 | 82 | 2.4 |

Table 10. Relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2016 and 2017. (S.E. = standard error)

| Species | Lake Barkley TW 2016 | | | Lake Barkley TW 2017 | | |
|---|---|---|---|---|---|---|
| | N | Mean *Wr* | S.E. | N | Mean *Wr* | S.E. |
| Gizzard shad | 96 | 70 | 1.6 | 176 | 80 | 0.9 |
| Channel catfish | 1 | 67 | | 2 | 92 | 1.0 |
| White bass | 11 | 96 | 3.7 | 8 | 86 | 2.2 |
| Striped Bass | | | | 2 | 90 | 5.9 |
| White bass/Striped bass hybrid | | | | 9 | 89 | 2.7 |
| Bluegill | 49 | 111 | 3.1 | 107 | 104 | 2.5 |
| Redear sunfish | 17 | 93 | 2.1 | 9 | 97 | 3.7 |
| Smallmouth bass | 4 | 86 | 3.6 | 11 | 95 | 3.8 |
| Spotted bass | 3 | 107 | 11.0 | | | |
| Largemouth bass | 37 | 101 | 1.9 | 118 | 95 | 1.2 |
| White crappie | | | | 3 | 88 | 6.6 |
| Black crappie | | | | 5 | 86 | 6.3 |
| Sauger | | | | | | |
| Freshwater drum | 6 | 84 | 4.4 | 14 | 97 | 3.0 |
| Silver carp | 9 | 81 | 2.9 | 41 | 83 | 2.1 |

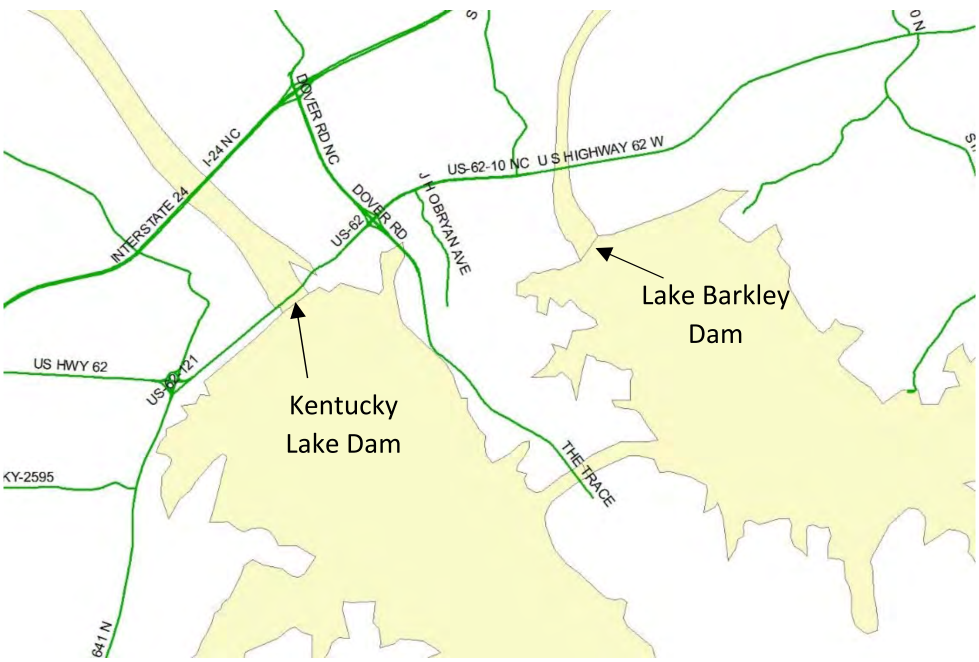


Figure 1. The tailwater electrofishing and creel survey at Kentucky Lake Tailwater extended from the dam downstream to the Interstate 24 bridge. The electrofishing and creel survey at Lake Barkley Tailwater extended from the dam downstream to the US Hwy 62 bridge.

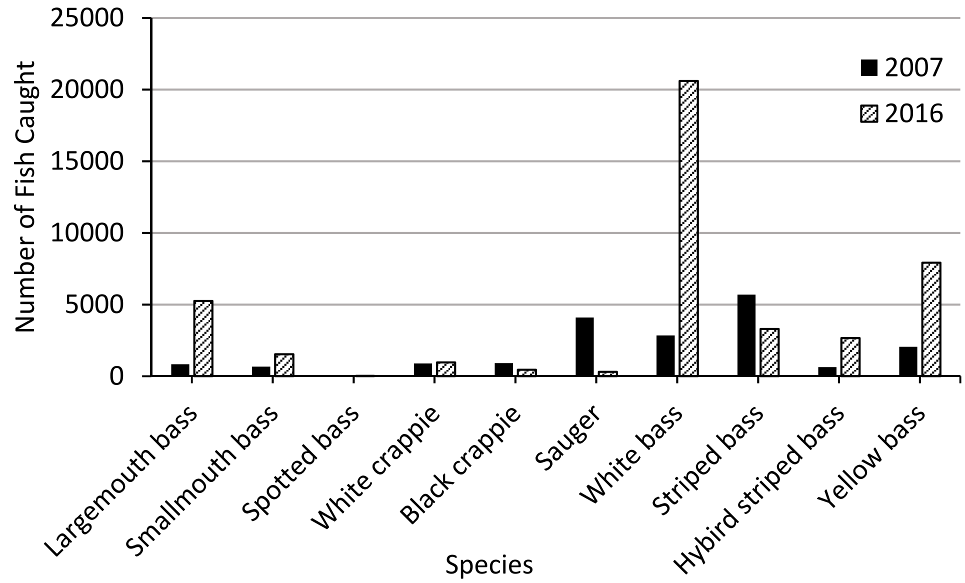


Figure 2. Estimated number of sport fish caught by species during creel surveys conducted at the Kentucky Tailwater in 2007 and 2016.

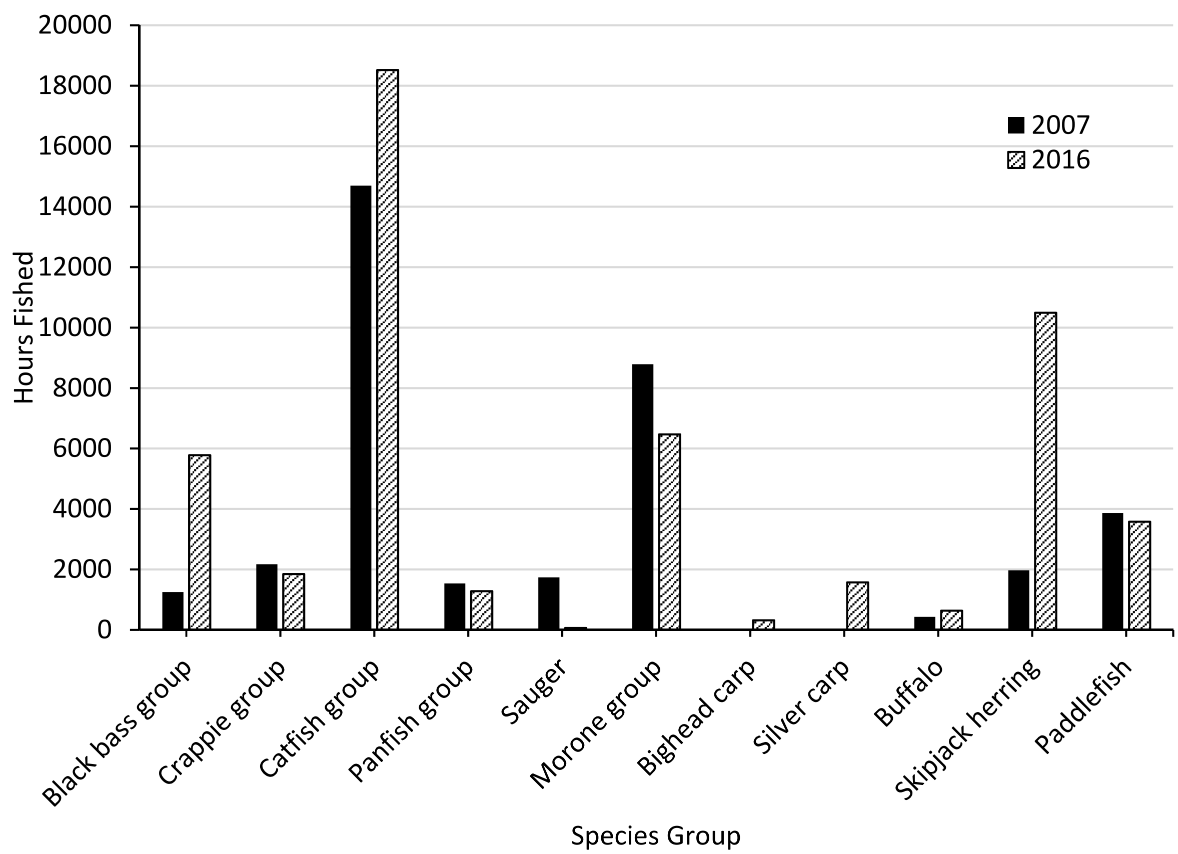


Figure 3. Total hours spent fishing by anglers targeting each species group on Kentucky Tailwater during creel surveys conducted in 2007 and 2016.

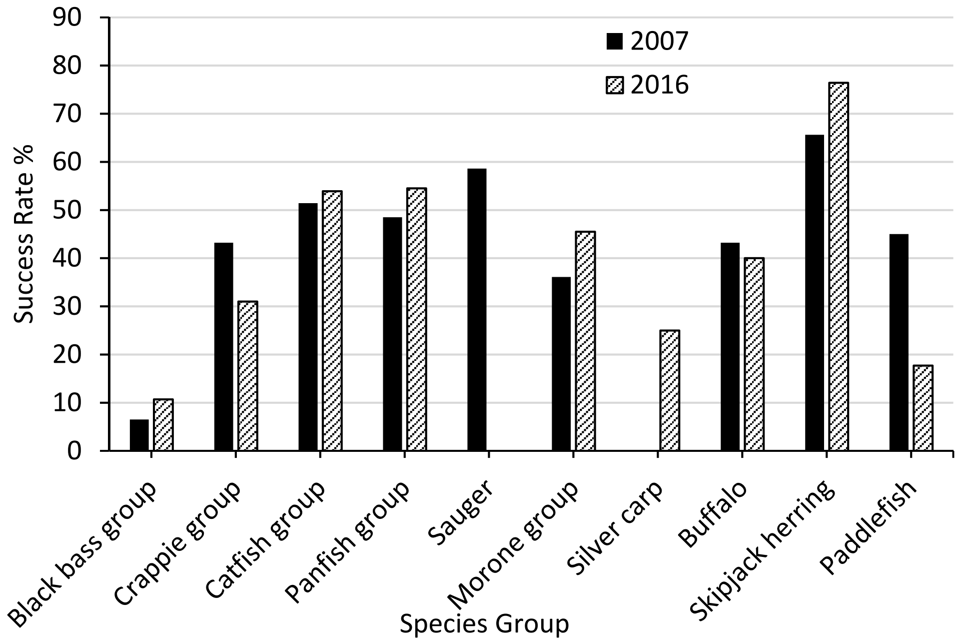


Figure 4. Success rate of anglers targeting specific species groups at Kentucky Tailwater during creel surveys conducted in 2007 and 2016.

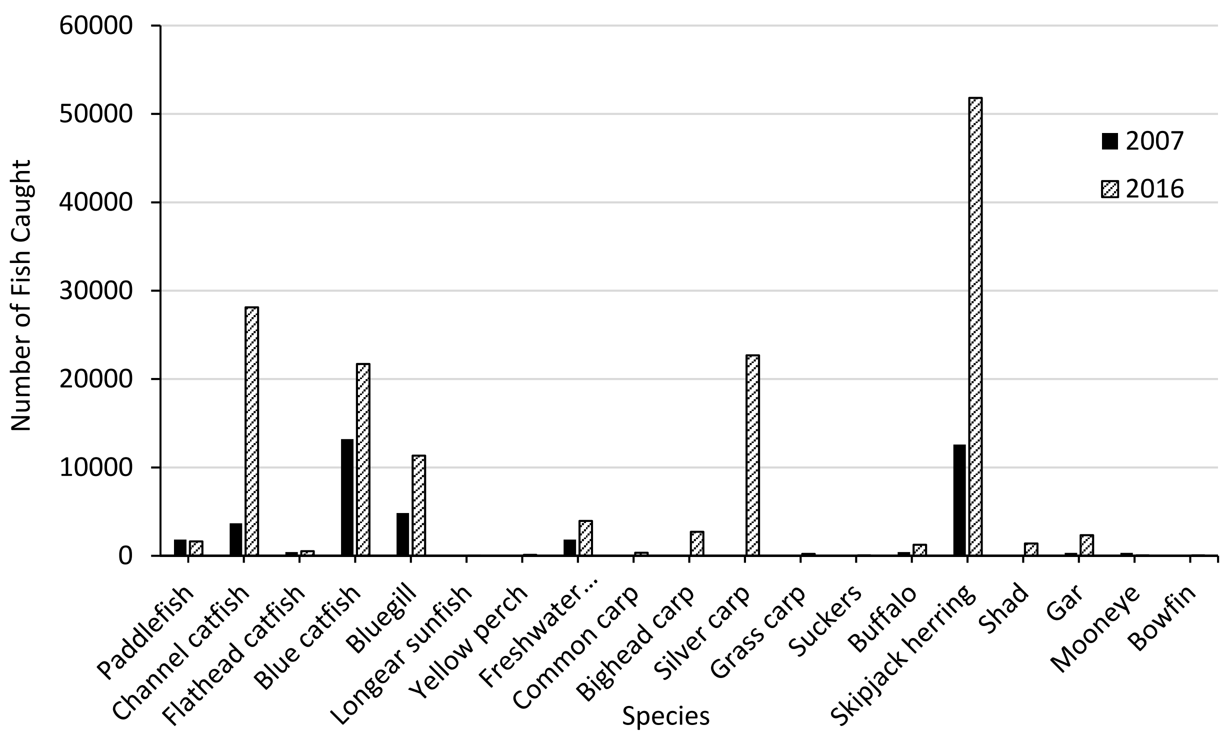


Figure 5. Estimated number of rough fish caught by species during creel surveys conducted at the Kentucky Tailwater in 2007 and 2016.

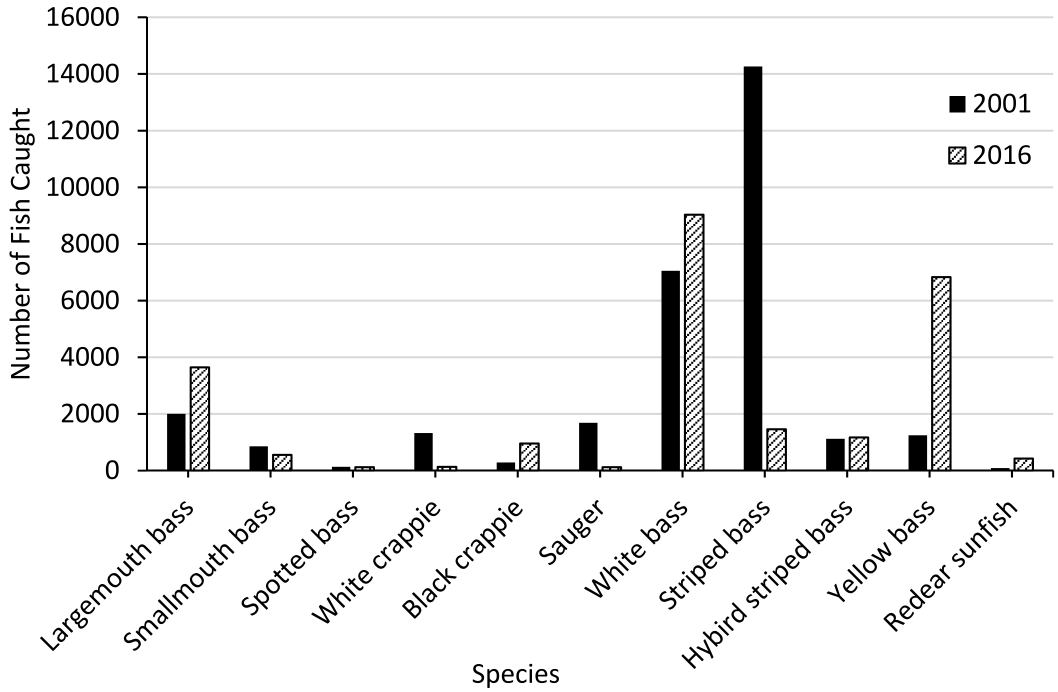


Figure 6. Estimated number of sport fish caught by species during creel surveys conducted at the Barkley Tailwater in 2001 and 2016.

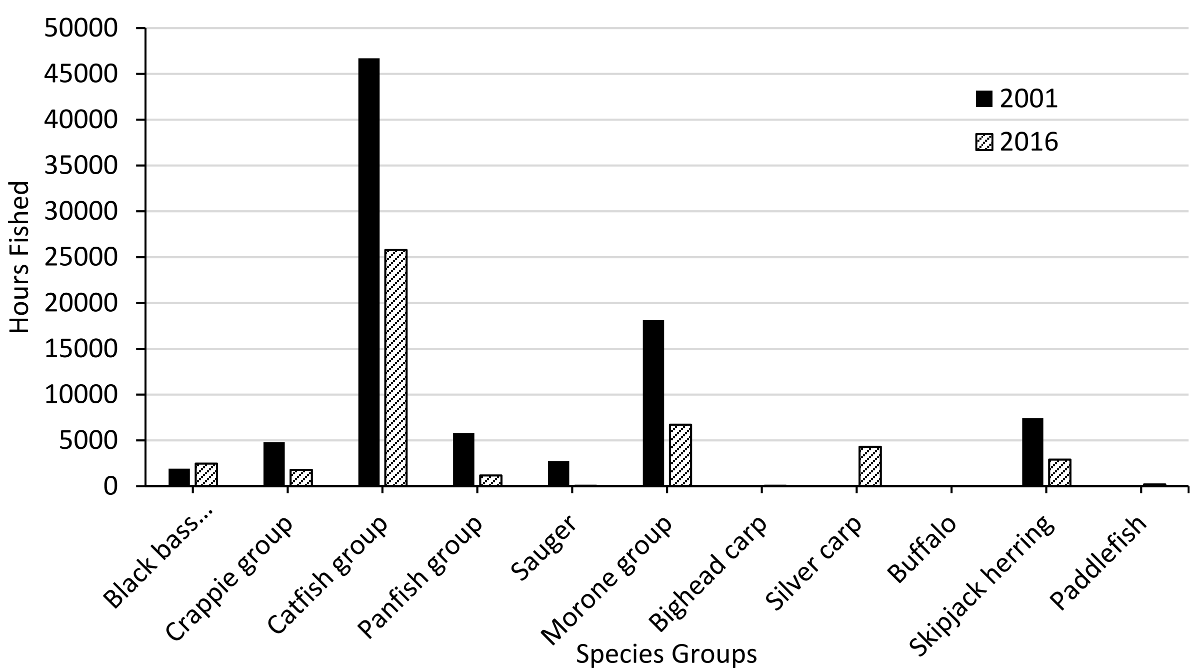


Figure 7. Total hours spent fishing by anglers targeting each species group on Barkley Tailwater during creel surveys conducted in 2001 and 2016.

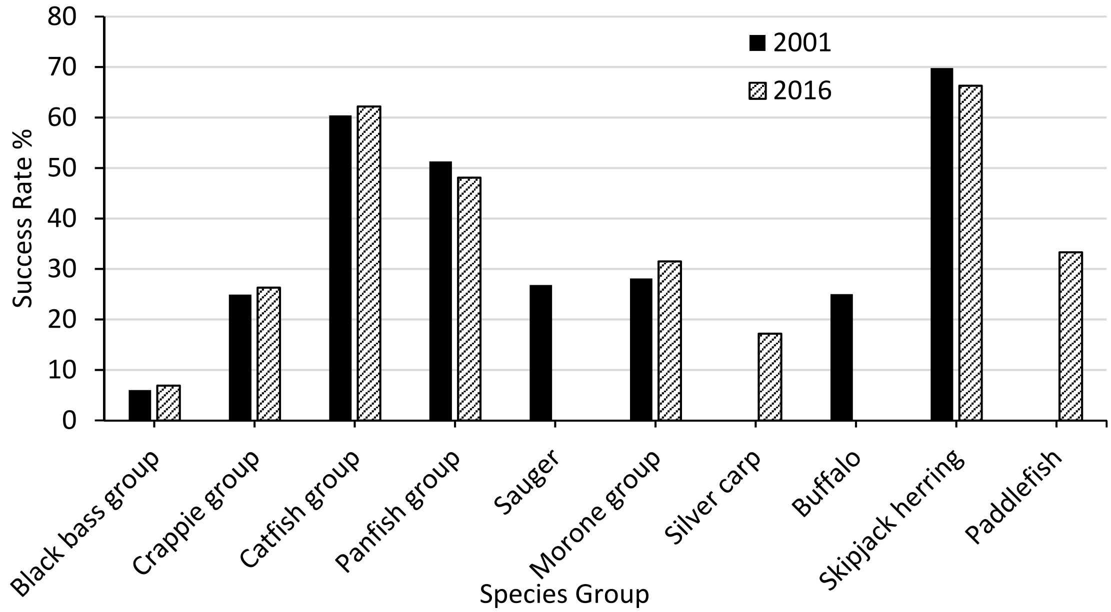


Figure 8. Success rate of anglers targeting specific species groups at Barkley Tailwater during creel surveys conducted in 2001 and 2016.

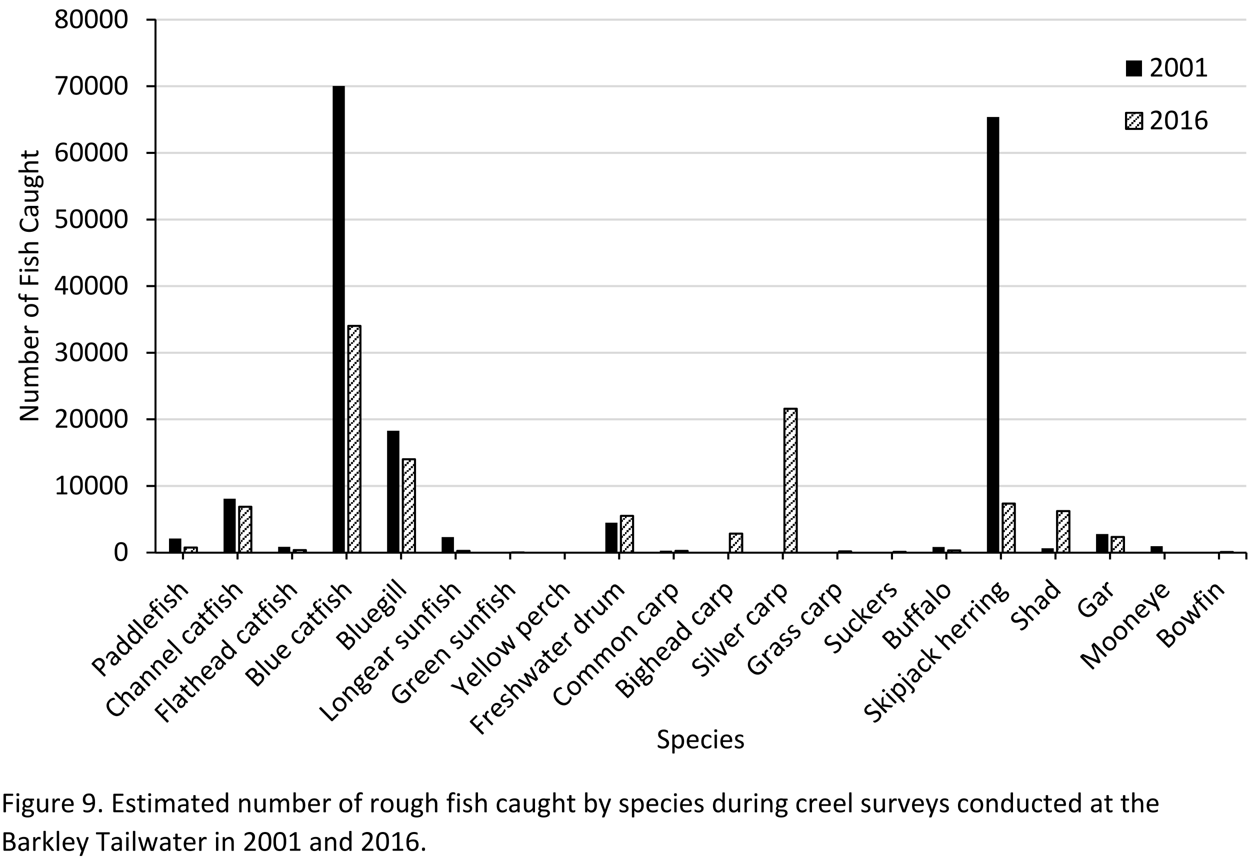


Figure 9. Estimated number of rough fish caught by species during creel surveys conducted at the Barkley Tailwater in 2001 and 2016.

Project 2: Impacts of Asian Carp Harvest Program on Sport Fish in Kentucky

FINDINGS

Asian Carp Harvest Program

The Asian Carp Harvest Program (ACHP) created by the Kentucky Department of Fish and Wildlife Resources (KDFWR) allows qualified commercial fishermen to fish specifically for Asian carp in waters where commercial fishing was previously restricted. However, this report focuses primarily on commercial harvest occurring in Kentucky Lake and Lake Barkley as they account for 98% of Asian carp harvested under the ACHP. The numbers in this report are based on monthly reports submitted by commercial fishermen fishing under the ACHP as they are required to fill out daily logs of their catch. The implementation of the ACHP has been a key element in the increased harvest of silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Hypophthalmichthys nobilis*) from Kentucky waters.

To date, commercial fishermen in Kentucky have harvested a total of 3,974,195 lbs of Asian carp through the ACHP since the program's inception in 2013 (3,901,668 lbs silver carp, 72,527 lbs bighead carp). Fishing seasons in this report correspond to the commercial fishing license year of April – March. The number of commercial fishermen using the ACHP grew in the 2016-2017 fishing season and therefore the amount of effort increased as well (346 fishing trips in the 2015-2016 season, and 558 fishing trips in the 2016-2017 season; Table 1). However, the number of commercial fishermen fishing under to ACHP (15) and the amount of effort (347 fishing trips) declined in the 2017-2018 season (April – December 2017). Harvest of Asian carp has followed this trend with commercial fishermen harvesting 775,461 lbs of Asian carp in the 2015-2016 season, 1,406,310 lbs in the 2016-2017 season and 765,721 lbs of Asian carp harvested thus far in the 2017-2018 season (Figure 1).

The observed decrease in Asian carp harvest is due largely to the inconsistency of Kentucky based Asian carp processors buying fish during the 2017-2018 fishing season. In the spring of 2017 one of the Asian carp processors in western Kentucky temporarily shut their doors. Fishermen reported an inconsistent demand for fish they harvested. Interestingly, processors in western Kentucky indicated that it is the fishermen not producing a steady supply of Asian carp that affects their ability to stay in business.

A very strong year class of silver carp was apparent in 2015 as large numbers of age-0 fish were observed in Kentucky Lake, Lake Barkley, and their associated tailwaters. This cohort was observed in 2016, as 8 to 14-inch size fish, incidentally captured in some commercial gillnets. In 2017, KDFWR staff began catching silver carp from the 2015-year class in experimental gill nets with 3" bar mesh. Commercial fishermen are restricted to using gill nets with a mesh size of 3.5" and larger in order to reduce bycatch of sportfish. Data indicates, that over the next few years, an increase in commercial harvest is probable as the 2015 silver carp cohort recruits to commercial gillnets. The primary method for harvesting Asian carp has been 4 to 5-inch mesh floating gillnets. Although reports indicate the utilization of mesh sizes ranging from 3.5-inch to 7-inches, communications with commercial fishermen suggest that bycatch is high with smaller mesh and larger mesh does not produce the same number of Asian carp as 4 and 5-inch mesh. During ride-alongs with commercial fishermen in 2016, nets with a mesh size of 4.25 inches were the most effective for harvesting silver carp (0.16 fish/yard). However, in 2017 nets with 3.5-inch mesh were the most effective for harvesting silver carp (0.31 fish/yard). This shift may be a result of the 2015-year class of silver carp beginning to become susceptible to the 3.5-

inch mesh (Table 2, Figure 2). It should also be considered that 3.5-inch mesh was only fished on one occasion in 2017 and therefore may have been a localized incident.

Asian carp harvest data was summarized by month of the year from April 2011 to December 2017 (Table 3). As expected, the number of trips made by commercial fishermen under the ACHP consistently decreased during paddlefish season (November-March) and increased again when paddlefish season ended (Figure 3). This shift is expected as many commercial fishermen fish Kentucky Lake and Lake Barkley with a special net permit during paddlefish season, which allows gill netting in the lakes without fishing under the ACHP. As a result, there is some commercial harvest of Asian carp taking place from November through March that is not recorded within the ACHP, but reported on monthly commercial fishing harvest reports. Over the past three seasons (April 2015 – December 2017) the number of trips being taken by commercial fishermen under the ACHP has been highest during the months of June through October (Figure 3). Average silver carp harvest per trip has varied by year peaking in April 2017 (5298 lbs/trip) and May 2016 (3640 lbs/trip) (Table 3). With the exception of the high harvest rate in April, the average silver carp harvest per trip was lower in every month of 2017 than in 2016 (Figure 4). This may be due in part to inexperienced fishermen targeting silver carp, or it could be an indication of changing population dynamics of silver carp in Kentucky and Barkley lakes. Additional information on silver carp population dynamics is presented in the Silver Carp Demographics annual report. Bighead carp average harvest rates were greater in 2017 (range of 0-122 lbs/trip) than in 2016 (range of 1-58 lbs/trip) (Table 3).

Ride-Alongs

KDFWR conducted 31 ride-alongs with commercial fishermen utilizing the ACHP from January through December 2017. Ride-along data is reported by calendar year. During ride-alongs 32,391 yards of gillnet was fished and 75,499 lbs of Asian carp were harvested. The majority of fishing effort during ride-alongs was in Lake Barkley as most commercial fishermen prefer to fish Lake Barkley. The number of ride-alongs in Kentucky Lake decreased from 3 in 2016 to 1 in 2017 (Table 4). The number of ride-alongs on Lake Barkley increased from 22 in 2016 to 28 in 2017, with the mean effort per trip remaining similar to previous years (Table 5). Following the increase in number of ride-alongs, the total weight of silver carp harvested from Lake Barkley also increased in 2017 (69,459 lbs) from 2016 (61,533 lbs). However, the mean weight of silver carp harvested per trip decreased slightly in 2017 (Table 5).

Bighead carp harvest per trip during ride-alongs in Lake Barkley continued to decrease in 2017 (Table 5). Average weight of bighead carp harvested per trip during ride-alongs (25 lbs/trip) was lower than bighead carp harvest averages for the ACHP as a whole in 2017 (56 lbs/trip) (Table 6). The average weight of silver carp harvested per trip during ride-alongs (2,386 lbs/trip) was slightly higher than for the ACHP (2,225 lbs/trip) in 2017 (Table 6).

Waypoints for deployment locations of nets were taken during ride-alongs in 2017 (Figure 5). During ride-alongs commercial fishers set nets primarily along secondary channels and on flats in the main lake. Embayments were fished occasionally when weather conditions did not permit fishing on the main lake or when large schools of Asian carp were observed inside the bays. The northern end of Lake Barkley received the most fishing pressure. This may be a result of the ease of access, as it is shorter distance for commercial fishermen to drive and transport fish. Another factor may be the sinuosity of Lake Barkley at this location which reduces impacts from high winds.

Sport Fish in Bycatch

For this report sport fish includes all fish listed in section one of 301 KAR1:060 and any catfish species. Increased effort by commercial fishermen fishing under the ACHP has translated into a growing amount of bycatch. However, the survival rate (fish that swim away after release) of sport fish increased from the 2011-2012 season (87.5% survival) to the 2012-2013 season (96.3% survival) and has remained relatively high through 2017 (95.5% survival; Table 1). Sport fish survival rates recorded during KDFWR ride-alongs were also high in 2017 (94.5%; Table 7). The ride-along data comes from a much smaller sample size (9% of commercial fishing trips) and the majority of ride-alongs occurred during the summer months when fish are most vulnerable due to higher temperatures. In relation to total bycatch, the number of sport fish captured was low (32% during ride-alongs in 2017; Table 7, 6% from all commercial fishermen reports in April-December 2017; Table 1).

During ride-alongs in 2017 there were 295 individuals captured as bycatch which is a marked decrease from bycatch in 2016 (n=583; Table 7). Although the proportion of sport-fish bycatch increased in 2017 (32%) from 2016 (16%), this did not translate into higher catch rates of sport fish, but decreasing catch rates of rough fish species, particularly smallmouth buffalo. Although catch rates of blue, channel, and flathead catfish increased in 2017, bycatch of striped bass and yellow bass decreased markedly from the previous year (Table 7). No sport fish were captured in Kentucky Lake during the single ride-along effort (Table 8). In Lake Barkley, the total bycatch decreased from the previous year, but the number of sport fish captured increased slightly in 2017 (Table 9). Nonetheless, the survival rate of sport fish bycatch in Lake Barkley increased from 71.4% in 2016 to 92.4% in 2017 (Table 9).

Paddlefish was the most common bycatch species during ride-alongs in 2017 making up 21% of all bycatch, followed by blue catfish and skipjack herring, both of which accounted for 16% (Table 7). The mean survival rate of paddlefish during ride-alongs was 48.4% but varied between water bodies and number captured. Other species of fish that were commonly observed as bycatch included common carp (11% of bycatch) and freshwater drum (9% of bycatch) (Table 7). The most common species of sport fish caught in commercial gillnets during ride-alongs was blue catfish (47 fish), followed by flathead catfish (19 fish), and channel catfish (17 fish) (Table 7). Survival rates of all sport fish remained high (≥80.0%). Only one crappie and very few *Moron*e sp. (3 fish total) were observed in commercial gill nets during ride-alongs in 2017 (Table 7).

A comparison of sport fish bycatch reported by commercial fishermen through monthly reports and information collected during ride-alongs shows a decrease since 2015 in number of sport fish captured per trip for most species (Table 10). The number of sport fish reported captured per trip is slightly higher during ride-alongs than from commercial fishermen reports (Figure 6). However, ride-alongs account for a small percentage of the total number of trips made by commercial fishers (9%). Therefore, the difference in bycatch rates is not significant enough to be of concern at this time. To date, there is no indication of negative impacts on the sport fishery resulting from the ACHP.

Paddlefish Bycatch

As KDFWR monitors sport fish bycatch through the ACHP it also provides the opportunity to monitor other species such as paddlefish. Paddlefish are considered a species of conservation need as their life history traits and value of their roe has potential to result in recruitment overfishing of the population. Consequently, there is a need to limit the impacts of the ACHP on paddlefish. Generally, experienced commercial fishermen can avoid capturing large numbers of paddlefish when they are targeting Asian carp by carefully selecting fishing locations. The number of paddlefish captured is variable over time, but did show an increasing trend from 2013 to 2016 (Table 1) with an alarming 889 paddlefish being captured during the 2015-2016 season. This large increase in the number of paddlefish captured through the ACHP was likely due to the substantial increase in effort that commercial fishermen were expending towards harvesting Asian carp. However, the number of paddlefish reported caught from April 2017 – December 2017 was substantially lower with a similar amount of commercial fishing effort as the 2015-2016 season (346 trips; Table 1). Therefore, the large increase in paddlefish catch in the 2015-2016 season may be more closely linked to the growing number of fishermen attempting to harvest Asian carp. Novice fishermen are less experienced with gillnets and not as knowledgeable in how to avoid capturing paddlefish while targeting Asian carp.

Paddlefish exhibited a relatively low survival rate (48.4% during ride-alongs in 2017, 69.0% total ACHP in 2016-2017) in relation to other species in the bycatch (Tables 1 & 7). However, the number of paddlefish captured during ride-alongs and through the ACHP as a whole in 2017, decreased when compared to 2015 and 2016 (Table 10). Since much of the ACHP effort is during the summer months (i.e. warmer water temperatures), paddlefish are vulnerable bycatch in this fishery. Therefore, water temperatures were recorded during ride-alongs conducted in 2016 and 2017 (Table 11). Another factor identified as possibly affecting paddlefish survival in gillnets was length of time the nets are left in the water (i.e. soak time). From conducting ride-alongs, it has been observed that the soak time of nets varies among fishermen and depends on the location being fished, weather, and water temperature. Overall, fishermen tend to leave nets in the water longer when water temperatures are cooler as it increases catch rates and like most fish, Asian carp will survive longer in the cooler temperatures. It has been observed that since paddlefish have an elongated operculum, it may be more likely for a gillnet to restrict the water flow over their gills than other fish species. However, there did not appear to be a marked difference in the survival rate of paddlefish based on temperature or soak time of nets (Table 11). This may be due to the small sample size and relatively small range of temperatures observed. To increase the sample size, water temperature and soak times will continue to be recorded during ride alongs in 2018.

Asian Carp Subsidy Program

In 2015, KDFWR created a US $0.05/lb subsidy to incentivize the harvest of Asian carp from Kentucky Lake and Lake Barkley. However, commercial fishermen expressed doubts in the effectiveness of the program due to the delayed sign-up process and the inconvenience of KDFWR staff meeting them at predetermined locations. Interest in the program was renewed at the close of paddlefish season in 2016 and four fishermen signed up for the subsidy program. Only one of the fishermen actively participated in the subsidy program making thirty-two trips to the lakes under the program (3 trips to Kentucky Lake and 29 trips to Lake Barkley). These fishing trips, verified by KDFWR personnel for the subsidy, resulted in 93,847 lbs of silver carp, 1,173 lbs of bighead carp, and 355 lbs of grass carp being harvested and sold to local processors. The total KDFWR expenditures toward the subsidy in 2016 was $4,768.76 (Table 12). All commercial fishing effort made under the subsidy was during the summer months when paddlefish season was closed.

In 2017, interest in the subsidy program was again renewed at the close of paddlefish season, with two fishermen signing up to receive subsidy funds. However, with only two fishermen actively participating in the program, KDFWR initiated a reform of the subsidy program in July 2017. The revised subsidy program allowed Asian carp processors to sign up for the subsidy. Processors that participated in the program were required to pay an additional $0.05/lb for Asian carp bought from fishermen who requested to use the program upon calling in their fishing location to KDFWR. This reform allowed any commercial fisher utilizing the ACHP in Kentucky Lake, Lake Barkley, or their associated tailwaters to be eligible to receive subsidy funds. Unfortunately, the programs' revision took longer than expected and the new program was not operable until October 2017. By this time many commercial fishermen were already preparing for the upcoming paddlefish season and were not actively pursuing Asian carp. However, two new fishermen did take advantage of the revised program through the processors; Two Rivers Fisheries and Schafer Fisheries. In 2017, all fishing trips covered under the subsidy program were conducted on Lake Barkley (53 trips). Pounds of Asian carp harvested totaled 204,222 lbs (202,554 lbs silver carp, 993 lbs bighead carp, 675 lbs grass carp) with $10,211.10 of subsidy funds spent in 2017 (Table 12).It is expected there will be renewed interest in the subsidy program at the close of the commercial paddlefish season in 2018.

Table 1. Measures of effort, catch, and bycatch reported by commercial fishermen fishing under the Asian Carp Harvest Program for each commercial fishing season from November 2011 - December 2017. Commercial fishing seasons are defined as April through March of the following year.

| | 2011-2012 | 2012-2013 | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017 | April 2017- December 2017 |
|---|---|---|---|---|---|---|---|
| Number of Days/Trips | 3 | 6 | 74 | 174 | 346 | 558 | 347 |
| Number of fishermen | 1 | 1 | 7 | 11 | 22 | 27 | 15 |
| Total number of bycatch | 174 | 869 | 7050 | 5,036 | 9,926 | 12,388 | 9,683 |
| number of sport fish caught | 8 | 54 | 84 | 221 | 893 | 814 | 538 |
| Sport fish released alive (%) | 87.5 | 96.3 | 98.8 | 96.8 | 94.4 | 92.1 | 95.5 |
| Number of paddlefish caught | 93 | 222 | 93 | 161 | 889 | 545 | 301 |
| Paddlefish released alive (%) | 96.8 | 92.3 | 87.1 | 73.9 | 72.1 | 69.0 | 69.4 |
| Weight silver carp harvested (lbs) | 994 | 2,140 | 242,101 | 780,730 | 742,119 | 1,392,207 | 744,511 |
| Weight bighead carp harvested (lbs) | 820 | 0 | 491 | 3,381 | 33,342 | 14,103 | 21,210 |

Table 2. Number of bighead carp, grass carp, and silver carp captured by gill net mesh size as observed during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program in 2016 and 2017. (CPUE = catch per unit effort)

| Year | Net Mesh Size | Effort (yds) | Silver carp | Silver carp CPUE (fish/yard) | Bighead carp | Grass carp |
|---|---|---|---|---|---|---|
| 2016 | 3.5 | 1883 | 155 | 0.08 | | 17 |
| | 4 | 2067 | 308 | 0.15 | | 1 |
| | 4.25 | 9300 | 1469 | 0.16 | 8 | 12 |
| | 5 | 16983 | 1811 | 0.11 | 44 | 13 |
| | 6 | 1067 | 3 | 0.00 | | |
| 2017 | 3.5 | 200 | 61 | 0.31 | 4 | 1 |
| | 4 | 1983 | 225 | 0.11 | 1 | 1 |
| | 4.25 | 23400 | 3918 | 0.17 | 19 | 31 |
| | 4.5 | 2283 | 68 | 0.03 | | |
| | 5 | 4125 | 212 | 0.05 | 3 | 1 |
| | 5.125 | 400 | 86 | 0.22 | 4 | 2 |

Table 3. Monthly number of fishing trips made and average total weight (lbs) of silver carp and bighead carp harvested per trip as reported by commercial fishermen fishing under the Asian Carp Harvest Program from April 2013 - December 2017. (S.E. = standard error)

| Fishing Season | Month | Number of Trips | Avg silver carp weight | S. E. | Avg bighead carp weight | S. E. |
|---|---|---|---|---|---|---|
| April 2013 - March 2014 | July | 12 | 2441 | 549.6 | 0 | 0.0 |
| | August | 12 | 4827 | 715.2 | 0 | 0.0 |
| | September | 27 | 3463 | 364.5 | 7 | 4.5 |
| | October | 16 | 1907 | 363.5 | 19 | 6.3 |
| | November | 6 | 4738 | 460.2 | 0 | 0.0 |
| April 2014 - March 2015 | April | 3 | 156 | 156.0 | 523 | 423.0 |
| | May | 1 | 1131 | 0.0 | 0 | 0.0 |
| | June | 17 | 7198 | 1164.4 | 0 | 0.0 |
| | July | 29 | 4510 | 627.9 | 15 | 7.8 |
| | August | 30 | 6200 | 936.1 | 24 | 15.6 |
| | September | 42 | 5461 | 705.3 | 2 | 1.7 |
| | October | 38 | 2677 | 218.0 | 0 | 0.0 |
| | January | 1 | 1000 | 0.0 | 0 | 0.0 |
| | February | 3 | 1424 | 210.4 | 93 | 29.2 |
| | March | 10 | 981 | 266.7 | 33 | 9.0 |
| April 2015 - March 2016 | April | 16 | 1830 | 519.4 | 190 | 45.1 |
| | May | 21 | 1995 | 363.1 | 135 | 47.2 |
| | June | 44 | 1532 | 188.8 | 441 | 122.1 |
| | July | 54 | 2413 | 164.8 | 46 | 12.4 |
| | August | 44 | 2359 | 179.9 | 34 | 12.9 |
| | September | 35 | 3039 | 253.1 | 44 | 13.4 |
| | October | 29 | 1922 | 228.6 | 8 | 12.6 |
| | November | 12 | 2808 | 430.7 | 71 | 42.4 |
| | December | 15 | 2234 | 429.8 | 31 | 25.4 |
| | January | 14 | 1092 | 282.9 | 28 | 12.2 |
| | February | 23 | 1551 | 325.9 | 8 | 8.9 |
| | March* | 41 | 2175 | 302.3 | 13 | 7.5 |
| April 2016 - March 2017 | April | 34 | 2086 | 240.0 | 35 | 16.7 |
| | May | 52 | 3640 | 264.2 | 58 | 13.9 |
| | June | 80 | 2986 | 178.8 | 30 | 11.7 |
| | July | 53 | 2220 | 135.4 | 15 | 8.3 |
| | August | 79 | 1887 | 121.6 | 9 | 3.5 |
| | September | 79 | 1890 | 121.9 | 13 | 4.6 |
| | October | 79 | 2582 | 184.6 | 28 | 13.0 |
| | November | 24 | 3435 | 578.2 | 1 | 1.1 |
| | December | 17 | 1627 | 309.8 | 7 | 3.5 |
| | January | 37 | 2369 | 310.1 | 37 | 16.5 |
| | February | 20 | 3346 | 656.8 | 22 | 10.9 |
| | March | 20 | 2295 | 497.9 | 31 | 16.0 |
| April 2017 - December 2017 | April | 24 | 5298 | 510.1 | 24 | 7.0 |
| | May | 22 | 2148 | 169.0 | 32 | 17.2 |
| | June | 91 | 2175 | 185.5 | 52 | 11.6 |
| | July | 73 | 1919 | 164.3 | 46 | 18.6 |
| | August | 57 | 1752 | 203.6 | 122 | 33.6 |
| | September | 45 | 1777 | 208.7 | 57 | 25.3 |
| | October | 29 | 1660 | 105.3 | 80 | 36.9 |
| | November | 2 | 524 | 93.0 | 0 | 0.0 |
| | December | 4 | 761 | 208.9 | 0 | 0.0 |

* Commercial fishermen began using the $0.05 / lb subsidy

Table 4. Fishing effort and total weight (lbs) of Asian carp harvested during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program on Kentucky Lake 2015 - 2017. (S.E. = standard error)

| Year | Effort * | Mean effort per trip | S. E. | Number of ride alongs | Number of fishermen | Total WT of silver carp harvested (lbs) | Mean WT of silver carp harvested/trip (lbs) | S. E. | Total WT of bighead carp harvested (lbs) | Mean WT of bighead carp harvested/trip (lbs) | S. E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 10467 | 1047 | 95.6 | 10 | 5 | 16589 | 1659 | 437.3 | 1200 | 120 | 66.6 |
| 2016 | 3117 | 1039 | 374.2 | 3 | 2 | 6064 | 2021 | 1524.8 | 229 | 76 | 30.0 |
| 2017 | 933 | 933 | | 1 | 1 | 0 | 0 | | 0 | 0 | |

*effort is calculated in yards of gillnet fished.

Table 5. Fishing effort and total weight (lbs) of Asian carp harvested during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program on Lake Barkley 2015 - 2017. (S.E. = standard error)

| Year | Effort * | Mean effort per trip | S. E. | Number of ride alongs | Number of fishermen | Total WT of silver carp harvested (lbs) | Mean WT of silver carp harvested/trip (lbs) | S. E. | Total WT of bighead carp harvested (lbs) | Mean WT of bighead carp harvested/trip (lbs) | S. E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 17850 | 1116 | 50.5 | 16 | 5 | 35130 | 2196 | 256.6 | 1608 | 101 | 43.1 |
| 2016 | 25135 | 1143 | 70.4 | 22 | 4 | 61533 | 2797 | 481.8 | 704 | 32 | 13.7 |
| 2017 | 30491 | 1089 | 90.1 | 28 | 8 | 69459 | 2481 | 421.3 | 558 | 20 | 6.3 |

*effort is calculated in yards of gillnet fished.

Table 6. Comparison of the average weight harvested per trip of silver carp and bighead carp during KDFWR ride-alongs, and through commercial fishermen reports for the Asian Carp Harvest Program in 2016 and 2017. (S.E. = standard error)

| | | SC | S. E. | BHC | S. E. |
|---|---|---|---|---|---|
| 2016 | Ride Alongs | 2,280 | 402.2 | 40 | 12.4 |
| | Commercial fishermen reports | 2,329 | 70.6 | 23 | 3.3 |
| 2017 | Ride Alongs | 2,386 | 395.0 | 25 | 8.2 |
| | Commercial fishermen reports | 2,225 | 92.7 | 56 | 7.6 |

Table 7. Species composition, number of individuals captured, and survival rate of bycatch observed during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program in 2016 and 2017.

| | | 2016 | | 2017 | |
|---|---|---|---|---|---|
| | Species | Number captured | Survival rate* | Number captured | Survival rate* |
| Sport Fish | Blue catfish | 27 | 74.1% | 47 | 93.6% |
| | Channel catfish | 10 | 80.0% | 17 | 82.4% |
| | Flathead catfish | 9 | 88.9% | 19 | 100.0% |
| | White bass | 1 | 0.0% | | |
| | Yellow bass | 20 | 50.0% | 1 | 100.0% |
| | Striped bass | 19 | 78.9% | 1 | 100.0% |
| | Hybrid striped bass | 2 | 100.0% | | |
| | Sauger | 1 | 0.0% | 2 | 100.0% |
| | Spotted bass | 1 | 100.0% | | |
| | Largemouth bass | 1 | 100.0% | 5 | 80.0% |
| | White crappie | | | 1 | 100.0% |
| | Total | 91 | 67.2% | 93 | 94.5% |
| Rough Fish | Paddlefish | 83 | 48.2% | 62 | 48.4% |
| | Skipjack herring | 23 | 17.4% | 47 | 12.8% |
| | Smallmouth buffalo | 145 | 99.3% | 13 | 84.6% |
| | Bigmouth buffalo | 8 | 100.0% | 4 | 100.0% |
| | Black buffalo | 17 | 94.1% | | |
| | Common carp | 48 | 97.9% | 33 | 93.9% |
| | Grass carp | 12 | 100.0% | 3 | 66.7% |
| | Gizzard shad | 5 | 0.0% | 3 | 33.3% |
| | Freshwater drum | 76 | 67.1% | 27 | 51.9% |
| | River carpsucker | 3 | 100.0% | | |
| | Redear sunfish | 1 | 100.0% | | |
| | Mooneye | 3 | 0.0% | | |
| | Chestnut lamprey | 1 | 0.0% | | |
| | Threadfin shad | 1 | 0.0% | | |
| | Blue sucker | 49 | 79.6% | | |
| | Longnose gar | 8 | 87.5% | 9 | 44.4% |
| | Shortnose gar | 9 | 44.4% | 1 | 100.0% |
| | Total | 492 | 60.9% | 202 | 63.6% |

* Survival rate of fish is defined as fish that swim away after release.

Table 8. Bycatch numbers and survival rates observed during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program on Kentucky Lake 2015 - 2017.

| Year | Number of ride alongs | Total number of bycatch | Total # of sport fish caught | Sport fish released alive (%) | Total # of paddlefish caught | Paddlefish released alive (%) |
|---|---|---|---|---|---|---|
| 2015 | 10 | 167 | 18 | 94.4 | 55 | 72.7 |
| 2016 | 3 | 15 | 0 | | 6 | 50.0 |
| 2017 | 1 | 6 | 0 | | 0 | |

Table 9. Bycatch numbers and survival rates observed during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program on Lake Barkley 2015 - 2017.

| Year | Number of ride alongs | Total number of bycatch | Total # of sport fish caught | Sport fish released alive (%) | Total # of paddlefish caught | Paddlefish released alive (%) |
|---|---|---|---|---|---|---|
| 2015 | 16 | 385 | 73 | 86.3 | 162 | 46.9 |
| 2016 | 22 | 494 | 84 | 71.4 | 49 | 38.8 |
| 2017 | 28 | 252 | 92 | 92.4 | 32 | 37.5 |

Table 10. Comparison of bycatch of sport fish reported through monthly reports by commercial fishermen fishing under the Asian Carp Harvest Program versus observations made by KDFWR staff during ride-alongs in 2015-2017. (S.E. = standard error)

| | 2015 | | | | | | 2016 | | | | | | 2017 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Totals | | Number captured per trip | | | | Totals | | Number captured per trip | | | | Totals | | Number captured per trip | | | |
| Species | ACHP | Ride-alongs | ACHP | S.E. | Ride-alongs | S.E. | ACHP | Ride-alongs | ACHP | S.E. | Ride-alongs | S.E. | ACHP | Ride-alongs | ACHP | S.E. | Ride-alongs | S.E. |
| Paddlefish | 980 | 361 | 3.46 | 0.52 | 13.88 | 5.31 | 582 | 83 | 1.02 | 0.08 | 2.96 | 0.60 | 314 | 62 | 0.90 | 0.12 | 2.00 | 0.95 |
| Blue catfish | 373 | 67 | 1.32 | 0.25 | 2.09 | 0.63 | 432 | 27 | 0.74 | 0.06 | 1.21 | 0.28 | 260 | 47 | 0.63 | 0.08 | 1.52 | 0.33 |
| Channel catfish | 67 | 26 | 0.24 | 0.05 | 0.81 | 0.19 | 47 | 10 | 0.08 | 0.02 | 0.36 | 0.16 | 28 | 17 | 0.06 | 0.02 | 0.55 | 0.20 |
| Flathead catfish | 194 | 21 | 0.69 | 0.08 | 0.66 | 0.18 | 224 | 9 | 0.38 | 0.04 | 0.39 | 0.17 | 170 | 19 | 0.41 | 0.06 | 0.61 | 0.19 |
| Catfish | 85 | | 0.30 | 0.05 | | | 43 | | 0.07 | 0.02 | | | 70 | | 0.17 | 0.05 | | |
| Bass | 36 | | 0.13 | 0.05 | | | 9 | | 0.02 | 0.02 | | | 10 | | 0.02 | 0.01 | | |
| Largemouth bass | 13 | 7 | 0.05 | 0.20 | 0.22 | 0.12 | 46 | 1 | 0.08 | 0.70 | 0.04 | 0.04 | 4 | 5 | 0.01 | <0.01 | 0.16 | 0.06 |
| Smallmouth bass | | | | | | | 1 | | <0.01 | | | | | | | | | |
| Spotted bass | | | | | | | 1 | 1 | <0.01 | | 0.04 | 0.04 | | | | | | |
| Hybrid striped bass | | | | | | | 2 | 2 | <0.01 | | 0.07 | 0.05 | | | | | | |
| Striped bass | 24 | 4 | 0.08 | 0.03 | 0.13 | 0.06 | 59 | 19 | 0.10 | 0.03 | 0.68 | 0.37 | 8 | 1 | 0.02 | <0.01 | 0.03 | 0.03 |
| Yellow bass | 3 | 3 | 0.01 | 0.01 | 0.09 | 0.70 | 21 | 20 | 0.04 | 0.02 | 0.71 | 0.45 | 1 | 1 | <0.01 | <0.01 | 0.03 | 0.03 |
| White bass | 2 | 2 | 0.01 | 0.01 | 0.06 | 0.06 | 2 | 1 | <0.01 | | 0.07 | 0.05 | | | | | | |
| Rock bass | | | | | | | 9 | | 0.02 | 0.01 | | | | | | | | |
| Sauger | 8 | | 0.03 | 0.02 | | | 1 | 1 | <0.01 | | 0.04 | 0.04 | 1 | 2 | <0.01 | <0.01 | 0.06 | 0.04 |
| Walleye | 1 | | <0.01 | | | | | | | | | | | | | | | |
| Crappie | 9 | | 0.03 | 0.01 | | | 7 | | 0.01 | 0.01 | | | | 1 | | | 0.03 | 0.03 |
| Redear sunfish | 1 | 1 | <0.01 | | 0.03 | 0.03 | 3 | 1 | 0.01 | | 0.04 | 0.04 | 1 | | <0.01 | <0.01 | | |

Table 11. Number and survival rate of paddlefish captured by commercial fishermen during KDFWR ride-alongs under the Asian Carp Harvest Program for each month in 2016 and 2017.

| Year | Month | Number paddlefish captured | % released alive | Mean water temp (°F) | Mean soak time (hours) |
|---|---|---|---|---|---|
| 2016 | January | 0 | | 45 | |
| | February | 0 | | | |
| | March | 4 | 50.0% | 54.4 | |
| | April | 15 | 66.7% | 62.5 | |
| | May | 9 | 55.6% | 69.4 | |
| | June | 44 | 45.5% | 81.9 | |
| | July | 2 | 0.0% | 81.5 | |
| | August | 1 | 100.0% | 81.5 | |
| | September | 8 | 62.5% | 80.5 | |
| | October | 0 | | | |
| | November | 0 | | | |
| | December | 0 | | | |
| 2017 | January | 0 | | | |
| | February | 0 | | | |
| | March | 0 | | | |
| | April | 6 | 0.0% | 67.6 | 13.0 |
| | May | 15 | 33.3% | 68.5 | 10.0 |
| | June | 35 | 60.0% | 79.5 | 8.3 |
| | July | 0 | | | |
| | August | 0 | | | |
| | September | 2 | 50.0% | 74 | 10.0 |
| | October | 0 | | | |
| | November | 0 | | | |
| | December | 4 | 75% | 50 | 21.3 |

Table 12. Summary of expenditures of Subsidy funds under the Asian Carp Harvest Program.

| Year | Total number of trips | Total pounds of Asian Carp caught | Total funds paid out |
|---|---|---|---|
| 2016 | 32 | 95,375 | $ 4,768.76 |
| 2017 | 53 | 204,222 | $ 10,211.10 |

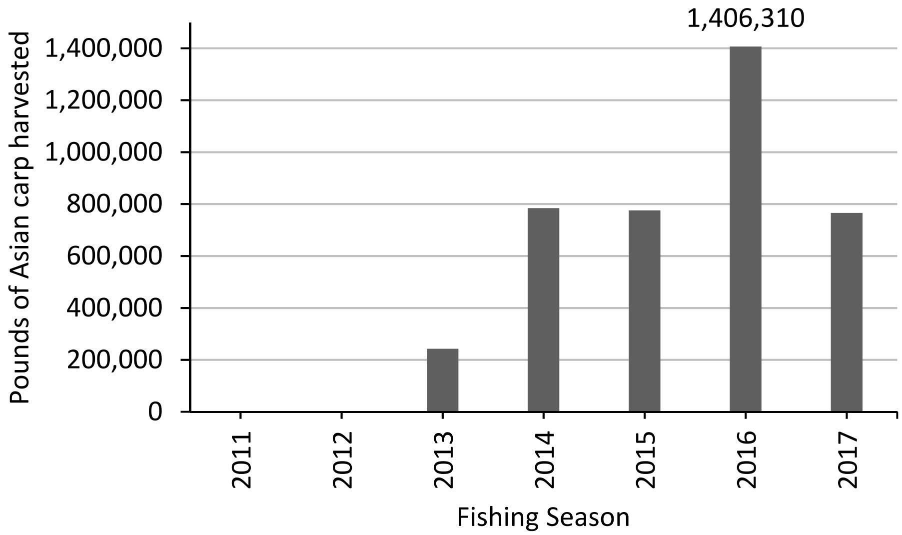


Figure 1. Pounds of Asian carp harvested through the Asian Carp Harvest Program. Program year runs from April 1 through March 31 of the following year, 2017 is only reported through December.

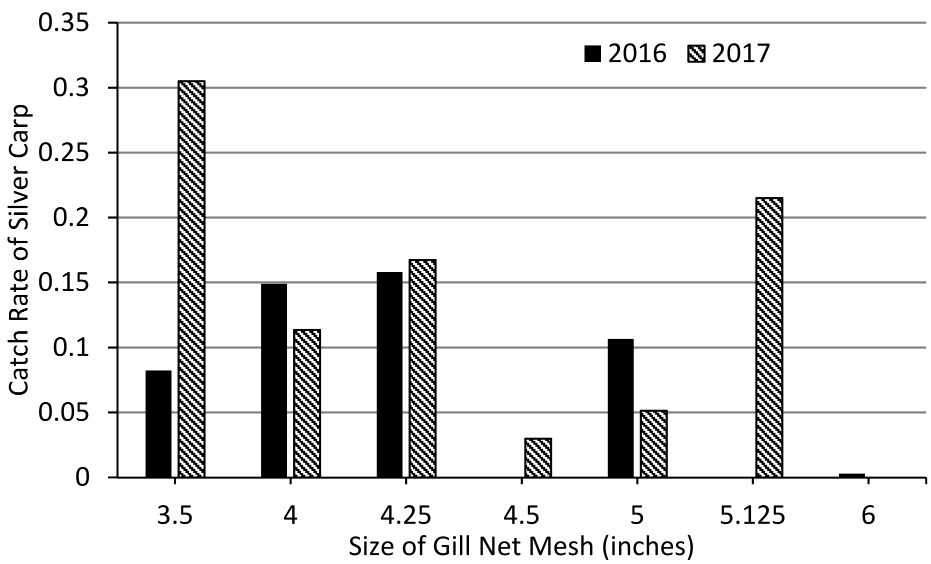


Figure 2. Catch rates (number of fish / yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program.

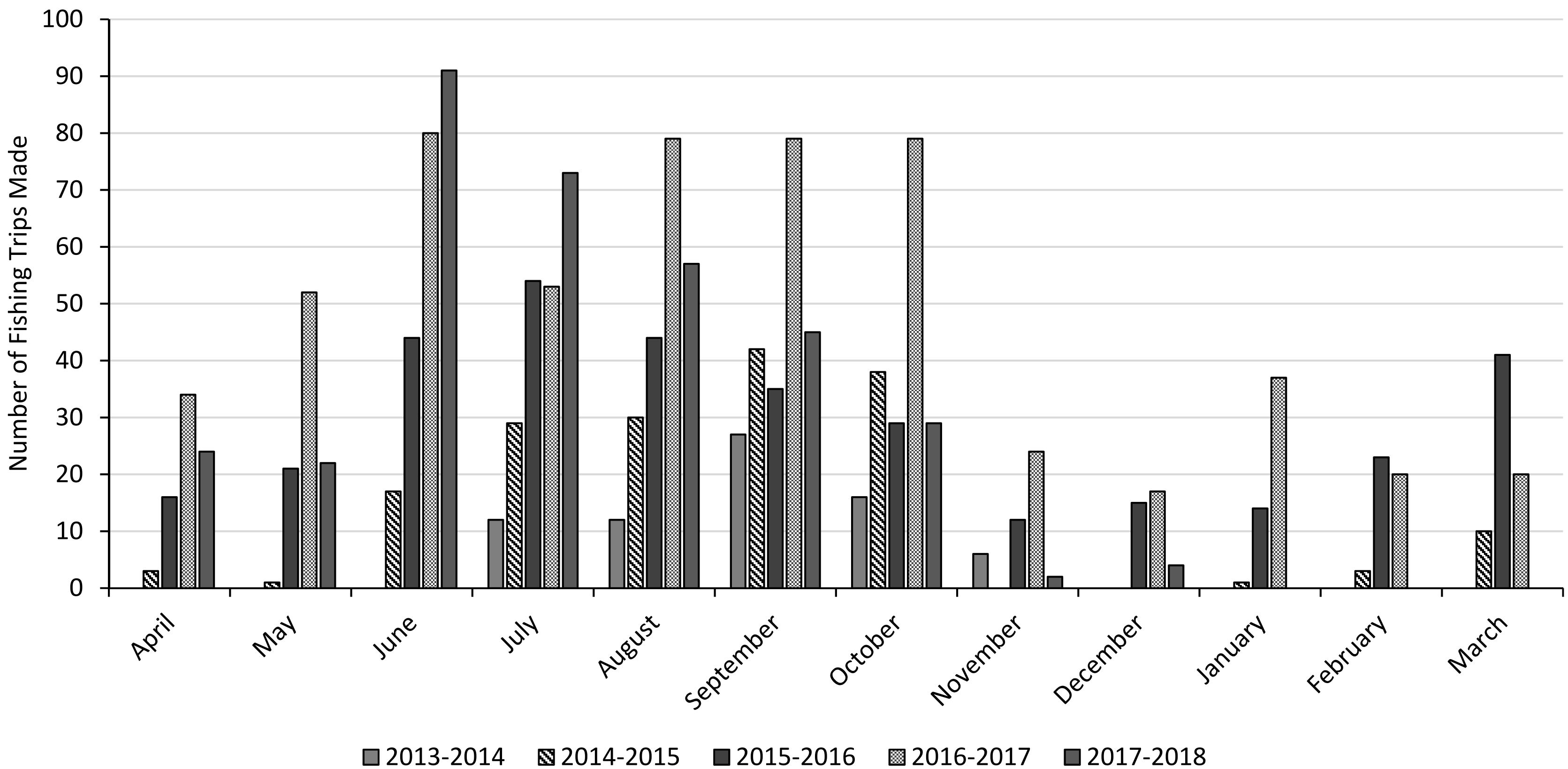


Figure 3. Number of fishing trips made monthly by commercial fishermen fishing under the Asian Carp Harvest Program from April 2013 - December 2017.

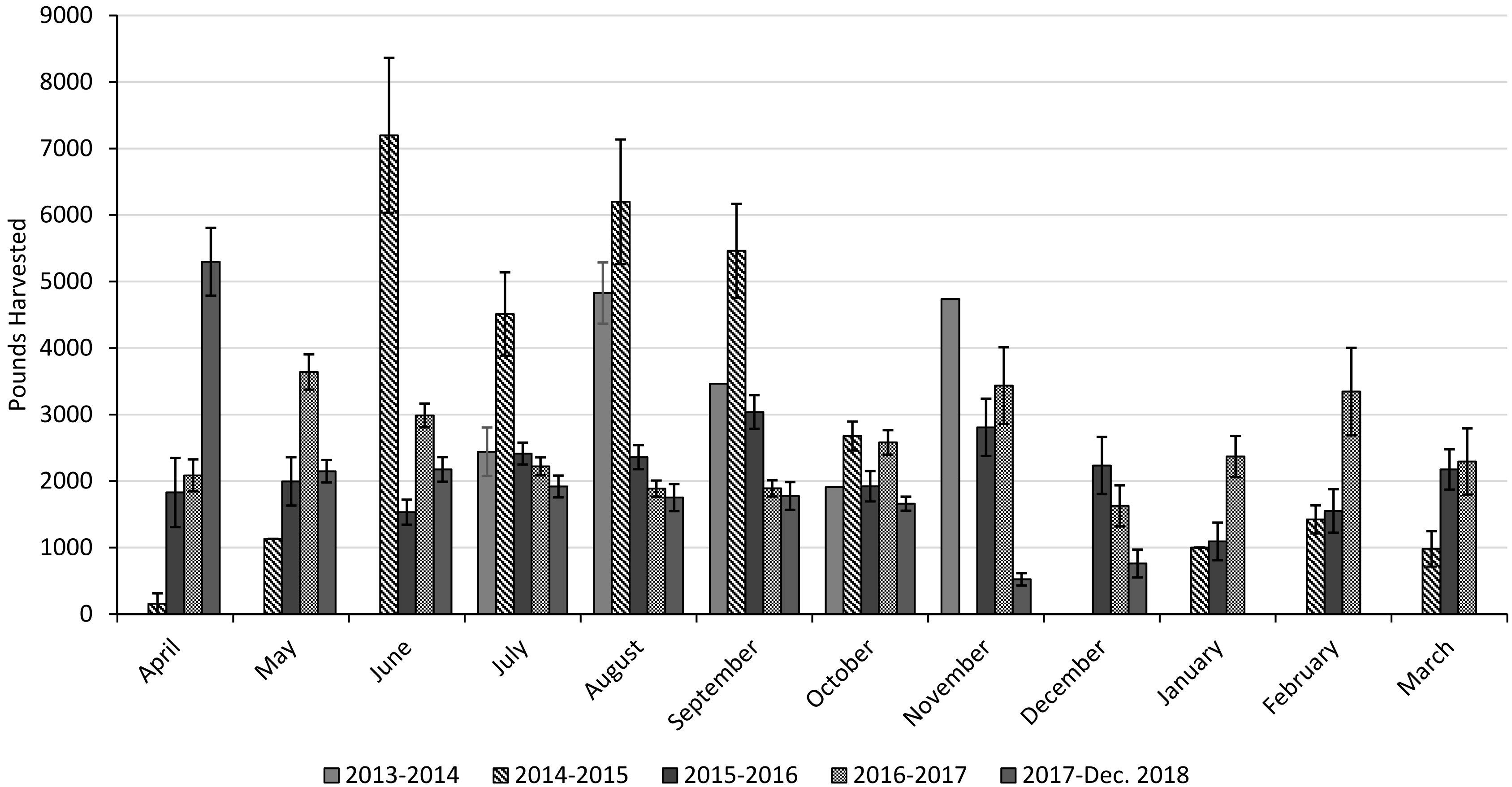


Figure 4. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishermen fishing under the Asian Carp Harvest Program April 2013 - December 2017.

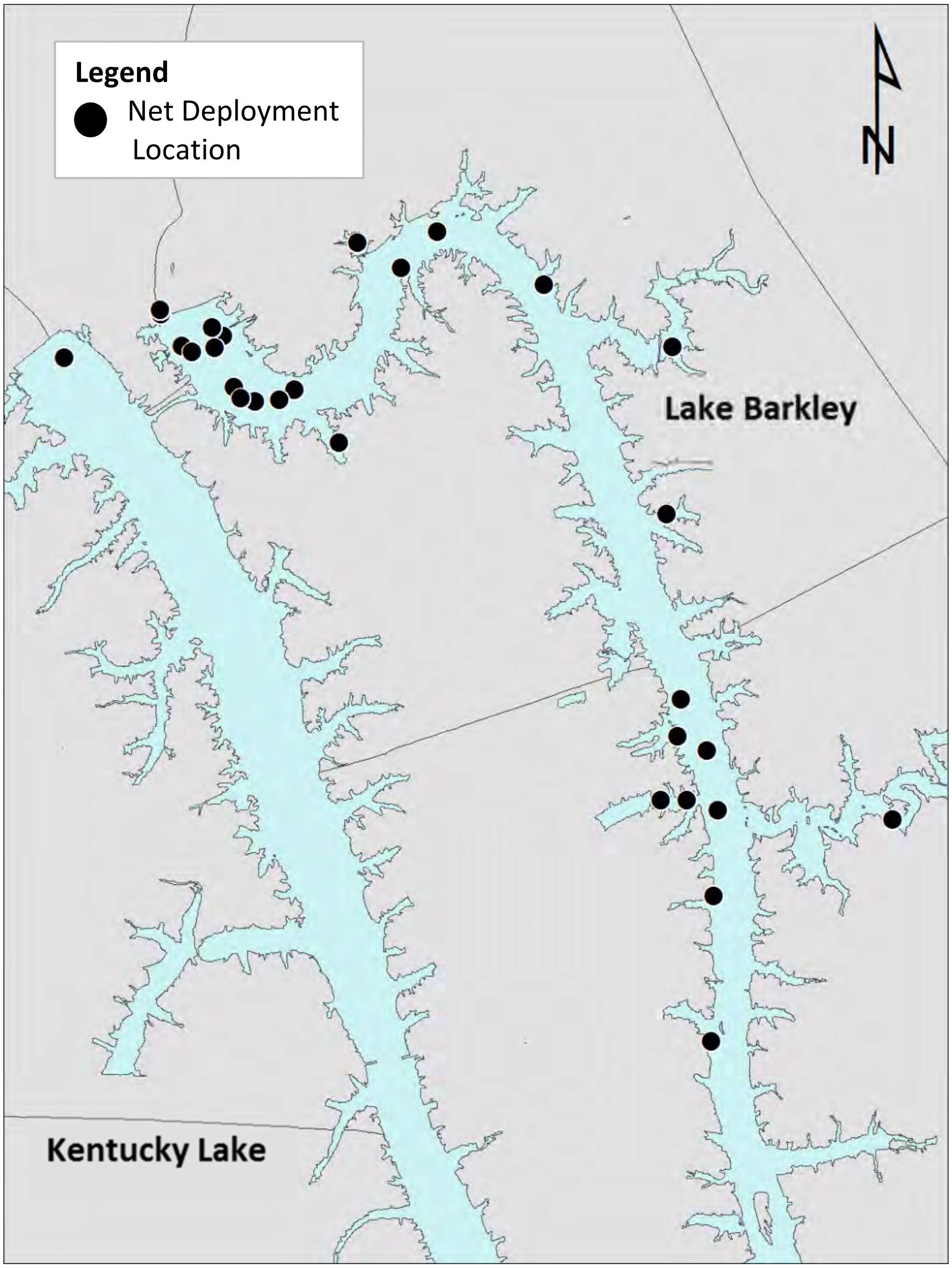


Figure 5. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff in 2017.

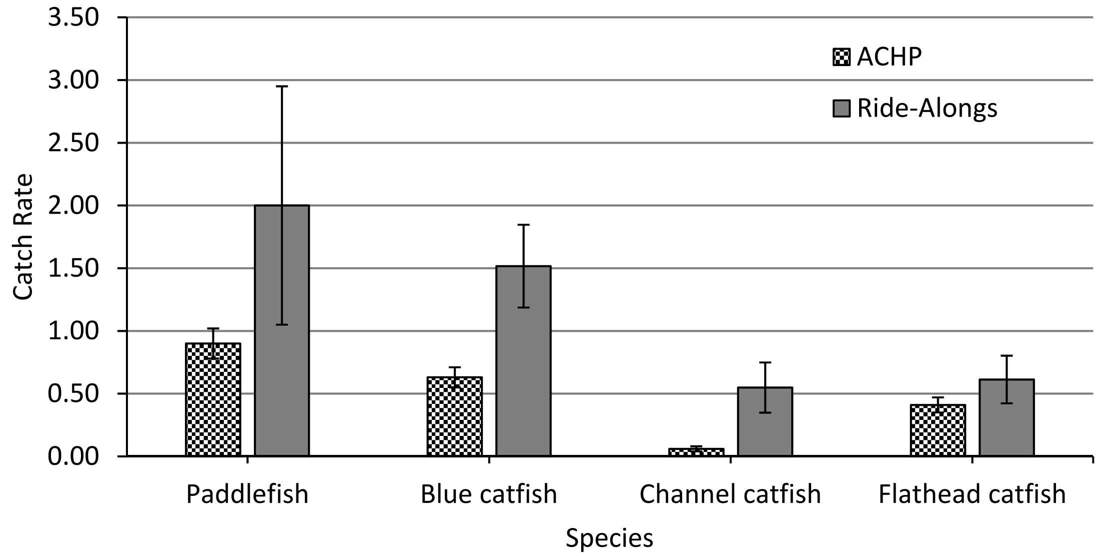


Figure 6. Comparison of catch rates for common bycatch species as reported by commercial fishermen utilizing the Asian Carp Harvest Program (ACHP) and through KDFWR ride-alongs with commercial fishermen.

Project 3: Silver Carp Demographics

FINDINGS

Silver Carp Population Dynamics

In 2015, KDFWR began a joint project with a graduate student at Murray State University to investigate silver carp (*Hypophthalmichthys molitrix*) demographics in Kentucky Lake. This study concluded in 2016. In 2017 KDFWR continued the demographics study on Lake Barkley in anticipation of comparing results to fish sampled from Kentucky Lake the previous year. Demographics of silver carp in Lake Barkley are desirable as this lake has more commercial fishing pressure which could be affecting population structure of silver carp differently than in Kentucky Lake. Silver carp population data was collected from fish captured in Kentucky Lake and Lake Barkley April – December 2017. Silver carp were captured with a variety of capture methods throughout this time frame including KDFWR sampling with gill nets, U.S. Fish and Wildlife Service Paupier net sampling, and the commercial fishery.

In October 2017 silver carp were sampled in both Kentucky Lake and Lake Barkley with gill nets and the USFWS Paupier net (see Experimental Gears Annual Report for detailed sampling procedures). Lengths and weights were recorded for 1,032 silver carp from Kentucky Lake and 426 silver carp from Lake Barkley. Silver carp captured from Lake Barkley were larger on average than silver carp captured in Kentucky Lake (Figures 1 and 2). Lake Barkley silver carp > 800mm were also heavier than silver carp of similar size captured in Kentucky Lake (Figure 3). Many species of fish present in both systems exhibit this trend in growth (Adam Martin KDFWR, personal communication). This could be the result of Lake Barkley being a more productive system, receiving runoff from intense agriculture on the eastern side of the lake and upstream. Commercial fishermen targeting silver carp prefer to fish Lake Barkley over Kentucky Lake, as they report it is easier to fish and the fish are bigger. Commercial fishers harvested 835,685 lbs of Asian carp from Lake Barkley in 2017, whereas only 83,241 lbs of Asian carp were harvested from Kentucky Lake in 2017 (KDFWR ACHP Database). Therefore, it could also be hypothesized that commercial fishing is relieving competition in Lake Barkley by removing the larger fish, allowing remaining silver carp to grow faster than those in Kentucky Lake. However, movement of silver carp between the two reservoirs has been documented through acoustic telemetry studies (Tracking Movement of Silver Carp in Kentucky Lake Annual Report). The size class most prevalent in both lakes (600-699mm in Lake Barkley; Figure 1, 500-599mm in Kentucky Lake; Figure 2) represents silver carp from the 2015-year class when young of year silver carp were documented in the lakes for the first time. Juvenile silver carp in Kentucky Lake exhibited rapid growth. In 2015, age-0 silver carp were observed in great numbers and were vulnerable to boat electrofishing. In 2016, juvenile silver carp were captured via electrofishing, and in 2017 silver carp of the 2015-year class were captured in gill nets with 3” bar mesh. Growth of the 2015-year class has been tracked as shown in Figure 4.

Commercial Fishery

Sixteen trips were made to commercial processing facilities which yielded data from 361 silver carp. Because most silver carp were provided by commercial fishermen that use large mesh gill nets, there is potential for size bias in these results. All silver carp were measured for total length (mm) and weight (kg), gonads were removed and weighed, sex recorded, and the first pectoral fin ray was removed for aging. The primary size of silver carp was 800-900mm which is similar to the size range of silver carp measured from Kentucky Lake the previous year (Figure 5). Ages of silver carp collected by commercial fishermen and used for the demographics study ranged from 3-10 years and were dominated by four and five-year-olds (Figure 6). This range of ages is also similar to silver carp from Kentucky Lake sampled in 2015-2016. Commercial fishermen predominately use gill nets with mesh sizes of 4.25" – 5". Therefore, it can be inferred that silver carp do not efficiently recruit to these commercial gill nets until 4 years of age. However, Silver carp can become sexually mature at 3 years of age thus the current commercial fishing effort alone cannot be expected to effectively reduce the number of silver carp present in the lakes. This highlights the importance of striving to identify additional methods for removing varying size classes of silver carp from Kentucky's waters.

The weighted catch curve regression produced an annual mortality rate of 47.9% for Kentucky Lake in 2016 ($R^2$ = 0.905; P = <0.008) and 60.6% for Lake Barkley in 2017 ($R^2$ = 0.905; P = <0.008) (Figures 7 and 8). The mortality estimate for Kentucky Lake is on the low end of the range estimated in other systems (Table 1). Whereas, Lake Barkley is closer to the mortality rate of silver carp in the Mississippi and Illinois Rivers, which have well-established commercial harvest. The Wabash River, which has a lower mortality rate does not have a commercial harvest. There is a growing commercial fishery at Kentucky Lake, however harvest of silver carp in Lake Barkley far exceeds that of Kentucky Lake to date.

The relationship between length and weight for silver carp in Lake Barkley was used to understand the relative health or condition of individual fish. The length weight equation for Lake Barkley silver carp was $Log_{10}$(weight(g)) = -5.88 + 3.31$Log_{10}$(length(mm)) (Figure 9). Using this equation, weights were predicted for silver carp at two lengths; 450mm (798g) and 800mm (5361g). Silver carp in Lake Barkley exhibited similar weight at length values to silver carp sampled from Kentucky Lake in 2016 (803g at 450mm; 5743g at 800mm). Relative weight (*W*r) of silver carp was calculated using the equation $Log_{10}(W_s)$ = -5.15756 + 3.06842($Log_{10}$TL) (Lamer, 2015). The mean relative weight for silver carp captured in Lake Barkley from April-December 2017 was 100.16 (N=320), which is indication that silver carp being harvested by commercial fishermen from Lake Barkley are in above average condition. However, fish sampled from Kentucky Lake in 2016 had a slightly higher relative weight of 104.03 (N=134).

Gonads of silver carp harvested from Lake Barkley were weighed to calculate the mean gonadosomatic index (GSI). This information was collected twice monthly from April – December 2017. The mean GSI for female silver carp from Lake Barkley peaked multiple times, possibly indicating multiple spawning events (Figure 10). However, the highest mean GSI for males and females in 2017 occurred in April, which coincides with high water flows in the lake (Figure 11). Spawning patches were also observed on female silver carp harvested from Lake Barkley on multiple occasions, suggesting that silver carp attempted to spawn in the lake. However, no young of year silver carp were observed in Lake Barkley in 2017. Tennessee Wildlife Resources Agency conducted larval sampling efforts with light traps and a bow mounted icthyoplankton net to capture Asian carp in Kentucky Lake and Lake Barkley. To date, they have not reported any findings of larval Asian carp from their sampling efforts in 2017.

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Stuck, J. G., Porreca, A. P., Wahl, D. H., & Colombo, R. E. (2015). Contrasting population demographics of invasive silver carp between an impounded and free-flowing river. North American Journal of Fisheries Management, 35(1), 114-122.

Table 1. Estimates of annual mortality of silver carp from multiple locations within their introduced range in the Mississippi River Basin. Mortality rates calculated using weighted catch curve regressions.

| Water Body | Silver carp mortality rate (%) | Reference |
|---|---|---|
| Lake Barkley | 60.6 | KDFWR data 2017 |
| Kentucky Lake | 47.9 | Murray State University data 2016 |
| Middle Mississippi River | 63.0 | Seibert et al. 2015 |
| Illinois River | 63.3 | Stuck et al. 2015 |
| Wabash river | 43.6 | Stuck et al. 2015 |

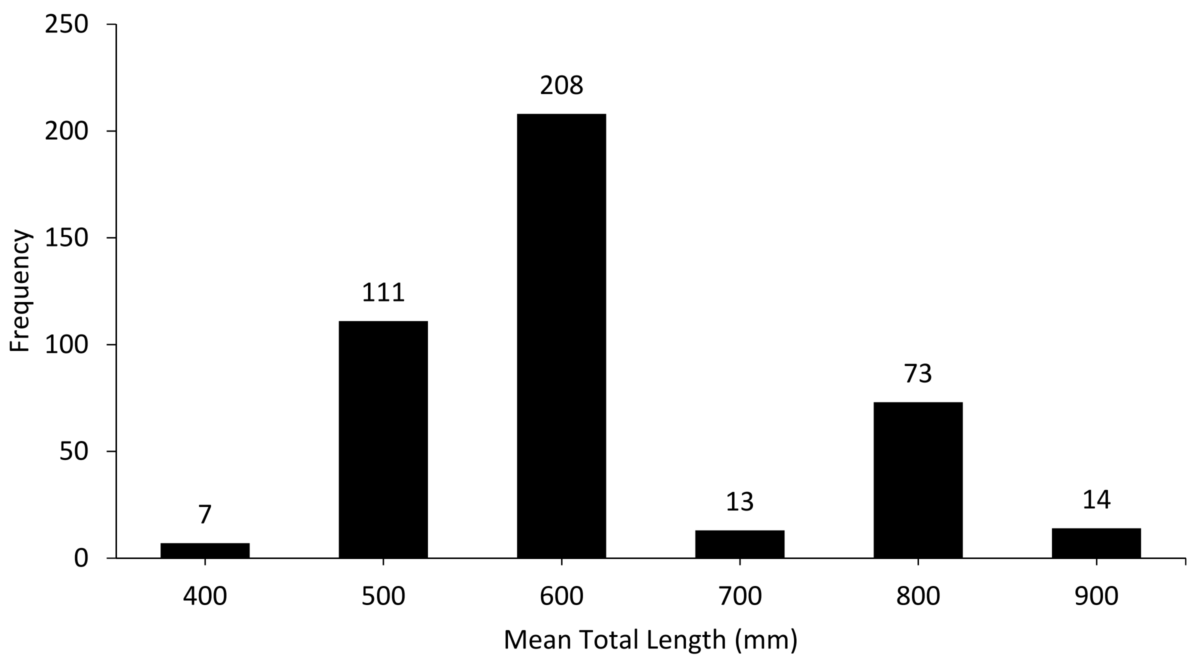


Figure 1. Length frequency histogram for distribution of lengths of silver carp (n=426) in Lake Barkley October 2017 using all capture methods.

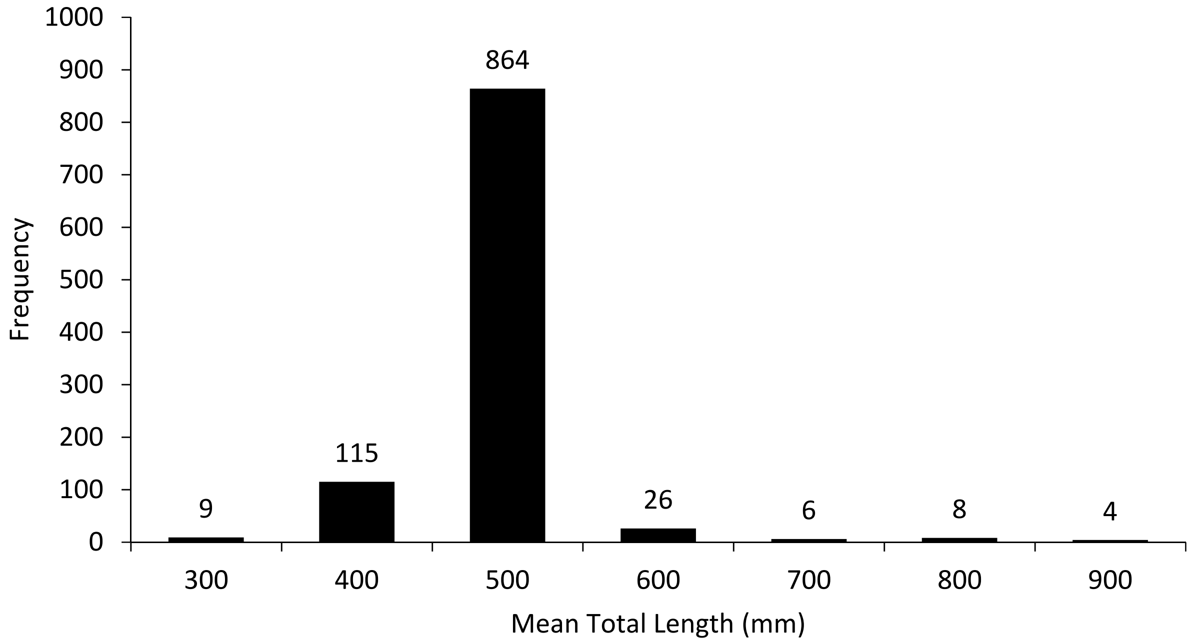


Figure 2. Length frequency histogram for distribution of lengths of silver carp (n=1032) in Kentucky Lake October 2017 using all capture methods.

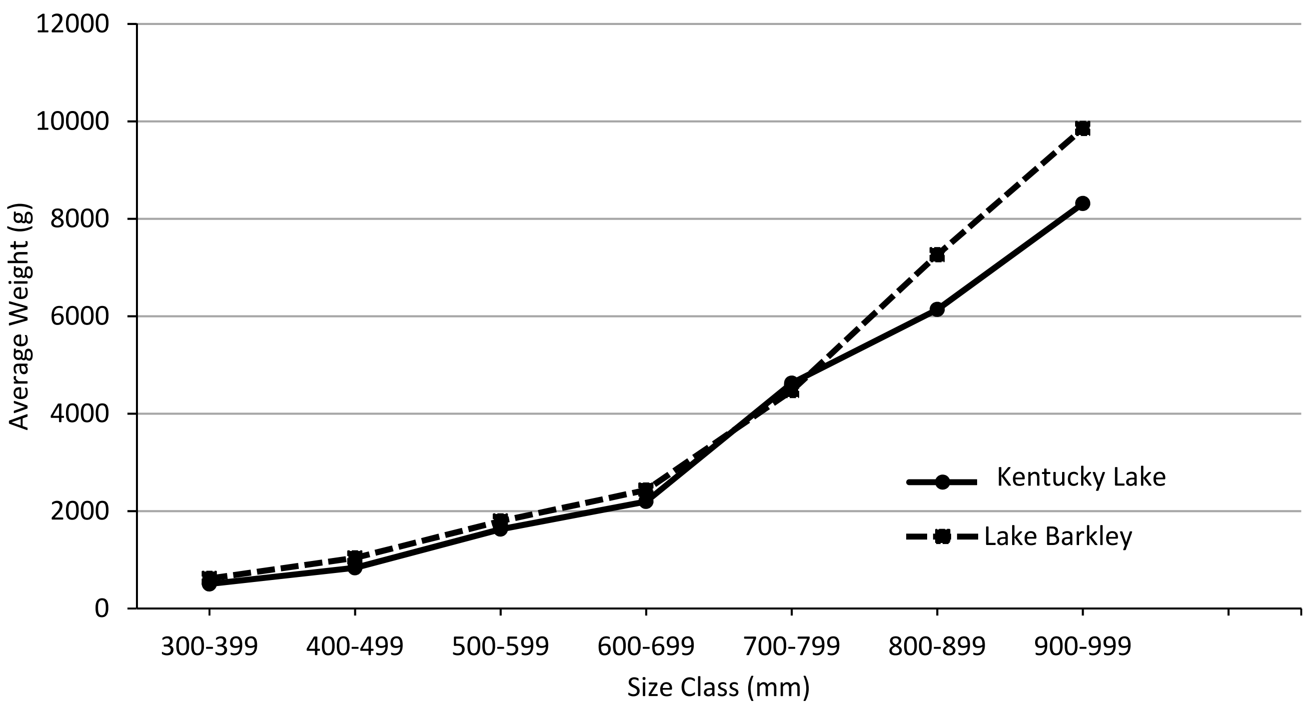


Figure 3. Average weight by size class for silver carp captured by the Paupier net from Big Bear embayment on Kentucky Lake and the northern portion of Lake Barkley in October of 2017.

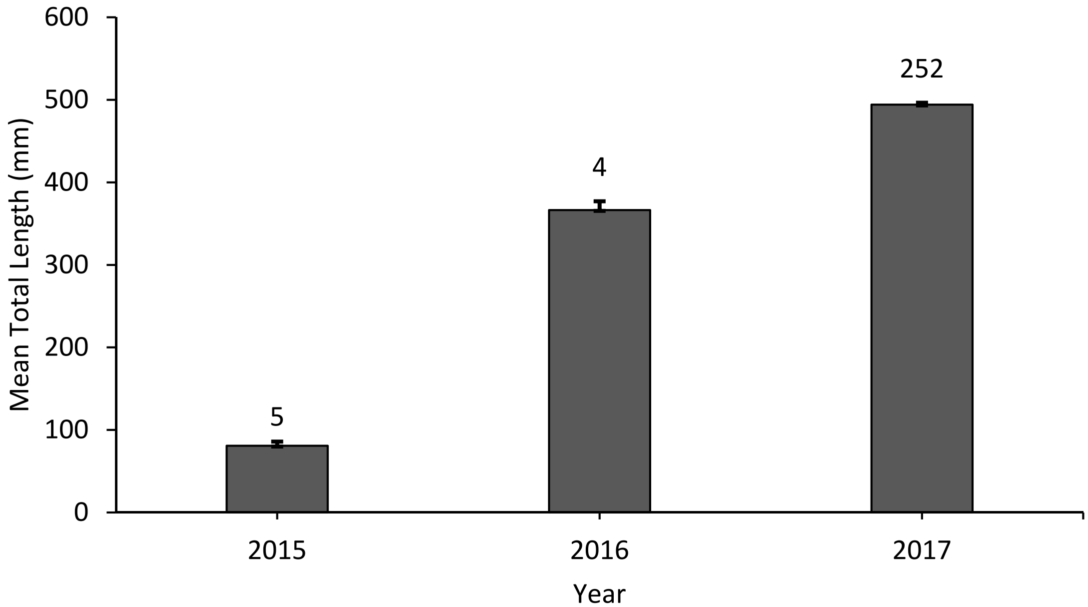


Figure 4. The mean total length of silver carp from the 2015 year class in Kentucky Lake as measured in July of each year. Error bars represent +/- 1 standard error.

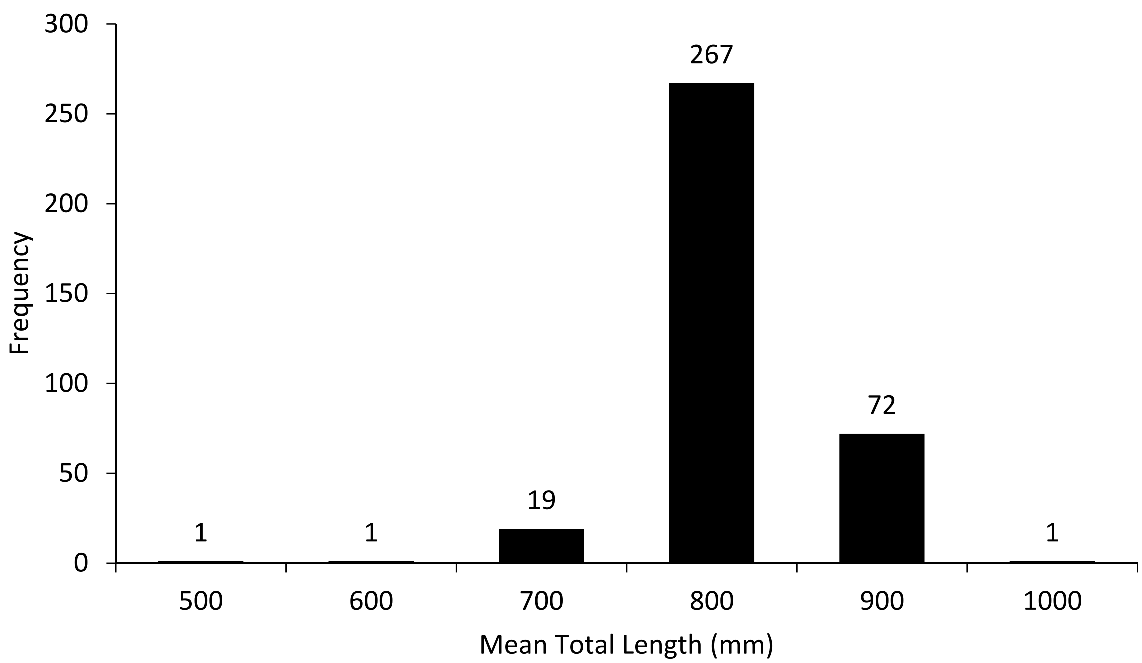


Figure 5. Length frequency histogram for distribution of lengths of silver carp (n=361) captured through the commercial fishery in Lake Barkley April - December 2017.

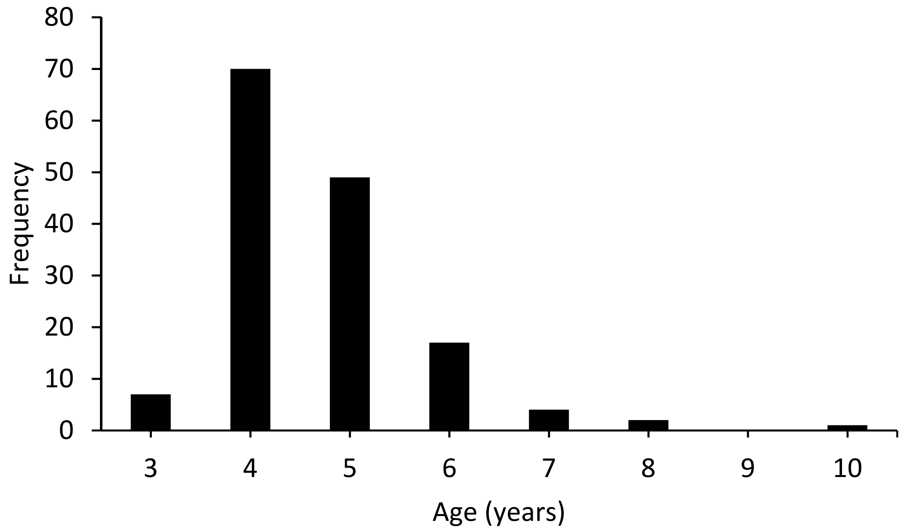


Figure 6. Distribution of ages represented by silver carp sampled through the commercial fishery in Lake Barkley April - December 2017 (N=150).

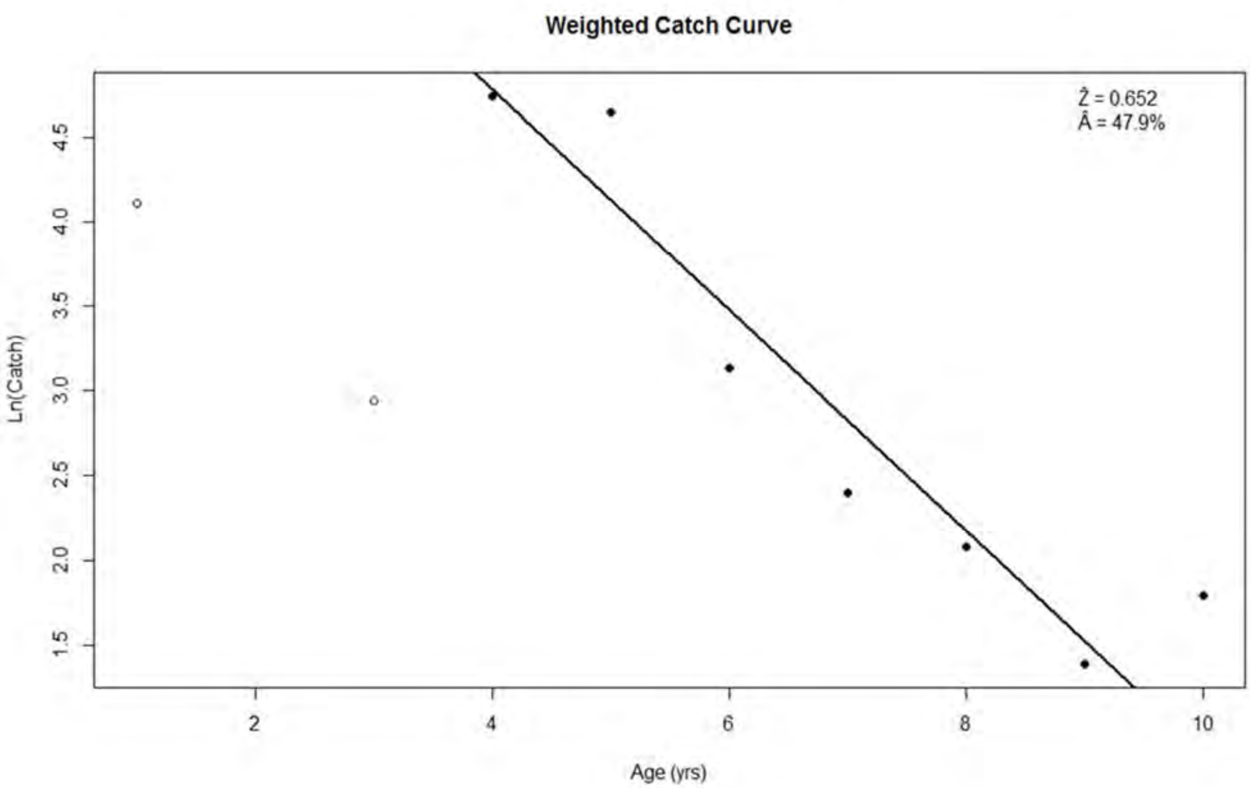


Figure 7. Weighted catch curve regression estimating mortality of silver carp in Kentucky Lake in 2016 (n= 354; R2 = 0.905; P-value = <0.008). The open circles show the ascending limb and were not used to estimate A and Z as they have not fully recruited to commercial fishing gear.

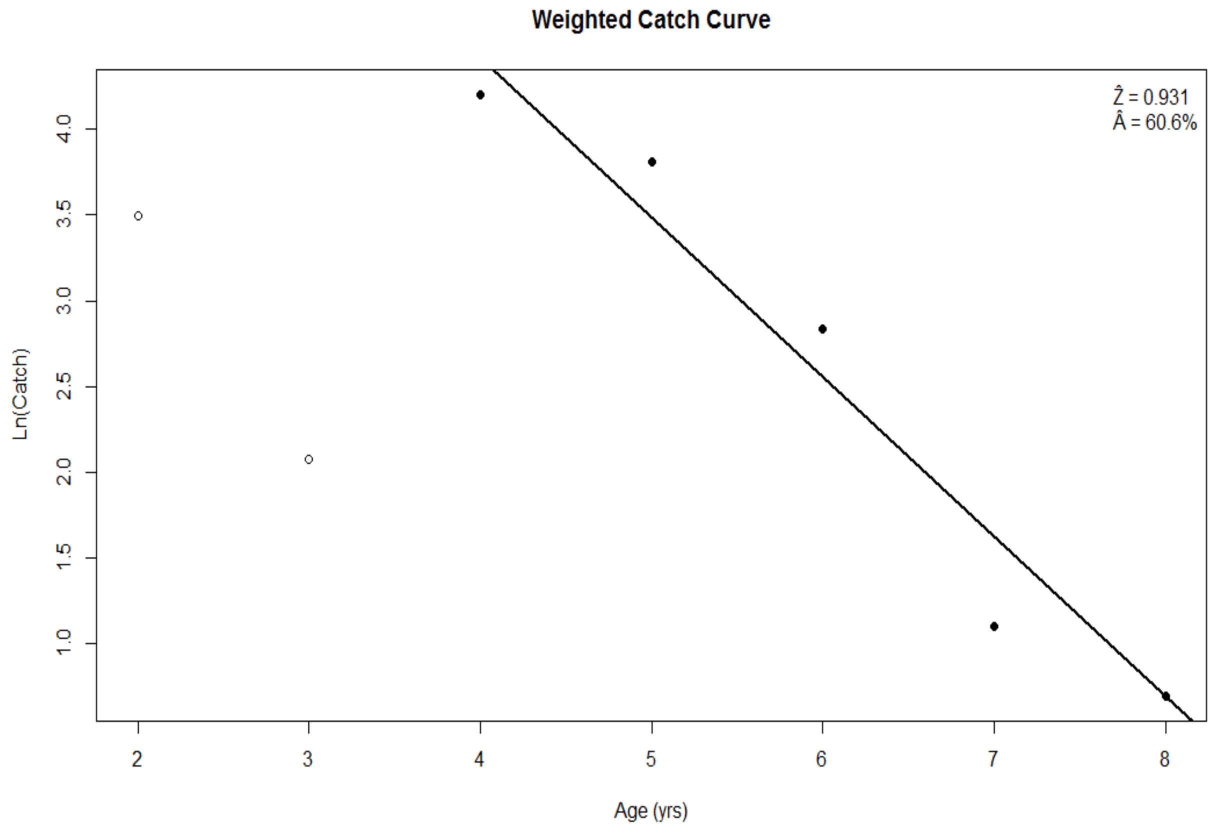


Figure 8. Weighted catch curve regression estimating mortality of silver carp in Lake Barkley in 2017 (n= 192; R2 = 0.905; P-value = <0.008). The open circles show the ascending limb and were not used to estimate A and Z as they have not fully recruited to commercial fishing gear.

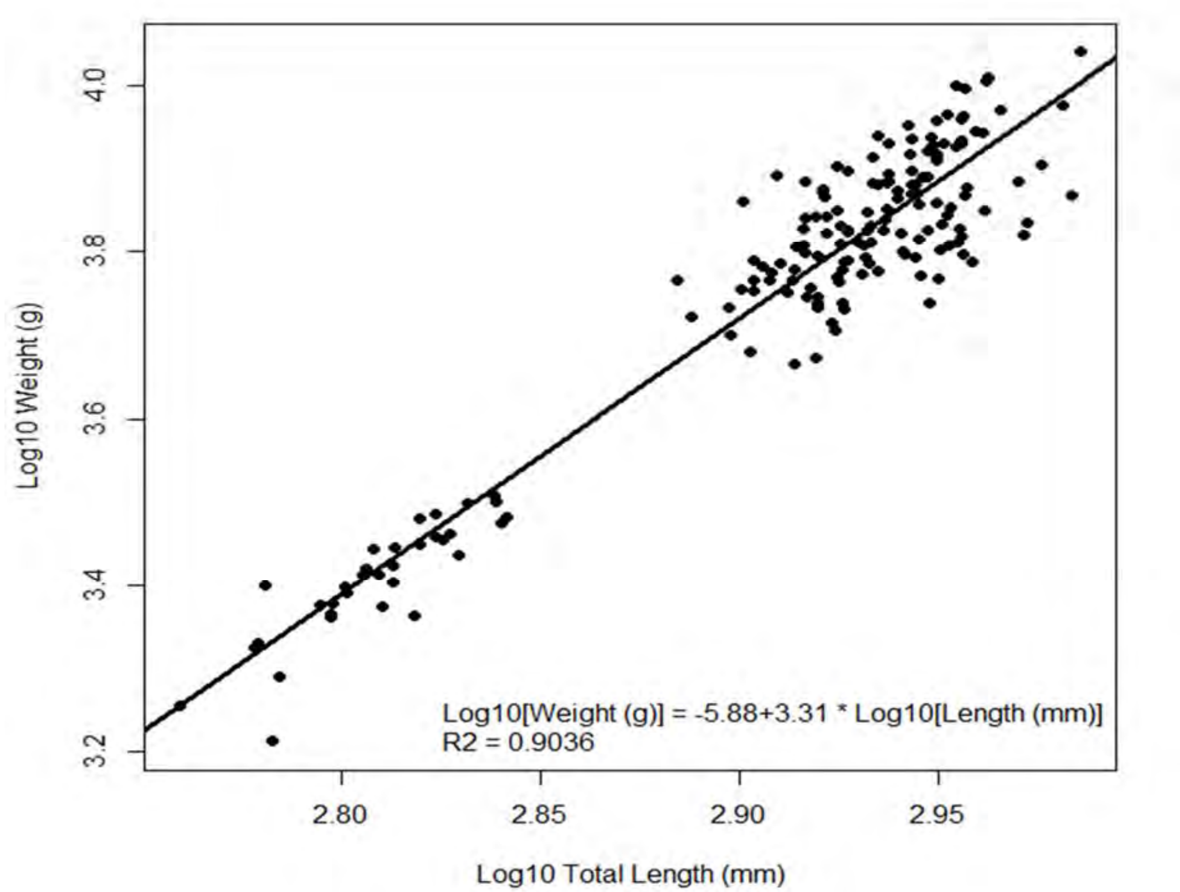


Figure 9. Log10 transformed relationship between length and weight for silver carp captured in Lake Barkley from April - December 2017.

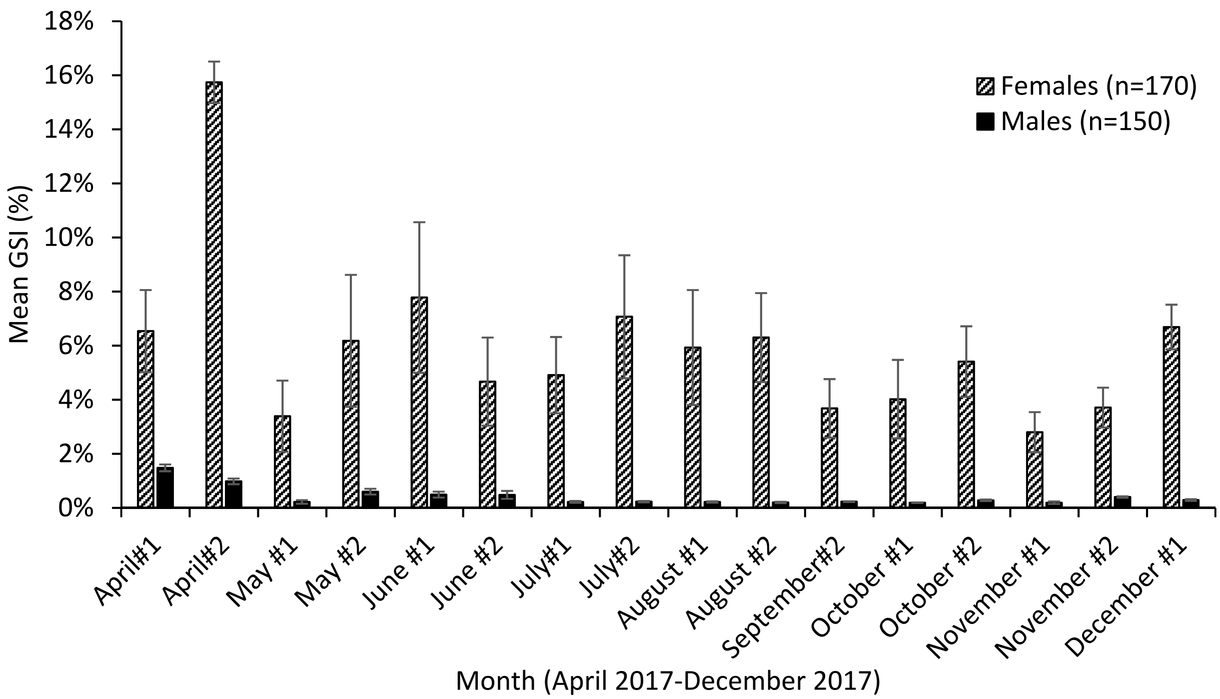


Figure 10. Mean gonadosomatic index (GSI) for silver carp captured in Lake Barkley through the commercial fishery from April - December 2017 (n=320). Error bars represent +/- 1 standard error.

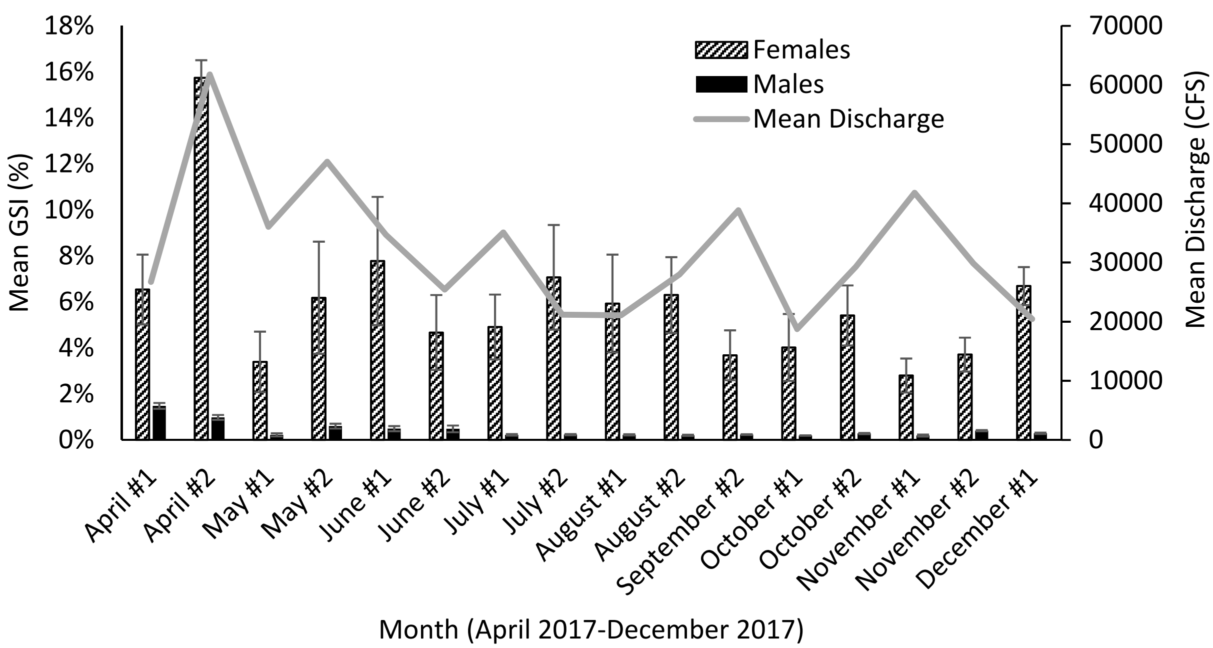


Figure 11. Mean gonadosomatic index (GSI) for silver carp captured in Lake Barkley through the commercial fishery from April - December 2017 (n=320), plotted against mean discharge (CFS) through Lake Barkley Dam. Error bars represent +/- 1 standard error.

Project 4: Tracking silver carp Movement in Kentucky Lake

FINDINGS

Tagged Fish

Kentucky Department of Fish and Wildlife Resources (KDFWR) worked with Murray State University (MSU) to continue a study tracking silver carp movement in Kentucky Lake. KDFWR assisted with all tagging events and data collection through manual tracking and VR2W receiver downloads. All data analysis for this report is provided by Dr. Tim Spier of Murray State University. silver carp were implanted with VEMCO V16 transmitters and tagged with an external tag. Surgeries were performed on 68 silver carp over five dates in 2017 (Table 1). All fish tagged during 2017 were captured by electrofishing. In April and October, the fish were captured by the USFWS "Paupier Net Boat" during their spring and fall night sampling on Kentucky Lake. The December fish were captured via boat electrofishing in the Lake Barkley tailwaters. All surgeries were performed near the point of capture and immediately released in the same area to minimize holding time. Mean surface temperature during the April surgeries was 17.5$^{o}$C, during the October surgeries was 21.8$^{o}$C, and during the December surgeries was 6.1$^{o}$C. Electroanesthesia was tested on some of the fish tagged in October. However, the electroanesthesia did not have any noticeable effect on fish behavior during surgeries. silver carp do not seem to react negatively during surgery even without anesthesia. Not enough fish were anesthetized to make any conclusions about long-term mortality. Mortality seems higher in fish tagged earlier in the year relative to those tagged later (Table 2); however, there has been more opportunity to track these fish, and thus more data exists on which to make conclusions. Two silver carp were found and returned within days of their surgery (one was shot by a bowfisherman and one was found floating), while 3 silver carp have been captured and returned by commercial fishermen. The surgery incision healed very well in all 3 commercial recaptures with no sign of infection or irritation. However, the jaw tags caused wounds so severe that these tags were replaced with an external Floy loop tag inserted just posterior of the dorsal fin in all surgeries conducted after April.

Tracking Effort

Boat-mounted hydrophones were used to manually track tagged silver carp on 38 separate trips during 2017. The average linear distance tracked during these trips was 46.6 km. Manual tracking was focused near the Kentucky Lake dam and around the Blood River embayment (Figure 1). No manual tracking was performed in Lake Barkley during 2017. On 3 separate dates individual silver carp in Kentucky Lake were followed and located at least once per hour for at least 24 hours.

Seven more VR2W passive receivers were deployed in Kentucky Lake, Lake Barkley, and the Lake Barkley tailwaters in 2017. Also, 2 receivers were deployed in the Kentucky Lake tailwaters in January 2018, while 1 receiver at Paris Landing in Kentucky Lake was lost in 2017. The passive receiver network currently consists of 20 VR2W receivers and extends from both tailwaters all the way to Danville, TN, in Kentucky Lake and to Carmack Bay in Lake Barkley (Figure 2). Both locks have receivers inside the lock chamber and just outside the lock on the upstream approach, so any tagged fish that leaves or enters either lake should be detected. Two receivers are deployed at either end of the canal which connects Kentucky Lake and Lake Barkley, so any tagged fish that moves between the lakes should also be detected.

Fish Detections

In December 2017 (and January 2018), several fish were tagged and released below the Lake Barkley dam, 5 VR2W receivers were deployed in Lake Barkley and its tailwaters, and some manual tracking was performed in Lake Barkley. Although some fish were detected in Lake Barkley, not enough locations were obtained to make any conclusions about silver carp in Lake Barkley. So, the following analysis will concentrate on silver carp in Kentucky Lake.

Although the dead silver carp and the fish that are possibly dead demonstrated some movement before they died, it is impossible to know exactly when the fish died. And, any fish that died after the surgery would not likely be representative of the typical silver carp in Kentucky Lake. Thus, all analysis was performed on only on live fish (which includes the 3 fish captured by commercial fishermen since those fish were alive up until their last detection at their date of capture).

In Kentucky Lake, 73 silver carp are presumed to still be alive. Of these 73 fish, 55 have been detected at least once by manual tracking (average detection dates = 3.2 days per fish, range = 1 – 14 days), and 37 have been detected at least once by the passive VR2W network (average detection dates = 38.5 days per fish, range = 1 – 252 days). The number of days between successive locations ranged from 1 – 462, and average time between successive locations was 7.9 days. However, 85% of the successive locations were within 7 days of each other, and 71% of successive locations were within 2 days of each other. Manual tracking and the passive receivers have also detected 4 Paddlefish which were tagged by the Missouri Department of Conservation (MDOC), 1 Bighead carp which was tagged by Southern Illinois University at Carbondale (SIUC), and 1 silver carp which was tagged by the U. S. Fish and Wildlife Service (USFWS).

All fish locations were converted to the nearest river kilometer (RK) and then the mean RK was determined for each fish on each date. Movement rates were calculated by determining the change in RK between successive locations for each fish, and then dividing this value by the number of days between successive locations (so, movement rates were recorded as km/day). Only successive locations which were within 7 days of each other were used to calculate movement rates. Mean daily movement rates were averaged weekly for each fish, and then mean daily movement was determined across all fish for each week. Mean daily speed (movement rate regardless of direction, i.e. absolute speed in km/day) and mean velocity (movement rate and direction, negative values indicate downstream movement and positive values indicate upstream movement) were averaged weekly and compared to mean daily surface temperature (°C), mean daily discharge (cubic meters per second, CMS), and mean daily lake elevation (meters above sea level) which were also averaged for each week. Only 2017 values were used because these are the only dates which have sufficient data for analysis. Mean number of fish analyzed per week was 5.3 fish (range 1 – 14 fish, 4 or more fish were detected in 81% of the weeks).

silver carp in Kentucky Lake did not move much during the first months of 2017, but when the lake elevation began to rise from winter pool the fish movement began to increase. silver carp tended to keep moving when the lake was at summer pool, but their movement dropped off once the lake went back to winter pool in fall of 2017 (Figure 3). Note that fish were detected each week, so any week which has a mean daily average speed of 0 km/day does not indicate missing data but instead indicates that fish were not moving during that week. The maximum mean daily speed was 3.6 km/day, and the maximum speed recorded for an individual silver carp was 20.8 km/day. Movement rates also seemed to be related to surface temperature since surface temperature and water levels are somewhat correlated (low during fall and winter, high during spring and summer; Figure 4). However, a direct comparison of mean speed per week to mean surface temperature per week suggests that movement is consistently low below a threshold temperature but becomes higher and more variable above the threshold (Figure 5). A 2-dimensional Kolmogorov-Smirnov test suggested that the relationship between speed and temperature changed once the temperature rose above 12.9°C ($D_{max}$ = 0.140, p = 0.0) while segmented regression showed that the relationship changed once temperature rose above 19.4°C (t = 2.635, p = 0.01, df = 48, $R^2$ = 0.24). Thus, silver carp do not move much in colder water, but at surface temperatures between 12.9 and 19.4°C their movement increases. However, silver carp movement decreased sharply once temperatures rose above 30°C. No clear relationship existed between mean speed per week and discharge levels (Figure 6).

Although mean speed per week provides an indication of overall activity level of the fish, mean velocity per week takes direction into account as well. silver carp in Kentucky Lake tended to move upstream in the first half of 2017 but then tended to move downstream in the second half of the year (Figure 7). Mean silver carp velocity before June 15, 2017 was positive (0.12 km/day) and significantly different from mean carp velocity after that date (-0.49 km/day, t=2.20, df=49, p=0.03).

To study silver carp movement on a finer scale, 3 separate fish were tracked on 3 separate dates. Each fish was located at least once per hour for at least 24 hours. The fish which was tracked at cooler water temperatures moved more than the 2 fish which were followed at warmer water temperatures (Figure 8). Maximum swimming rate during the 24-hour tracking was just over 3.2 km/hour. Another estimate of fine-scale movement was obtained by studying successive locations between adjacent VR2W positions. Based on the VR2W data, the maximum swimming rate was 4.3 km/hour for silver carp.

Six silver carp which were tagged and released into Kentucky Lake moved into Lake Barkley, and 1 of those fish moved back into Kentucky Lake. Two of these fish probably moved into Lake Barkley before the VR2 receivers were deployed in the canal because these fish were not detected in the canal. However, the remaining four fish were detected in the canal as they moved between the lakes. Two of the 3 silver carp which were recaptured by commercial fishermen had been tagged and released in Kentucky Lake but were captured in Lake Barkley. One of the MDOC Paddlefish was originally detected in Lake Barkley but is now residing in Kentucky Lake.

One silver carp which was tagged and released into Kentucky Lake apparently left through 1 of the locks before any receivers were placed in the locks, but then returned to Kentucky Lake via the Kentucky Lake lock. This fish was released and detected in Kentucky Lake, but then was not located for several months. Its next detection was inside the Kentucky Lock chamber, but at that time it was not detected on the receiver that is just outside the lock chamber; thus, the fish likely was in the Kentucky Lake tailwaters and entered the lock from the downstream end. Later, it was detected first inside the lock chamber, then on the receiver that is just outside the lock chamber, and then a few hours later it was detected in the canal. No other silver carp were directly detected entering or leaving through the lock chambers; however, the silver carp which was tagged by USFWS was released in the Ohio River and then was detected in Lake Barkley, so it must have entered via one of the locks. Similarly, all the MDOC Paddlefish in Kentucky Lake were tagged and released outside the lake, so they must have all entered through 1 of the lock chambers. In fact, 2 of these Paddlefish were directly detected by the VR2W receivers as they entered the Kentucky Lake lock chamber and then entered Kentucky Lake.

Batteries in the transmitters of silver carp which were first tagged in 2016 may start losing their power sometime in 2018. However, many fish have been tagged since then and should have live batteries for several years KDFWR and MSU also plan to tag more silver carp in 2018. Thus, silver carp movement data will continue to be collected in Kentucky Lake and Lake Barkley for the next several years. The effect of using anesthetics during surgery, such as $CO_2$, on silver carp survival will be investigated in 2018. The batteries in the passive VR2W receivers will likely need to be replaced during 2018 to keep this valuable network functioning. More VR2W receivers will be deployed in the northern end of Kentucky Lake to fine tune the large-scale movement data; the VR2W network in Lake Barkley will also be further developed. One VR2W receiver was lost at Paris Landing in 2017, so this receiver will be replaced in 2018. In the upcoming year, much more effort will be directed toward 24-hour tracking to collect more fine-scale, diurnal movement data to inform removal efforts.

Table 1. Summary of silver carp surgically implanted with acoustic transmitters in Kentucky Lake and the Lake Barkley tailwaters during 2017.

| | # Tagged | | Mean TL (mm) | | Mean W (g) | | |
|---|---|---|---|---|---|---|---|
| Surgery Date | F | M | F | M | F | M | Release Location |
| 2017-04-11 | 11 | 4 | 896 | 837 | 8,690 | 5,546 | Camp Currie |
| 2017-04-12 | 3 | 9 | 868 | 797 | 6,797 | 5,898 | Sledd Creek |
| 2017-10-17* | 7 | 8 | 880 | 841 | 7,707 | 6,019 | Big Bear |
| 2017-10-18 | 2 | 3 | 897 | 814 | 7,605 | 5,443 | Sledd Creek |
| 2017-12-21** | 16 | 2 | 746 | 663 | 3,831 | 2,700 | Barkley Tailwater |
| Total | 39 | 26 | 829 | 808 | 7,242 | 6,547 | |

* 1 silver carp of unknown sex was also tagged on this date

** 2 silver carp of unknown sex were also tagged on this date

Table 2. Summary of estimated mortality of tagged silver carp in Kentucky Lake in 2016 and 2017. Mortality was assumed when fish were consistently found in the same location. Fish marked "maybe" are not clearly alive or dead. Fish marked "Recaptured" were alive up until they were captured by commercial fishermen.

* 1 silver carp tagged on this date was shot soon after by a bowfisherman

** 1 silver carp tagged on this date was found floating soon after by an angler

| Surgery Date | Alive | Dead | Maybe | Recaptured |
|---|---|---|---|---|
| 2016-05-11 | 5 | 8 | | |
| 2016-05-16 | 1 | | | |
| 2016-06-02 | 7 | 3 | | |
| 2016-11-08 | 2 | | | |
| 2016-11-09 | 3 | 4 | 1 | |
| 2016-11-10 | | 3 | | |
| 2016-12-13 | 22 | 4 | 3 | 3 |
| 2017-04-11* | 7 | 4 | 3 | |
| 2017-04-12** | 6 | 4 | 1 | |
| 2017-10-17 | 12 | | 4 | |
| 2017-10-18 | 5 | | | |
| 2017-12-21 | 20 | | | |
| Grand Total | 90 | 30 | 12 | 3 |

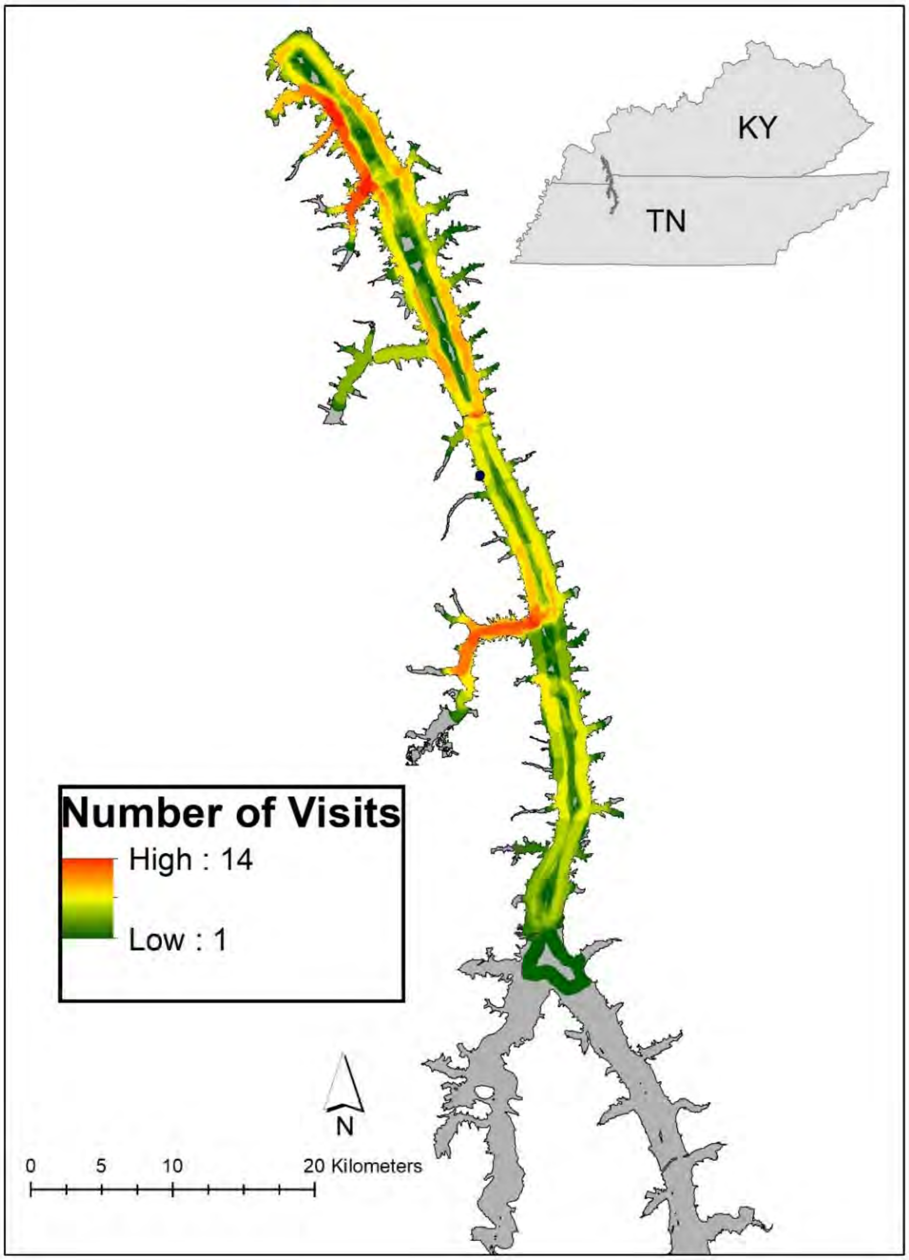


Figure 1. Tracking effort in Kentucky Lake during 2017. “Number of Visits” is determined based upon a 500 m listening radius around the direction of travel.

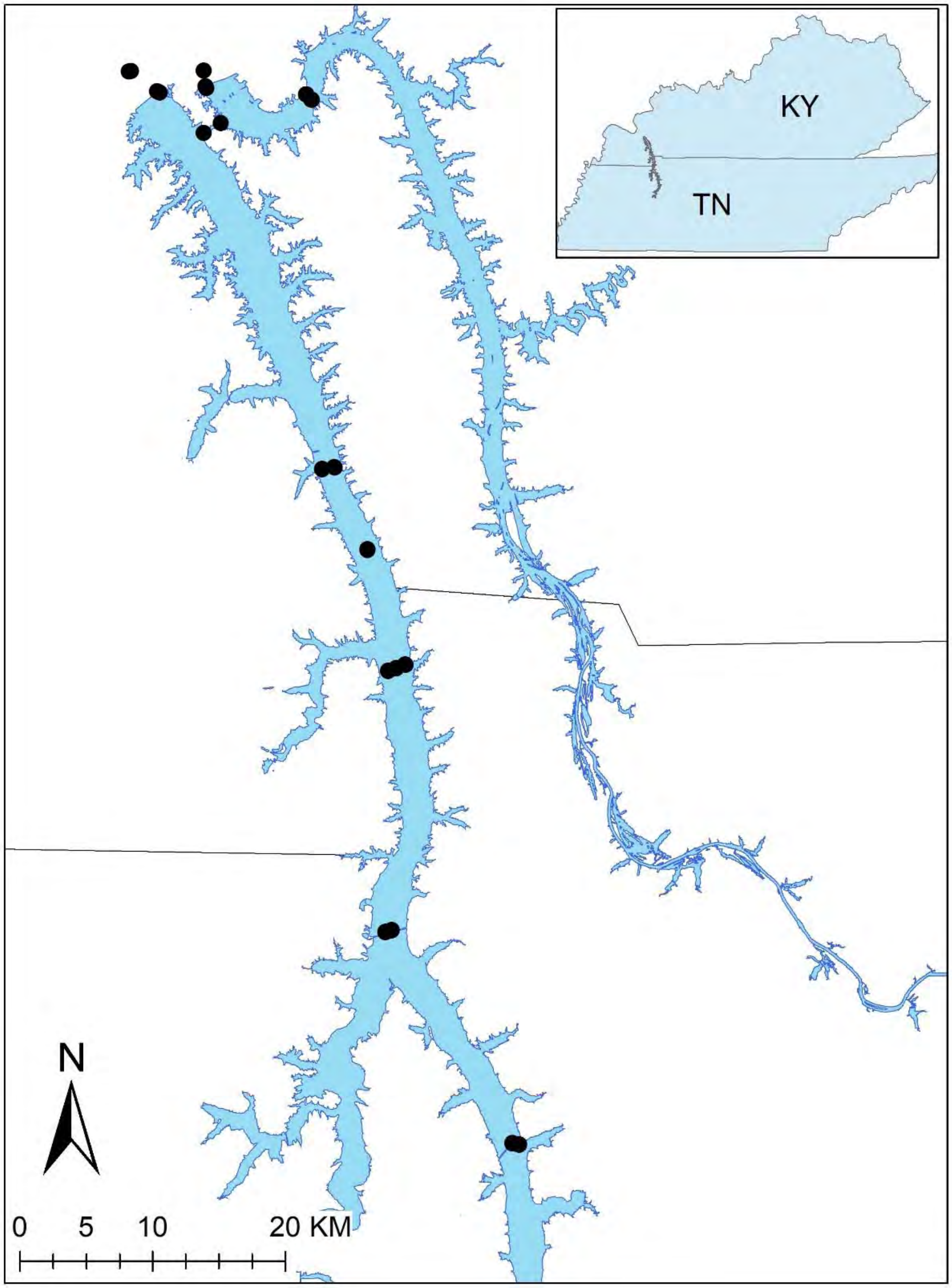


Figure 2. Location of VR2W passive receivers deployed throughout Kentucky Lake by Kentucky Department of Fish and Wildlife Resources and Murray State University.


Figure 3. Comparison of silver carp mean speed per week (km/day, blue bars) and Kentucky Lake mean lake level per week (m, orange line) during 2017.

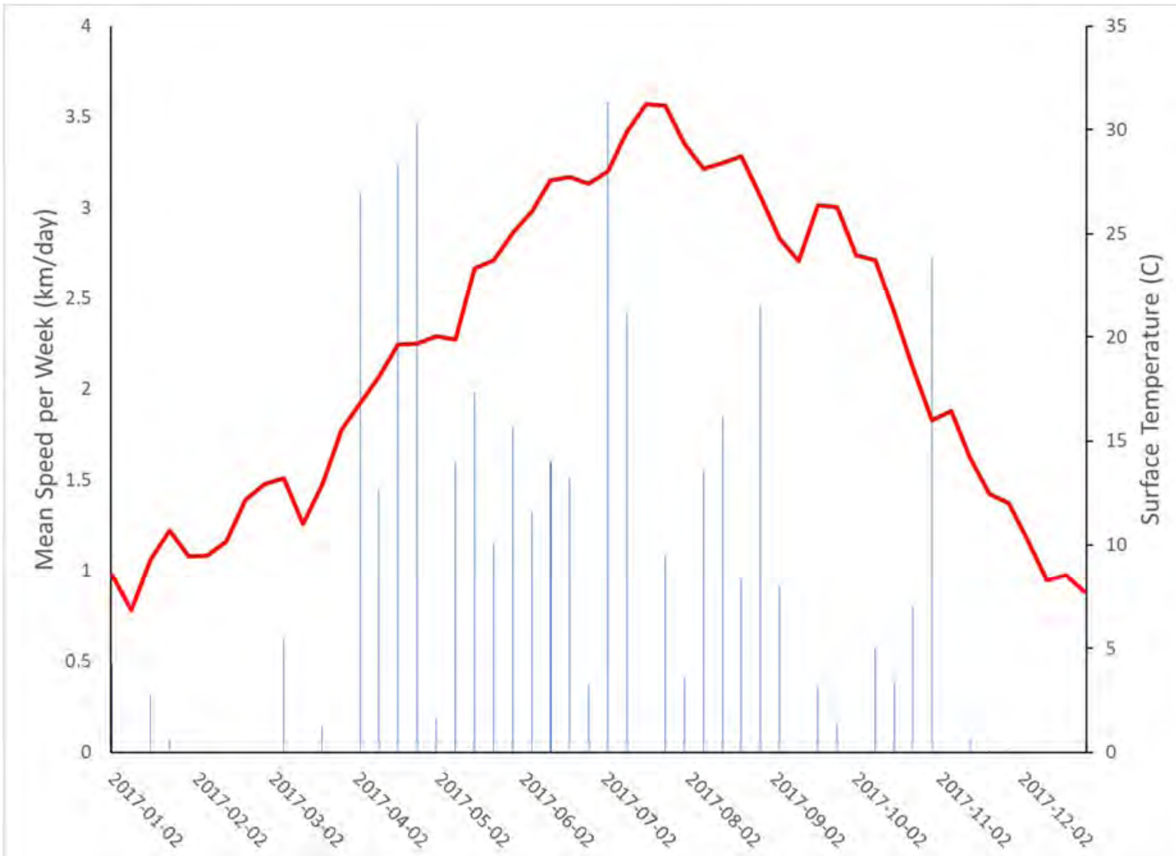


Figure 4. Comparison of silver carp mean speed per week (km/day, blue bars) and Kentucky Lake mean surface temperature per week (C, red line) during 2017.

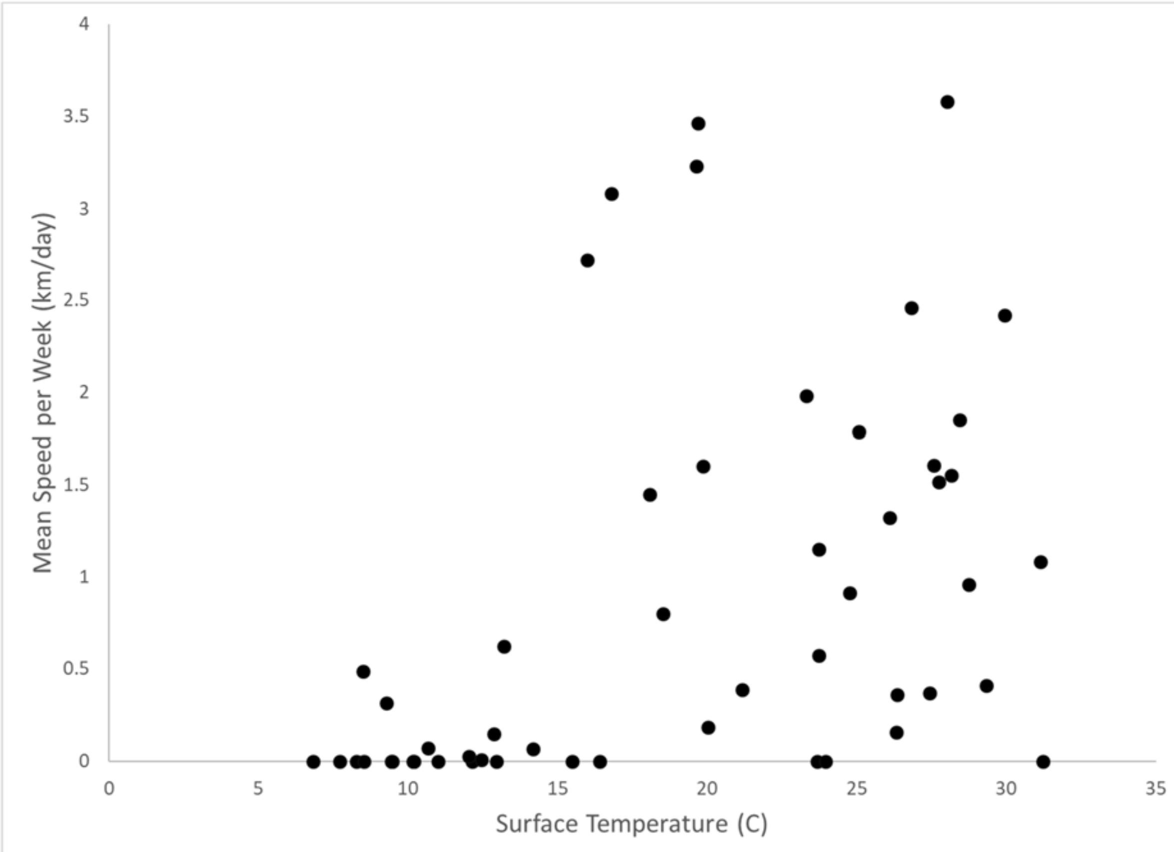


Figure 5. Comparison of silver carp mean speed per week (km/day) to Kentucky Lake mean surface temperature per week (C) during 2017.

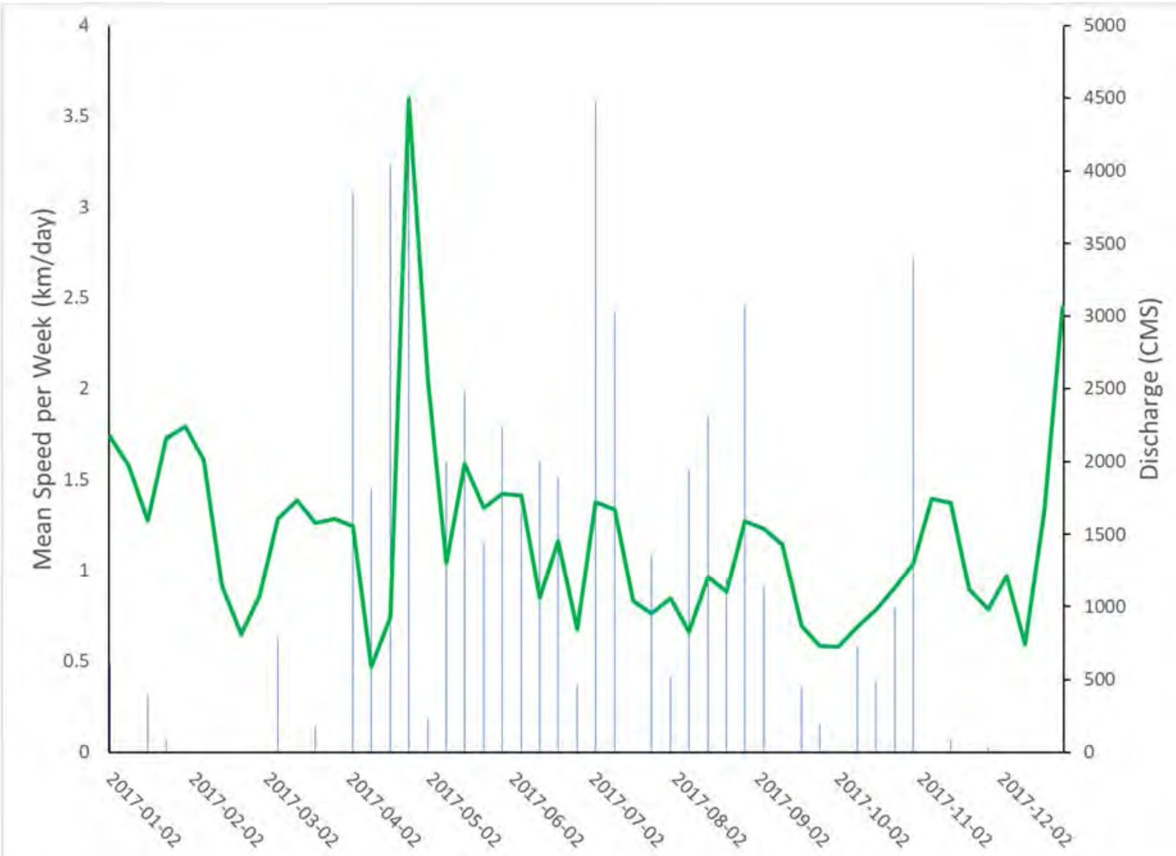


Figure 6. Comparison of silver carp mean speed per week (km/day) and Kentucky Lake mean discharge per week (CMS, green line) during 2017.

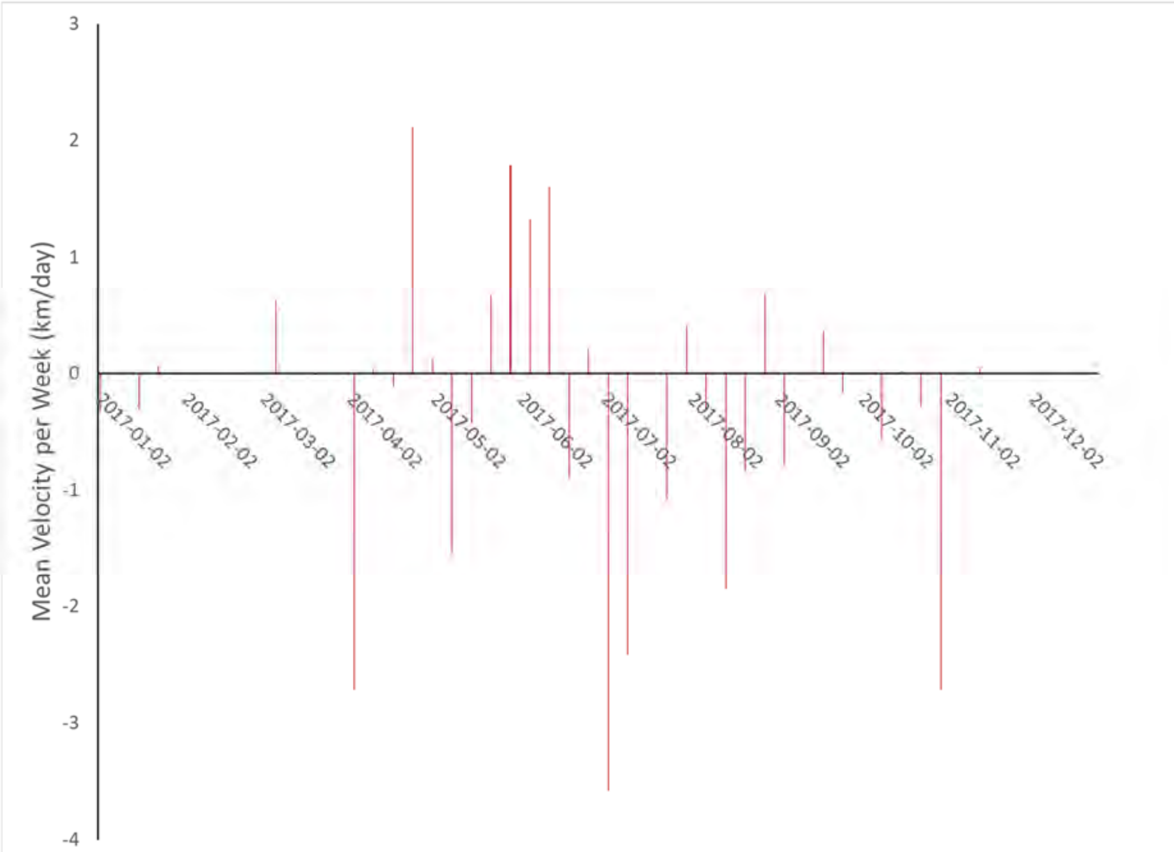


Figure 7. Mean silver carp velocity per week in Kentucky Lake during 2017. Positive numbers indicate upstream movement and negative numbers indicate downstream movement.

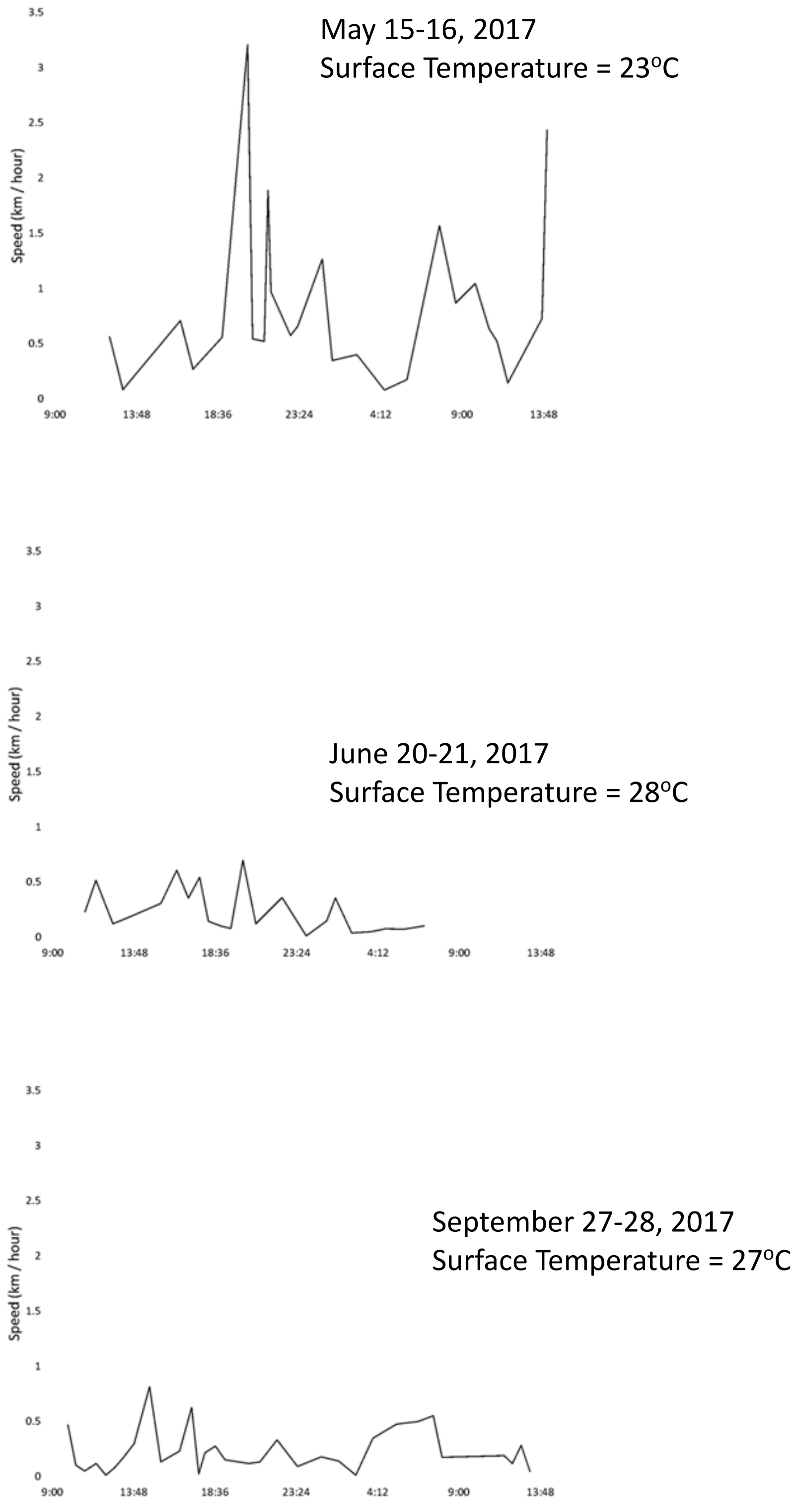


Figure 8. Diurnal movement rates of silver carp in Kentucky Lake on 3 separate dates. Fish were located at a minimum of once per hour for at least 24 hours.

## Project 5: Identifying New Gear Types for Capturing Asian Carp

Kentucky Department of Fish and Wildlife Resources (KDFWR) worked with several entities to use new or experimental gears for capturing Asian carp in Kentucky Lake and Lake Barkley in 2017. KDFWR coordinated with Two Rivers Fisheries to test an experimental gear type in the Honker Bay of Lake Barkley. This gear design is used for capturing Asian carp from large reservoirs in China. Two Rivers Fisheries provided all of the materials and labor used for building the gear frame. The gear used was a 2-inch mesh seine, attached to a large square, floating frame at the four corners. The frame was constructed of wood and 55-gallon drums for floatation. On one side of the frame was an extension with a winch for hoisting the net up through the water column (Figure 1). The premises behind the net design was to allow the net to sit on the bottom of the lake, attract silver carp to the center of the net frame via lights, and hoist the net up when large numbers of fish were spotted inside the net frame. Use of this gear type was attempted on five occasions with oversight by KDFWR personnel. However, no successful captures of silver carp were observed. Two River Fisheries staff attributed the lack of success to fish being able to see the barrels on the frame and swimming away when the net began to move. Due to the flexibility of the frame, the gear was damaged during high winds and was disassembled. KDFWR has continued correspondence with Two Rivers Fisheries regarding testing additional gear types for capturing Asian carp.

### Gill Netting

KDFWR conducted experimental sampling efforts targeting Asian carp via gill nets, electrofishing, and bottom trawl in the lakes and tailwaters. Gill netting and bottom trawl effort was in response to angler reports of large numbers of silver carp in localized areas. The bottom trawl was used on one occasion in Kentucky Lake. A total of 144 fish comprised of 15 species were captured with the bottom trawl (Table 1). However, no Asian carp were captured using this method. Gill nets were fished a total of 4 times on Kentucky Lake with 24 different species caught. Asian carp made up 15.2% of individual fish captured (1 bighead carp, 22 silver carp). Gill nets were fished 3 times on Lake Barkley, during which 19 fish species were caught. Asian carp comprised 36.3% of individual fish captured (1 bighead carp, 18 grass carp, 149 silver carp). During sampling efforts, a combination of floating and sinking nets fished for varying lengths of time (overnight:>12 hours, and day:<6 hours) were used. Asian carp capture rates were similar for floating nets and sinking nets when fished both overnight and during the day (Figure 2). However, Asian carp capture was greater during overnight sets. Bycatch capture rates were similar during both overnight and day sets (Figure 3). For this study bycatch is determined as fish of any species excluding Asian carps (black carp, grass carp, bighead carp, and silver carp). Gill nets used for sampling consisted of a variety of mesh sizes ranging from 1.5” to 5”. For both reservoirs combined, bycatch was highest in the 1.5” mesh (n=92) and lowest in 5” mesh (n=23) (Table 2). Asian carp capture was greatest in 3” mesh in both Kentucky (n=16) and Barkley lakes (n=130) (Table 2). The majority of Asian carp captured in this mesh size were spawned in 2015 which was the first year that young of year Asian carp were documented in the lakes. This year class of Asian carp are growing quickly and are expected to begin recruiting to commercial gears in 2018 (3.5” mesh gill nets).

Electrofishing

Targeted sampling with electrofishing was conducted in the tailwaters of Lake Barkley Dam on six occasions. The Barkley tailwaters were chosen for this sampling effort because high densities of silver carp are known to congregate below the dam, and the architecture of the dam structure allows for fish to be effectively targeted with electrofishing. A total of 18,440 lbs of silver carp were captured through 6.83 hrs of electrofishing with a mean CPUE of 274 fish/hour per trip (Table 3). A subsample of 20 silver carp were individually weighed and measured from each day of effort. Silver carp in the Barkley tailwaters had a mean length and weight of 31.5 inches and 11.0 lbs respectively.

Targeted sampling via electrofishing was conducted in the tailwaters of Kentucky Lake Dam on one occasion. However, with the low CPUE (6 fish/hour) compared to Barkley tailwaters, it was determined that removal efforts should remain focused on Barkley tailwaters (Table 3). Electrofishing is not an effective method of removal in the Kentucky tailwaters due to a larger area of water where the fish can easily escape the electrical current. Targeted electrofishing for Asian carp was also conducted in Cooper Creek adjoining the lower Tennessee River. This sampling effort was in response to sightings of large numbers of silver carp by fisheries biologists of the Western Fisheries District. A total of 0.29 hours electrofishing effort was conducted to capture 260 lbs of silver carp (Table 3). A subsample of 20 silver carp were individually weighed and measured exhibiting a mean length of 19.5 inches and mean weight of 3.1 lbs.

Paupier Net

In November 2016 the U. S. Fish and Wildlife Service (USFWS) from Columbia, Missouri, conducted sampling efforts with Paupier nets in the Big Bear embayment of Kentucky Lake. This was the first time this gear had been used in Kentucky Lake or in a reservoir of comparable size. The Paupier nets produced 1,406 silver carp in 9.12 hours of effort (Table 4). Lengths and weights were taken from a random subsample of silver carp captured by the Paupier net with lengths ranging from 9.4 to 37.8 inches.

In 2017 the USFWS continued sampling efforts with the Paupier net on Kentucky Lake to evaluate the most effective time of day to sample Asian carp in the lakes, determine the size structure and length/weight relationships of Asian carp, and determine the fish community associated with Asian carp in Kentucky Lake and Lake Barkley. The USFWS crew sampled two embayments on Kentucky Lake; Sledd Creek and Big Bear, and just above the dam on Lake Barkley. Each area was sampled for one night in the months of April, July, and October. KDFWR staff assisted with sampling efforts by providing tender boats to record catch and take measurements on designated species. During sampling efforts, a total of 30,654 fish were captured comprised of 40 species (Tables 4 and 5). Aside from gizzard shad and threadfin shad, silver carp made up the majority of the catch on all sampling occasions with a total of 5,853 silver carp captured throughout all sampling periods.

The highest CPUE of silver carp was seen in the Sledd Creek embayment of Kentucky Lake in October (510.5 fish/hour), followed distantly by Sledd Creek in April (303.3 fish/hour) (Table 6). Interestingly, July was the month of lowest silver carp capture in all locations sampled, with the lowest CPUE being in Sledd Creek (47.5 fish/hour; Table 6). During sampling efforts in July, it was obvious that silver carp were present in the sampling area with large numbers jumping out of the water surrounding the boats. However, the reduced capture rate may be due to the fish being more active in warmer water temperatures and out-swimming the nets.

Silver carp CPUE in the Big Bear embayment of Kentucky Lake increased markedly from Paupier net sampling efforts conducted in 2016 (Table 4). This noticeable increase may be due in part to altered sampling schedule of the Paupier net crew; as in 2016 sampling was conducted during both day and night time periods, whereas in 2017 sampling efforts were conducted only in the evening to midnight time frame because this is when their capture rates were the highest. Silver carp captured in Kentucky Lake ranged from 8.0 to 37.8 inches in length, with the majority being in the 19-23 inch class range. Silver carp captured in Lake Barkley ranged from 11.8 to 37.4 inches in length, with the majority falling in the 23-28 inch class range. On average, silver carp captured in Lake Barkley were larger than silver carp captured in Kentucky Lake with the Paupier net. The dominant size class of silver carp apparent in 2017 sampling represents the 2015-year class when young of year silver carp were documented in the lakes for the first time. However, it is notable that very few silver carp captured with the Paupier net were larger than 28 inches in length (3.1%). Silver carp of this size and larger are known to be in the lakes as shown through commercial fishing reports and other sampling efforts. Therefore, it may be a limitation of the Paupier net to capture silver carp in this size class as they are able to out-swim the net in the open waters of Kentucky and Barkley lakes. For a more detailed analysis of silver carp size structures captured by the Paupier net please reference the Silver Carp Demographics Annual Report. Forty-six silver carp captured by the Paupier net were surgically implanted with acoustic transmitters for the telemetry study. Some Asian carp were also euthanized and used by Tennessee Technological University and Southern Illinois University for graduate student research projects.

Black Carp Sampling

KDFWR staff assisted the USFWS (Carterville, IL) conduct sampling efforts on the lower Ohio River and tributaries targeting black carp. Sampling efforts consisted of electrofishing, gill nets, and hoop nets. Specific sampling protocols were established by the USFWS. KDFWR staff assisted with sampling efforts three days in June on the lower Ohio River. No black carp were captured during those sampling efforts.

A single black carp was captured by a commercial fisherman in Lake Barkley in November, 2017. This was the first documented capture of a black carp in the Cumberland River system. KDFWR staff were on board the fisherman’s boat conducting a routine ride-along at the time of capture to record information on harvest of other Asian carp species and identified the fish. The fish was captured in the northern portion of Lake Barkley, less than one mile from the dam (37.0083825, -88.2105405). The fish was caught in a 200’x10’x5” gill net along with 6 silver carp, 1 paddlefish, and 1 smallmouth buffalo. The net was set on the edge of the main river channel at a water depth of 16 ft, approximately 100 yards from an island. Contacts were made with the appropriate personnel with the U.S. Fish and Wildlife Service and the U.S. Geological Survey. The fish was dissected and sections were shipped on ice to the respective laboratories for analysis. The black carp had a total length of 37.8 inches and weighed 31.3 lbs. The fish was determined to be diploid and a sexually mature male. The gut contents are still being analyzed by personnel at the USGS lab in Colombia, Missouri, however field observations indicated that the stomach contained numerous *Viviparidae* snails.

In January, 2018, a black carp was collected in Kentucky Lake by a commercial fisherman. This was the first documented capture of a black carp in the Tennessee River system. The fish was captured 12 miles south of the dam (36.85392, -88.15520). The fish was collected in a 3.5” bar-mesh gill net. Protocols for processing the black carp were followed with sections of the fish being shipped on ice to the respective laboratories for analysis. The black carp had a total length of 35.3 inches and weighed 22.5 lbs. The fish was determined to be diploid and a sexually mature male. The gut contents are still being analyzed by personnel at the USGS lab in Colombia, MO. KDFWR is increasing public awareness of black carp identification as more captures in the Cumberland and Tennessee river systems are probable.

Conclusions

Of all gear types used to capture Asian carp in 2017, gill nets remain the most dependable and effective method of catching Asian carp in Kentucky Lake and lake Barkley with minimal bycatch. During KDFWR gill netting 3-inch mesh caught the largest number of Asian carp, most of which are representative of the 2015 year class. These fish are expected to begin recruiting to 3.5-inch mesh nets which commercial fishermen may use. However, the majority of commercial fishers use 4.25-inch mesh nets, as they yield the size of Asian carp desired by processors. Therefore, the most effective method for capturing large numbers of Asian carp smaller than what is targeted by commercial fishermen is the Paupier net. Paupier net sampling will be continued as the operating USFWS crew is available. In the tailwaters of Lake Barkley Dam, electrofishing is an effective method of Asian carp removal and will be continued in 2018. KDFWR will continue exploring other gear types in Kentucky Lake, Lake Barkley and their associated river systems. Coordination with multiple entities to increase removal of Asian carp from Kentucky's waters will also be pursued.

Literature Cited

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

Table 1. Number of fish captured by species in the Little Bear embayment of Kentucky Lake in December 2017 with a benthic trawl.

| Species | Number Collected |
|---|---|
| Bluegill Sunfish | 92 |
| Black Crappie | 9 |
| Bullhead Minnow | 1 |
| Freshwater Drum | 1 |
| Largemouth Bass | 4 |
| Longnose Gar | 1 |
| Minnow Spp. | 2 |
| Redear Sunfish | 1 |
| Sand Shiner | 1 |
| Shortnose Gar | 1 |
| Silver Chub | 9 |
| Threadfin Shad | 7 |
| White Crappie | 1 |
| Yellow Bass | 13 |
| Yellow Perch | 1 |

Table 2. Capture rates (number of fish) of Asian carp and bycatch in gill nets by mesh size during targeted sampling efforts in Barkley and Kentucky Reservoirs in 2017.

| | 1.5" | | 2" | | 3" | | 4" | | 5" | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reservoir | Asian Carp | Bycatch | Asian Carp | Bycatch | Asian Carp | Bycatch | Asian Carp | Bycatch | Asian Carp | Bycatch |
| Kentucky | 0 | 58 | 0 | 22 | 16 | 23 | 7 | 16 | 0 | 9 |
| Barkley | 0 | 34 | 0 | 16 | 130 | 58 | 34 | 22 | 4 | 14 |

Table 3. Electrofishing effort and resulting catch during Asian carp removal efforts from Lake Barkley and Kentucky Lake tailwaters, and Cooper Creek in 2017.

| Date | Location | Effort (hours) | Water Temperature (˚F) | Pounds of Asian Carp Removed | CPUE (fish/hr) |
|---|---|---|---|---|---|
| 6/29/2017 | Barkley TW | 0.67 | | 3037 | 313 |
| 7/19/2017 | Barkley TW | 1.36 | | 3527 | 193 |
| 7/27/2017 | Barkley TW | 1.07 | 87.0 | 3952 | 408 |
| 8/2/2017 | Barkley TW | 1.12 | | 2469 | 195 |
| 9/21/2017 | Barkley TW | 1.13 | 76.6 | 3549 | 403 |
| 9/26/2017 | Barkley TW | 1.48 | 79.2 | 1906 | 131 |
| 7/3/2017 | Kentucky TW | 0.50 | 82.0 | 33 | 6 |
| 10/3/2017 | Cooper Creek | 0.29 | 74.2 | 260 | 297 |

Table 4. Paupier net effort and catch rates of Asian carp species from sampling conducted in Big Bear embayment of Kentucky Lake November 2016 through October 2017. (S.E. = Standard error)

| Date | Net Hours | Number of silver carp captured | Mean silver carp CPUE (fish/hr) | S.E. | Number of grass carp captured | Number of bighead carp captured |
|---|---|---|---|---|---|---|
| November 2016 | 9.12 | 1,406 | 168.9 | 23.0 | 3 | |
| April 2017 | 2.60 | 731 | 266.1 | 69.4 | 2 | 2 |
| July 2017 | 2.87 | 138 | 47.7 | 12.5 | 1 | 1 |
| October 2017 | 2.12 | 516 | 229.2 | 40.3 | | 2 |

Table 5. CPUE (fish/hr) of bycatch species collected during Paupier net sampling in 2017 listed by month.

| Species | April | July | October |
|---|---|---|---|
| Black crappie | 0.2 | 0.1 | 0.9 |
| Black buffalo | 0.0 | 0.2 | 0.0 |
| Brook silverside | 0.1 | 18.8 | 0.5 |
| Blue catfish | 0.2 | 0.2 | 0.5 |
| Bluegill | 1.1 | 0.5 | 7.6 |
| Bigmouth buffalo | 0.8 | 0.4 | 2.8 |
| Common carp | 0.0 | 0.4 | 1.2 |
| Channel catfish | 0.6 | 7.6 | 9.2 |
| Emerald shiner | 5.2 | 65.0 | 0.0 |
| Flathead catfish | 0.0 | 0.0 | 0.2 |
| Freshwater drum | 0.4 | 0.1 | 4.8 |
| Goldeneye | 0.0 | 0.0 | 0.9 |
| Golden shiner | 0.1 | 2.3 | 6.0 |
| Green sunfish | 0.0 | 0.1 | 0.0 |
| Grass carp | 1.2 | 0.6 | 0.4 |
| Gizzard shad | 624.6 | 283.7 | 461.5 |
| Inland silverside | 1.2 | 0.0 | 0.0 |
| Longear sunfish | 0.1 | 0.0 | 2.3 |
| Logperch | 0.0 | 0.1 | 0.2 |
| Largemouth bass | 1.6 | 0.5 | 4.2 |
| Longnose gar | 0.1 | 0.5 | 0.0 |
| Mooneye | 0.1 | 0.1 | 0.0 |
| Paddlefish | 0.1 | 0.0 | 0.0 |
| Pumpkinseed | 0.1 | 0.0 | 0.0 |
| Readear sunfish | 0.0 | 0.1 | 0.4 |
| River carpsucker | 0.0 | 0.1 | 0.2 |
| Spotted bass | 0.1 | 0.0 | 0.0 |
| Skipjack herring | 1.6 | 5.3 | 23.7 |
| Smallmouth buffalo | 2.4 | 1.1 | 3.7 |
| Smallmouth bass | 0.0 | 0.1 | 0.0 |
| Shortnose gar | 1.2 | 0.6 | 0.7 |
| Spotted sucker | 1.6 | 0.2 | 3.4 |
| Striped bass | 0.1 | 0.0 | 0.0 |
| Spotted gar | 0.0 | 0.4 | 1.1 |
| Threadfin shad | 302.9 | 394.9 | 39.4 |
| White bass | 1.2 | 0.2 | 14.3 |
| White crappie | 0.9 | 0.9 | 3.5 |
| Yellow perch | 0.0 | 0.0 | 0.2 |

Table 6. CPUE (fish/hr) of silver carp by month and location for Paupier net sampling conducted during 2017.

| | Sampling Location | | |
|---|---|---|---|
| Month | Sledd Creek | Big Bear Creek | Lake Barkley |
| April | 303.3 | 281.5 | 170.1 |
| July | 47.5 | 48.1 | 89.4 |
| October | 510.5 | 243.6 | 142.6 |

Figure 1. Experimental gear built by Two Rivers Fisheries deployed in Honker Bay of Lake Barkley.

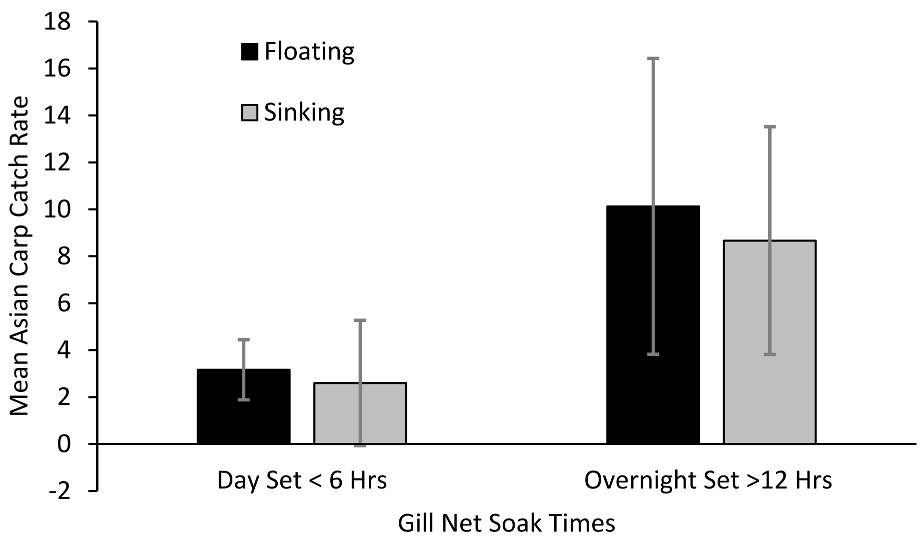


Figure 2. Comparison of mean catch totals for Asian carp captured in floating and sinking gill nets between day sets and overnight sets in 2017. Error bars represent 95% confidence intervals.

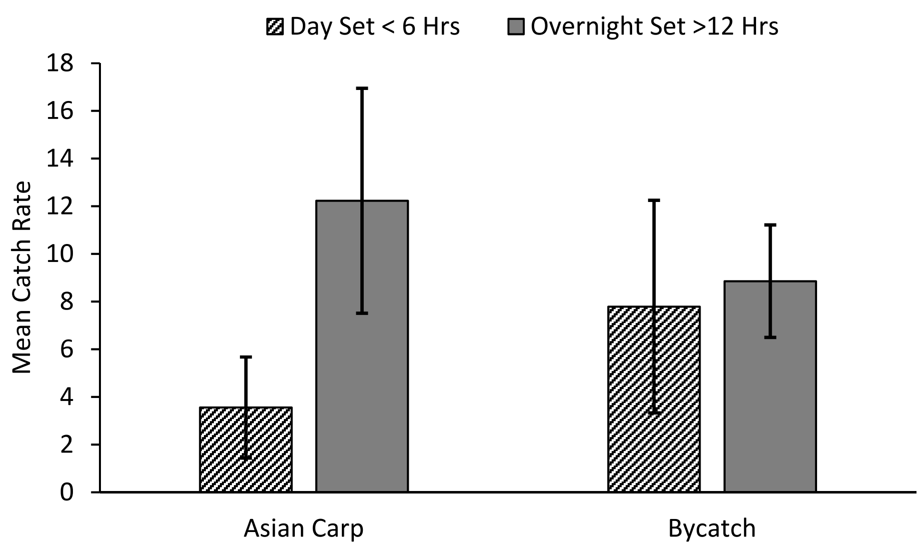


Figure 3. Comparison of mean catch totals for Asian carp and bycatch captured in gill nets during day sets and overnight sets in 2017. Error bars represent 95% confidence intervals.

## Asian Carp Telemetry in the Ohio River

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### Introduction:

After several Asian Carp species became established throughout the lower Mississippi basin during the 1980's, it was only a matter of time before these highly mobile fish had dispersed upstream into other large river basins. To date, Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*) are the only species of bigheaded Carp to become well-established throughout the lower Ohio River Basin (ORB). Populations of both species have grown steadily since invading the basin and having successfully spawned within the lower half of the Ohio River, with their spawning range expanding as far upriver as the Cannelton Pool where age-0 Asian Carp were recently collected.

Despite the current circumstances in the lower half of the ORB, there are still pools located in the middle and upper Ohio River that do not contain established populations of bigheaded carp. This situation prompted several state and federal agencies to make a cooperative effort towards preventing the Asian Carp from being established in these areas. This agency collaboration became even more essential after the Great Lakes and Mississippi River Interbasin Study (GLMRIS) identified some previously unrecognized connections between the upper ORB and the Great Lakes. If the Asian Carp were allowed to gain access to the Great Lakes via one of these pathways, they could certainly cause irreparable damage to the many important commercial and recreational fisheries that exist in these water bodies.

In response to this potential threat, Fish and Wildlife agencies with a shared interest in the basin have recently started working together towards learning as much as they can about the populations of Asian Carp that are threatening the upper Ohio River. The Asian Carp Telemetry Project was one of the first multi-agency research efforts to involve these fish populations the have invaded the ORB. The project uses ultrasonic acoustic telemetry to study the distribution and movement of the Bighead and Silver carp that inhabit the middle to upper Ohio River. In addition to the project's main objective of identifying when Asian Carp spread into new areas of the river, it also records smaller scale movements that could be essential to the ongoing efforts to reduce the densities of Bighead and Silver Carp populations that are prevalent in some areas of the Ohio River.

The primary objectives for the Ohio River Asian Carp Telemetry Project in 2017 were as follows:

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

### Methods

*Establishment of the Receiver Array:*

The first primary component of the Asian Carp Telemetry Project is a relatively large (~500 miles) telemetry array that started to take shape in 2013 following the initial deployment of 60 VEMCO (model VR2W) ultrasonic receivers. Over the next four years, the array expanded each time an entire pool was added and field crews started populating them with new receiver stations. The KDFWR, USFWS and ODOW were responsible for maintaining the vast majority of receiver stations that were established in 2013-2017.

The new site locations were chosen according to the current density of the receivers in the area and the specific habitat types needed to accomplish one or more of the project objectives. The three habitat types required by objectives for this project are 1) the mainstem of the Ohio River, 2) tributaries that are large enough for Asian Carp, and 3) the lock chambers/approaches at Lock & Dam (L&D) facilities located within the array. The stations in the mainstem river were established by securing receivers to navigational buoys using 10'-12' steel rods. Tributaries rarely contain buoys, so the VR2W's were deployed to these sites by being attached to man-made structures (i.e. bridge piers and docks), or by being secured to metal stands that were anchored to the bottom of the creek/river. At the L&D sites, the receivers were placed in protective metal sleeves and then lowered into the ladder-wells located along the walls of the locks/approaches.

The tributary and L&D receivers remained in the river all year to continuously track the movements of the project's tagged carp. In contrast, most mainstem receivers were retrieved during mid-December 2016 and then placed in storage for the next 3 – 4 months of winter, which was when the buoys were most likely to disappear. Hence, in early 2017, the array wasn't complete until the end of March when KDFWR, USFWS and ODOW biologists had successfully returned all overwintering receivers to their respective sites in the mainstem Ohio River.

Soon after the redeployment efforts were completed, the KDFWR began working with the USFWS to identify prominent tributaries within the telemetry array that didn't have adequate receiver coverage. Also, when VR2W's were available, most navigable tributaries received two receiver stations (up to 1 mi. apart), which helped to expand the telemetry coverage and make it possible to identify the direction that each tagged carp was moving. Other improvements in 2017 included efforts to deploy a fourth receiver at all seven L&D facilities located within the array. Each new station was established in the L&D's upstream approach to work with existing receivers in both lock chambers and the downstream approach as they monitor for tagged carp that are attempting to transfer pools. The final addition to the telemetry array in 2017 involved deploying temperature (temp) loggers alongside VR2W's at the furthest upstream receiver stations that have already been established in larger tributaries. These temp loggers should provide the data required to determine if a tributary's water temperature has any influence on the behavior/movements of tagged Asian Carp.

*Implanting Ultrasonic Transmitters*

During the spring and summer of 2017, KDFWR and USFWS biologists utilized a combination of pulsed DC electrofishing and gill nets to collect both Bighead Carp and Silver Carp that could be surgically implanted with ultrasonic transmitters. Most of the effort in 2017 was concentrated on the low-density AC populations in the Markland and Meldahl pools to replace tagged Asian Carp containing transmitters that are scheduled to shut down in summer 2018. Tagging efforts in 2017 were also conducted in the Cannelton Pool. The higher density of Asian Carp in this pool made it possible to collect and tag a suitable number of fish over a shorter time period.

Upon the collection of a Bighead or Silver Carp, the surgical procedure outlined by Summerfelt et al. (1990) was used to implant a VEMCO (model V16-6H) ultrasonic transmitter into the carp's abdominal cavity via an incision (~2" long) made posterior to its pelvic fin and anterior to its anus. After carefully implanting the transmitter, the incision was closed using 3 - 4 simple interrupted sutures. Following the completion of each surgery, specific details about the procedure (i.e. location, crew, transmitter #) were recorded along with the length, weight and sex of the fish. And then finally, each tagged carp was released within a mile of its sampling location after being marked with a uniquely numbered aluminum jaw tag (5/8" wide) that allows for the quick identification of the fish if it's ever recaptured.

The VEMCO model V16-6H transmitters (.625" diameter & 3¾" long) have been utilized every year from 2013 to 2017 in order to ensure that the tagged AC can be detected via all receiver in the array. Full compatibility allows the receivers to decipher the unique Tag ID encoded into each ultrasonic signal, which is randomly transmitted (@ 69 kHz) every 20 – 60 seconds. These transmitters have an above-average battery life of 5 years, which was the result of using a high-capacity lithium battery without equipping any additional sensors (i.e. temperature or pressure). For standardization purposes, all transmitters are programmed to shut down upon reaching the end of their 5-year life span, which occurs regardless of remaining battery power.

*Data Collection, Management & Analysis*

With the array nearly doubling in size over the past several years, the KDFWR, USFWS and ODOW worked together to develop a more efficient protocol for maintaining receiver stations and offloading new data at regular intervals. Since 2016, project biologists have utilized a method that required the array to be divided into two parts. The first was a 170-mile section of the river located on the downstream end of the array and included Cannelton, McAlpine, and the first half of the Markland Pool. In both 2016 and 2017, KDFWR's project biologist accepted responsibility for up to 40 receiver stations that were established throughout this 170-mile stretch of the Ohio River. The second part of the telemetry array covered at least some portion of seven different pools (Upper Markland, Meldahl, Greenup, RC Byrd, Racine, Bellville and Willow Island). The USFWS and ODOW ultimately shared responsibility for the 100+ receiver stations spread throughout this 330-mile section of the array.

As previously noted, most receiver work completed by participating agencies (KDFWR, USFWS & ODOW) between May and November 2017 was comprised of monthly efforts to offload new data from any of the VR2W's found throughout the two sections of the array. Upon completion of the monthly site visits, biologists created a dataset of all recently offloaded tag detections that was shared with other participating agencies via a file transfer protocol (FTP) site. The download and compilation of new detections were completed regularly during 2017 to ensure that all parties would have access to the most up-to-date dataset possible.

Since the receiver protocol allowed agencies to be more efficient at completing their monthly downloads, it has led to the accumulation of tremendous amounts of new data that needed to be properly managed. As in previous years, the KDFWR was responsible for organizing the new telemetry data that each agency collected and uploaded to the FTP site in 2017. In order to accomplish this task, KDFWR's project biologist regularly downloaded new telemetry datasets from the FTP site and reviewed each file in order to identify/remove any incomplete, duplicate or erroneous data. If detections of tagged fish from other studies were found within the dataset, the information was forwarded to the appropriate contact(s). All data entries still present after the completion of the review process were considered valid tagged carp detections and were subsequently imported into the 2017 telemetry database. This database eventually contained all 2017 project data, including the total detections, details from each tagged carp and the locations of all active receiver stations.

On two separate occasions in 2017, the telemetry database was reduced to create two separate datasets containing tagged carp detections on an hourly or daily time scale. These smaller, more manageable datasets were often analyzed via simple spreadsheet programs in order to keep track of tagged carp movements on a broader scale (i.e. pool transfers) and/or over longer time periods (i.e. weeks & months). However, when the raw dataset (> 8 mil. detections in 2017) was required, project biologists often conducted the analysis using R statistics software with the VTrack package (v1.11), which is a collection of tools that were specifically developed to handle the large telemetry datasets often produced by VEMCO equipment. Finally, ArcMap (v10.5) software was used to create the maps and complete the other GIS work conducted for the Asian Carp Telemetry Project in 2017.

**Results and Discussion**

*Establishment of Project's Receiver Array*

The project's 500-mile telemetry array included at least a portion of nine different pools in the Ohio River and contained a total of 158 acoustic receiver stations, which were distributed over a selection of mainstem, tributary and L&D sites (Figure 1). After completing the initial efforts to redeploy overwintering VR2W's to existing mainstem sites, the focus shifted towards deploying receivers to new sites within tributaries that were suggested by regional biologists. When these targeted efforts were completed by mid-summer 2017, the project's telemetry array had gained 33 additional receiver stations located in 18 tributaries, including 15 creeks and small rivers that have never been monitored for tagged Carp (Figure 2). The final efforts to add new stations to the array were those conducted by the USFWS to improve the receiver coverage at L&D facilities. Once completed, each of the array's seven L&D's had a new site in the upstream approach that complemented its three existing stations that continuously monitor for any tagged carp trying to move into an adjacent pool.

The 2017 efforts to add new stations to the array targeted only tributaries and L&D's because the distribution of receivers across the three habitat types was already heavily skewed towards mainstem sites, which has been the case since the first year of the project in 2013. When the project's array had a total of 123 receiver stations in 2016, the mainstem sites (n = 81) represented almost 66% of that total, while tributary (n = 21) and L&D (n = 21) sites combined to make up only 34% of those stations (Table 1). In 2017, the decision was made to avoid replacing the VR2W's that go missing from the more problematic mainstem stations and the previously mentioned focus on tributaries and L&D's has helped to improve how the receivers are distributed among the 3 primary habitat types. So by the end of 2017, the project's array contained a combination of 76 mainstem (48%), 54 tributary (34%) and 28 L&D (18%) sites for a total of 158 receiver stations, which are all used to track the project's 500+ tagged Asian Carp.

*Implanting Ultrasonic Transmitters*

Since the vast majority of the ~4 weeks of tagging efforts that the KDFWR and USFWS conducted through the summer of 2017 occurred in pools containing low density populations, they were only able to tag a total of 17 Asian Carp, which included both Bighead (n=2) and Silver Carp (n=15) that were collected from the Markland (n = 12) and Meldahl (n = 3) pools (Table 2). However, in October 2017, only one week of effort was required to collect and tag an additional 90 Silver Carp from the higher density population residing in the Cannelton Pool. All 107 Asian Carp tagged in 2017 will continue to be tracked via the receiver array until the transmitters shut down during 2022.

From all tagging efforts conducted in 2013 - 2017, the Ohio River Telemetry Project currently has an unadjusted total of 508 Asian Carp implanted with ultrasonic transmitters, which when broken down by species includes 464 Silver Carp (91.3%) and 44 Bighead Carp (8.7%) (Table 2). All tagged carp for this project were sampled from 5 separate pools, but as expected, the majority (83.3%) of them originated from Cannelton and McAlpine, which are the only two pools with higher density carp populations. The length frequency distribution indicates that the majority of Silver Carp collected/tagged from the higher density pools (Cannelton & McAlpine) had mean lengths of 30 - 35 in, but those from the Markland and Meldahl pools were slightly larger carp that measured 35 – 40 in long (Figure 4). A similar size evaluation of tagged Bighead Carp showed that all but two fish were > 41 in long with no noticeable differences in total length between pools (Figure 5). The original tags placed in 19 Asian Carp collected/tagged from the Meldahl Pool during 2013 are expected to begin shutting down upon reaching the end of their transmitter's 5-year battery life during the summer of 2018.

*Detections of Tagged Asian Carp*

In 2017, KDFWR's project biologist made numerous efforts to error-check and format telemetry datasets that were offloaded monthly by field crews from the KDFWR, ODOW, USFWS and WVDNR. Soon after importing the final error-checked datasets into the telemetry database, it was determined that between Jan 01 and Dec 14 of 2017, eighty-one (51.2%) of the 158 receivers in the array made a combined total of ~8,175,000 detections of tagged Asian Carp (Table 3). Upon further analysis, this dataset contained at least one detection from 263 (51.8%) of the 508 total carp that have been tagged during the project. The 2017 database was eventually reduced to create two separate datasets with 346,478 hourly and 35,064 daily detections that were later used to analyze the large-scale movements of the tagged carp.

The original 2017 dataset was analyzed using R statistics with the VTrack package. At its simplest level, VTrack was able to manage (i.e. sort, filter, etc) the 8+ million tagged carp detections in a manner similar to how a spreadsheet program works with smaller data files, but without having to change/reduce the original dataset. Although many receivers had similar numbers of tagged carp detections, there were still some areas where the receivers contained substantially more detections than other locations in the array (Figure 3). The area containing the largest proportion of tagged carp detections was the McAlpine Pool, which was not unexpected from a mid-sized pool (~75 miles) that contains 22 active receivers and as many as 237 tagged carp. In total, the receivers in McAlpine combined to make 6.7 million tagged carp detections, or >80% of all those made in 2017, which is over 10 times more than the project's 2nd most detections (n = 573,578) that were recorded by receivers in the Meldahl Pool (Table 3).

All 2017 detections from the upper McAlpine Pool and the OH-Brush Creek area of the Meldahl Pool were analyzed to determine if seasons have an influence on Asian Carp habitat preferences. The analysis started by splitting the total detections, and the related numbers of unique carp, into groups based on the season that they were recorded in, which included winter (Jan - Feb), spring (Mar - May), summer (Jun - Aug) and Fall (Sep - Nov). According maps showing that the total number of tagged carp detections that receivers in the upper McAlpine Pool made during the winter (Figure 6), spring (Figure 7), summer (Figure 8) and Fall (Figure 9) of 2017, it appears that tagged carp preferred to occupy the tributaries for considerably longer time periods, regardless of season, which was also demonstrated in a map of the total detections from the entire year (Figure 10). Another notable trend from the seasonal comparisons is that mainstem receivers near the mouths of the tributaries appear to record higher numbers of both seasonal and total detections than other mainstem sites, which could indicate that tagged carp may frequently exit a tributary, but then they appear more likely to re-enter the tributary, or another one nearby, than move about the mainstem river. A similar comparison of seasonal habit preferences were conducted with the total detections from receivers located in and around the OH-Brush Creek area of the Meldahl Pool. The maps showing the total detections made by each receiver during the winter (Figure 11), spring (Figure 12), summer (Figure 13), and fall (Figure 14) produced similar conclusions regarding the tagged carp's year-round preference to either occupy tributaries or remain near mainstem site(s) that are located within close proximity of a tributary. Similarly, tagged carp appear to refrain from venturing too far upstream/downstream when there are fewer tributaries in the immediate area, which may be a reason why receivers located further away from OH-Brush Creek often detect smaller numbers of unique carp (Figure 15).

*Movements of Tagged Asian Carp*

The 2017 hourly detections were used to estimate the monthly mean ranges of both the Bighead Carp and Silver Carp. To be certain that only live fish detections were used in the estimate, any tagged carp detected by a single receiver in 2017 were not included in the range calculations. All remaining hourly detections were grouped by month and pool. A tagged carp's range is defined as the total number of river miles between its most upstream and downstream detections that were made over a specific time period (i.e. month). The mean monthly ranges were compared for tagged Bighead and Silver Carp located in the three most active pools of the receiver array, which were McAlpine, Markland and Meldahl (Figure 16). During most months, Bighead Carp appeared to traverse a larger stretch of the river, except in April 2017, when Silver Carp in Markland exhibited a mean range that was more than double that of Bighead Carp from any pool (Table 5). Regardless of pool, both species of tagged carp appeared to be most active from April to August 2017, but during this 5-month period, Bighead Carp were more likely to cover greater distances between their most upstream and downstream detections (Figure 17). Although the Silver Carp did remain active after Bighead Carp movements ended abruptly in September, their mean ranges in September thru November were considerably smaller than they were in the months of spring and summer.

Other movements that were closely monitored in 2017 included attempts by tagged carp to pass through a L&D in order to transfer into an adjacent upstream/downstream pool. A preliminary check of telemetry data from L&D receivers, and those at nearby mainstem sites, initially identified up to 16 tagged carp that were detected by receivers located in two different pools, which indicates that a transfer may have occurred. However, after the movements of each fish was thoroughly examined, it was determined that only 8, or 50%, of the 16 tagged carp had made "valid" pool transfers in 2018, which included a Bighead, 6 Silver Carp and one unknown (Table 6). Seven, or 87.5%, of the 8 valid transfers consisted of moving either upstream or downstream through McAlpine L&D. The only valid pool transfer in 2017 that didn't involve McAlpine or Cannelton was completed by a tagged carp that moved downstream through RC Byrd L&D. The close examination of the telemetry data also identified 8 tagged carp that couldn't be credited with making a “valid” transfer despite having detections in least two different pools (Table 7). In this case, seven tagged carp (a Bighead, 5 Silver Carp & one unknown) were characterized as having made a “possible” pool transfer. However, these transfers could not be validated because the only receiver to detect the tagged carp in the adjacent pool was in the upstream/downstream approach on the opposite side of the same L&D that these fish were trying to circumvent. It is possible for ultrasonic signals to bounce off the concrete walls of a lock chamber. If this scenario occurs at a high enough frequency, the transmitter’s signal could eventually reach a receiver located in the opposite lock approach. All seven of these tagged carp returned to their original pool soon after being detected by receivers in the opposite approach lending credence to this hypothesis. Each of these events will ultimately be considered as “possible” pool transfers, but they can be validated if the tagged carp are ever detected by another receiver located in the adjacent pool. The remaining pool transfer involved a Bighead Carp that moved downstream into the McAlpine Pool via the Markland L&D without a single detection. The tagged carp was then detected by a receiver in the Kentucky River before making an immediate return trip to the Markland Pool, which once again required the tagged carp to pass undetected through Markland L&D. The high rate of speed needed to complete the round trip and the requirement of passing multiple receivers without detection makes it unlikely that the tagged carp ever left the Markland Pool. So ultimately, the event was officially designated an "invalid" pool transfer.

Table 1. Total amounts and distribution (%) of the 3 types of receiver sites that contributed to the project's telemetry array in 2016 - 2017.

| Pool | RM's Added by Pool | 2016 | | | | | | | | 2017 | | | | | | | | 2016 to 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mainstem | | Tributary | | L&D | | Total | | Mainstem | | Tributary | | L&D | | Total | | |
| | | # Sites | % of sites in Pool | # Sites | % of sites in Pool | # Sites | % of sites in Pool | # Total Sites | % of 2016 total | # Sites | % of sites in Pool | # Sites | % of sites in Pool | # Sites | % of sites in Pool | # Total Sites | % of 2017 total | Total Change |
| Willow Island | 3.0 | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.8 | 1 | 50.0 | 0 | 0.0 | 1 | 50.0 | 2 | 1.3 | 1 |
| Belleville | 42.2 | 8 | 66.7 | 1 | 8.3 | 3 | 25.0 | 12 | 9.8 | 9 | 47.4 | 6 | 31.6 | 4 | 21.1 | 19 | 12.0 | 7 |
| Racine | 33.6 | 4 | 57.1 | 0 | 0.0 | 3 | 42.9 | 7 | 5.7 | 3 | 33.3 | 2 | 22.2 | 4 | 44.4 | 9 | 5.7 | 2 |
| RC Byrd | 41.7 | 7 | 46.7 | 5 | 33.3 | 3 | 20.0 | 15 | 12.2 | 4 | 36.4 | 3 | 27.3 | 4 | 36.4 | 11 | 7.0 | - 4 |
| Greenup | 61.8 | 7 | 63.6 | 1 | 9.1 | 3 | 27.3 | 11 | 8.9 | 9 | 47.4 | 6 | 31.6 | 4 | 21.1 | 19 | 12.0 | 8 |
| Meldahl | 95.2 | 26 | 68.4 | 9 | 23.7 | 3 | 7.9 | 38 | 30.9 | 24 | 63.2 | 10 | 26.3 | 4 | 10.5 | 38 | 24.1 | 0 |
| Markland | 95.3 | 11 | 64.7 | 3 | 17.6 | 3 | 17.6 | 17 | 13.8 | 10 | 34.5 | 15 | 51.7 | 4 | 13.8 | 29 | 18.4 | 12 |
| McAlpine | 75.3 | 10 | 66.7 | 2 | 13.3 | 3 | 20.0 | 15 | 12.2 | 9 | 40.9 | 10 | 45.5 | 3 | 13.6 | 22 | 13.9 | 7 |
| Cannelton | 53.7 | 7 | 100.0 | 0 | 0.0 | 0 | 0.0 | 7 | 5.7 | 7 | 77.8 | 2 | 22.2 | 0 | 0.0 | 9 | 5.7 | 2 |
| Totals | 501.8 | **81** | 65.9 | **21** | 17.1 | **21** | 17.1 | **123** | 100 | **76** | 48.1 | **54** | 34.2 | **28** | 17.7 | **158** | 100 | 35 |

Table 2. Total numbers and species composition (%) of the Bighead Carp and Silver Carp collected from 5 pools of the Ohio River and then tagged for the AC Telemetry Project in 2013 – 2017.

| Year | Asian Carp Species | Pool | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Cannelton | McAlpine | Markland | Meldahl | RC Byrd | |
| 2013 | Silver Carp | - | - | 0 | 6 | - | 6 |
| | Bighead Carp | - | - | 0 | 13 | - | 13 |
| 2014 | Silver Carp | - | 115 | 6 | 10 | - | 131 |
| | Bighead Carp | - | 4 | 4 | 0 | - | 8 |
| 2015 | Silver Carp | - | 22 | 3 | 5 | - | 30 |
| | Bighead Carp | - | 1 | 1 | 5 | - | 7 |
| 2016 | Silver Carp | 92 | 94 | 6 | 0 | 0 | 192 |
| | Bighead Carp | 4 | 1 | 4 | 2 | 3 | 14 |
| 2017 | Silver Carp | 90 | - | 12 | 3 | - | 105 |
| | Bighead Carp | 0 | - | 2 | 0 | - | 2 |
| Project Totals | Silver Carp | 182 | 231 | 27 | 24 | 0 | 464 |
| | Bighead Carp | 4 | 6 | 11 | 20 | 3 | 44 |
| | Total | **186** | **237** | **38** | **44** | **3** | **508** |
| Species Composition (%) | Silver Carp | 35.8 | 45.5 | 5.3 | 4.7 | 0.0 | 91.3 |
| | Bighead Carp | 0.8 | 1.2 | 2.2 | 3.9 | 0.6 | 8.7 |
| | Total | **36.6** | **46.7** | **7.5** | **8.7** | **0.6** | **100.0** |

Table 3. The mean lengths & weights of tagged Asian Carp collected from 5 pools of the Ohio River in 2013 – 2017.

| Pool | Species | N | Mean Total Length (in) | Mean Total Weight (lbs) |
|---|---|---|---|---|
| Cannelton | Silver Carp | 182 | 32.5 | 12.85 |
| | Bighead Carp | 4 | 44.9 | 34.24 |
| | All Asian Carp | 186 | 32.8 | 13.31 |
| McAlpine | Silver Carp | 226 | 33.8 | 15.22 |
| | Bighead Carp | 6 | 46.0 | 39.48 |
| | Grass Carp | 1 | 41.0 | 25.00 |
| | All Asian Carp | 234 | 34.2 | 15.93 |
| Markland | Silver Carp | 27 | 35.8 | 21.41 |
| | Bighead Carp | 11 | 46.3 | 50.28 |
| | All Asian Carp | 38 | 38.8 | 29.99 |
| Meldahl | Silver Carp | 24 | 37.8 | 25.01 |
| | Bighead Carp | 20 | 45.5 | 46.00 |
| | All Asian Carp | 44 | 41.3 | 34.55 |
| Greenup | Silver Carp | 0 | --- | --- |
| | Bighead Carp | 0 | --- | --- |
| | All Asian Carp | 0 | --- | --- |
| RC Byrd | Silver Carp | 0 | --- | --- |
| | Bighead Carp | 3 | 47.6 | 54.90 |
| | All Asian Carp | 3 | 47.6 | 54.90 |
| All Pools | Silver Carp | 460 | 33.6 | 15.14 |
| | Bighead Carp | 44 | 45.8 | 45.72 |
| | Grass Carp | 1 | 41.0 | 25.00 |
| | All Asian Carp | 505 | 34.7 | 17.91 |

Table 4. The total detections (Total Dtxns) and the numbers of unique AC offloaded from receivers in 2017 and then grouped by season, pool and site type.

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

Table 5. Mean monthly ranges of tagged Bighead and Silver Carp that were detected by receivers in the McAlpine, Markland and Meldahl pools during 2017. The range calculations only included tagged carp that were detected by at least 2 different receiver stations over the course of the entire year.

| Pool | Asian Carp Species | Mean Monthly Ranges (in River Miles) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
| McAlpine | Bighead Carp | 0.00 | -- | -- | -- | 7.00 | 56.90 | -- | 46.80 | -- | -- | -- | -- |
| | Silver Carp | 0.47 | 0.41 | 0.87 | 9.37 | 12.49 | 12.05 | 5.43 | 4.59 | 3.79 | 3.24 | 1.65 | 1.16 |
| Markland | Bighead Carp | -- | -- | 0.00 | 28.43 | 28.43 | 37.78 | 6.54 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Silver Carp | -- | -- | -- | 68.20 | 0.80 | 9.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Meldahl | Bighead Carp | 0.40 | 0.47 | 0.13 | -- | 22.05 | 57.50 | 13.30 | 9.80 | 5.03 | 0.07 | 0.20 | 0.00 |
| | Silver Carp | 0.06 | 0.17 | 0.20 | 32.36 | 11.83 | 10.01 | 12.86 | 18.18 | 6.76 | 1.55 | 0.20 | 0.09 |
| All Pools | Bighead Carp | 0.30 | 0.47 | 0.08 | 28.43 | 18.00 | 42.51 | 7.21 | 7.56 | 1.89 | 0.03 | 0.08 | 0.00 |
| | Silver Carp | 0.40 | 0.36 | 0.81 | 10.78 | 11.91 | 11.33 | 5.60 | 5.18 | 3.96 | 3.10 | 1.30 | 0.97 |

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

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

Table 7. Pool-to-Pool transfers in 2017 that could not be validated. These events have been categorized either as 1) "Possible Transfers" of tagged AC that were only detected by receivers associated with the initial L&D site, or as 2) "Invalid Transfers" that were based solely on what were later identified as False detections. 

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

Figure 1. A map of the project's entire 500-mile telemetry array with the eight separate Locks and Dam locations that are monitored for upstream/downstream transfers of tagged Asian Carp. The 2017 array included 158 receiver stations that were distributed across three distinct habitat types, which included the mainstem river, the tributaries, and the L&D's.


Figure 2. A map showing the distribution of the receiver stations that were established within tributaries from 2016-2017. An increased emphasis on this particular habitat type in 2017 succeeded in adding 15 new locations to the 13 tributaries that were already being monitored for tagged AC by the end of 2016.

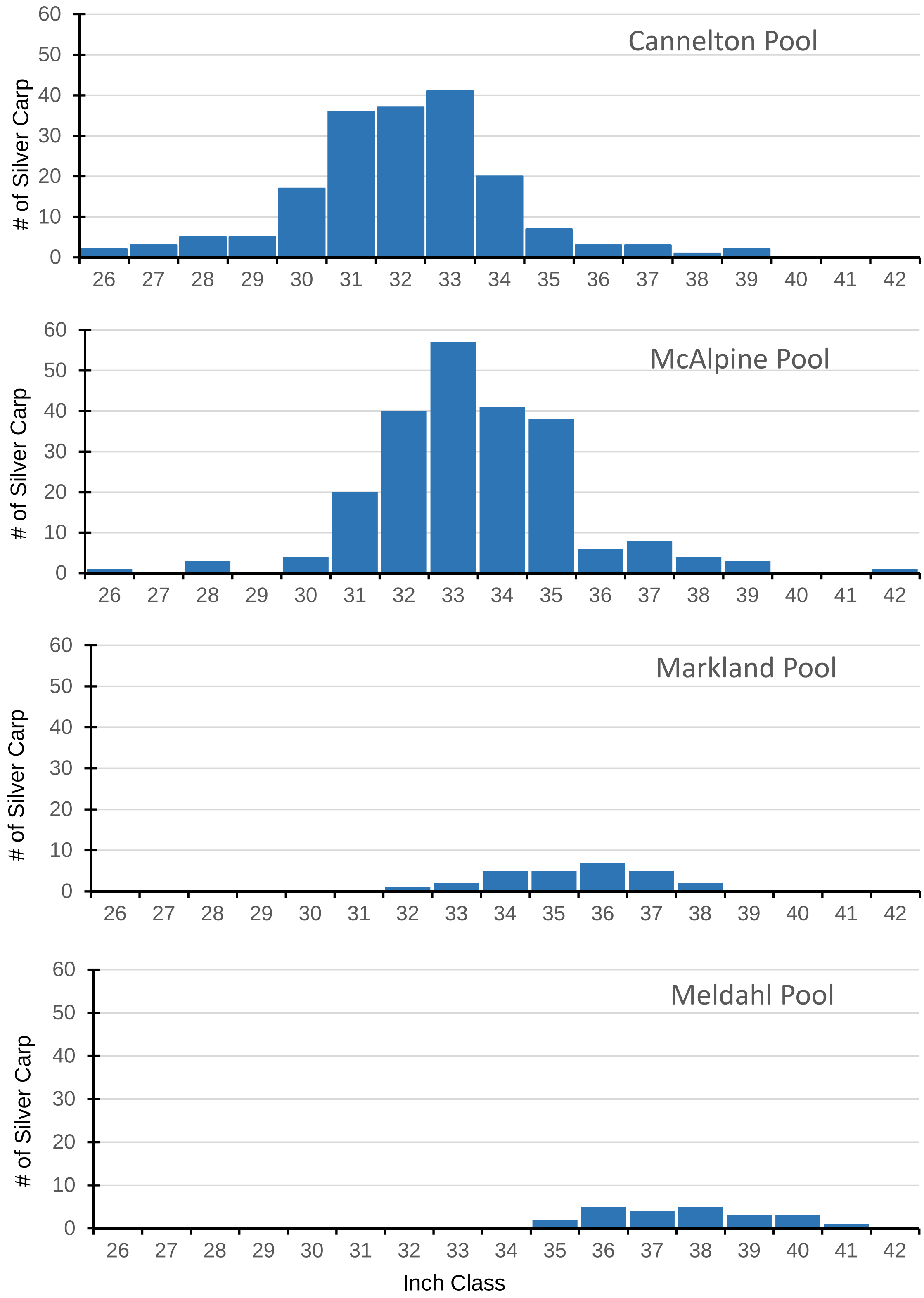



Figure 3. The length frequency of Silver Carp collected from each pool during 2013 – 2017 that were ultimately implanted with transmitters.

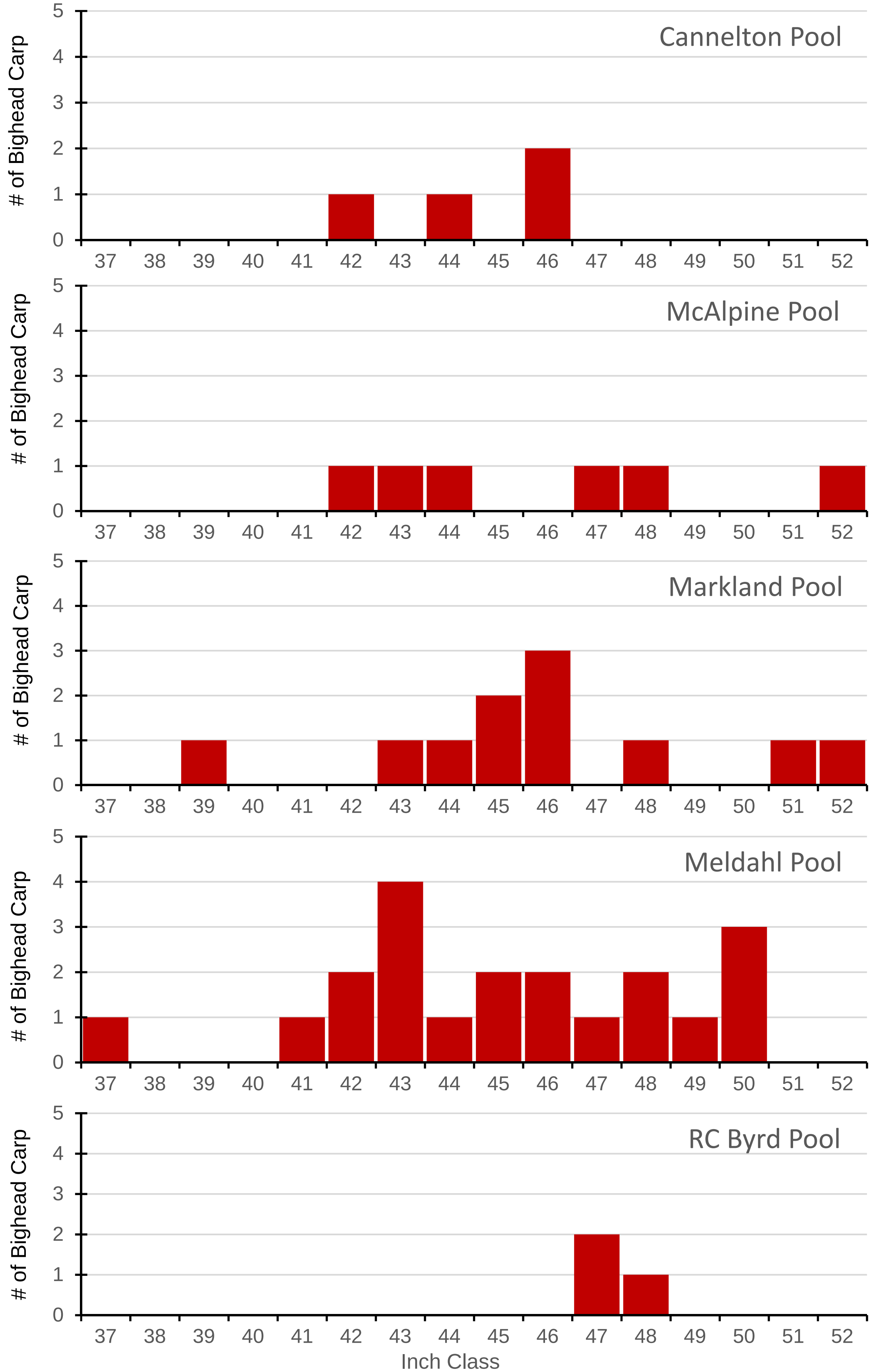



Figure 4. The length frequency of Bighead Carp collected from each pool during 2013 – 2017 that were ultimately implanted with transmitters.

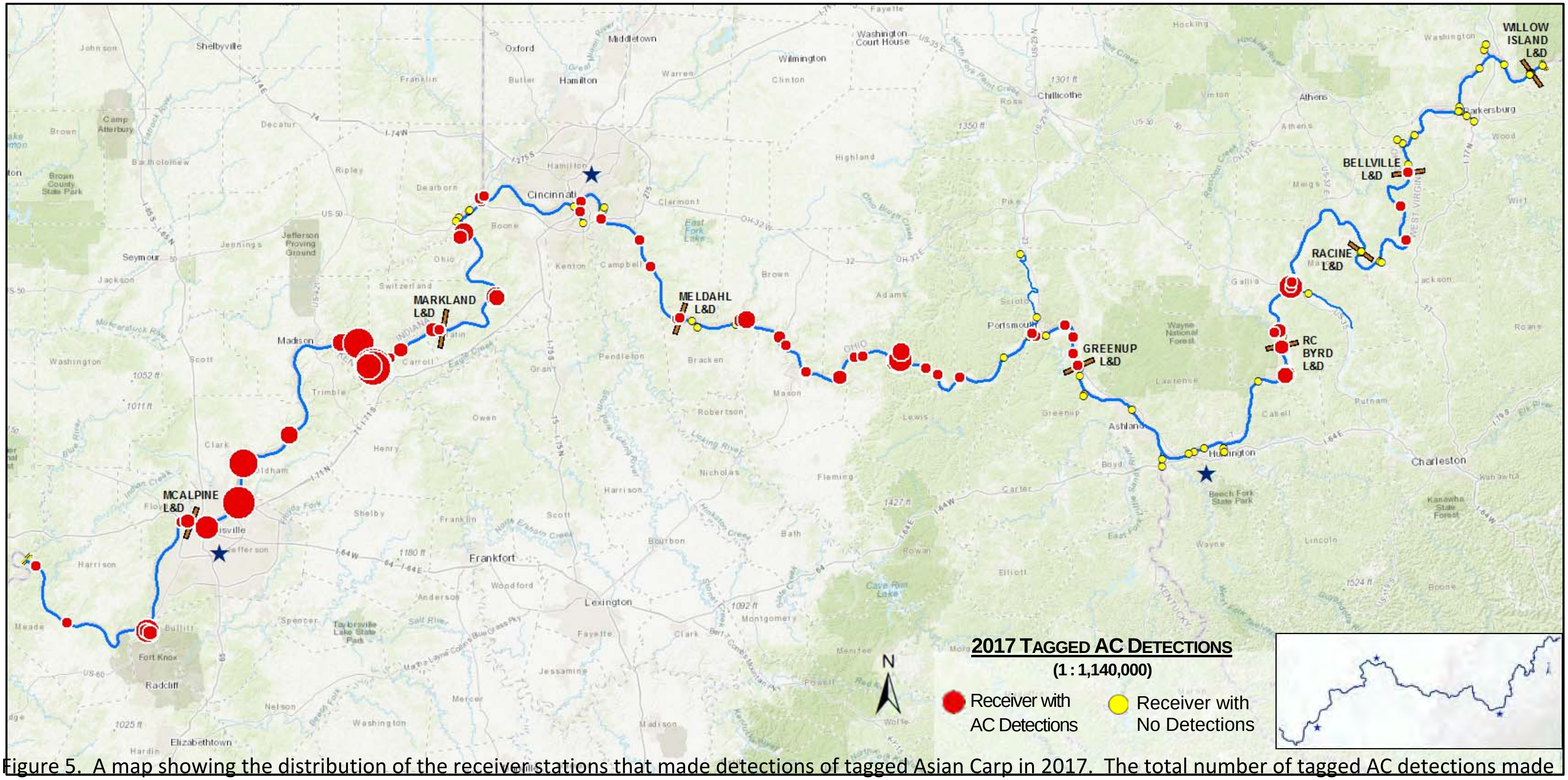
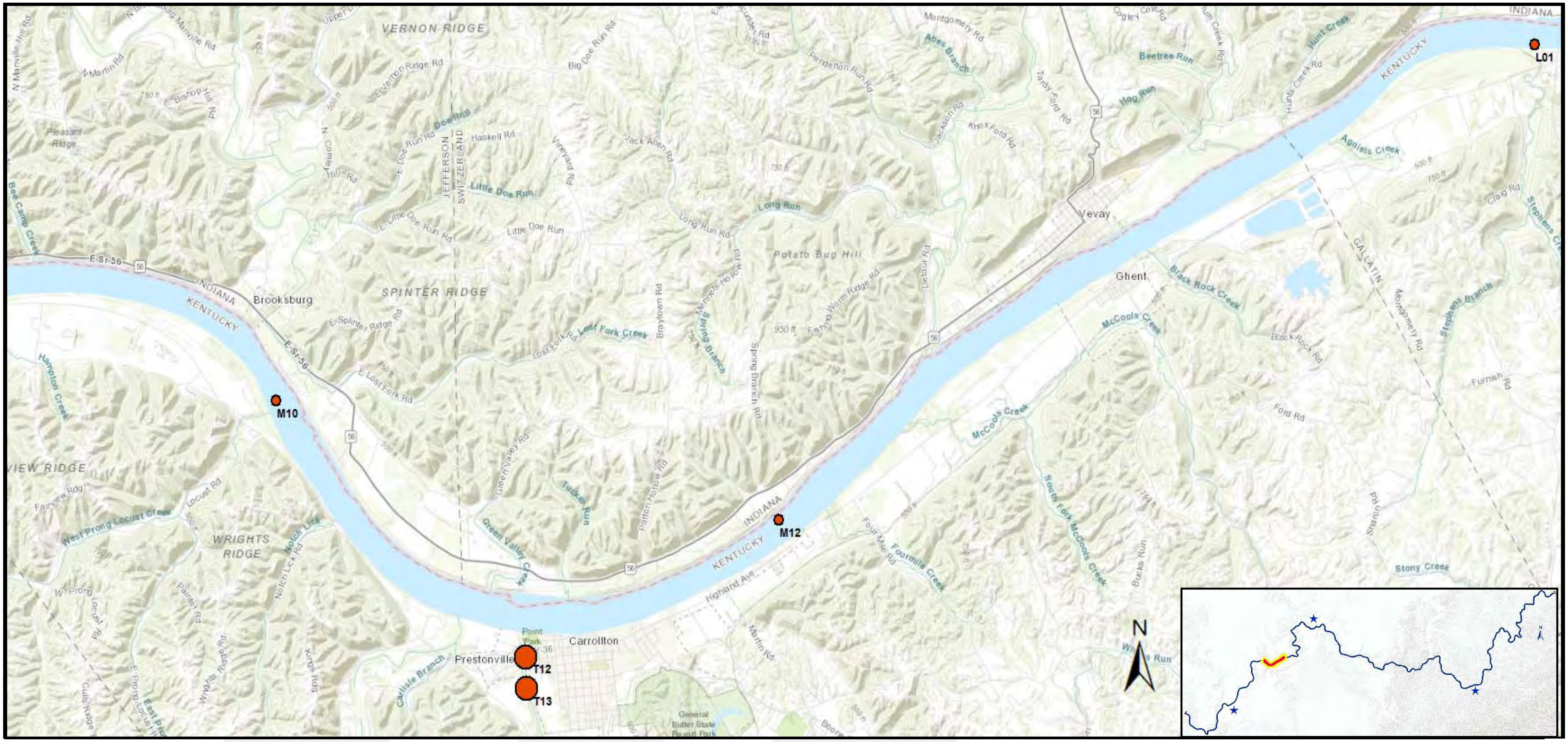
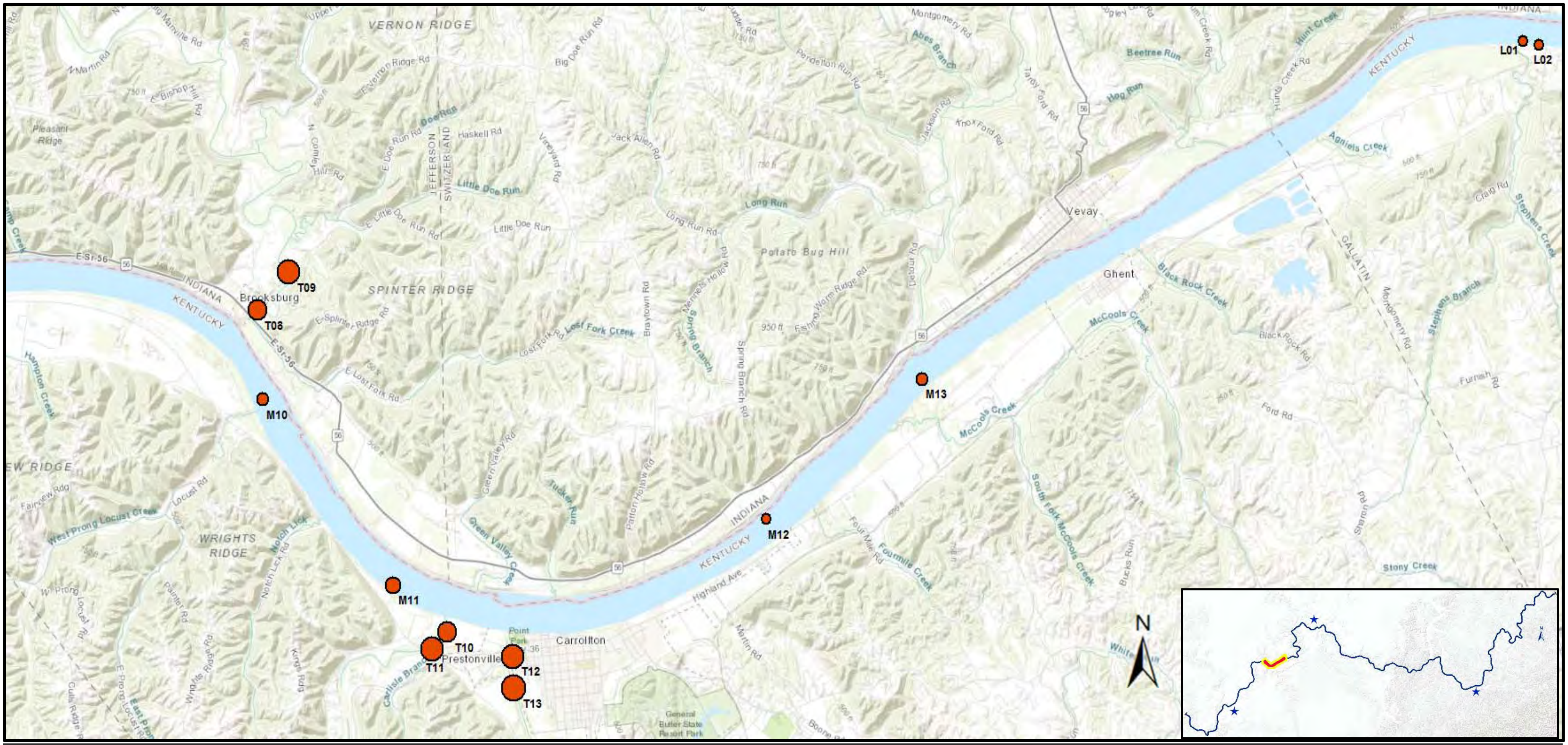



Figure 5. A map showing the distribution of the receiver stations that made detections of tagged Asian Carp in 2017. The total number of tagged AC detections made by each receiver is denoted via the diameter of its corresponding red circle.



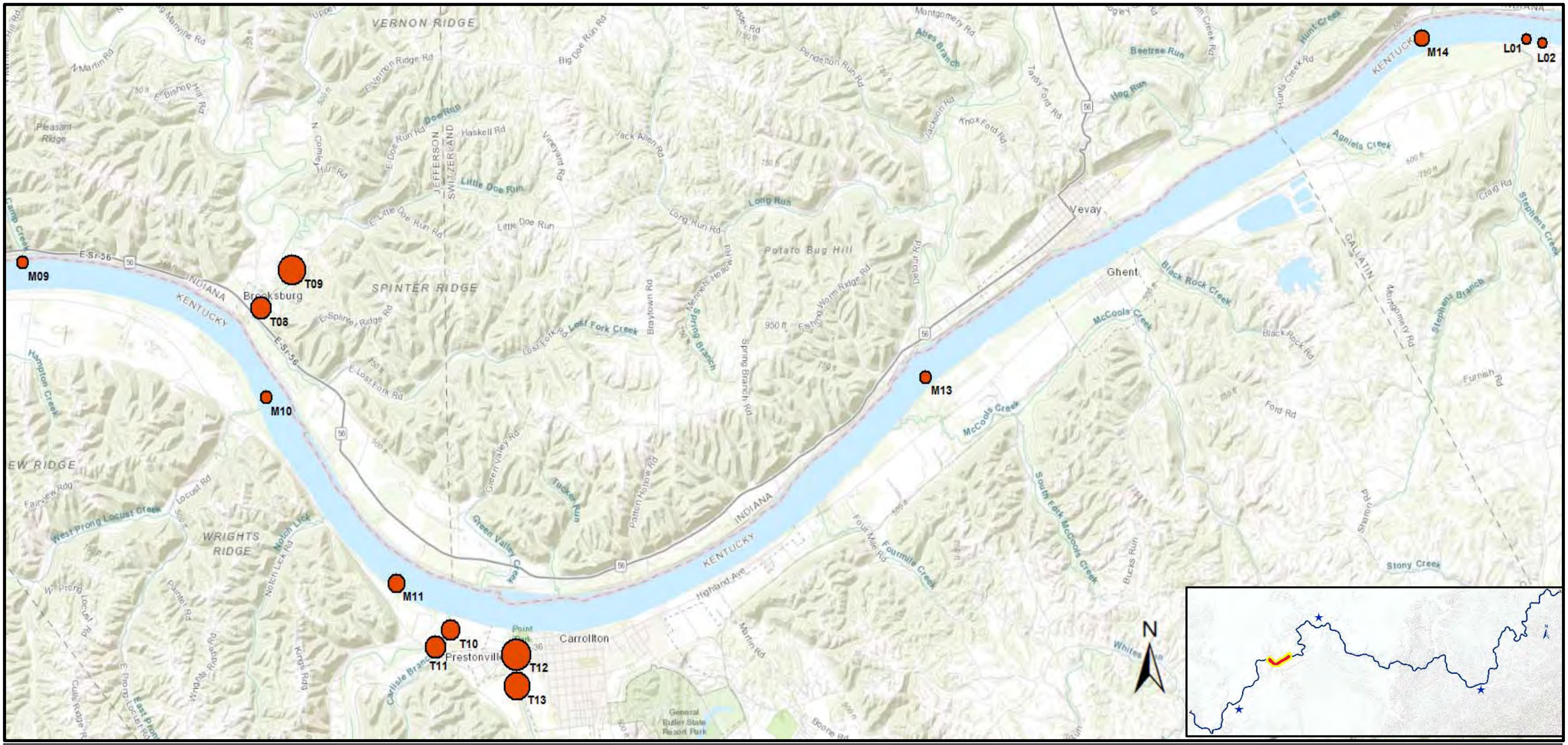

| Map ID # | M10 | T12 | T13 | M12 | L01 |
|---|---|---|---|---|---|
| Site Name | Near Locust Creek | KY River (lower) | KY River (upper) | Craig's Bar | Markland L&D (DS Approach) |
| # Winter Detections | 7 | 185,124 | 209,164 | 15 | 1 |
| # Unique Tags | 1 | 44 | 44 | 4 | 1 |

Figure 6. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during the winter (JAN – FEB) of 2017. The total number of tagged AC detections that the receivers recorded during this winter season were used to determine the diameter of the red circle that marks each site. Also, the Map ID # next to each circle corresponds to an entry in the table that provides additional information for each site (i.e. total # of winter detections & # of unique tags).



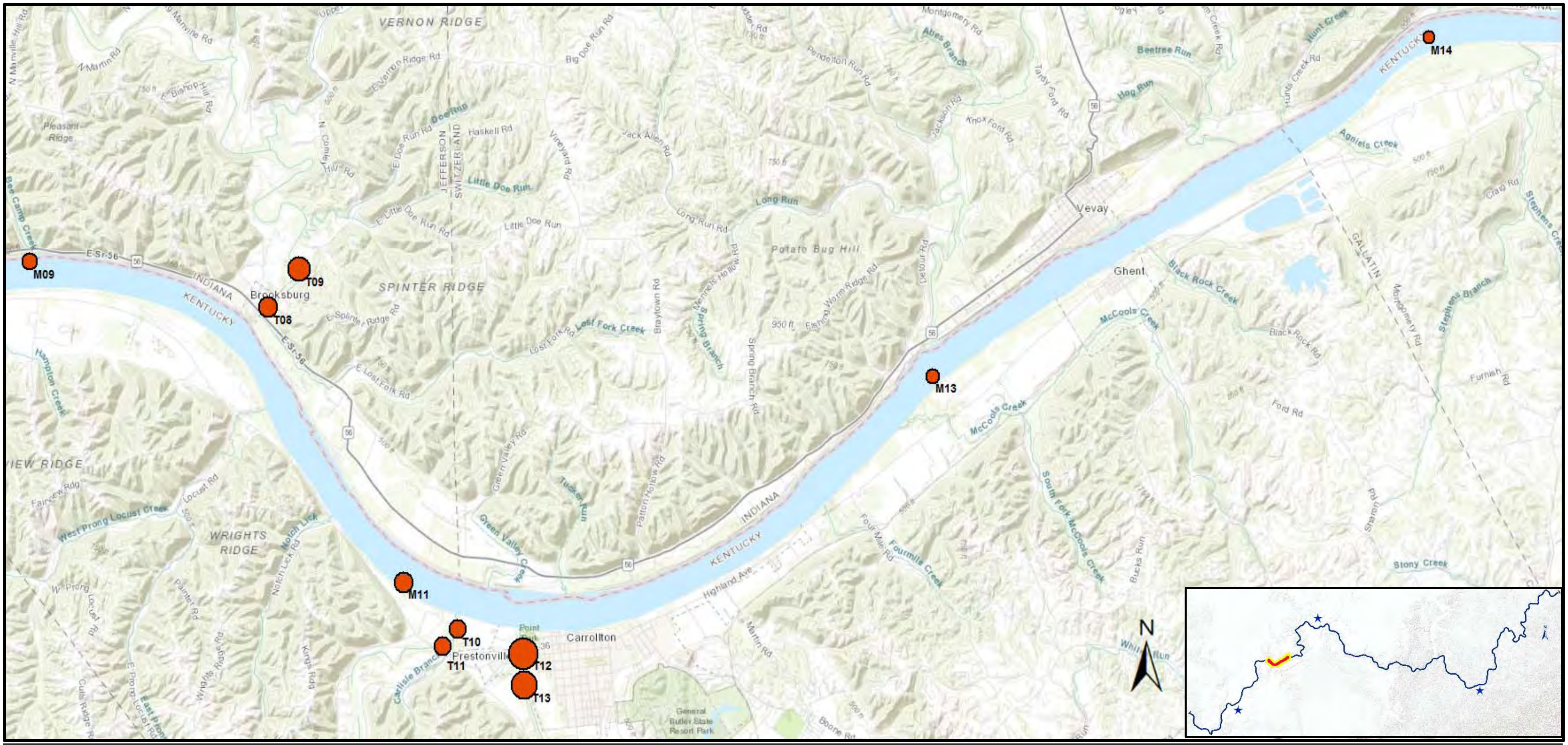

| Map ID # | T08 | T09 | M10 | M11 | T10 | T11 | T12 | T13 | M12 | M13 | L01 | L02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site Name | Indian-Kentuck Creek (lower) | Indian-Kentuck Creek (upper) | Near Locust Creek | Below Little KY River | Little KY River (lower) | Little KY River (upper) | KY River (lower) | KY River (upper) | Craig's Bar | Near Indian Creek | L&D Approach | L&D 600' Lock |
| # Spring Detections | 148,564 | 204,554 | 4,380 | 43,379 | 149,262 | 216,356 | 221,207 | 254,836 | 6 | 1,058 | 73 | 4 |
| # Unique Tags | 55 | 42 | 64 | 105 | 90 | 61 | 118 | 115 | 1 | 59 | 4 | 2 |

Figure 7. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during the spring (MAR – MAY) of 2017. The total number of tagged AC detections that the receivers recorded during this spring season were used to determine the diameter of the red circle that marks each site. Also, the Map ID # next to each circle corresponds to an entry in the table that provides additional information for each site (i.e. total # of spring detections & # of unique tags).



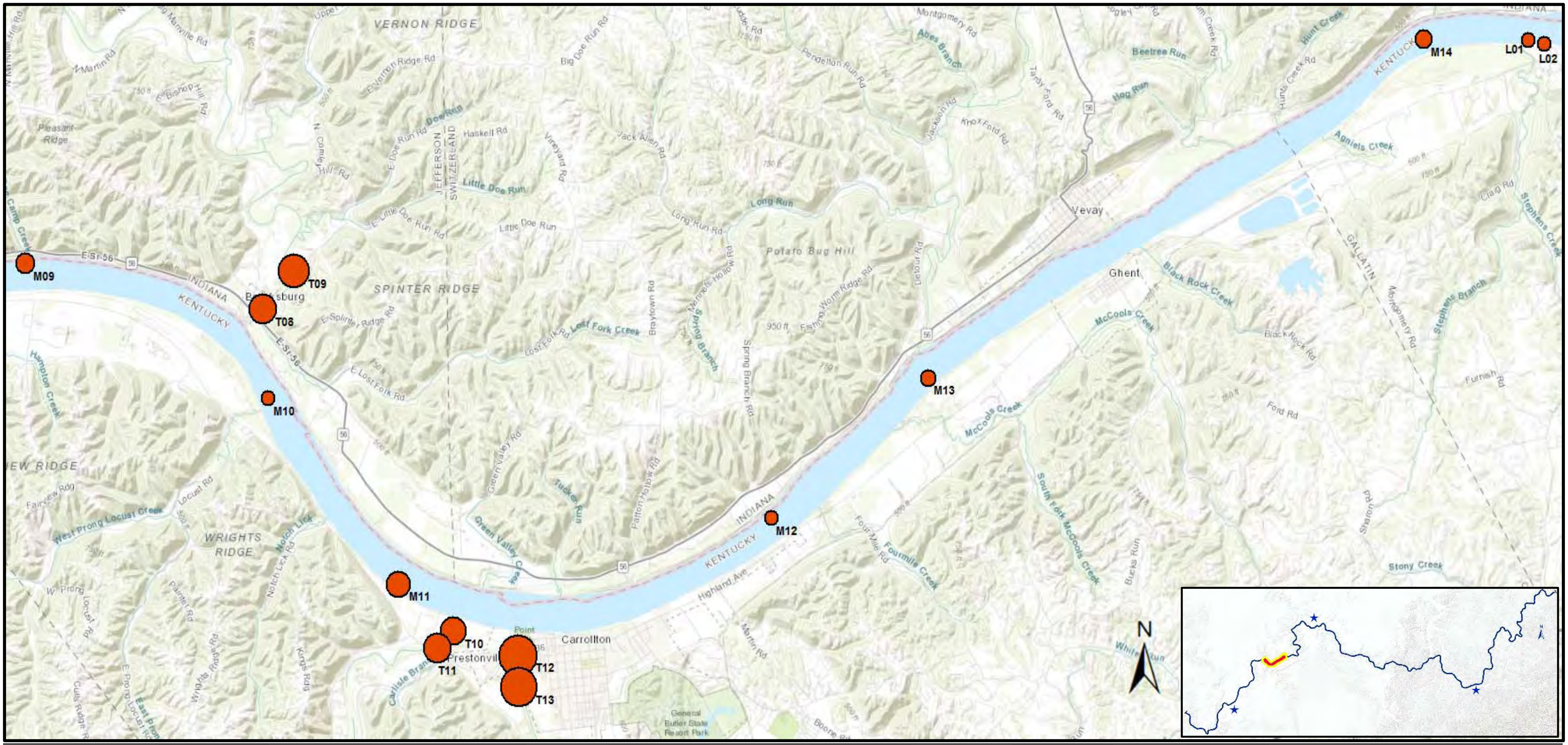

| Map ID # | M09 | T08 | T09 | M10 | M11 | T10 | T11 | T12 | T13 | M13 | M14 | L01 | L02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site Name | Near Bee Camp Creek | Indian-Kentuck Creek (lower) | Indian-Kentuck Creek (upper) | Near Locust Creek | Below Little KY River | Little KY River (lower) | Little KY River (upper) | KY River (lower) | KY River (upper) | Near Indian Creek | DS of Markland L&D | L&D Approach | L&D 600' Lock |
| # Summer Detections | 4,680 | 169,428 | 327,905 | 3,519 | 71,929 | 129,956 | 166,809 | 372,945 | 292,262 | 3,612 | 19,343 | 425 | 430 |
| # Unique Tags | 5 | 56 | 41 | 26 | 106 | 69 | 47 | 92 | 90 | 56 | 28 | 3 | 1 |

Figure 8. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during the summer (JUN – AUG) of 2017. The total number of tagged AC detections that the receivers recorded during this summer season were used to determine the diameter of the red circle that marks each site. Also, the Map ID # next to each circle corresponds to an entry in the table that provides additional information for each site (i.e. total # of summer detections & # of unique tags).



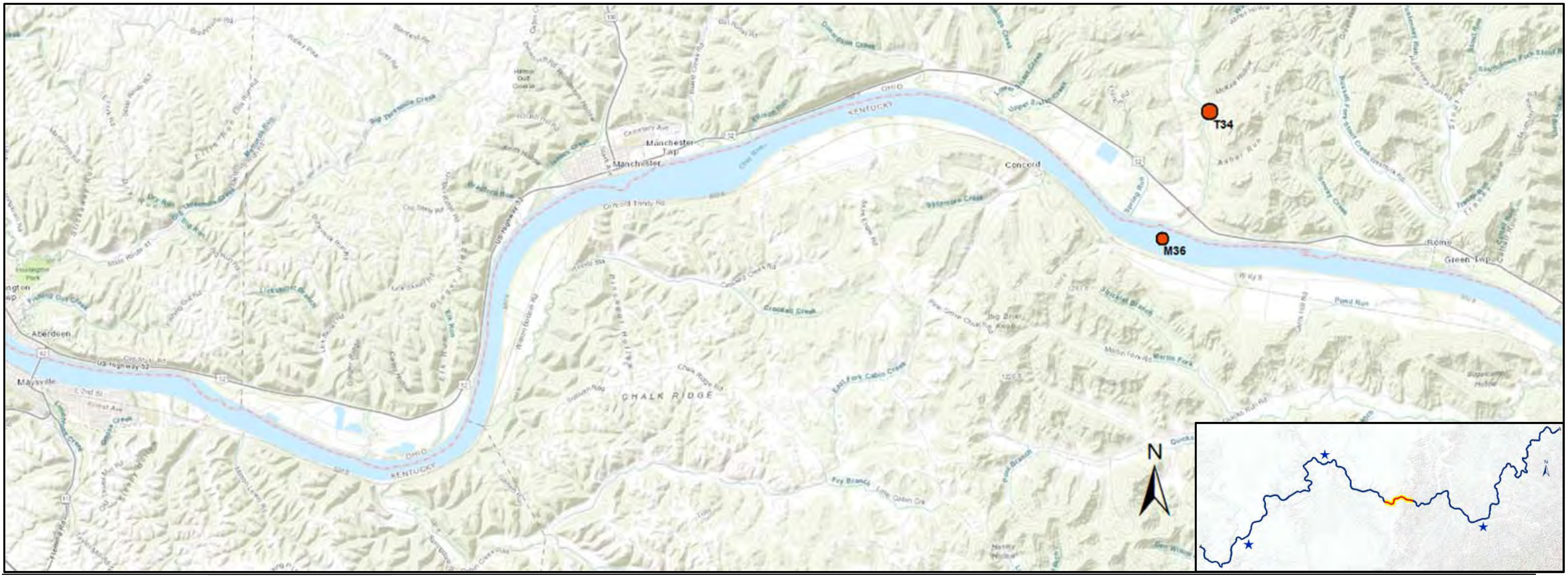

| Map ID # | M09 | T08 | T09 | M11 | T10 | T11 | T12 | T13 | M13 | M14 |
|---|---|---|---|---|---|---|---|---|---|---|
| Site Name | Near Bee Camp Creek | Indian-Kentuck Creek (lower) | Indian-Kentuck Creek (upper) | Below Little KY River | Little KY River (lower) | Little KY River (upper) | KY River (lower) | KY River (upper) | Near Indian Creek | DS of Markland L&D |
| # Fall Detections | 31,328 | 136,499 | 185,928 | 102,203 | 96,643 | 87,803 | 364,745 | 297,452 | 6,480 | 4,419 |
| # Unique Tags | 39 | 38 | 28 | 71 | 40 | 37 | 56 | 58 | 12 | 5 |

Figure 9. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during the fall (SEP – NOV) of 2017. The total number of tagged AC detections that the receivers recorded during this fall season were used to determine the diameter of the red circle that marks each site. Also, the Map ID # next to each circle corresponds to an entry in the table that provides additional information for each site (i.e. total # of fall detections & # of unique tags).



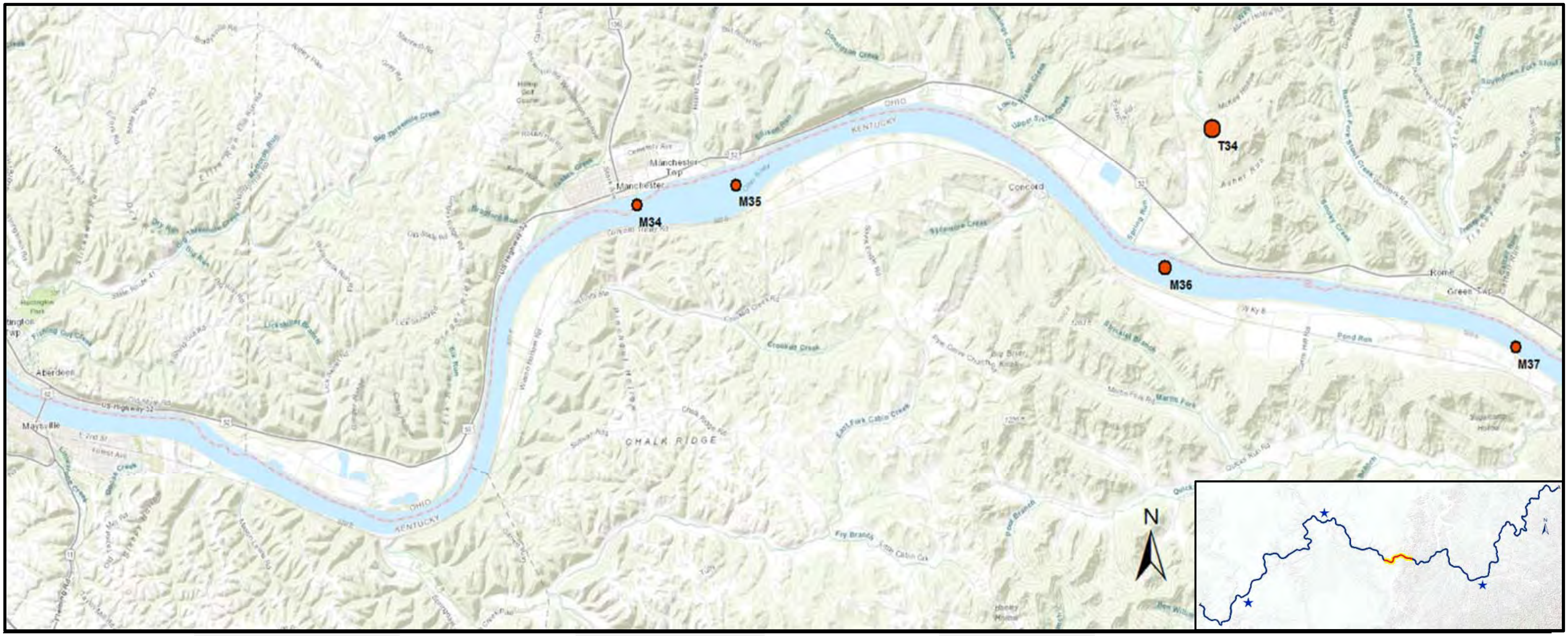

| Map ID # | M09 | T08 | T09 | M10 | M11 | T10 | T11 | T12 | T13 | M12 | M13 | M14 | L01 | L02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site Name | Near Bee Camp Creek | Indian-Kentuck Crk (lower) | Indian-Kentuck Crk (upper) | Near Locust Creek | Below Little KY River | Little KY River (lower) | Little KY River (upper) | KY River (lower) | KY River (upper) | Craig's Bar | Near Indian Creek | DS of Markland L&D | L&D Approach | L&D 600' Lock |
| # Total Detxns | 45,397 | 460,362 | 719,242 | 7,906 | 239,757 | 375,960 | 472,027 | 1,211,781 | 1,105,730 | 21 | 11,365 | 23,766 | 499 | 434 |
| # Unique Tags | 40 | 75 | 49 | 69 | 127 | 104 | 71 | 131 | 128 | 5 | 91 | 29 | 6 | 2 |

Figure 10. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during 2017 (JAN – DEC). The overall number of tagged AC detections that the receivers recorded throughout 2017 were used to determine the diameter of the red circle that marks each site. Also, the Map ID # next to each circle corresponds to an entry in the table that provides additional information for each site (i.e. total # of detections & # of unique tags).



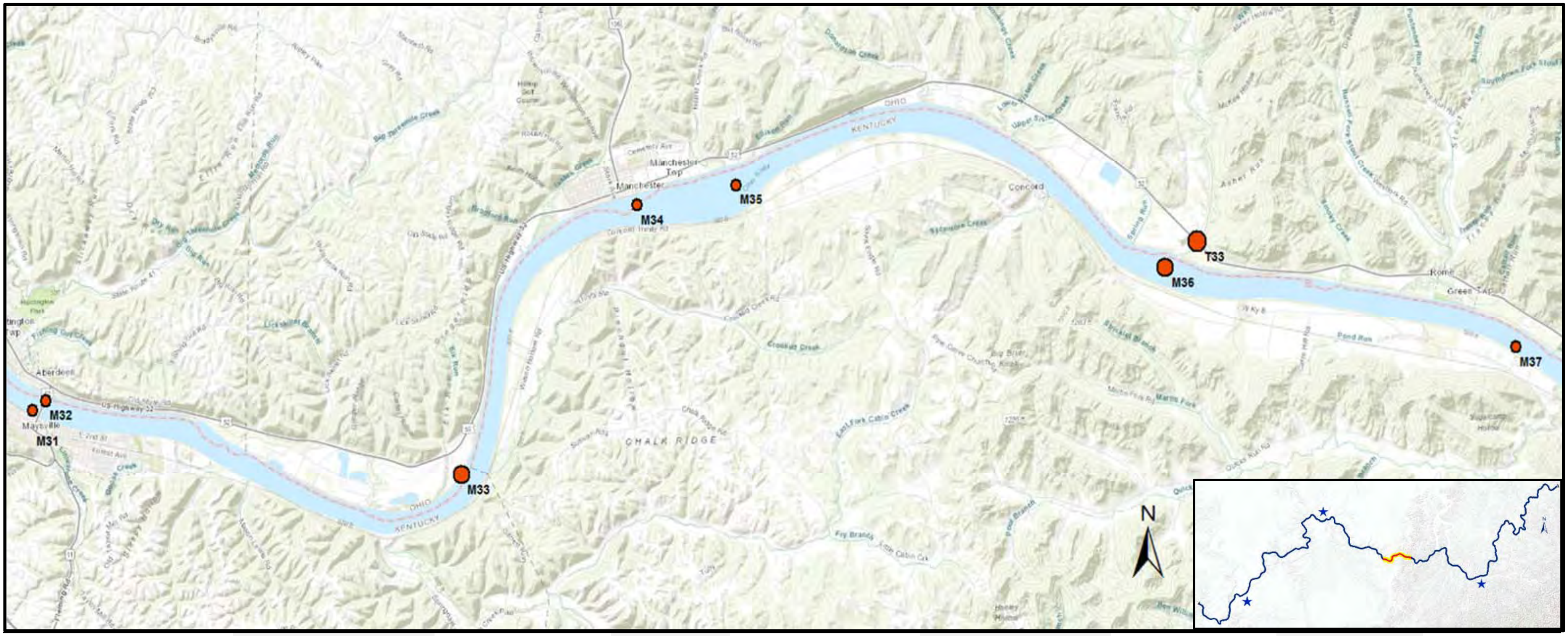

| Map ID # | M36 | T34 |
|---|---|---|
| Site Name | Above OH-Brush Creek Island | OH-Brush Creek (upper) |
| # Winter Detections | 2,362 | 40,004 |
| # Unique Tags | 9 | 9 |

Figure 11. The receiver stations in and around the OH-Brush Creek area of the Meldahl Pool (Maysville, KY to Rome, OH) with tagged AC detections that were made during the winter (Jan - Feb) of 2017. The diameters of the red circles used to represent these stations in the map were determined by the total number of tagged AC detections that each receiver logged during the 2017 winter season. Also, the ID #'s accompanying these circles are used to provide additional information for each site via the table located above.



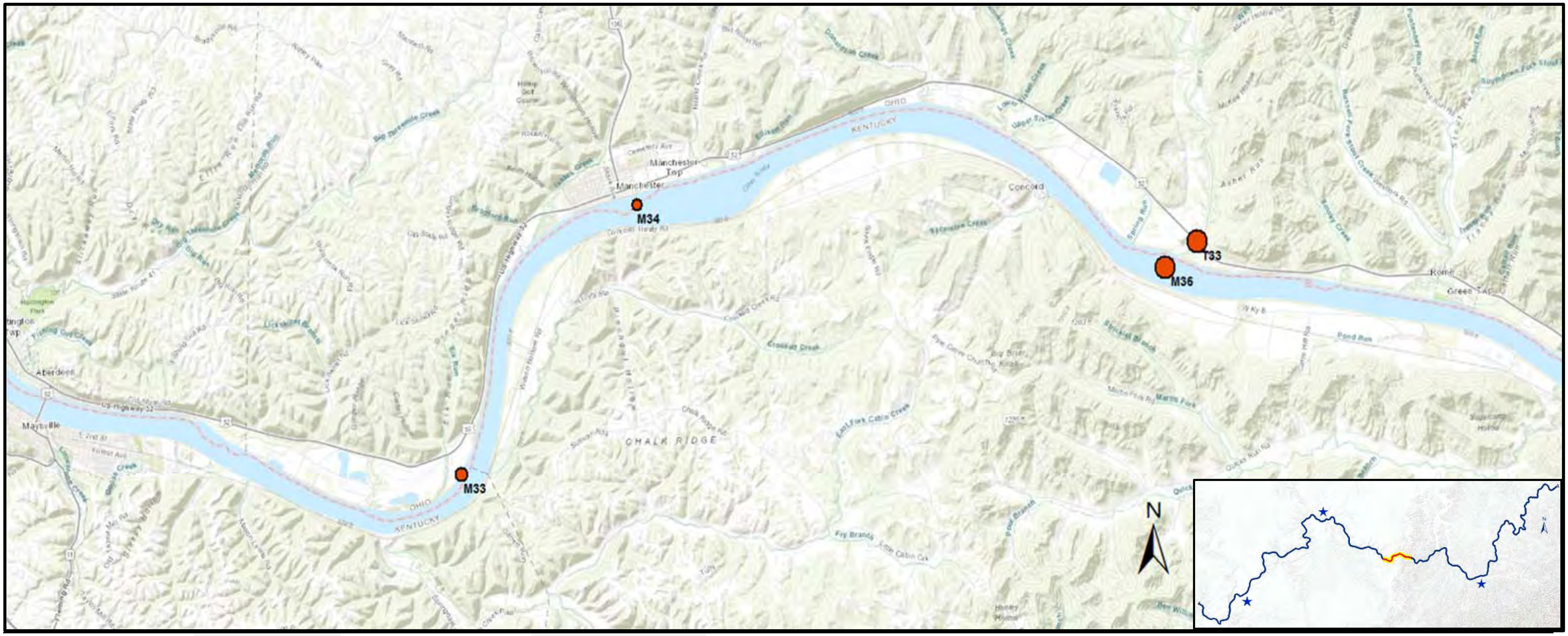

| Map ID # | M34 | M35 | M36 | T34 | M37 |
|---|---|---|---|---|---|
| Site Name | Below Manchester Island #2 | Above Manchester Island #1 | Above OH-Brush Creek Island | OH-Brush Creek (upper) | Quarry near Rome, OH |
| # Spring Detections | 492 | 7 | 2,731 | 14,942 | 38 |
| # Unique Tags | 1 | 1 | 13 | 10 | 4 |

Figure 12. The receiver stations in and around the OH-Brush Creek area of the Meldahl Pool (Maysville, KY to Rome, OH) with tagged AC detections that were made during the spring (Mar - May) of 2017. The diameters of the red circles used to represent these stations in the map were determined by the total number of tagged AC detections that each receiver logged during the 2017 spring season. Also, the ID #'s accompanying these circles are used to provide additional information for each site via the table located above.



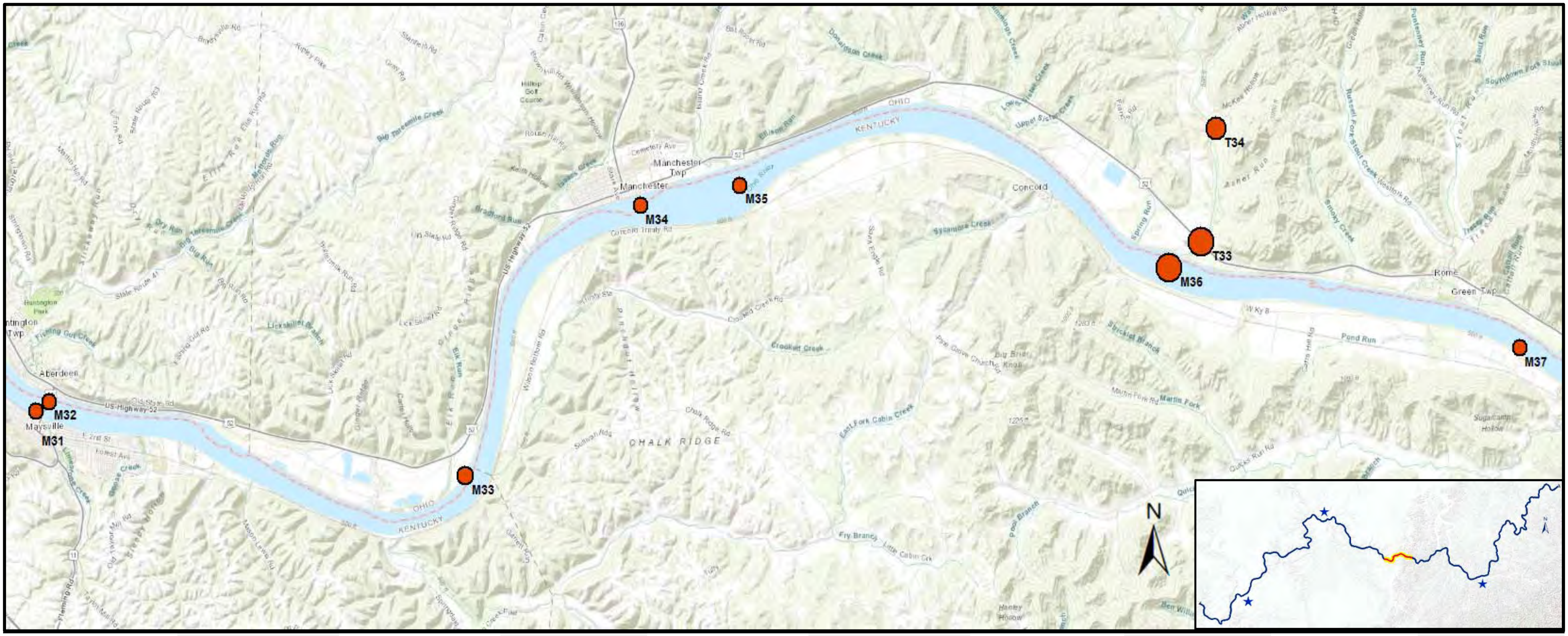

| Map ID # | M31 | M32 | M33 | M34 | M35 | M36 | T33 | M37 |
|---|---|---|---|---|---|---|---|---|
| Site Name | Below US-62 Bridge (Maysville) | Above US-62 Bridge (Maysville) | ERSHIG Dolphin | Below Manchester Island #2 | Above Manchester Island #1 | Above OH-Brush Creek Island | OH-Brush Creek (lower) | Quarry near Rome, OH |
| # Summer Detections | 35 | 97 | 15,172 | 712 | 72 | 42,128 | 84,782 | 611 |
| # Unique Tags | 1 | 2 | 8 | 10 | 3 | 12 | 12 | 8 |

Figure 13. The receiver stations in and around the OH-Brush Creek area of the Meldahl Pool (Maysville, KY to Rome, OH) with tagged AC detections that were made during the summer (Jun – Aug) of 2017. The diameters of the red circles used to represent these stations in the map were determined by the total number of tagged AC detections that each receiver logged during the 2017 summer season. Also, the ID #'s accompanying these circles are used to provide additional information for each site via the table located above.




| Map ID # | M33 | M34 | M36 | T33 |
|---|---|---|---|---|
| Site Name | ERSHIG Dolphin | Below Manchester Island #2 | Above OH-Brush Creek Island | OH-Brush Creek (lower) |
| # Fall Detections | 4,344 | 441 | 115,050 | 103,897 |
| # Unique Tags | 4 | 6 | 11 | 12 |

Figure 14. The receiver stations in and around the OH-Brush Creek area of the Meldahl Pool (Maysville, KY to Rome, OH) with tagged AC detections that were made during the fall (Sep - Nov) of 2017. The diameters of the red circles used to represent these stations in the map were determined by the total number of tagged AC detections that each receiver logged during the 2017 fall season. Also, the ID #'s accompanying these circles are used to provide additional information for each site via the table located above.




| Map ID # | M31 | M32 | M33 | M34 | M35 | M36 | T33 | T34 | M37 |
|---|---|---|---|---|---|---|---|---|---|
| Site Name | Below US-62 Bridge (Maysville) | Above US-62 Bridge (Maysville) | ERSHIG Dolphin | Below Manchester Island #2 | Above Manchester Island #1 | Above OH-Brush Creek Island | OH-Brush Creek (lower) | OH-Brush Creek (upper) | Quarry near Rome, OH |
| # Total Detections | 35 | 97 | 19516 | 1654 | 79 | 194731 | 209830 | 54950 | 649 |
| # Unique Tags | 1 | 2 | 8 | 10 | 3 | 13 | 12 | 10 | 9 |

Figure 15. The receiver stations in and around the OH-Brush Creek area of the Meldahl Pool (Maysville, KY to Rome, OH) with tagged AC detections that were made during 2017. The diameters of the red circles used to represent these stations in the map were determined by the total number of tagged AC detections that each receiver logged during 2017. Also, the ID #'s accompanying these circles are used to provide additional information for each site via the table located above.

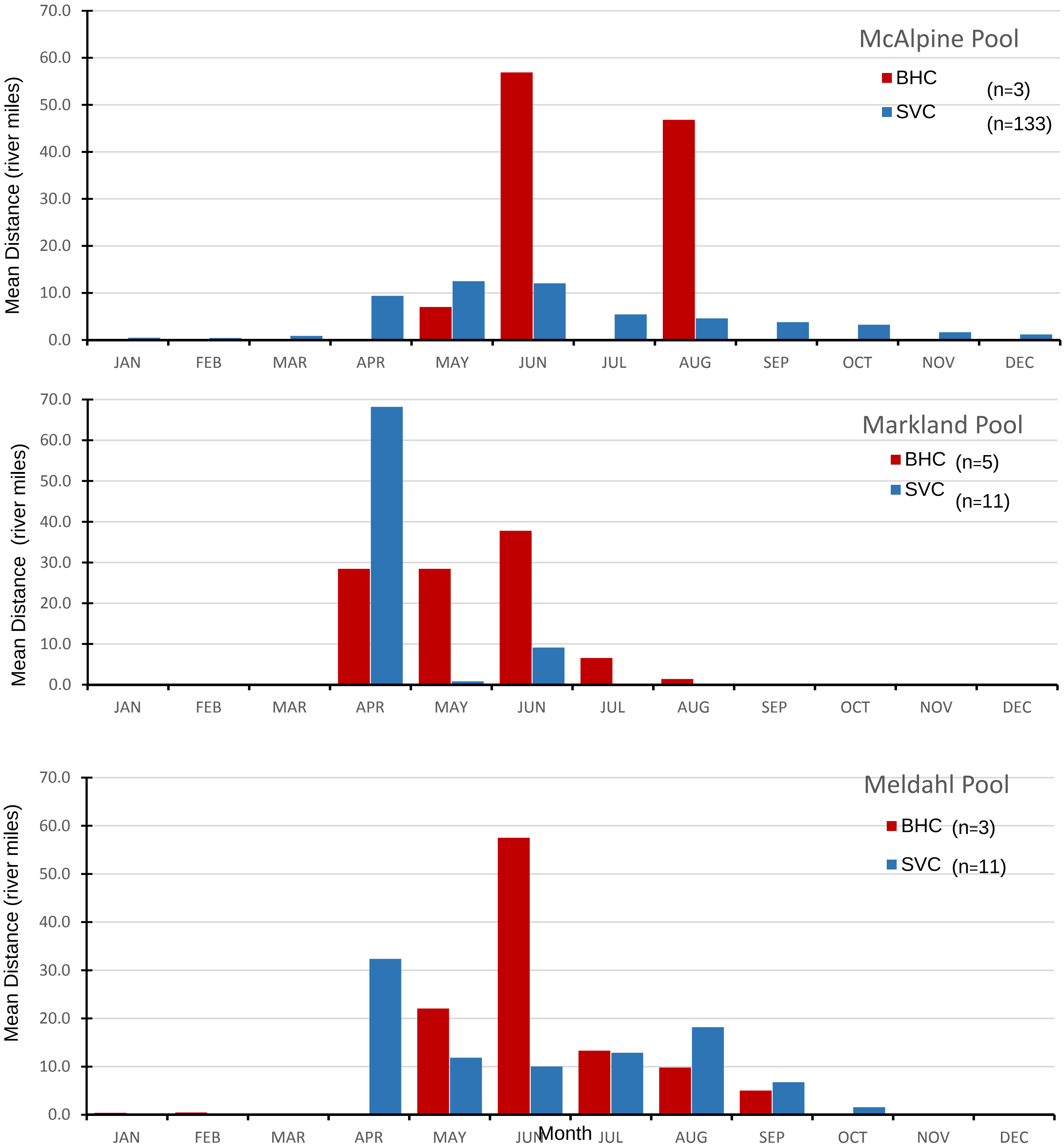



Figure 16. The mean monthly distances (in river miles) between the most upstream and downstream detections for tagged Bighead Carp and Silver Carp in the three most active pools of the telemetry project. Only tagged carp that were detected by 2 or more receivers during 2017 were included in the distance calculations.

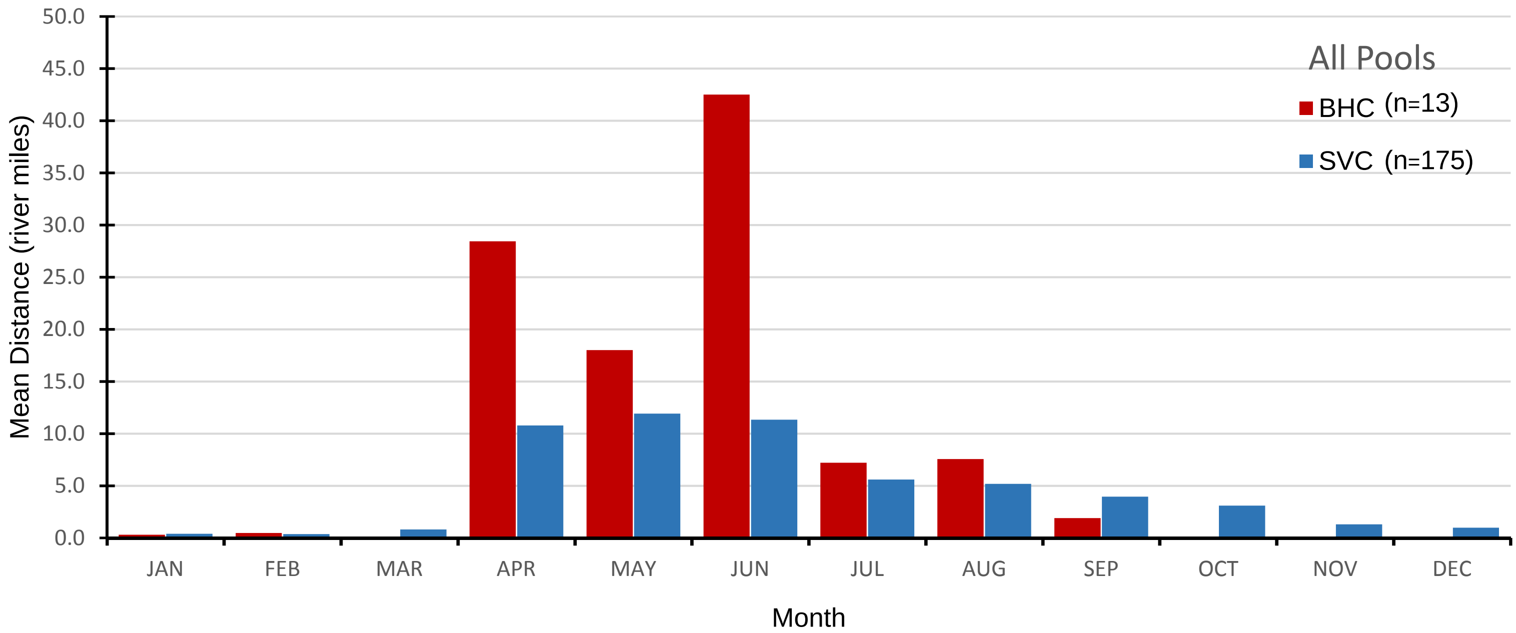



Figure 17. The mean monthly distances (in river miles) between the most upstream and downstream detections for all tagged Bighead Carp and Silver Carp that were detected by 2 or more receivers during 2017.

**Monitoring and Response to Asian Carp in the Ohio River**

**Project Lead:** Kentucky Department of Fish and Wildlife Resources, Andrew Stump

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

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

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

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

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

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

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

Targeted Sampling – sampling that uses gear and/or techniques intended to specifically target one species (i.e. Silver Carp and Bighead Carp) and exclude others (i.e. native species).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

were sampled by KDFWR with electrofishing and gill nets (see monitoring section for additional details on fish community sampling). Data from fish community sampling were used to separate species-specific information as detailed below.

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

*Compilation and Incorporation of Other ORB Data Sources*

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

**Results:**

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

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

Spring gill netting in 2016 (Cannelton through Greenup) produced an overall CPUE of 0.02 fish/set (n = 1, SE = 0.02) for Bighead Carp, 0.35 fish/set (n = 22, SE = 0.16) for Silver Carp, and 0.03 fish/set (n = 2, SE = 0.02) for Grass Carp (Table 5). Sixty-two sets made up 18,590ft of net, yielding a total catch of 165 fish and 13 unique taxa. No Asian carps were caught with gill nets above Meldahl Locks and Dam.

Smallmouth buffalo and Silver Carp made up over 50% of the total catch by number. In contrast, spring gill netting in 2017 produced an overall CPUE of 0.10 fish/set (n = 10, SE = 0.06) for Bighead Carp, 0.70 fish/set (n = 31, SE = 0.34) for Silver Carp, and 0.19 fish/set (n = 17, SE = 0.10) for Grass Carp (Table 5). Eighty-five sets made up 19,100ft (5,800m) of net, yielding a total catch of 197 fish and 11 unique taxa. No Silver Carp were captured above Meldahl Locks and Dam, but one Bighead Carp was captured in the R.C. Byrd pool. Once again, smallmouth buffalo and Silver Carp made up over 50% of the total catch by number; however, Bighead Carp made up ~5% of the total catch in contrast to the <1% seen in 2016.

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

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

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

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

*Assessing Asian Carp Population Demographics*

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

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**Figures:**

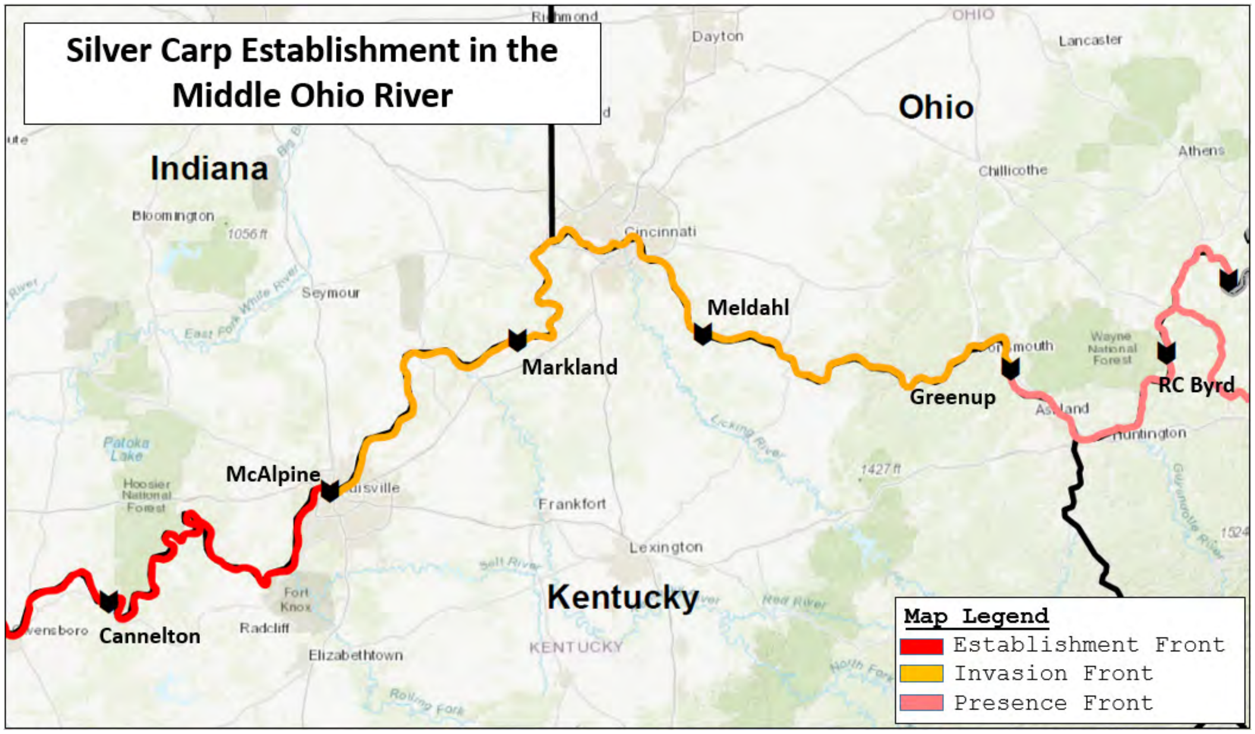


Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

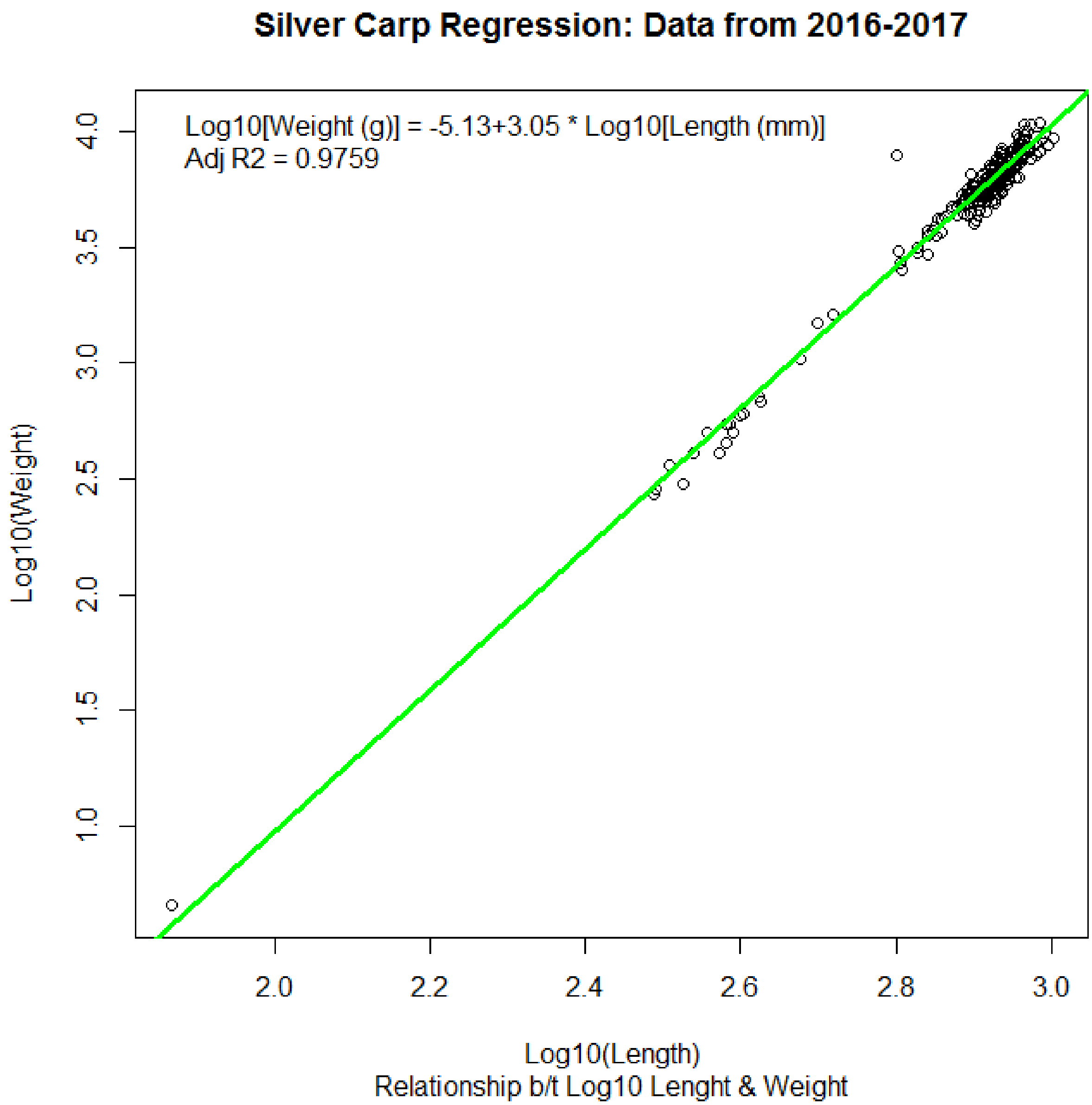


Figure 2. A scatterplot of $\log_{10}$-transformed lengths (mm) and weights (g) from *H. molitrix* captured from August through December in 2016 and 2017 with a regression line describing the relationship between lengths and weights in the ORB (n = 336).

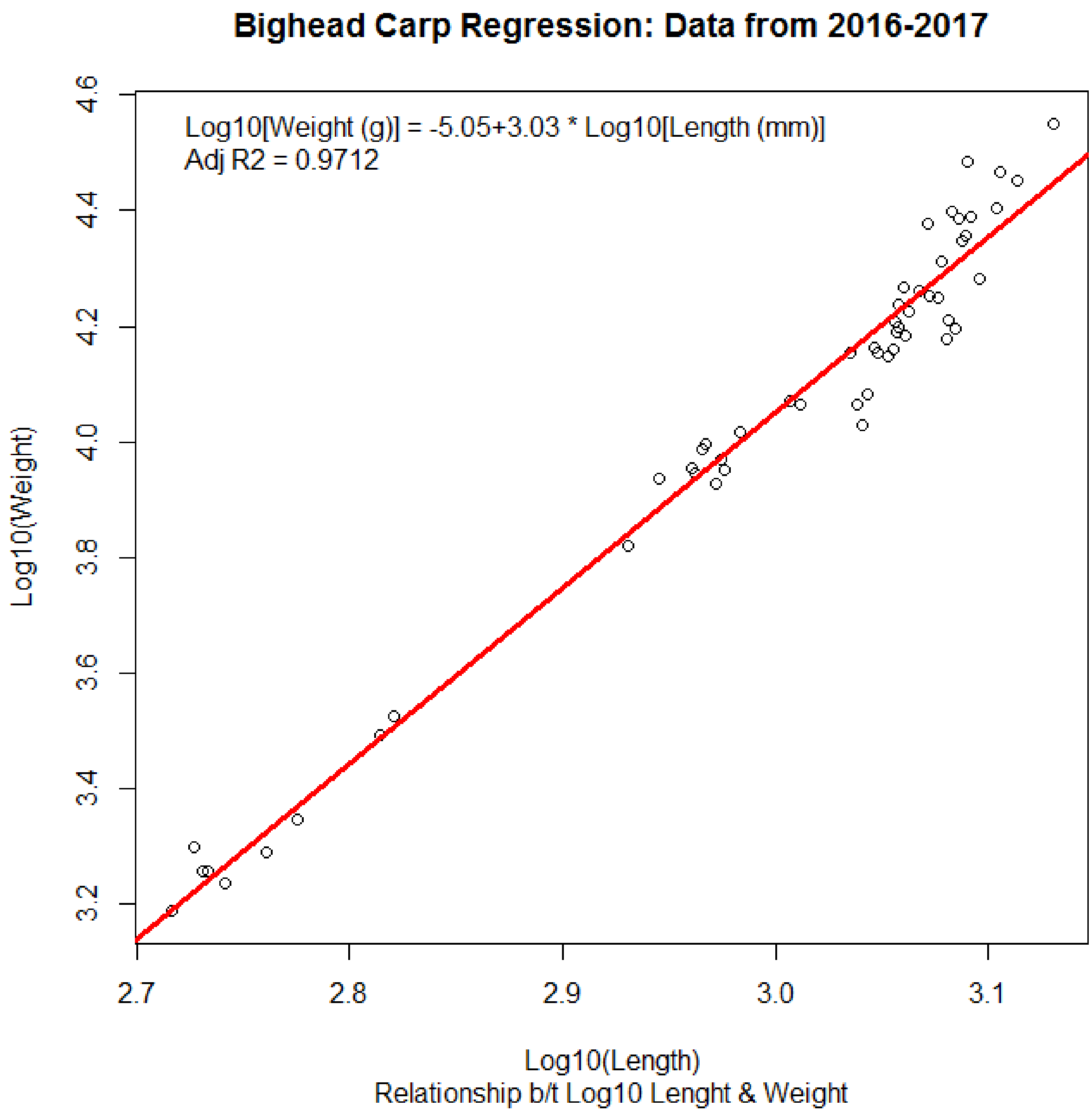


Figure 3. A scatterplot of $log_{10}$-transformed lengths (mm) and weights (g) from all *H. nobilis* captured from August through December in 2016 and 2017 with a regression line describing the relationship between lengths and weights in the ORB (n = 55).

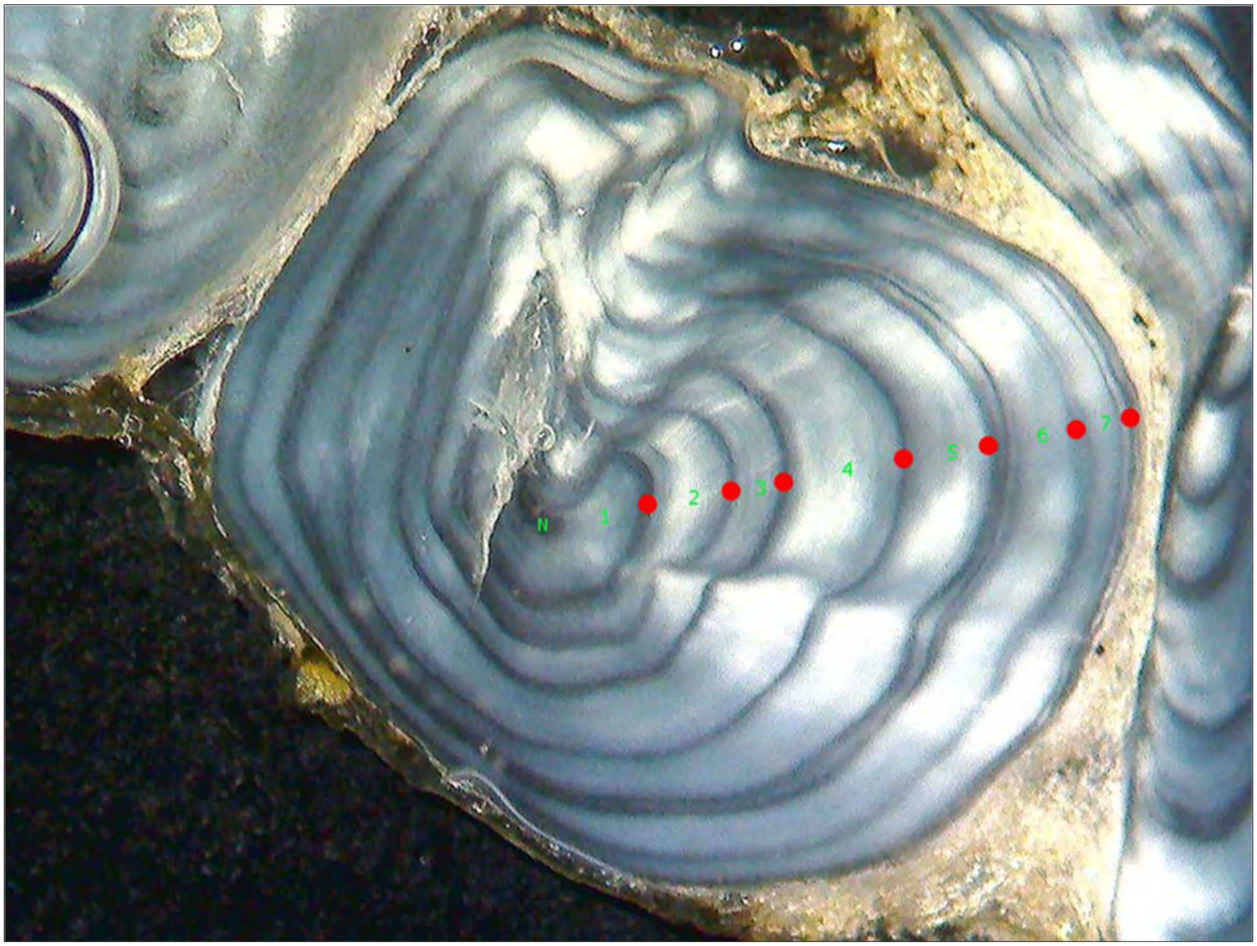


Figure 4. An image of a spine cross-section collected from a 7-year-old silver carp in the Cannelton pool, captured in May 2016.

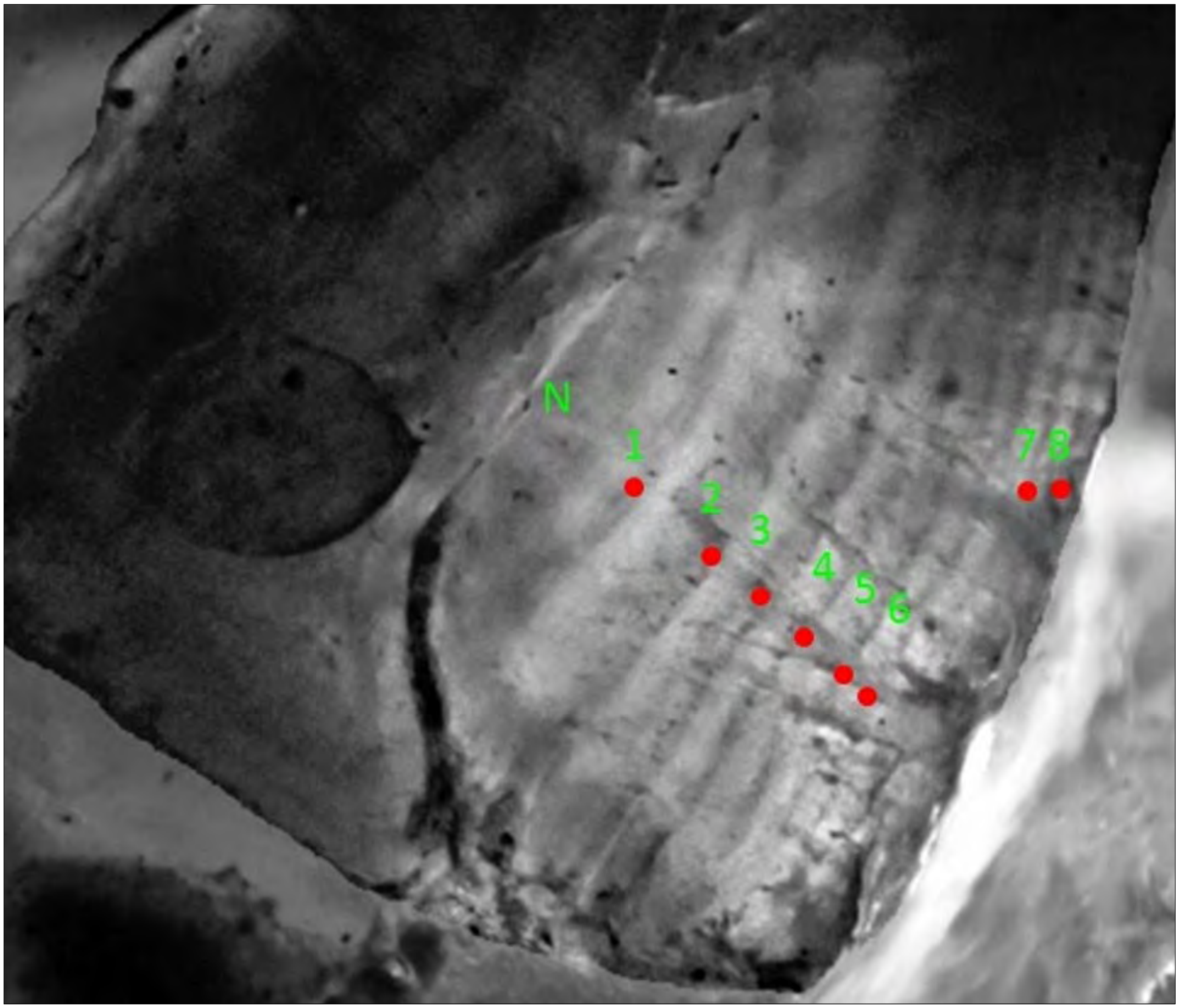


Figure 5. An image of a silver carp otolith collected from an 8-year-old fish, captured in the McAlpine pool in July 2013.

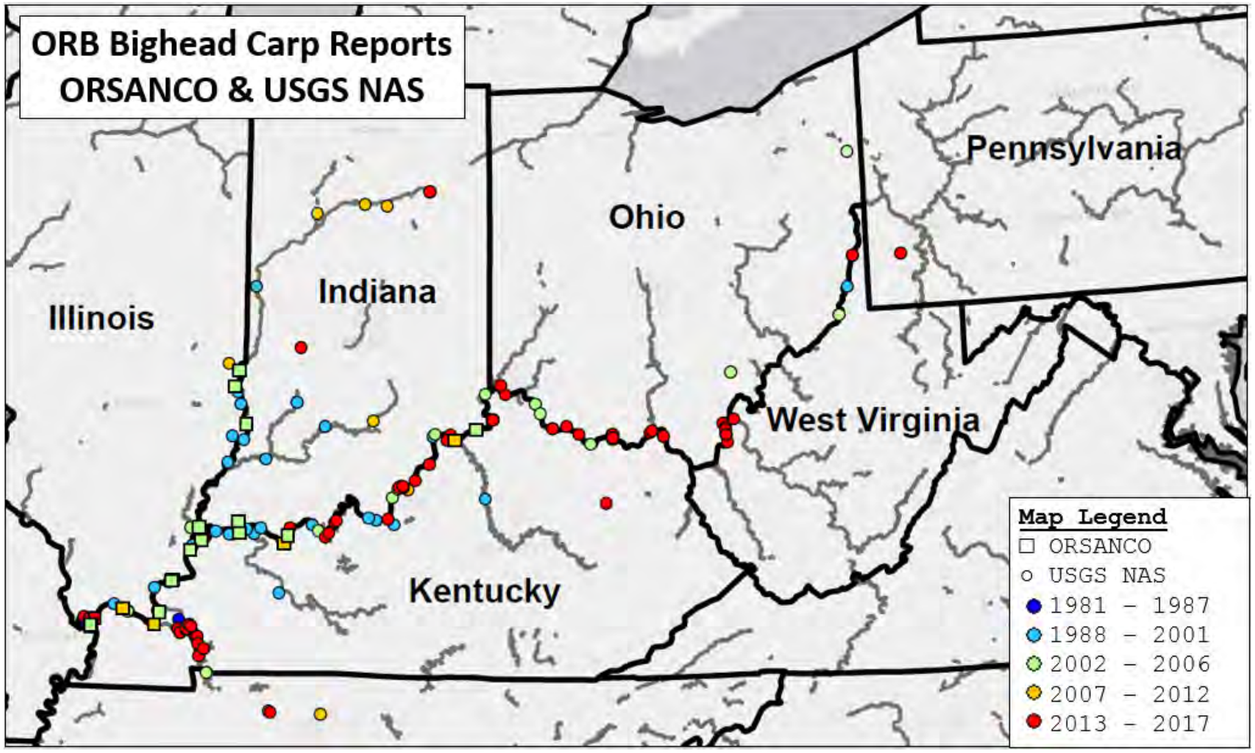


Figure 6. A range map of bighead carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

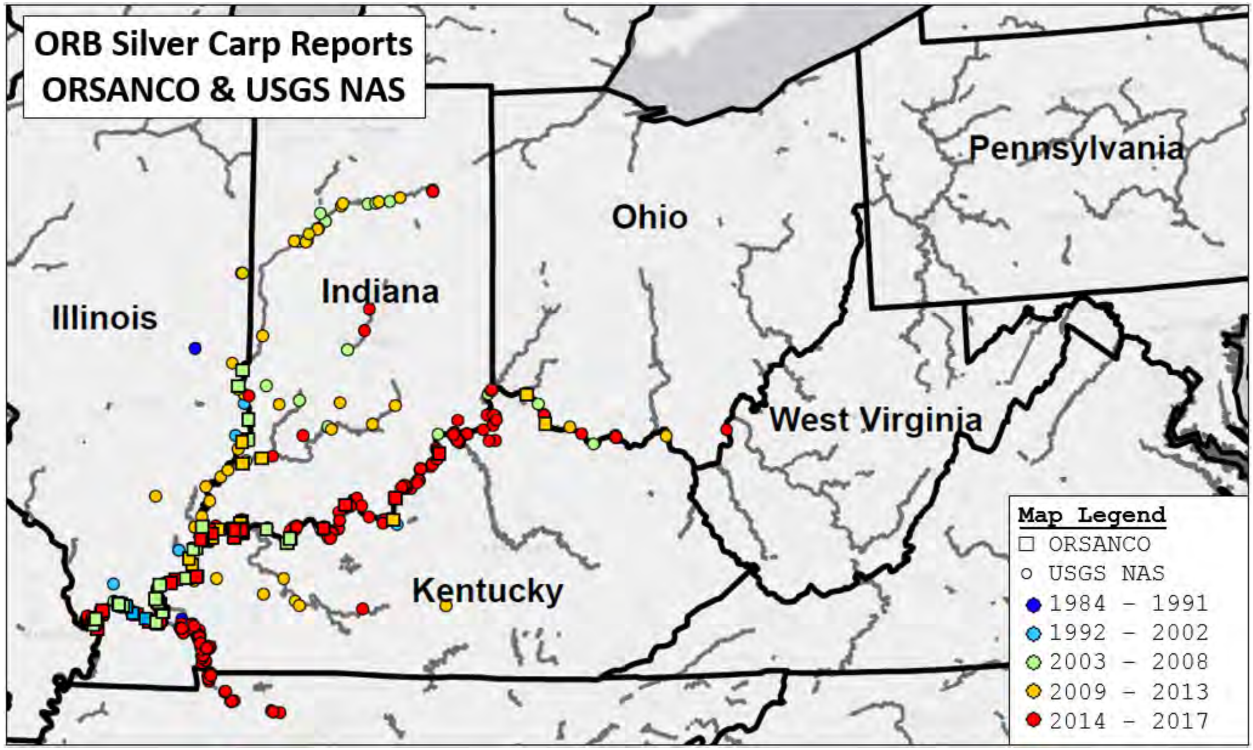


Figure 7. A range map of silver carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

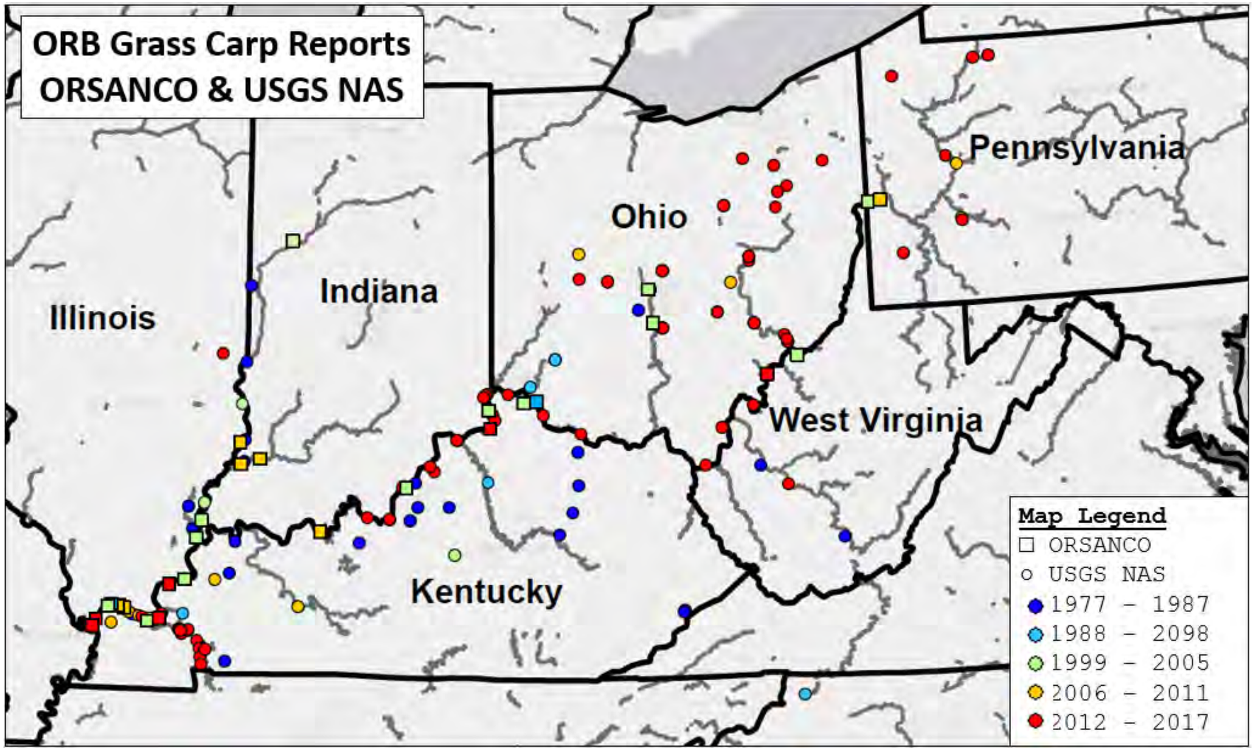


Figure 8. A range map of grass carp reported within the ORB, organized by date using data queried from ORSANCO and the USGS NAS databases.

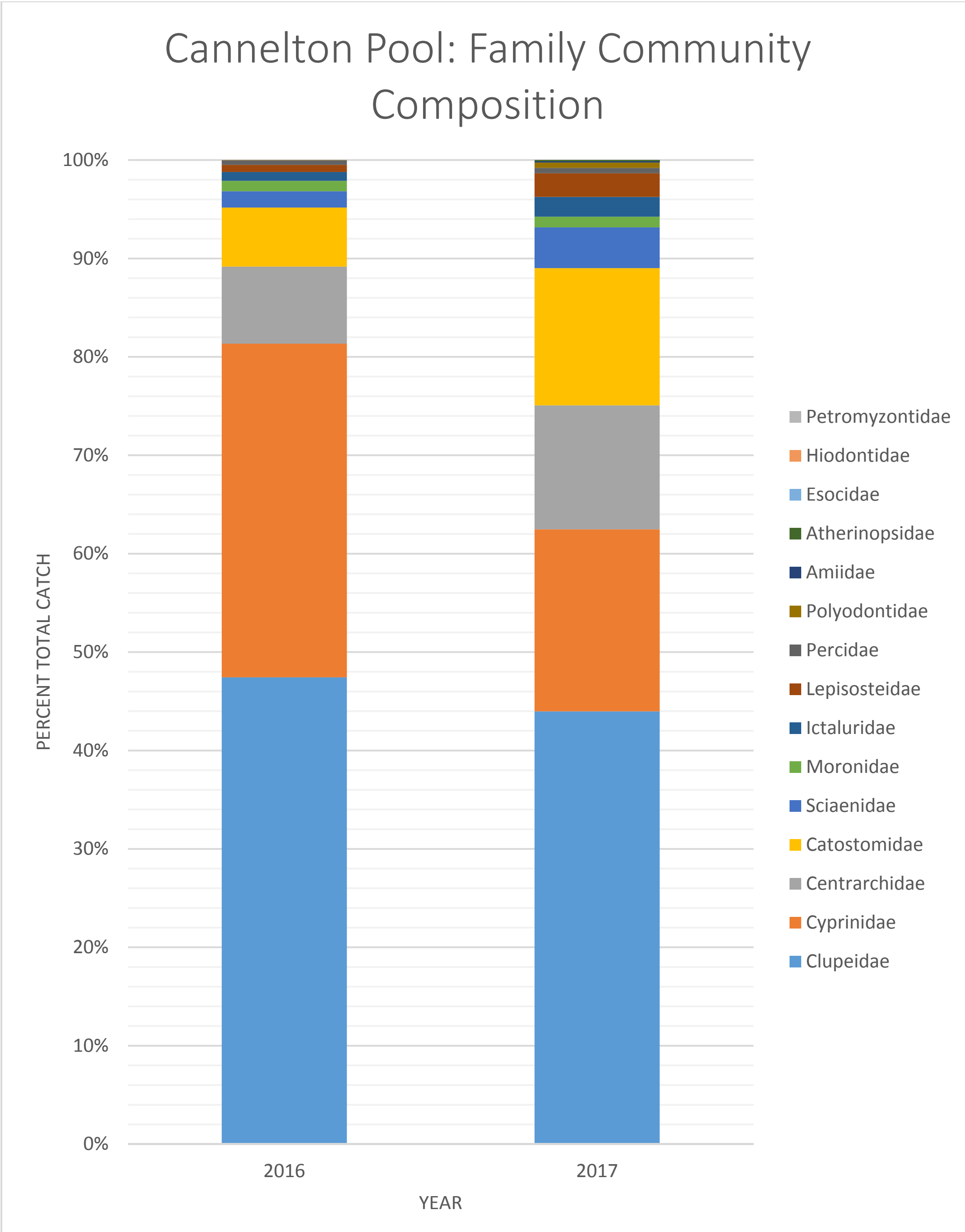


Figure 9. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Cannelton pool.

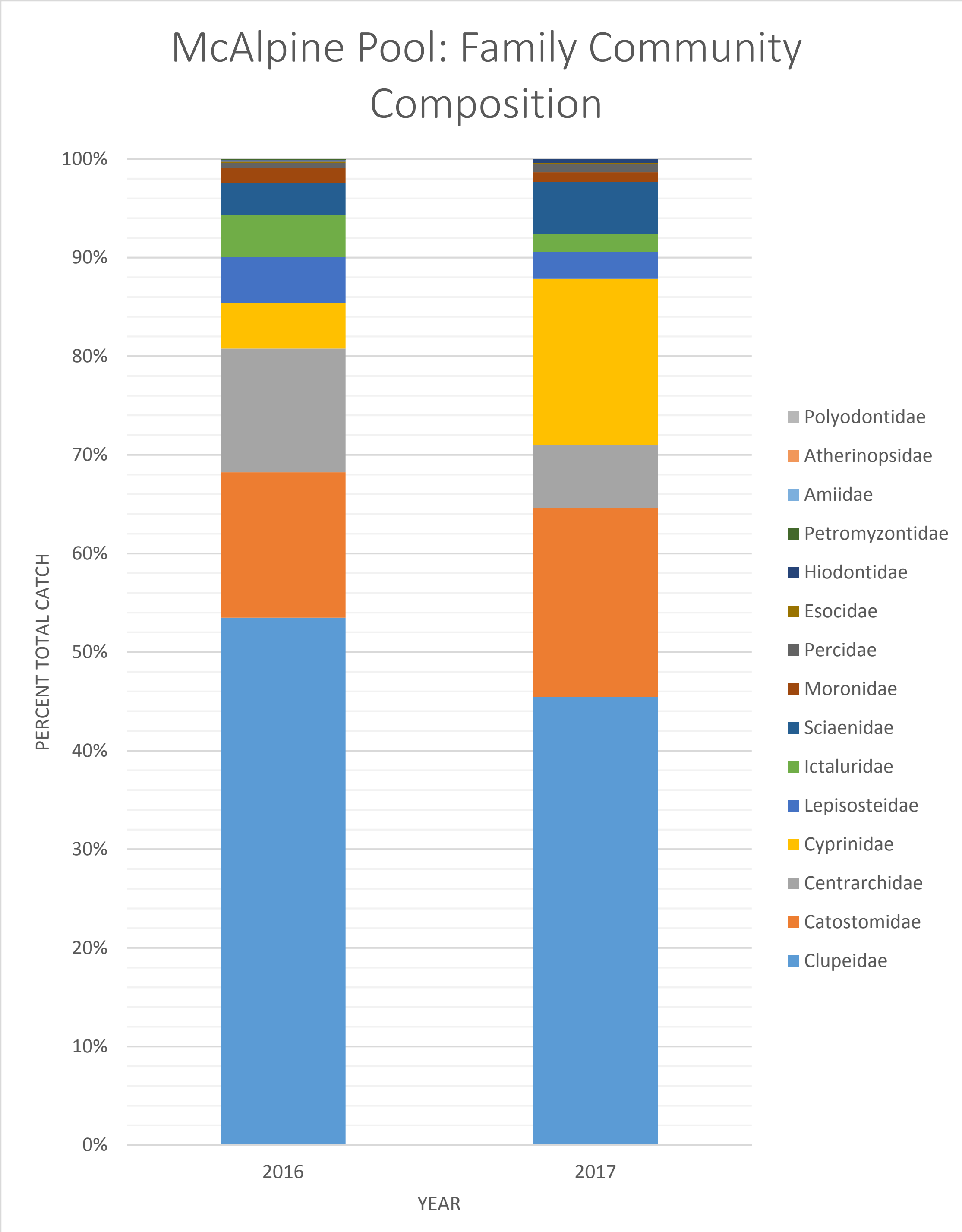


Figure 10. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the McAlpine pool.

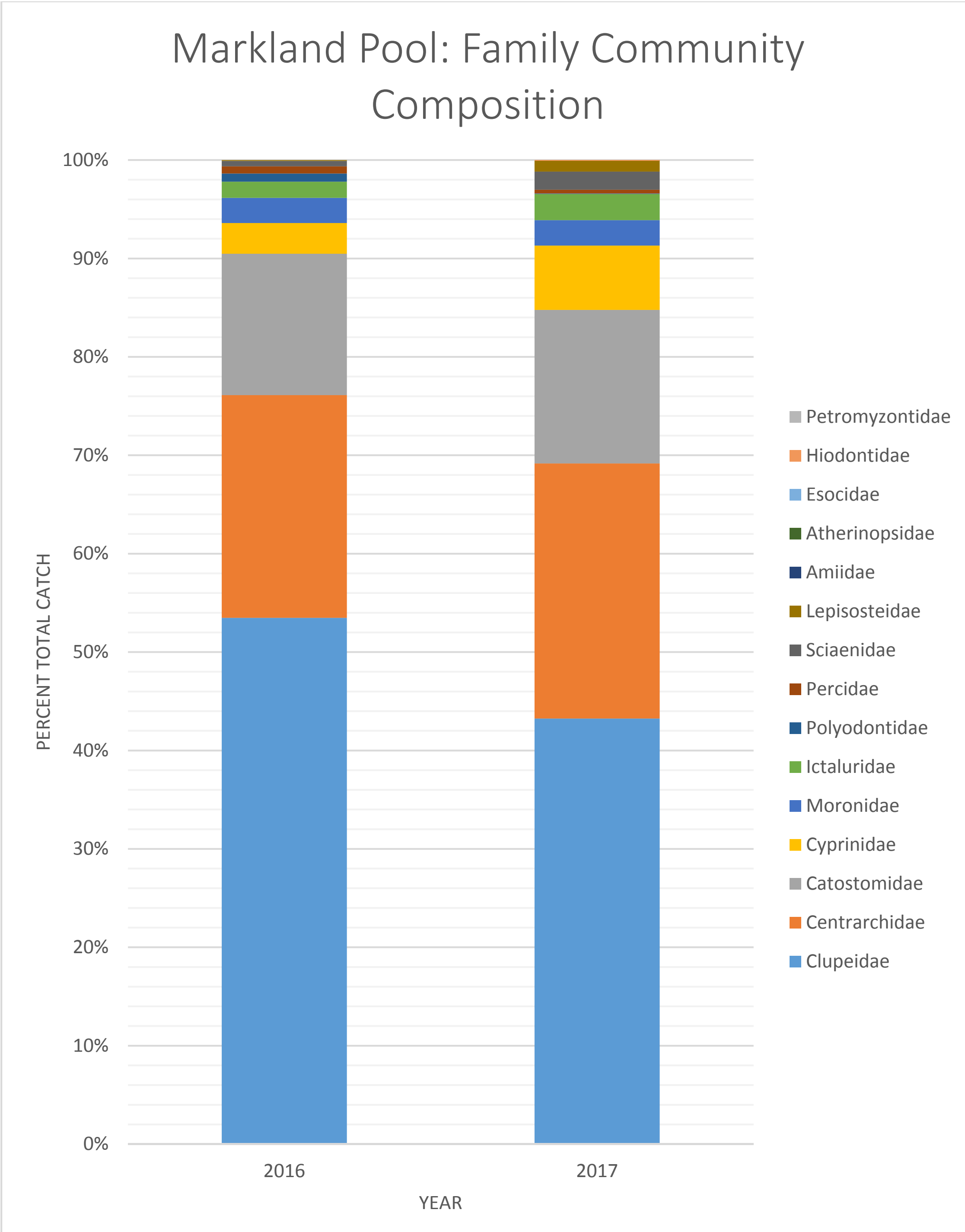


Figure 11. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Markland pool.

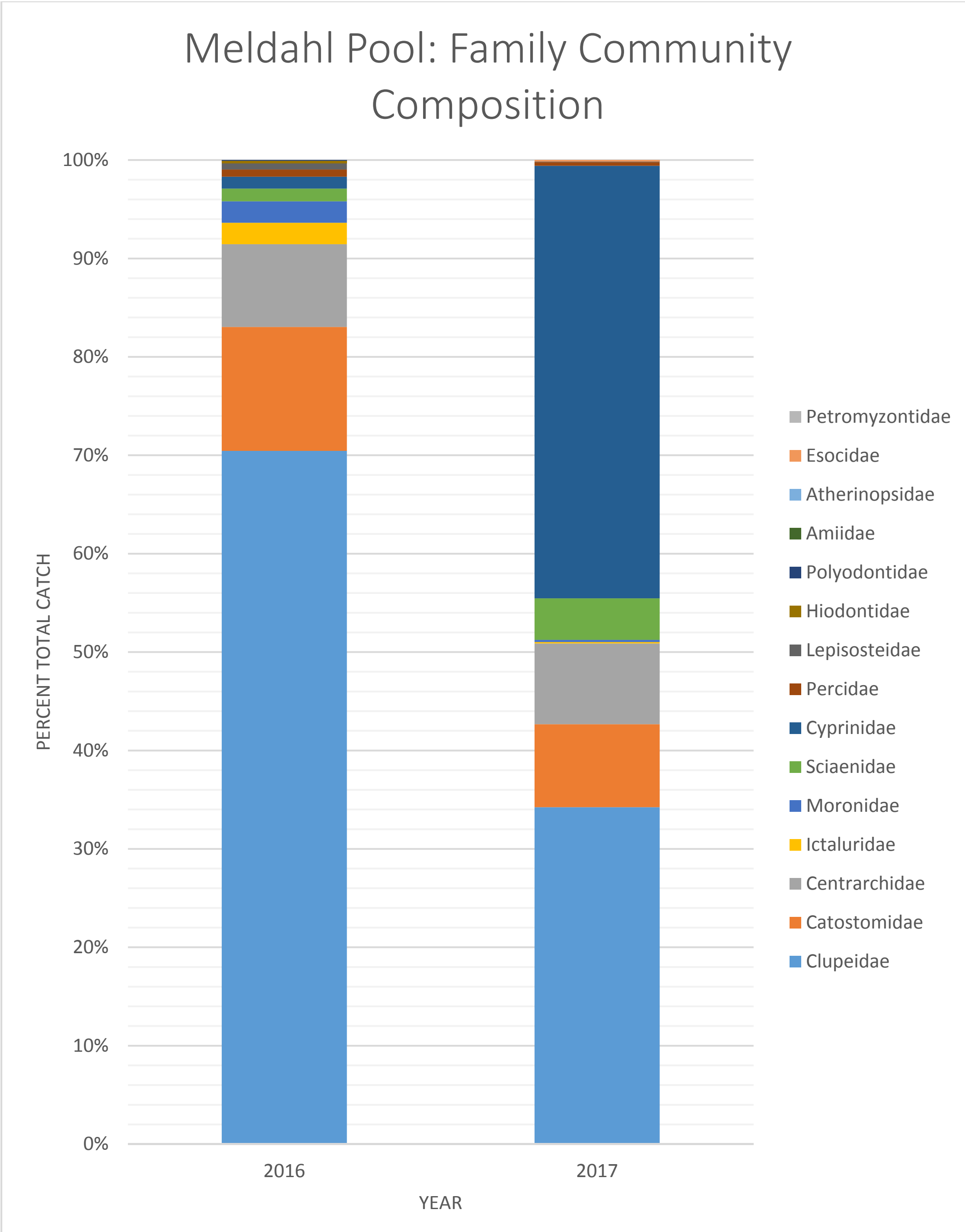


Figure 12. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Meldahl pool.

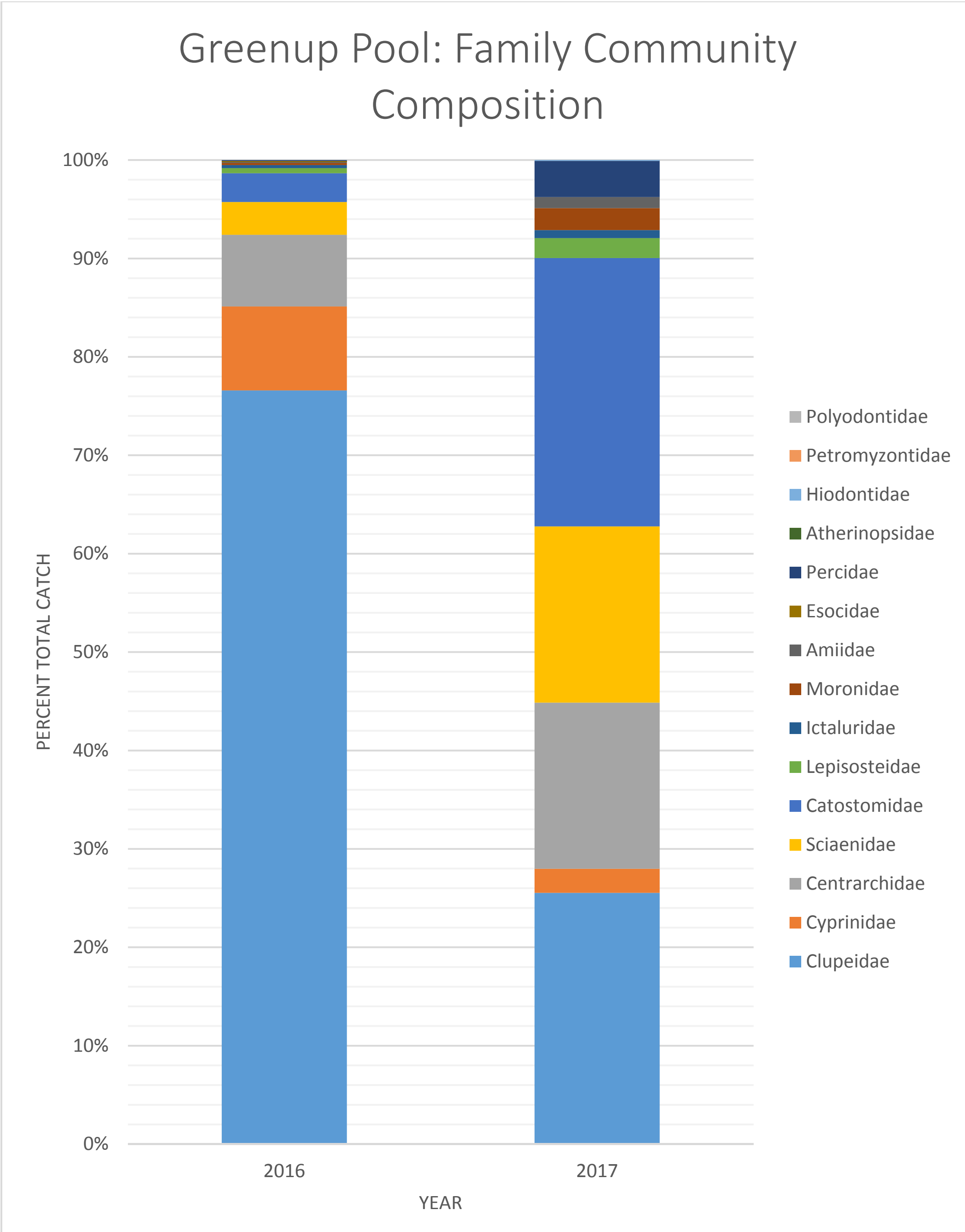


Figure 13. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the Greenup pool.

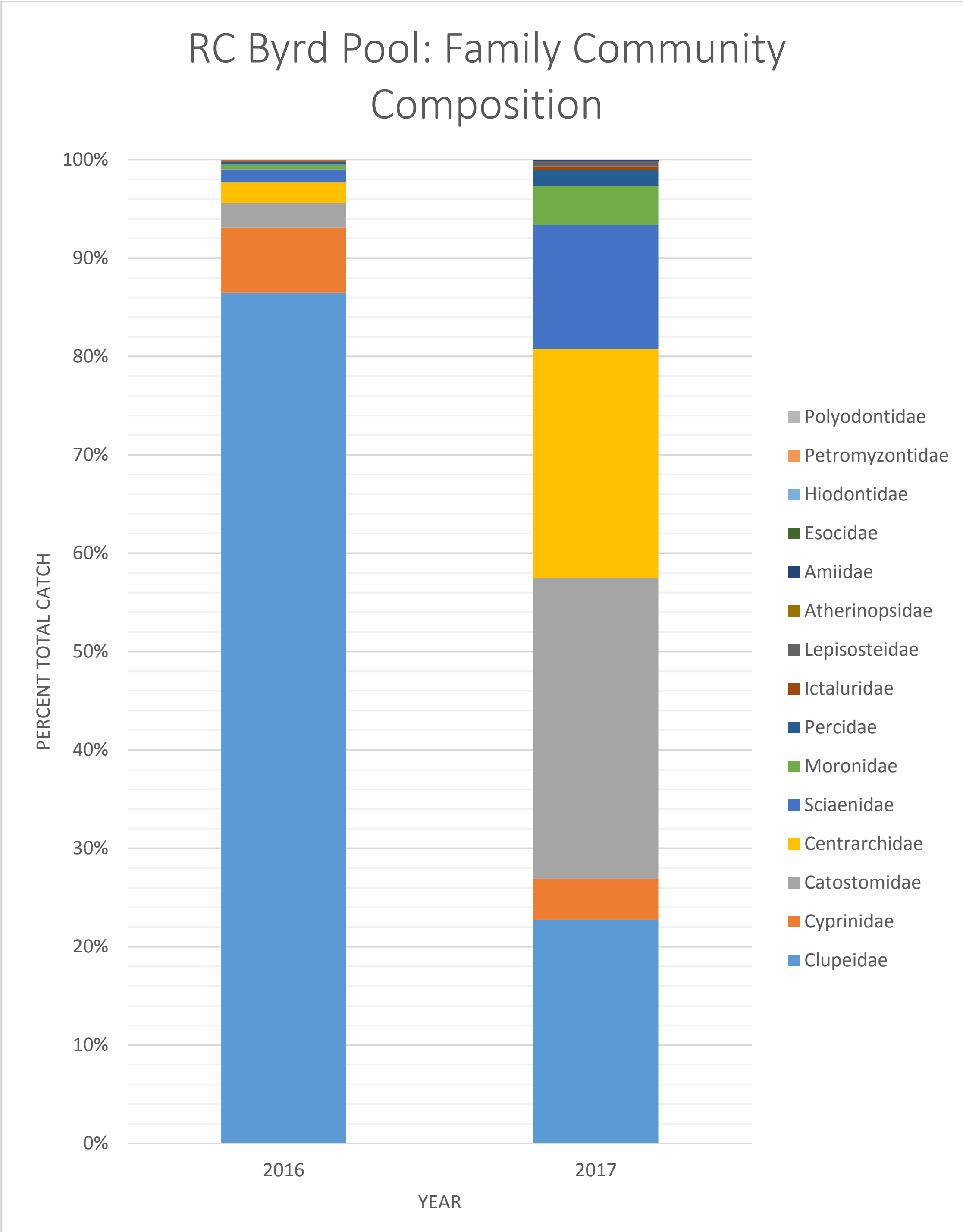


Figure 14. Percent total catch by number of each family identified from fall community sampling in 2016 and 2017 in the RC Byrd pool.

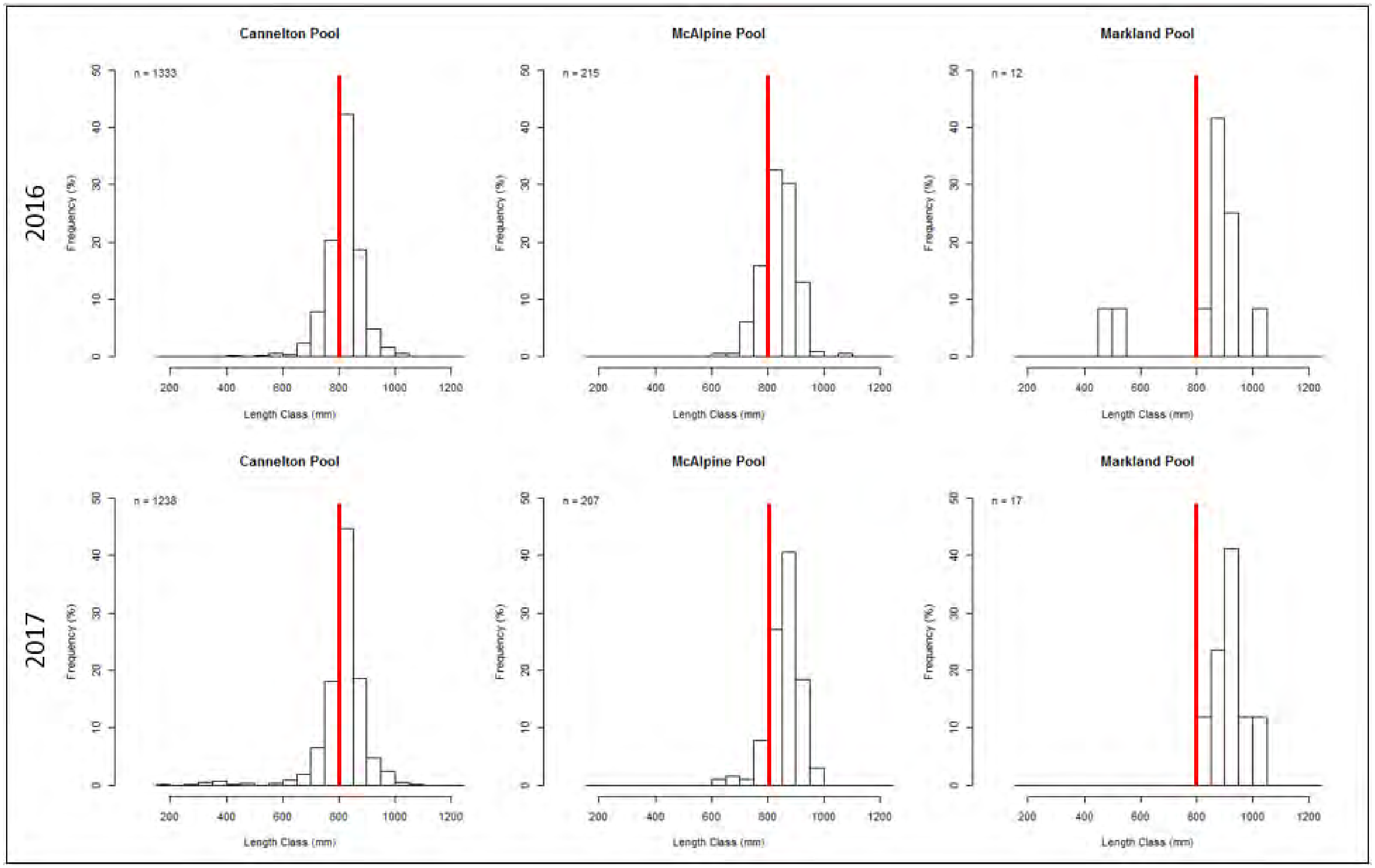


Figure 15. Length frequencies of silver carp captured during sampling efforts in 2016 and 2017. A line at 800mm highlights the change in length-classes from fish captured farther upriver with Cannelton being the farthest pool downstream and Markland the farthest pool upstream.

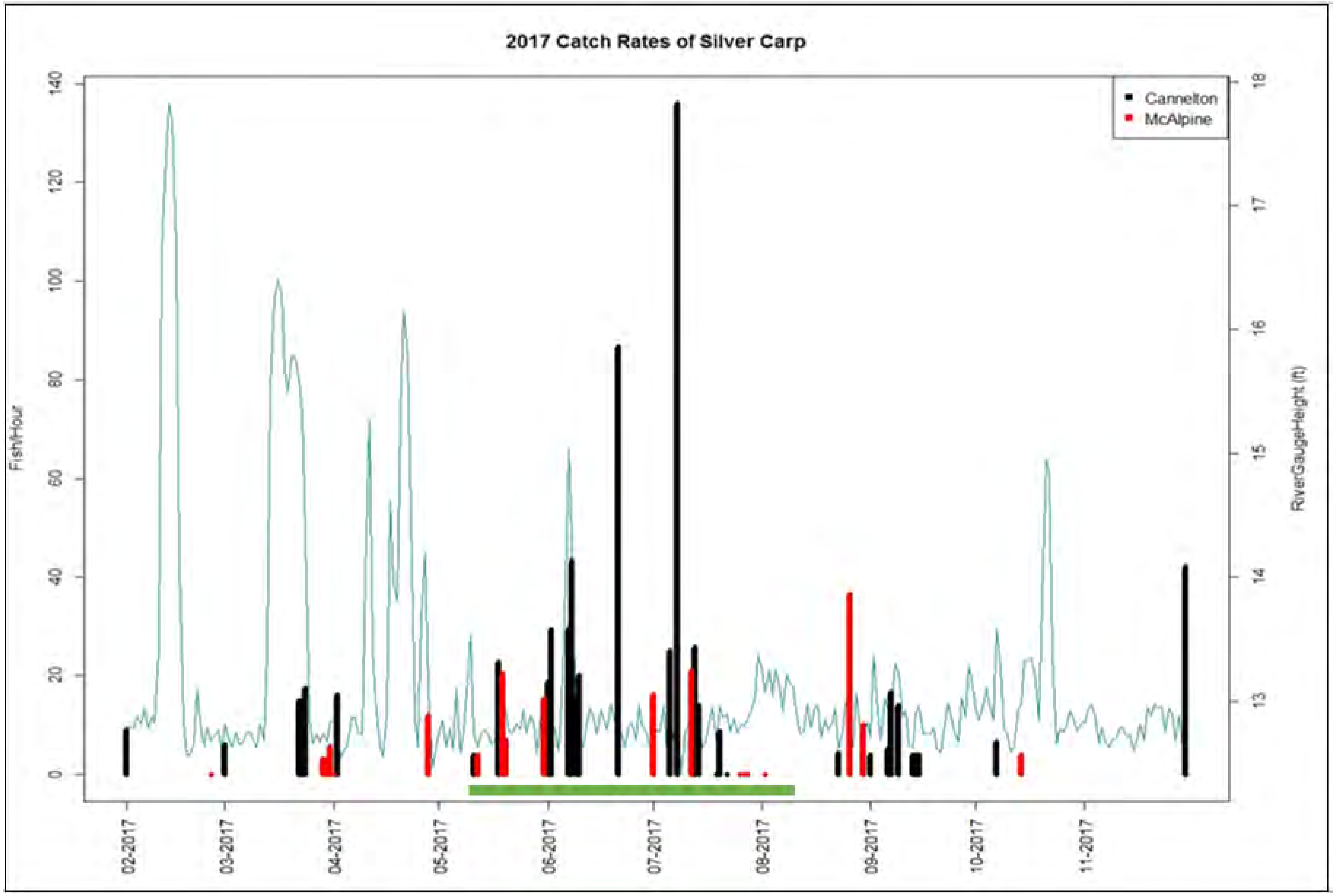


Figure 16. A histogram showing catch rates by month of silver carp captured in Cannelton and McAlpine in 2017 along with the gauge height in feet. The green line between the months of May and August indicate the period where spawning patches appear on females.

| Year | Intercept | Slope |
|---|---|---|
| 2016 | -4.938 | 2.991 |
| 2017 | -5.250 | 3.092 |

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

Figure 17. (Top) A table with individual intercepts and slopes for regressions of silver carp log-transformed lengths (mm) and weights(g) in 2016 and 2017. (Bottom) An ANOVA table showing the results of the ANCOVA analysis for the linear regression model ($y = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x1x\ 2 + \varepsilon$), 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.

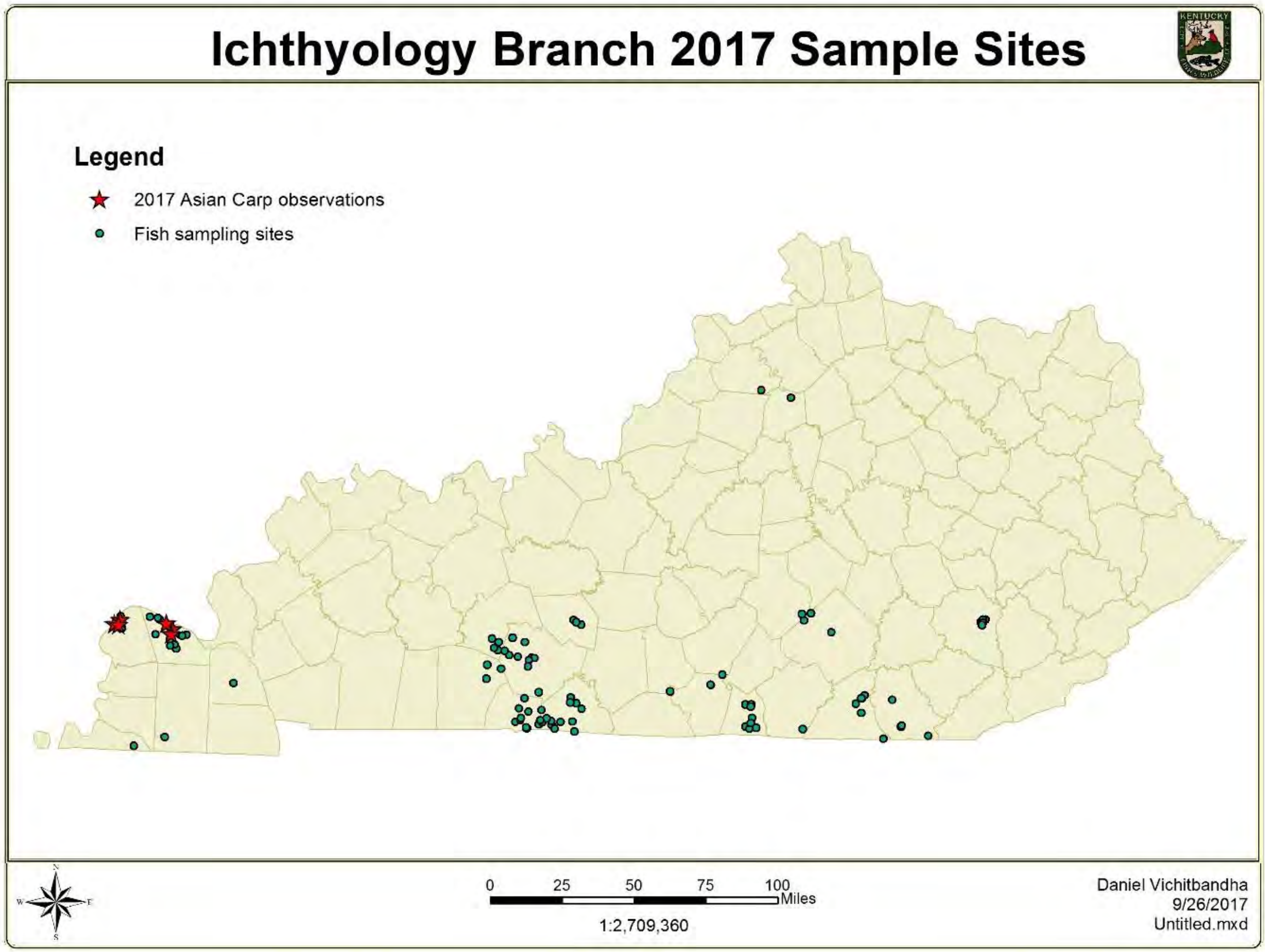


Figure 18. A map of Kentucky showing the sites where the KDFWR ichthyology branch conducted 2017 project sampling with incidental Asian carp observations indicated using red stars.

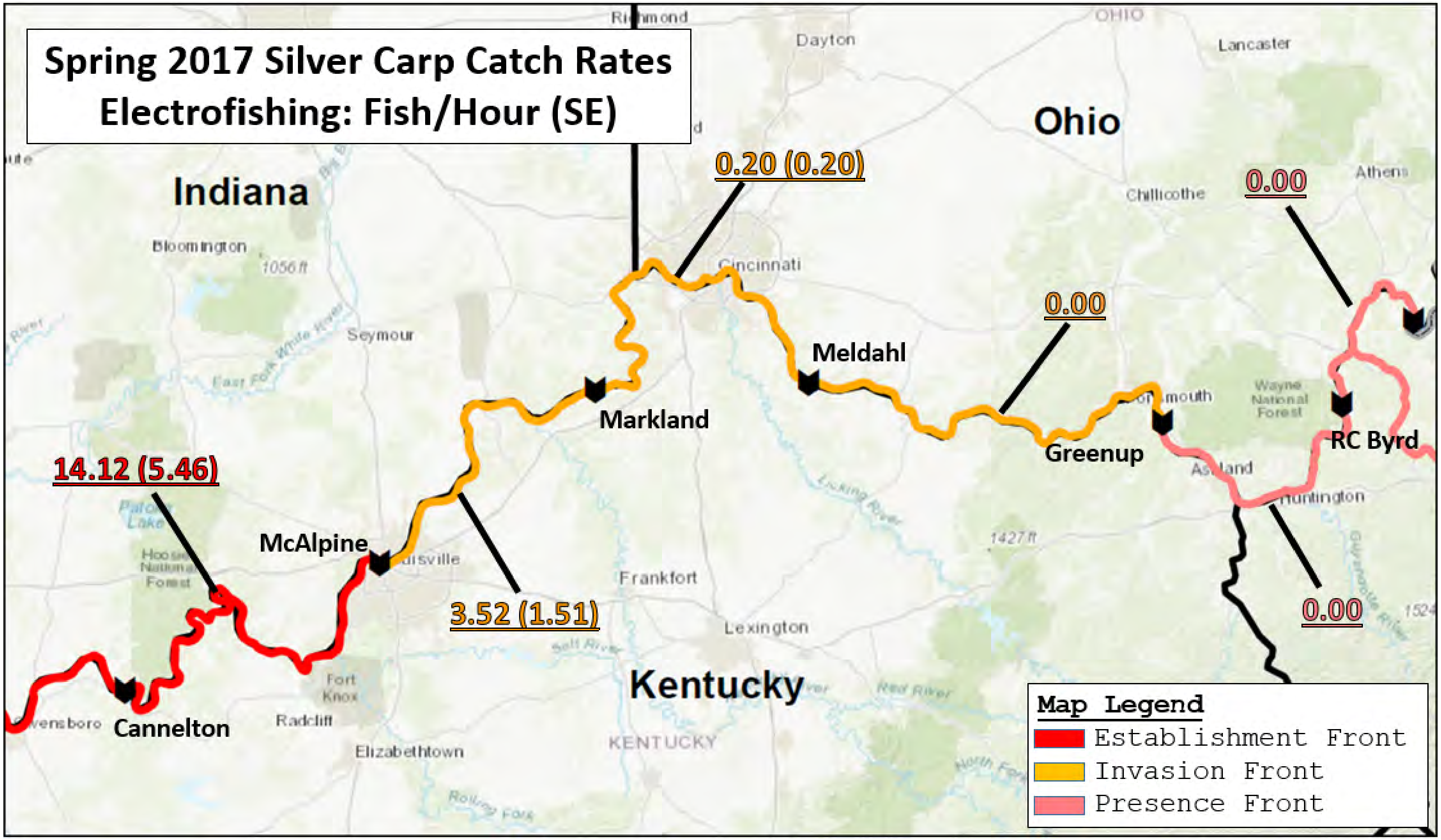


Figure 19. Mean silver carp catch rates by navigation pool using boat electrofishing during targeted sampling in 2017. Standard errors are in parenthesis.

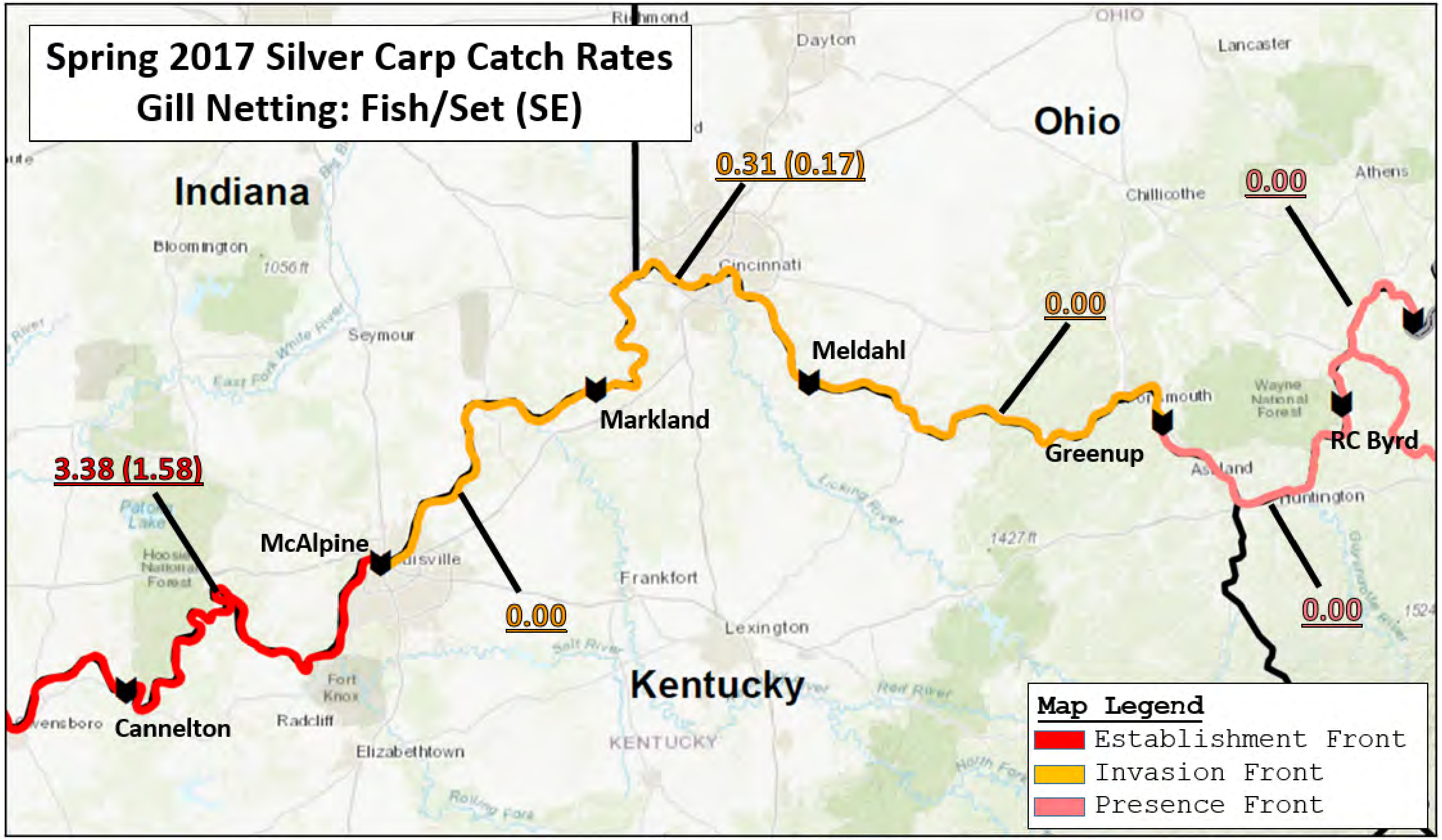


Figure 20. Mean silver carp catch rates by navigation pool using gill netting during targeted sampling efforts in Spring 2017. Standard errors are in parenthesis.

**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 | |

## Control and Removal of Asian Carp in the Ohio River

**Project Lead:** Kentucky Department of Fish and Wildlife Resources, Andrew Stump

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

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

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

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

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

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

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

Bigheaded Carps – a term used to reference the collection of the bigheaded carps (*Hypophthalmichthys spp.*) and their hybrids, found in the Ohio River basin.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Project Highlights:**

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

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

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**Figures:**

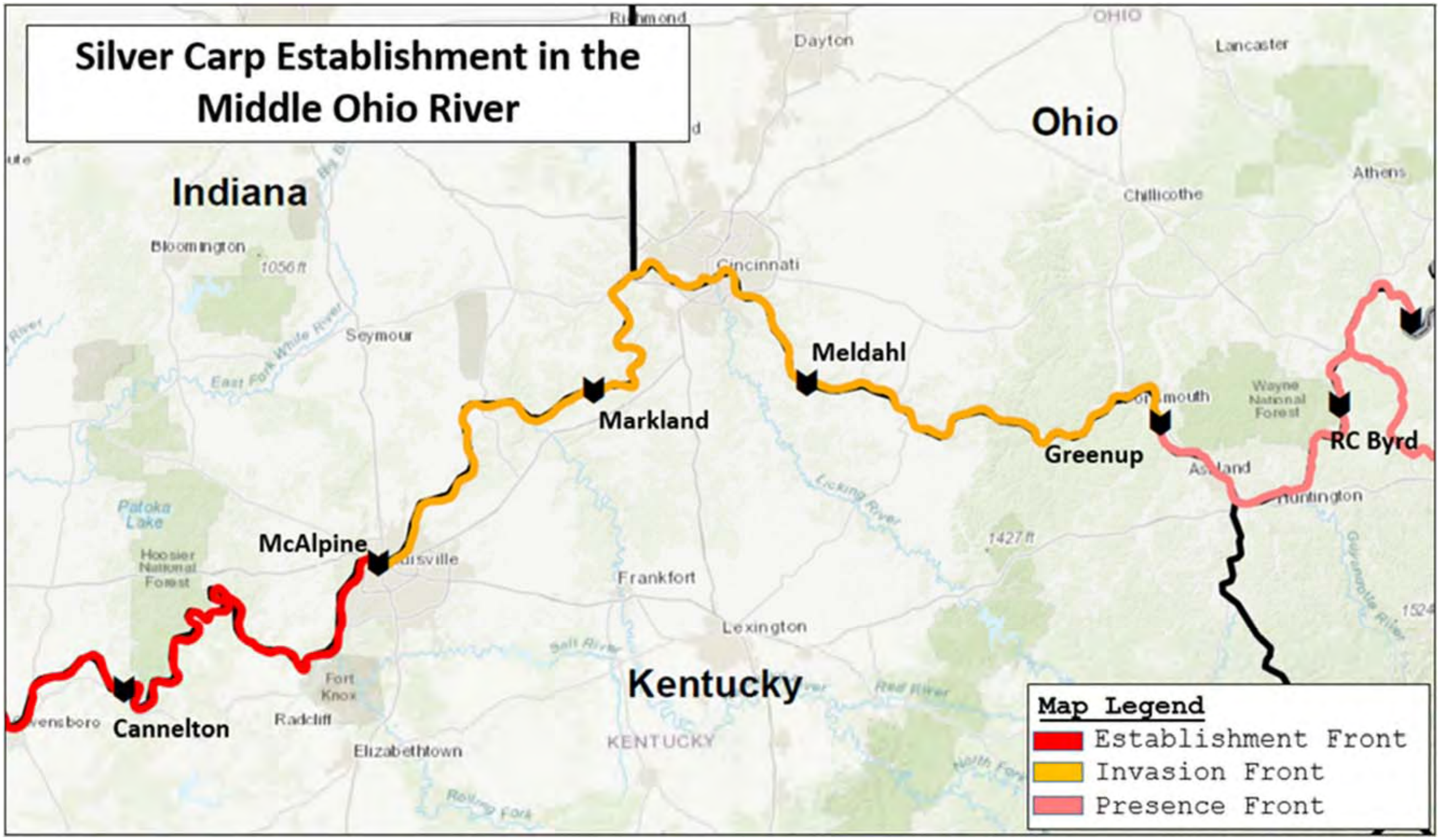


Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

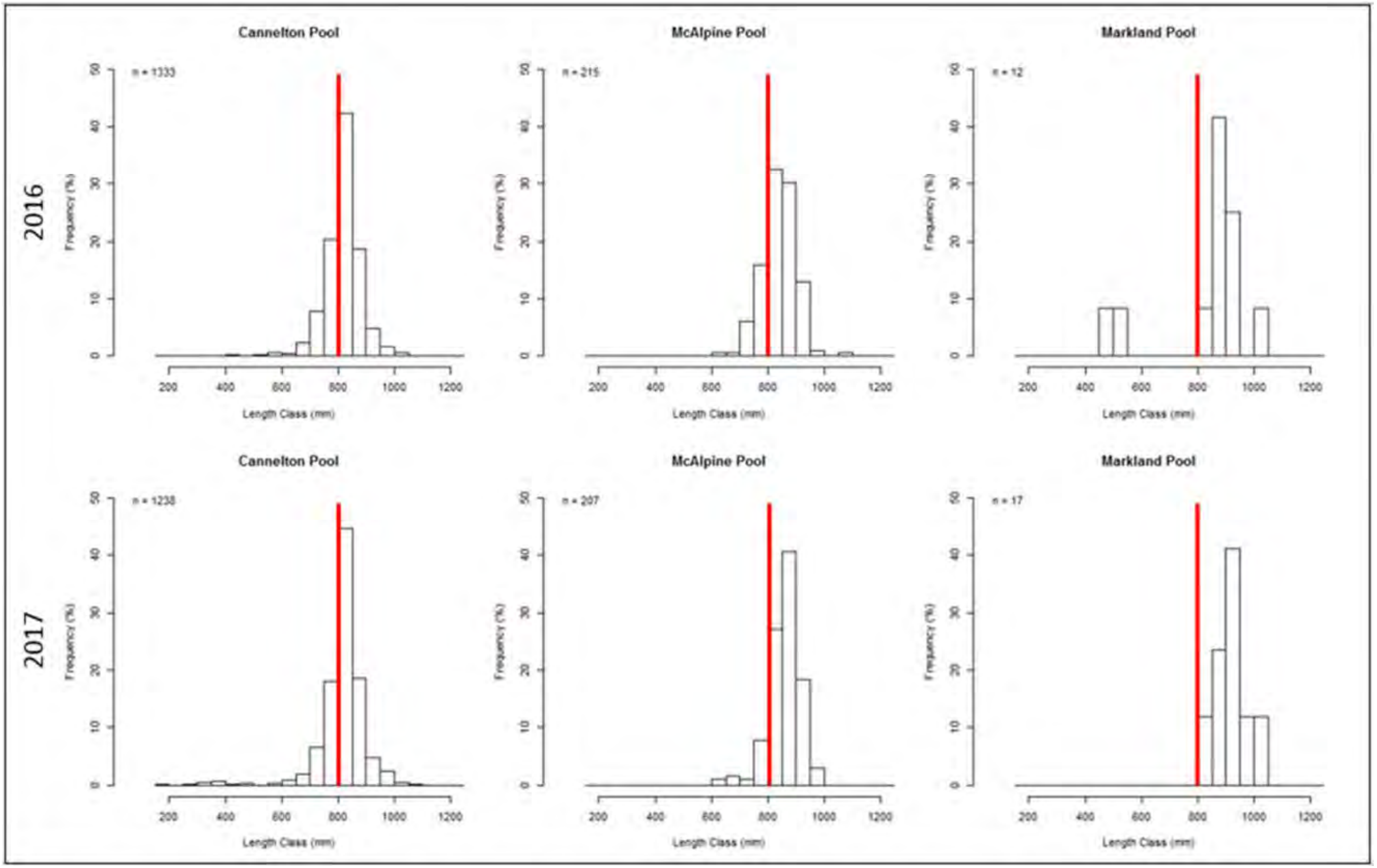


Figure 2. Length frequencies of silver carp captured during sampling efforts in 2016 and 2017. A line at 800mm highlights the change in length-classes from fish captured farther upriver with Cannelton being the farthest pool downstream and Markland the farthest pool upstream.

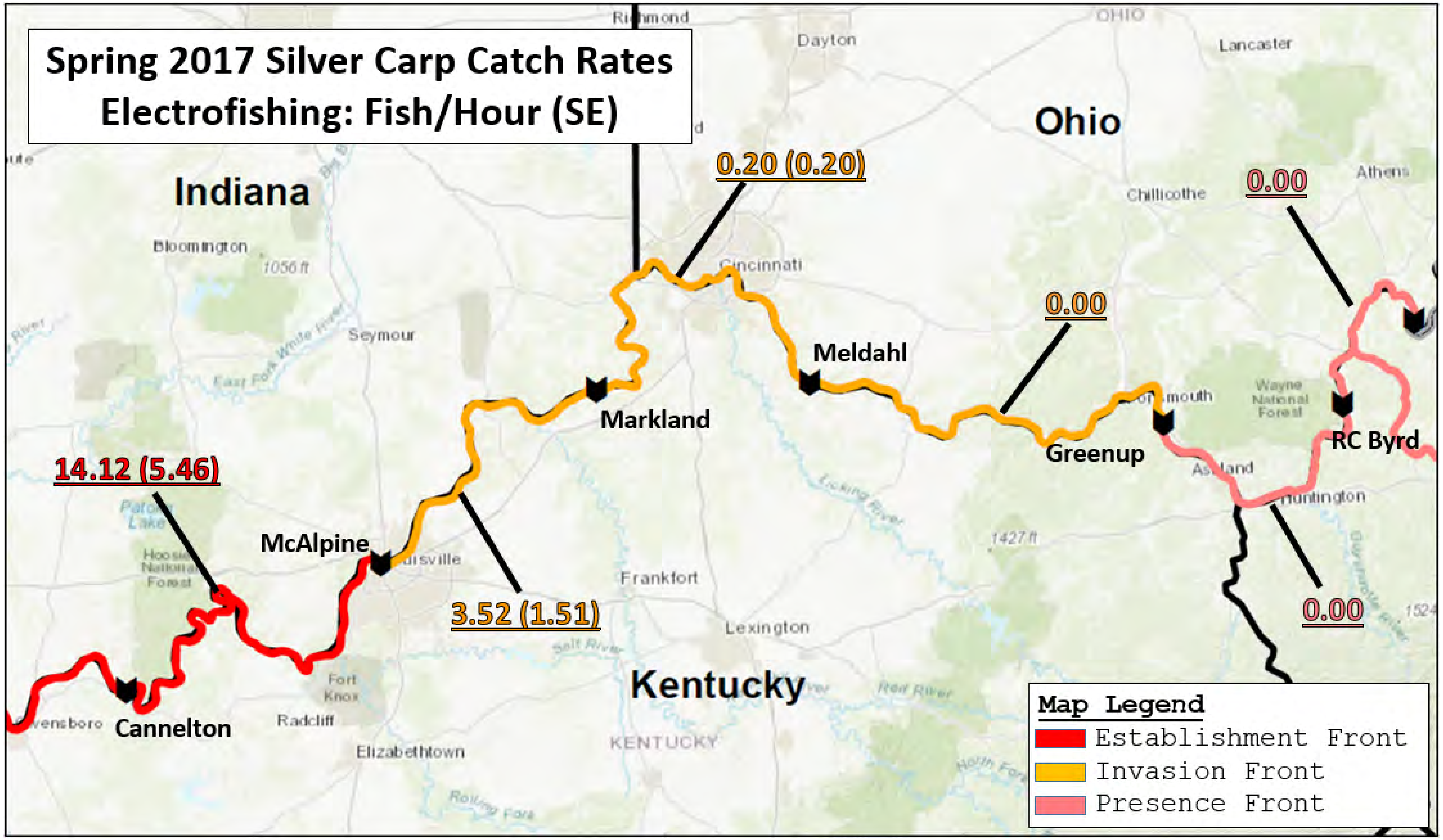


Figure 3. Mean silver carp catch rates by navigation pool using boat electrofishing during targeted sampling in 2017. Standard errors are in parenthesis.

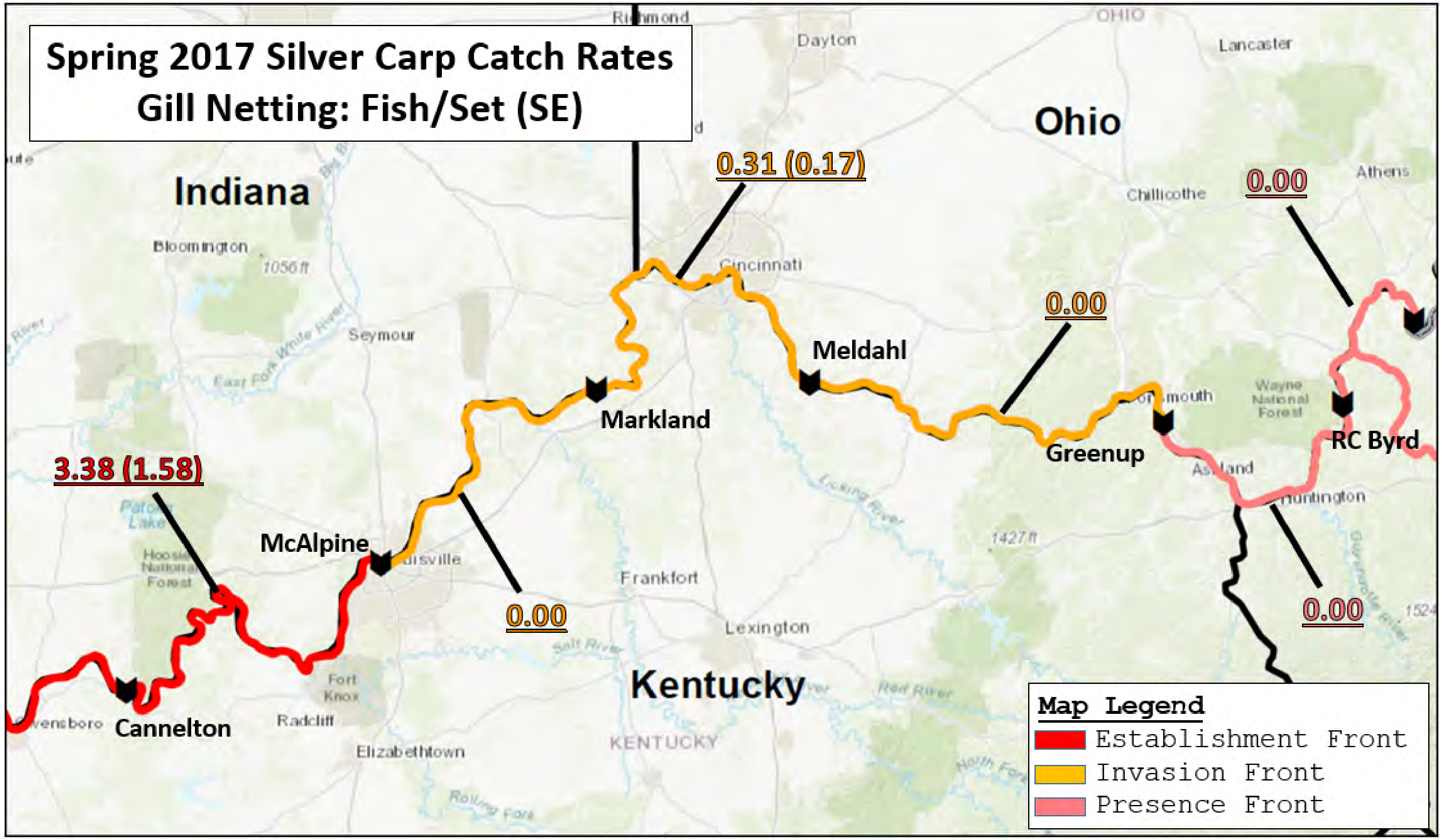


Figure 4. Mean silver carp catch rates by navigation pool using gill netting during targeted sampling efforts in Spring 2017. Standard errors are in parenthesis.

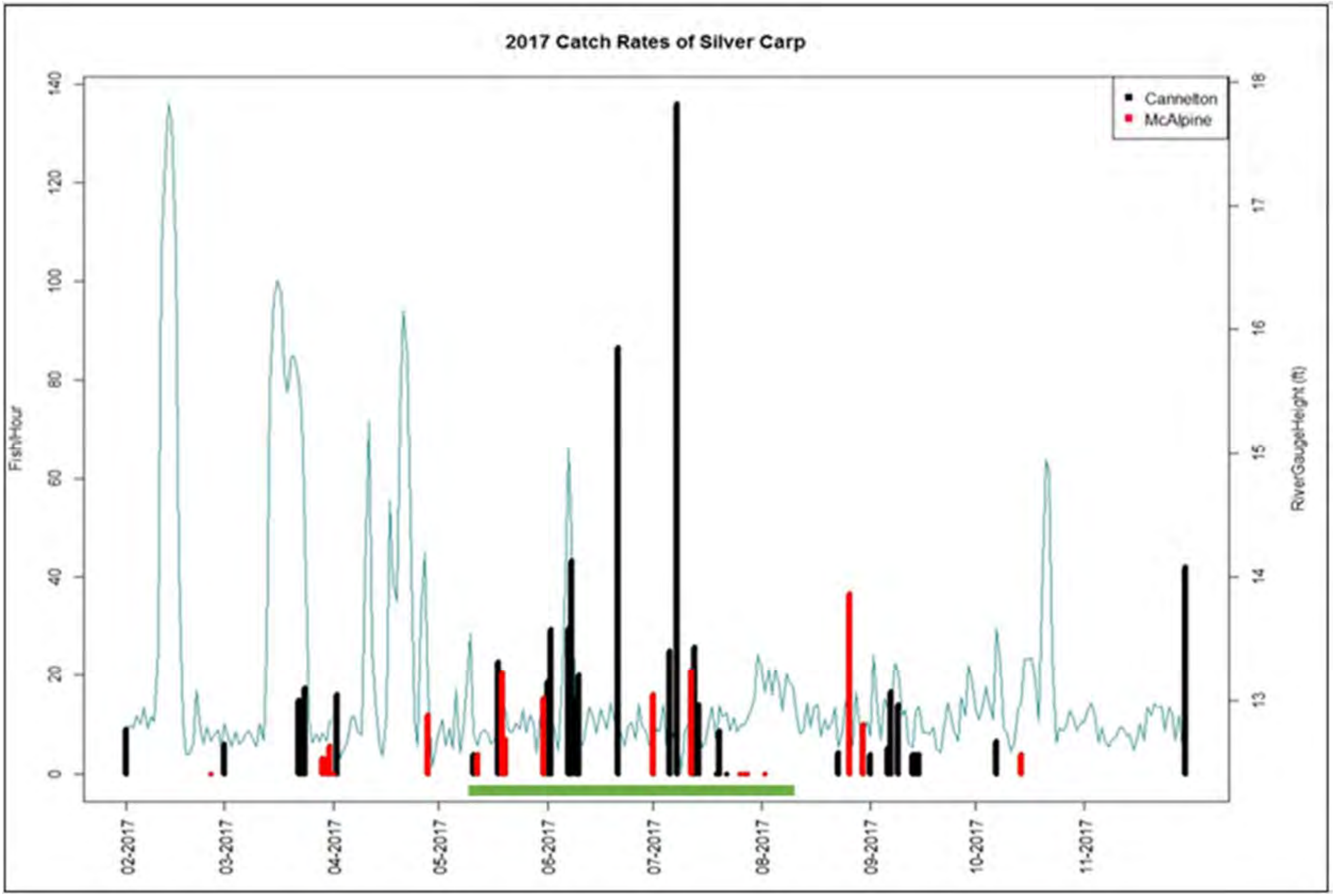


Figure 5. A histogram showing catch rates by month of silver carp captured in Cannelton and McAlpine in 2017 along with the gauge height in feet. The green line between the months of May and August indicate the period where spawning patches appear on females.

**Tables:**

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

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

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

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

# Asian Carp Containment and Suppression in the Upper Ohio River

**Project Lead:** Kentucky Department of Fish and Wildlife Resources, Andrew Stump

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

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

## Introduction:

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

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

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

## Objectives:

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

## Methods:

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

*Clarification of Terminology Referenced in This Document*

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

<u>Bigheaded Carps</u> – a term used to reference the collection of the bigheaded carps (*Hypophthalmichthys spp.*) 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 describe the variety of fixed sites within a pool (e.g. Tributary, Tailwater, Embayment, Island Back-Channel, and Main Stem River).
<u>Presence Front</u> – The farthest upstream extent where Asian carp populations occur, but reproduction is not likely taking place.
<u>Targeted Sampling</u> – sampling that uses gear and/or techniques intended to specifically target one species and exclude others (i.e. silver carp and bighead carp).

*Physical Removal of Asian Carps*

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

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

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

*Surgical Implantation of Acoustic Transmitters*

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

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

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

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

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

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

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

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

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

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

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

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

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

**Project Highlights:**

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

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

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**Figures:**

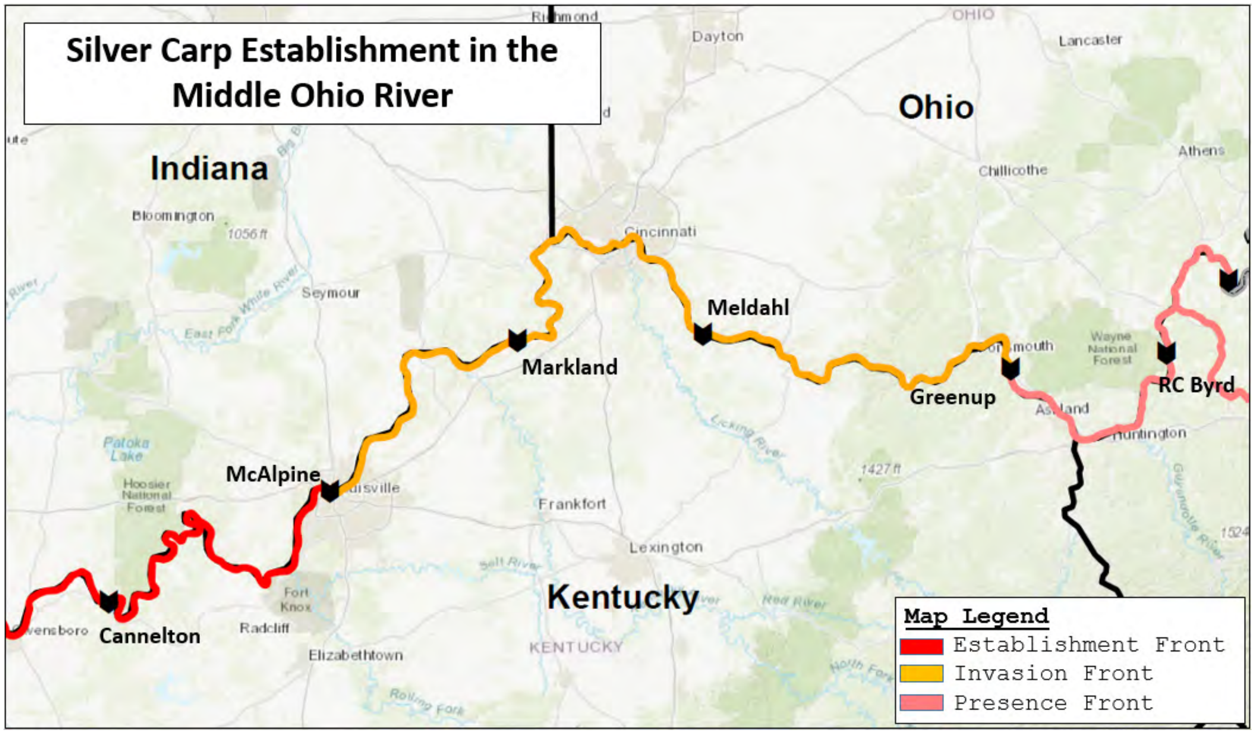


Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

**Tables:**

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

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

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

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

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

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

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

**Lead Agency:** US Fish and Wildlife Service (USFWS)

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

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

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

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

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

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

**Project Objectives:**

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

**Project Highlights:**

- In 2017, the project's extensive array of 158 stationary receivers logged more than 8 million detections from a total of 263 tagged Silver and Bighead carp that were spread across five different pools of the Ohio River.

- Over the course of this study, most of the fish being detected by receivers were found in the same pool where they were originally tagged. Between their first and last detections of 2017, more than 80% of the tagged carp detected last year had moved a net total of five miles or less in either an upstream or a downstream direction.
- Tributary usage by tagged carp in the Cannelton, McAlpine and Markland pools was significantly greater than their use of the mainstem Ohio River, but in the Capt. A Meldahl Pool, tagged carp appeared to occupy the mainstem river more often than any of its tributaries.
- Asian carp have a greater probability (0.18) of moving from the mainstem river into tributaries than moving from tributaries into the mainstem (0.13).
- Preliminary pool-to-pool transition probabilities are still quite small for both Bighead and Silver Carp
- Annual survival of tagged Silver Carp was estimated at nearly 77%, while tagged Bighead Carp survival was more than 85%, but with greater confidence interval margins.

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

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

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

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

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

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

**Results and Discussion:**

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

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

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

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

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

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

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

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

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

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

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

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

**Recommendations:**

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

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## Figures and Tables:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

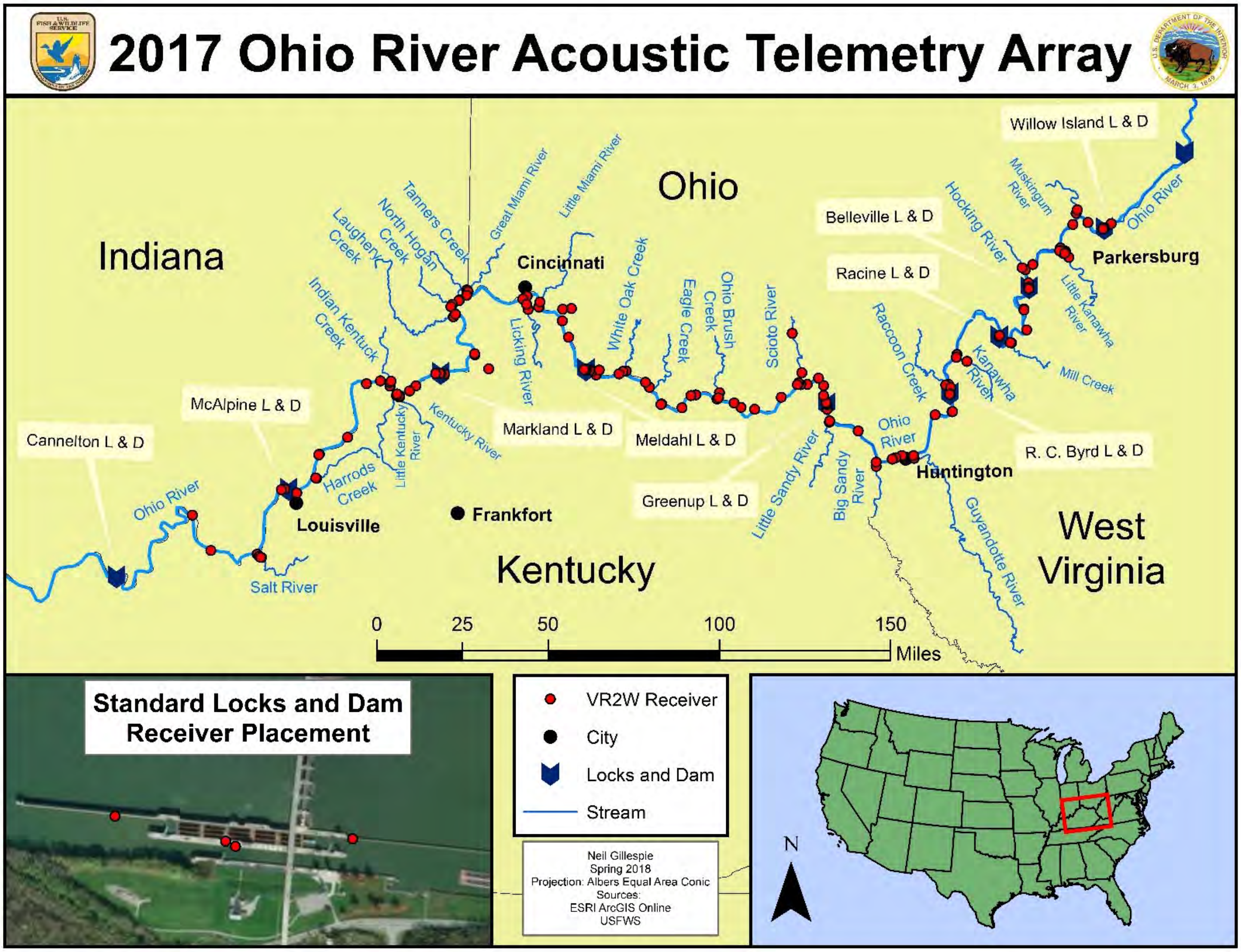


Figure 1. Locations of stationary VR2W and VR2AR receivers in 2017. Individual points may represent more than one receiver at this scale.

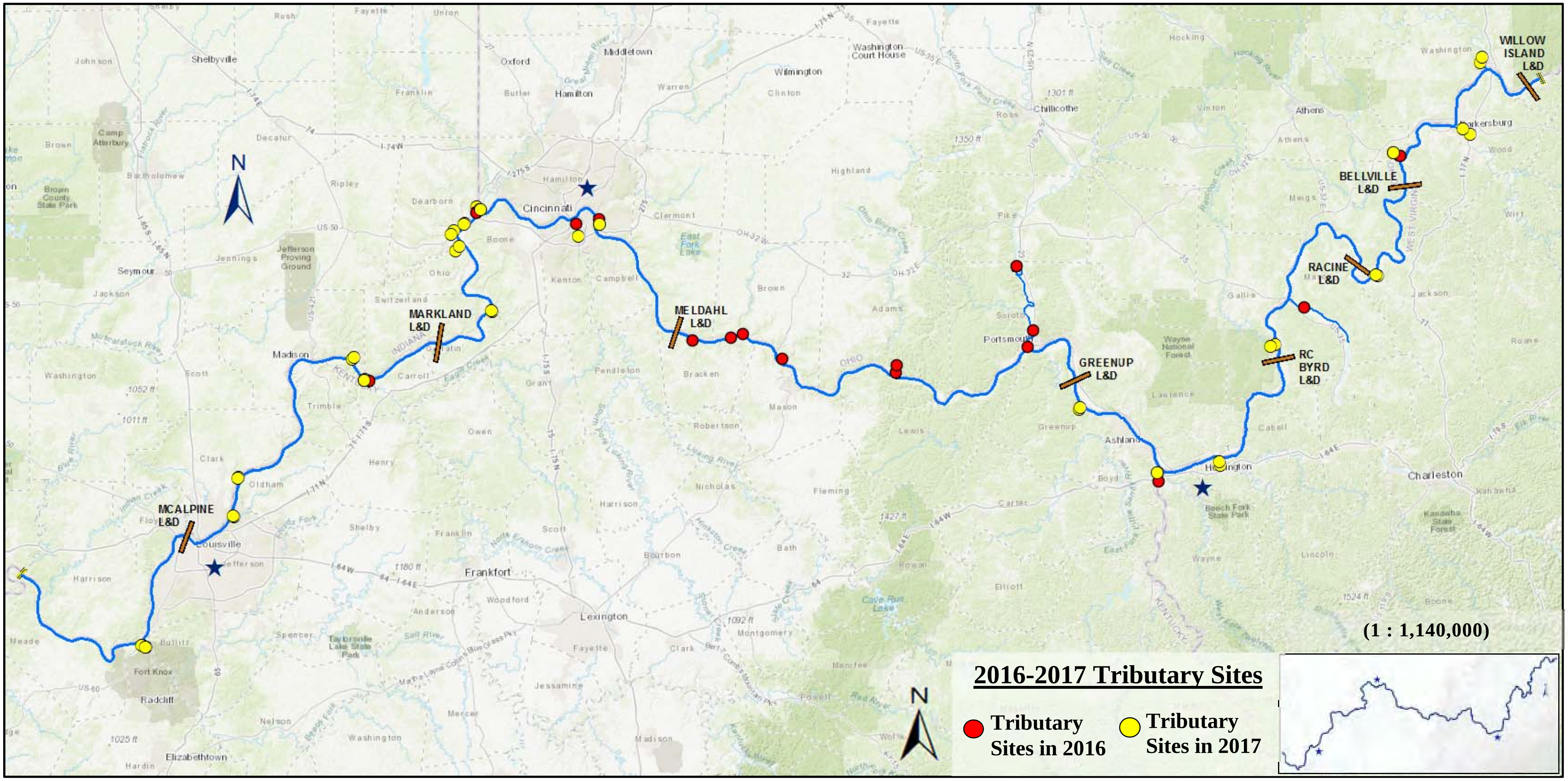


Figure 2. Distribution of the receiver stations that were located in tributaries during 2016 - 2017. The 2017 efforts to extend the project's receiver coverage of tributaries succeeded in establishing as many as two new stations in 15 previously unmonitored streams and small rivers, which was in addition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

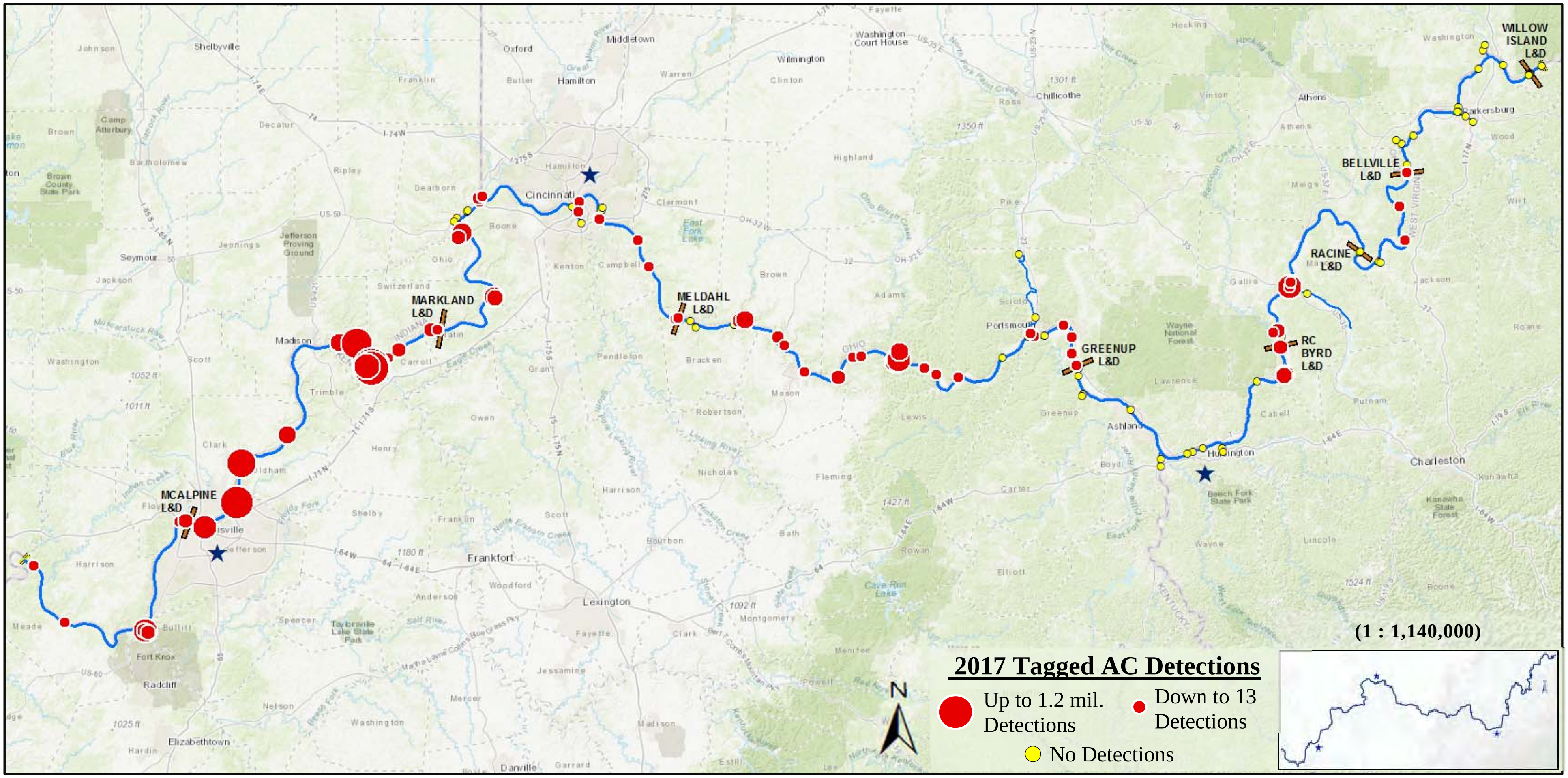


Figure 3. The distribution of the receiver stations that made at least one valid detection of a tagged Asian Carp in 2017. The diameter of each red circle on the map corresponds to the total amount of tagged carp detections that were made by the receiver that had been deployed to that location.

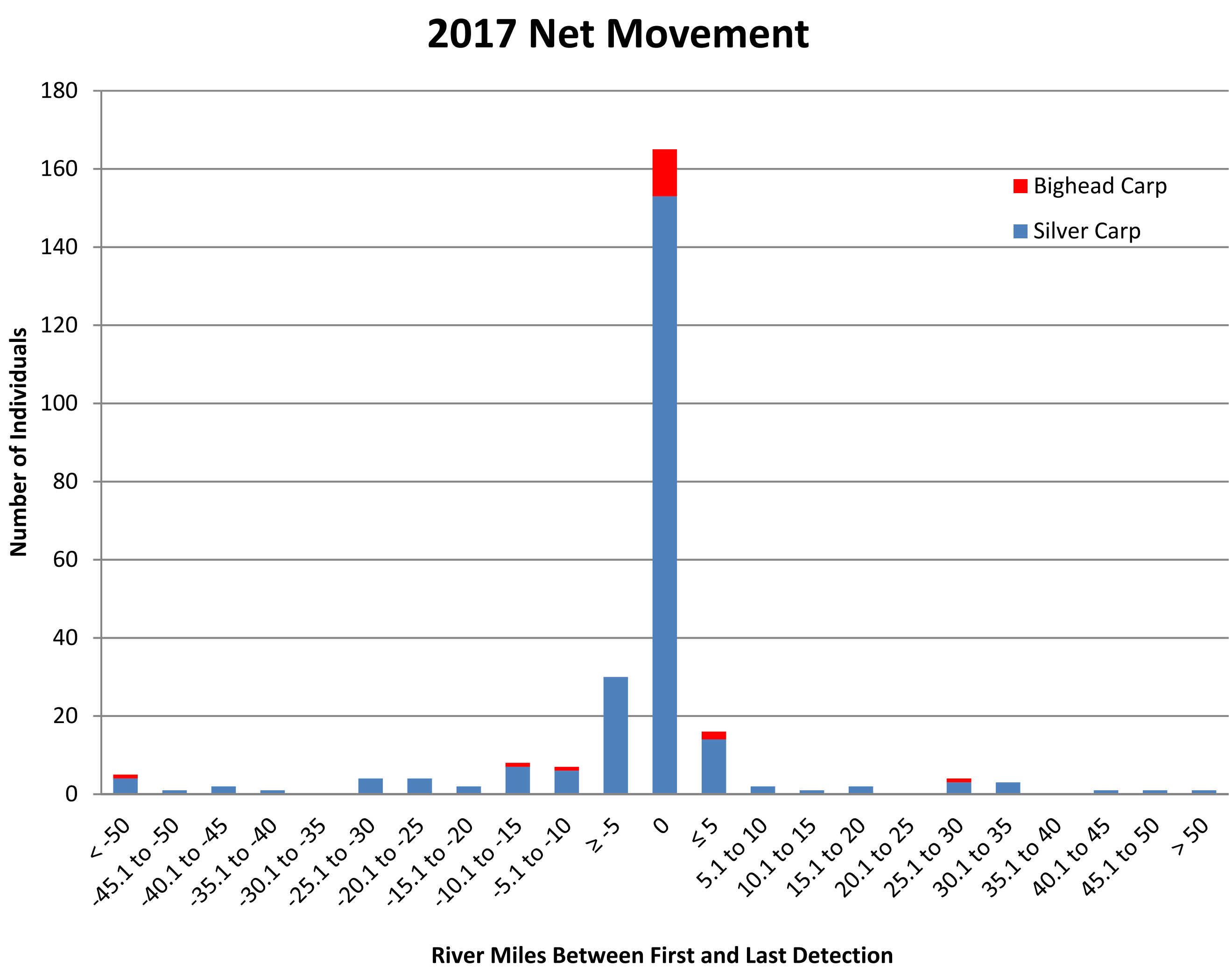


Figure 4. Net upstream and downstream movement of Asian carp in the Ohio River from first to last detection in 2017.

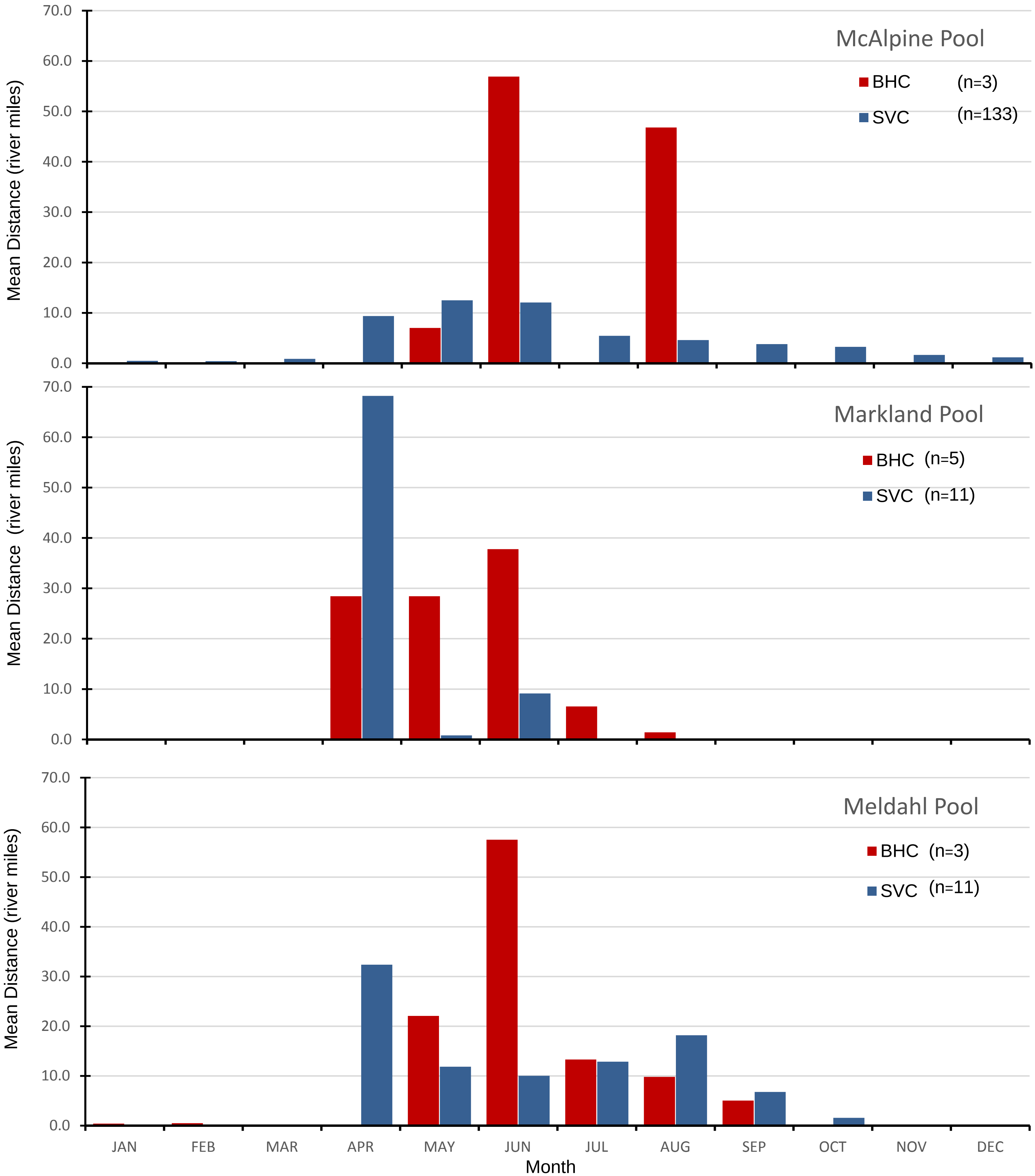


Figure 5. The mean monthly distances (in river miles) between the most upstream and downstream detections for tagged Bighead Carp and Silver Carp in the three most active pools of the telemetry project. Only tagged carp that were detected by 2 or more receivers during 2017 were included in the distance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

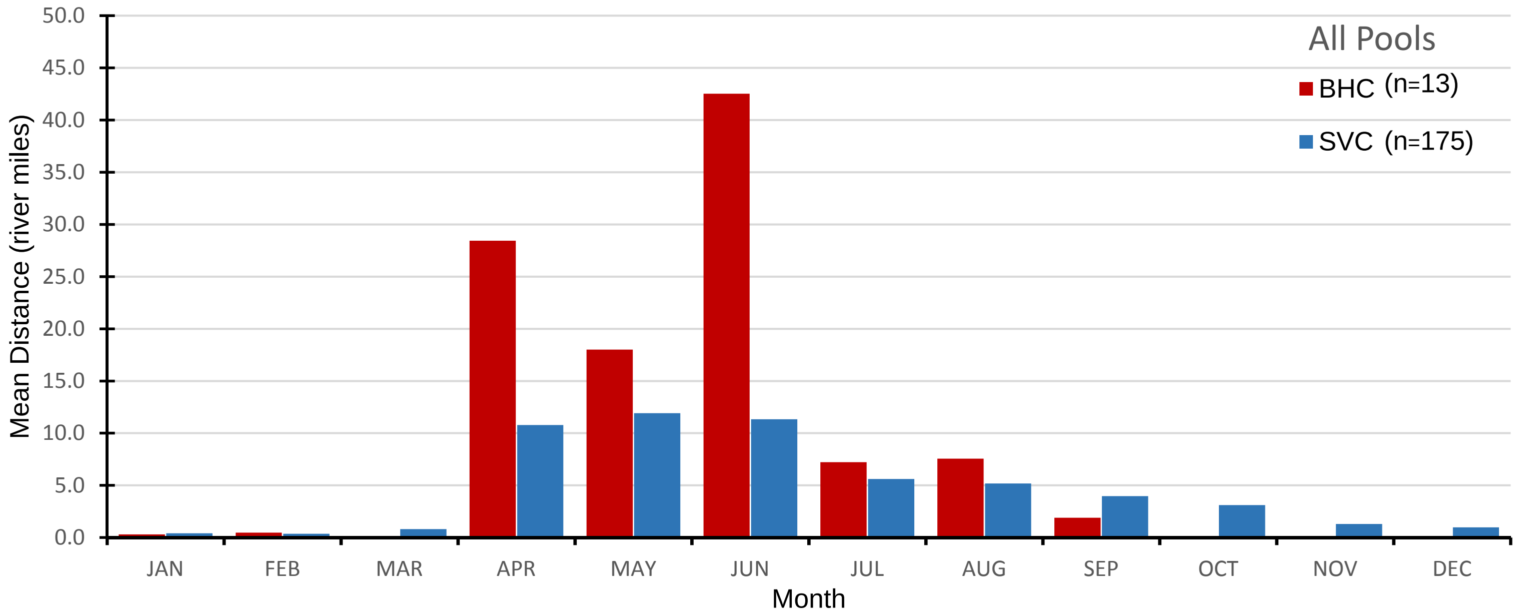


Figure 6. The mean monthly distances (in river miles) between the most upstream and downstream detections for all tagged Bighead Carp and Silver Carp that were detected by 2 or more receivers during 2017

## Ohio River Asian Carp Detection Probabilities - 2017

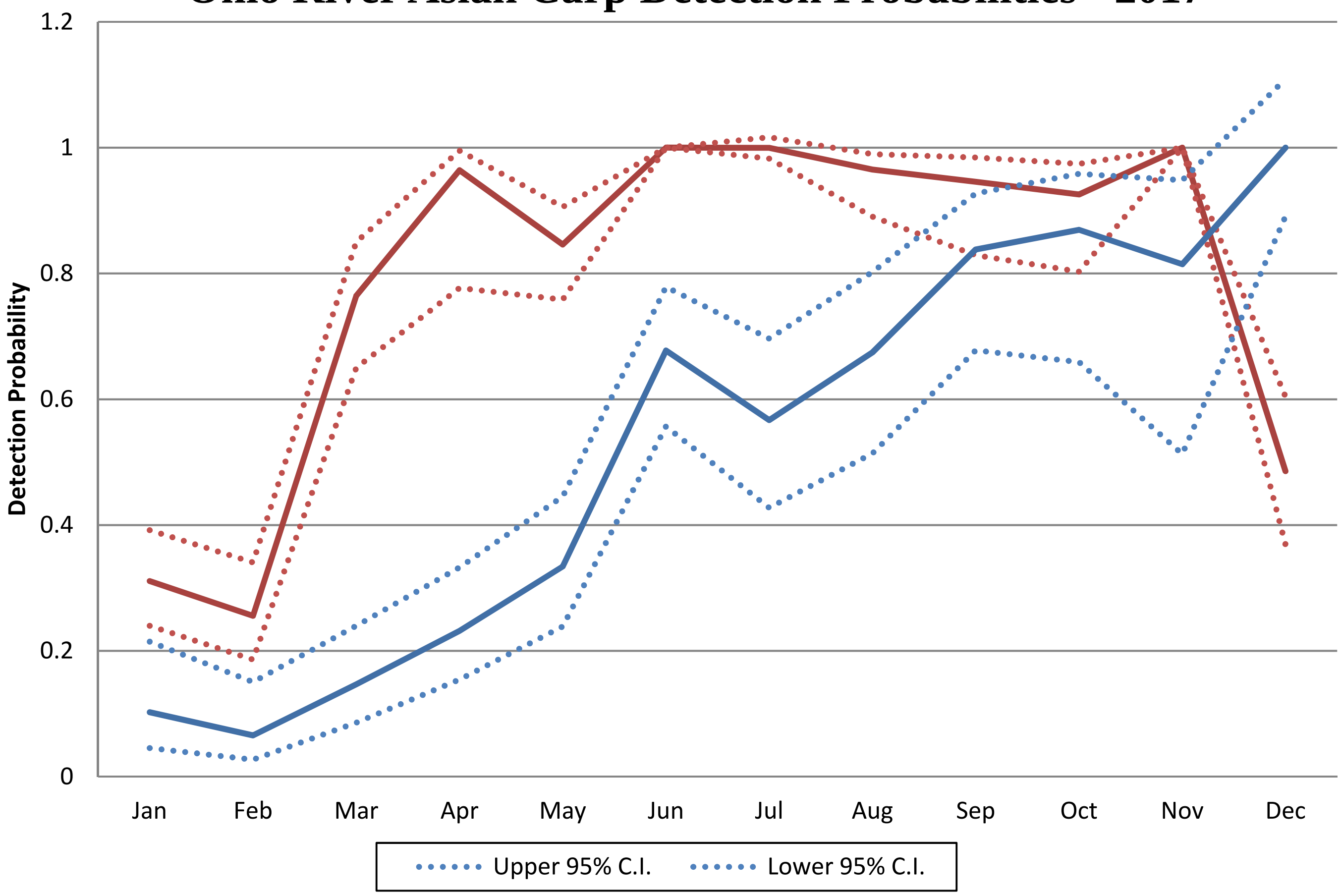


Figure 7. Detection probabilities with upper and lower 95% confidence intervals of telemetered Asian carp within the mainstem Ohio River and its tributaries during 2017.

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

**Project Lead:** Indiana Department of Natural Resources

**Geographic Location:** Ohio River Basin

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

**Statement of Need:**

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

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

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

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

**Project objectives:**

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

**Project Highlights:**

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

**Methods:**

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

*Ichthyoplankton tows:*

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

*Surface trawl:*

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

*Electrofishing:*

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

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

*Environmental variables:*

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

**Results:**

*Ichthyoplankton tows:*

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

*Surface trawl:*

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

*Electrofishing:*

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

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

*Habitat Parameters:*

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

**Discussion:**

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

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

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

Evaluation of abiotic habitat parameters showed juvenile carp were found in habitats with significantly greater water temperature, lower depth, lower secchi visibility, and lower conductivity. This suggests shallow, turbid, and potentially more productive habitats promote survival and recruitment of Asian carp.

Additionally, we observed no significant effects of water color, presence of woody debris, or presence of aquatic vegetation. Future sampling may benefit by sampling these variables quantitatively to reduce subjectivity. Although we were limited by a small sample size and suitable analyses for this dataset, this information will be used to help guide future sampling and management efforts.

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

**Recommendation:**

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

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

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

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