Title: Early detection and evaluation of Invasive carp removal in the Ohio River

Geographic Location: Ohio River basin, extending from the J.T. Myers Pool (RM 845.9) to the R.C. Byrd pool (RM 279.2) along with the Dashields (RM 13.3), Montgomery Island (RM 31.7), and New Cumberland (RM 54.4) pools of the Ohio River, in addition to the Wabash, Allegheny, and Monongahela rivers.

Participating Agencies: Illinois Department of Natural Resources (ILDNR), Indiana Department of Natural Resources (INDNR), Kentucky Department of Fish and Wildlife Resources (KDFWR), Pennsylvania Fish and Boat Commission (PFBC), Southern Illinois University (SIU), U.S. Fish and Wildlife Service (USFWS), West Virginia Division of Natural Resources (WVDNR), West Virginia University (WVU)

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 invasive carp has been implemented since their introduction in the early 1980's (Kolar et al. 2005). However, an innate ability to tolerate a wide range of conditions allowed them to overcome the initial management efforts and eventually establish invasive populations all over the Mississippi River basin, which included the lower Ohio River and most of its larger tributaries.

This project began with the primary task of establishing a coordinated approach to monitoring carp populations in the Ohio River that occur across various stages of introduction. Its main objective has been to gather details about the distribution and habitat preferences of invasive carp populations, which can provide valuable information and guidance to the ongoing management efforts. Additional project goals included collecting data about possible impacts to native fish assemblages and providing a means to conduct regular assessments of long-term invasive carp removal efforts.

Objectives:

1. Evaluate management actions using changes in relative abundance, population characteristics, and distribution of invasive carps within intensive management zones.
2. Monitor long-term trends in native fish communities as indicators of change due to Invasive carp invasion.
3. Survey Invasive carp presence in upstream areas where they are rarely detected to inform response and containment efforts.
4. Determine spatial distributions (hotspots) and densities of Invasive carps in the lower Wabash River to inform and assess harvest.
5. Utilize hydroacoustics surveys to determine biomass densities and verify patterns of relative abundance for Invasive carp species within strategic management zones.

Project Highlights:

- With current sampling efforts being unable to capture Bighead, Grass and/or Black carps with any regularity, Silver Carp are still the primary focus of management efforts in the middle Ohio River. However, in upstream areas located ahead of the Silver Carp invasion front, Bighead Carp continue to be the top priority.

- With the lower precision involved in tracking the long-term trends in abundance through Silver Carp catch rates, other methods for monitoring and evaluation, (i.e. hydroacoustics and occupancy modeling) are being developed to inform decision making.
- After the start of contract fishing in 2019, the next two years (2020-2021) of sampling resulted in relatively stable Silver Carp catch rates. However, this changed in 2022 when targeted monitoring efforts finished with a mean catch rate (8.7 carp/transect) that was nearly double that of previous years. The reason for this increase is still being determined, but even during the years with stable catch rates, there was still some evidence of major shifts in the characteristics of the Silver Carp population.
- Preliminary results of the Community Size Spectra (CSS) analysis suggests that invasive carp populations in the Cannelton to RC Byrd pools have not yet reach a threshold of abundance to negatively influence the size structure of the native fish community.
- There was no substantial range expansion for either Bighead or Grass Carp during this project period, however, Black Carp have now been found in the upper Wabash River. Also, in addition to a new record of capture in the upper Scioto River, Silver Carp were officially collected from new pools of the upper Ohio River (i.e., R.C. Byrd and Racine) where their presence had been suspected but wasn't confirmed until 2022.

Methods:

Clarification of this Document's Terminology

With carp populations still expanding throughout the Mississippi River basin, they will undoubtedly move into new areas being managed by agencies that have no previous encounters with the species. And yet, at some point, each and every one of them will have to mitigate the impacts that these highly disruptive fish have on their resource. As a result, it has become increasingly important to clarify the terminology used in any related technical documents, which include these annual reports. Hence, the following is a list of defined terms that required further explanation in the project's previous reports.

- *Invasive Carp*: One of four fish species originating from the Asian continent (Silver Carp, Bighead Carp, feral Grass Carp, and Black Carp).
- *Bigheaded Carp*: One of two *Hypophthalmichthys* spp. (i.e. Silver (*H. molitrix*) & Bighead (*H. nobilis*) carp), or a hybrid of the two.
- *Community Size Spectra (CSS)*: An approach to describe the size structure of fish communities by quantifying the decrease in abundance among increasing body size classes.
- *Establishment Front*: Furthest upstream range of invasive carp where the population demonstrates both reproduction and natural recruitment.
- *Invasion Front*: Furthest upstream extent where invasive carp reproduction was observed (eggs, embryos, or larvae), but lacks any evidence of natural recruitment.
- *Presence Front*: Furthest upstream extent where invasive carp have been sampled, but there is no evidence of actual reproduction.
- *Targeted Sampling*: Use of standard sampling gear/techniques to target invasive carp while purposely excluding all other native species.

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

In the spring of each year, project partners conduct targeted sampling of invasive carp to obtain the data needed to estimate a relative abundance for the selected pools. The funding increases that were initially realized in 2021 continued to facilitate a higher amount of targeted sampling effort in the current reporting period as well. During spring 2022 (11 April – 25 May), field crews from three agencies conducted targeted sampling for invasive carp in six pools of the Ohio River that stretched from Cannelton (establishment front) to RC Byrd (presence front) (Figure1). The fixed sampling sites in each pool were pulled from a larger group that was generated by a stratified-random design process completed in 2015. Although it would have been statistically ideal to sample all sites each year, this initial group produced in 2015 had an extremely high number of sites per pool that would have required an excessive amount of additional funding and personnel to sample annually.

All six pools sampled in 2022 were segmented with ~24 fixed electrofishing transects. In addition, the last two pools on the upstream end (Greenup & RC Byrd) had 8-12 gill net sites as well. To ensure coverage within each pool, sites were divided between the mainstem river, island back-channels, tributaries/embayments, and dam tailwaters. The mainstem river was clearly the most abundant habitat type in each pool, but its size, depth and low-quality habitat created an area where it very difficult to regularly sample invasive carp with the current gear-types. As a result, tributaries that were vulnerable to the available gear provided most of the sampling locations (~68%) used in 2022. This decision was also influenced by the abundance of telemetry data demonstrating that bigheaded carp spend a great deal of their time in these tributaries.

Standardized methods were used to sample these transects, which included 900 seconds of diurnal electrofishing conducted in a general downstream direction using a single dipper. Invasive carp were specifically targeted using increased driving speeds and allowable pursuit of fish upon sightings. During active sampling, most of the non-target species were ignored, but special attention was given to any small, shad-like species to avoid the possible misidentification of juvenile invasive carps. Relative abundance was inferred using CPUE data and compared to previous years to determine if there were changes in the mean and median fish caught per transect.

Gill nets used in targeted sampling are typically 45m (150ft) in length, 3m (14ft hobbled to 10ft) in depth, and constructed of large mesh (12.5cm (5-in) bar mesh) with a foam core float line that keeps them suspended near the surface. The nets are set perpendicular from the shoreline and fished for two hours, during which noise and water disturbance is created with the intention of driving any bigheaded carps into the entanglement gear. Relative abundance was inferred using CPUE data and comparisons to previous years were only used to identify any changes in the number of fish caught per net. With low catch totals and a high level of zero-inflated net sets, the gill net catch rates from 2022 were not directly compared to those from previous sampling efforts.

Hydroacoustics Analysis

Mobile hydroacoustic sampling was conducted during spring and fall months in the Wabash River between Terre Haute, IN and the confluence with the Ohio River. Summer sampling was attempted but did not occur due to extensive low water levels. Hydroacoustic sampling consisted of two 200-kHz split-beam BioSonics transducers that were horizontally oriented toward the center of the river while sampling. The fish community was also sampled in the same stretch of the Wabash River using daytime electrofishing for determining size-specific species proportional abundances that are needed for analyzing hydroacoustic data. Electrofishing transects consisted of 900 seconds of pedal time following standardized long-term monitoring protocols (McClelland et al. 2012).

The Carterville FWCO completed hydroacoustic sampling during October 2022 in Cannelton and McAlpine pools of the Ohio River. Hydroacoustic data collection followed methods described in the Large River Hydroacoustics Mobile Survey Standard Operating Procedure, Region 3 U.S. Fish and

Wildlife Service. Briefly, we deployed a BioSonics DTX echosounder multiplexing two, 200 kHz, side-looking split-beam transducers offset in angle to maximize water column coverage (Figure 2). Both transducers were deployed from the vessel's port side at a depth of 0.5 m on a bracket mounted to a mechanical rotator. The rotator ensured that the transducers tilted downwards at appropriate angles such that the top edge of the shallow beam was parallel with the water surface. Hydroacoustic data collection was split among main channel, side channel, backwater, and tributary habitats. Within each pool, we collected hydroacoustic data in all side channels > 0.5 mi in length, navigable tributaries (up to two miles from confluence), and backwaters because invasive carps often inhabit these areas. In the main channel, we selected ~35% of available one-mile sites for data collection using a random sampling approach. This resulted in 79 and 53 miles of main channel transects for Cannelton and McAlpine pools, respectively. Transducer direction (shore vs thalweg) was randomly assigned to each main channel site. Both shore- and thalweg-facing transects were completed along each bank for all side channels with widths great enough to ensure sample area of thalweg-facing transects didn't overlap (i.e. thalweg facing hydroacoustic beams on opposite banks don't overlap in the middle of the side channel). In narrow side channels, two shore-facing transects were completed. Tributary data collection consisted of shore-facing transects with the boat centered within the channel and completed in both the upstream and downstream direction to ensure both banks were sampled. In backwaters, data were collected along the shoreline with the transducers facing towards shore. Calibration data were collected for both transducers prior to each survey to adjust hydroacoustic measurements.

Hydroacoustic data processing followed methods outlined in MacNamara et al. (2016) and the Large River Hydroacoustics Mobile Survey Standard Operating Procedure, Region 3 U.S. Fish and Wildlife Service using Echoview Version 13.0. Raw data and calibration files were imported into a mobile survey template for processing. Processing included a 1-m nearfield exclusion zone, bottom-line exclusions, and removal of bad data regions where wake disturbance or vegetation contributed to poor data quality. A single target detection algorithm (split beam method 2) facilitated the detection of individual fish targets using parameters suggested in Parker-Stetter et al. (2009). Using the equation developed by Love (1971), we estimated the target strength (TS) of 250 mm fish during each survey and used that value as a TS threshold to remove fish less than 250 mm from analyses. Groups of individual targets originating from the same fish were combined to make individual fish tracks reducing the potential of overcounting. Fish targets and sample volume estimates were then exported from Echoview for further analysis.

To apportion hydroacoustic targets to fish species, the Carterville FWCO, INDNR, and KDFWR collected community data using a dozer trawl and boat electrofishing. Community data collection followed the same hydroacoustics sampling design detailed above with two exceptions: 1) side channels sites were larger (1 mi) and sampling only occurred on one randomly selected bank to ensure that sites were long enough to complete electrofishing transects and 2) due to logistical limitations, only 35 main channel community sites were sampled per pool (Figure 3). Deployments of both community sampling gears (dozer trawl and boat electrofishing) were planned for all sites, but deployment of the gear was at the discretion of the boat operator based on river conditions (e.g., water velocity and debris). Deployment of each gear was standardized to allow for comparisons among sites. The dozer trawl was deployed for 5-minutes at ~4.8 km/h, following the Long-Term River Monitoring power goal tables to maximize catch. Boat electrofishing transects were 15 minutes in a general downstream direction with one dip netter. A power goal, intended to transfer a minimum of 3000 Watts from water to fish, was implemented (Gutreuter et al. 1995) at a 40% duty-cycle and 80 pulses per second (pulsed DC). All fish greater than 250 mm were identified to species, weighed (g), and measured (total length; TL).

To reduce bias in our hydroacoustic estimates, we used a Bayesian hierarchical model to account for uncertainty in TS measurements and a paucity of community data at hydroacoustic sites. For this analysis, we modified the methods described in DuFour et al. (2021). Briefly, we used a fitted quadratic regression model to calculate the probability of a fish being a Silver Carp given its length (Figure 4). Our most complex model describing the fish community included pool, habitat, TL, and TL2 as fixed effects and community site nested within habitat and both community site and habitat nested within pool as random effects using a Bernoulli distribution. We compared the most complex model and four models containing a subset of variables from the full model using k-fold cross validation (CV). The most parsimonious model describing the community data had TL and TL2 as fixed effects and Community Site as a random effect; therefore, the results of this model were used in subsequent calculations. We also modeled TS as a function of individual fish track to obtain a mean TS and credible intervals (CrI's) for each fish track. Mean TS and CrI's were converted to total length (TL) using the multi-species, side-aspect equation developed by Love (1971) (Figure 5). Importantly, TL based on TS is uncertain, as are the model parameters describing the fish community. To account for this uncertainty, we integrate across TL and the model parameters to estimate the probability that an individual is a Silver Carp based on its TS (for details see DuFour et al. 2021). To solve this integration, we used Monte Carlo simulations (n = 1000) to estimate the number of Silver Carp at each site and converted this abundance to density by dividing by the volume of water sampled by hydroacoustics (i.e., Wedge_Volume_Sampled). To examine the potential effects of habitat and pool on the mean density of Silver Carp, we calculated the mean and 90% CrI's by habitat and pool. Non-overlapping CrI's were used to indicate differences between habitats and among pools.

Our models differ from those described in DuFour et al. (2021) in three ways. First, because Silver Carp make up a large proportion of fish between 500 and 900 mm in our community sampling, but Silver Carp < 500 or > 900 mm are rarely captured, we use a quadratic regression to describe the probability of a fish of a given length being a Silver Carp rather than a logistic regression as in DuFour et al. (2021). Second, following discussions of our analyses with M. DuFour, we determined that converting TS to backscattering cross section was not necessary and modelled TS directly. Third, we used k-fold CV rather than leave-one-out (LOO) CV for model selection because model diagnostics suggested that LOO CV likely resulted in biased model selection criteria and k-fold CV is a reliable alternative to this method (Vehtari et al. 2017).

Assessing Invasive Carp Population Demographics

Population demographics information was collected on a subset of fish, post-spawn, between July and October 2022. Data was used to determine length distributions, age distributions, sex ratios, and report body condition of fish collected in the Cannelton, McAlpine, and Markland pools. Length distributions were formed using 25 mm length bins. Ages were estimated using lapilliar otoliths (Cannelton: n = 96; McAlpine: n = 131; and Markland: n = 8) encased in epoxy and thin-sectioned using agreed upon methods that were developed in 2021 during an invasive carp ORB workshop. Age distributions were summarized by percent total and visualized within a histogram.

Length-weight relationships were derived from log10 transformed lengths and weights of fish (Figure 7). A single regression line used to compare length-weight relationships to previous years. Regressions were achieved with the general linear model (lm()) in base R (R Core Team 2021) with lengths being measured in millimeters and weight measured in grams. The equations developed for the ORB as well as other waterbodies are reported below (Table 1 and 2) in the form of:

$$\log10[Weight\_g] = a + b * \log10[Length\_mm]$$

Lastly, body condition was reported using relative weight equations developed by James Lamer (Lamer 2015). Condition was only reported using data from fish, post spawn, between the months of August and September. Differences in body condition were compared between Cannelton, McAlpine, and Markland pools in 2022 and for Cannelton and McAlpine in previous years.

Using Community Size Spectra to Monitor the Impacts of Invasive Carp

Invasive carp management needs to work toward scientifically defensible targets but establishing those targets has been challenging. Community size spectra (CSS) describe the size structure of communities by quantifying the decrease in abundance among increasing body size classes and it accounts for all species captured in standard surveys. CSS have been used extensively as indicators of fishery sustainability (and over-fishing) and to set targets in marine systems and research in both marine and freshwater ecosystems has grown during the last decade due in large part to a large research investment by the European Union (Blanchard et al. 2014, Petchy and Belgrano 2010, Figure 8). The CSS essentially measures the ratio of large individuals to small individuals in the community and summarizes the immense complexity of food web dynamics into two simple parameters, the slope and centered y-intercept (termed elevation), which have direct biological meaning representing ecological efficiency and ecological capacity, respectively (Murry and Farrell 2014). The CSS slope and elevation are fairly stable in large river systems (Murry and Farrell 2014) but do react in predictable ways to environmental change including changes in species dominance (Broadway et al. 2015). Large-bodied low trophic position fish, such as invasive carp will tend to flatten the CSS (which is typically steeper under piscivore dominance).

In 2022, WVU researchers completed the first year of their efforts toward (1) understanding the dynamics of CSS relative the carp invasion, (2) evaluating the effectiveness of CSS as a community-level indicator of invasive carp impacts, (3) the use of CSS to establish community-level pool-specific restoration goals, and (4) evaluate the sensitivity of CSS to use as an early warning indicator. WVU also initially intended to utilize the CSS approach to determine carp harvest goals, however, they now believe that to be a next step objective.

Development of an Effective Monitoring Program

With the invasive carps' tendency to behave much differently than native fish communities, KDFWR initiated a pilot study to determine whether occupancy modeling could become an effective substitute for current abundance measures that were initially developed for sportfish populations. During these efforts, all surveys included half-mile boat electrofishing transects that were conducted in a downstream direction using a single dipper. Most sites were visited on three or more occasions to account for imperfect detection. During each survey, a power goal was implemented with the intention of transferring a minimum of 3000 watts from water to fish (Gutreuter et al. 1995). At the conclusion of each transect, the presence/absence of carp was documented along with the data that was collected from captured fish. Invasive carp occupancy and detection were estimated via the use of a hierarchical model that is available in the 'unmarked' R package (Fisk and Chandler 2011).

The pilot study's initial sampling efforts in 2021 were conducted at ten randomly selected sites located within the first 79 miles of the Kentucky River. In 2022, the focus was shifted towards the Ohio River where electrofishing efforts were concentrated within the 114-mile long Cannelton Pool. For these efforts, the Cannelton Pool was divided into upper, middle, and lower sections with 13 randomized sites in each one. The proportion of tributary to mainstem river sites were solely based on the number of accessible tributaries that were available in each section.

Monitoring Ahead of the Invasion Front

Targeted sampling for Invasive Carp was conducted in November 2022 in the Montgomery Pool of the Ohio River. Sampling was conducted in the Montgomery Slough (RM 949.78 to 950.11) where positive eDNA hits for Bighead Carp were found historically. Gill nets used in sampling were 90 meters (300 feet) in length, ~4 meters (12 feet) in depth, and constructed of 8 cm, 10 cm, or 13 cm (3", 4", or 5", respectively) bar mesh. Three gill nets were fished for approximately 48 hours each. Additional 2022 gill net sampling in the Montgomery and New Cumberland pools had to be canceled due to excessive flows.

Fish community monitoring was conducted in May 2022 at the tailwaters of Lock 6 (Pool 5) and Lock 5 (Pool 4) on the Allegheny River and the tailwaters at Grays Landing (Maxwell Pool) and Charleroi (Elizabeth Pool) locks and dams on the Monongahela River. Five consecutive 10-minute transects were conducted on each bank (pedal time = 100 minutes) beginning either immediately below the lock chamber or as close as possible to the dam wall. Pulsed DC electrofishing (at 60 pps) was conducted using an ETS MBS unit that was set to a 30% duty cycle and operated at range of 250-550 V. These electrofishing efforts targeted all fish species, which were usually identified and enumerated in the field. However, those that could not be immediately identified were brought back to the laboratory for further examination. All sportfish were measured and weighed before a scale sample was collected for age and growth analysis.

Fish community monitoring was also conducted in the Montgomery Island Pool of the Ohio River using beach seines in August 2022. Six fixed locations were sampled using a 30 m (100') seine with 1 cm (3/8") mesh. A single seine haul was conducted at each of the six locations. Any fish species readily identifiable in the field were enumerated and released; all other species were retained for identification and enumeration in the laboratory.

Fall fish community monitoring was conducted in the Montgomery Pool and the Dashields Pool of the Ohio River using gill nets and night electrofishing. A total of 55 randomly selected sites were sampled from September 15th though October 31st. For each site, sampling consisted of a 2 hr. minimum gill net set using either 8 cm, 10 cm, or 13 cm (3", 4", or 5", respectively) bar mesh, as well as a 15-minute night electrofishing run (ETS MBS unit, 25% duty cycle, 60 pps, 100-550 volts). All individuals captured in gill nets were enumerated and any sportfish were also measured. For all species sampled via the electrofishing efforts, a subset of ten individuals (≥ 125 mm TL) from each 25 mm size class were measured and weighed for WVU's Community Size Spectra Analysis. If field identification was possible, individual fish measuring less than 125 mm were enumerated and released. Otherwise, the fish were retained for identification and enumeration in the laboratory, which is still ongoing.

Additionally, fish community monitoring was also conducted via pulsed-DC boat electrofishing, gill netting and boat ramp seining in fall 2022 in the R.C. Byrd and Racine pools of the Ohio River. Surveys completed in the R.C. Byrd Pool will complement the Community Size Spectra (CSS) analysis being completed by WVU. Electrofishing surveys were completed during the day at the same fixed sites throughout each pool. Surveys consisted of 15-minute (900 seconds of pedal time) timed transects that began at the marked coordinates and continued downstream in the mainstem river and large tributaries. Surveys of smaller tributaries and embayments began at the marked coordinates and continued upstream to the completion of the timed transect, or until navigation was blocked, upon which the remainder of the timed transect was completed in the main channel just downstream of the mouth. All species were collected during these surveys. Schools of small fish (minnows and shad) were sub-sampled by dipping a portion of each school encountered. Small shad-like fish were examined closely to identify potential juvenile invasive carp. All fish were identified, and any non-minnow species were measured for total length (mm). For each transect, a maximum of 20 fish per species were measured for total weight (g). If an invasive carp was sampled, it was euthanized on site unless a closer examination confirmed the presence of a transmitter used in the telemetry efforts.

Gill net surveys consisted of two hour sets during the day at fixed sites throughout the R.C. Byrd and Racine pools. These efforts utilized both 14 and 24 ft deep 5" gill nets (150-300 ft long) that were hobbled down to 10ft (4.3m to 3m) and 20ft (7.3m to 6.1m), respectively. The size/depth of the gill net being used was determined by the habitat, depth and suitability at each site. Each net set was actively monitored, and an effort was made to drive fish into each net via the boat's outboard motor. All by-catch was identified to species and any non-target fish (excluding invasive carps) were immediately released. Any invasive carp were examined for telemetry tags, and if none were found, each one was euthanized on site. Boat ramp seine hauls were conducted at select boat ramps located directly on, or adjacent to, the mainstem Ohio River in the R.C. Byrd and Racine pools. One seine haul was conducted at each ramp with a 30ft seine (3/16" mesh) that had a 6ft bag (1/8" mesh). Seine hauls were completed within the concrete boundaries of each boat ramp. Of all the fish captured by the seine, larger individuals of well-known species were identified, enumerated and released. Any other fish were brought back to the laboratory for further examination.

Incidental sampling for Invasive carp continued to take place through the annual sportfish surveys that are conducted on each of the three rivers (i.e., Allegheny, Monongahela, Ohio). During March 2022, nocturnal boat electrofishing using an ETS MBS unit (60 pps, 30% Duty Cycle, 250-550 V) was conducted at multiple sites on the Allegheny (Pools 4, 6, 7 & 8), Monongahela (Emsworth, Braddock, Charleroi & Grays Landing pools) and Ohio (New Cumberland Pool) rivers. This sampling consisted of four non-overlapping 10-minute electrofishing transects on each bank beginning immediately downstream of the lock and dam for overall effort of 80 minutes per pool. Adult *Sander* species may have been the primary target during these surveys, but the presence/absence of invasive carp species was also recorded. In October 2022, additional sampling was conducted at four fixed sites in Pool 4 of the Allegheny River for a total effort of 1.5 hrs. The electrofishing gear and settings were similar to those used during the Sander species surveys in March. The primary target of the October surveys was black bass, but once again, the presence/absence of invasive carp were recorded at the end of each transect. In November 2022, electrofishing was conducted on the Monongahela River (Maxwell & Elizabeth pools), the Allegheny River (Pools 4, 5, 8 & 9) and the Ohio River (Dashields Pool). These efforts were conducted via pulsed DC electrofishing using both the same gear and settings as the Sander surveys completed during Spring 2022. The November surveys consisted of four non-overlapping 10-min transects conducted on each bank. Transects began directly below the lock and dam and continued until there was a total effort of 80 minutes of pedal time in each pool. Adult *Sander* species were once again the target of these surveys, but presence/absence of invasive carp was also recorded.

Results:

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

During spring 2022, project partners used 58.3 hours of targeted boat electrofishing to successfully collect a total of 455 fish across three different species of invasive carp, which included Silver (98.0%), Grass (1.7%) and Bighead (0.3%) carps (Table 3). As in previous years, most of the invasive carp were captured from the 44 electrofishing sites located within the Cannelton Pool (n = 389 carp). The other 190 transects completed in five different pools of the middle to upper Ohio River contributed less than 15% of the overall sample (n = 66 carp), which included 53 invasive carp from the McAlpine Pool and only 11 from Markland. Although the overall yields remain much lower than other areas of the basin with high density populations, the 2022 targeted monitoring results indicated that Silver Carp in the Cannelton Pool have rebounded from a slight decline in 2021 (4.4 carp/transect) and achieved an average catch rate of 8.7 invasive carp/transect, which was the highest for Cannelton since annual carp sampling began in 2016 (Figure 9). The 2022 catch rates for Silver Carp in pools located directly upstream of Cannelton remained extremely low and included an average of 1.1 fish/transect for McAlpine and only 0.2 fish/transect in the Markland Pool. The average catch rates per pool for other invasive carp species also remained negligible. Upon completion of the 2022 targeted sampling efforts, project partners managed to capture a total of 8 Grass Carp and one Bighead Carp, which are similar results to those obtained in previous years.

Gill net sampling in 2022 was limited to the Greenup and RC Byrd pools of the Ohio River, which were the uppermost of the six pools selected for invasive carp monitoring. During spring 2022, a combined total of 4,500 feet of gill nets were set at twenty sites located across Greenup (n=8) and RC Byrd (n=12). These efforts caught a total of only 3 invasive carp, which included two Bighead Carp from RC Byrd and a single Grass Carp from the Greenup Pool (Table 4). Gill nets also captured a total of 12 non-target fish belonging to one of three different species with the most common being both the blue catfish (n=5) and the common carp (n=5) (Table 5). Flathead Catfish was the only other by-catch species, which were caught by gill nets set at two different sites located within the Greenup pool.

Hydroacoustic Analysis

Hydroacoustic sampling in the Wabash River occurred at four main channel sites spanning 85 river miles during May of 2022 (Figure 9). Spring densities of bigheaded carp were highest at the most upstream sites above Hutsonville, Illinois (river mile 172; Figure 10). Spring bigheaded carp densities were extremely low further downstream at river miles 128 and 156. Mean daily springtime discharge during hydroacoustic sampling at New Harmony, Indiana (USGS gage 03378500) was relatively high at 58,874 ft3/sec which prevented sampling further downstream from these locations due to flooding. Extremely low water levels during summer 2022 precluded any Wabash River hydroacoustic sampling. Fall sampling occurred at two four-mile long sites due to an extensive and prolonged low-water period prohibiting access to other sampling locations (Figure 9). These locations were downstream from the study sites accessible in spring and were separated from one another by 63 river miles. Fall bigheaded carp densities were higher than spring densities, likely due to low fall water levels, where densities were highest near New Harmony, Indiana at river mile 52 and intermediate near St. Francisville, Illinois at river mile 115 (Figure 11). Mean daily fall discharge during hydroacoustic sampling at New Harmony, Indiana (USGS gage 03378500) was 6,608 ft3/sec.

Community data comprised samples from 97 (Cannelton = 45, McAlpine = 52) electrofishing and dozer trawl sites. Boat electrofishing collected more total fish > 250 mm (n = 597) than dozer trawling (n = 172). A total of 242 Silver Carp were captured with 141 captured by each gear.

Model results suggest the greatest mean Silver Carp densities occurred in the Little Blue River and Indian-Kentuck Creek in Cannelton and McAlpine pools, respectively (for site-specific estimates contact the Carterville FWCO). Silver Carp densities were < 5 fish/1000m3 at all sites. Longitudinal trends exist within both pools with Silver Carp densities increasing in the downstream direction (Figure 12). In both pools, habitat differences existed both within and among pools. On average, tributaries had the greatest Silver Carp densities followed by backwaters, side channel, and main channel sites in McAlpine, whereas Cannelton Pool main channel sites had greater densities than side channels. Cannelton Pool had greater SVCP densities than McAlpine Pool in main channel and tributary habitats, but McAlpine Pool had greater densities in the side channels.

Assessing Invasive Carp Population Demographics

By the end of the reporting period, a total of 3 Bighead Carp and 9 Grass Carp had been captured during the 2022 sampling efforts. Two of the Bighead Carp were found in gill nets that were used to sample the RC Byrd Pool during spring monitoring efforts. The other was captured in September 2022 when boat electrofishing was conducted in the Markland Pool to collect data for age & growth analysis and the ongoing length/weight regression that is being constructed for Bighead Carp (Figure 13). Of the 9 captured in 2022, eight Grass Carp ranging from 719 mm to 983 mm TL were collected via electrofishing being conducted in the Cannelton and Markland pools for the spring targeted sampling efforts. With the small number of both Bighead and Grass Carp collected in 2022, there will be no additional demographics provided for either species.

Silver Carp sampled from the Cannelton Pool during this reporting period continued to exhibit the bimodal length distribution that was initially observed in 2021 and only 1% of the fish caught in 2022 had total lengths of 600 mm or less (Figure 13). However, the Silver Carp sampled from McAlpine in 2022 did not form the obvious bimodal length distribution that the pool displayed in 2021. In this case, the majority of male (69.9%) and female (77.2%) Silver Carp caught from McAlpine during this period had total lengths that ranged from 650 to 750 mm (25.6 – 29.5 in). During 2022, the overall sample of Silver Carp obtained from McAlpine consisted of 58% male and 42% female fish, which was slightly more skewed than in Cannelton where a nearly identical number of male (n = 263) and female (n = 266) carp were captured during the same time period. As in previous years, the sample of Silver Carp (n = 28) caught from the Markland Pool in 2022 exhibited a much wider length range. Approximately 25% of all Silver Carp sampled from Markland were quite small (250 – 325 mm TL) and yet an additional 43% of those caught from the same pool exhibited total lengths that were as high as 850 to 950 mm (Figure 14).

Results of otolith examinations conducted during this reporting period were used to determine the Silver Carp sampled from the Cannelton Pool in the second half of 2022 had ages that ranged from 3 to 13 years (Figure 15). Even though the 10-year range was larger than what was previously obtained from Cannelton, age-4 and age-5 fish continued to be the most frequently sampled in both 2021 (65.0%) and 2022 (64.6%). Silver Carp collected from the McAlpine Pool during the late summer and fall of 2022 exhibited a narrower age range of 3 - 9 years (Figure 16). However, the most frequently encountered age group of Silver Carp from McAlpine was once again age-4 and age-5 fish, which made up more than 86% of the 2022 sample.

Body condition of Silver Carp collected in Fall 2022 was determined using relative weight (W_r) equations generated from over seven years of length-weight measurements. The average W_r of Silver Carp collected from Cannelton in 2022 was nearly 94, which was a slight decline from the mean W_r of carp collected in 2021 (~95) from the same pool (Figure 17). Similar comparisons of body condition for Silver Carp in the McAlpine Pool have determined that the mean W_r of fish caught in 2022 (~97) was also down slightly from the average condition (W_r = ~100) of carp in 2021. A comparison of average body condition across three consecutive pools of the middle Ohio River continues to indicate that Silver Carp in Cannelton and McAlpine have a similar length-weight relationship, but in the Markland Pool, the same species appears to have substantially higher average relative weights (Figure 18).

Using Community Size Spectra to Monitor the Impacts of Invasive Carp

The community size-spectra (CSS) approach appears promising as part of the invasion detection program, as well as to establish harvest/depletion targets (Novak in prep). Table 7 summarizes findings from available data 2015 – 2020 from community electrofishing. These should be considered preliminary and there are some outliers (e.g. Greenup 2015) that WVU needs to examine in greater detail. Preliminary conclusions are that throughout Cannelton to RC Byrd pools invasive carp seem to have not yet reached a threshold of abundance to negatively influence the community size structure. This tentative conclusion was based on not only the Ohio River data (Table 7), but also relative to trends observed in the La Grange Pool of the Illinois River where carp have had a measurable impact.

Because of the limited Ohio River data (artifact of 6 years of sampling with several gaps in the data series, Table 7), additional data was also acquired from the Illinois River that represents annual community electrofishing surveys from 1994 to 2021. Through this longer time series (Figure 19), WVU was able to analyze 3 distinct time periods, pre-invasion (1994-2004), the impactful invasion phase (2005-2013), and finally post-invasion (2014-2021). It is not being suggested that the invasion is over in the Illinois River or that there will not be another impactful event, rather, with the data presently available, WVU has tracked shifts in community size structure that tentatively appear as though the fish community has stabilized around a steeper equilibrium (Figure 19).

These changes can be more directly observed in the traditional CSS plot (Figure 20). Based on differing mean slope values and non-overlapping errors of the slope, the size structure of the post-invasion period on the Illinois River is statistically different, steeper, than the pre-invasion period (right pane of Figure 19). The time series for the Illinois River serves as a proof of concept for what is possible on the Ohio. Large fluctuations in CSS slope serve as an indicator of likely/potential influence of invasive carp on the food web (left pane of Figure 20; i.e. abundance surpasses a critical threshold to elicit the change in food web structure).

To be effective on the Ohio River, dedicated surveys need to be conducted within each pool annually. In addition to the data presented here, WVU also worked with the USFWS data from 2021-2022 (Andrew Peters, Tyler Gross, Lane Burton) for Winfield, Racine, and Willow Island upstream pools (Belleville and RC Byrd were not targeted and had low sample size). Current analyses (i.e. preliminary), show statistically similar CSS slopes among all pools (Figure 21). The USFWS team sampled pools monthly from May – November and WVU observed a stronger monthly pattern that will be investigated further in the coming year.

Development of an Effective Monitoring Program

Building on the previous pilot project in 2021, KDFWR sampled sites in the Cannelton Pool using a protocol for the purpose of developing standardized methods for occupancy sampling. In July – August 2022, KDFWR conducted electrofishing transects at 39 sites on three different occasions for a total of 117 sampling events. Silver Carp were observed during at least one visit to 38 (97.4%) of these sites and during all three visits to 29 of them (74.4%). The probability of detecting Silver Carp (p) in the Cannelton Pool of the Ohio River was estimated to be around 90.3% (SE = 2.8%). Also, the probability that Silver Carp occupied (Psi) any randomly selected transect in the Cannelton Pool was estimated to be approximately 97.5% (SE = 2.5%). KDFWR ran a simulation model that utilized these estimated values (p = 0.903; Psi = 0.975) while varying the number of sites and visits (Figure 22). The results of this model indicated that increasing site visits from 2 to 3 did improve the occupancy estimates by reducing their standard errors, but additional visits (4-5) were unlikely to provide any further benefits.

Monitoring Invasive Carps Ahead of the Invasion Front

In 2022, the targeted gill net sampling conducted by PFBC in the Montgomery Pool of the Ohio River was unsuccessful at capturing any species of invasive carp. In contrast, the most frequently captured fish species during these efforts were Smallmouth Buffalo and Common Carp, which comprised 56% and 25% of the overall sample, respectively. Unfortunately, the additional gill netting efforts scheduled for November through December 2022 had to be canceled due to poor conditions (i.e. high flow rates and excessive debris).

In May 2022, community monitoring efforts were conducted in both the Allegheny (pool 4 & pool 5) and the Monongahela (Maxwell Pool & Elizabeth Pool) rivers using 1.67 hrs of pulsed DC nocturnal electrofishing at each location. PFBC staff captured 32 - 40 distinct fish species near the tailwaters of the four pools with total counts ranging from 975 fish in Pool 5 of the Allegheny River to 2,134 fish in the Elizabeth Pool of the Monongahela River (Table 7). Emerald Shiner, Channel Shiner, Mimic Shiner, and Golden Redhorse comprised nearly 60% of the total catch across all pools. Like previous years, no invasive carp species were observed or captured during these electrofishing efforts.

Beach seining conducted in the Montgomery Island Pool of the Ohio River during August 2022 was successful at collecting a total of 8,561 individual fish belonging to 25 distinct species (Table 8). Two species comprising most of the sample were the Emerald Shiner (61.6%) and Mimic Shiner (13.8%). As in previous years, none of the fish collected during the 2022 seining efforts belonged to any of the four invasive carp species.

During September and October 2022, PFBC used nocturnal electrofishing and gill nets to conduct fish community sampling at 55 random sites in the Dashields and Montgomery Island pools of the Ohio River, which included the navigable tributaries of each pool. Although the laboratory identification of small fish and related data entry is still ongoing, it has been determined that no adult invasive carp were either captured or observed during these sampling efforts.

As in previous years, the PFBC continued to track incidental captures of invasive carp made by any other projects during their 2022 sampling efforts. These efforts included targeted *Sander* spp. surveys that were conducted in March and November at 16 separate tailwaters within the Allegheny, Monongahela, and Ohio rivers. It also included black bass surveys conducted in October 2022 at four fixed sites in one pool of the Allegheny River. PFBC staff ultimately reported that no invasive carp species were either captured or observed during any of the 2022 gamefish surveys.

In Fall 2022, WVDNR conducted fish community surveys in the R.C. Byrd and Racine pools of the Ohio River, which consisted of a total of 6.8hrs of diurnal electrofishing effort. These surveys resulted in the collection of 2,149 individual fish belonging to 42 different species (Table 9). Gizzard Shad (50.1%), Channel Shiner (10.8%) and Emerald Shiner (10.6%) constituted the bulk of the fish collected from both pools, while Largemouth bass (3.4%) and Bluegill (6.7%) represented the most common sportfish species. Relative weights (where applicable) were within the mean for all species. The electrofishing catch rates were quite variable between sites, habitat types, pools and years. Differences in catch rates between pools and years appears to be most attributed to changes in river conditions (i.e. flow and turbidity). It remains unclear if the relative abundance of each species will be useful when assessing the effects of invasive carp. Therefore, in the future, WVDNR is more likely to use mean abundance across multiple years to identify impacts that the encroaching invasive carp population will have on native fish communities.

Throughout Fall 2022, WVDNR also conducted gill net surveys at 17 different sites (3,900 total net ft) in the R.C. Byrd and Racine pools. These surveys resulted in the capture and removal of three invasive carp (2 Bighead and 1 Silver) from the Racine Pool and the only gill net bycatch from these efforts included two paddlefish (Table 10). As in previous years, gill net results remained quite variable in 2022 and included a large proportion of sites that yielded no fish. Additional effort will be made to determine if all sites are appropriate for targeting invasive carp. There continues to be no discernable trends in the species composition of the gill net samples collected from either pool.

WVDNR staff also conducted seine hauls at six boat ramps in the R.C. Byrd and Racine pools in Fall 2022. These efforts yielded an overall total of 2291 fish belonging to 10 distinct species (Table 11). The size of the samples collected in 2022 varied greatly by site and ranged from 16 to 897 individual fish. Like the electrofishing results, Emerald Shiners were the most frequently caught species in the Racine Pool and represented nearly 68% of the total fish. However, the most common species caught by the seines in R.C. Byrd were Channel Shiners, which contributed to over 75% of those samples. Mean diversity abundance during this sampling period will be used to measure the diversity of small, littoral fish communities in the mainstem Ohio River.

Compilation and Incorporation of Other ORB Data Sources

During previous years, project sampling efforts, ORSANCO records, and the USGS NAS database were all used to monitor for any changes to invasive carp distributions. However, reporting rates and participation have improved over time to the point where these sources have started to provide overlapping information. Hence, in 2020, the USGS NAS database became the sole source for records used to create complete ORB distribution maps for each of the four invasive carp species. Notable changes to invasive carp distributions in 2022 included a further increase in the range of black carp populations, which were recently found in the upper Wabash River basin (Figure 23). Silver Carp were also recently reported as being collected from the upper Scioto River, as well as the R.C. Byrd and Racine pools of the upper Ohio River (Figure 24). The boundaries of Bighead and Grass carp distributions remained relatively unchanged, but some new records from inside each species' previously known range were reported in 2022 (Figure 25, Figure 26).

Discussion:

With the 2022 sampling efforts once again failing to capture Bighead, Grass and/or Black carps with any regularity, there continues to be some difficulty with determining if the current level of effort will provide managers with the ability to make informed decisions about either of these three species. However, at present, Silver Carp are considered to be the most prolific of the four invasive carp species that currently inhabit the Ohio River basin. Also, most managers agree that Silver Carp pose the greatest threat to native fish populations and the different user groups that occupy the resource. Hence, most of the evaluation efforts associated with this project will continue to focus almost entirely on the management and spread of Silver Carp populations that reside within the Ohio River and its primary tributaries.

Catch, or catch per unit effort (CPUE), continues to be used in the Ohio River to determine if temporal changes in average catch rates are sufficient in tracking the relative abundance of carp populations. Since

2017, average catch rates of invasive carp have been low and data is highly dispersed. These results are more indicative of aggregated distributions of invasive carps and are further complicated by a high number of zero-catch runs that are infrequently interrupted by larger catches. Median catches may be less sensitive to infrequent large catches, but much like the mean estimates, they still lack the precision necessary to track relatively small changes in CPUE by pool. Therefore, long-term trends and consistent reductions in catch will be necessary to determine if contract removal and agency efforts begin to reduce invasive carp abundance along the intensive management zone. For the first time since contract fishing was first implement in 2019, there was a notable increase in the mean catch of Silver Carp during the spring of 2022, and there continues to be evidence indicating major shifts in population characteristics.

In 2021, Silver Carp populations displayed strong bimodal length frequency distributions in both the Cannelton and McAlpine pools, which often indicates the presence of younger fish that would be able to replace older carp that either aged-out or were removed by contract fishing efforts. In 2022, Silver Carp in the Cannelton Pool once again had a notable bimodal length frequency distribution, which further supports the possibility that recent spawning has been successful enough to replenish the larger, older fish that are being removed by the contract fishing program. However, the 2022 length frequency results from McAlpine Pool indicate that the previous bimodal distribution in this pool has weakened substantially, which may be evidence of a previously failed spawn or just an increase in mortality (or emigration) rates of the larger individuals within its Silver Carp population. Additionally, the body condition of Silver Carp in the McAlpine Pool continues to decline in much the same way that it has in Cannelton, which is located directly downstream. These steady declines in body condition over time may indicate that the Silver Carp populations in both the McAlpine and Cannelton pools are getting too crowded. Also, a wider range of Silver Carp length classes continue to be sampled from the Markland Pool, which is in stark contrast to that pool's historical data that was dominated by larger fish that more than likely immigrated into that stretch of the river. This wider range of length classes in the Markland Pool, the dominance of age-4 and age-5 fish in McAlpine and the strong bimodal length distribution found in Cannelton have provided further evidence that we are in the midst of a long-term shift in the Silver Carp populations that have established themselves within the middle Ohio River.

In response to the results of the 2021 Kentucky River pilot project, in 2022, KDFWR continued to test if occupancy modeling could be applicable to the ongoing management of the invasive carp populations in the middle Ohio River. The most recent efforts within the Cannelton Pool indicate that Occupancy modeling may in fact provide a new way to develop better sampling designs and to account for the imperfect detection of Silver Carp within larger river systems. After the relative success of the occupancy modeling in the Cannelton Pool, a third year of sampling will be conducted within the McAlpine Pool during summer 2023. During these efforts, the actual catches of invasive carp will continue to be tracked along with the presence/absence data. KDFWR expects that both the detection and occupancy probabilities will decline as the Silver Carp sampling efforts continue to shift further upstream. The objective of these combined efforts is to demonstrate how a less data intensive monitoring protocol can still be used to recommend useful management actions in system as big as the Ohio River.

We found that both habitat and pool affected mean Silver Carp densities. These results support previous research evaluating density gradients across invasion fronts (MacNamara et al. 2016; Erickson et al. 2021) and Silver Carp habitat use (DeGrandchamp et al. 2008; Gillespie et al. 2017; Pretchel et al. 2018). Our results suggest that Silver Carp densities are greater in tributaries than in either main channel or side channel habitats. Due to the paucity of side channel data in Cannelton Pool (N = 1), however, these results should be interpreted cautiously. Generally, our findings of greater Silver Carp densities in tributaries relative to other habitats agree with previous studies (Gillespie et al. 2017; Pretchel et al. 2018). However, some literature suggest that tributary usage is less than mainstem usage in some Ohio River pools (Gillespie et al. 2017). These conflicting results indicate that fine-scale environmental characteristics may have a greater impact on Silver Carp habitat use than large-scale habitat features as suggested by Glubzinski et al. (2021).

The longitudinal trends in our data also support previous literature (DeGrandchamp et al. 2008; MacNamara et al. 2016) and findings from 2021 hydroacoustic surveys describing invasion ecology within impounded rivers. Once populations become established upstream of a barrier, they expand their range upstream towards the next barrier. For Silver Carp, range expansion is often associated with larger individuals (MacNamara et al. 2016; Lenaerts et al. 2021). The apparent longitudinal gradient in our density estimates may depict this upstream expansion but more information is needed to evaluate longitudinal changes in fish size within these pools.

Density estimates obtained from side-looking hydroacoustics have increased levels of uncertainty because bias is introduced from multiple sources. For example, target strength, which is converted to fish length, is a stochastic variable which depends on the physical (e.g., fish length and swim bladder presence) and behavioral (e.g., swimming direction and vertical movements) characteristics of the insonified fish (Foote 1980; Ona 1990; Boswell et al. 2009). In addition, the orientation of insonified fish targets relative to the transducer greatly affects measured TS (Boswell et al. 2009; Johnson et a. 2019a). We use a side-aspect TS-TL equation to convert TS measurements to TL (Love 1971). This equation assumes fish are oriented perpendicular to the transducer at the time of sampling. Deviation from this assumption affects the total number of fish targets included in analyses and fish size estimated from TS (Boswell et al. 2009; Johnson et a. 2019a). Because we orient our transects parallel to the current, fish facing against or with the current will be oriented near-perpendicular to the transducer, validating our use of a side-aspect equation. In areas with reduced current (backwaters), target orientation relative to the transducer may deviate from perpendicular causing the use of Love’s 1971 equation to bias density and size estimates. Some additional sources of bias in side-looking hydroacoustic estimates include near-surface effects on sound propagation (Balk et al 2017), subjectivity during processing (i.e., interpretation of echograms, exclusion lines, and editing of fish tracks), and apportioning of hydroacoustic targets to species using community data.

Although hydroacoustics accurately samples pelagic fish populations (Johnson et al. 2019b), the use of community data to apportion hydroacoustic targets to species can bias estimates. The tools we used to collect community data (dozer trawl and boat electrofishing) have size and species-related biases. For example, boat electrofishing is biased towards large individuals (Chick et al. 1999; Bayley and Austin 2002). Because community data are used to apportion hydroacoustic targets to species, these gear-specific biases are transferred to the hydroacoustic estimates. The combination of gears used here should reduce the effects of gear-specific biases, improving our assessment of the fish assemblage. Further, our Bayesian hierarchical models incorporate much of the uncertainty inherent to hydroacoustic estimates, reducing bias contributed by community sampling gears (DuFour et al. 2021).

Our use of Bayesian hierarchical modeling improves Silver Carp density estimates by incorporating uncertainty from TS measurements, thresholding, and community sampling in the models. Previous methods ignored these sources of uncertainty, likely biasing density estimates. Additionally, this approach provides the capability of inferring the probability of a fish being a Silver Carp for lengths that have no community data. The ability to infer the probability of a fish target being a Silver Carp for lengths lacking Silver Carp catch data improves our estimates by reducing the effect of sparse or missing community data. Further, this approach is applicable in multiple situations because it has the flexibility to incorporate different patterns within species composition data as well as variable data distributions within the hydroacoustics data, which are affected by site characteristics and sampling design.

In congruence with objective 6.2 of the early detection and removal project plan, we took steps towards evaluating and improving the hydroacoustics survey design. First, we reallocated our effort into pools with established invasive carp populations. Because we use community sampling to apportion hydroacoustic targets, relatively high invasive carp catches are necessary to estimate invasive carp densities from hydroacoustic surveys. Pools with low catches of invasive carps inevitably have hydroacoustically derived invasive carp densities functionally equal to zero, reducing the usefulness of these surveys. The reallocation of effort to high-density pools allowed for the use of a random sampling design and improved spatial coverage of our survey within each pool. The Carterville FWCO also deployed a dozer trawl in addition to state partners' boat electrofishing efforts to increase and improve sampling of the pelagic fish community. The addition of the dozer trawl added 172 total fish > 250 mm and 121 Silver Carp to the community dataset, doubling the Silver Carp catches. Furthermore, we implemented a Bayesian hierarchical design for data analyses that accounts for the uncertainty in hydroacoustic data, improving estimates of Silver Carp densities. Lastly, the Carterville FWCO and its Wilmington sub-station collected ~220 miles of hydroacoustic data in Newburgh Pool to help evaluate our sampling design. We will use a resampling analysis to determine the optimum transect length and number of transects needed to provide reliable hydroacoustically derived density estimates. The changes implemented in this report and the additional data collected will increase the usefulness of hydroacoustics surveys for informing invasive carp management in the Ohio River Basin.

The CSS of the pools of the Ohio River appear to be energetically robust and stable over time and space (Table 7, Figure 21), which is consistent with patterns observed in the upper St. Lawrence River (Murry and Farrell 2014). In the lower invaded pools (Cannelton and McAlpine), we cannot say whether the carp have not reached a level to produce an impact or if harvest efforts are maintaining them below an impactful threshold, in either event, they do not appear to have reached a density that impacts food web processes. However, our companion work, essentially a proof-of-concept evaluation of the Illinois River (Figure 19), clearly shows that CSS are sensitive to carp impacts. As they reach an impactful threshold (yet to be determined), we see greater interannual variation. Whether or not this variation will serve as an early warning indicator cannot yet be determined. Of greater likelihood for early detection will be using CSS of the zooplankton community. Sass et al. (2014) in the Illinois showed massive changes in the zooplankton community concomitant with increases in invasive carp. They used traditional taxonomically-based zooplankton assessments, but we believe that the zooplankton CSS will be more responsive. Samuel Johnston (2023), who lead the WVU field crews in 2021 and 2022 completed his masters thesis (April 2023) and showed that there were no differences in zooplankton community structure assessed by both traditional taxonomic and CSS approaches, although the CSS of Cannelton and McAlpine were more variable then the upstream pools (potential early warning). S. Johnston's thesis was part of the Early Life monitoring objective. While Johnston (2023) shows the strong potential for a zooplankton CSS-based early detection indicator, Novak's work in the Illinois River demonstrates the use of CSS to establish recovery targets (i.e. pre-invasion state) that reflect food web structure and function.

Establishing a running baseline and understanding typical interannual variation is key ahead of the invasion front. Maintaining a continuous sampling regime in Markland to RC Byrd is a priority and establishing a more robust baseline for the more upstream pools is a secondary but important objective. We believe that continuing zooplankton sampling will also provide an important early warning indicator.

Recommendations:

Targeted, standardized sampling should continue to add to our body of evidence indicating changes in relative abundances of invasive carps along the invasion front. However, occupancy modeling should continue to be explored to determine its use and efficacy in monitoring distributions and evaluating change in carp populations in the Ohio River. Also, with the presence of younger fish in the Markland Pool, and the consistently wider length range of sampled carp, it is recommended that surveys for young-of-year recruitment continue to be conducted in that pool.

The new sampling design and analytical approach used during 2022 moved the hydroacoustic program closer to our goal of using side-looking hydroacoustics to evaluate Silver Carp densities within Ohio River pools. We recommend the continuation and further evaluation and development of the sampling design and analytical approaches to maximize the usefulness of the hydroacoustics program. Our results provide initial insights into Silver Carp densities throughout two Ohio River pools and the habitats within those pools. The approaches outlined in this report should be used in additional pools with established Silver Carp populations (e.g., Smithland Pool.), during future years to acquire a robust dataset that can be used to inform management decisions and evaluate the hydroacoustics program.

The use of the dozer trawl dramatically increased the number of total fish and effectively doubled Silver Carp catches. For this reason, we recommend the continuation of dozer trawl sampling as a part of the hydroacoustics program.

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Table 1. Length-Weight equations and the estimated weights of Silver Carp (450mm & 800mm) for eight different systems that contribute to the Mississippi River Basin. Published data for systems outside of the Ohio River Basin was obtained from Hayer et al. 2014.

System (w/-Specific Locales)	Length-Weight Regression Equation	Predicted weight (g) for 450mm	Predicted weight (g) for 800mm	Reference
Ohio River	Log10 Weight_g = -5.22 + 3.09(Log10 Length_mm)	952	5631	ORB Technical Report 2022
Illinois River	Log10 Weight_g = -5.29 + 3.12(Log10 Length_mm)	972	5856	Irons et al. 2011
Middle Mississippi River	Log10 Weight_g = -5.29 + 3.11(Log10 Length_mm)	915	5477	Williamson and Garvey 2005
Missouri River (Gavins Point)	Log10 Weight_g = -6.92 + 3.70(Log10 Length_mm)	788	6628	Wanner and Klumb 2009
Missouri River (Interior Highlands)	Log10 Weight_g = -5.35 + 3.13(Log10 Length_mm)	900	5453	Wanner and Klumb 2009
Big Sioux River (Missouri River tributary)	Log10 Weight_g = -5.53 + 3.21(Log10 Length_mm)	970	6150	Hayer et al. 2014
James River (Missouri River tributary)	Log10 Weight_g = -5.26 + 3.11(Log10 Length_mm)	981	5869	Hayer et al. 2014
Vermillion River (Missouri River tributary)	Log10 Weight_g = -4.82 + 2.90(Log10 Length_mm)	748	3971	Hayer et al. 2014

Table 2. Length-Weight equations and the estimated weights of Bighead Carp (450mm & 800mm) at five locations within the Mississippi River Basin. Published data was used for river systems located outside of the Ohio River Basin.

System-(w/ Specific Locales)	Length-Weight Regression Equation	Predicted weight (g) for 450mm	Predicted weight (g) for 800mm	Reference
Ohio River	Log10 Weight_g = -4.57 + 2.86(Log10 Length_mm)	1043	5406	ORB Technical Report 2022
Illinois River (La Grange)	Log10 Weight_g = -4.84 + 2.95(Log10 Length_mm)	970	5298	Irons et al. 2010
Missouri River (Males)	Log10 Weight_g = -5.42 + 3.15(Log10 Length_mm)	866	5306	Schrank and Guy 2002
Missouri River (Females)	Log10 Weight_g = -5.40 + 3.13(Log10 Length_mm)	803	4860	Schrank and Guy 2002
Missouri River (Gavins Point)	Log10 Weight_g = -4.86 + 2.96(Log10 Length_mm)	985	5409	Wanner and Klumb 2009
Missouri River (Interior Highlands)	Log10 Weight_g = -4.30 + 2.75(Log10 Length_mm)	991	4825	Wanner and Klumb 2009

Table 3. Results of the targeted electrofishing efforts for Invasive Carp that were conducted during April – May 2022 throughout six different pools of the Ohio River.

Dates: 4/11 - 5/25	Ohio River Pools						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	All Pools
EF Effort (h)	11.00	11.75	13.5	12.25	3.75	6.08	58.3
# Transects	44	47	54	49	15	25	234
# IC Spp	2	2	2	1	0	1	3
	Invasive Carp Counts						
Bighead Carp	0	1	0	0	0	0	1
Grass Carp	6	0	2	0	0	0	8
Silver Carp	383	52	9	1	0	1	446
All Carp	389	53	11	1	0	1	455
	CPUE (fish/transect)						
Bighead Carp	0.00	0.02	0.00	0.00	0.00	0.00	0.005
(95% CI)	-	(0.0 - 0.06)	-	-	-	-	(0.0 - 0.01)
Grass Carp	0.14	0.00	0.04	0.00	0.00	0.00	0.03
(95% CI)	(0.02 - 0.26)	-	(0.0 - 0.09)	-	-	-	(0.01 - 0.06)
Silver Carp	8.70	1.11	0.17	0.02	0.00	0.04	1.91
(95% CI)	(5.67 - 11.73)	(0.55 - 1.67)	(0.03 - 0.30)	(0.0 - 0.06)	-	(0.0 - 0.12)	(1.18 - 2.63)
All IC Carp	8.84	1.13	0.20	0.02	0.00	0.04	1.95
(95% CI)	(5.83 - 11.85)	(0.56 - 1.70)	(0.04 - 0.36)	(0.0 - 0.06)	-	(0.0 - 0.12)	(1.22 - 2.67)

Table 4. Results of the gill netting conducted during spring 2022 in the Greenup and RC Byrd pools for annual sampling efforts that specifically targeted Invasive Carp.

	Ohio River Pools		
	Greenup	RC Byrd	Total
Effort (net ft)	1800	2700	4500
# Net sets	8	12	20
# Fish Spp	4	3	5
# Total Fish	8	7	15
	Invasive Carp Counts		
Bighead Carp	0	2	2
Grass Carp	1	0	1
Silver Carp	0	0	0
All Carp	1	2	3
	CPUE (fish/set)		
Bighead Carp	0.00	0.17	0.10
(95% CI)	-	-	(0.0 - 0.01)
Grass Carp	0.13	0.00	0.05
(95% CI)	-	-	(0.01 - 0.06)
Silver Carp	0.00	0.00	0.00
(95% CI)	-	-	-
All IC Carp	0.13	0.17	0.15
(95% CI)	-	(0.0 - 0.12)	(1.22 - 2.67)

Table 5. A by-catch summary of the non-target species that were captured by the gill nets used during the targeted monitoring efforts in spring 2022.

	Ohio River Pools		
By-Catch Spp	Greenup	RC Byrd	Total
Blue Catfish	3	2	5
Common Carp	2	3	5
Flathead Catfish	2	0	2
Total	7	5	12

Table 6. Number of sites (N) and average mean and upper and lower 90% credible intervals (CrI) for Silver Carp density (SVC/1000m^3) within main channel (MC), side channel (SC), tributary (TRIB), and backwater (BW) habitats within Cannelton and McAlpine pools.

Pool	Habitat	N	Average Mean SVCP Density	Average Lower 90% CrI	Average Upper 90% CrI
Cannelton	MC	71	0.078	0.077	0.0789
Cannelton	SC	1	0.0049	0.0043	0.00549
Cannelton	TRIB	16	2.540	2.530	2.560
McAlpine	MC	45	0.028	0.0277	0.0288
McAlpine	SC	14	0.114	0.112	0.116
McAlpine	TRIB	12	0.940	0.927	0.952
McAlpine	BW	3	0.191	0.189	0.192

Table 7. Summary of annual CSS for middle Ohio River pools during years with available data. Pools are arranged from downstream (Cannelton) to upstream (RC Byrd). KDFWR provided data for Cannelton to Meldahl, while WVDNR covered Greenup and RC Byrd.

Pool	Year							Mean	Slope
	2015	2016	2017	2018	2019	2020	2022	Slope	CV[A]
Cannelton	---	-1.66	-1.46	-0.79	-1.12	-1.59		-1.33	27.5%
McAlpine	-1.51	-1.19	-1.95	---	-1.66	-1.87		-1.64	18.4%
Markland	-1.87	-3.38	-2.61	---	-2.28	---		-2.53	25.2%
Meldahl	-1.47	-2.06	-1.92	-2.00	---	---		-1.86	14.5%
Greenup	-0.49	-1.88	-2.03	-2.27	---	---		-1.67	47.9%
RC Byrd	---	-2.41	-2.18	-3.35	---	---		-2.65	23.3%
Winfield							-1.28		
Racine							-1.24		
Willow Island							-1.33		

[A] = coefficient of variation (CV)

Table 8. Total counts, by pool and overall, for the fish species sampled from four different pools of the Allegheny and Monongahela Rivers during nocturnal electrofishing surveys conducted in spring 2022.

Fish Species	Allegheny River		Monongahela River		Total	% Total
	Pool 4	Pool 5	Elizabeth	Maxwell		
Bigeye Chub	3	1			4	0.07
Black Buffalo	3				3	0.05
Black Crappie	2	2	3		7	0.12
Black Redhorse	37	22	53	15	127	2.18
Blackside Darter		3			3	0.05
Bluebreast Darter	2				2	0.03
Bluegill	10	3	43	6	62	1.07
Bluntnose Minnow	1	2	35	7	45	0.77
Brook Silverside				4	4	0.07
Brown Trout - Hatchery	1				1	0.02
Channel Catfish	9	33	12	3	57	0.98
Channel Darter		1	2		3	0.05
Channel Shiner	53	1	479	124	657	11.30
Common Carp	5	8	8		21	0.36
Common Shiner	1				1	0.02
Creek Chub			3		3	0.05
Emerald Shiner	277	119	532	479	1,407	24.19
Flathead Catfish	2			3	5	0.09
Freshwater Drum	19	10	41	7	77	1.32
Gizzard Shad	2	12		1	15	0.26
Golden Redhorse	133	123	170	469	895	15.39
Green Sunfish			1	16	17	0.29
Greenside Darter			2		2	0.03
Johnny Darter	1	3	7	1	12	0.21
Largemouth Bass	2		12	12	26	0.45
Logperch	4	7	17	8	36	0.62
Longhead Darter	3				3	0.05
Longnose Gar	5	19	36	13	73	1.26
Mimic Shiner	80	25	358	85	548	9.42
Muskellunge				1	1	0.02
Northern Hog Sucker	4	8	4	3	19	0.33
Ohio Lamprey	2	1			3	0.05
Pumpkinseed	1		32	1	34	0.58
Quillback	7	4	6	4	21	0.36
Rainbow Trout - Hatchery				1	1	0.02
Redside Dace			1		1	0.02
River Carpsucker		2	6		8	0.14

Table 8. Continued

Fish Species	Allegheny River		Monongahela River		Total	% Total
	Pool 4	Pool 5	Elizabeth	Maxwell		
River Chub		1			1	0.02
River Redhorse	42	122	11	6	181	3.11
Rock Bass	23	6	23	32	84	1.44
Rosyface Shiner	1				1	0.02
Sand Shiner	1				1	0.02
Sauger	11	7	39	71	128	2.20
Silver Redhorse	91	95	27	25	238	4.09
Smallmouth Bass	152	99	54	72	377	6.48
Smallmouth Buffalo	61	57	6		124	2.13
Smallmouth Redhorse	38	64	8	14	124	2.13
Spotfin Shiner	2	3	3		8	0.14
Spottail Shiner	2				2	0.03
Spotted Bass			4	2	6	0.10
Trout Perch	6	3			9	0.15
Walleye	51	109	42	67	269	4.63
White Bass			41	2	43	0.74
Yellow Perch			13	3	16	0.28
Combined Totals	1,150	975	2,134	1,557	5,816	
Species Counts	40	33	36	32	54	

Table 9. Total counts and percent abundance of the twenty-six fish species captured during the beach seine surveys conducted in the Montgomery Pool of the Ohio River during 2022.

Fish Species	Total Count	% Abundance
Bigeye Chub	51	0.60
Blacknose Dace	1	0.01
Bluegill	182	2.13
Bluntnose Minnow	426	4.98
Brook Silverside	20	0.23
Channel Shiner	744	8.69
Emerald Shiner	5,272	61.58
Freshwater Drum	1	0.01
Gizzard Shad	165	1.93
Greenside Darter	1	0.01
Johnny Darter	2	0.02
Logperch	33	0.39
Mimic Shiner	1,181	13.80
Northern Hog Sucker	3	0.04
Quillback	1	0.01
Rainbow Darter	1	0.01
River Redhorse	13	0.15
Sand Shiner	69	0.81
Smallmouth Bass	16	0.19
Spotfin Shiner	283	3.31
Spottail Shiner	5	0.06
Spotted Bass	2	0.02
Streamline Chub	22	0.26
Trout Perch	1	0.01
White Sucker	6	0.07
Unidentified cyprinid spp.	60	0.70
Total	8,561	

Table 10. Summary statistics for all fish species sampled during fall 2022 electrofishing surveys conducted at 6 sites (1.5 hrs) in the RC Byrd Pool and 22 sites (5.3 hrs) in the Racine Pool.

	R.C. Byrd Pool				Racine Pool			
Fish Species	N	Wr	Mean CPUE (fish/hr)	95% CI	N	Wr	Mean CPUE (fish/hr)	95% CI
Black Crappie	0	-	-	-	2	-	0.36	0.49
Bluegill Sunfish	3	-	2.00	3.92	141	93.1	26.85	14.95
Bluntnose Minnow	0	-	-	-	16	-	2.91	2.69
Bullhead Minnow	0	-	-	-	2	-	0.36	0.49
Channel Catfish	1	85.6	0.67	1.31	4	95.4	0.73	0.84
Channel Shiner	27	-	18.00	35.28	205	-	38.26	37.88
Common Carp	1	99.6	0.67	1.31	18	102.0	3.27	1.90
Emerald Shiner	59	-	39.33	58.65	169	-	31.23	19.91
Flathead Catfish	2	-	1.33	1.65	2	92.7	0.36	0.49
Freshwater Drum	9	106.1	6.00	5.99	28	96.0	5.53	2.53
Gizzard Shad	141	86.9	94.00	73.59	936	87.1	173.05	87.79
Golden Redhorse	6	-	4.00	2.02	13	-	2.43	1.14
Green Sunfish	0	-	-	-	13	-	2.51	2.69
Highfin Carpsucker	1	-	0.67	1.31	3	-	0.55	0.78
Hybrid Striped Bass	1	82.6	0.67	1.31	5	84.3	0.91	0.88
Hybrid Sunfish	1	-	0.67	1.31	1	-	0.18	0.36
Largemouth Bass	15	108.6	10.00	9.66	58	107.8	11.33	4.15
Longear Sunfish	0	-	-	-	2	-	0.36	0.49
Longnose Gar	2	89.5	1.33	1.65	1	71.6	0.25	0.49
Mooneye	0	-	-	-	2	-	0.50	0.97
Muskellunge	0	-	-	-	3	90.3	0.55	0.78
Northern Hogsucker	0	-	-	-	2	-	0.36	0.49
Orangespotted Sunfish	0	-	-	-	18	-	3.27	6.41
Redear Sunfish	1	-	0.67	1.31	7	110.2	1.27	1.30
River Carpsucker	1	-	0.67	1.31	8	92.8	1.60	1.08
River Redhorse	0	-	-	-	3	-	0.55	0.78
Sauger	6	-	4.00	7.84	19	94.8	4.23	3.30
Saugeye	0	-	-	-	1	71.8	0.18	0.36
Silver Redhorse	0	-	-	-	8	-	1.94	1.91
Skipjack Herring	11	-	7.33	11.35	11	-	2.13	1.56
Smallmouth Bass	2	85.5	1.33	1.65	5	89.1	0.91	1.15
Smallmouth Buffalo	11	88.1	7.33	5.51	76	78.7	13.82	4.75
Smallmouth Redhorse	0	-	-	-	12	-	2.18	1.77
Spotfin Shiner	0	-	-	-	1	-	0.18	0.36
Spotted Bass	3	93.2	2.00	1.75	7	100.4	1.27	1.20
Spotted Sucker	0	-	-	-	14	-	3.85	5.80
Walleye	0	-	-	-	1	81.8	0.18	0.36
Warmouth	0	-	-	-	3	-	0.55	0.59
Western Banded Killifish	0	-	-	-	4	-	0.73	0.84
White Bass	0	-	-	-	13	83.8	3.38	4.54
White Crappie	0	-	-	-	6	95.6	1.09	1.17
Yellow Perch	1	-	0.67	1.31	1	-	0.18	0.36

Table 11. Results of the gillnetting efforts conducted in the RC Byrd and Racine pools during Fall 2022.

Gillnet Sampling	R.C. Byrd	Racine	Total
Effort (net ft)	1,350	2,550	3,900
Soak Time (hrs)	18.1	32.4	50.5
# Sites	6	11	17
Total Fish Caught	0	5	5
Bighead Carp	0	2	2
Grass Carp	0	0	0
Silver Carp	0	1	1
Paddlefish	0	2	2

Table 12. Fish counts by species and percent total catch from seine hauls conducted in the RC Byrd and Racine pools of the Ohio River during Fall 2022.

Fish Species	R.C. Byrd (3 Sites)		Racine (3 Sites)	
	N	% Catch	N	% Catch
Bluegill Sunfish	1	0.10	35	2.79
Bluntnose Minnow	1	0.10	2	0.16
Channel Shiner	782	75.34	332	26.50
Eastern Banded Killifish	0	-	1	0.08
Emerald Shiner	251	24.18	848	67.68
Orangespotted Sunfish	0	-	3	0.24
Spotfin Shiner	0	-	5	0.40
Steelcolor Shiner	2	0.19	2	0.16
Western Banded Killifish	0	-	23	1.84
Western Mosquitofish	1	0.10	2	0.16
Total	1,038		1,253	

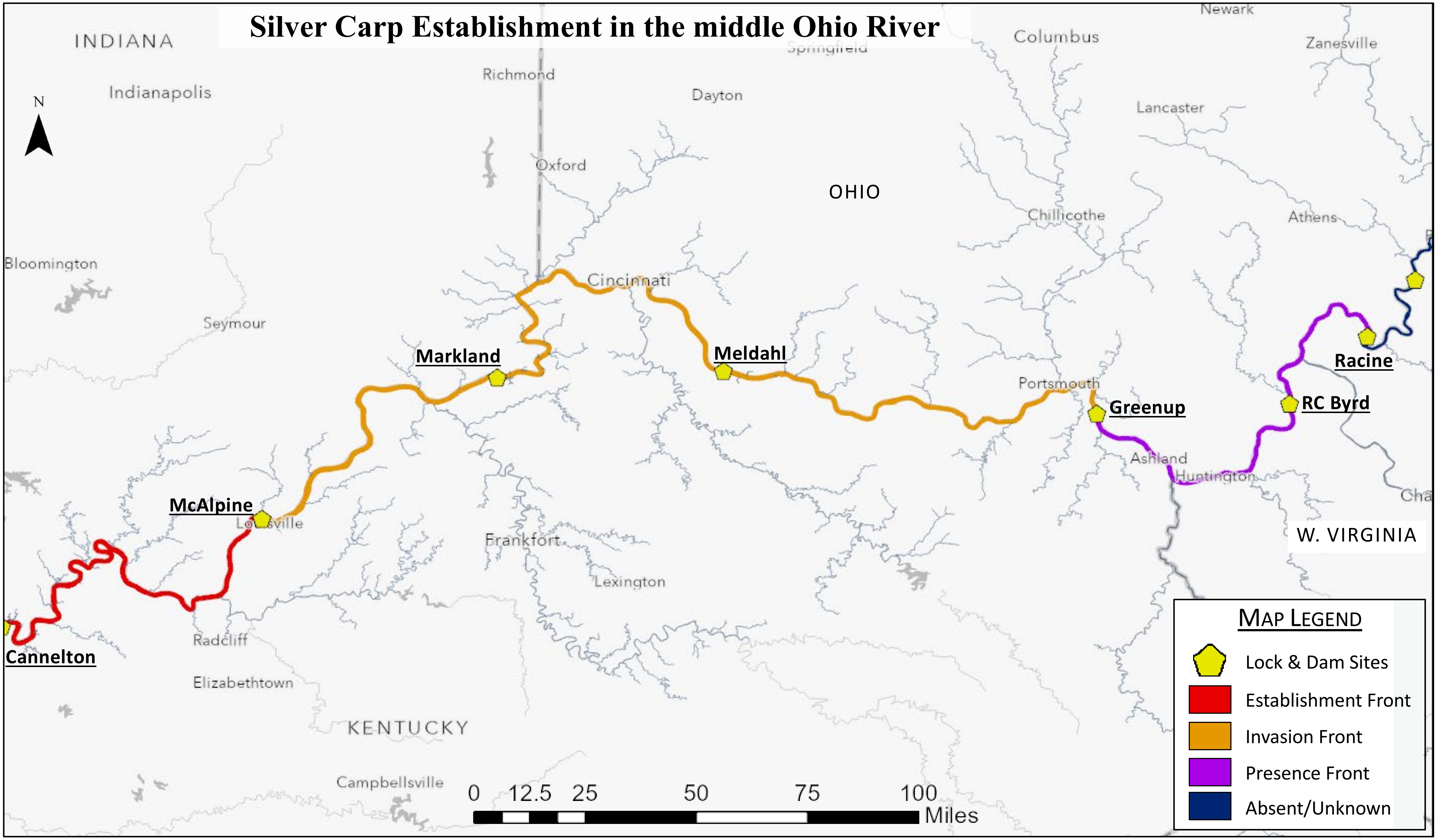

Figure 1. A section of the middle Ohio River consisting of six pools (Cannelton - Racine) that are colored according to the Silver Carp population's invasion status in 2022. A pool's status is reevaluated each year following the analysis of sampling data that's collected for several ongoing research projects in the Ohio River Basin.

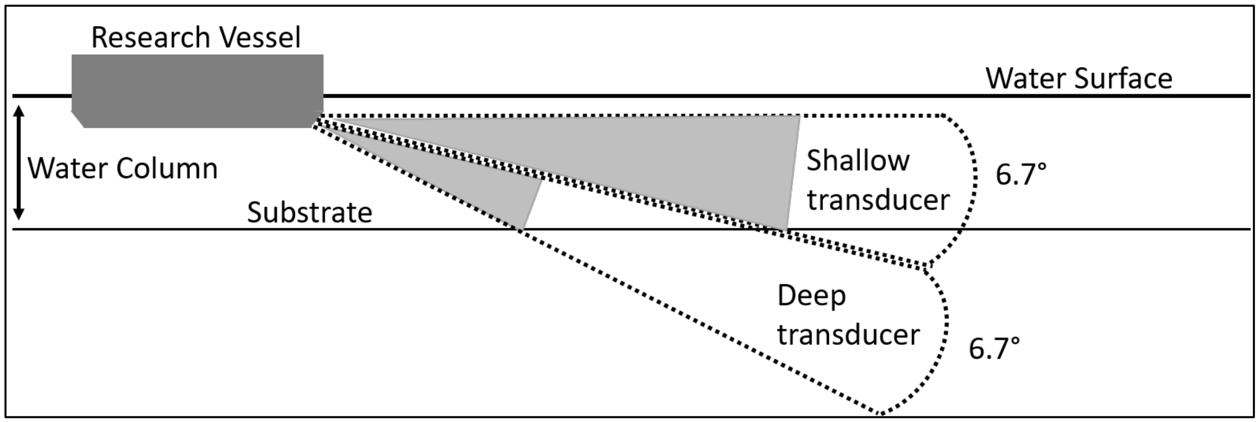

Figure 2. Depiction of hydroacoustic beams with transducers offset to maximize water column coverage for two split-beam echosounders.

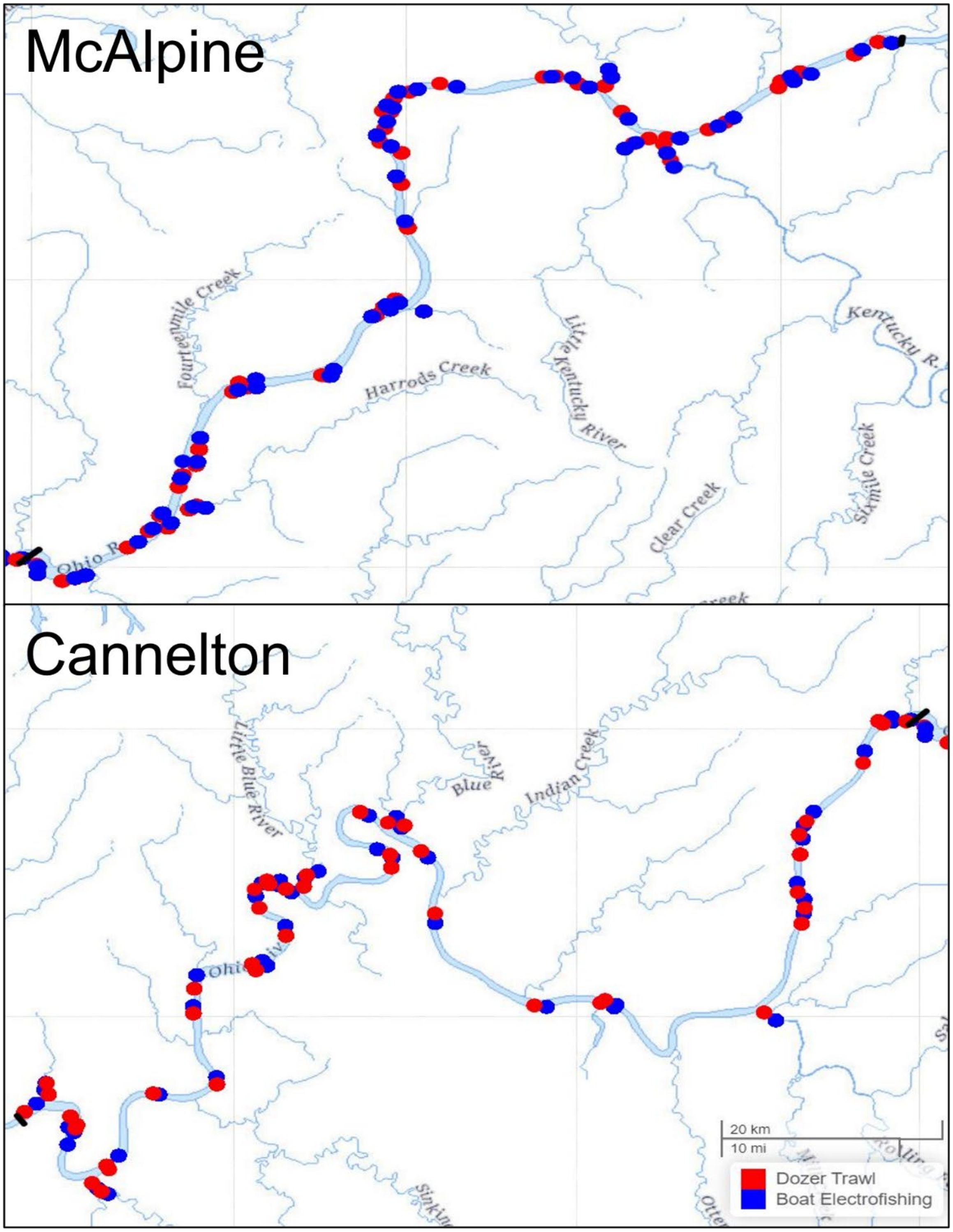

Figure 3. Map of dozer trawl (red) and boat electrofishing (blue) sites in McAlpine (top) and Cannelton (bottom) pools during October 2022. Community data were used to apportion hydroacoustic targets to species. Black lines across the river indicate dam locations.

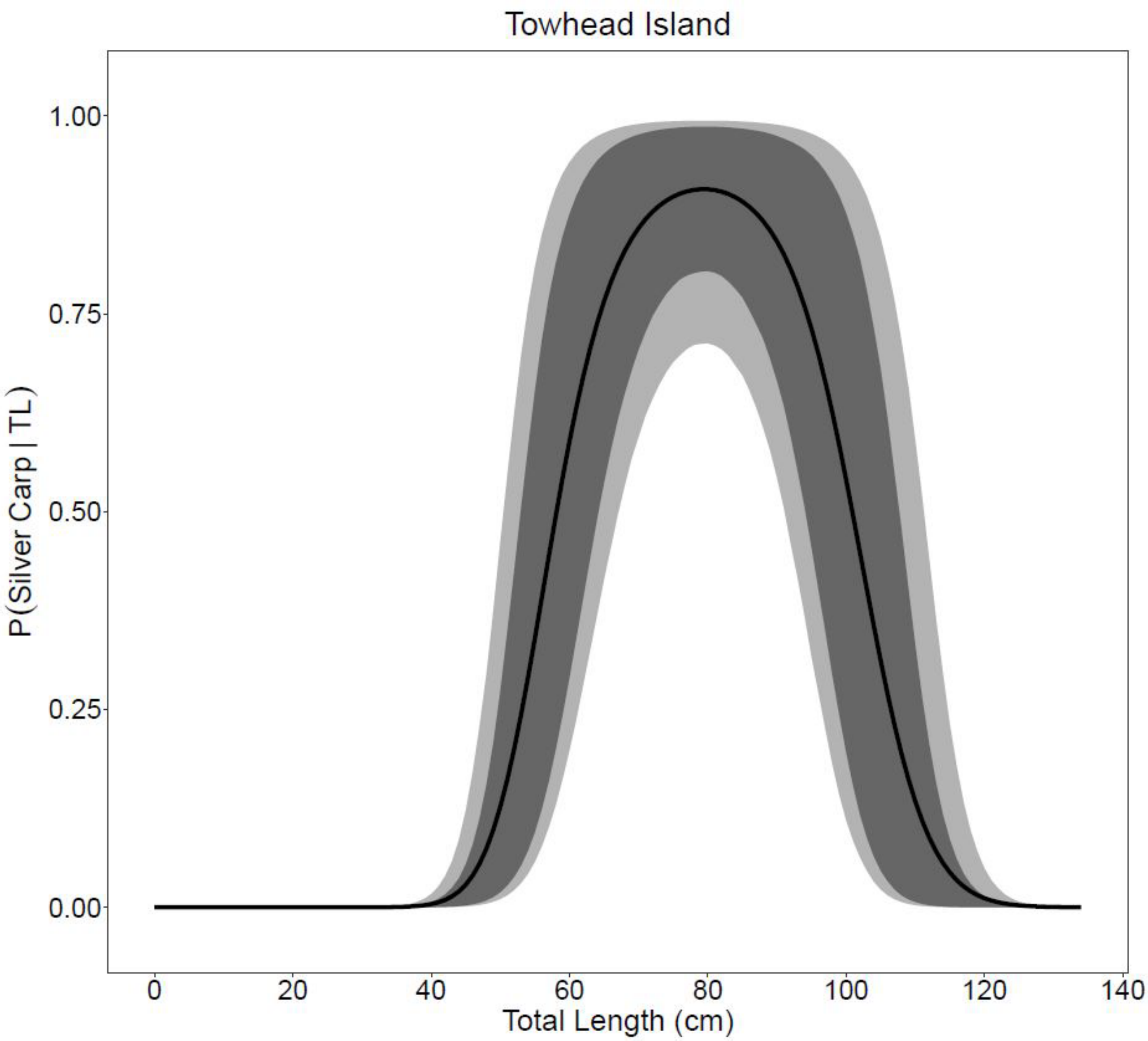

Figure 4. Estimated probability of a fish being a Silver Carp given its total length for Towhead Island. The dark line is the mean probability, and the gray-shaded areas represent the 90% (light) and 75% (dark) credible intervals, respectively.

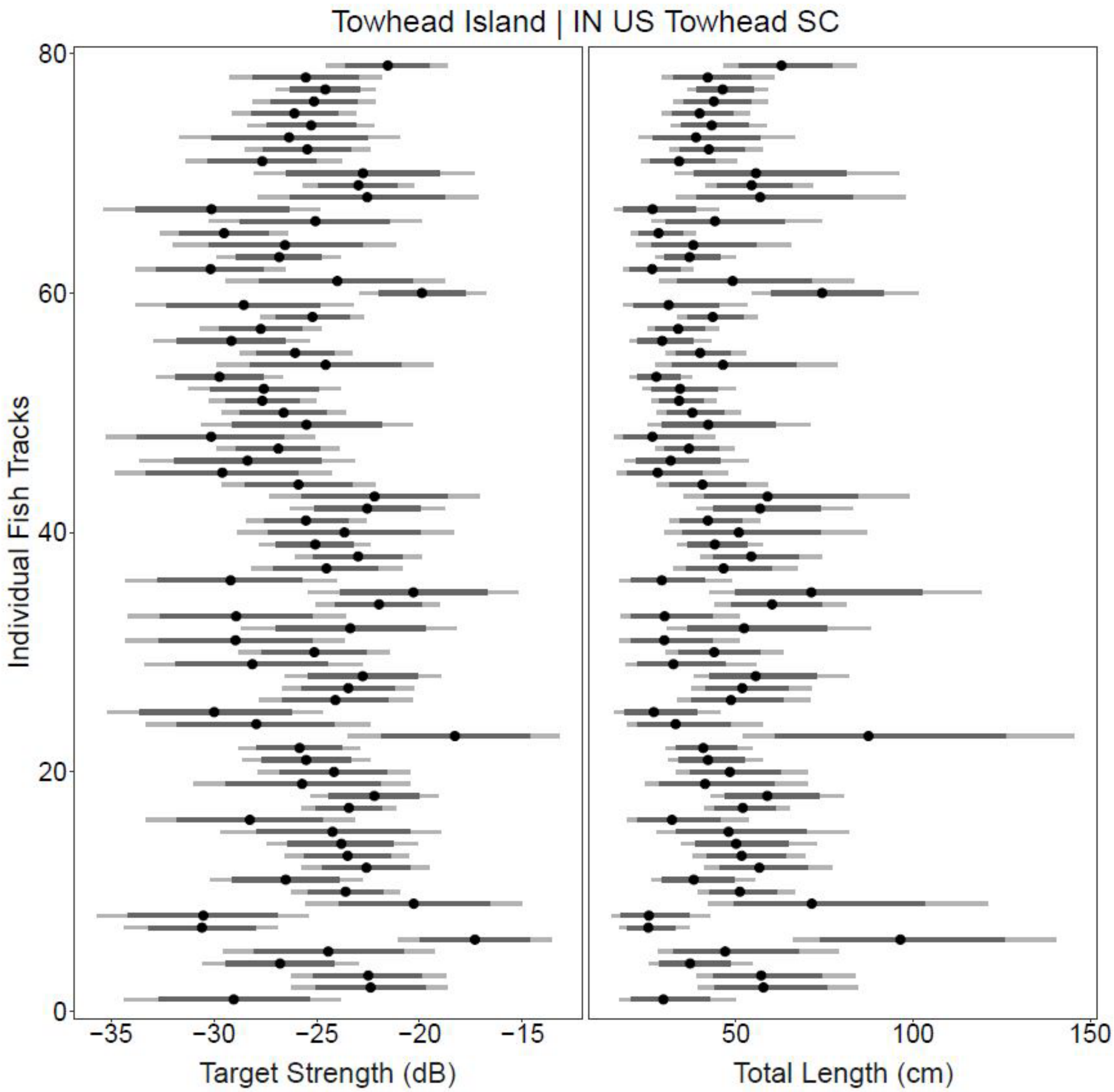

Figure 5. Estimated mean TS (dB) and TL (cm) for all fish tracks a Towhead Island for the upstream, shore-facing transect. Black dots represent the estimated mean TS and TL. Dark and light gray lines represent 75% and 90% credible intervals, respectively.

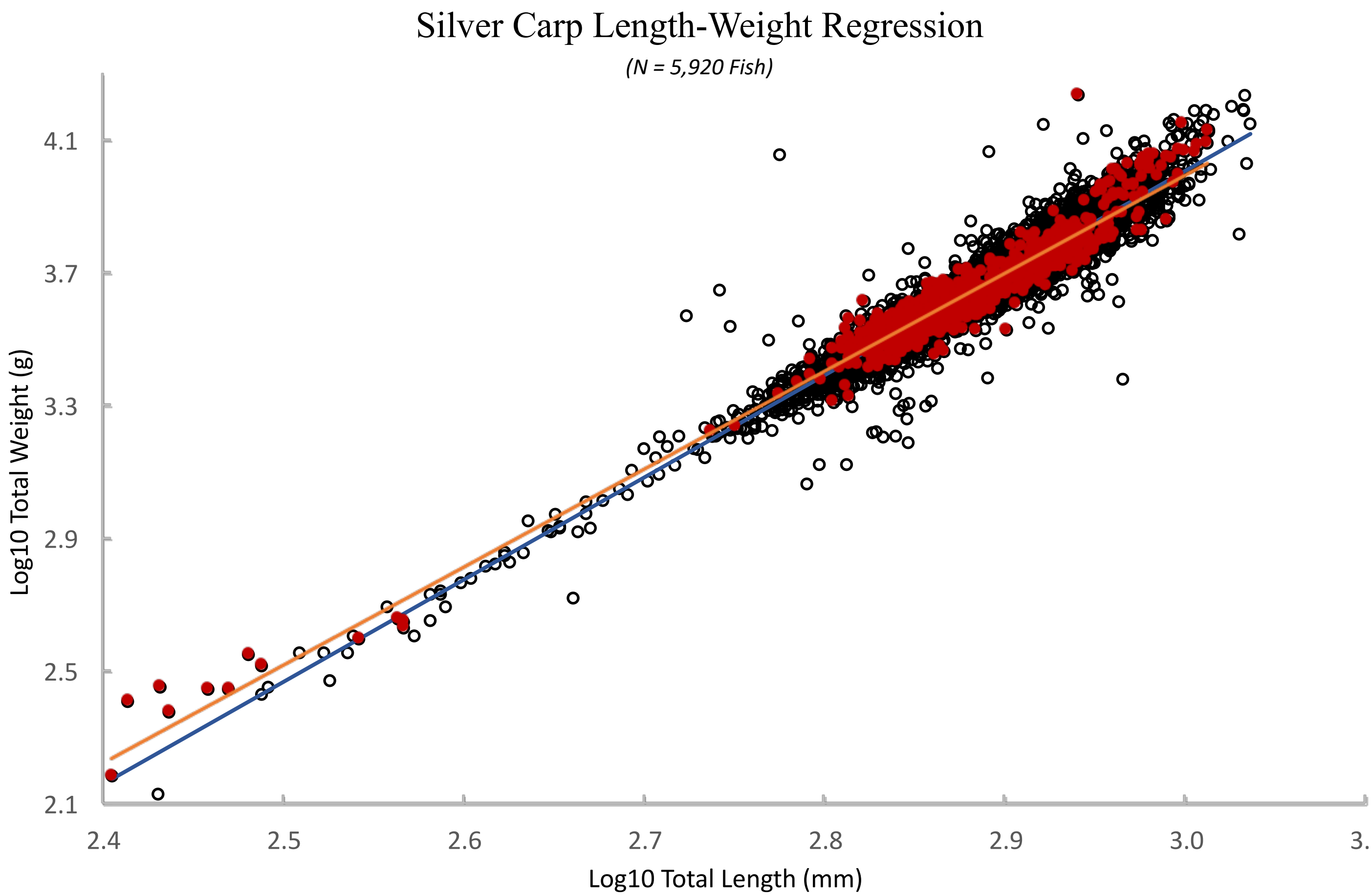

Figure 6. The log-transformed length-weight relationship of the Silver Carp collected from the middle Ohio River. Darker circles illustrate lengths & weights of Silver Carp sampled in 2015 – 2021. The length-weight data from 2022 and the resulting regression line is provided in red. The dark line represents the regression equation (see Table 1) generated from the entire Silver Carp length-weight dataset from 2015 through 2022.

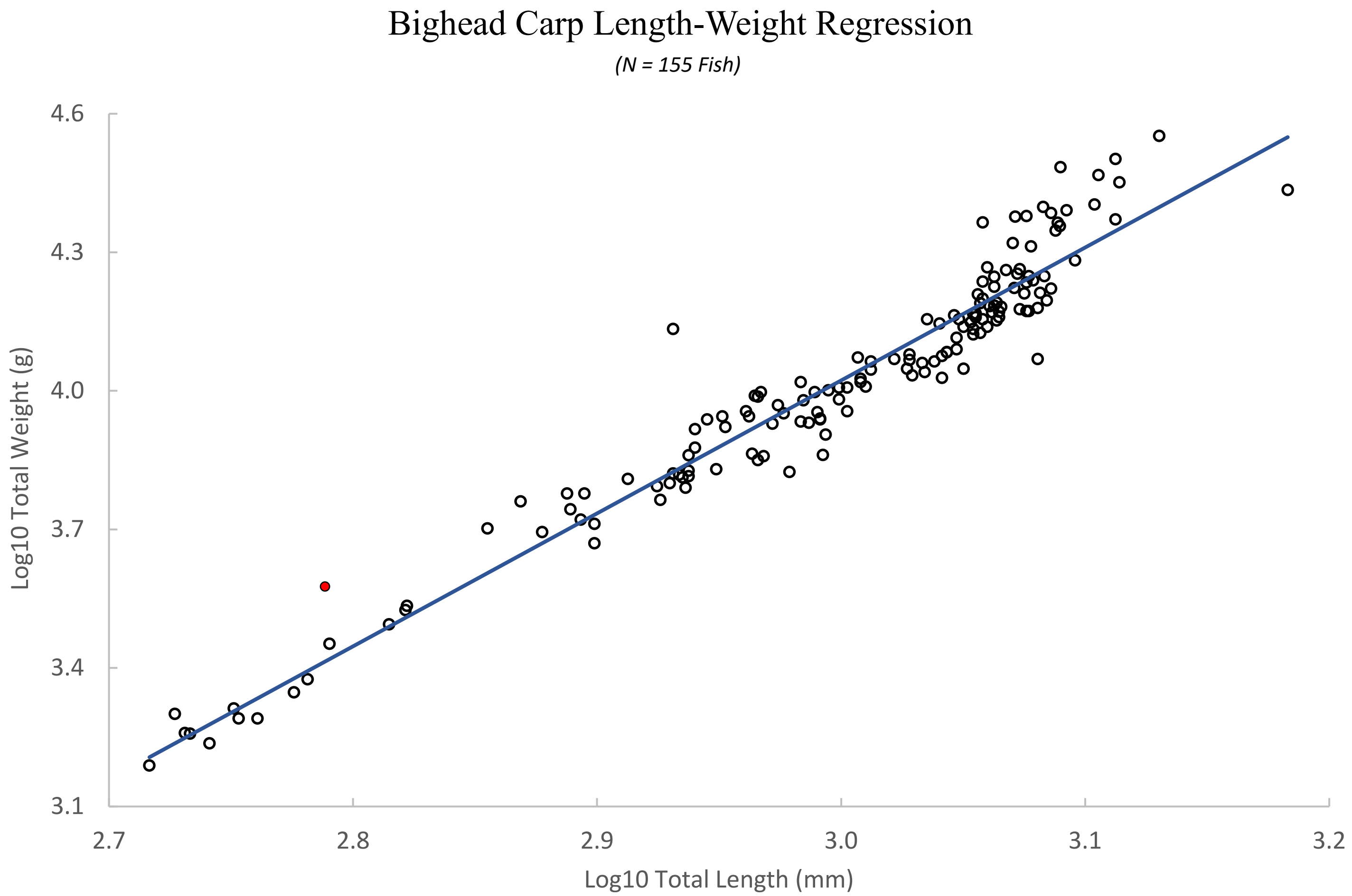

Figure 7. The log-transformed length-weight relationship of Bighead Carp collected from the middle Ohio River. The darker circles illustrate the length and weights of the fish sampled through 2021, while the only Bighead Carp collected in 2022 is present as a red circle. The dark line represents a regression equation (see Table 2) generated from all of the length-weight data collected between 2015 and 2022.

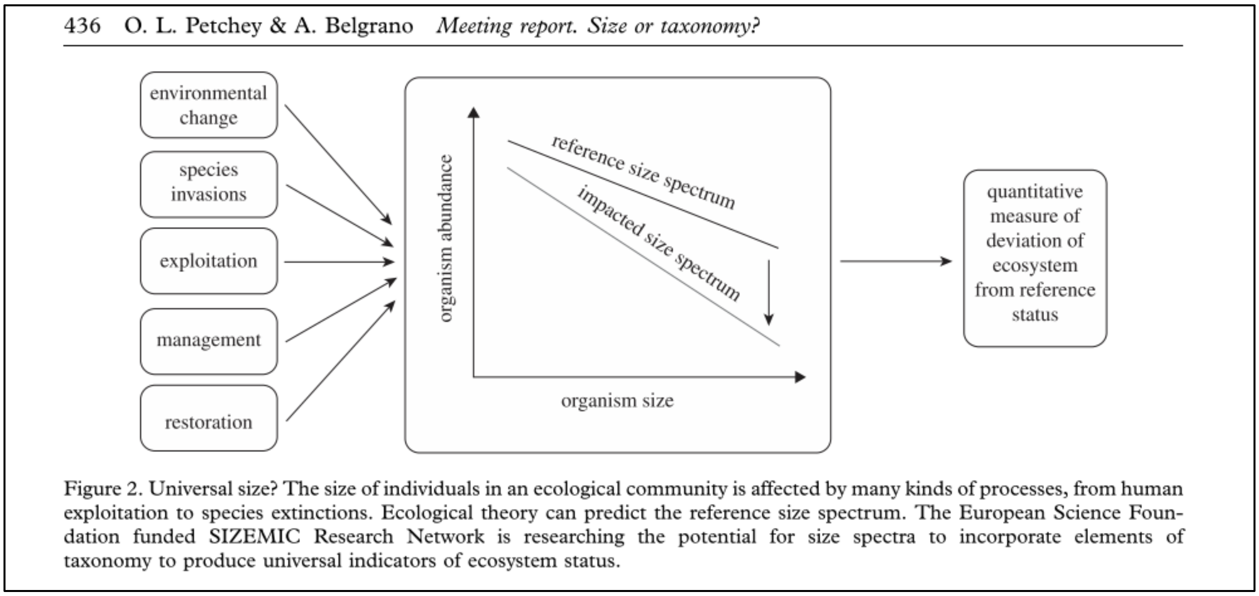

Figure 2. Universal size? The size of individuals in an ecological community is affected by many kinds of processes, from human exploitation to species extinctions. Ecological theory can predict the reference size spectrum. The European Science Foundation funded SIZEMIC Research Network is researching the potential for size spectra to incorporate elements of taxonomy to produce universal indicators of ecosystem status.

Figure 8. (From Petchey and Owen 2010) An illustration of the impacts of overfishing that leads to a reduction in the elevation and an increase in slope due to the loss of large fish. In the case of the Ohio River, a flattening of the line would indicate the replacement of large piscivores by invasive carp.

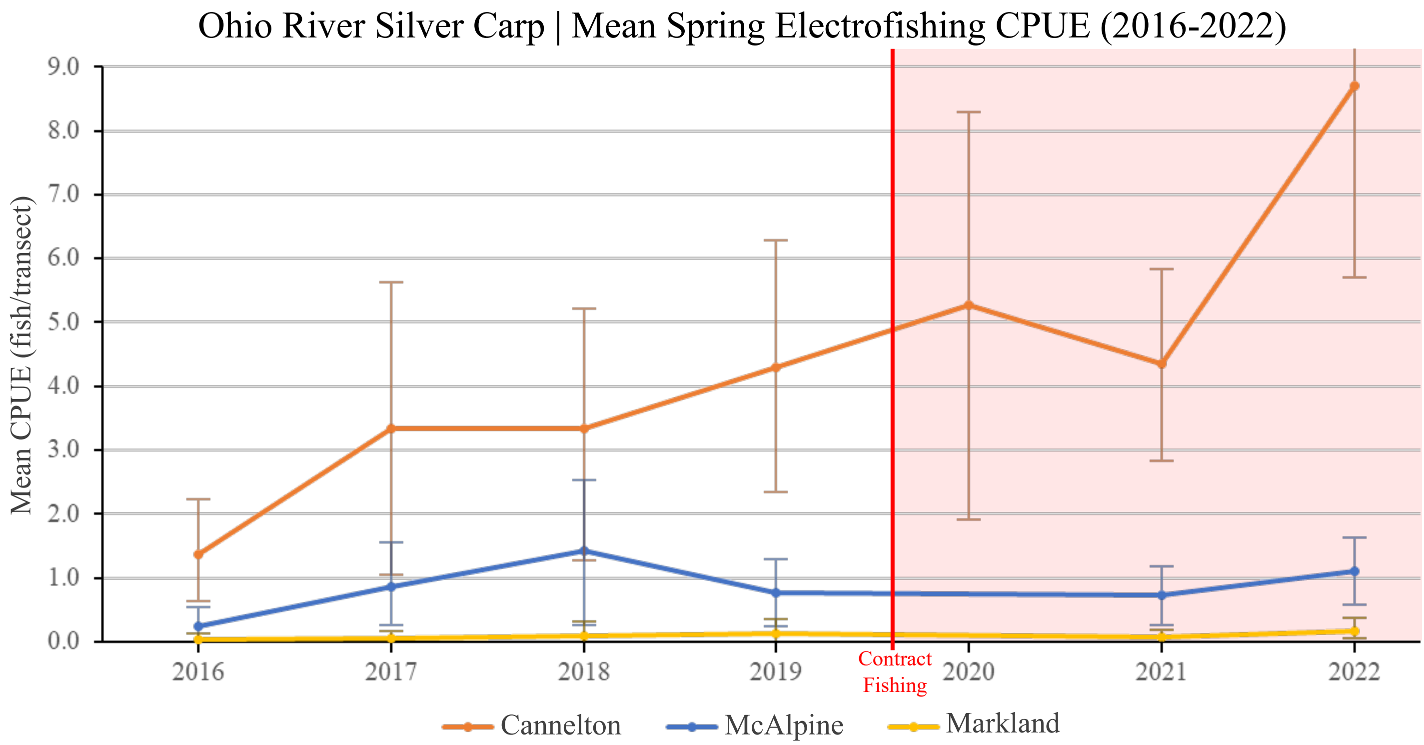

Figure 8. Mean electrofishing CPUE (fish/transect) for Silver Carp in three pools (Cannelton, McAlpine and Markland) of the Ohio River that were sampled each spring from 2016 to 2022. Error bars represent the 95% confidence intervals for the mean catch rates. Because of its potential impact on Cannelton's silver carp population, the timeline for the contract fishing efforts has been provided (shaded in red).

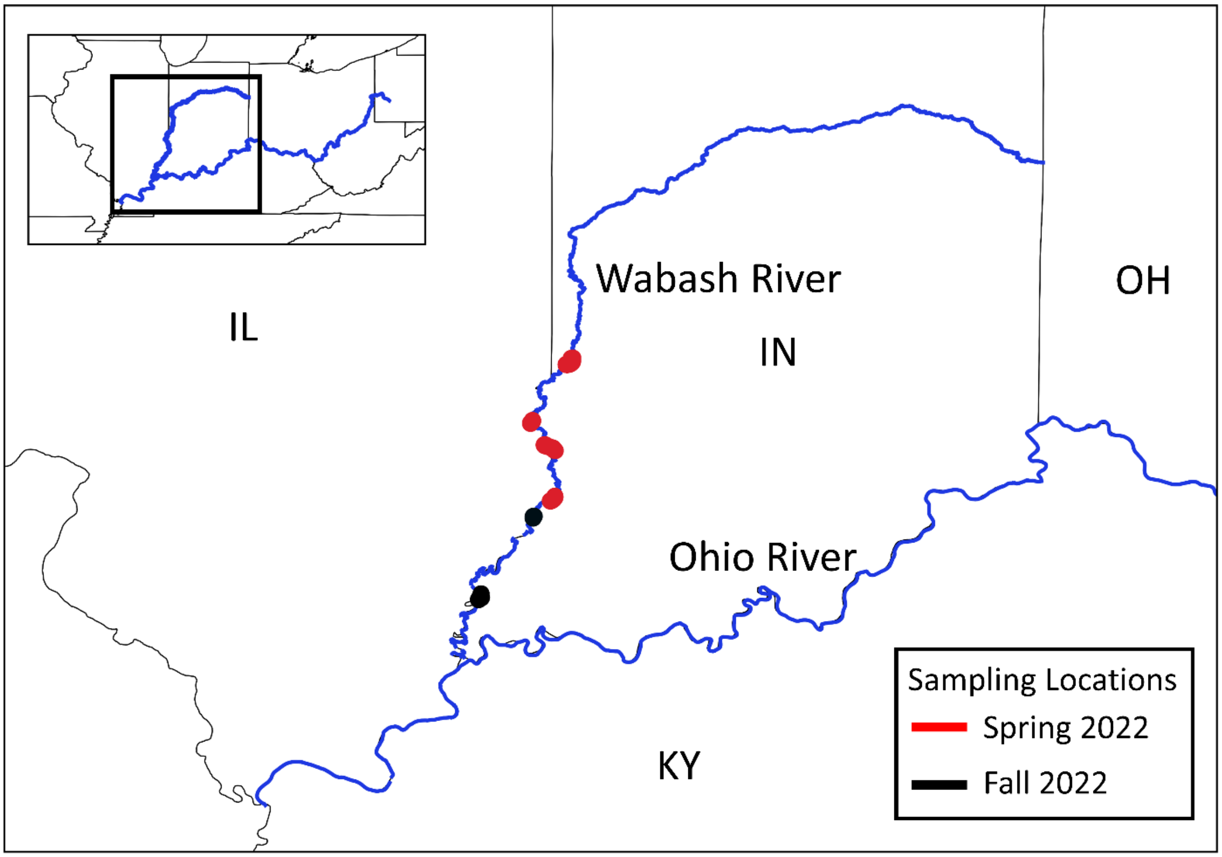

Figure 9. Locations of mobile hydroacoustic sampling conducted during spring and fall months of 2022 in the Wabash River. High-flow conditions prevented hydroacoustic sampling in the lower portion of the river, and an extended low-flow period precluded upstream sites to be sampled during fall.

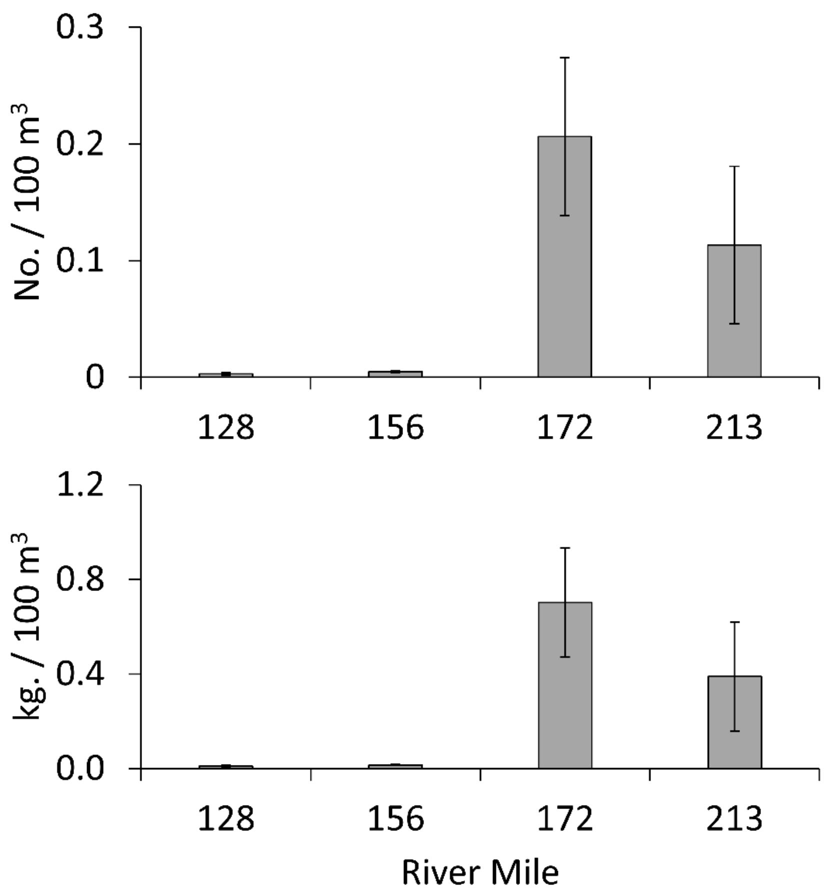

Figure 10. Mean (standard deviation) bigheaded carp densities from four four-mile long main channel reaches of the Wabash River during spring (May) of 2022. Mean daily discharge during spring sampling was 58,874 ft^3/sec (USGS gage 03378500). River mile 128: Vincennes, IN; river mile 156: Palestine, IL; river mile 172: Hutsonville, IN; river mile 213: Terre Haute, IN.

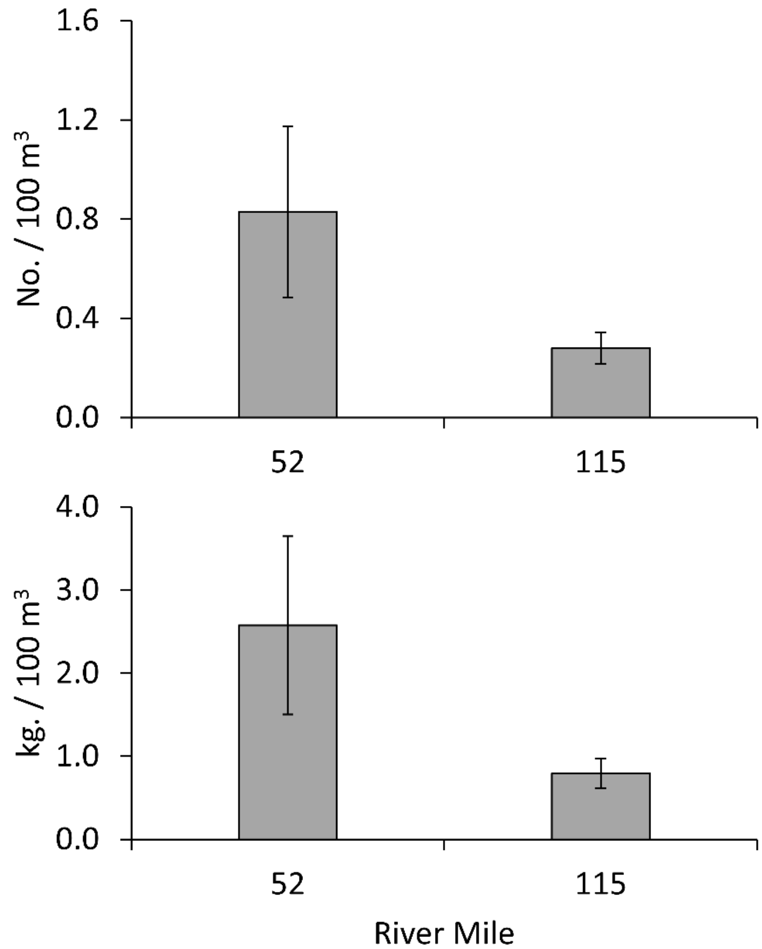

Figure 11. Mean (standard deviation) bigheaded carp densities from four-mile long main channel reaches of the Wabash River during fall (October) of 2022. Mean daily discharge during fall sampling was 6,608 ft^3/sec (USGS gage 03378500). River mile 52: New Harmony, IN; river mile 115: St. Francisville, IL.

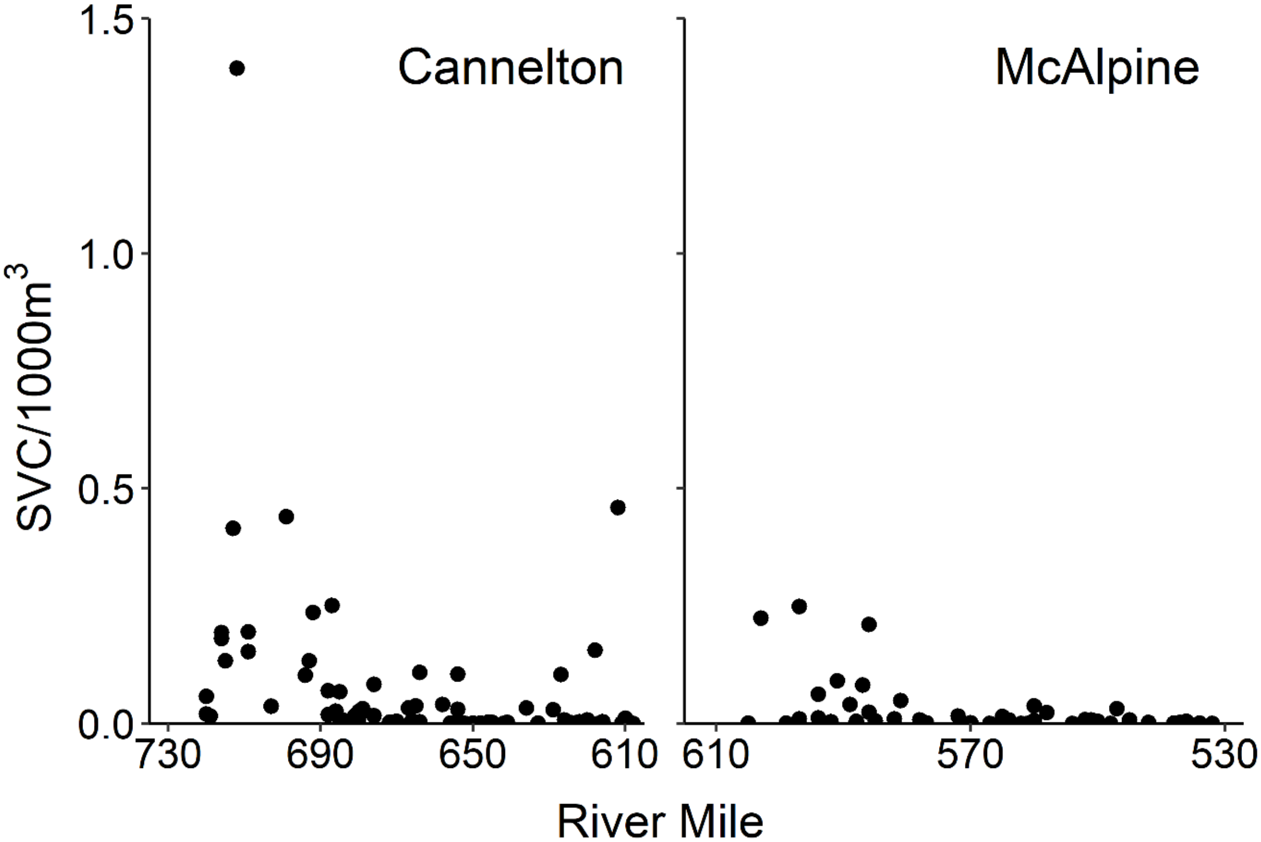

Figure 12. Change in hydroacoustically derived Silver Carp (SVC) density with river mile for main channel sites in Cannelton and McAlpine pools during October 2022. River miles decrease from downstream to upstream within the Ohio River (left to right on x-axis).

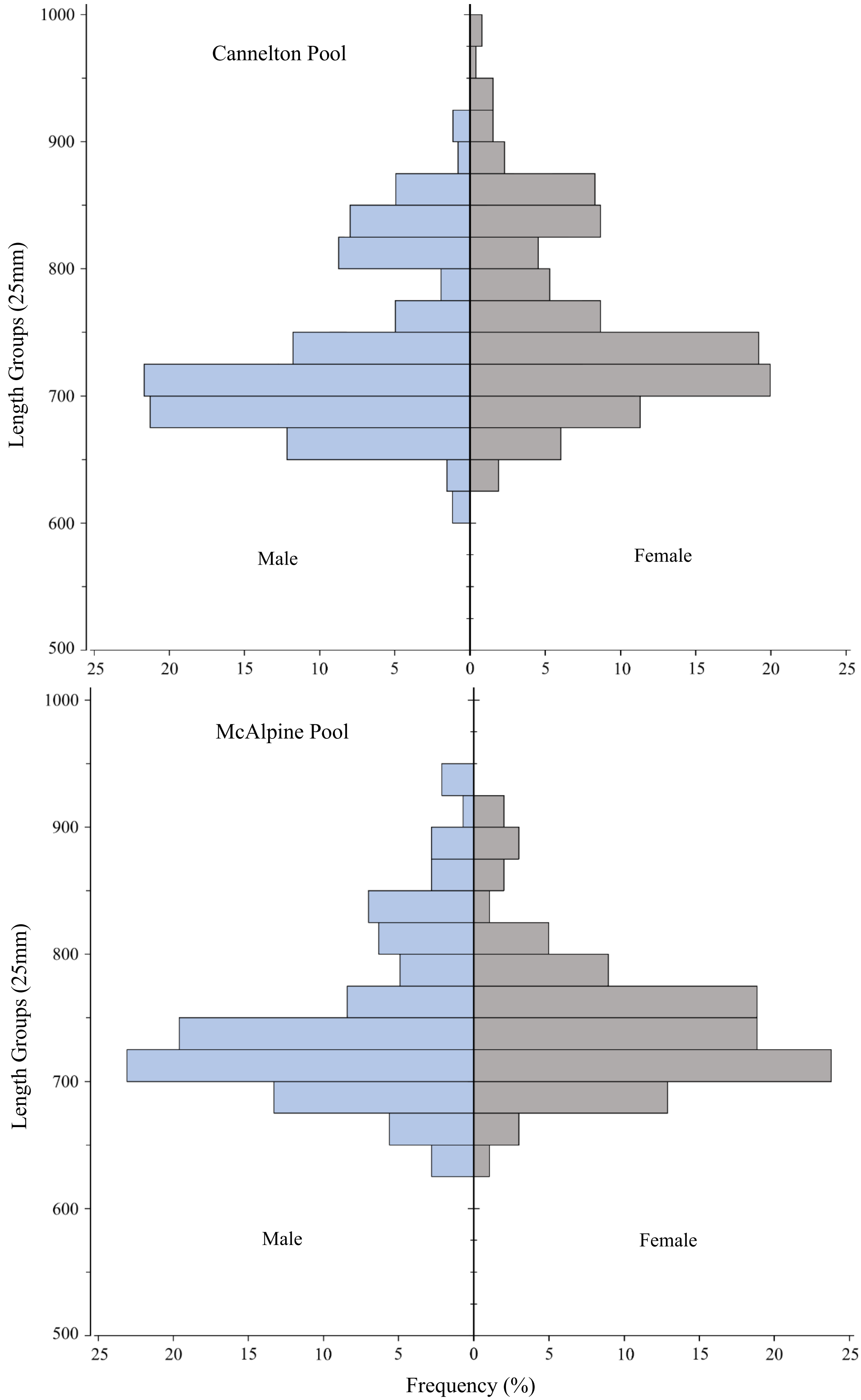

Figure 13. Length frequency (25 mm bins) distributions for male and female Silver Carp collected from the Cannelton and McAlpine pools during 2022.

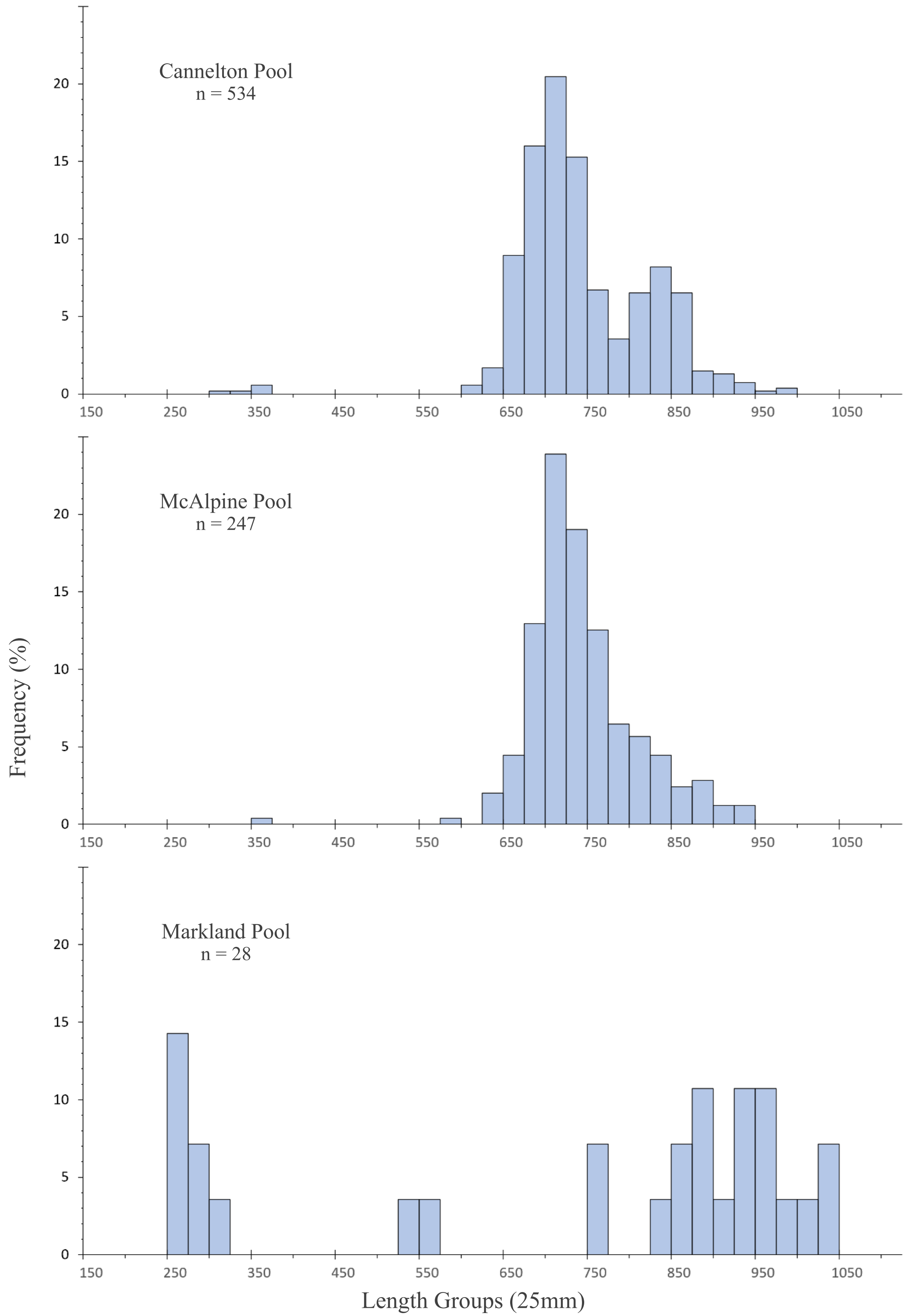

Figure 14. The length frequency distribution (25mm bins) for Silver Carp collected from the Cannelton, McAlpine and Markland pools in 2022.

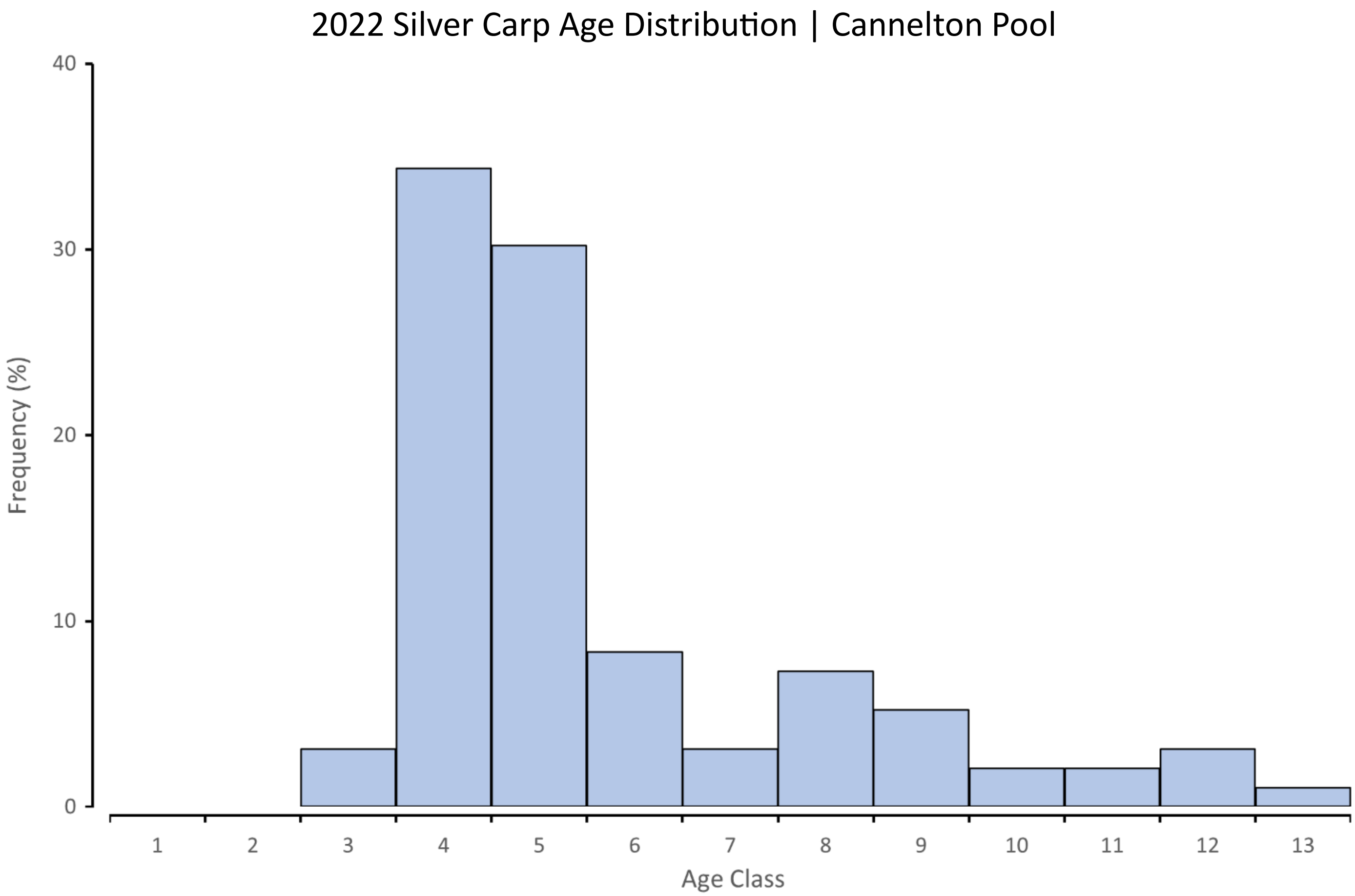

Figure 15. Age distribution of Silver Carp that were collected from the Cannelton Pool in fall 2022.

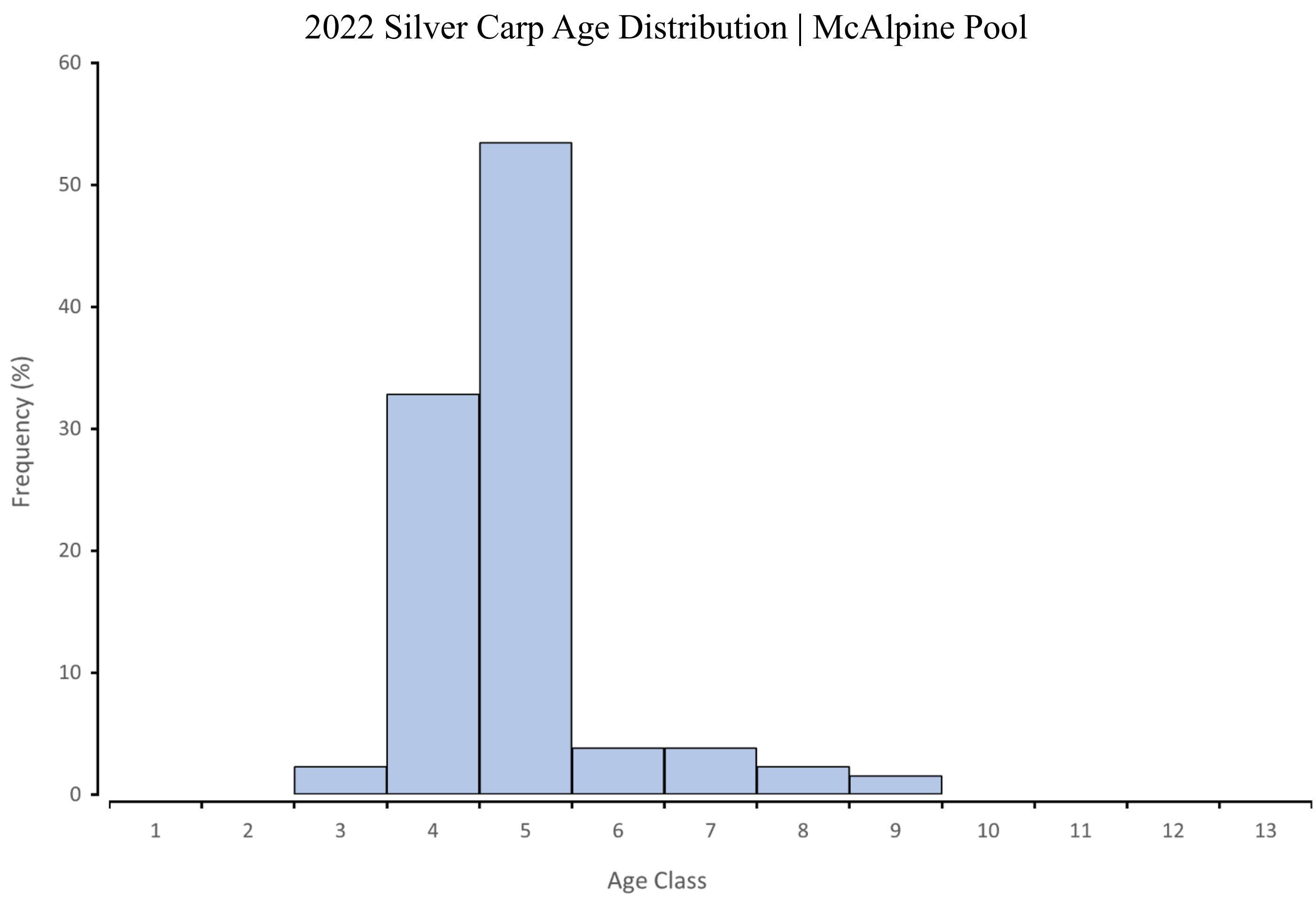

Figure 16. Age distribution of Silver Carp that were collected from the McAlpine Pool in fall 2022.

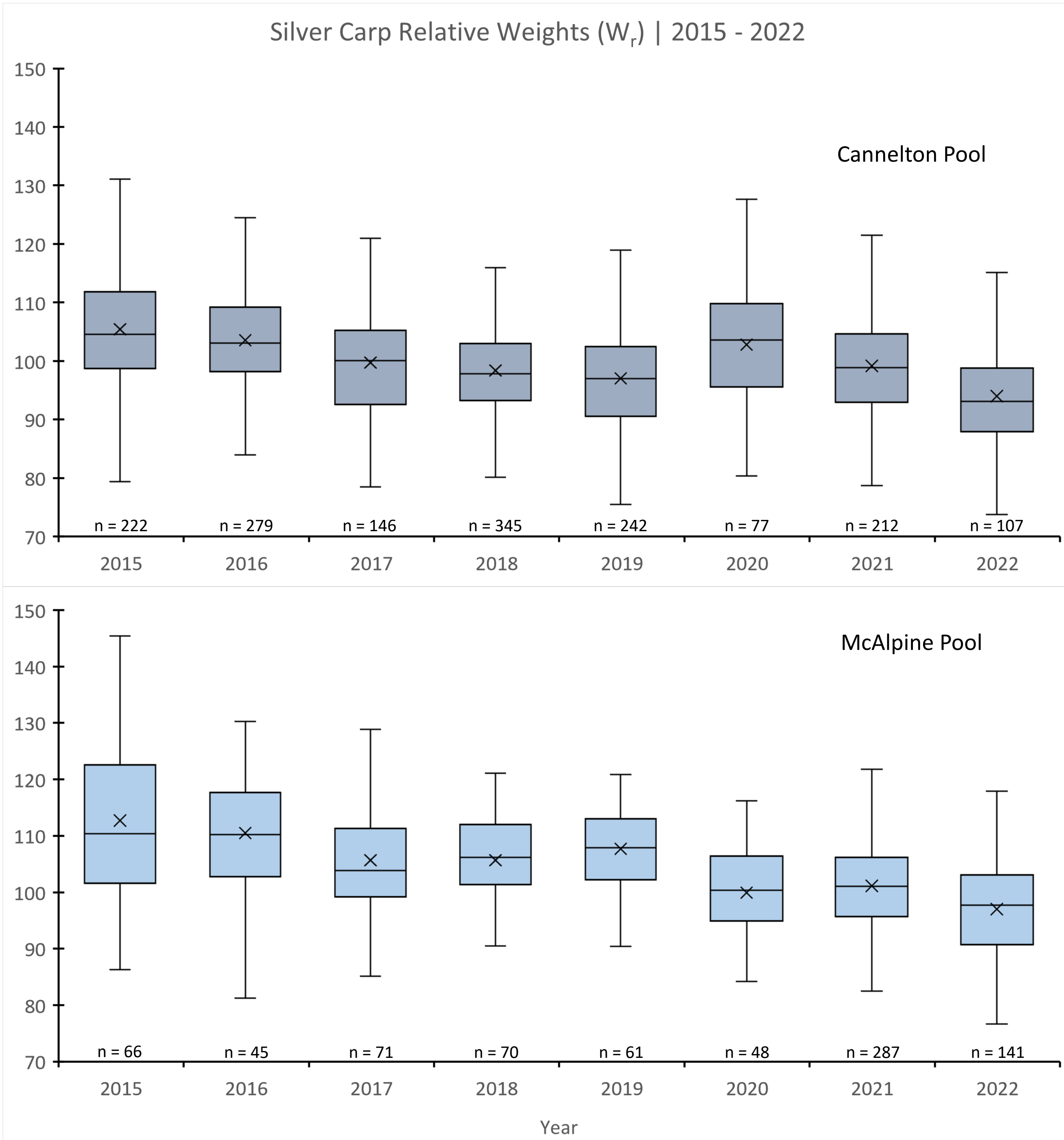

Figure 17. Relative weight (W_r) comparisons for Silver Carp captured from the Cannelton and McAlpine pools in August – November of 2015 through 2022. The standard weights needed for the W_r calculations were generated using the 50th percentile regression methods outlined in Lamer et al, 2015.

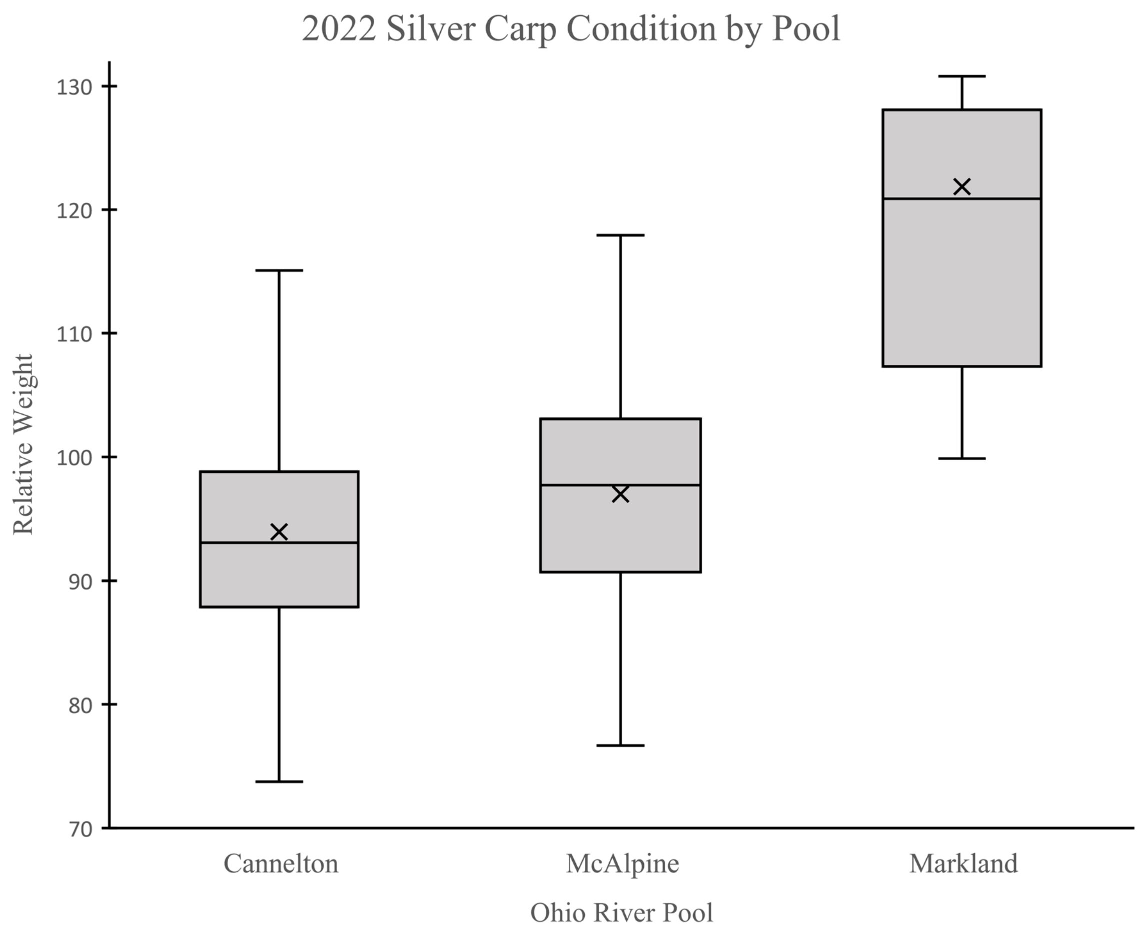

Figure 18. Relative weight (W_r) comparisons for Silver Carp collected in August – November 2022 from the Cannelton, McAlpine and Markland pools of the middle Ohio River. The standard weights needed for the W_r calculations were generated using the 50^{th} percentile regression methods outlined in Lamer et al, 2015.

Figure 19. (from B. Novak masters thesis) Trends in CSS slope in the Illinois River between 1994 – 2021. Three time periods are illustrated that are driven by patterns in the data. The pre-invasion period (1994 – 2004) maintains a slope around a mean (or equilibrium) value of -0.22 (+/- 0.005 s.e.), then the invasion period between 2005 – 2013 is evidenced by a period of radical fluctuations in size structure ranging between -0.2 and -0.4. The -0.2 slope is consistent with the pre-invasion period, but the -0.4 are very steep reflecting an increase in small fish or a loss of large fish. WVU conjectures (to be determined) that this may reflect new year classes of carp entering the system. Alternatively, the lower catch of large fish may be related to reduced effectiveness of the gear, as carp occupying the largest size classes are notoriously difficult to sample accurately. Regardless, these alternatives lead to real changes in the sampled community that can be tracked using CSS. Finally, and open to interpretation, a new steeper equilibrium was formed between 2014 and 2021, during this period lower interannual variation appears, suggesting stabilization around a new mean slope value (-0.28 +/- 0.008 s.e.).

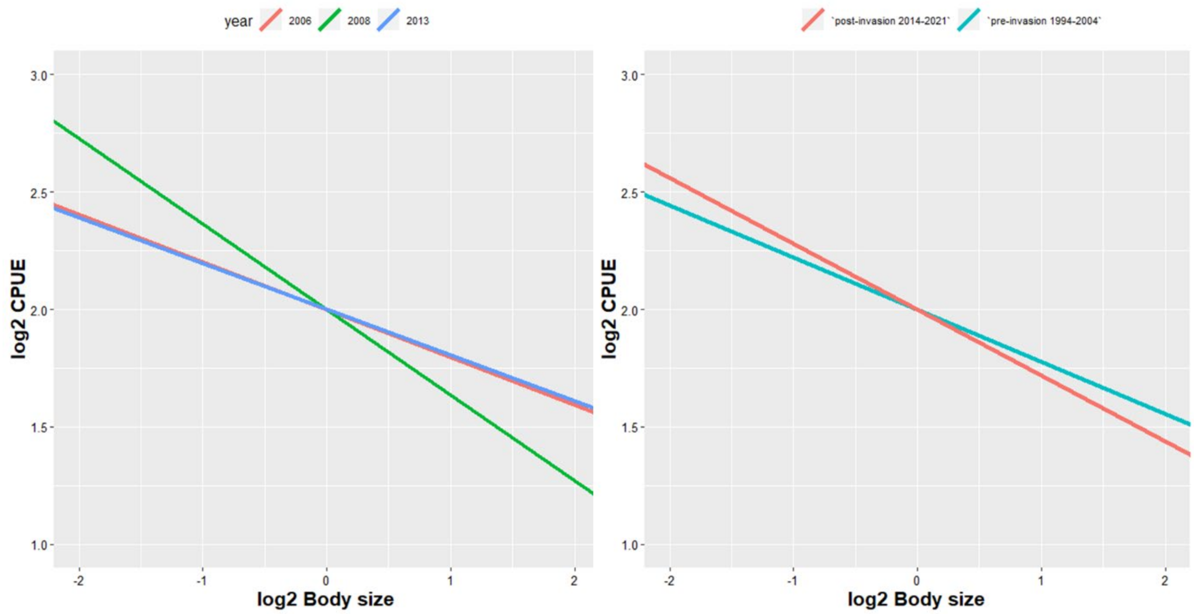

Figure 20. (from B. Novak masters thesis) Traditional view of CSS log2 CPUE against log2 body size (in this case total length) demonstrates in the right pane the difference in mean CSS slope between the pre- and post-invasion time periods and in the left pane among the high interannual variation observed during the impactful invasion period (2005 – 2013).

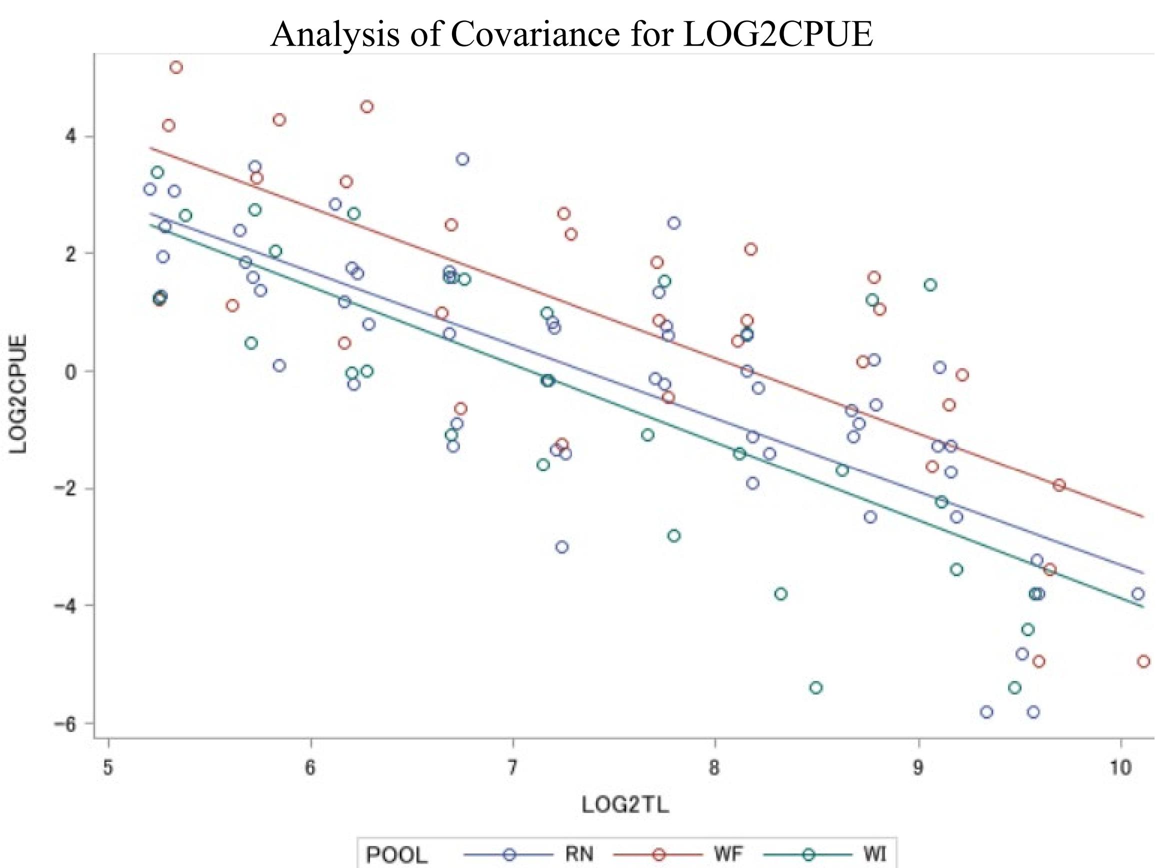

Figure 21. CSS of Racine, Winfield, and Willow Island pools in 2022. CSS slopes were not significantly different among pools with individual slopes of -1.24 +/- 0.13, -1.28 +/- 0.20, and -1.33 +/- 0.23 respectively.

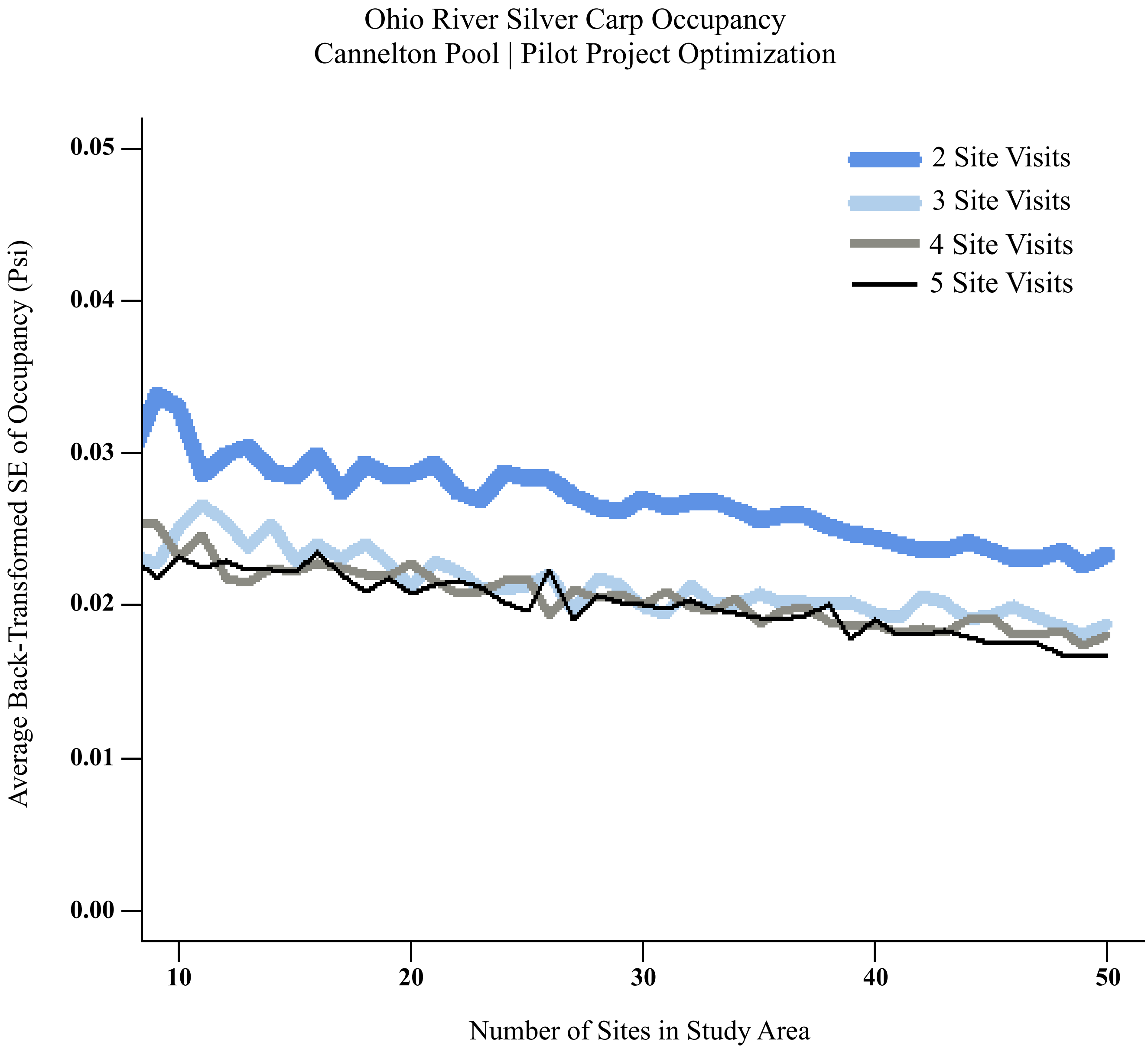

Figure 22. A graph of the average back-transformed standard error (SE) for occupancy estimates under different configurations for the number of selected sites and site visits. In general, increasing the number of visits from two to three shows a moderate improvement in the reduction of standard error estimates of site occupancy. However, further increases in site visits are unnecessary since they provide little to no improvement.

Black Carp Reports | Ohio River Basin

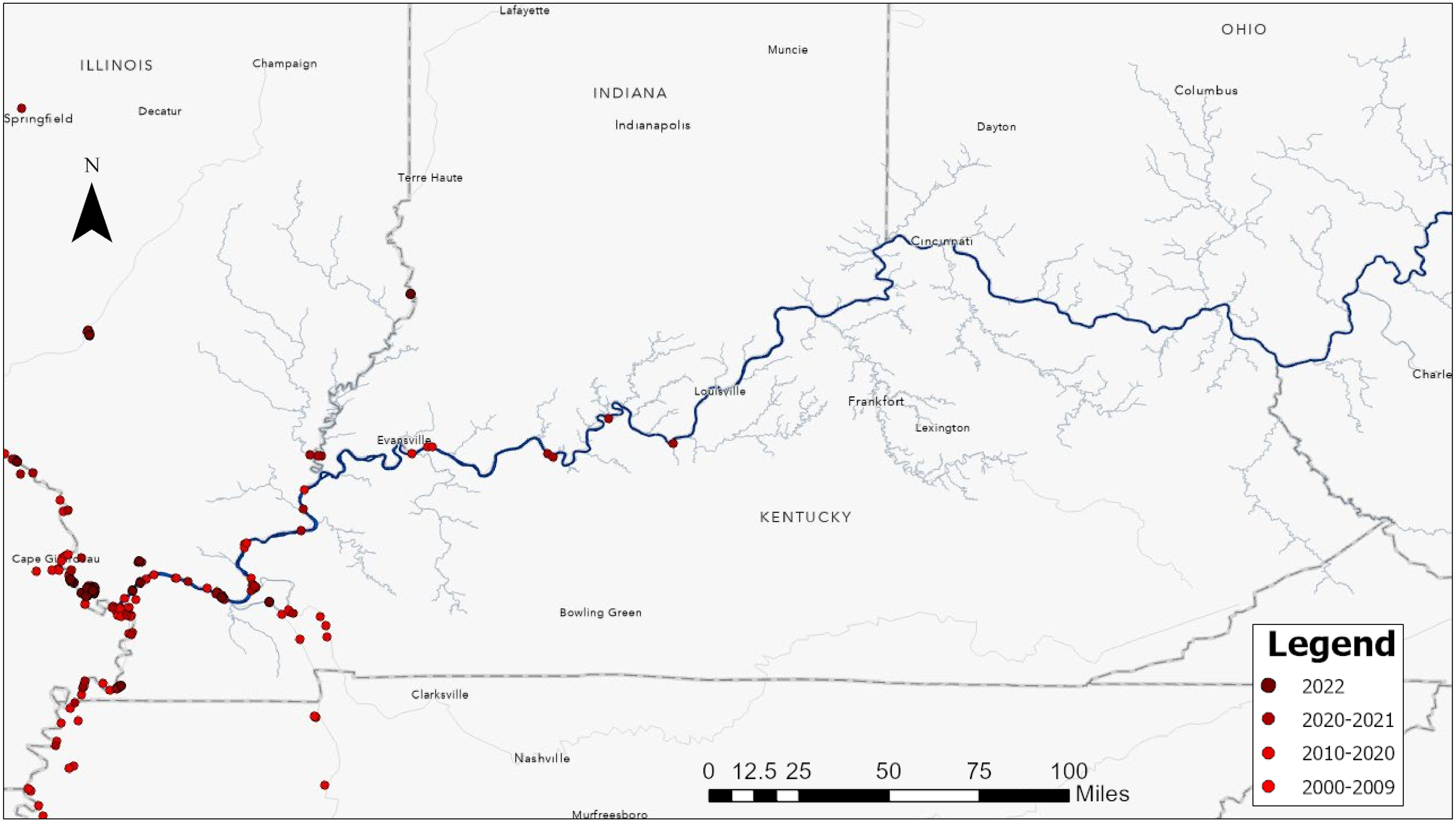

Figure 23. A map of the Ohio River Basin that shows the collection sites of Black Carp that were added to the USGS Nonnative Aquatic Species (NAS) database between 2003 and 2022.

Silver Carp Reports | Ohio River Basin

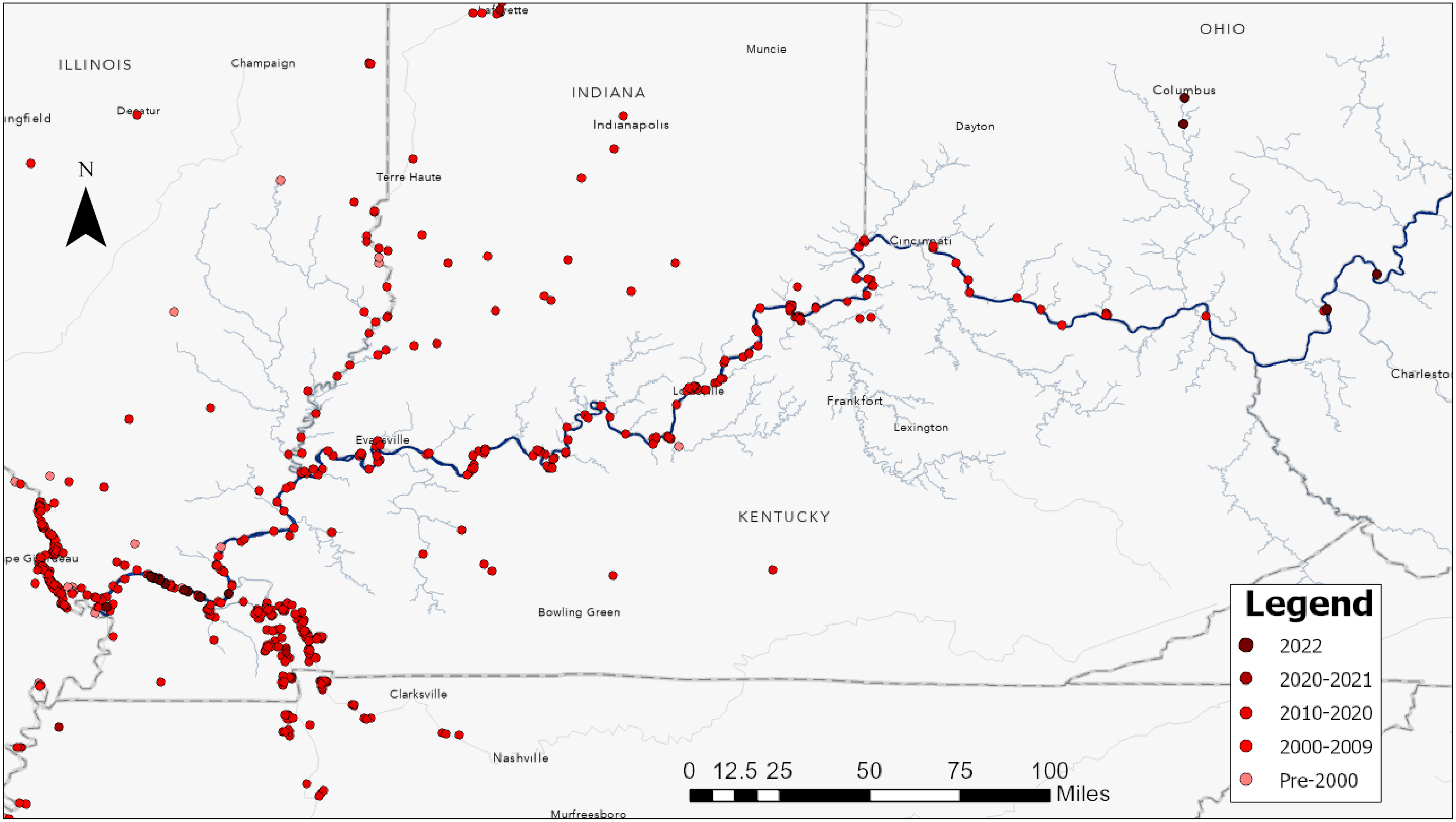

Figure 24. A map of the Ohio River Basin that shows the collection sites of Silver Carp that were added to the USGS Nonnative Aquatic Species (NAS) database between 1972 and 2022

Bighead Carp Reports | Ohio River Basin

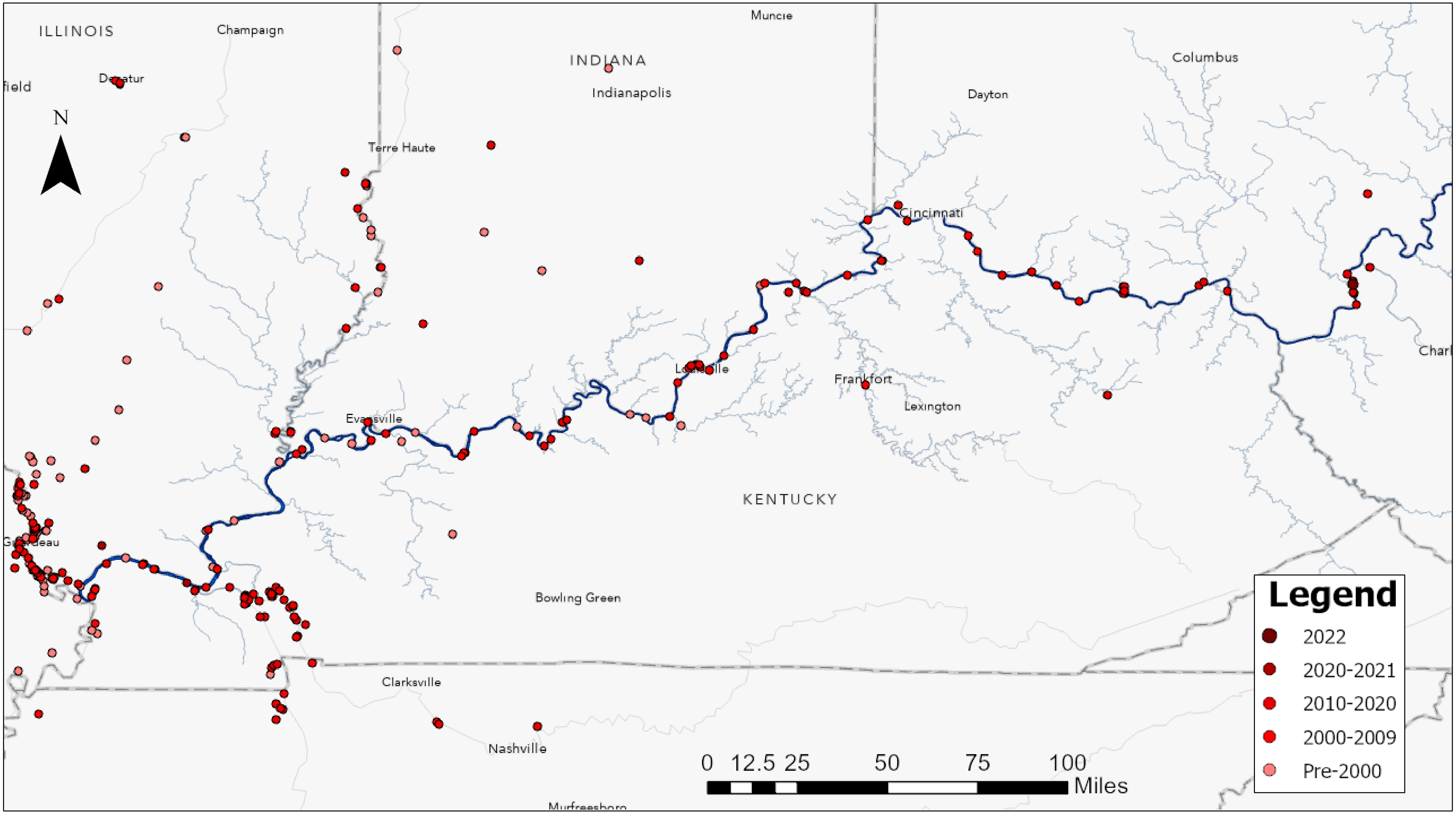

Figure 25. A map of the Ohio River Basin that shows the collection sites of Bighead Carp that were added to the USGS Nonnative Aquatic Species (NAS) database between 1980 and 2022

Grass Carp Reports | Ohio River Basin

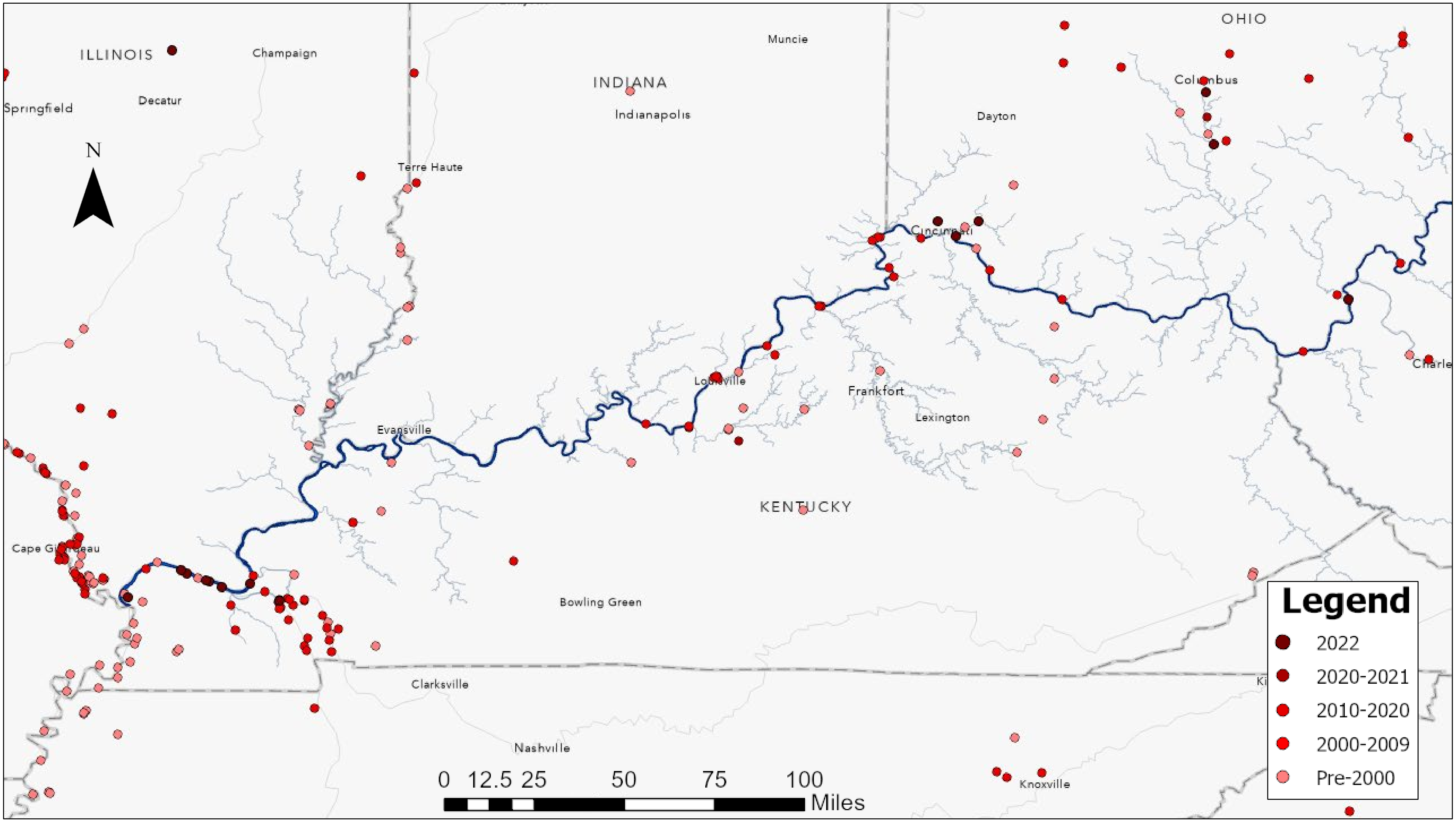

Figure 26. A map of the Ohio River Basin that shows the collection sites of Grass Carp that were added to the USGS Nonnative Aquatic Species (NAS) database between 1968 and 2022.