Commonwealth of Kentucky

Date: June 30, 2019

Period: 01 April 2018
through
31 March 2019

ANNUAL PERFORMANCE REPORT

for

Asian Carp Research and Monitoring

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Department of Fish and Wildlife Resources

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STATE: Kentucky

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2018 – February 28, 2019

Research and Survey Section

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

Project Objectives:

1. Monitor species composition, abundance, and condition of fish from Barkley Dam tailwaters and Kentucky Dam tailwaters to identify trends over time and make comparisons to historical data.
2. Compare current creel survey angler use and catch statistics to those collected in previous years' surveys conducted in the Kentucky Dam tailwater and Barkley Dam tailwater.
3. Determine current tailwater angler opinions about the impacts of increasing densities of Asian carp on their fishing effort and success.

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 2018 to assess fish species composition and relative abundance. The total number of fish captured during these efforts was 5,684 fish comprised of 53 species during 7.25 hours of effort. 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 bluegill 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, gizzard shad (77), smallmouth bass (82), smallmouth buffalo (78), and bigmouth buffalo (75) exhibited low mean relative weights. In the Barkley Tailwater, gizzard shad (75), freshwater drum (82), and bigmouth buffalo (84) exhibited less than ideal condition. Mean relative weights for silver carp remained low in Kentucky (73) and Barkley (83) tailwaters in 2018. 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 30 silver carp were captured, and 113 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 2018, therefore, there is no reporting for objectives 2 and 3 in this report. The next creel survey in the Kentucky Lake and Lake Barkley tailwaters will be conducted in 2019.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 28 February 2019
Work accomplished – 28 February 2019

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

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). Sampling consisted of standardized 900-second runs using pulsed DC electrofishing in the spring and fall of 2018 to assess species composition and relative abundance. 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). Spring sampling for this project is scheduled to occur in the months of April, May, and June. However, due to high water events in 2018, sampling did not occur in either tailwater in April. Fall sampling is scheduled for September, October, and November. However, due to high water events and scheduling conflicts, sampling only occurred in October of 2018. All fish were identified to the lowest taxonomic level and total length (inches) was recorded. Weight (pounds) 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 species (silver carp; *Hypophthalmichthys molitrix*, bighead carp; *Hypophthalmichthys nobilis*, and grass carp; *Ctenopharyngodon idella*), which were euthanized after measurements were recorded.

Spring sampling in the Kentucky Tailwater resulted in the capture of 1,020 total fish comprised of 36 species during 3.0 hours of effort in 2018. Similar to previous years, members of the Clupeidae family (skipjack herring, gizzard shad, and threadfin shad) were the most abundant species captured, comprising 37.8% of the total catch (Figure 2). Other prominent rough fish species captured during spring sampling at Kentucky Tailwater included members of the Lepisosteidae (gars) and Catostomidae (suckers) families (Figure 2). Silver carp catch per unit effort (CPUE) decreased notably between 2017 (38.3 fish/hr) and 2018 (3.0 fish/hr; Table 1). However, this decrease is largely 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 behavior which made silver carp much more vulnerable to the sampling 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 in 2018 was largemouth bass (46.0 fish/hr), followed by bluegill (13.7 fish/hr) (Table 1). However, in 2018, percent catch of sunfish species was the lowest since the survey began in 2015 (9.0%; Figure 2). Percent catch of Moronidae (temperate basses) and Ictaluridae (catfish) species increased in 2018 from 2017 (Figure 2).

Fall sampling in the Kentucky Tailwater resulted in the capture of 3,364 total fish comprised of 21 species during 1.25 hrs of effort in 2018. Similar to previous years, Clupeid species, predominately threadfin shad, were the most abundant group captured, comprising 95.9% of the total catch during sampling in 2018 (Figure 3). Due to the schooling behavior exhibited by threadfin shad, saturation is often reached during fall electrofishing runs in the tailwaters. 2018 sampling produced the highest percent of total catch and CPUE (2,557 fish/hr) of threadfin shad since the survey began in 2015 (Figure 3, Table 2). However, CPUE of gizzard shad in 2018 (22 fish/hr) was the lowest recorded since the initiation of the survey (Table 2). Largemouth bass were the most prominent sport fish species captured in the Kentucky Tailwater during fall sampling in 2018 with a CPUE of (7 fish/hr; Table 2). However, catch rates of all black bass species and sunfish species declined in 2018 from previous surveys. This noted decrease may be partially due to a reduction in sampling time conducted in fall of 2018. These catch rates will be closely monitored during future surveys. Silver carp made up a similar portion of the percent total catch as was documented in 2017 (0.3%: Figure 3).

Spring sampling in the Barkley Tailwater resulted in the capture of 908 total fish comprised of 29 species during 2.0 hours of effort in 2018. Similar to previous years, the catch was dominated by sunfish and black bass species (32.3% and 19.7% of the total catch respectively). These were followed by Lepisosteids (9.6%), Asian carps (9.4%), and Clupeids (5.8%). Asian carps, predominately silver carp, were documented as having the highest CPUE and percent of the total catch since the survey began in 2016 (42 fish/hr, 9.4%; Table 3, Figure 4). Members of the Moronidae and Ictaluridae families also achieved the highest catch rates and percent of the total catch for those species during 2018 spring sampling in the Barkley Tailwater (Table 3, Figure 4).

Fall sampling in the Barkley Tailwater resulted in the capture of 392 total fish comprised of 25 species in 1.0 hrs of effort in 2018. Complementary to previous years, Clupeid species, primarily threadfin shad, were still the most abundant species captured in Barkley Tailwater during fall sampling in 2018, comprising 31.9% of the total catch (Figure 5). However, the percent of total catch and CPUE for Clupeid species was the lowest recorded since the survey began in 2016 (Figure 5, Table 4). This decrease could be a result of decreased sampling effort in 2018 due to high water conditions. Threadfin shad are known to travel in schools, and this decrease in catch may also be indicative of environmental conditions not conducive for the large schools to aggregate in the tailwaters during the sampling timeframe. However, there is the possibility that competition for space and resources presented by Asian carp populations in the tailwaters has negatively impacted the threadfin shad populations. This will continue to be investigated in future surveys. Other prevalent fish species caught in Barkley Tailwater during 2018 fall sampling were sunfish species (31.4% of total catch), Cyprinids (minnows and shiners) (11.2% of total catch), and Asian carps (7.4% of total catch) (Figure 5). Silver carp CPUE during fall sampling in Barkley Tailwaters increased again in 2018 from previous years (2016 = 4.0 fish/hr, 2017 = 13.67 fish/hr, 2018 = 29 fish/hr) (Table 4).

Length frequency distribution for silver carp captured in Kentucky Tailwater during spring sampling in 2018 ranged from 12-36 inches, and were dominated by the 18-23 inch classes (N=9; Table 1). In comparison, silver carp length distribution in 2017 ranged from 11-37 inches and were dominated by 15-17 inch classes. Silver carp lengths from Barkley Tailwater in spring were similar to those observed in 2017 and ranged from 16-33 inches (N=84; Table 3). Fall sampling in Kentucky Tailwater captured silver carp with lengths ranging from 16-31 inches (N= 11) as compared to 2017 when silver carp lengths ranged from 12-36 inches (N=19; Table 2). Silver carp lengths from Barkley Tailwater during fall sampling ranged from 16-37 inches (N=29; Table 4). During all sampling efforts in 2018, no silver carp less than 12 inches in length, or young of year silver carp, were captured in the Kentucky or Barkley tailwaters.

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 density 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 for this project resulted in the removal of 30 silver carp from Kentucky Tailwater and 113 silver carp from Barkley Tailwater in 2018.Targeted electrofishing sampling for silver carp conducted through KDFWR's Experimental Gears project removed over 1,300 silver carp from the Barkley Tailwaters in 2018.

Relative weights (*Wr*) were calculated for selected species collected during fall sampling to monitor fish condition (Tables 5 and 6). 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 decreased between 2017 and 2018, but remained higher than observations in 2015 and 2016 (Table 5). Relative weights recorded in 2018 for yellow bass, white bass, and smallmouth buffalo were the highest observed since the survey began in 2015. However, also in 2018, smallmouth bass, largemouth bass, freshwater drum, bigmouth buffalo, and silver carp presented the lowest mean relative weights observed for those species since 2015 (Table 5). The low mean *W*r for silver carp is especially concerning (*W*r = 73), as this may be an indication of increased competition for resources in the tailwaters as the silver carp population grows. In the Barkley Tailwaters the mean *W*r for silver carp remained similar to previous years (*W*r = 83), and indicates silver carp in the Barkley Tailwaters are in better condition than silver carp in the Kentucky Tailwaters (Table 6). However, the sample sizes of silver carp captured in this study are low compared to the actual population size (29 fish in Barkley Tailwater, 11 fish in Kentucky Tailwater) and may not be a true representation of condition for the silver carp population in these locations as a whole. During sampling in the Barkley Tailwater in 2018, mean relative weight values decreased for smallmouth bass and freshwater drum (Table 6). However, white bass, bluegill, redear sunfish, spotted bass, and smallmouth buffalo had the highest mean *W*r values observed since 2016. Mean relative weight values remained similar to previous years for largemouth bass and gizzard shad (Table 6).

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.

The Western Fisheries District branch of the KDFWR fisheries division collected some data on sportfish in the Kentucky and Barkley tailwaters previous to this study. Data was collected from fish in both tailwaters in the fall of 2002, 2011, and 2015. Fish were captured through standardized electrofishing runs, measured, and weighed. Using this historical data, comparisons of sport fish catch rates and condition were made to the information presented in this report. These comparisons did not reveal any appreciable declines in sport fish numbers or condition since Asian carp have become abundant in the tailwaters. Sport fish, including: catfish, *Morone* sp., black bass, sunfish, and crappie, in the Kentucky and Barkley tailwaters still show good condition despite the high densities of Asian carp in these areas.

Creel Survey

A creel survey is scheduled to be conducted in Kentucky Tailwater and Barkley Tailwater every three years. This is to allow rotation of the creel survey technician between Kentucky Lake, Lake Barkley, and the tailwaters. The last creel survey conducted in the Kentucky and Barkley tailwaters was from February 15, 2016 through November 15, 2016. Therefore, the next creel survey will be conducted in 2019, on the same schedule. The creel survey is designed to have random, non-uniform probability with the days and time periods to be surveyed each week randomly selected. The overall temporal sampling scheme is a minimum of 10 days per month in each tailwater, consisting of at least 3 weekend days in each tailwater. There are three time periods: morning, afternoon, and late evening. The late evening time period is only utilized for a portion of the survey to collect snagging and bow fishing data. Daily surveys have two parts, angler counts conducted from the bank with binoculars, and angler interviews. All anglers are counted at a randomly chosen time each day in order to calculate a daily average for total effort. An attempt is made to interview all anglers in the tailwater area. This survey is an access point survey and no boat will be used. Data recorded during each tailwater creel survey is used to compare current estimated angler use and catch statistics to those collected in previous tailwater surveys. Anglers will also be administered an angler attitude survey to gauge angler opinions regarding the impacts of increasing Asian carp densities on their fishing effort and success. The Kentucky Tailwater survey extends from the Kentucky Lake Dam downstream to the Interstate 24 bridge. The Barkley Tailwater survey extends from the Lake Barkley Dam downstream to the US Hwy 62 bridge (Figure 1).

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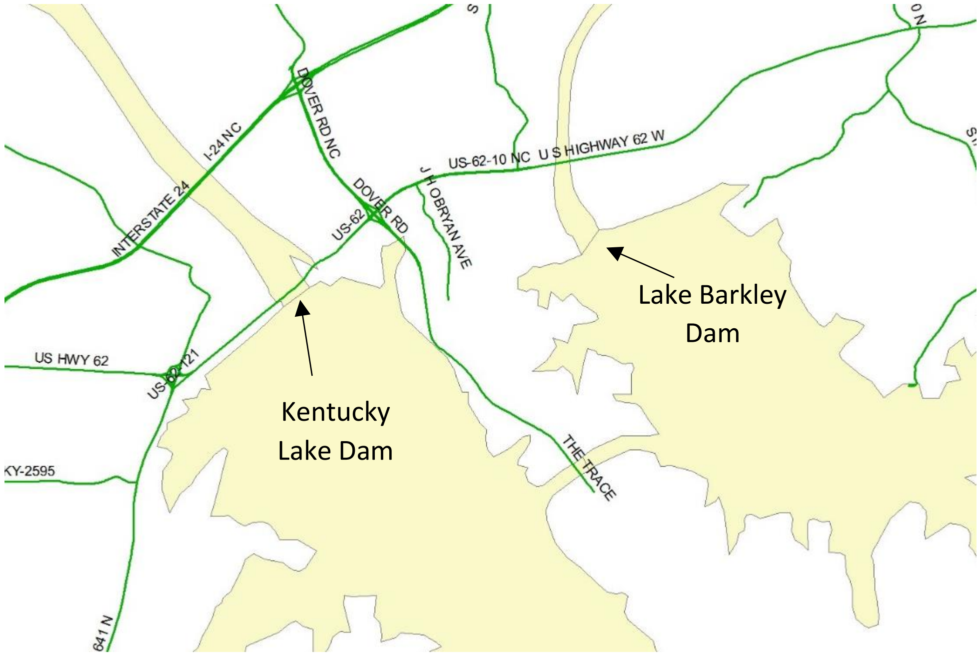

Figure 1. The tailwater electrofishing and creel survey at Kentucky Lake Tailwater extended from the dam downstream to the Interstate 24 bridge. The electrofishing and creel survey at Lake Barkley Tailwater extended from the dam downstream to the US Hwy 62 bridge.

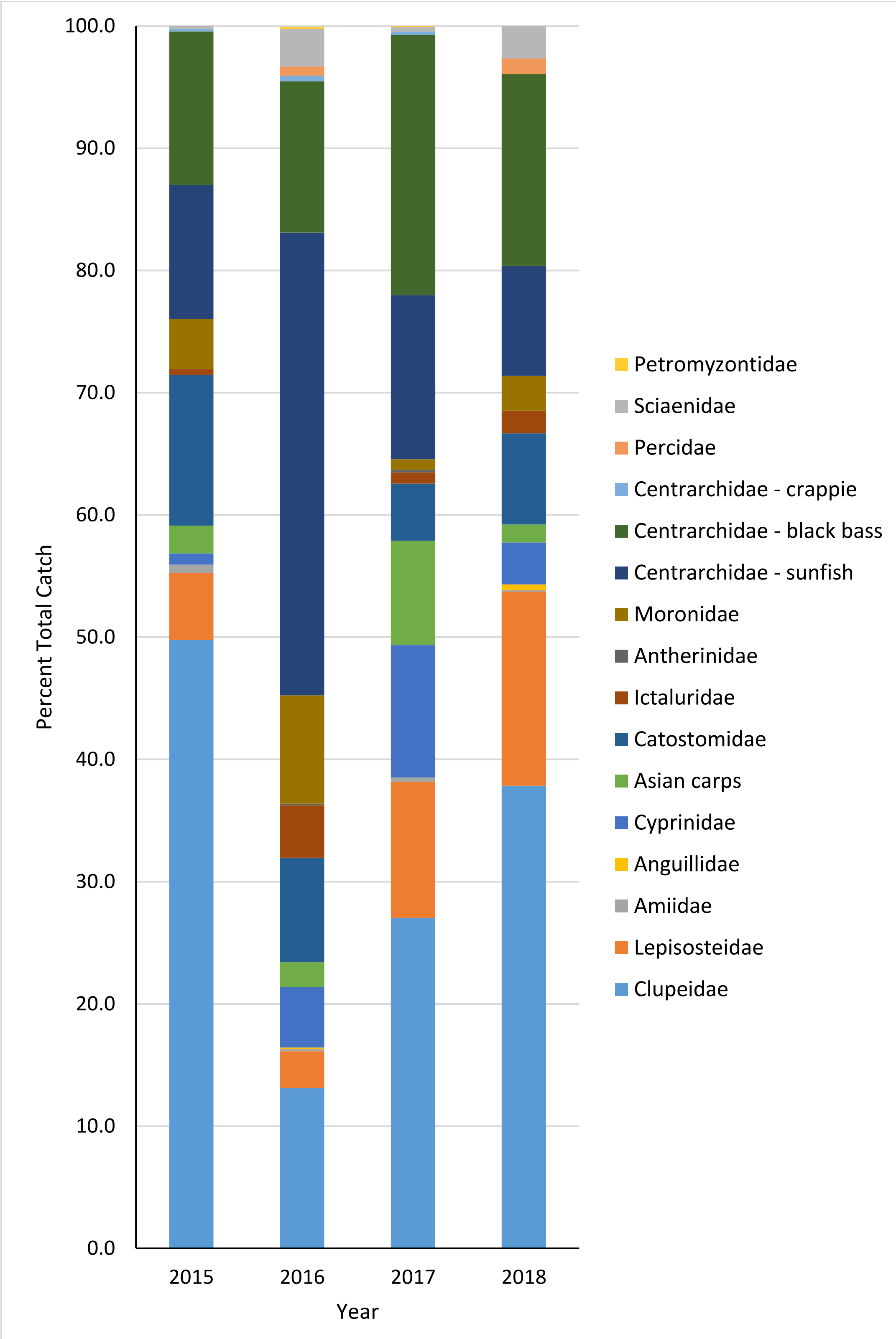

Figure 2. Comparison of percent total catch by number of each family identified from spring community sampling via electrofishing in Kentucky Tailwater, 2015 – 2018.

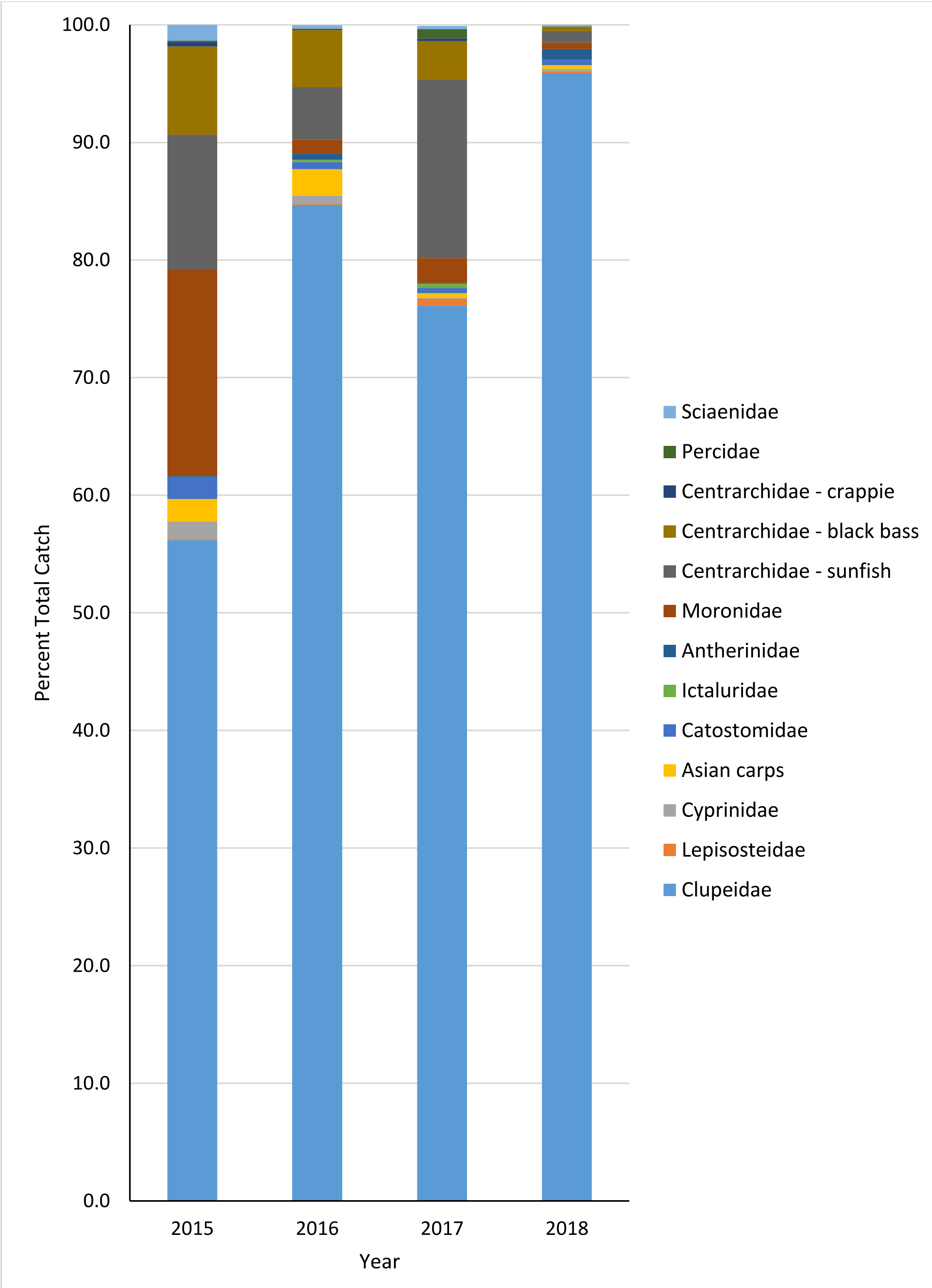

Figure 3. Comparison of percent total catch by number of each family identified from fall community sampling via electrofishing in Kentucky Tailwater, 2015 – 2018.

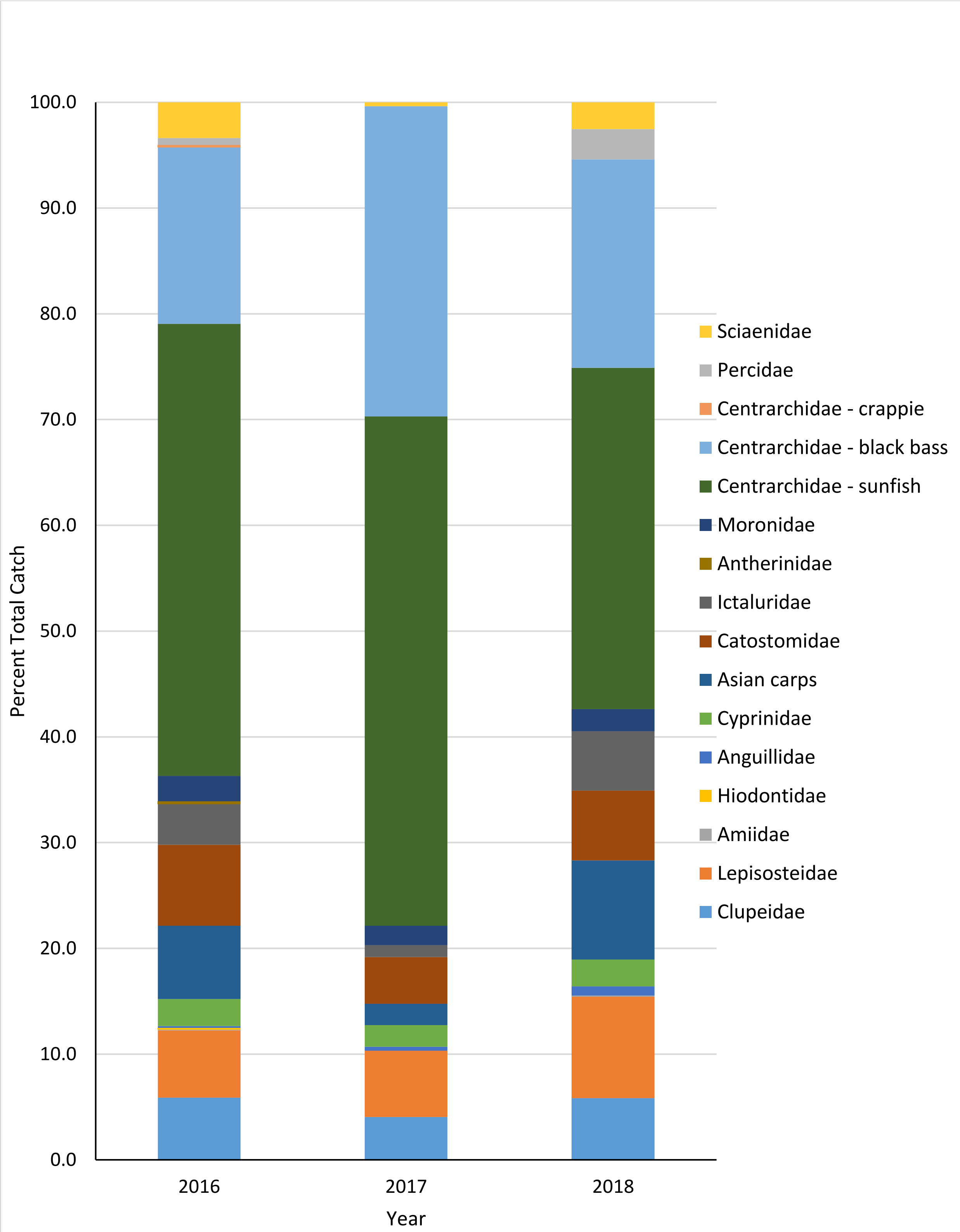

Figure 4. Comparison of percent total catch by number of each family identified from spring community sampling via electrofishing in Barkley Tailwater, 2016 – 2018.

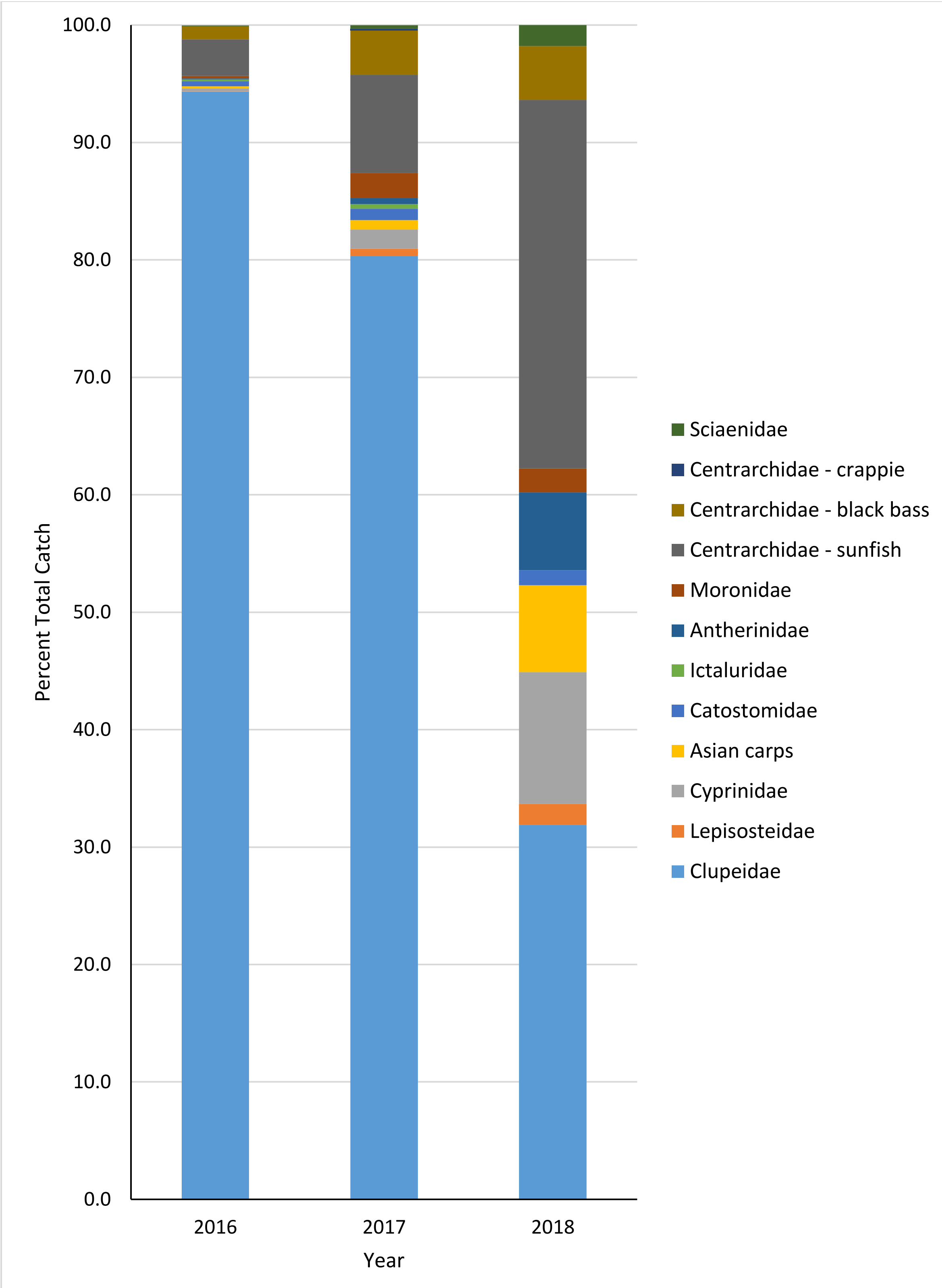

Figure 5. Comparison of percent total catch by number of each family identified from fall community sampling via electrofishing in Barkley Tailwater, 2016 – 2018.

Table 1. Length frequency and CPUE (fish/hr) for select species of fish collected during 3.0 hours of electrofishing at the Kentucky Tailwater in spring of 2018. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																													TOTAL	CPUE	S.E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	30	34	36			
Skipjack herring		1	1																											2	1	0.7
Gizzard shad*				2	17	16	17	24	13	16	15	4			1															377	126	70.7
Threadfin shad				1	1	5																								7	2	1.7
Grass carp																1	1				1					2	1			6	2	1.2
Silver carp													1					2	1	1		1	2						1	9	3	1.6
Smallmouth buffalo												7	8	14	5	10	4	3	2	2	1		1		1					58	19	4.6
Bigmouth buffalo													2				1	2		2	2	1								10	3	1.6
Channel catfish														1																1	0	0.3
Flathead catfish						1	1	2	2	5	1	1	1		1	1						1						1		18	6	2.4
White bass						1	3			2																				6	2	1.4
Yellow bass					2	9	4	1																						16	5	5.0
Bluegill		1	10	10	9	8	1	2																						41	14	3.2
Redear sunfish						1				1																				2	1	0.5
Smallmouth bass					1	2		1			2	3	2	1	3		3		1											19	6	2.6
Spotted bass					1	1	1																							3	1	0.5
Largemouth bass		2			1	1	5	5	9	27	23	15	2	6	6	7	6	5	3	2	2	1								138	46	9.2
Sauger														1	1															2	1	0.5
White bass/Striped bass hybrid						3	1	1		2																				7	2	2.3

* species were randomly subsampled

Table 2. Length frequency and CPUE (fish/hr) for select species of fish collected during 1.25 hours of electrofishing at the Kentucky Tailwater in fall of 2018. (CPUE = catch per unit effort; S.E. = standard error)

Species	Inch Class																							TOTAL	CPUE	S.E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	27	31	36			
Skipjack herring			2	1																				3	2	1.6
Gizzard shad			5	1			3	6	3	2	1	4	1		1									27	22	10.2
Threadfin shad*	1	47	51																					3196	2557	1845.1
Silver carp																1	2	4	1	2		1		11	9	6.9
Smallmouth buffalo																		1						1	1	0.8
Bigmouth buffalo																					1		1	2	2	1.0
White bass													2	5										7	6	5.6
Yellow bass		1	3			1	1	2	1															9	7	4.3
Striped bass				1														1						2	2	1.0
Bluegill		6	5	2	5	5	2																	25	20	4.0
Smallmouth bass					1													1						2	2	1.0
Spotted bass			1																					1	1	0.8
Largemouth bass				1		1					2							3	1	1				9	7	2.9

* species were randomly subsampled

Table 3. Length frequency and CPUE (fish/hr) for select species of fish collected during 2.0 hours of electrofishing at the Barkley Tailwater in spring of 2018. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																															TOTAL	CPUE	S. E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	32	33			
Skipjack herring		1	1								2																					4	2	1.5
Gizzard shad*						2	8	13	6	7	2		2	1																		49	25	18.4
Grass carp																									1							1	1	0.5
Silver carp*																1	1	1		2			4	8	12	4	2	2	4	2	1	84	42	28.4
Smallmouth buffalo													2	6	9	10	7	6	3	3	4	3		2	1							56	28	6.7
Bigmouth buffalo													1							1												2	1	1.0
Black buffalo																						1										1	1	0.5
Channel catfish											1																					1	1	0.5
Flathead catfish				1		1		3	9	7	11	3	5	1	1	2	1	3					1			1						50	25	5.4
White bass						1	1	6	1		3	1	1	1																		15	8	4.2
Yellow bass						1	3																									4	2	1.1
Bluegill*			6	15	20	21	3	1																								113	57	31.2
Redear sunfish		1		2	2	1	2		1	2	3																					14	7	2.0
Smallmouth bass				2	3	1	3	1	2	4			2	1	1	1																21	11	2.3
Largemouth bass*		4	1		4	16	23	12	11	16	23	7	3	2	6	3	3	5	1		1											158	79	10.6

* species were randomly subsampled

Table 4. Length frequency and CPUE (fish/hr) for select species of fish collected during 1.0 hour of electrofishing at the Barkley Tailwater in fall of 2018. (CPUE = catch per unit effort; S. E. = standard error)

Species	Inch Class																														TOTAL	CPUE	S. E.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27	28	31	32	37			
Skipjack herring		1	23	7	1	2																									35	35	18.0
Gizzard shad*			1			4	3	8	1	4	1		1																		23	23	8.1
Threadfin shad*	1	45	19																												67	67	12.8
Silver carp																2	2	1		3	5	1	3	3		4	2	1	1	1	29	29	17.2
Smallmouth buffalo																									1						1	1	1.0
Bigmouth buffalo																				1											1	1	1.0
White bass														1	2																3	3	3.0
Striped bass			1																												1	1	1.0
Bluegill*	1	21	27	6	6	3																									70	70	14.5
Redear sunfish							1				1																				2	2	1.2
Smallmouth bass						1	1			1			1																		4	4	1.6
Spotted bass												1																			1	1	1.0
Largemouth bass						2	1	1	2	1	1	2	2						1												13	13	5.0
White bass/Striped bass hybrid																1	1		1	1											4	4	4.0

* species were randomly subsampled

Table 5. Mean relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Kentucky Tailwaters in 2015 - 2018. (S.E. = standard error)

Species	2015			2016			2017			2018		
	N	Mean *Wr*	S.E.	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	21	77	2.0
Blue catfish							1	108				
Channel catfish				1	102		1	105				
Flathead catfish				7	98	6.2	19	100	6.3			
Yellow bass	29	74	1.2	29	84	1.8	104	83	2.2	7	90	12.3
White bass	7	92	4.1	13	99	2.6	2	97	20.4	7	108	1.3
Striped bass										1	101	
White bass/Striped bass hybrid				2	81	7.5						
Bluegill	69	88	1.7	49	103	3.7	220	93	2.2	18	89	6.4
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	1	82	
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	7	93	5.5
White crappie	2	79	0.9	2	90	8.7	3	76	7.3			
Black crappie	1	91	0.0				12	90	2.7			
Sauger	1	87	0.0				3	97	21.8			
Freshwater drum	12	91	5.4	11	100	2.7	17	92	3.3	5	89	3.8
Smallmouth buffalo	10	76	2.9	15	79	1.5	22	77	1.4	1	78	
Bigmouth buffalo							3	86	1	2	75	7.4
Silver carp	6	84	2.3	75	89	1.6	19	82	2.4	11	73	3.2

Table 6. Mean relative weight (*Wr*) and standard error for a subsample of fish collected during fall electrofishing at Barkley Tailwaters in 2016 - 2018. (S.E. = standard error)

Species	2016			2017			2018		
	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.	N	Mean *Wr*	S.E.
Gizzard shad	96	70	1.6	176	80	0.9	18	75	2.5
Channel catfish	1	67		2	92	1.0			
Flathead catfish	13	94	1.7	17	106	5.8			
Yellow bass	2	88	8.7	73	79	1.3			
White bass	11	96	3.7	8	86	2.2	3	98	4.9
Striped Bass				2	90	5.9			
White bass/Striped bass hybrid				9	89	2.7	4	103	4.6
Bluegill	49	111	3.1	107	104	2.5	31	115	8.3
Redear sunfish	17	93	2.1	9	97	3.7	2	106	14.6
Smallmouth bass	4	86	3.6	11	95	3.8	3	87	5.6
Spotted bass	3	107	11.0				1	125	
Largemouth bass	37	101	1.9	118	95	1.2	10	95	3.4
White crappie				3	88	6.6			
Black crappie				5	86	6.3			
Freshwater drum	6	84	4.4	14	97	3.0	7	82	3.5
Smallmouth buffalo	21	84	1.4	28	84	1.6	1	99	
Bigmouth buffalo	2	88	4.0	1	79		1	84	
Silver carp	9	81	2.9	41	83	2.1	29	83	2.7

STATE: Kentucky

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2018 – March 31, 2019

Research and Survey Section

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

Project Objectives:

1. Monitor sport fish bycatch of the Asian carp harvest program (ACHP) through review of commercial fishing reported harvest as well as ride alongs with commercial fishers.
2. Monitor sport fish condition as Asian carp harvest increases.
3. Increase removal of Asian carp from Kentucky Lake, Lake Barkley and their respective tailwaters through subsidy program.

ACTIVITY

Asian Carp Harvest Program

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 5,891,774 lbs of Asian carp through the ACHP.

April-December of 2018 commercial fishermen participating in the ACHP made a record of 918 fishing trips to target Asian carp and harvested 1,880,253 lbs of Asian carp from Kentucky's waters. 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. KDFWR conducted 24 ride-alongs with commercial fishermen utilizing the ACHP from January through December 2018. During ride-alongs 28,327 yards of gillnet was fished and 53,785 lbs of Asian carp were harvested. Smallmouth buffalo was the most common bycatch species during ride-alongs in 2018 making up 27% of all bycatch, followed by Freshwater drum (20%) and blue catfish (12%). In relation to total bycatch, the number of sport fish captured is low (25% during ride-alongs in 2018; 3% from all commercial fishermen reports in April-December 2018). The survival rate of sport fish captured through the ACHP during the 2018-2019 season was 96.4%. 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 prior fishing. KDFWR again revised the subsidy program in 2018 and funds are now paid directly to the commercial fishermen at the end of each month. Another change made in 2018 was KDFWR allowed commercial fishermen fishing in Kentucky Lake and Lake Barkley on a net permit to receive the subsidy for Asian carp harvested while fishing on their net permit. This has retained interest in the subsidy and fishermen have continued to use the program. Total pounds of Asian carp harvested and claimed under the subsidy program in 2018 amounts to 722,740 lbs, with total expenditure of $36,136.98. (Not grant funded)

A. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2019
Work accomplished - 31 March 2019

B. SIGNIFICANT DEVIATIONS

None

C. REMARKS

None

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 (bighead carp: *Hypophthalmichthys nobilis*, silver carp: *Hypophthalmichthys molitrix*, grass carp: *Ctenopharyngodon idella*, and black carp: *Mylopharyngodon piceus*) 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 Asian carp from Kentucky waters.

To date, commercial fishermen in Kentucky have harvested a total of 5,891,774 lbs of Asian carp through the ACHP since the program's inception in 2013 (5,780,705 lbs silver carp, 111,069 lbs bighead carp). The total harvest of Asian carp would be higher if grass carp harvest was included, however, commercial fishing reports did not delineate grass carp from common carp historically. This information will be added in future reports. Fishing seasons in this report correspond to the commercial fishing season of April – March. The number of commercial fishermen using the ACHP and the number of trips made by those fishermen has varied over the years (Table 1). The observed decrease in effort and Asian carp harvest in the 2015-2016 and 2017-2018 seasons was due largely to the inconsistency of Kentucky based Asian carp processors buying fish during those seasons. Fishermen reported an inconsistent demand for fish they harvested and therefore, invested less effort in fishing for Asian carp. In the 2018-2019 season the number of fishermen using the ACHP held steady at 21 fishermen, but the number of trips made increased greatly, resulting in the highest poundage of Asian carp harvested through the ACHP to date 1,880,253 (Table 1, Figure 1). This turnaround in fishing effort and harvest of Asian carp from Kentucky's waters is likely a result of sustained demand for Asian carp from processors in western Kentucky and Illinois.

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 gill nets. In 2017, KDFWR staff began catching silver carp from the 2015-year class in experimental gill nets with 3" bar mesh in Lake Barkley. However, commercial fishermen were restricted to using 3.25" or greater bar mesh. During KDFWR sampling efforts with gill nets, bycatch information was gathered and analyzed. Observations indicated no increased risk to sport fish by using nets with 3" bar mesh (KDFWR, Monitoring Silver and Bighead Carp Relative Abundance and Density in Barkley and Kentucky Reservoirs Project Report). Therefore, in 2018, KDFWR passed an emergency regulation that allowed commercial fishermen under the ACHP to use gill nets with 3" bar mesh. Thus far, this decrease in mesh size has not had an appreciable effect on bycatch (Table 1). Previous reports indicated that over the next few years an increase in commercial harvest is probable as the 2015 silver carp cohort recruits to commercial gillnets. This prediction seems to be holding true as commercial harvest increased reached its highest level in 2018-2019 season. Historically, the primary method for harvesting Asian carp has been 4 to 5-inch mesh floating gillnets. However, during the 2018-2019 season, commercial fishermen adapted to the influx of

Asian carp from the 2015 cohort and began using predominately 3.5” bar mesh gill nets. This mesh size was also observed to have the highest capture rate of silver carp during ride alongs conducted with commercial fishermen (Figure 2). Silver carp capture rates in 3.5” mesh during the 2018-2019 season was also the highest ever recorded for the ACHP (0.55 fish/yard; Table 2). Silver carp capture rates in 2018-2019 were also high in 3.75” mesh nets (0.40 fish/yard), but distantly followed by 4” mesh (0.12 fish/yard) (Table 2). It should be noted that the majority of fish harvested through the ACHP are harvested from Lake Barkley. Commercial fishermen prefer fishing Lake Barkley over Kentucky Lake as it is shallower, has more embayments to corral fish in, less recreational traffic, and the Asian carp appear to be larger. The difference in size of Asian carp between the two reservoirs has also been observed in KDFWR sampling efforts and is described in detail in the Monitoring Silver and Bighead Carp Relative Abundance and Density in Barkley and Kentucky Reservoirs Project Report.

Asian carp harvest data was summarized by month of the year from April 2013 to December 2018 (Figures 3, 4, & 5). As expected, the number of trips made by commercial fishermen under the ACHP typically 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. During the past three seasons (April 2015 – March 2018) the number of trips being taken by commercial fishermen under the ACHP has been highest during the months of June through October. However, in the 2018-2019 season the number of trips peaked in August, but has remained fairly high through December (Figure 3). Total pounds of silver carp harvested per month is shown in Figure 4. October of 2018 had the highest weight of silver carp harvested since the ACHP began, followed by December 2018. Average pounds of silver carp harvested per trip has varied by year. With the exception of October, November, and December, the average pounds of silver carp harvested per trip was lower in every month of 2018 than in 2017 (Figure 5). This shift could indicate a change in the population dynamics of silver carp in Kentucky and Barkley lakes. As noted previously, commercial fishermen shifted the mesh sizes they were using in 2018 from predominately 4.25” to 3.5” mesh. Therefore, it is likely that although the total pounds of Asian carp harvested was lower, the number of Asian carp being harvested was higher in 2018 than in previous years. However, KDFWR does not require commercial fishermen to count the number of fish harvested, so this cannot be verified.

<u>Ride-Alongs</u>

KDFWR conducted 24 ride-alongs with commercial fishermen utilizing the ACHP from January through December 2018. Ride-along data is reported by calendar year. During ride-alongs 28,327 yards of gillnet was fished and 53,785 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 increased from 1 in 2017 to 3 in 2018, with an increase in mean effort from previous years (Table 3). The number of ride-alongs on Lake Barkley decreased from 28 in 2017 to 21 in 2018, with the mean effort per trip remaining similar to previous years (Table 4). The mean weight of silver carp harvested per trip in 2018 (2345 lbs/trip) remained similar to 2017 values (2481 lbs/trip) (Table 4).

Bighead carp harvest per trip during ride-alongs in Lake Barkley continued to decrease in 2018 (Table 4). Average weight of bighead carp harvested per trip during ride-alongs (16 lbs/trip) was lower than bighead carp harvest averages for the ACHP as a whole in 2018 (41 lbs/trip) (Table 5). However, the average weight of silver carp harvested per trip during ride-alongs (2,219 lbs/trip) was slightly higher than for the ACHP (2,008 lbs/trip) in 2018 (Table 5).

Waypoints for deployment locations of nets were taken during ride-alongs in 2018 (Figure 6). 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 2018 (96.4% survival; Table 1). However, sport fish survival rates recorded during KDFWR ride-alongs were much lower in 2018 (64.7%; Table 6). The ride-along data comes from a much smaller sample size (2% 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 (25% during ride-alongs in 2018; Table 6, 3% from all commercial fishermen reports in April-December 2018; Table 1). During ride-alongs in 2018 there were 359 individuals captured as bycatch which is a slight increase from bycatch in 2017 (n=295; Table 6). However, this was a result of higher numbers of rough fish being caught, not sport fish.

Smallmouth buffalo was the most common bycatch species during ride-alongs in 2018 making up 27% of all bycatch, followed by Freshwater drum (20%) and blue catfish (12%) (Table 6). The number of paddlefish captured as bycatch decreased in 2018 (n=38) from 2017 (n=62). However, the mean survival rate of paddlefish during ride-alongs also decreased to 31.6% in 2018 (Table 6). The most common species of sport fish caught in commercial gillnets during ride-alongs was blue catfish (n=42), followed by channel catfish (n=12), and flathead catfish (n=8) (Table 6). Survival rates of sport fish species varied, but the sample size is too small to draw conclusions from at this time.

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 7). Recreationally and commercially important bycatch reported captured per trip is significantly higher during ride-alongs than from commercial fishermen reports (Figure 7, Table 7). This troubling trend suggests anywhere from 50-75% of bycatch is likely not reported in harvest logs. However, ride-alongs account for a small percentage of the total number of trips made by commercial fishers (2%). To date, there is no indication of negative impacts on the sport fishery resulting from the ACHP.

Sport Fish Condition

Condition of sport fish in Lake Barkley and Kentucky lakes has been monitored by KDFWRs Western Fisheries District (WFD) staff since 1985 (CITE REPORT). Sport fish condition is calculated as relative weight (Wr). This information allows a long term perspective on sport fish condition, especially white crappie, black crappie, and largemouth bass. These three species are the primary sport fish targeted by anglers in the lakes. As Asian carp numbers increase in the reservoirs, it also increases the potential for competition of resources between these invasive species and economically important sport fish. For this report WFD provided information on sport fish condition since the ACHP program began in 2013. To date, sport fish condition has remained stable in Lake Barkley (Table 8). On Kentucky Lake, a slight decline in condition of white and black crappie in the 8.0-9.9" and ≥10" has been observed in recent years (Table 9). All though these declines are not outside of realistic annual variability, they should continue to be monitored. The somewhat opposing trends in the lakes could be a result of several factors including; higher harvest rates of Asian carp from Lake Barkley, Lake Barkley is a more fertile system (Yurista et al. 2004), and higher passage rates of Asian carp through Kentucky Dam (Tracking Movements of Silver Carp in Kentucky and Barkley Lakes Project Report). Sport fish condition in the lakes is highly variable and will continue to be monitored in following years.

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 closely monitor 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 2018 – December 2019 was substantially lower with higher commercial fishing effort than previous years (918 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.

Paddlefish exhibited a relatively low survival rate (31.6% during ride-alongs in 2018, 84.5% total ACHP in 2017-2018) in relation to other species in the bycatch (Tables 1 & 6). However, the number of paddlefish captured during ride-alongs and through the ACHP as a whole in 2018, decreased when compared to previous years (Table 7). 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 have been recorded during ride-alongs conducted since 2016 (Table 10). 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. Therefore, KDFWR staff have also been recording soak times of nets since 2017 (Table 10). However, there did not appear to be a marked difference in the survival rate of paddlefish based on temperature or soak time of nets. 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 2019.

The number of paddlefish captured as bycatch during the ACHP has decreased each year since 2015, even as effort by commercial fishermen targeting Asian carp has increased. This decline in the bycatch of paddlefish could be interpreted in several ways. On one hand, novice fishermen are less experienced with gillnets and not as knowledgeable in how to avoid capturing paddlefish while targeting Asian carp. Therefore, the decrease in paddlefish bycatch could be explained by these anglers gaining experience and refining their ability to better target Asian Carp. However, the bycatch of other species has not declined over the same time period (Table 7). Furthermore, the ACHP bycatch numbers reported by commercial fishermen are notably unreliable and differ significantly from observations conducted during ride-alongs (Figure 7). Paddlefish numbers and condition are also of concern because they compete directly with silver and bighead carp for food resources. A decline in their condition or numbers in the lakes could be a result of the high densities of Asian carp in the lakes. Additionally, paddlefish are actively targeted by commercial fishermen on the lakes and throughout Kentucky's major waterways during the annual net season. Commercial fishermen are required to submit reports of their harvest throughout the net season and the information is summarized in the Stream Fisheries Investigation Annual Report. Harvest of paddlefish during net season in 2018 decreased greatly from previous years, being the lowest on record. There are many factors that may have influenced this decline in harvest, but potential impacts that may be caused by increasing Asian carp numbers is of great concern. The ACHPshould continue to be closely monitored to ensure that the decline in bycatch of paddlefish is not indicative of their population numbers in the lakes.

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 11). 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 11).

In 2018, participation in the subsidy program increased again at the close of paddlefish season. Beginning in May, nine fishermen participated in the subsidy. However, KDFWR began receiving negative feedback from commercial fishermen and processors regarding delays in payment and re-imbursement of subsidy funds. Therefore, KDFWR discontinued the subsidy program at the end of August 2018, to re-assess the best way forward with the program. In October of 2018, KDFWR re-started the subsidy program and returned to allocating funds directly to commercial fishermen. Commercial fishermen are required to sign up as a vendor with the state, and once approved, they can receive payments from KDFWR for the subsidy. In order to reduce oversight from KDFWR staff, commercial fishermen are to submit all receipts for fish sold with their daily reports at the end of each month. These documents are verified by KDFWR staff and submitted for payment. Using this method of payment, eight fishermen participated in the subsidy October – December 2018. Another change made in 2018 was KDFWR allowed commercial fishermen fishing in Kentucky Lake and Lake Barkley on a net permit to receive the subsidy for Asian carp harvested while fishing on their net permit. This has retained interest in the subsidy and fishermen have continued to use the program. Total pounds of Asian carp harvested and claimed under the subsidy program in 2018 amounts to 722,740 lbs, with total expenditure of $36,136.98 (Table 11).Commercial fishing for Asian carp in Kentucky's waters is gaining national attention. KDFWR routinely receives calls from interested fishermen, processors, and other entities inquiring about the profitability of the industry. KDFWR recognizes that commercial fishing for Asian carp is currently the most cost effective method of mass removal of these invasive fish from Kentucky's water ways. Therefore, KDFWR has taken several steps to encourage commercial harvest of Asian carp and support the industry. The first step that KDFWR took was creating the Asian Carp Harvest Program outlined in this report. The subsidy for Asian carp to incentivize harvest from Kentucky and Barkley lakes followed in 2015. In 2018, KDFWR again took measures to increase commercial harvest by creating a free commercial license available to individuals to target and harvest only Asian carp. Another effort in 2018 was installation of a commercial grade flake ice machine at Kentucky Dam Village State Park. The ice machine began operating in August of 2018 and ran through early November. The ice machine was shut down for the winter, and will be re-opened in March of 2019. Commercial fishermen listed on the Asian Carp Harvest Program are allowed access to the ice machine 6 days/week for free. Having free ice allows commercial fishermen to properly care for harvested fish in warm temperatures and increases the value of their catch to processors.

Beginning in January 2019, KDFWR will start another venture to assist the Asian carp commercial fishery in Kentucky by partnering with the Kentucky Fish Center (KFC) (Commonwealth of Kentucky Master Agreement #7581900000427). The goal of the partnership is to develop, build, and maintain a commercial Fish House in western Kentucky in order to encourage commercial harvest of Asian carp in Kentucky Lake, Lake Barkley, and other Kentucky waterways. This entity will receive a forgivable loan from the state of Kentucky in return for certain harvest goals being met on an annual basis (Table 12). One of the top complaints of Asian Carp fishermen is that they do not always have a reliable market to sell their catch. As part of the agreement, the KFC is now required to purchase all Asian carp harvested in Kentucky at a guaranteed price from commercial fishermen, and then will sell those fish through an open online auction. The KFC will also provide pick-up of fish at convenient locations, assist commercial fishermen with equipment needs as possible, and further develop the domestic market for Asian carp products. This will provide a consistent buyer for Asian Carp fishermen and assuage the fears of new potential fishermen that they will not be able to sell their product. Furthermore, as a benefit and encouragement to processors, the KFC will also be able to provide a more consistent supply of fish. A steady supply of high quality fish will also be ensured to processors purchasing Asian carp from the KFC. It is the intent of KDFWR and the Commonwealth of Kentucky to incentivize the KFC for no more than six years as the KFC grows and becomes self-sustaining. Kentucky is a pioneer in the commercial fishery for Asian carp, and KDFWR will strive to continue supporting this enterprise as a means to reduce the number of Asian carp in Kentucky's waterways.

Literature Cited:

Yurista, P. M., D. S. White, G. W. Kipphut, K. Johnston, G. Rice and S. P. Hendricks. 2004. Nutrient patterns in a mainstem reservoir, Kentucky Lake, USA, over a 10-year period. Lake and Reservoir Management 20:148-163.

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 2018. Commercial fishing seasons are defined as April through March of the following year.

Commercial Fishing Season	Number of Days/Trips	Number of fishermen	Total number of bycatch	Number of sport fish caught	Sport fish released alive (%)	Number of paddlefish caught	Paddlefish released alive (%)	Weight silver carp harvested (lbs)	Weight bighead carp harvested (lbs)
2011-2012	3	1	174	8	87.5	93	96.8	994	820
2012-2013	6	1	869	54	96.3	222	92.3	2,140	0
2013-2014	74	7	7050	84	98.8	93	87.1	242,101	491
2014-2015	174	11	5,036	221	96.8	161	73.9	780,730	3,381
2015-2016	346	22	9,926	893	94.4	889	72.1	742,119	33,342
2016-2017	558	27	12,388	814	92.1	545	69.0	1,392,207	14,103
2017-2018	380	19	10,463	547	98.2	284	73.6	777,480	21,613
April 2018-December 2018	918	21	28,546	919	96.4	200	84.5	1,842,934	37,319

Table 2. Number of bighead 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 2016 - 2018. (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
2018	3.5	6883	3778	0.55	8	24
	3.75	167	67	0.40		
	4	3250	381	0.12	4	3
	4.25	14100	920	0.07	54	8
	4.5	2767	145	0.05	4	
	5	867	5	0.01	1	

Table 3. 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 - 2018. (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	
2018	5067	1689	88.9	3	2	3998	1333	551.7	28	9	4.3

*effort is calculated in yards of gillnet fished.

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 Lake Barkely 2015 - 2018. (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	50.45	16	5	35130	2196	256.6	1608	101	43.1
2016	25135	1143	70.42	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
2018	23260	1108	81.7	21	10	49248	2345	477.1	362	17	7.8

*effort is calculated in yards of gillnet fished.

Table 5. 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 - 2018. (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
2018	Ride Alongs	2219	422.6	16	6.9
	Commercial fishermen reports	2008	56.02	41	4.25

Table 6. Species composition, number of individuals captured, and survival rate of species observed in bycatch during KDFWR ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program in 2016 - 2018.

		2016		2017		2018	
	Species	Number captured	Survival rate*	Number captured	Survival rate*	Number captured	Survival rate*
Sport Fish	Blue catfish	27	74.1%	47	93.6%	42	90.5%
	Channel catfish	10	80.0%	17	82.4%	12	100.0%
	Flathead catfish	9	88.9%	19	100.0%	8	87.5%
	White bass	1	0.0%				
	Yellow bass	20	50.0%	1	100.0%	6	33.3%
	Striped bass	19	78.9%	1	100.0%	3	33.3%
	Hybrid striped bass	2	100.0%			1	100.0%
	Sauger	1	0.0%	2	100.0%	3	33.3%
	Spotted bass	1	100.0%				
	Largemouth bass	1	100.0%	5	80.0%	3	66.7%
	Redear sunfish	1	100.0%			2	50.0%
	Black crappie					5	50.0%
	White crappie			1	100.0%	6	66.7%
	Total	92	70.2%	93	94.5%	91	64.7%
Rough Fish	Paddlefish	83	48.2%	62	48.4%	38	31.6%
	Lake sturgeon					1	100.0%
	Skipjack herring	23	17.4%	47	12.8%	18	0.0%
	Smallmouth buffalo	145	99.3%	13	84.6%	98	100.0%
	Bigmouth buffalo	8	100.0%	4	100.0%	7	100.0%
	Black buffalo	17	94.1%			2	100.0%
	Common carp	48	97.9%	33	93.9%	27	100.0%
	Grass carp	12	100.0%	3	66.7%		
	Gizzard shad	5	0.0%	3	33.3%		
	Freshwater drum	76	67.1%	27	51.9%	73	71.2%
	River carpsucker	3	100.0%				
	Mooneye	3	0.0%				
	Chestnut lamprey	1	0.0%				
	Threadfin shad	1	0.0%				
	Blue sucker	49	79.6%				
	Spotted gar					2	50.0%
	Longnose gar	8	87.5%	9	44.4%		
	Shortnose gar	9	44.4%	1	100.0%	2	50.0%
	Total	491	58.5%	202	63.6%	268	70.3%

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

Table 7. 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 2015-2018. (S.E. = standard error). Totals are calculated by calendar year.

	2015						2016						2017						2018					
	Totals		Number captured per trip				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.	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	200	37	0.22	0.03	1.54	0.53
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	433	42	0.47	0.04	1.75	0.37
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	84	12	0.09	0.01	0.50	0.13
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	130	8	0.14	0.02	0.33	0.13
Catfish	85		0.30	0.05			43		0.07	0.02			70		0.17	0.05			220		0.23	0.04		
Bass	36		0.13	0.05			9		0.02	0.02			10		0.02	0.01			12		0.01	<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	8	2	0.01	<0.01	0.08	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							1	1	<0.01	<0.01	0.04	0.04
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	6	2	0.01	<0.01	0.08	0.06
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	13	6	0.01	<0.01	0.25	0.15
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	3	3	<0.01	<0.01	0.13	0.70
Walleye	1		<0.01																					
Crappie	9		0.03	0.01			7		0.01	0.01				1			0.03	0.03	8	7	0.01	0.01	0.29	0.21
Redear sunfish	1	1	<0.01		0.03	0.03	3	1	0.01		0.04	0.04	1		<0.01	<0.01			2	1	<0.01	<0.01	0.04	0.04

Table 8. Number of fish, mean relative weight (Wr), and standard error values for each length group of sportfish collected during standardized sampling in Lake Barkley from 2013-2018.

		Length group								
		5.0-7.9 in			8.0-9.9 in			≥10 in		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
Black crappie	2018	68	93	2.5	32	105	2.9	18	103	3.3
	2017	77	95	1.2	75	94	1.4	32	94	1.7
	2016	229	91	0.7	155	96	1.0	49	95	1.0
	2015	135	94	1.0	100	93	0.9	87	100	0.7
	2014	167	92	0.6	97	97	0.8	17	100	2.4
	2013	4	94	3.3	11	93	2.6	48	93	0.8

		Length group								
		5.0-7.9 in			8.0-9.9 in			≥10 in		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
White crappie	2018	58	89	1.8	88	101	1.1	64	102	1.2
	2017	39	91	2.9	47	94	1.5	116	98	0.9
	2016	261	87	0.5	324	93	0.5	168	97	0.7
	2015	922	87	0.3	328	93	0.7	110	100	1.1
	2014	52	83	1.6	79	96	0.9	97	99	0.9
	2013	27	84	2.0	23	96	1.0	150	99	0.7

		Length group								
		8.0-12.0 in			12.0-15.0 in			≥15 in		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
Largemouth bass	2018	48	103	1.4	76	103	1.0	55	103	1.2
	2017	47	92	1.2	35	95	1.6	38	95	0.8
	2016	42	95	2.2	72	96	1.2	83	98	0.8
	2015	62	105	1.0	143	102	0.7	117	103	0.5
	2014	107	95	0.8	138	93	0.7	82	98	1.2
	2013	145	110	8.3	167	98	0.7	112	100	0.9

Table 9. Number of fish, mean relative weight (Wr), and standard error values for each length group of sportfish collected during standardized sampling in Kentucky Lake from 2013-2018.

		Length group								
		5.0-7.9 in			8.0-9.9 in			≥10 in		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
Black crappie	2018	76	85	1.6	254	87	0.5	111	89	0.7
	2017	123	87	0.8	332	87	0.4	90	87	0.6
	2016	208	99	0.6	230	98	0.5	81	97	0.7
	2015	625	93	0.4	251	90	0.4	50	92	1.2
	2014	373	86	0.5	105	84	0.8	101	91	0.7
	2013	76	85	1.1	126	93	0.8	176	96	0.6

		Length group								
		5.0-7.9 in			8.0-9.9 in			≥10 in		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
White crappie	2018	48	84	2.2	56	86	1.8	117	94	0.7
	2017	16	86	2.1	135	89.72	0.66	84	88.82	0.98
	2016	23	98	2.2	79	100	0.9	45	97	1.5
	2015	243	89	0.6	255	89	0.5	95	97	1.3
	2014	166	81	0.6	45	87	1.4	91	91	0.9
	2013	37	83	1.6	42	93	1.4	112	96	0.7

		Length group								
		8.0-12.0 in			12.0-15.0 in			≥15 in		
Species	Year	No.	Wr	Std err	No.	Wr	Std err	No.	Wr	Std err
Largemouth bass	2018	114	93.11	0.75	46	91.76	1.28	26	90.07	2.22
	2017	91	89	0.9	28	84	1.7	34	89	2.1
	2016	180	105	0.8	87	92	1.0	97	98	0.9
	2015	52	98	1.7	160	102	0.8	72	103	1.5
	2014	185	92	0.7	112	88	1.0	47	91	1.9
	2013	145	91	0.7	85	89	1.1	64	92	1.4

Table 10. 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 - 2018.

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
2018	January	0			
	February	0			
	March	0			
	April	4	75.0%	54.9	11.0
	May	9	60.0%	66.1	10.2
	June	12	35.0%	81.7	10.6
	July	0			
	August	12	0.0%	82.9	11.6
	September	0			
	October	0			
	November	0			
	December	0			

Table 11. Summary of Asian carp harvest and expentidures 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	41	94,121	$4,706.06
2017	70	191,921	$9,596.05
2018	565	722,740	$36,136.98

Table 12. Harvest goals outlined by the state of Kentucky to be met by the Kentucky Fish Center for receipt of forgivable loan annually.

Year	Goal
Year 1	5 million pounds Asian carp harvested statewide
	3 million pounds from Kentucky and Barkley lakes
Year 2	8 million pounds Asian carp harvested statewide
	5 million pounds from Kentucky and Barkley lakes
Year 3	10 million pounds Asian carp harvested statewide
	5 million pounds from Kentucky and Barkley lakes
Year 4	15 million pounds Asian carp harvested statewide
	5 million pounds from Kentucky and Barkley lakes
Year 5	20 million pounds Asian carp harvested statewide
	5 million pounds from Kentucky and Barkley lakes

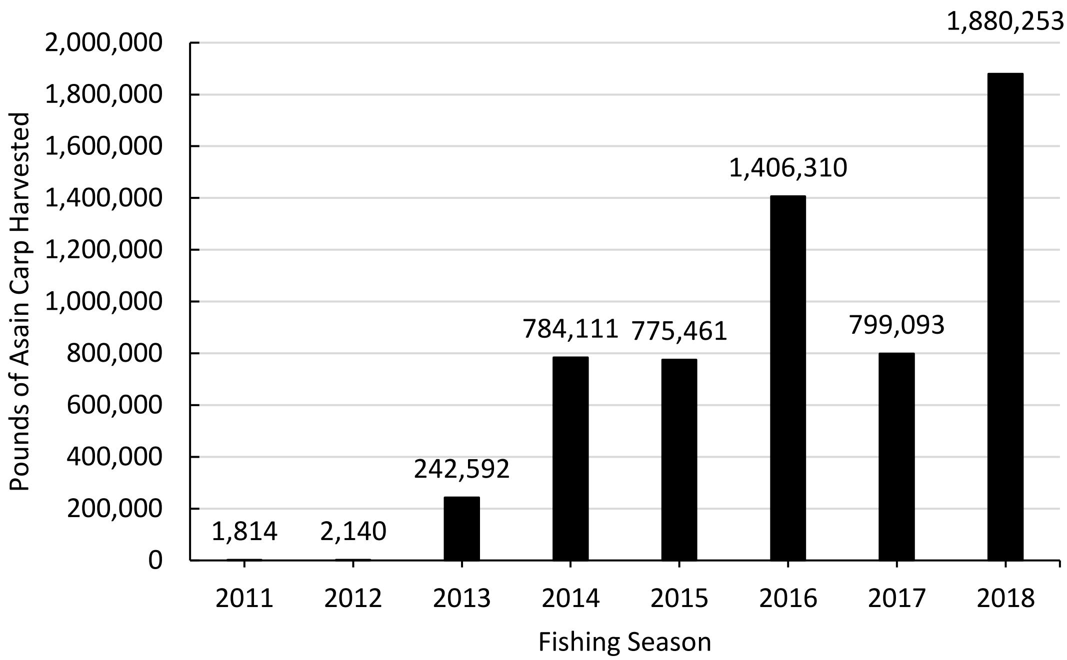

Figure 1. Pounds of Asian carp harvested through the Asian Carp Harvest Program. Program year runs from April 1 through March 31 of the following year, 2018 is only reported through December.

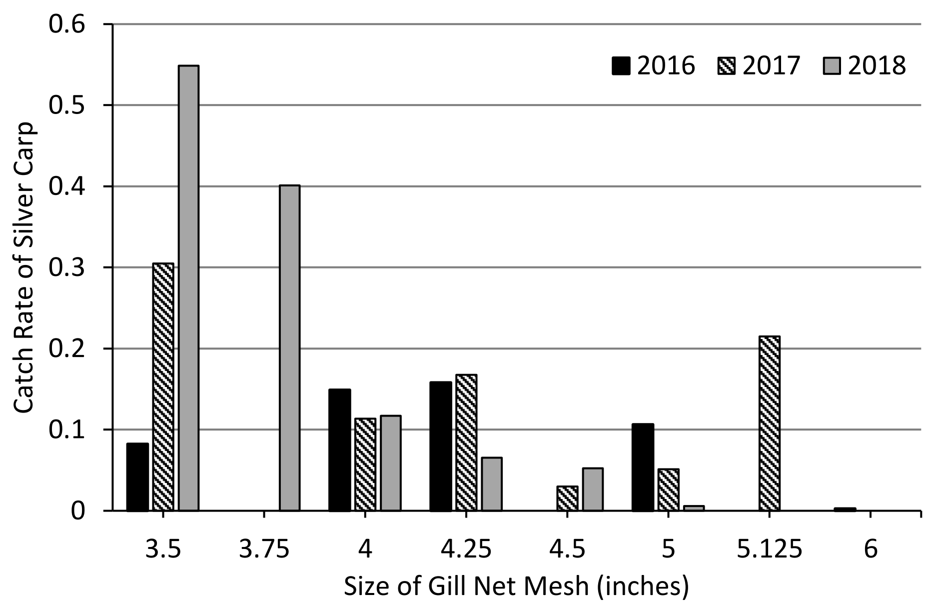

Figure 2. Catch rates (number of fish / yard of net) of silver carp by gill net mesh size during ride-alongs with commercial fishermen fishing under the Asian Carp Harvest Program.

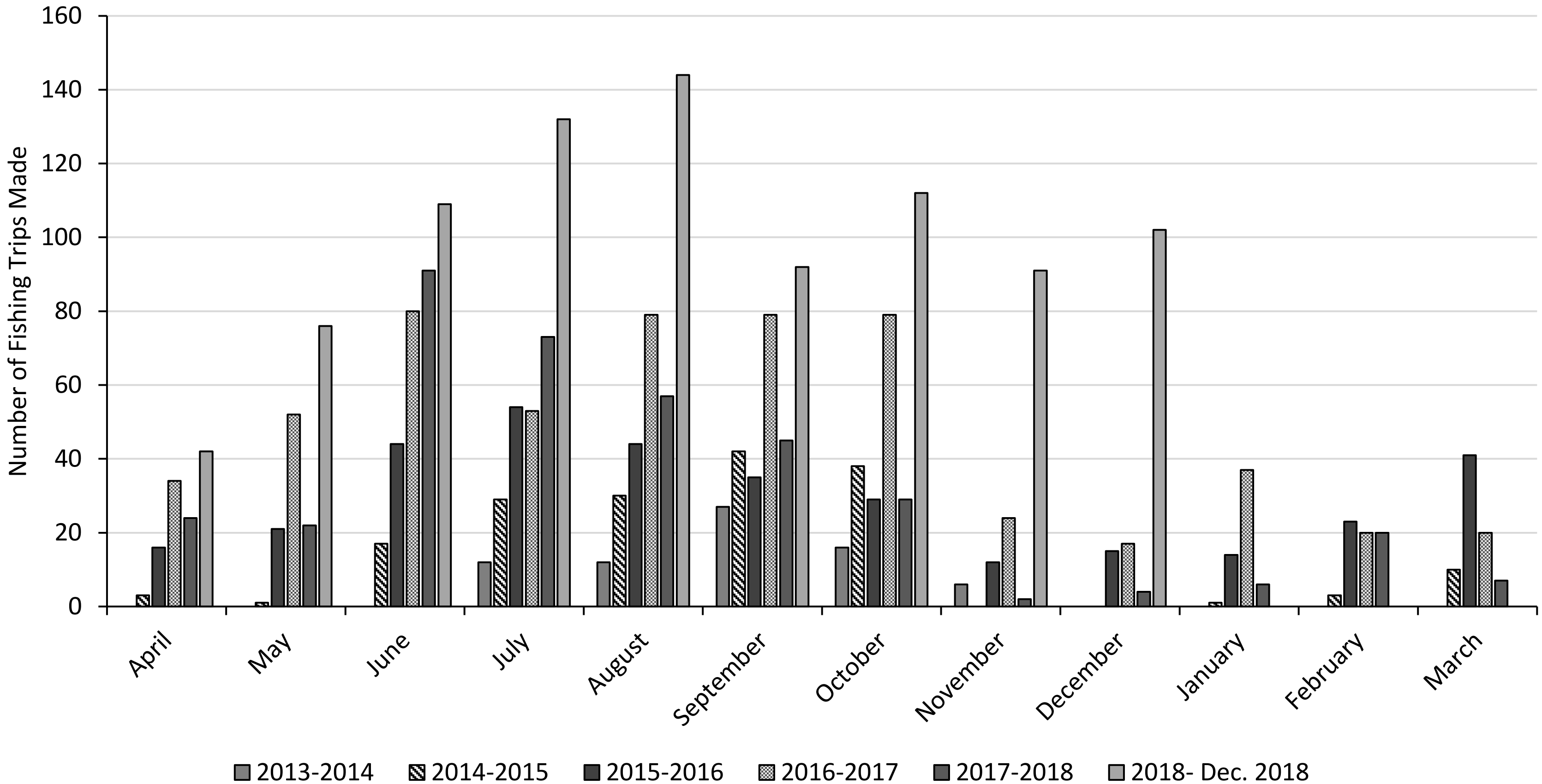

Figure 3. Number of fishing trips made monthly by commercial fishermen fishing under the Asian Carp Harvest Program from April 2013 - December 2018.

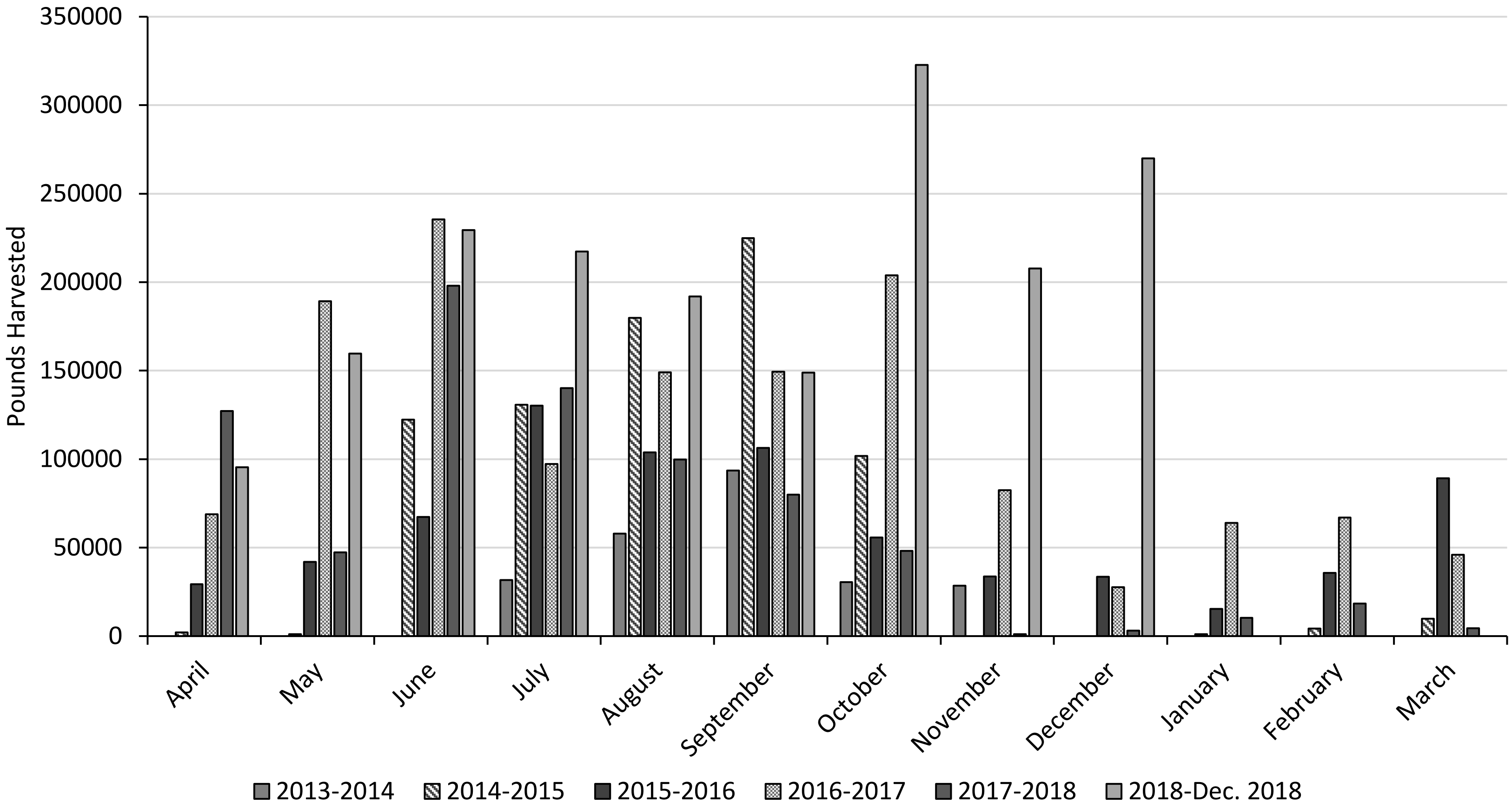

Figure 4. Total pounds of silver carp harvested monthly by commercial fishermen fishing under the Asian Carp Harvest Program from April 2013 - December 2018.

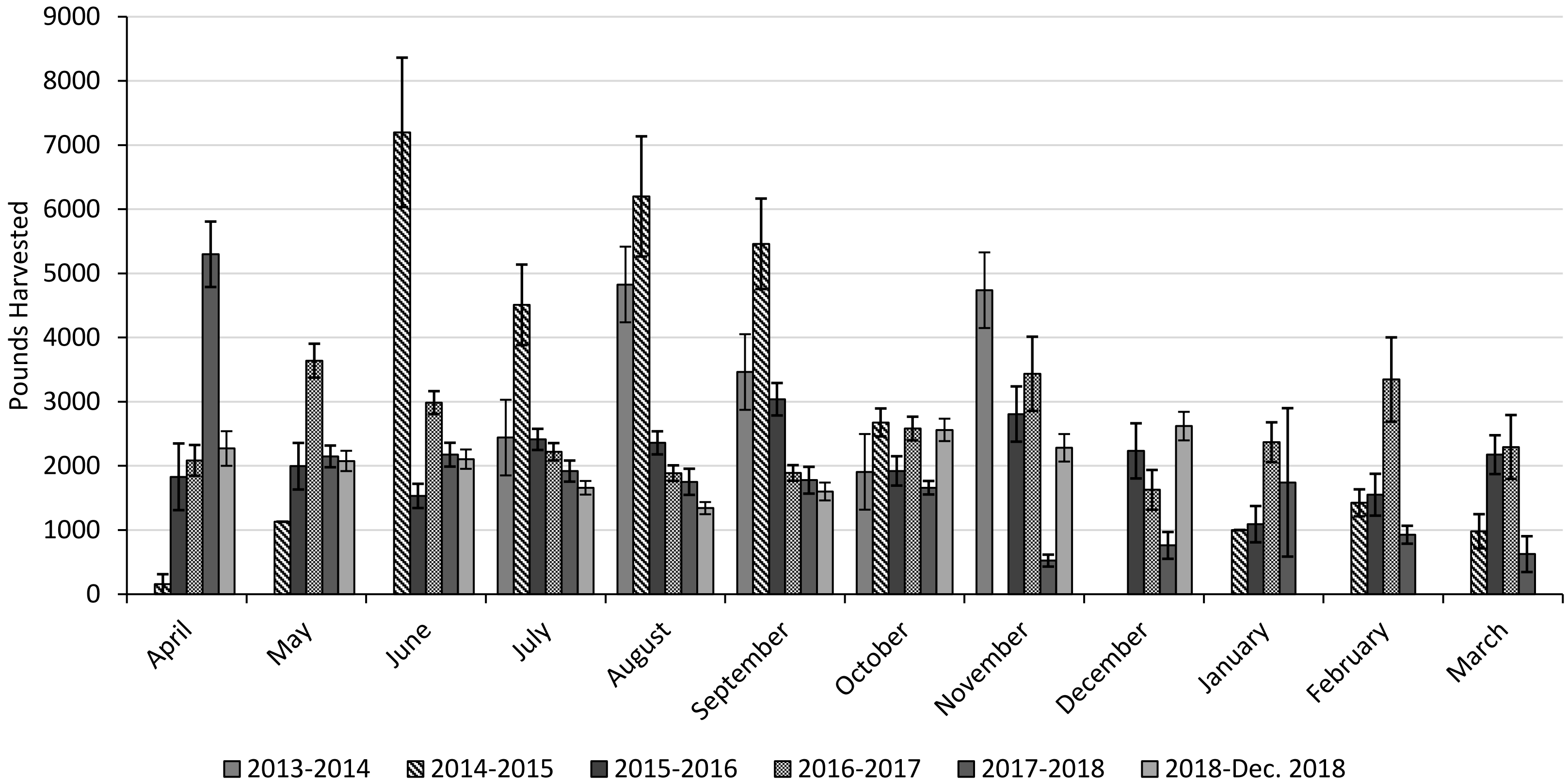

Figure 5. Monthly average total weight (lbs) of silver carp harvested per trip by commercial fishermen fishing under the Asian Carp Harvest Program April 2013 - December 2018. Error bars represent Standard Error values

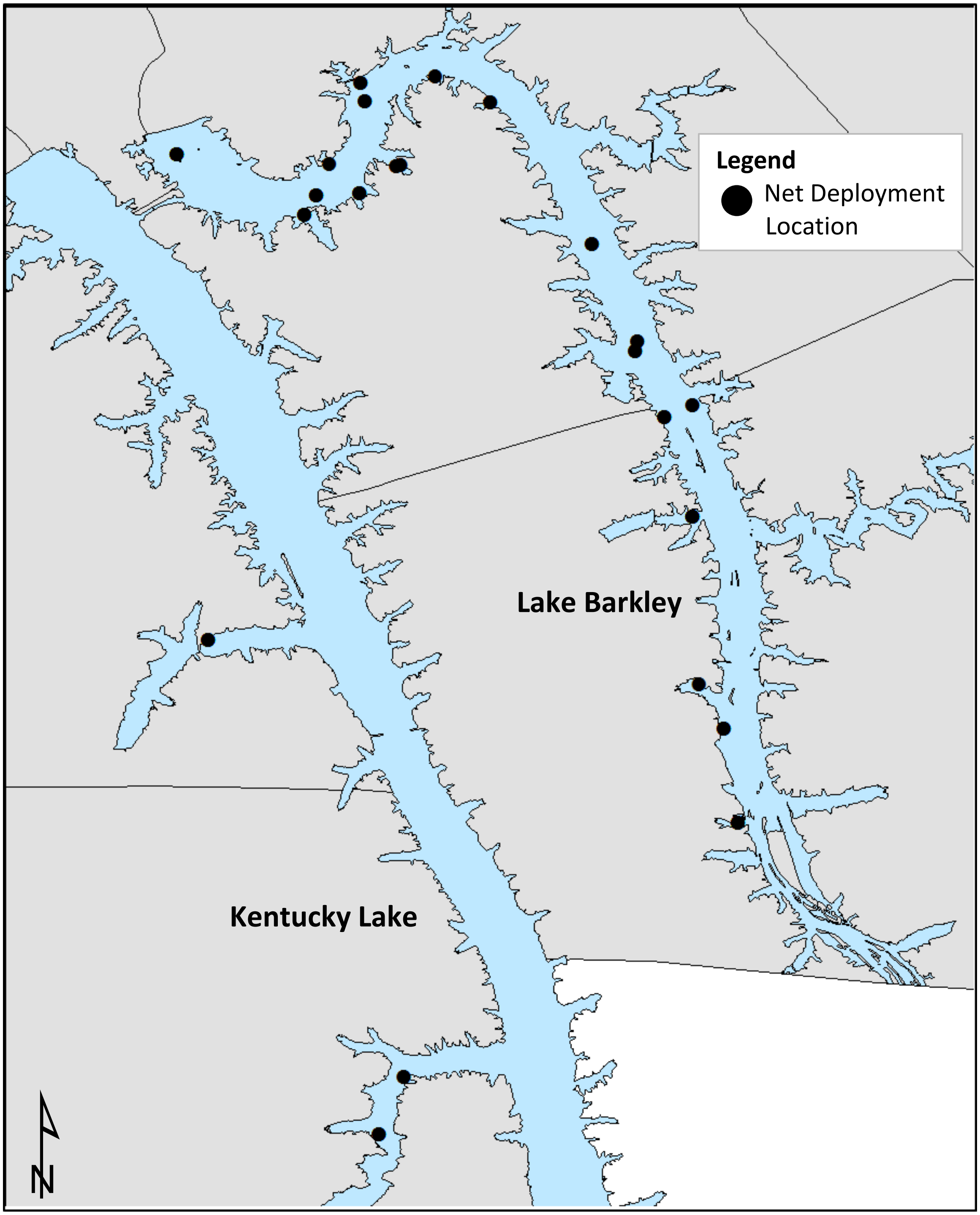

Figure 6. Locations where nets were deployed by commercial fishermen during ride-alongs conducted by KDFWR staff in 2018.

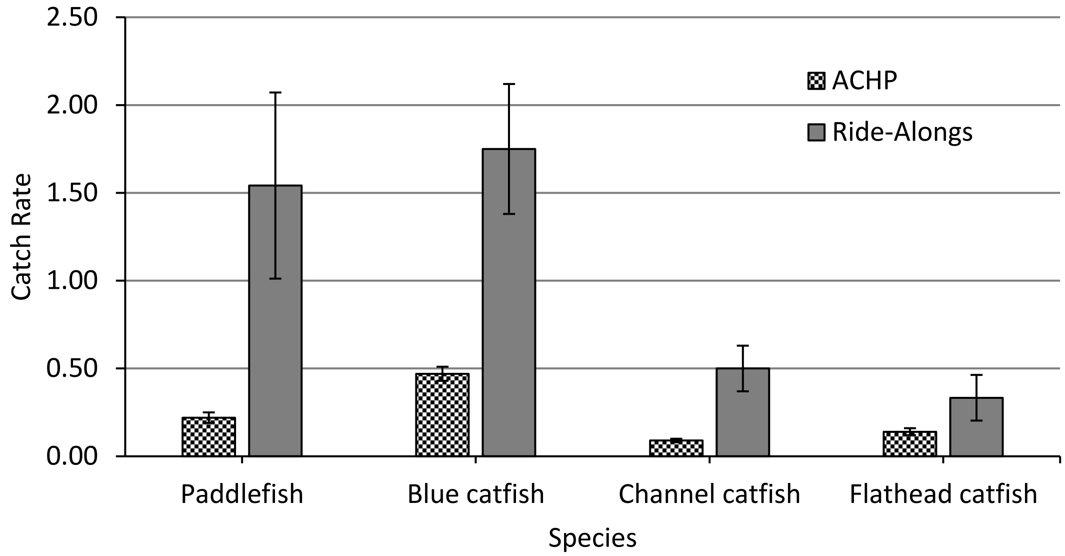

Figure 7. Comparison of catch rates for common bycatch species as reported by commercial fishermen utilizing the Asian Carp Harvest Program (ACHP) and through KDFWR ride-alongs with commercial fishermen. Error bars represent Standard Error values.

STATE: Kentucky

GRANT NO: F-95-5

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2018 – March 31, 2019

Research and Survey Section

Project 3: 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 (KDFWR) worked with Murray State University (MSU) to continue a study tracking Silver Carp movement in Kentucky Lake. Surgeries were performed on 44 Silver Carp over three dates in 2018. Boat-mounted hydrophones were used to manually track tagged Silver Carp on 25 separate trips in Kentucky Lake, and for the first time significant tracking effort was performed in Lake Barkley (9 separate trips during 2018). A large network of VR2W passive receivers was 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 and 2018, so large scale movement rates (km/day) and fine scale movement rates (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 rose above 13.3^{0}C in the spring and movement decreased when temperature fell below this range in the fall. Silver Carp in Kentucky Lake tended to be found in the lower portion of the lake in the first half of 2018 and then further upstream in the second half of the year. Twenty fish were detected crossing one of the dams (2 Paddlefish, 1 unknown, and 17 Silver Carp). Three of the Silver Carp left through one of the dams and then later returned. Dam crossings seemed to be mostly related to overall activity level. In 2019, 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. Fish tagging will continue in 2019 in anticipation of the Bio-Acoustic Fish Fence deterrent system to be installed below Lake Barkley Dam.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2019
Work accomplished – 31 March 2019

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

Project 3: 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 44 Silver Carp over three dates in 2018 (Table 1). All fish tagged during 2018 were captured by electrofishing. Most fish were captured via boat electrofishing in the Lake Barkley tailwaters. All surgeries were performed near the point of capture and fish were immediately released in the same area to minimize holding time. Mean surface temperature during the January surgeries was 4.1^{0}C, during the April surgeries was 14.3^{0}C, and during the November surgeries was 16.7^{0}C. Carbon dioxide was tested as an anesthetic during the November surgeries, but not enough fish were anesthetized to make any conclusions about long-term mortality. Silver Carp normally do not react negatively to surgery even without anesthesia, so the carbon dioxide had no noticeable effect. We will be testing the carbon dioxide more in order to see if long-term survival is improved. The majority of fish were released into the Barkley tailwaters in anticipation of installation of the Bio-Acoustic Fish Fence (BAFF) at the lower approach to Barkley Lock. We attempted to capture more fish in Kentucky Lake for tagging; these fish were easy to capture with boat electrofishing during the warmer months, but during that time the water was too warm for surgeries. Once the water cooled enough to perform surgeries, the fish were no longer easy to catch with electrofishing. We will try to capture more fish in Kentucky Lake with gill nets during the colder months.

This year marks the first time we were able to tag the 2015 year class, some of which may have been spawned in Kentucky Lake. Although we were not able to age any of the tagged fish, the 3 fish tagged in November were most likely from the 2015 year class based upon their size (KDFWR: Monitoring Silver and Bighead Carp Relative Abundance and Density in Barkley and Kentucky Reservoirs Project Report 2018).

Mortality

Factors which cause mortality in tagged fish were investigated in 2018 as many Silver Carp have been tagged, and several years of data collected on those fish. The locations of each fish were examined individually in ArcGIS, and any fish that was located 3 or more times in the same location over a long period of time was considered dead. The mortality of fish from each tagging date is summarized in Table 2. Note that lower mortality rates in more recently-tagged fish might be due to a lack of many relocations on those fish.

Percent mortality was calculated for each capture method on each date, and an ANOVA was used to show that mean percent mortality differed significantly among capture methods ($F_{2,14} = 4.79$, $p = 0.026$). A Tukey HSD post-hoc test showed that mortality was significantly lower in fish captured via electrofishing compared to those captured by the Paupier boat or by gill nets (Figure 1). Temperature also appeared to influence percent mortality (Figure 2), but a linear regression showed no significant relationship between percent mortality and water temperature ($F_{1,15}$ = 3.271, p = 0.091, R^2 = 0.12). However, a 2-dimensional Kolmogorov-Smirnov test showed that a significant change in the relationship occurred at 17.3^{0}C (D_{max} = 0.137, p = 0.040) which suggests that this water temperature is a threshold beyond which mortality tends to increase. An ANCOVA which looked at the simultaneous effect of capture method, water temperature, and their interaction on percent mortality showed that none of these factors significantly affected percent mortality when analyzed in this manner (capture method – $F_{2,11}$ = 3.784, p = 0.0562; water temperature – $F_{1,11}$ = 0.001, p = 0.973; interaction – $F_{2,11}$ = 0.027, p = 0.974).

Some of the tagged Silver Carp which were recaptured by commercial fishermen exhibited large wounds where jaw tags had been placed. Therefore, beginning with the surgeries on October 17, 2017, fish were tagged with a Floy Loop Tag just posterior to the dorsal fin which should be less intrusive than the jaw tags. Mortality rates were very low on several dates after the switch to Floy Loop tags (Table 2), but these results could also have been influenced by the capture methods and temperatures as demonstrated above. No evidence exists that suggests the Floy Loop tags cause injuries comparable to the jaw tags, so they will continue to be used in future surgeries.

Logistic regression was used to investigate the influence of fish length, weight, and sex on survival. Length was negatively related to survival (z = -4.797, p << 0.001) but neither weight nor sex had an influence on post-surgery survival. A separate logistic regression was used to test if fish condition (as measured by Fulton's K) had an effect on survival; this regression showed that Fulton's K had a significant, negative effect on survival (z = -2.900, p = 0.00374). However, this effect is likely not biologically significant, as the mean value of K for fish which survived the surgery was 1.01 and the mean value of K for dead fish was 1.09.

Tracking Effort

Boat-mounted hydrophones were used to manually track tagged Silver Carp on 25 separate trips in Kentucky Lake, and for the first time significant tracking effort was performed in Lake Barkley (9 trips during 2018). The average linear distance tracked during these trips was 66 km in Kentucky Lake and 36.3 km in Lake Barkley. Manual tracking was focused near both dams, and some tracking extended down both the Tennessee River and the Cumberland River (Figure 3). On 1 date a Silver Carp was followed and located at least once per hour for 24 hours.

During 2018, 3 VR2W passive receivers were lost and replaced in Kentucky Lake (1 in the tailwaters and 2 in the canal). Two other VR2Ws were malfunctioning and had to be replaced as well. New passive receivers were deployed near Pisgah Bay and Big Sandy in order to increase the precision of our movement estimates. In Lake Barkley, 1 new VR2W was added to the array associated with the lock, and 4 new receivers were deployed throughout the lake above the dam (Taylor Bay, Little River, Devil's Elbow, and Fort Donaldson, Figure 4). The new receiver deployed below the Lake Barkley Dam is designed to complement the existing receivers in this area in an attempt to obtain complete coverage in order to collect sufficient dam passage data prior to the installation of the BAFF deterrent system (Figure 5). In Kentucky Lake, 29 trips were taken in order to download data from the VR2Ws, while in Lake Barkley 18 trips were taken for this reason.

The VR2W network stretches from the tailwaters of both lakes, through both locks, into the canal connecting the lakes, and well upstream of both dams. This project is also in coordination with the

Tennessee Wildlife Resource Agency (TWRA), Tennessee Technological University (TTU), Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), and Alabama Wildlife and Freshwater Fisheries Division, who have deployed receivers upstream from ours in the Tennessee River.

Fish Detections

During 2018, 22 different Silver Carp were detected via active tracking and 25 different Silver Carp with the VR2Ws in Kentucky Lake (Table 3). In Lake Barkley, 40 fish were detected with the boat-mounted hydrophone and 58 on the VR2W receivers (Table 4). Not only have the TWRA and the MDWFP deployed VR2Ws, but also they have tagged many Silver Carp and released them into the Tennessee River. We have detected some of these fish in Kentucky Lake and Lake Barkley, along with a Silver Carp which was tagged by the U. S. Fish and Wildlife Service (USFWS) (Table 3 and Table 4,). We have detected other species which were tagged by other agencies, such as Paddlefish, Grass Carp, Bighead Carp, and some unknown species, in both Kentucky Lake and Lake Barkley (Table 5 and Table 6).

The Silver Carp which were tagged by other agencies should be considered a different population than the fish which were tagged in the lower Kentucky Lake and Lake Barkley systems. Also, any fish which were detected that had been tagged by other agencies might bias results of this report because these might be the most nomadic of the fish tagged in the Tennessee River. Thus, the following analysis will concentrate only on Silver Carp which were tagged by KDFWR and MSU. Some fish moved freely between Kentucky Lake and Lake Barkley, but since we do not have many manual relocations above the Lake Barkley Dam, and the VR2W network was only recently completed in Lake Barkley, we will not analyze and data from Lake Barkley. The following analysis of Kentucky Lake Silver Carp which were tagged by KDFWR and MSU covers all of 2017 and all of 2018. A separate report combining data from all fish in the Tennessee River System is being prepared by TTU as funded by the 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 2 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. In this way, all fish are weighted equally, and no single fish can have a disproportionate influence on the calculations simply because that fish was detected more often.

Mean daily speed (movement rate regardless of direction, i.e. absolute speed in km/day) was averaged weekly and compared to mean daily surface temperature (^{0}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. Mean number of fish analyzed per week was 3.8 fish (range 1 – 13 fish, 3 or more fish were detected in 69% of the weeks). 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 in any week was 21.4 km/day (N = 4 fish), and the maximum speed recorded for an individual Silver Carp was 60.9 km/day. Movement rates seemed to be loosely related to surface temperature (Figure 6). The Silver Carp had clear seasonal movement patterns during both years; the fish do not move much during the colder months, show a spike in activity early in the spring, and then they maintain a steady rate of activity until water temperatures decline in the fall. 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 7). A 2-dimensional Kolmogorov-Smirnov test suggested that the relationship between speed and temperature changed once the temperature rose above 13.3^{0}C (D_{max} = 0.118, p = 0.000). Silver Carp movement decreased sharply once temperatures rose above 30^{0}C.

The movement of Silver Carp did not seem to be related to discharge levels (Figure 8) or lake elevation (Figure 9). Several spikes in activity occurred in both years, but these spikes did not seem to relate to discharge levels or lake elevation.

Silver Carp movement can be studied at several scales; for example, the previous analysis summarized each fish's swimming rate in km/day and then summarized these values by week. Such an analysis is good for looking at overall activity levels across times, and it gives an idea of the distances that a Silver Carp can cover in a day. These values are based upon an "average" location and an "average" time each day, which gives an estimate of the general location of a fish each day. However, this analysis underestimates the swimming rates of fish because it is greatly influenced by the time periods when the fish is not moving much. To understand short-term swimming rates, we focused only on those times when a fish was actually moving. That is, we also looked at swimming speed when a fish was moving from one set of VR2W receivers to the next nearest set of receivers, which we call "On the Move" or OTM swimming speed.

The mean OTM speed of Silver Carp was 1.1 km/hr which would translate into approximately 26.4 km/day (Table 7). Silver Carp which were tagged by other agencies had a higher mean OTM speed which might be due to these fish being more nomadic than the population which were tagged in the lower Kentucky Lake and Lake Barkley systems.

Not only is swimming speed and activity important, but also of interest is the location of the fish within Kentucky Lake over time. To determine the average location of the Silver Carp over time first the average river kilometer (RK) for each fish on each day was calculated. Next, the mean RK for each fish each month, which provides the average location of each fish each month. Finally, the mean RK across all fish each month was determined which provides a general idea of the location of the carp population within Kentucky Lake each month. The median RK for 2017 – 2018 was 63.9 km which is near the mouth of Jonathan Creek, so the mean location of Silver Carp each month was compared to this location. To understand the relative position of Silver Carp, the median value of 63.9 km was subtracted from each month's mean RK to get an adjusted RK. The adjusted RK for a month would be negative if the average location of the fish were downstream from Jonathan Creek, and positive if the average location was upstream from Jonathan Creek.

The Silver Carp showed more obvious directionality of movement in 2018 compared to 2017 (Figure 10). In early 2018, the fish were mostly found in the lower end of the lake, closer to the dam, while later in the year they moved upstream.

Dam Passage

Twenty tagged fish crossed the dams during 2017 – 2018 (Table 8). All of these crossing had undisputable evidence that the fish crossed, e.g. the fish was detected several km from one side of the dam and then later was detected several km on the other side. Often the crossing fish were detected in or around the lock, but many fish crossed the dam without being detected inside the lock. These missed detections are likely due to low batteries in the receiver and are not due to the inability of VR2W's to detect fish inside the chamber. Several fish were detected inside the lock and on receivers positioned just above and just below each lock; however, these fish were not counted as crossing the dam because it is possible that a fish could be detected on these receivers without actually moving from one side of the dam to the other. Two of the 20 fish that crossed the dam were Paddlefish which were tagged by the Missouri Department of Conservation, and 1 was an unknown fish that has not yet been identified. Three of the 17 Silver Carp which crossed the dam crossed more than once. All 3 fish started in Kentucky Lake; 1 left through the Kentucky Dam lock and returned through this lock; 1 crossed over into Lake Barkley, left through the Lake Barkley Dam lock, and returned through the Kentucky Dam lock; and 1 left through the Kentucky Dam lock and returned through the Lake Barkley Dam lock. Four of the 20 Silver Carp which crossed the dam were tagged by the MDWFP and the rest were fish tagged by KDFWR and MSU. A few other fish which were tagged by other agencies outside the lake have been detected inside the lakes, and these fish must also have crossed through one of the dams before we had VR2W's deployed inside the locks.

Dam crossings were somewhat related to overall Silver Carp activity in that few crossings took place during the colder months when the fish were not very active (Figure 6, Table 8). Once the water began to warm up, the fish began to move more and cross the dams more (Figure 6, Figure 11). Discharge did not seem to influence dam crossings much, except that no crossings occurred during extreme discharge events early in 2018 or later that year (Figure 12). However, water temperatures were colder at this time and the lack of crossing was probably more related to temperature. Rising water levels seemed to trigger dam crossings (Figure 13), but again this could also be related to rising water temperatures and an overall increase in activity.

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 further investigated in 2019. The VR2W network in both lakes is well-developed, and no significant gaps exist. The network will require a great deal of maintenance in 2019 and into the future as receivers need to be downloaded, batteries need to be replaced, and malfunctioning receivers need to be replaced. Effort toward 24-hour tracking in 2018 was less than planned due to scheduling conflicts. The 24-hour tracking data will be a priority in 2019 in order to collect more fine-scale, diurnal movement data to inform removal efforts. In anticipation of the BAFF deterrent system installation in the Lock of Barkley Dam, factors such as barge lockage, will be analyzed to determine if they clearly influence passage of fish.

Table 1. Summary of Silver Carp surgically implanted with acoustic transmitters in Kentucky Lake and the Lake Barkley tailwaters during 2018.

	# Tagged		Mean TL (mm)		Mean W (g)		
Surgery Date	F	M	F	M	F	M	Release Location
2018-01-25	17	7	747	729	4,128	3,643	Barkley Tailwaters
2018-04-19*	12	4	690	724	3,496	3,830	Barkley Tailwaters
2018-11-08	2	1	558	537	1,858	1,592	Hancock Bio. Stat.
Total	31	12	713	711	3,737	3,534	

* 1 Silver Carp of unknown sex was also tagged on this date

Table 2. Summary of estimated mortality of tagged Silver Carp in Kentucky Lake and Lake Barkley. Mortality was assumed when fish were consistently found in the same location. Fish marked "Recaptured" were alive up until they were captured by commercial fishermen.

Surgery Date	Alive	Dead	Recaptured	Capture Method	Water Temperature (C)
2016-05-11	5	8		gill net	20.6
2016-05-16	1			gill net	20.6
2016-06-02	7	3		gill net	25.6
2016-11-08		1		Paupier***	18.3
2016-11-08		1		gill net	18.3
2016-11-09	1			Paupier	18.3
2016-11-09	1	6		gill net	18.3
2016-11-10		3		gill net	18.3
2016-12-13	19	9	4	gill net	7.8
2017-04-11*	6	8		Paupier	17.3
2017-04-12**	5	6		Paupier	17.8
2017-10-17	6	10		Paupier	21.8
2017-10-18	2	3		Paupier	21.8
2017-12-21	20			electrofisher	6.1
2018-01-25	24			electrofisher	3.9
2018-04-19	17			electrofisher	14.3
2018-11-08	3			electrofisher	16.2
Grand Total	117	58	4		

* 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
***Paupier electrofishing boat crewed by the USFWS

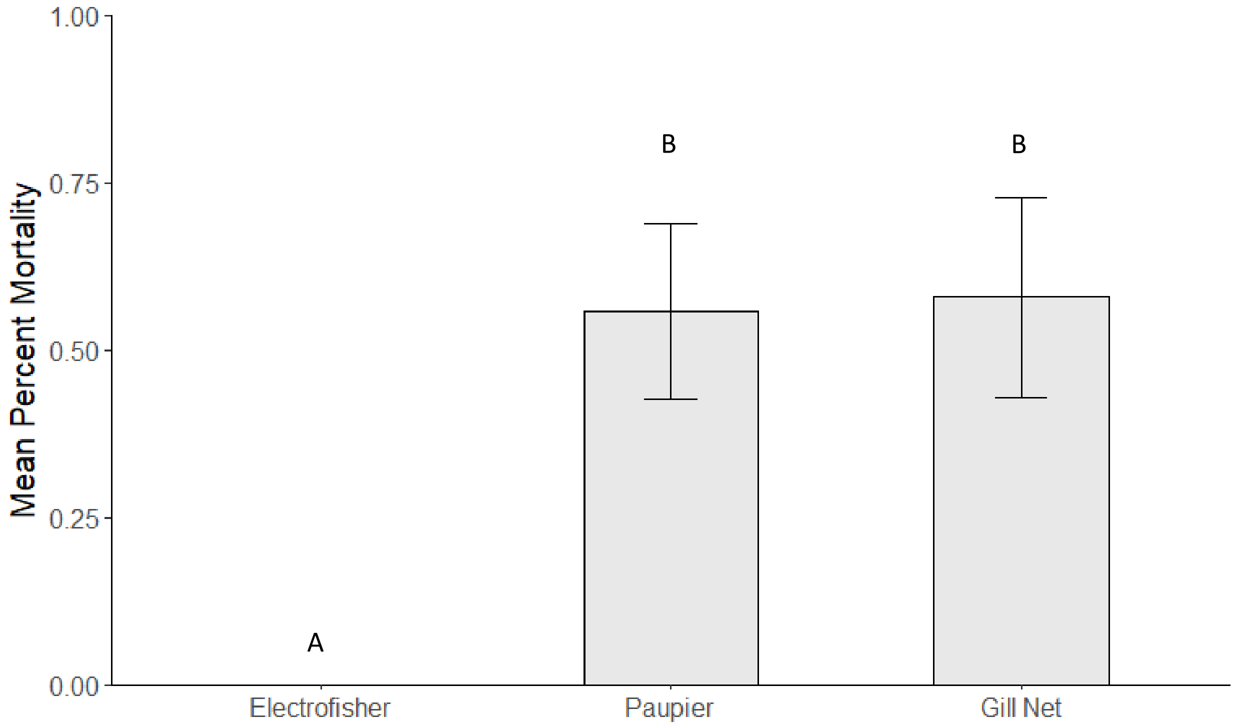

Figure 1. Mean percent mortality (± SE) of tagged Silver Carp in Kentucky Lake and Lake Barkley by capture method, 2016 – 2018. Values with different subscripts were significantly different based upon a Tukey HSD post-hoc test with $\alpha = 0.05$.

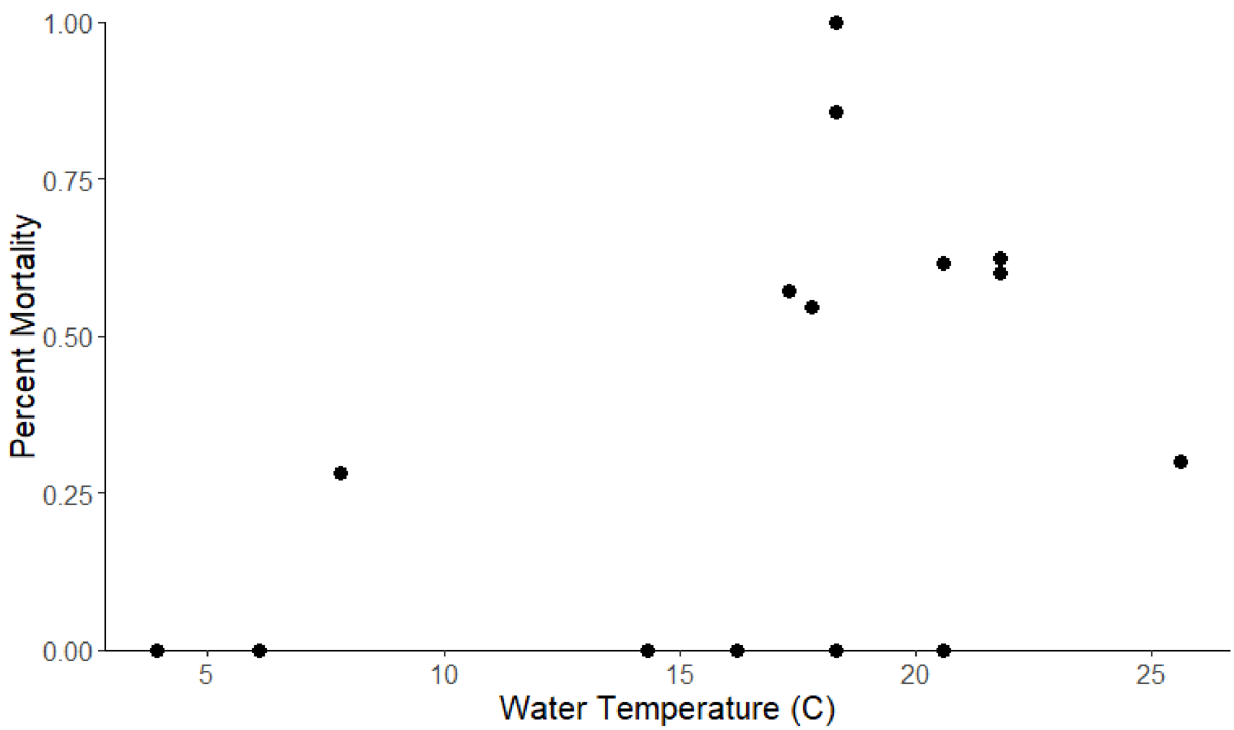

Figure 2. Percent mortality compared to water temperature for tagged Silver Carp in Kentucky Lake and Lake Barkley, 2016 – 2018. Percent mortality was not significantly influenced by temperature across the entire temperature range ($F_{1,15}$ = 3.271, p = 0.091, R^2 = 0.12) but a 2-dimensional Kolmogorov-Smirnov test showed that a significant change in the relationship occurred at 17.3^{0}C (D_{max} = 0.137, p = 0.040).

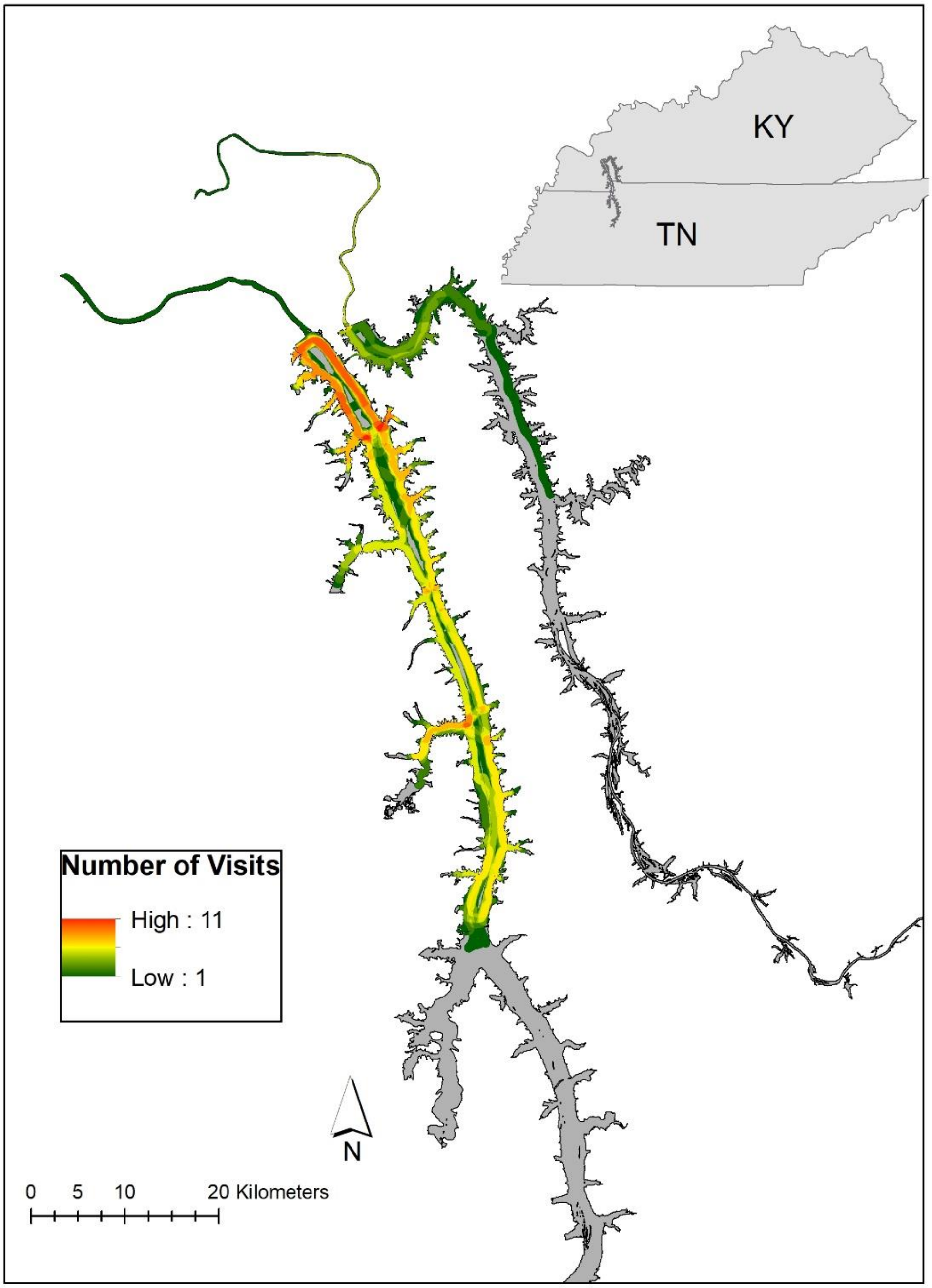

Figure 3. Manual tracking effort in Kentucky Lake and Lake Barkley during 2018. “Number of Visits” is determined based upon a 500 m listening radius around the direction of travel.

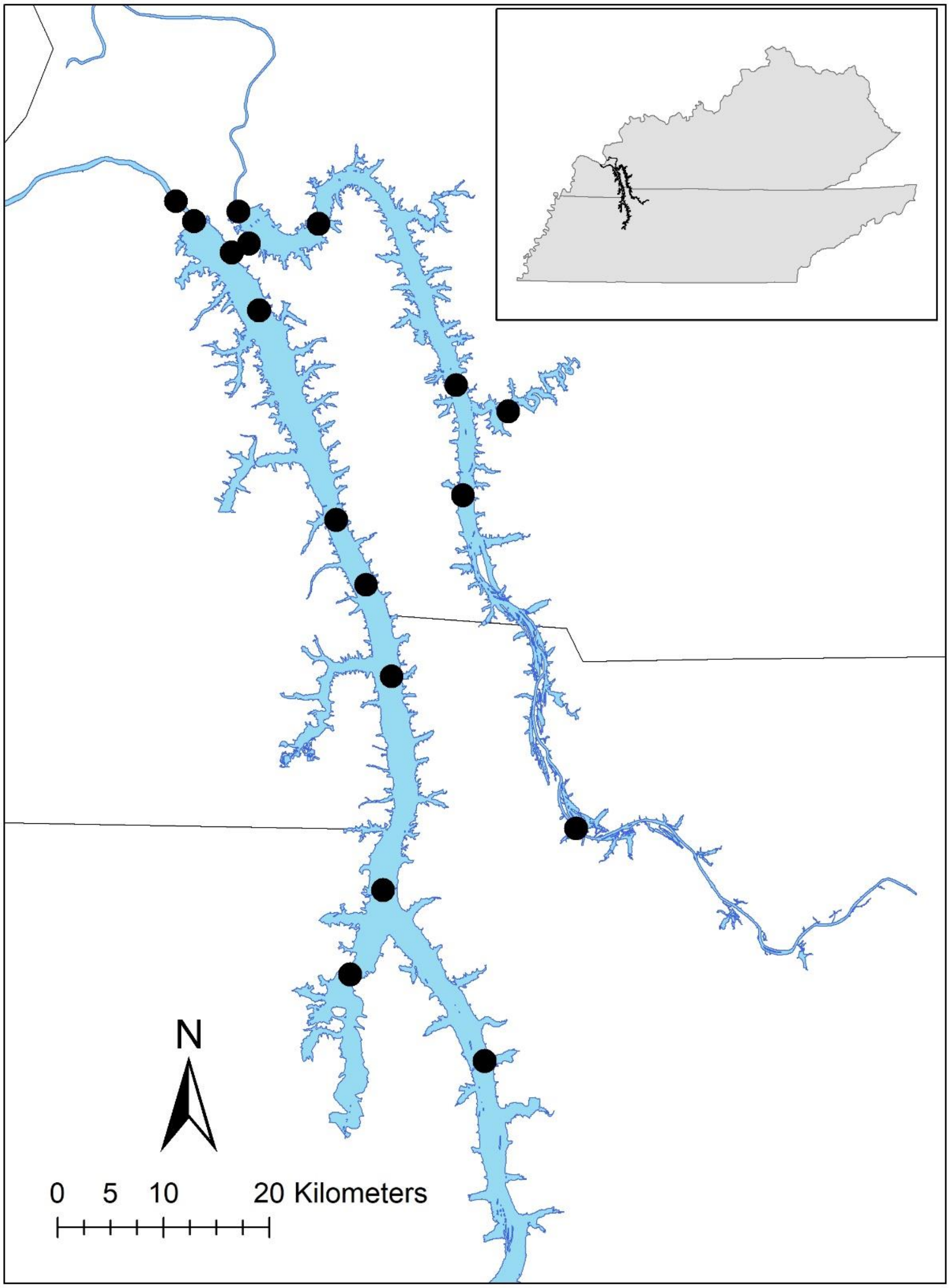

Figure 4. Location of VR2W passive receivers deployed throughout Kentucky Lake and Lake Barkley. Black dots indicate the location of one or more receivers.

Figure 5. Yellow dots indicate location of passive VR2W receivers deployed around the Lake Barkley Dam and tailwaters.

Table 3. Summary of live Silver Carp detections by origin, detection type, and year for Kentucky Lake and the Lower Tennessee River. Table values indicate the number of different individuals detected in each category.

Agency fish	2016		2017		2018	
were tagged by	Manual	VR2W	Manual	VR2W	Manual	VR2W
KDFWR	33	30	21	26	22	25
MDWFP					1	9
TWRA					5	10

[1]KDFWR = Kentucky Department of Fish and Wildlife Resources, MDWFP = Mississippi Department of Wildlife, Fisheries, and Parks, TWRA = Tennessee Wildlife Resource Agency

Table 4. Summary of live Silver Carp detections by origin, detection type, and year for Lake Barkley and the Lower Cumberland River. Table values indicate the number of different individuals detected in each category.

Agency fish	2017		2018	
were tagged by	Manual	VR2W	Manual	VR2W
KDFWR[1]	1	23	40	58
MDWFP			1	8
TWRA			1	2
USFWS			1	1

[1]KDFWR = Kentucky Department of Fish and Wildlife Resources, MDWFP = Mississippi Department of Wildlife, Fisheries, and Parks, TWRA = Tennessee Wildlife Resource Agency, USFWS = U. S. Fish and Wildlife Services

Table 5. Summary of other live fish detections by species, detection type, and year for Kentucky Lake and the Lower Tennessee River. Table values indicate the number of different individuals detected in each category.

	2016		2017		2018	
	Manual	VR2W	Manual	VR2W	Manual	VR2W
Paddlefish[1]	1	3	1	5	1	3
Bighead Carp	1	1	1	1	1	1
Unknown					2	2

[1]Paddlefish was tagged by the Missouri Department of Conservation, Bighead Carp was tagged by Southern Illinois University at Carbondale, and the Unknown fish have not yet been identified

Table 6. Summary of other live fish detections by species, detection type, and year for Lake Barkley and the Lower Cumberland River. Table values indicate the number of different individuals detected in each category.

	2016 Roaming VR2W	2017 VR2W	2018 VR2W
Paddlefish[1]	1	1	1
Grass Carp			1
Unknown			1

[1]Both the Paddlefish and the Grass Carp were tagged by the Missouri Department of Conservation, and the Unknown fish has not yet been identified

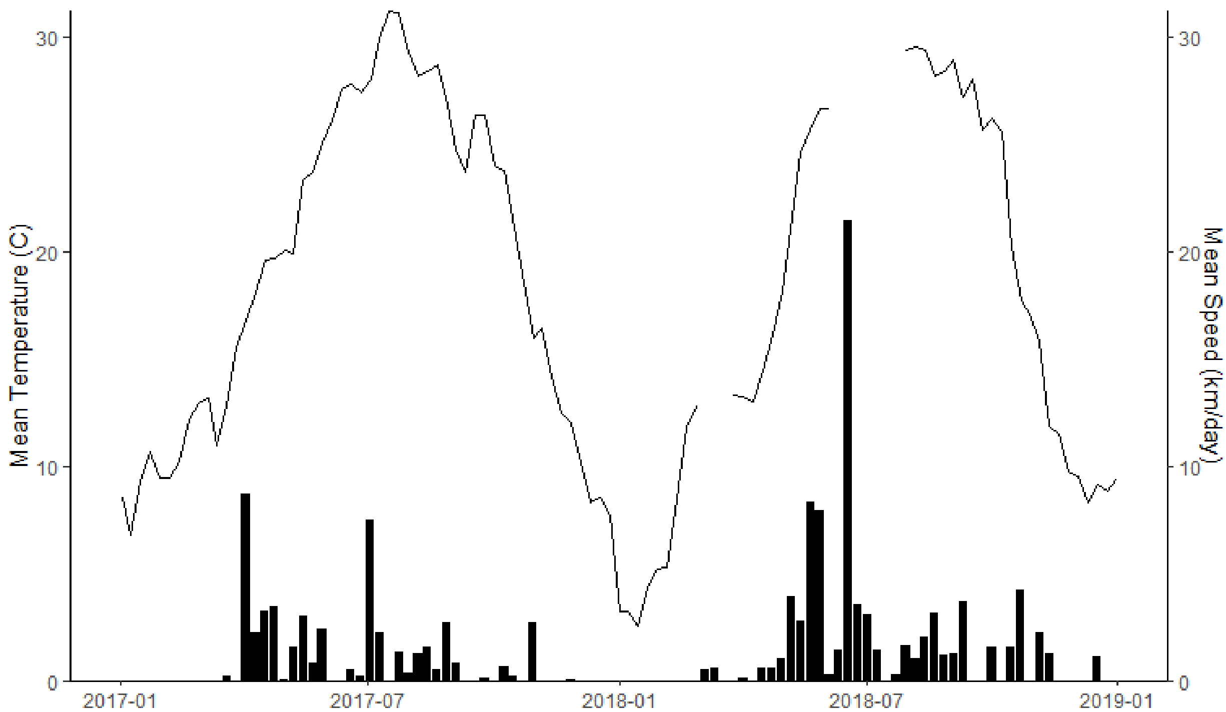

Figure 6. Mean weekly surface temperature (C, solid line) and mean weekly swimming speed (km/day, black bars) for Silver Carp in Kentucky Lake, 2017 – 2018.

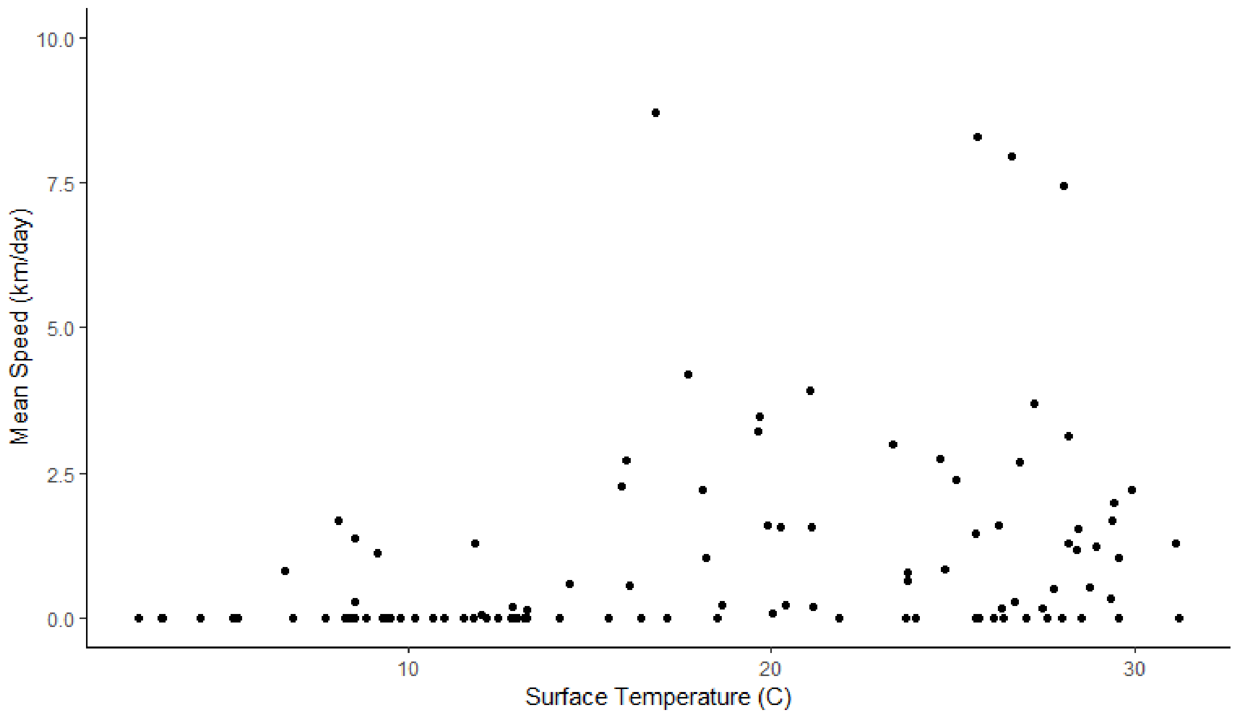

Figure 7. Comparison of Silver Carp mean weekly swimming speed (km/day) and mean weekly surface temperature (C). A 2-dimensional Kolmogorov-Smirnov test suggests that the relationship between speed and temperature changes once temperatures rise above 13.3^{0}C (D_{max} = 0.118, p = 0.000).

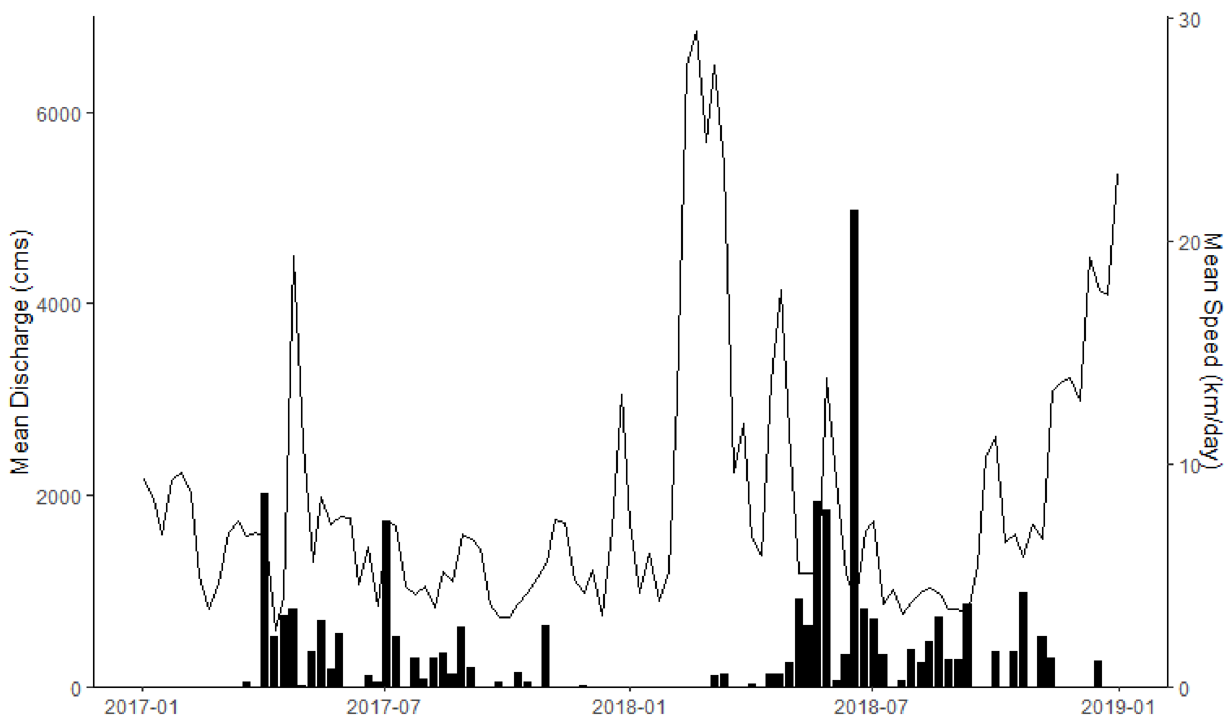

Figure 8. Mean weekly discharge (cms, solid line) and mean weekly swimming speed (km/day, black bars) for Silver Carp in Kentucky Lake, 2017 – 2018.

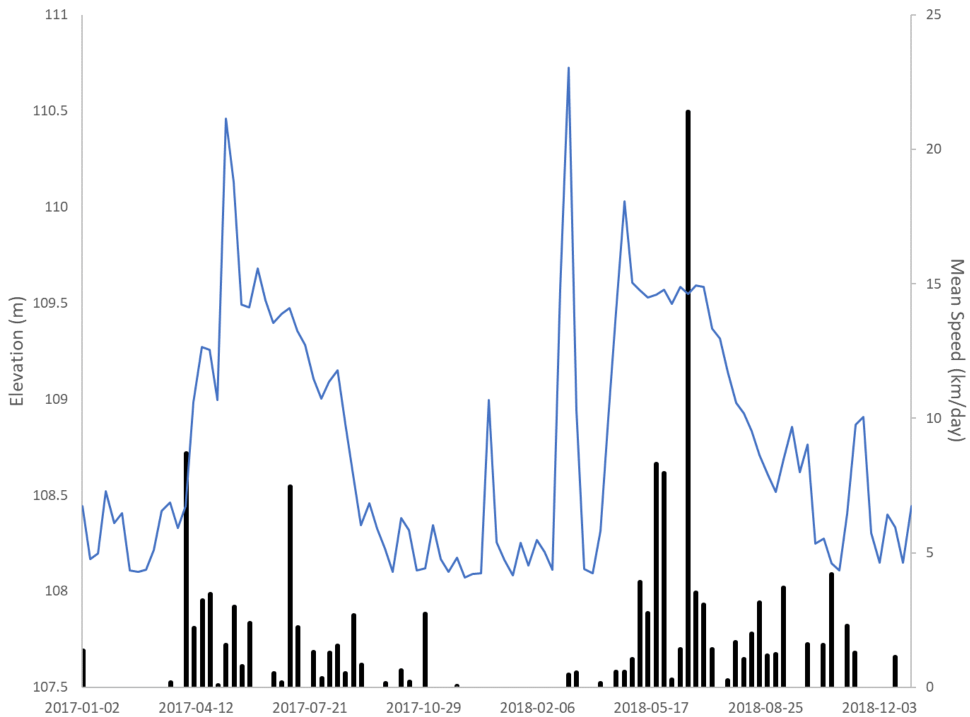

Figure 9. Mean weekly elevation (m, solid line) and mean weekly swimming speed (km/day, black bars) for Silver Carp in Kentucky Lake, 2017 – 2018.

Table 7. Mean "On the Move" speed (OTM) for Silver Carp in Kentucky Lake, 2017 – 2018. OTM speed represents the swimming speed of a fish when it is swimming from one set of VR2W receivers to the next nearest set of receivers.

Agency	Mean Swimming Speed (km/hr)	s.d.	N	Range (km/hr)
KDFWR[1]	1.1	0.6	20	(0.2 – 2.4)
MDWFP	2.8	1.0	10	(1.8 – 4.4)
TWRA	1.6	0.7	5	(0.6 – 2.3)

[1]KDFWR = Kentucky Department of Fish and Wildlife Resources, MDWFP = Mississippi Department of Wildlife, Fisheries, and Parks, TWRA = Tennessee Wildlife Resource Agency

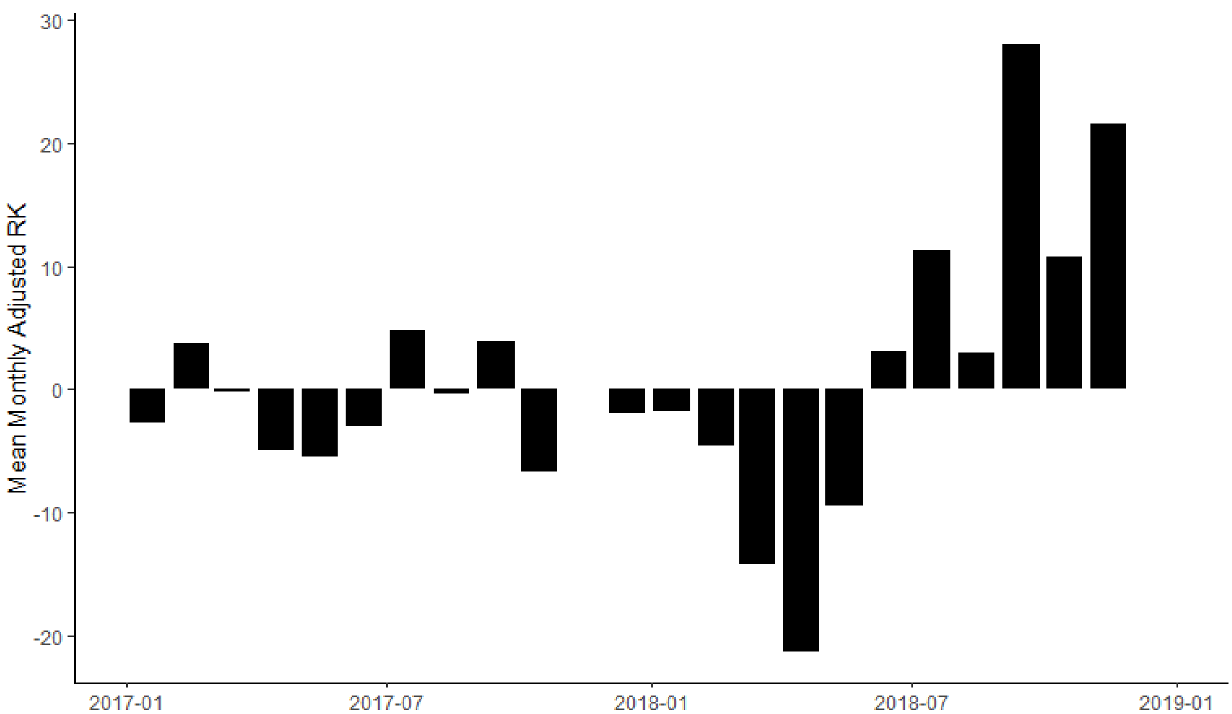

Figure 10. Mean monthly adjusted river kilometer (RK) for Silver Carp in Kentucky Lake. The RK is adjusted relative to RK 63.9 which is the median RK over 2017 – 2018 and which is near the mouth of Jonathan Creek. Negative values represent locations downstream from Jonathan Creek while positive values indicate locations upstream from Jonathan Creek. The Kentucky Lake Dam is at RK 36 which would be an adjusted RK of -27.9.

Table 8. Summary of dam crossings at Kentucky Lake and Lake Barkley, 2017 – 2018.

Dam	Transmitter	When Crossed	Direction	Detected in Lock during Passage	Species	Agency[1]	Release Location
Kentucky	A69-1601-55722	2017-05-02	upstream	Y	Paddlefish	MDC	Outside Lakes
Kentucky	A69-1601-54748	2017-05-17	upstream	Y	Paddlefish	MDC	Outside Lakes
Kentucky	A69-1601-51729	2018-01-26*	downstream	N	Silver Carp	KDFWR	HBS Dock
Barkley	A69-1601-54220	2018-04-15*	upstream	N	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1601-52072	2018-04-24	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1601-51748	2018-04-28	downstream	N	Silver Carp	KDFWR	Camp Currie
Kentucky	A69-1601-56736	2018-04-29*	downstream	N	Silver Carp	MDWFP	Indian Creek
Barkley	A69-1601-56732	2018-05-01*	downstream	N	Silver Carp	MDWFP	Indian Creek
Kentucky	A69-1601-56725	2018-05-01*	downstream	N	Silver Carp	MDWFP	Indian Creek
Kentucky	A69-1601-56733	2018-05-03	downstream	N	Silver Carp	MDWFP	Indian Creek
Barkley	A69-1602-28451	2018-05-09	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1602-29250	2018-05-26	upstream	Y	unknown	unknown	unknown
Barkley	A69-1602-28427	2018-06-08	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Barkley	A69-1602-28432	2018-06-24	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1601-51748	2018-06-27	upstream	Y	Silver Carp	KDFWR	Camp Currie
Barkley	A69-1602-28485	2018-07-04	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Barkley	A69-1601-56733	2018-07-06	upstream	Y	Silver Carp	MDWFP	Indian Creek
Barkley	A69-1602-28424	2018-07-10	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Barkley	A69-1602-28453	2018-07-23	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1602-28444	2018-08-09	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1601-52012	2018-08-21*	downstream	N	Silver Carp	KDFWR	Sledd Creek
Barkley	A69-1601-52079	2018-09-10	upstream	Y	Silver Carp	KDFWR	Barkley Tailwaters
Kentucky	A69-1601-56732	2018-09-29	upstream	Y	Silver Carp	MDWFP	Indian Creek

*Crossing date is approximate because not enough detections are available to pinpoint crossing.

[1]KDFWR = Kentucky Department of Fish and Wildlife Resources, MDC = Missouri Department of Conservation, MDWFP = Mississippi Department of Wildlife, Fisheries, and Parks, TWRA = Tennessee Wildlife Resource Agency

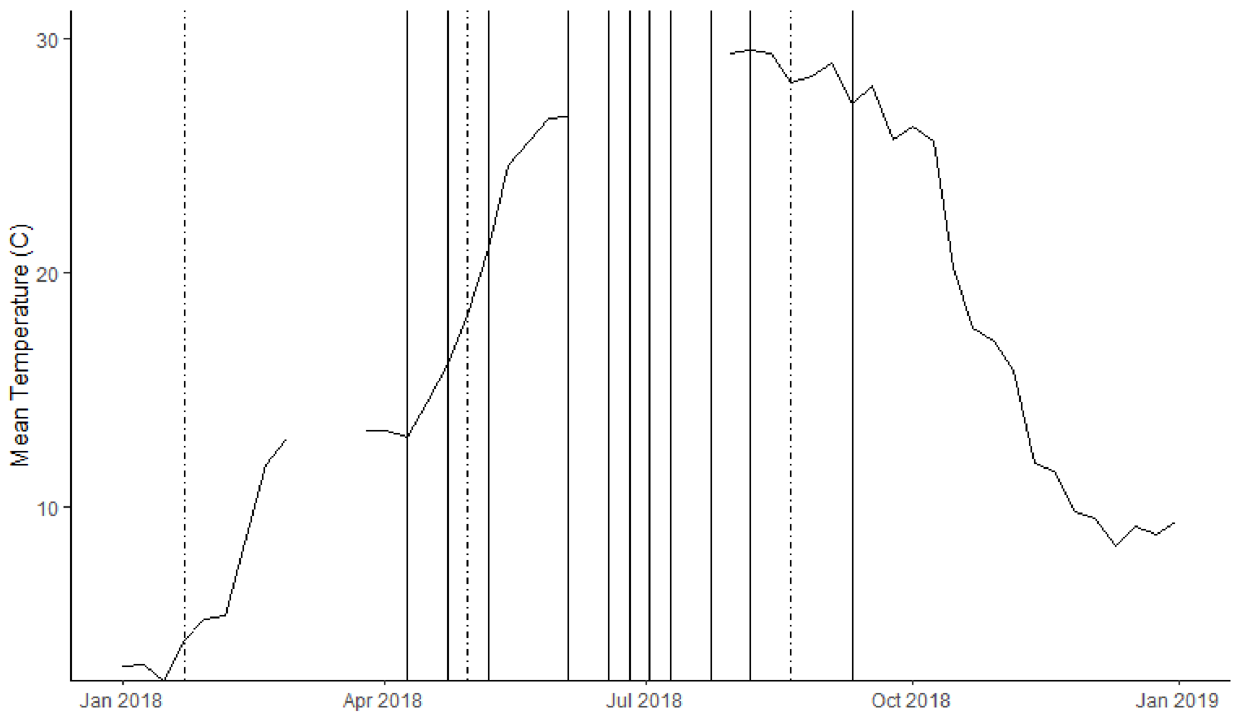

Figure 11. Silver Carp weekly dam crossings and surface temperature (^{0}C) of Kentucky Lake. Dashed lines indicate downstream crossings and solid lines indicate upstream crossings. Dam crossings include both Kentucky Lake Dam and Lake Barkley Dam.

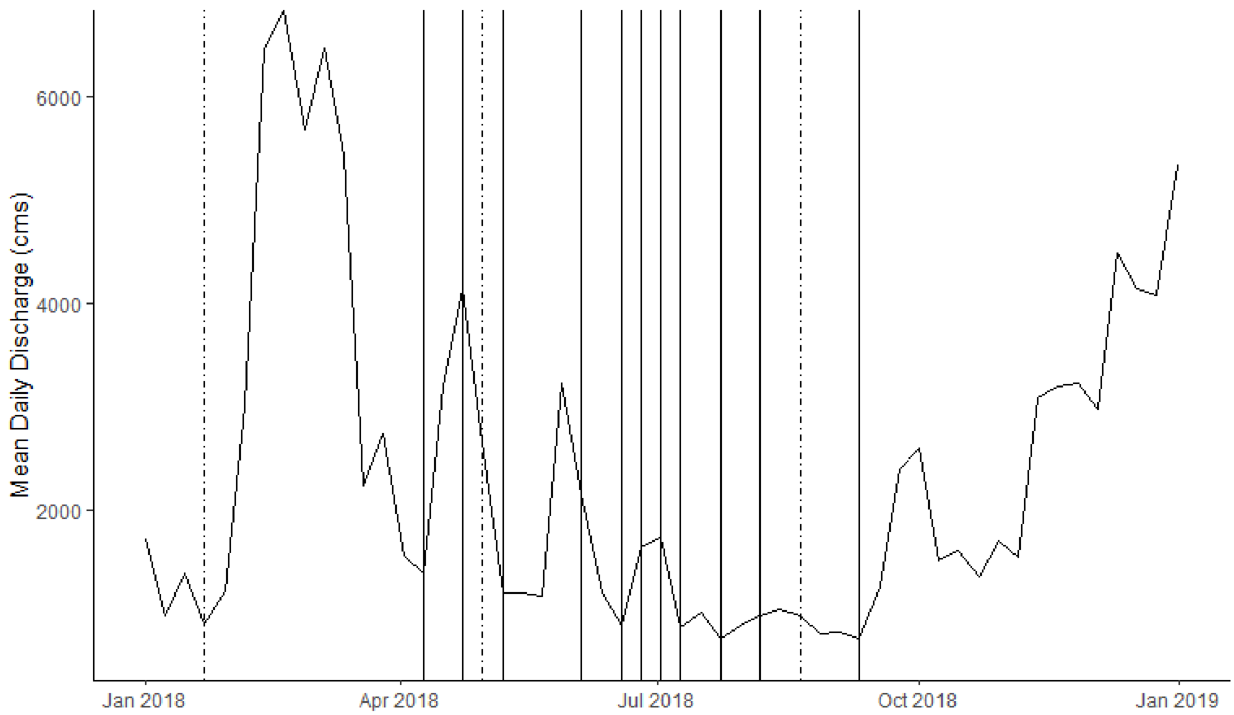

Figure 12. Silver Carp dam weekly crossings and mean daily discharge (cms) of Kentucky Lake. Dashed lines indicate downstream crossings and solid lines indicate upstream crossings. Dam crossings include both Kentucky Lake Dam and Lake Barkley Dam.

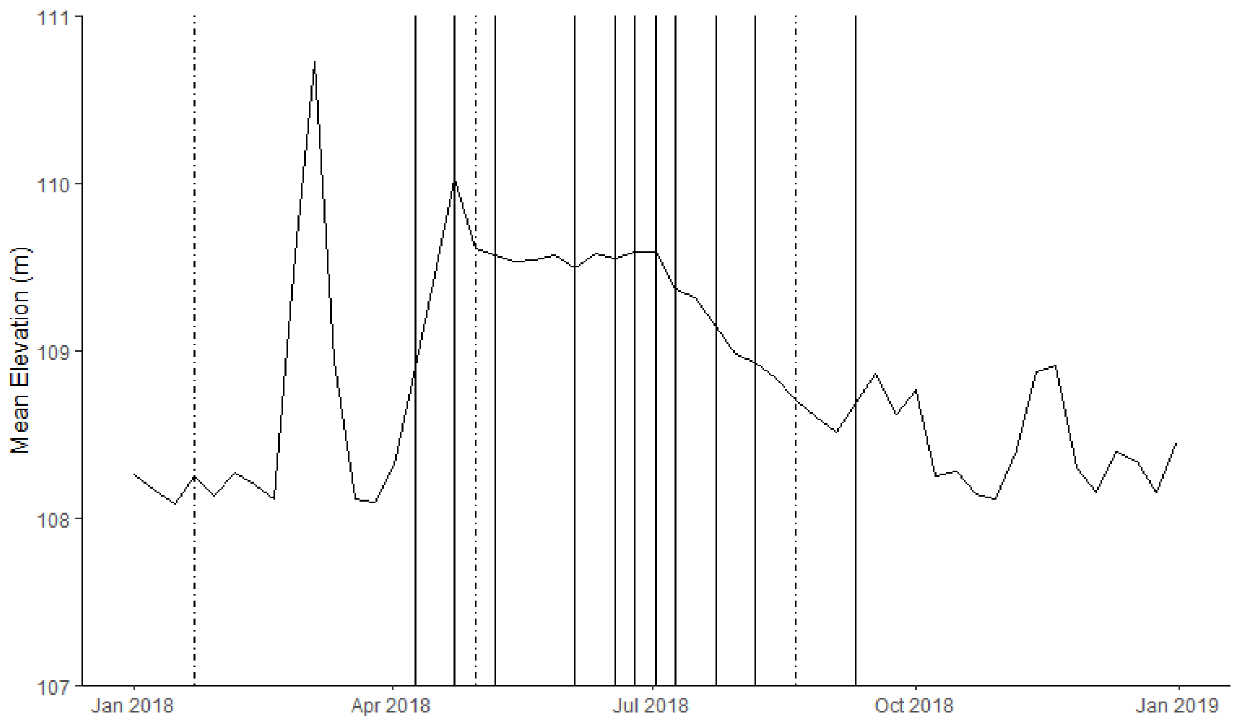

Figure 13. Silver Carp dam weekly crossings and mean elevation (m) of Kentucky Lake. Dashed lines indicate downstream crossings and solid lines indicate upstream crossings. Dam crossings include both Kentucky Lake Dam and Lake Barkley Dam.

STATE: KENTUCKY

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2018 – March 31, 2019

Research and Survey Section

Project 4: Monitoring Silver and Bighead Carp Relative Abundance and Density in Barkley and Kentucky Reservoirs

Project Objectives:

1. Estimate relative abundance of silver carp and bighead carp in Barkley and Kentucky reservoirs
   1.1. Investigate Asian carp age and growth, condition, gonadosomatic index, sex ratios, and fecundity to assess removal efforts as commercial fisheries grow in Barkley and Kentucky reservoirs.
   1.2. Monitor the condition of fish species that may compete directly with silver carp and bighead carp for food at multiple life stages including gizzard shad, bigmouth buffalo, and paddlefish.
2. Estimate density of silver carp in Barkley and Kentucky reservoirs.
3. When young of year Asian carp are present in Barkley and Kentucky reservoirs; compare gear types for capturing juvenile Asian carp, estimate hatch date of Asian carp, and identify potential spawning areas.

A. ACTIVITY

Standard sampling data indicated that overall catch rates for carp (silver; *Hypophthalmichtys molitrix*, bighead; *Hypophthalmichtys noblis*, grass; *Ctenopharyngodon idella* and common carp; *Cyprinus carpio*), in Barkley reservoir were higher in July (N=331) and decreased in October (N=212). Overall catch rates for carp in Kentucky reservoir were consistent between July (N=505) and October sampling (N=522). Catch rates for bighead carp were observed to be higher in both reservoirs in July (Barkley; N=13, Kentucky; N=11) when compared to October (Barkley; N=3, Kentucky; N=3).

Standard sampling data indicated that catch per unit effort (CPUE) measured in fish per linear yard of gill net for silver carp, was highest in 3” mesh and lowest in 5” mesh. CPUE was observed to be higher in the embayment sites when compared to main channel sites. Barkley reservoir had a mean total CPUE of 0.123 fish/yard for the embayment sites and 0.033 fish/yard for the main channel sites. Kentucky reservoir had a mean total CPUE of 0.224 fish/yard for the embayment sites and 0.080 fish/yard for the main channel sites. A difference was detected in mean CPUE when comparing main channel habitats to embayment habitats within Barkley or Kentucky reservoirs (P=0.007, P=0.03). However, no difference was detected in mean CPUE when comparing Barkley and Kentucky reservoirs (N=16, $F_{1,31}$=3.22, P=0.08).

Data suggested the 600mm size class of silver carp dominated Barkley reservoir and the 600mm size class was slightly dominate over the 500mm size class in Kentucky reservoir. Silver carp ages ranged from 2 to 10 years old within Barkley reservoir and from 2 to 11 years old within Kentucky reservoir, with age 3 silver carp being the most abundant in both reservoirs.
Annual mortality for silver carp from Barkley reservoir was estimated at 67% and instantaneous mortality was estimated at 1.12 (N=129, $F_{1,6}$=28.1, P=0.00182, R^2=0.82). Annual mortality for silver carp from Kentucky reservoir was estimated at 60% and instantaneous mortality was estimated at 0.92 (N=82, $F_{1,7}$=9.5, P=0.017, R^2 =0.58).
Tagging effort for the estimating density of Bigheaded carp (silver and bighead) project resulted in tagging 1292 silver carp (Barkley=619, Kentucky=673). Only two fish have been reported to date, no analysis was conducted at this time. No young of year fish were detected in Barkley and Kentucky reservoirs during 2018.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 31 March 2019
Work accomplished – 31 March 2019

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

Objective 1: Estimating relative abundance of silver and bighead carp in Barkley and Kentucky reservoirs

FINDINGS

Relative abundance of silver and bighead carp in Barkley and Kentucky reservoirs

Kentucky Department of Fish and Wildlife Resources (KDFWR) initiated a standard sampling project in 2018. The objective of this project was to monitor the status of silver carp (*Hypophthalmichtys molitrix*) and bighead carp (*Hypophthalmichtys noblis*) populations in Barkley and Kentucky reservoirs and assess the effect of the commercial fishery through time. Stratified standard sampling was conducted in the summer (July) and the fall (October) using gill nets with 3", 4" and 5" bar mesh webbing. Nets were fished throughout both reservoirs at four locations (Figure 1). Eight 300' nets, were fished overnight at each site, four nets in the main channel habitat and four nets in the embayment habitat. Additional data from commercial fishing and/or Paupier net sampling was used to strengthen some analyses.

Standard sampling data indicated that overall catch rates for carp (silver, bighead, grass (*Ctenopharyngodon idella*) and common (*Cyprinus carpio*)), in Barkley reservoir were highest in July (N=331) and decreased in October (N=212). Overall catch rates for carp in Kentucky reservoir were consistent between July (N=505) and October sampling (N=522) (Table 1). Catch rates for bighead carp were observed to be higher in both reservoirs in July (Barkley; N=13, Kentucky; N=11) when compared to October (Barkley; N=3, Kentucky; N=3) (Table 1). Although catch rates were insufficient for meaningful relative abundance analysis at this point this data will provide a baseline for long-term population trend analysis.

Standard sampling data indicated that catch per unit effort (CPUE), measured in fish per linear yard of gill net, for silver carp, was highest in 3" mesh and lowest in 5" mesh. CPUE was observed to be higher in the embayment sites when compared to main channel sites. Barkley reservoir had a mean total CPUE of 0.123 fish/yard for the embayment sites and 0.033 fish/yard for the main channel sites. Kentucky reservoir had a mean total CPUE of 0.224 fish/yard for the embayment sites and 0.080 fish/yard for the main channel sites (Table 2). Using a T-test a significant difference was detected in mean CPUE when comparing main channel habitats to embayment habitats within Barkley or Kentucky reservoirs (P=0.007, P=0.03). However, no difference was detected in mean CPUE when comparing Barkley and Kentucky reservoirs through an ANOVA (N=16, $F_{1,31}$=3.22, P=0.08).

A length-frequency histogram was created for silver carp from Barkley and Kentucky reservoirs from all capture methods in 2018. Data suggested the 600mm size class of silver carp dominated Barkley reservoir. This was also observed in data collected in 2017 (KDFWR 2017). However, data suggested the 500mm and 600mm size classes had similar frequencies in Kentucky reservoir, with 600mm being slightly more dominate. In 2017 the 500mm size class was significantly dominate over the 600mm size class. Data from 2018, suggested Barkley reservoir exhibited a higher frequency of silver carp above 600mm and very few fish below 600mm (Figure 2). Whereas, Kentucky reservoir exhibited a higher frequency of silver carp below 600mm and fewer fish above 600mm size class (Figure 3).

Age & Growth

Fin rays were collected from silver carp in Barkley and Kentucky reservoirs, during fall sampling in 2018 for aging. Ages ranged from 2 to 10 years old within Barkley reservoir and from 2 to 11 years old within Kentucky reservoir, with age 3 silver carp being the most abundant in both reservoirs (Figure 4 & 5).

Figure 4, compares age frequencies of silver carp in Barkley reservoir between 2017 and 2018. In 2017, age 2 fish (2015 cohort) were not fully recruited into the sampling gear. It was observed in 2018 that the frequency of age classes older than age 3, had reduced in frequency when compared to 2017. KDFWR does not have data to support this trend in Kentucky reservoir from 2017 to 2018.

Data suggest that Kentucky reservoir had a higher frequency of age 2 silver carp in 2018 than Barkley reservoir. Logically there would be a higher occurrence of age 2 fish in the reservoir with the most active lock, that being Kentucky reservoir with ~ 4777 locking events compared to Barkley with ~ 1784 locking events (Data from 2017, Personal communication from Caleb Skinner, Lock Master ACOE). A higher incidence of movement was observed, at the Kentucky Lock compared to Barkley Lock (KDFWR Silver Carp Telemetry Project Report 2018, Table 8). Consequently, the age 2 age class of carp are likely immigrating into the reservoirs through the lock chambers at the dams.

A von Bertalanffy growth model was constructed for the 2015 cohort of silver carp in Barkley and Kentucky reservoirs. Initially growth models were created for each of the sexes, however a T-test determined there was no significant difference between male and female growth rates (Barkley: N=59, T_{50}=0.98, P=0.33; Kentucky: N=47, T_{45}=-0.019, P=0.85). Consequently, sexes were aggregated within each reservoir for this report. In an effort to increase data points for this analysis, fish that are considered age 4 were collected in the winter of 2018 and it was assumed no growth occurred for the remainder of the season. This information will be amended with data collected in 2019 and verified for accuracy in the Annual Performance Report for 2019. The von Bertalanffy model predicted a larger theoretical maximum length (L_∞) of silver carp in Barkley reservoir (875mm) than in Kentucky reservoir (677mm) (Figure 6, 7 & 8). A significant difference was observed between the growth rates of silver carp in the two reservoirs (N=106, T_{104}=12.44, P= <0.005). The higher L_∞ of silver carp in Barkley reservoir could potentially be a compensatory growth response resulting from the considerably higher commercial fishing pressure in this reservoir (KDFWR Asian Carp Harvest Program Project Report 2018, Tables 3 & 4). Furthermore, Barkley is a more productive reservoir when compared to Kentucky as a result of the difference between their watersheds. Logically Barkley reservoir would have more food resources available to facilitate silver carp growth than Kentucky reservoir. If this hypothesis holds true, then the 2015 cohort of silver carp in Kentucky reservoir will not be fully vulnerable to current commercial fishing gears for another 2 or 3 years. As the commercial fishing efforts intensify in response to the Kentucky Fish Center (KFC) objectives (KDFWR Asian Carp Harvest Program Project Report 2018, Table 10), increased harvest effort should be directed toward Kentucky reservoir. Increased removal efforts are recommended to diminish the impacts of over population and improve the catchability of silver carp by commercial fishing gears, as this is the best mechanism KDFWR currently has to control this species.

Mortality

Catch-curve regressions were developed for silver carp by reservoir. Data for age frequency were $\log_{10}(x+1)$ transformed to compensate for heteroscedasticity. A Chapman-Robson analysis was performed to estimate annual mortality (Â) and instantaneous mortality (Z). Previous mortality estimates for annual performance reports excluded age-3 fish because that age class was not fully recruited into the sampling gear. In 2018 age-3 silver carp were included in the analysis because sampling gears were diversified to include gill nets with a mesh size of 3”-5” bar mesh and the Paupier net (electrified butterfly trawl), where as in previous years fish were primarily collected through commerical fishing effort that utilized 4.25" and larger bar mesh gill nets.

Annual mortality for silver carp from Barkley reservoir was estimated at 67% and instantaneous mortality was estimated at 1.12 (N= 129, $F_{1,6}$=28.1, P=0.00182, R^2=0.82, Figure 9). Annual mortality for silver carp from Kentucky reservoir was estimated at 60% and instantaneous mortality was estimated at 0.92 (N=82, $F_{1,7}$=9.5, P=0.017, R^2=0.58, Figure 10). Kentucky reservoirs' analysis yielded a lower than expected R^2 value, the irregular data series attributed to this. Annual mortality estimates increased from Barkley reservoir in 2017 (60.6%) and Kentucky reservoir in 2016 (47.9%) (KDFWR 2017).

Silver carp exhibit variable recruitment in Barkley and Kentucky reservoirs. In addition, movement of a portion of the population through the lock and dam structures, has led to the violation of several of the assumptions mortality models include. Through the telemetry receiver array, silver carp movement has been observed through both Barkley and Kentucky locks. However, Kentucky lock is hypothesized to be responsible for more movement of silver carp from the rivers into the reservoirs because of its higher frequency of use. Telemetry data also suggests that there is more silver carp immigrating into the reservoirs than are emigrating into the rivers (KDFWR Silver Carp Telemetry Project Report 2018, Table 8).

The 2015 cohort of silver carp are the dominate cohort in the reservoirs. KDFWR plans to estimate annual mortality specific to this cohort in 2019. A cohort mortality estimate will yield a more precise outlook of the commercial fishery's potential and allow further discussion into the change in mortality rate between Kentucky reservoir in 2016 and 2018. Additionally, in 2019, the Bio-Acoustic Fish Fence (BAFF) is schedule to be installed and tested at Barkley lock. If this device is effective, then demographic estimates, such as mortality, will become more accurate as the silver carp population shifts to being a closed population.

Condition

Linear regressions were constructed to describe the $\log_{10}$length-$\log_{10}$weight relationship for silver carp in Barkley and Kentucky reservoirs. The length-weight equation for Barkley reservoir was estimated at Log_{10}(weight(g)) = 2.9783(Log_{10}(length(mm))-4.9323 (Figure 11). The length-weight equation for Kentucky reservoir was estimated at Log_{10}(weight(g)) = 2.8733(Log_{10}(length(mm))-4.6457 (Figure 12). Weights were predicted for Barkley reservoir at three lengths: 450mm (933g), 650mm (2789g) and 800mm (5176g) and Kentucky reservoir: 450mm (650g), 650mm (2733g) and 800mm (4963g). The model produced in 2018 indicated an increased weight at 450mm from previous models but lower weights at 800mm (Table 3). In previous reports weight at 650mm was not described, however because the 600mm size class was dominate on both reservoirs this metric was considered relevant in 2018.

Data collected from fall standard sampling was used to analyze relative weights (*W*r). Relative weight was calculated using the equation $Log_{10}(W_s)$= -5.15756 + 3.06842(Log_{10}TL) for silver carp and $Log_{10}(W_s)$= -4.65006 + 2.88934(Log_{10}TL) for bighead carp (Lamer, 2015). The mean *W*r for silver carp in Barkley reservoir was 90 (N=69, S.E.=±0.80) and the mean *W*r for silver carp in Kentucky reservoir was 90 (N=52, S.E.=±0.98). The mean *W*r for bighead carp in Barkley reservoir was 101 (N=3) and the mean *W*r for bighead carp in Kentucky reservoir was 97 (N=3).

Silver carp relative weights (*W*r) were also calculated using commercial fishing data from October and November of 2018. Barkley reservoir's mean *W*r was 93 (N=87, S.E.=±0.46). No commercial fishing data was available from Kentucky reservoir from the fall of 2018 to perform an analysis of silver carp relative weights. Aggregating commercial fishing data collected throughout 2018 from Barkley reservoir yielded a mean *W*r of 93 (N=777, S.E.=±0.33) and Kentucky reservoir yielded a mean *W*r of 100 (N=33, S.E.=±5.76). Mean relative weights have slightly decreased from observations in 2017, falling to just below average condition (KDFWR 2017).

<u>Gonadosomatic Index (GSI)</u>

Mean GSI scores, for female silver carp from Barkley reservoir were lower in 2018 than observed in 2017. Data collected in 2018 included fish captured through electrofishing and gill nets with ≥3" bar mesh webbing. In 2017, GSI data collected was less robust, primarily from fish caught by the commercial fishery, which predominantly used gill nets with ≥4.25" bar mesh webbing (KDFWR 2017). Silver carp from the commercial fishery in 2017 were larger (800-900mm) and sexually mature individuals, whereas fish collected in 2018 were smaller (600-700mm) and contained individuals that were not sexually mature. It is hypothesized that the 2015 cohort of silver carp will completely attain sexual maturity in 2019 at age 4 falling within the established range of age at maturity (Kamilov 1985; Costa-pierce 1992, Nico et al. 2019).

In 2018 no peak in mean discharge (CFS) through Barkley Reservoir Lock and Dam was observed with a corresponding peak in female silver carp mean GSI values from Barkley reservoir, until November (Figure 13). By this time, water temperatures were approaching the lower threshold, conducive to egg development or larval fish survival if spawning had occurred. However, there was also an increase in GSI values during the month of May. This rise was likely stimulated by increasing water temperatures instead of a surge in water flow. No successful spawning events were detected during this period.

Sex ratios were calculated for silver carp in both reservoirs, from aggregated data in 2018. Barkley reservoir was calculated to be comprised of 48% males (N=602) and 52% females (N=640), a 0.94:1.06 ratio. Kentucky reservoir was calculated to be comprised of 51% males (N=405) and 49% females (N=384), a 1.05:0.95 ratio.

<u>Monitoring fish species with potential direct competition from silver carp</u>

During standard sampling effort in 2018, capture rates of species with potential direct competition from silver carp were low (Table 5 & 6). Low catch rates for these species may be a result of lower relative abundance when compared to Asian carp. Additionally, water temperatures were ~10^{o} cooler in October than in July, which may have been significant enough to reduce the activity level or alter the habitat use of these species. Relative weights (*W*r) were calculated for the individuals in the fall using standard weight equations from Blackwell et al. 2000. However, the sample size was insufficient for any inference about the population in either reservoir. Two bigmouth buffalo (*Ictiobus cyprinellus*) were collected in Barkley reservoir with a mean *W*r of 80. Three bigmouth buffalo were collected in Kentucky reservoir with a mean *W*r of 86. A total of two paddlefish (*Polyodon spathula*) were collected, one from each reservoir. The paddlefish from Barkley was determined to have a *W*r of 81 and the paddlefish from Kentucky was found to have a *W*r of 106 (Table 4).

Throughout both standard sampling periods, sportfish by-catch consisted of 2.8% of total by-catch from Barkley reservoir and 0.6% of total by-catch from Kentucky reservoir. Smallmouth buffalo (*Ictiobus bubalus*) and freshwater drum (*Aplodinotus grunniens*) were the predominant by-catch in both reservoirs (66.8% in Barkley, 77.8% in Kentucky). Catfish spp. (*Ictaluridae*) comprised 15.2% of total by-catch from Barkley reservoir and 10.2% of total by-catch from Kentucky reservoir. Blue catfish were the majority of the catfish species collected in both reservoirs. Paddlefish capture rates were observed to be 2.3% from Barkley reservoir and 1.4% from Kentucky reservoir (Tables 5 & 6).

One gizzard shad (*Dorosoma cepedianum*) was collected during standard sampling efforts on either reservoir. It is unlikely that a representative sample of *Dorosoma spp.* would be collected with the current gear utilized through the standard sampling project plan. If information becomes a priority for these species, then a targeted sampling plan will need to be drafted.

Using fish collected through sampling with the Paupier net (electrified butterfly trawl) and traditional boat electrofishing in October 2018, gizzard shad mean relative weight in Kentucky reservoir was estimated at 103 (N=268, S.E.=±1.70), using the formula presented in Blackwell et al. 2000. Based on this analysis, adult gizzard shad condition is above average in Kentucky reservoir. Gizzard shad mean relative weight was estimated at 92 (N=35, S.E.=±3.08) in Barkley reservoir. These relative weight values are improvements from 2017, where Kentucky reservoir *W*r was estimated at 82 (N=155, S.E.= ±1.63) and Barkley reservoir *W*r was estimated at 87 (N=125, S.E.= ±1.99). 2019 will be the first year with a complete standard sampling regime, KDFWR will continue to monitor by-catch and evaluate the impacts of bigheaded carp (silver & bighead) and commercial fishing on the fishery.

Objective 2: Estimating density of silver carp in Barkley and Kentucky reservoirs

<u>Mark-Recapture Effort</u>

Kentucky Department of Fish and Wildlife Resources (KDFWR) worked with personnel from Tennessee Wildlife Resources Agency (TWRA), United States Fish and Wildlife Service (USFWS), United States Geological Service (USGS), Murray State University (MSU), and volunteers from United States Forest Service at Land Between the Lakes (LBL) to tag silver carp in Barkley and Kentucky reservoirs. Fish were tagged with a Floy Tag Company, FT-4 Lock-on tag, with a unique identification number. Initially the targeted sample size was 500 fish per reservoir, with a subset of 20% of tagged fish receiving a secondary tag. The primary tag was placed posterior of the dorsal fin and the secondary tag was placed anterior of the dorsal fin. Fish were captured using short set gill nets (<4 hours) and D.C. electrofishing. Tagging effort occurred over eight days (four on each reservoir), and a total of 1292 silver carp were tagged. A total of 619 silver carp were tagged on Barkley reservoir with a mean length of 684mm and a mean weight of 3830 grams. On Kentucky reservoir, 673 silver carp were tagged with a mean length of 627mm and a mean weight of 2570 grams. A broader range of silver carp length classes were collected in Kentucky reservoir when compared to those collected in Barkley reservoir (Figures 14 & 15). Both reservoirs were dominated by fish in the 600mm size class, which was consistent with observations through other sampling efforts.

As of February 2019 only three fish have been returned through commercial fishing efforts. The first tag return was on October 5, 2018 from Blood River on Kentucky reservoir. This fish was tagged and released on September 5, 2018 at Taylor Bay on Barkley reservoir. No length or weight data was available for this fish. The second tag return was on December 4, 2018 from Nickell Branch on Barkley reservoir. This fish was tagged and released on September 7, 2018 at Nickell Branch on Barkley reservoir. Length and weight data was collected from the returned fish, no significant change in weight was observed. The area around where the tag was inserted into the tissue exhibited signs that the fish was still in the process of healing. The area did not appear to be infected, but did display some localized redness. The third tag return was on February 26, 2019 from Crooked Creek on Barkley reservoir. This fish was tagged and released on September 7, 2018 at Crooked Creek on Barkley reservoir. This fish appeared to be in good condition, the tagging location did not appear to be infected, but similar to the previous fish, displayed some redness around tag insertion site.

Within the silver carp population in the reservoirs, individuals express a variety of movement patterns. From fish that are very sedentary, to fish that are extremely dynamic. These observations are supported by data collected through the acoustic array that is reported in Project 4 (KDFWR Sliver Carp Telemetry Project Report 2018, Figure 7). The two tagged fish that have been reported exhibit movement behaviors within the range observed.

It is hypothesized because of the lower average size of silver carp tagged in Kentucky reservoir, individuals are not vulnerable to the size gill nets commercial fishermen are currently utilizing. Furthermore, Kentucky reservoir had ~5067 yards of gill nets fished whereas Barkley reservoir has ~23260 yards of gill nets fished in 2018 (KDFWR Asian Carp Harvest Program Project Report 2018, Tables 3 & 4).

It is recommended that a second tagging event occur upstream in Kentucky reservoir in the spring of 2019. This second tagging event will be equally beneficial to the TWRA, as the Asian carp commercial fishing industry develops in Tennessee. Expanding the geographic area where silver carp are tagged will increase likelihood of tag returns and strengthen the estimate of fish density. If tag returns remain low in 2019, it is recommended that a reward be offered to commercial fisherman to increase tag reporting rates.

Objective 3: Asian carp young of year monitoring and gear evaluations

Kentucky Department of Fish and Wildlife Resources observed no young of year Asian carp in Barkley or Kentucky reservoirs in 2018. Critical Species Investigation-West coordinated with Western Fisheries District to report any larval Asian carp collected through their larval fish tows during the summer and to collect any young of year Asian carp if present during fall sportfish sampling. TWRA conducted larval light trap, larval tows, and mini-fyke sampling upstream of Kentucky waters throughout 2018. No evidence of young of year Asian carp was recorded during these efforts. TWRA responded to several reports of young of year Asian carp sightings, however sampling efforts yielded primarily shad (*Dorosoma spp.*). KDFWR will continue to respond to reports of Asian carp spawning or young of year, from the public as incidents arise. Critical Species Investigation-West will continue to collaborate with Western Fisheries District, Murray State University, and TWRA should Asian carp spawning or young of year be reported.

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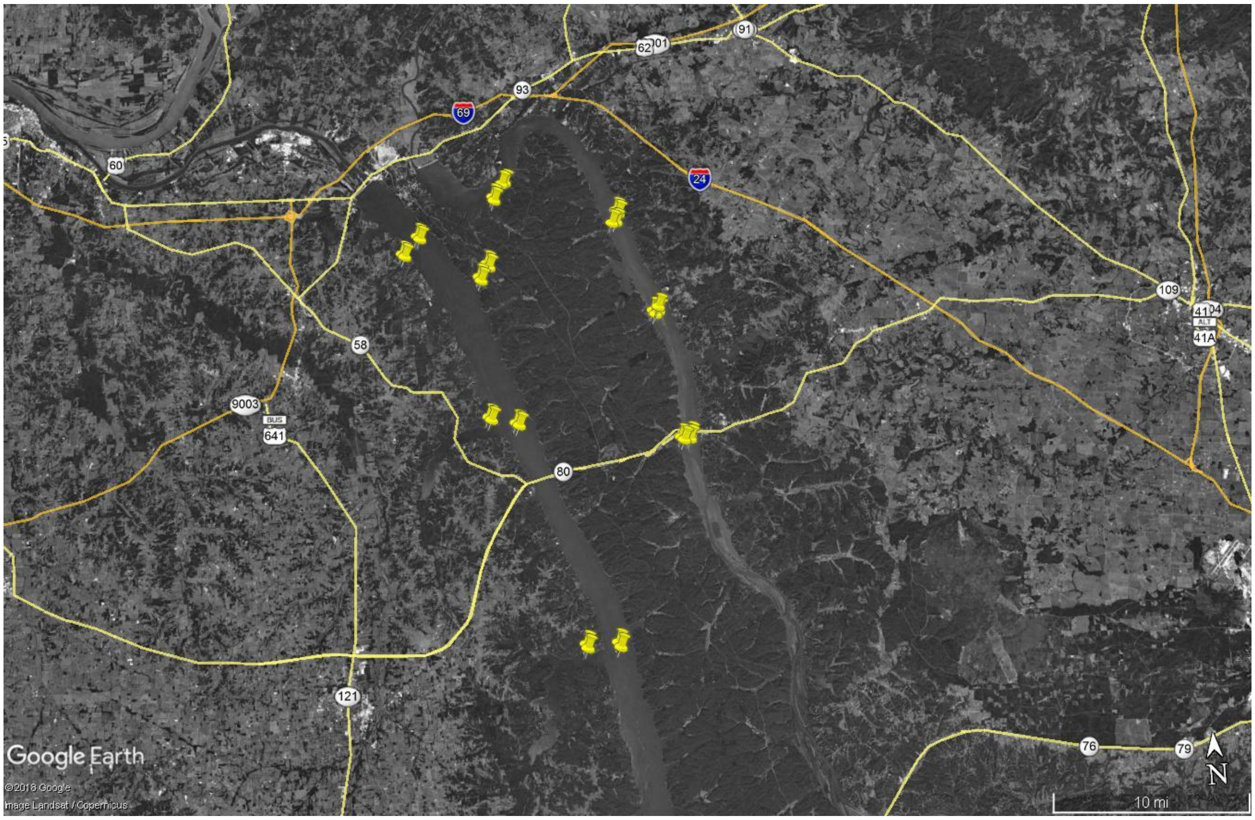

Figure 1. Location of standard sampling sites, where gill nets were fished by Kentucky Department of Fish and Wildlife Resources in 2018.

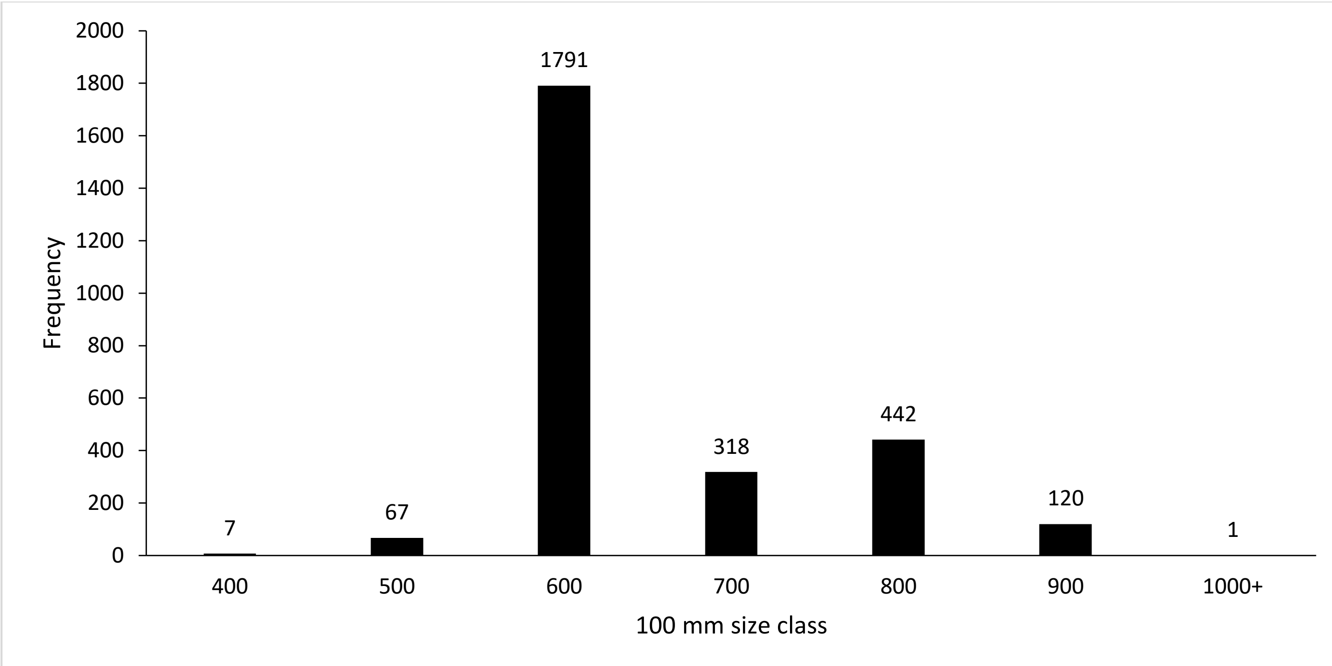

Figure 2. Length-frequency distribution of silver carp in Barkley reservoir, collected from all methods in 2018 (N=2746).

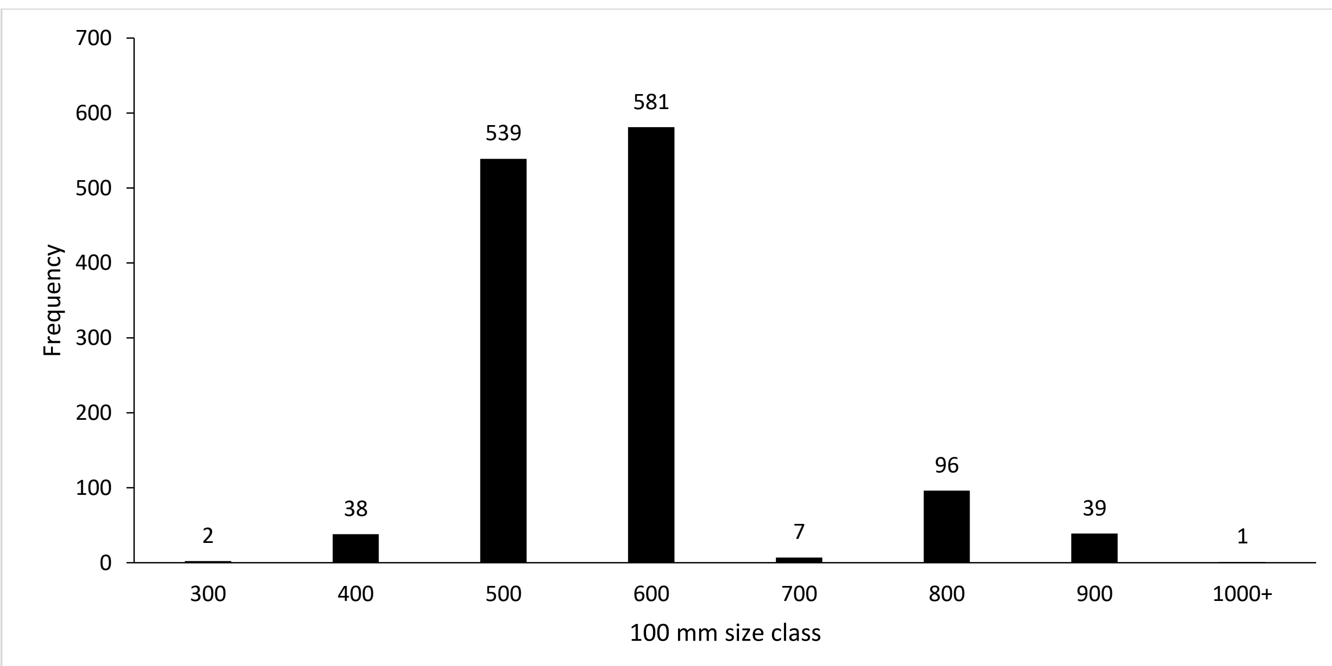

Figure 3. Length-frequency distribution of silver carp in Kentucky reservoir, collected from all methods in 2018 (N=1303).

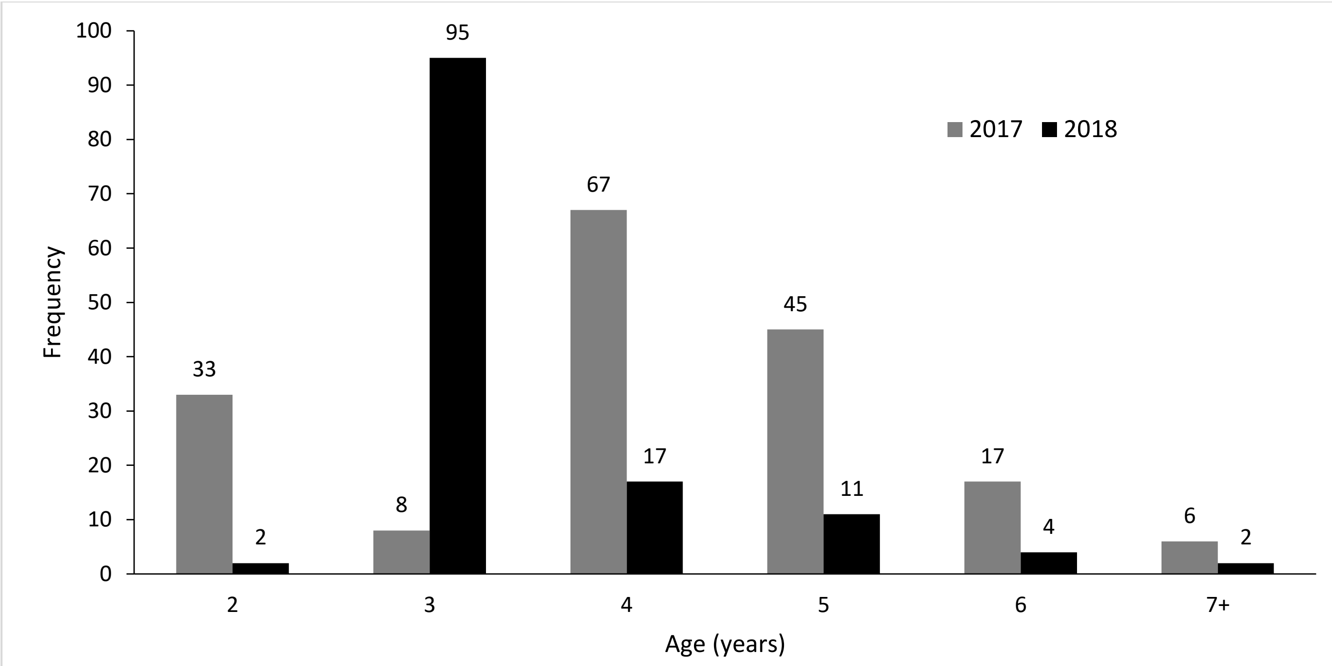

Figure 4. Age-frequency distribution of silver carp collected from Barkley reservoir in 2017 (N=176) compared to 2018 (N=131).

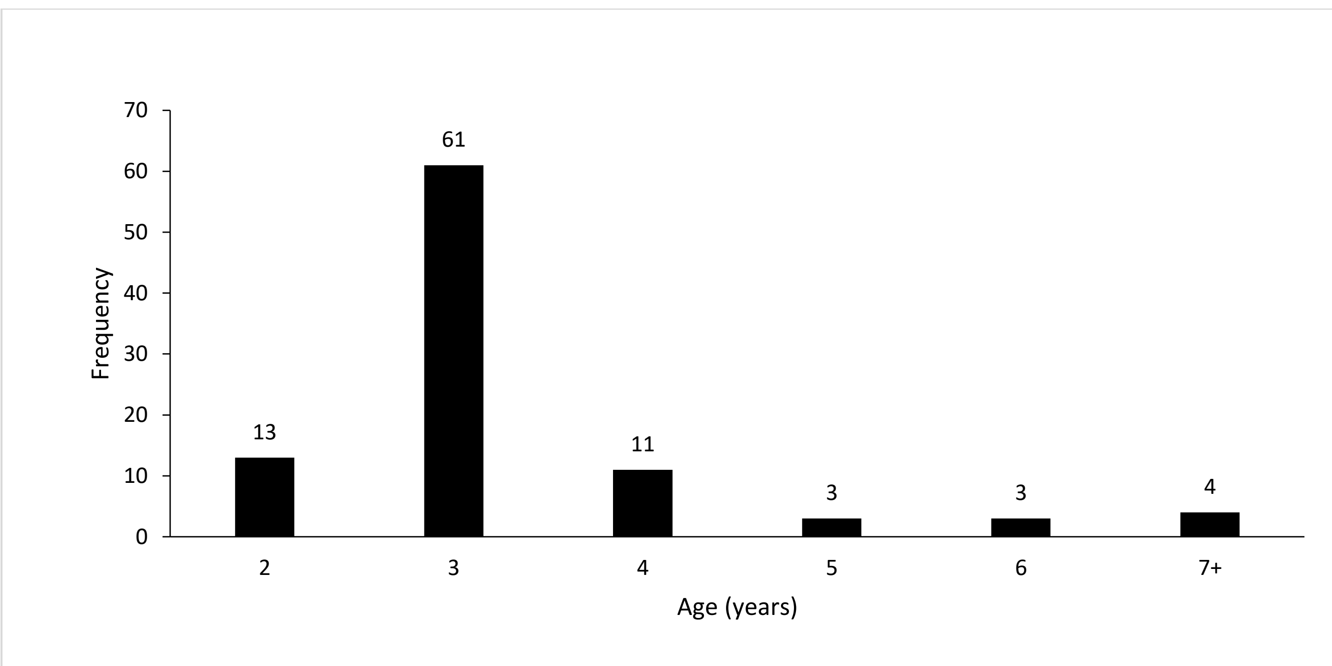

Figure 5. Age-frequency distribution for silver carp collected from Kentucky reservoir in 2018 (N=95).

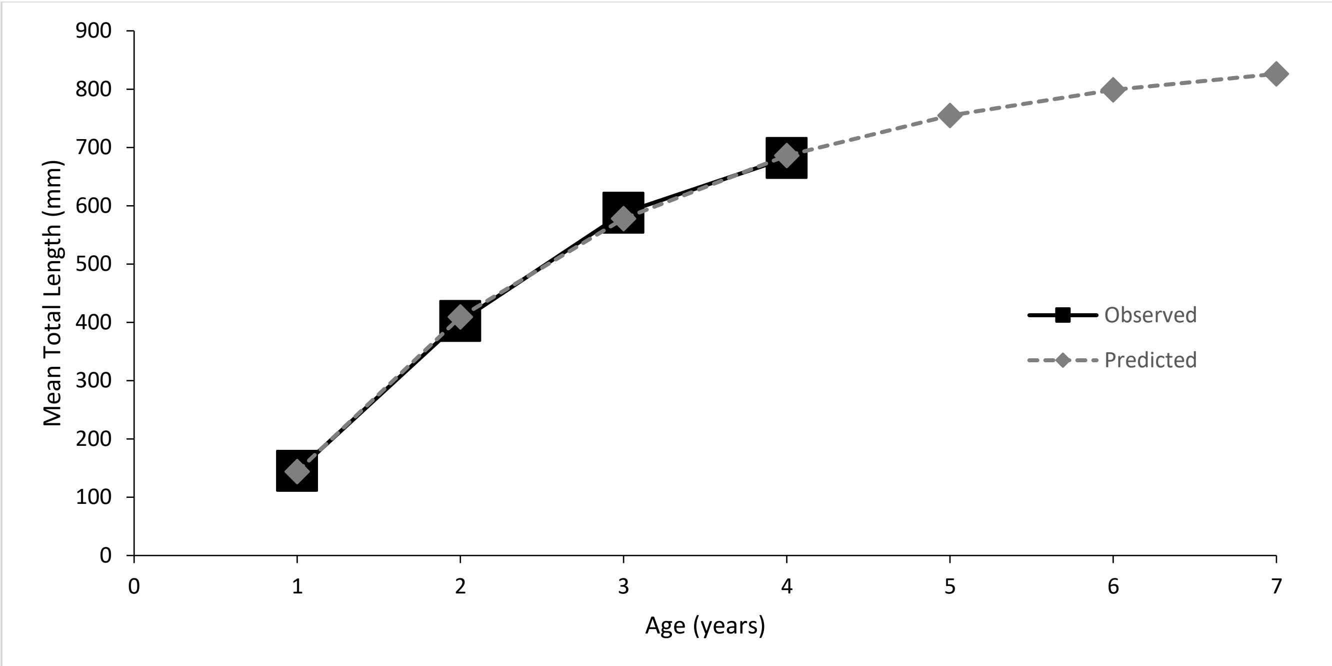

Figure 6. The von Bertalanffy growth model for predicted mean total length at age plotted against observed mean total length at age of silver carp from Barkley reservoir in 2018.

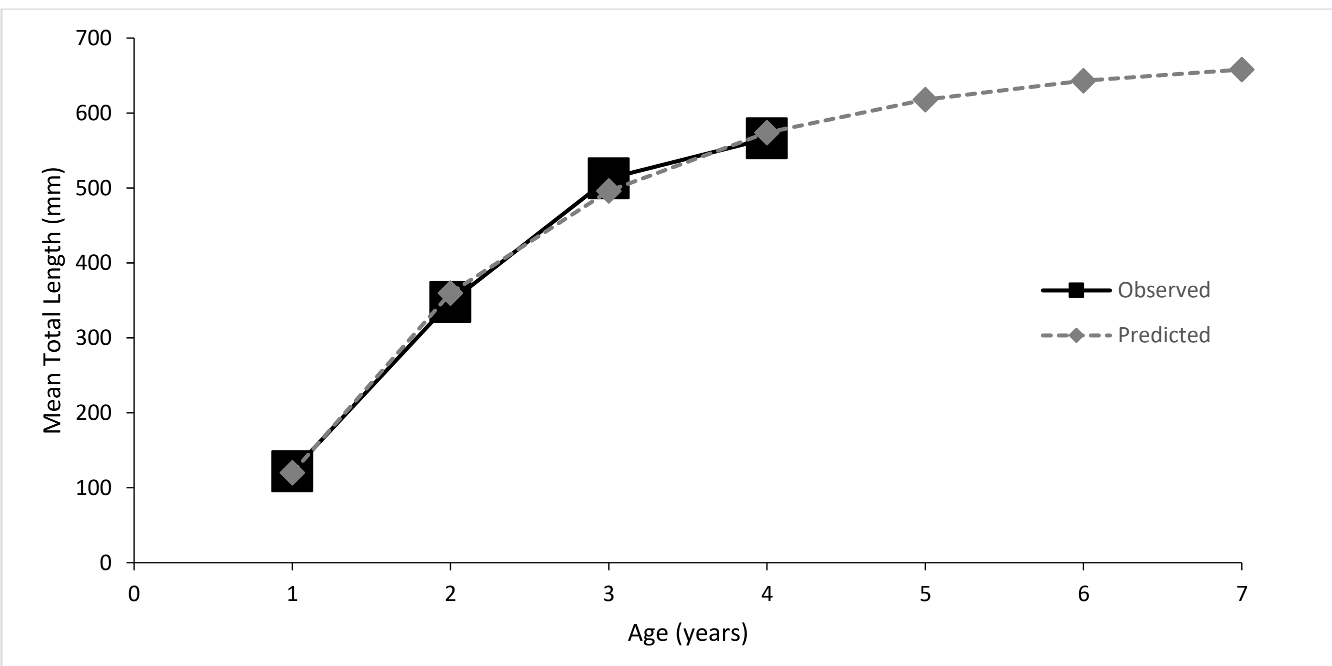

Figure 7. The von Bertalanffy growth model for predicted mean total length at age plotted against observed mean total length at age of silver carp from Kentucky reservoir in 2018.

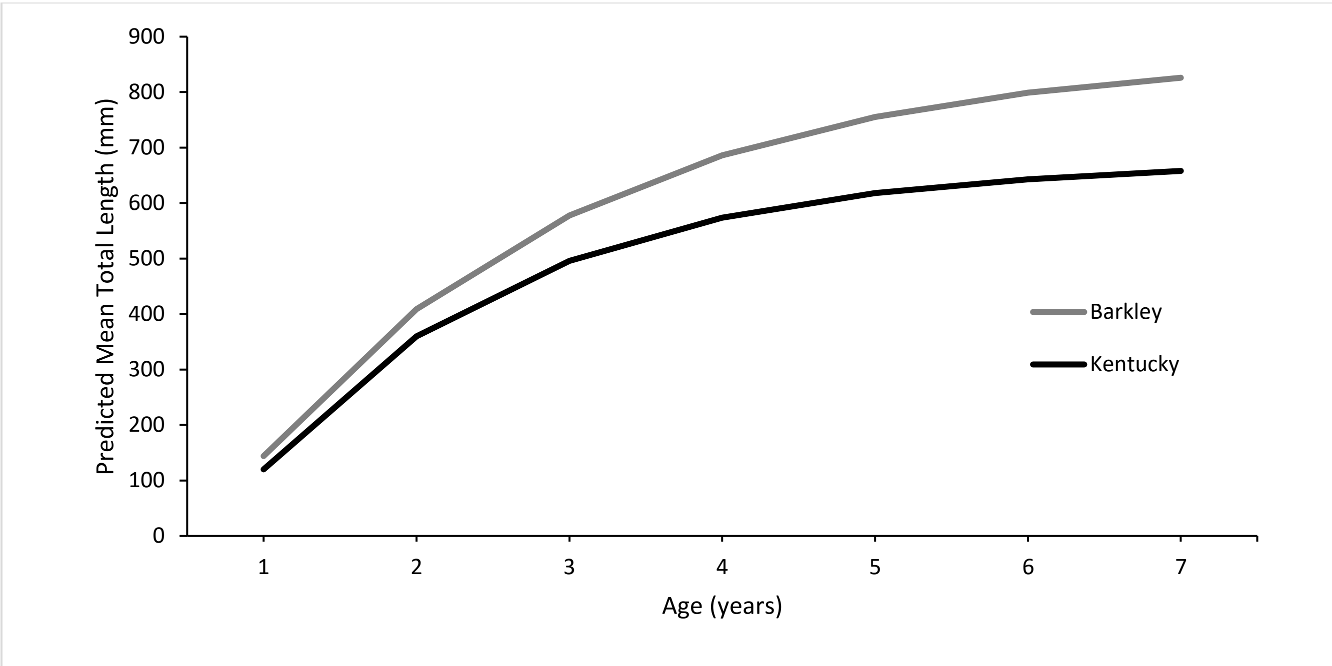

Figure 8. The von Bertalanffy growth model for predicted mean total length at age for silver carp from Barkley and Kentucky reservoirs.

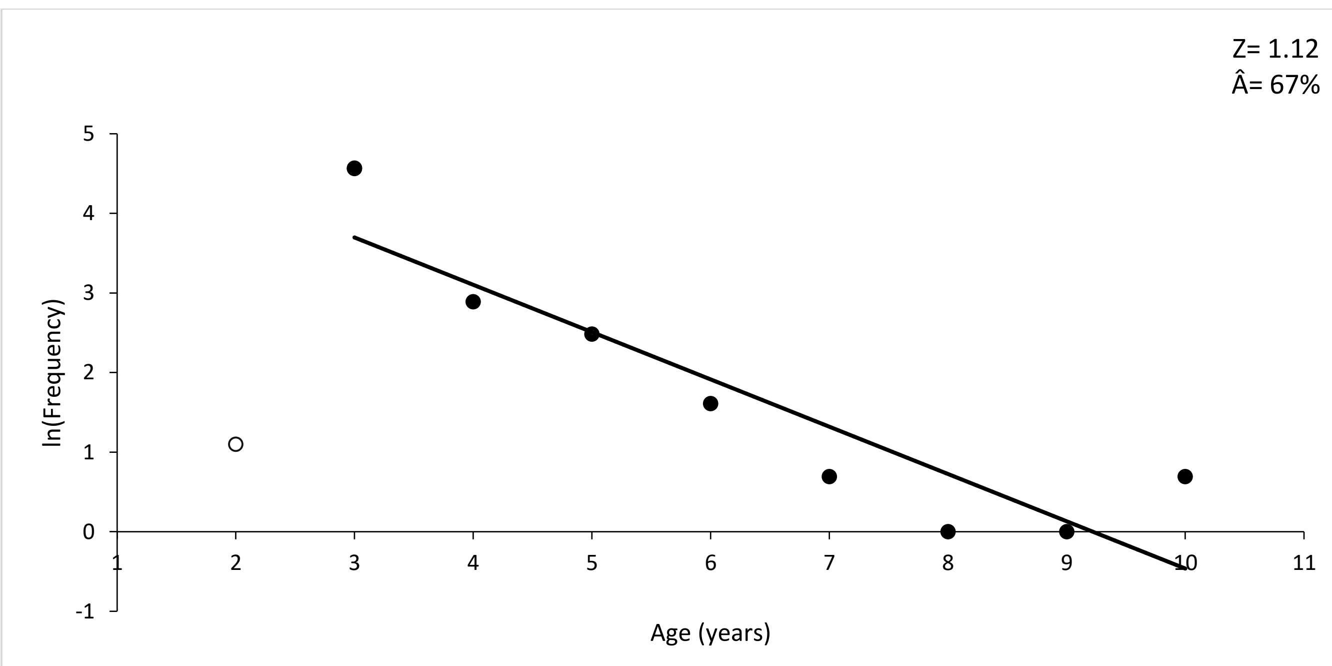

Figure 9. Catch-curve regression estimating mortality of silver carp in Barkley reservoir in 2018 (N=129, $F_{1,6}$=28.1, P=0.00182, R^2=0.82). The open circle shows the ascending limb and was not used to estimate A and Z as these fish have not fully recruited to the gears used for data collection.

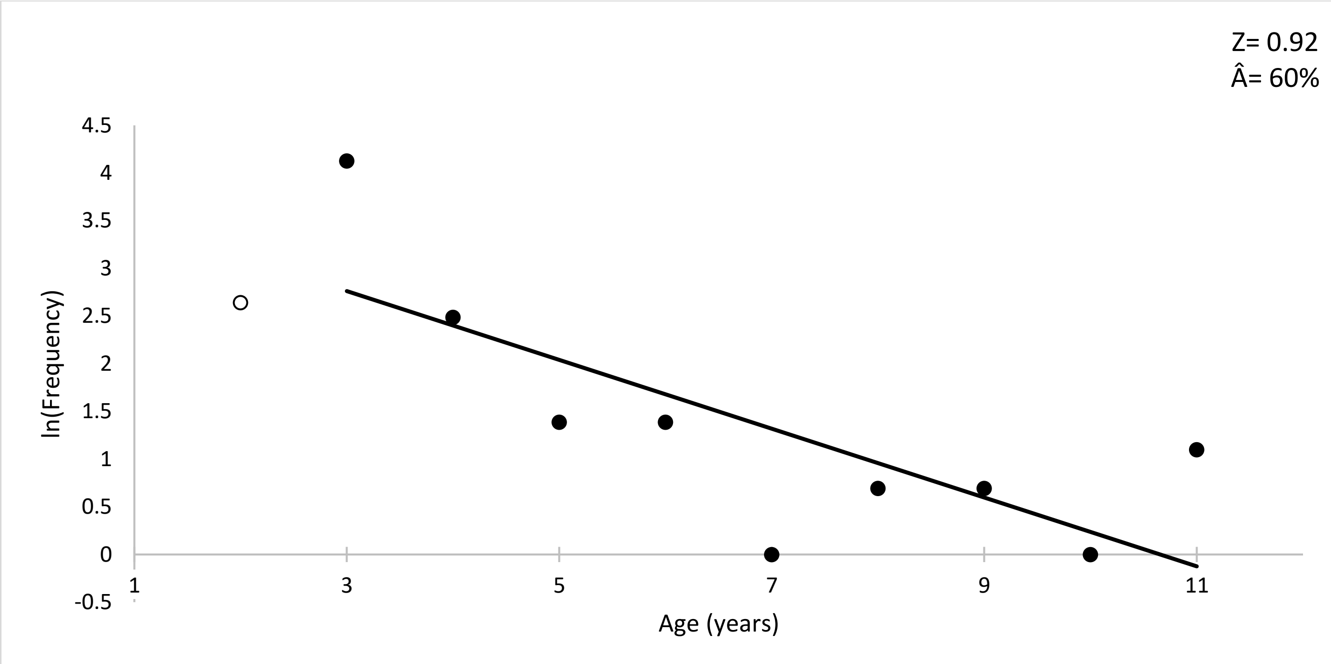

Figure 10. Catch-curve regression estimating mortality of silver carp in Kentucky reservoir in 2018 (N=82, $F_{1,7}$=9.5, P=0.017, R^2=0.58). The open circle shows the ascending limb and was not used to estimate A and Z as these fish have not fully recruited to the gears used for data collection.

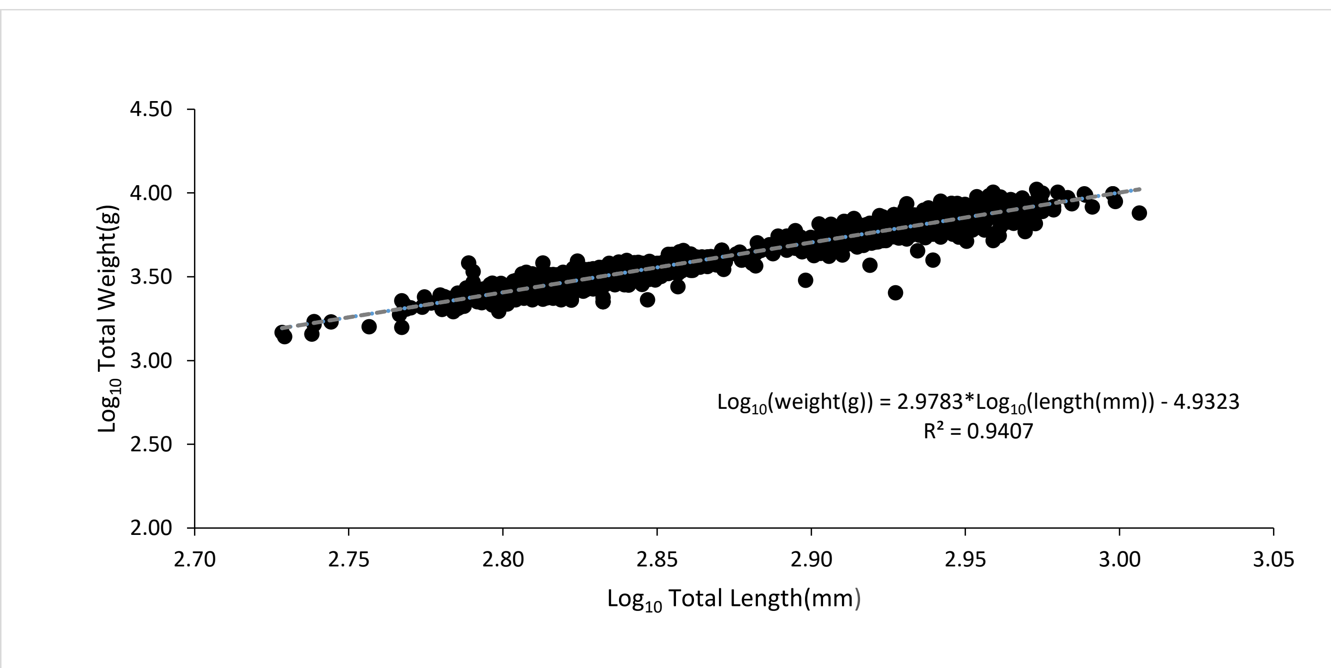

Figure 11. A scatterplot of Log_{10} transformed lengths and weights for silver carp collected from Barkley reservoir in 2018 with a regression line describing the relationship between lengths and weights (N=1704).

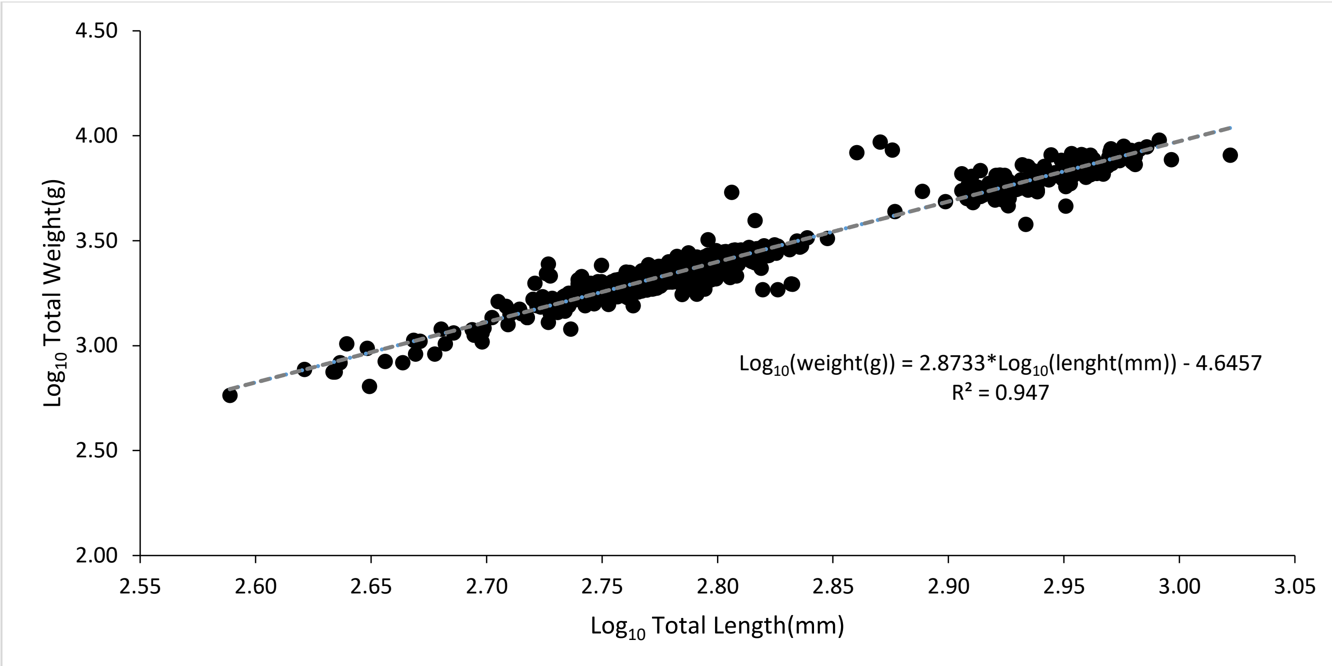

Figure 12. A scatterplot of Log_{10} transformed lengths and weights for silver carp collected from Kentucky reservoir in 2018 with a regression line describing the relationship between lengths and weights (N=1052).

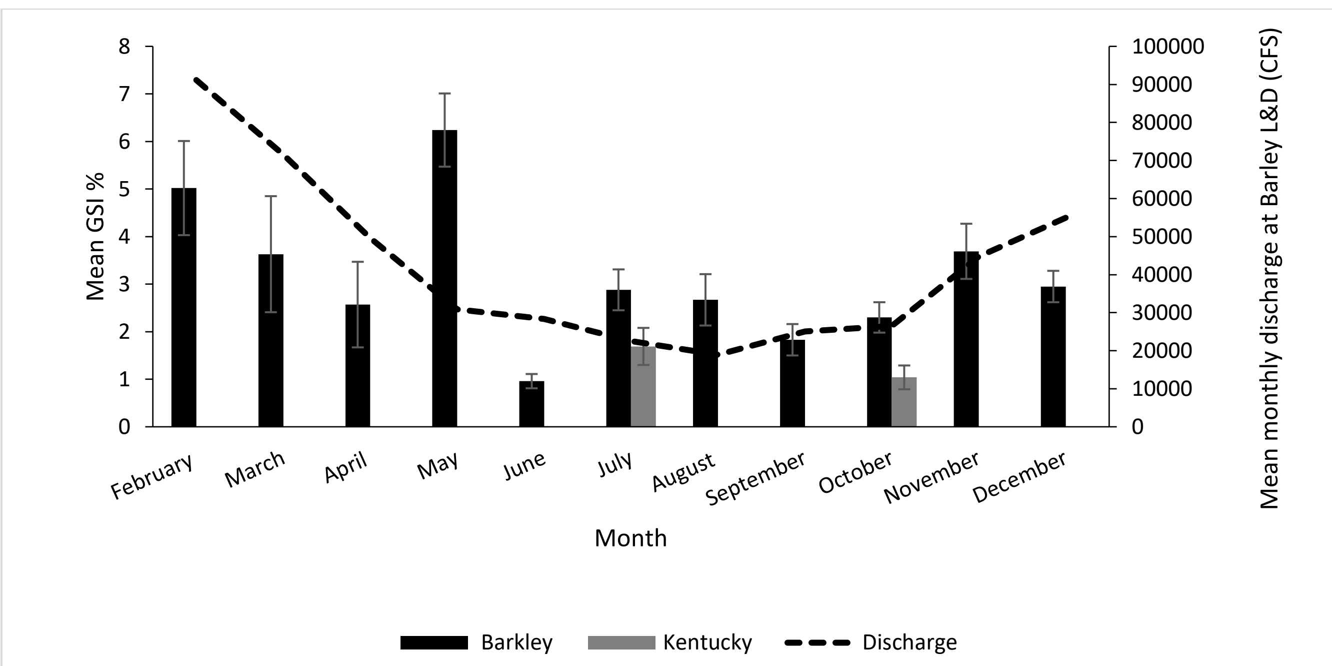

Figure 13. Mean gonadosomatic index (GSI) for silver carp captured in Barkley (N=321) and Kentucky (N=64) reservoirs from February through December 2018, plotted against mean monthly discharge (cubic feet per second, CFS) through Barkley Lock and Dam. I-represents (±) standard error.

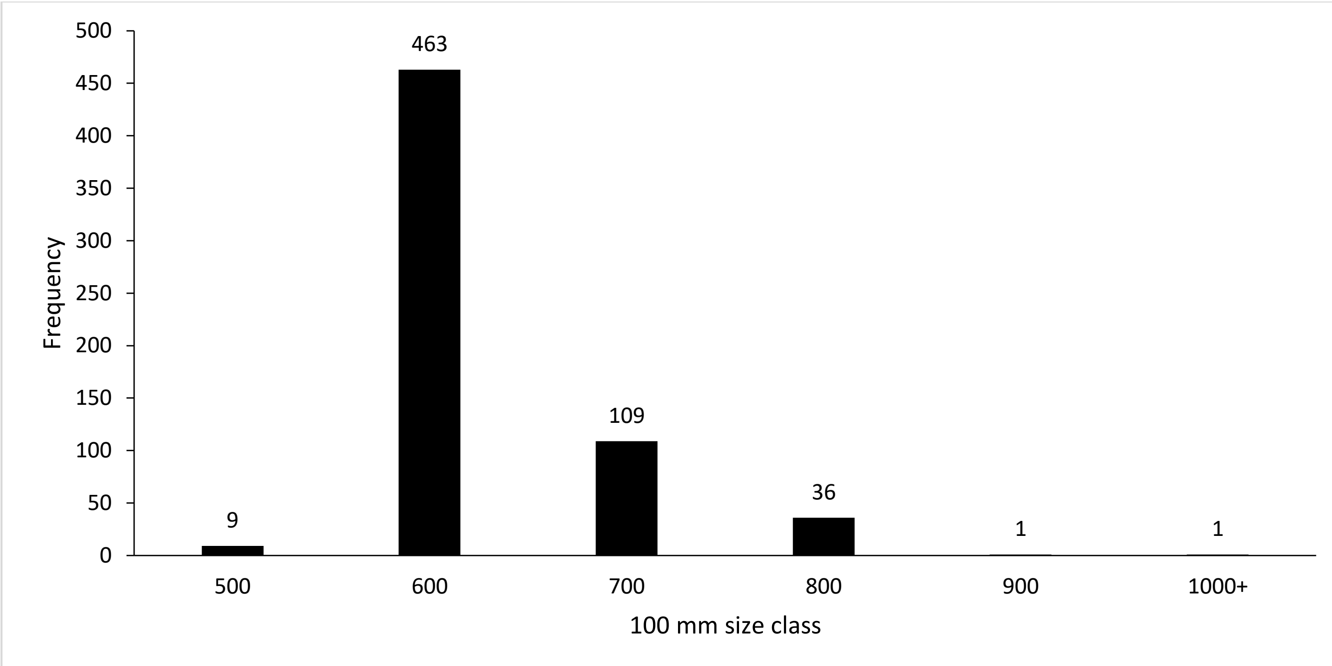

Figure 14. Length-frequency distribution of silver carp collected during the Mark-Recapture project in September 2018, on Barkley reservoir (N=619, mean total length=684mm).

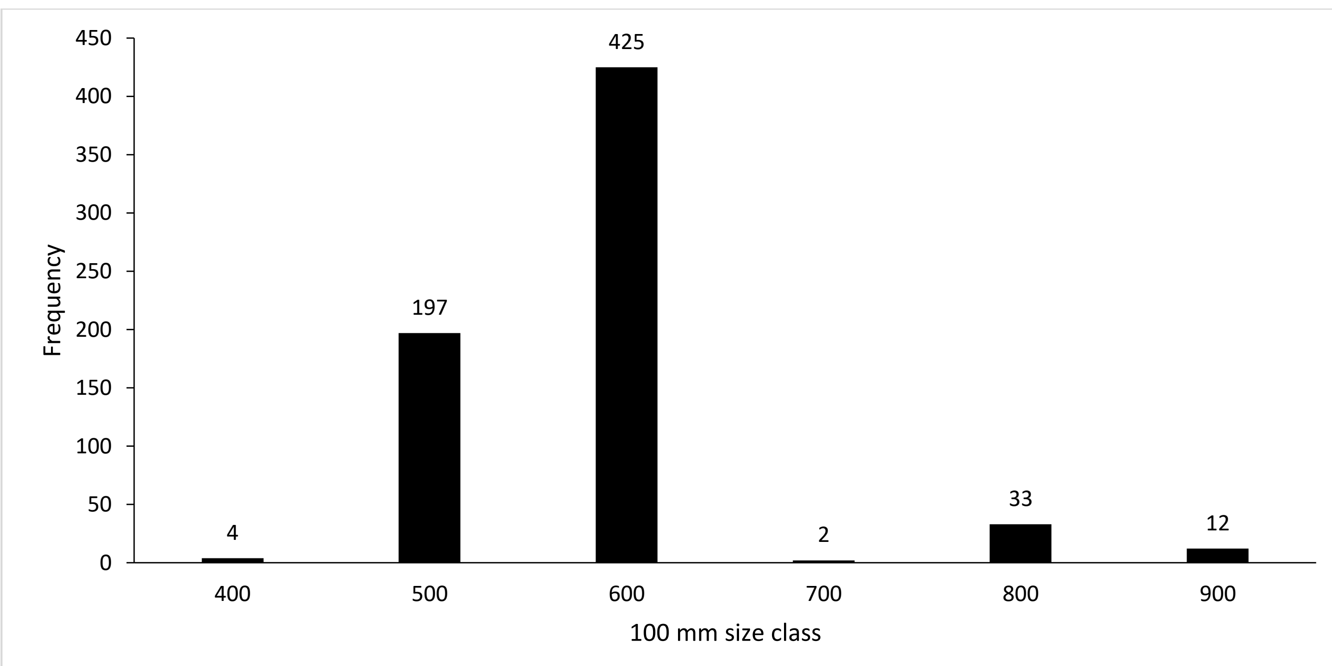

Figure 15. Length-frequency distribution of silver carp collected during the Mark-Recapture project in September 2018, on Kentucky reservoir (N=673, mean total length=627mm).

Table 1. The number of carp captured during each standard sampling period by reservoir in 2018.

	Barkley Reservoir			Kentucky Reservoir		
Species Captured	July	October	Totals	July	October	Totals
Bighead carp	13	3	16	11	3	14
Common carp	9	13	22	13	13	26
Grass carp	4	3	7	4	12	16
Silver carp	305	193	498	477	494	971
Totals	331	212	543	505	522	1027

Table 2. A summation of catch per unit effort (CPUE) for silver carp in Barkley and Kentucky reservoirs, by month and habitat type in 2018. CPUE reported in fish/linear yard of gill net.

Barkley Reservoir

		Bar mesh size			
Site	Month	3"	4"	5"	Mean Total CPUE
Main Channel	July	0.088	0.024	0	0.038
	October	0.079	0.008	0	0.029
					0.033
Embayment	July	0.388	0.069	0.002	0.153
	October	0.208	0.064	0.004	0.092
					0.123

Kentucky Reservoir

		Bar mesh size			
Site	Month	3"	4"	5"	Mean Total CPUE
Main Channel	July	0.313	0.034	0.004	0.117
	October	0.109	0.019	0	0.043
					0.08
Embayment	July	0.448	0.088	0.008	0.181
	October	0.72	0.079	0	0.266
					0.224

Table 3. A summation of estimated weights (grams) for silver carp at three lengths (millimeters) from Barkley and Kentucky reservoirs in 2018, compared to previous estimates reported (Barkley-2017 & Kentucky-2016).

Reservoir	Year	Predicted weight(g) at 450mm	Predicted weight(g) at 650mm	Predicted weight(g) at 800mm
Barkley	2017	798	2789	5361
	2018	933		5176
Kentucky	2016	803	2733	5743
	2018	950		4963

Table 4. A summation of relative weight (*W*r) values for species with potential direct competition from silver carp, individuals were collected from fall 2018 standard sampling with gill nets.

Reservoir	Date	Species	Total length (mm)	Weight (g)	Wr
Barkley	10/4/2018	Bigmouth buffalo	700	5460	86
Barkley	10/4/2018	Bigmouth buffalo	810	7400	74
Kentucky	10/9/2018	Bigmouth buffalo	854	9990	85
Kentucky	10/9/2018	Bigmouth buffalo	563	2760	86
Kentucky	10/11/2018	Bigmouth buffalo	755	6950	87
Barkley	10/5/2018	Paddlefish	676*	4280	81
Kentucky	10/11/2018	Paddlefish	850*	11350	106

* indicates fork length instead of total length.

Table 5. The number of fish captured by species and percent of total by-catch during standard sampling from Barkley reservoir in 2018.

Species Captured	July	October	Totals	Percent
Black buffalo	6	3	9	4.1
Blue catfish	10	14	24	11.1
Bigmouth buffalo	4	2	6	2.8
Channel catfish	1	1	2	0.9
Flathead catfish	3	4	7	3.2
Freshwater drum	41	21	62	28.6
Gizzard shad	1	0	1	0.5
Largemouth bass	1	1	2	0.9
Paddlefish	4	1	5	2.3
Redear sunfish	0	1	1	0.5
River carpsucker	3	3	6	2.8
Skipjack herring	2	4	6	2.8
Smallmouth buffalo	64	19	83	38.2
White crappie	1	0	1	0.5
Yellow bass	0	2	2	0.9
Totals	141	76	217	

Table 6. The number of fish captured by species and percent of total by-catch during standard sampling from Kentucky reservoir in 2018.

Species Captured	July	October	Totals	Percent
Black buffalo	5	3	8	2.2
Blue catfish	12	9	21	5.8
Bigmouth buffalo	2	3	5	1.4
Channel catfish	3	4	7	1.9
Flathead catfish	5	4	9	2.5
Freshwater drum	93	39	132	36.7
Largemouth bass	1	1	2	0.6
Paddlefish	4	1	5	1.4
River carpsucker	6	14	20	5.6
Skipjack herring	0	3	3	0.8
Smallmouth buffalo	75	73	148	41.1
Totals	206	154	360	

STATE: Kentucky

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2018 – February 28, 2019

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

In order to effectively reduce Asian carp populations Kentucky Department of Fish and Wildlife Resources (KDFWR) continues to explore other gear types for capturing Asian carp. KDFWR coordinated with Two Rivers Fisheries, U. S. Geological Survey, and U. S. Fish and Wildlife Service to assist with testing of experimental gears for capturing Asian carp in Kentucky and Barkley lakes. KDFWR also conducted experimental sampling efforts targeting Asian carp via gill nets, and electrofishing in the lakes and tailwaters.

KDFWR staff assisted the USFWS (Carterville, IL) conduct sampling efforts for black carp on the Ohio, Tennessee, and Cumberland rivers. No black carp were captured during those sampling efforts. However, 4 black carp were captured by commercial fisherman in Kentucky and Barkley lakes in 2018. One black carp was also captured by a bow fisher in the Barkley Dam tailwaters in June, 2018. KDFWR staff of the Ichthyology branch captured the first young of year black carp ever reported in Kentucky during sampling efforts in Ballard County, Kentucky.

B. TARGET DATES FOR ACHEIVEMENT AND ACCOMPLISHMENTS

Planned achievement date – 28 February 2019
Work accomplished – 28 February 2019

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

E. RECCOMENDATIONS

Continue project as designed

Project 5: Identifying New Gear Types for Capturing Asian Carp

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 (Hypophthalmichthys molitrix and Hypophthalmichthys 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. This commercial fishery relies on gillnets as the gear used, which 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 3.5-inch to 5-inch mesh nets which capture adult Asian carp but are not efficient in capturing juvenile Asian carp.

Kentucky Department of Fish and Wildlife Resources (KDFWR) worked with several entities to use new or experimental gears for capturing Asian carp (bighead carp: *Hypophthalmichthys nobilis*, silver carp: *Hypophthalmichthys molitrix*, grass carp: *Ctenopharyngodon idella*, and black carp: *Mylopharyngodon piceus)* in Kentucky Lake and Lake Barkley in 2018. These entities include U. S. Geological Survey (USGS), U. S. Fish and Wildlife Service (USFWS), and Two Rivers Fisheries (TRF). Testing of gear types provided by these entities was conducted in addition to targeted removal efforts carried out by KDFWR staff utilizing gill nets and electrofishing.

Gill Netting

KDFWR conducted experimental sampling efforts targeting Asian carp via gill nets and electrofishing in the lakes and tailwaters. Dimensions of gill nets used for removal efforts ranged depending on water conditions and previous catch rates. The gill nets fished most frequently were 300' long with 100' panels of each 3", 4", and 5" bar mesh webbing, and 12' deep webbing tied down to 10' so that the net bagged out in the water column. Gill nets with 1.5" and 2" bar mesh were fished on three occasions, but produced no silver or bighead carp, so use was discontinued. Gill nets were fished a total of 5 times on Kentucky Lake with 17 different species caught. Asian carp made up 64% of individual fish captured (5 bighead carp, 4 grass carp, 187 silver carp). Gill nets were fished 15 times on Lake Barkley, during which 22 fish species were caught. Asian carp comprised 61% of individual fish captured (8 bighead carp, 47 grass carp, 646 silver carp). During sampling efforts, a combination of floating and sinking nets were used and fished for varying lengths of time (overnight: >12 hours, and day: <6 hours). Efforts during the day utilized active fishing methods of herding fish towards the nets with boat motor noise or an electrofishing boat. Overnight sets consisted of setting nets just prior to dark, leaving them to soak overnight, and retrieving them the following morning after sunrise. During day sets, Asian carp capture rates were slightly greater for floating nets compared to sinking nets. However, floating nets exhibited slightly lower catch rates for Asian carp than sinking nets when set overnight (Figure 1). Similar to 2017, Asian carp capture was still greater during overnight sets for both net types.

Bycatch capture rates were found to be higher in nets set overnight versus nets set for short periods during the day, but remained similar in proportion to the number of Asian carp captured (1.9 and 1.4 Asian carp captured for every bycatch fish caught during day sets and overnight sets respectively) (Figure 2). 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” bar mesh. Asian carp capture was greatest in 3” mesh in both Kentucky (n=171) and Barkley lakes (n=578) (Table 1). 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 silver carp is growing quickly and have begun recruiting to commercial gears during the 2018 commercial license year in Lake Barkley (3.25” mesh gill nets). Silver carp in Kentucky Lake are not growing as rapidly, but are expected to begin recruiting to commercial fishing gears in 2019. Additionally, KDFWR recently changed the Asian Carp and Scaled Rough Fish Program regulation to allow commercial fishers to use gill nets with 3” bar mesh and larger for harvesting Asian carp. Therefore, commercial fishers will be able to catch Asian carp at smaller sizes than previously allowed.

Electrofishing was also used in conjunction with gill nets sets during the day in order to herd fish towards the nets. An additional 125 silver carp were captured by dippers on electrofishing boats during these efforts. During KDFWR gill netting efforts, overnight sets have been found to capture more Asian carp per yard of net than active day sets. Setting gill nets overnight is the traditional method for most local commercial fishermen. However, there are a growing number of commercial fishermen traveling to Kentucky waters from other states and some have very different approaches to capturing Asian carp with gill nets. Approaches include using differing set configurations of nets, varying methods for quickly deploying nets to encircle schools of fish, and alternative ways to build gill nets. The majority of fishermen traveling from out of state employ active gill net sets during the day and have had good success with their methods in Lake Barkley. KDFWR staff observed some of these methods while conducting ride-alongs with commercial fishermen using the Asian Carp Harvest Program in December of 2018 and plans to incorporate some of this methodology into removal efforts in 2019.

Electrofishing

Targeted sampling with electrofishing was conducted in the tailwaters of Lake Barkley Dam, the Clarks River, and tributaries of the lower Cumberland River. These locations were chosen for this sampling effort due to reports of high densities of silver carp. Additionally, the architecture of Lake Barkley Dam allows for fish to be effectively targeted with electrofishing at certain water levels. Electrofishing runs were not standardized, and typically lasted until the boat was laden with fish. Fish were then transferred to a chase boat on the water, or totes on a trailer at the Barkley Tailwaters Boat Ramp. Settings were on low-pulse DC current and varied on water conditions to achieve approximately 8amps. Depending on the density of fish in an area and presence of recreational fishermen, electrofishing runs extended the length of the dam and down either bank. Five sampling trips were made to the Barkley tailwaters. A total of 8,896 lbs of Asian carp were captured through approximately 2.74 hrs of electrofishing (Table 2). One sampling trip was made to the Clarks River, during which 904 lbs of Asian carp were removed in 1.41 hrs, resulting in a catch per unit effort (CPUE) of 159 fish/hr, (Table 2). Five sampling trips were conducted in tributaries of the lower Cumberland River. These efforts resulted in the removal of 8,556 lbs of Asian carp during 5.9 hours of effort (Table 2). The highest catch per unit effort (CPUE) of all electrofishing effort was observed in tributaries of the lower Cumberland River, 962 fish/hr (Table 2). A random 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 24.8 inches and 5.9 lbs respectively. The fish captured during this sampling effort in 2018 were smaller that Asian carp captured in the Barkley tailwaters in 2017 when the average length and weight of silver carp was 31.5 inches and 11.0 lbs respectively.

Merwin Trap and Pound Net

In October of 2018, staff from the USGS Columbia, MO office brought two large trap-style nets to Lake Barkley: the Merwin trap and a Great Lakes pound net (Figure 3 and 4). Both gears were deployed by USGS and KDFWR staff in the Taylor Bay and Jake Fork embayments of Lake Barkley. The gears were fished for two weeks and checked once a day for catches. The Merwin trap captured 175 fish comprised of 11 species. The pound net captured 401 fish comprised of 17 species. Neither gear type captured any bighead or grass carp. Capture rates of silver carp were low for both gears; 5 in the pound net, 1 in the Merwin trap. This was the first time that either of these gear types had been fished in Lake Barkley, or a water body of comparable size. Conversations with the USGS alluded to Asian carp catch rates being increased by use of bait that is being developed by the USGS. KDFWR plans to continue working with the USGS on testing experimental gear types for capturing Asian carp in western Kentucky.

At the conclusion of the two-week sampling period with the Merwin trap and pound net, staff from Two Rivers Fisheries observed the gears and offered some advice on modifications that may improve catch rates. The USGS agreed to leave these nets with TRF to make modifications and continue testing. TRF staff made major modifications to the Merwin trap and KDFWR assisted with testing of this new net type (Figure 5). This net was fished for one week in December of 2018 in the Taylor Bay embayment of Lake Barkley. However, no Asian carp were captured during this test. TRF is currently working on creating a new version of a large trap net that KDFWR will assist with testing in 2019.

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 3). 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. 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 USFWS is currently writing a document to submit for publication about this sampling effort.

In 2018 the USFWS returned to Kentucky and Barkley lakes to continue sampling efforts with the Paupier net. Sampling was scheduled to occur in October for one week, but was only conducted for three days because of inclement weather (one day in Kentucky Lake, two days in Lake Barkley). This sampling was for targeted removal of Asian carp, primarily silver carp, and resulted in the removal of 1,496 individual fish (approximately 7,935lbs). This sampling effort also resulted in the highest average CPUE observed in the lakes with the Paupier net, 308.3 fish/hr (Table 3). Bycatch during sampling on Kentucky Lake consisted of mainly gizzard shad. Lengths and weights of several size classes were recorded in order to calculate relative weights. Bycatch on Lake Barkley during Paupier net sampling was minimal in 2018 as the USFWS used larger mesh trawls for targeted Asian carp removal. These larger mesh nets also reduced the amount of drag created by the trawl which improved speed and maneuverability of the boat during sampling runs.

Silver carp captured in Kentucky Lake ranged from 15.0 to 34.4 inches in length, with the majority being in the 20-25 inch class range. Silver carp captured in Lake Barkley ranged from 15.7 to 37.5 inches in length, with the majority falling in the 23-28 inch class range. On average, silver carp captured with the Paupier net in Lake Barkley were larger than silver carp captured in Kentucky Lake. The dominant size class of silver carp apparent in 2018 sampling continued to represent 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 (8.6%). 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 likely able to out-swim the net in the open waters of Kentucky and Barkley lakes.

Black Carp Sampling

KDFWR staff assisted the USFWS (Carterville, IL) conduct sampling efforts on the lower Ohio River, Cumberland River and Tennessee River targeting black carp. Sampling efforts consisted of electrofishing, gill nets, and hoop nets. KDFWR staff assisted with sampling for one day in both the lower Tennessee and Cumberland rivers, four days each in Kentucky and Barkley lakes, and two days on the Ohio River. No black carp were captured during those sampling efforts. Capture of other Asian carp species during KDFWR efforts is listed in the gill netting section of this report.

The first reported capture of black carp in Kentucky waters outside of the Ohio River occurred in November, 2017. This fish was captured by a commercial fisherman using gill nets to target silver carp. Other reports of black carp captures soon followed in Kentucky Lake (January 2018), Lake Barkley (June, July, August 2018), and the tailwaters of Lake Barkley Dam (June 2018). All black carp captured in the lakes were caught by commercial fishermen in gill nets. The fish captured in the Barkley tailwaters was shot by a bow fisher, and is the first recorded capture of a black carp by a bow fisher. All black carp reported were collected by KDFWR staff, dissected, and sections were shipped on ice to the respective laboratories for analysis (Black Carp Processing Protocol, USGS). Of the black carp mentioned above, 2 were male and 3 were females. Ages ranged from 2-3 years old. Length ranged from 35.3 - 39.4 inches, and weight ranged from 22.4 – 34.1 lbs. The gut contents are being analyzed by personnel at the USGS lab in Colombia, Missouri, and they are currently working on preparing a manuscript for publication regarding diet analysis of wild caught black carp in the United States.

In addition to the captures of black carp mentioned above, KDFWR staff captured a young of year black carp in Gar Creek, a tributary of the Ohio River in Ballard County, Kentucky. This black carp was captured during routine sampling conducted by the Ichthyology branch staff of KDFWR, and was tentatively identified as a black carp by the state ichthyologist, Matt Thomas. The fish was sent to the USGS for further analysis and was confirmed to be a young of year black carp. This finding is significant as this is the first reported capture of a young of year black carp in the wild outside of the Dutchtown ditch, southeast of Cape Girardeau, Missouri. For more information on this specimen please reference the Ichthyology branch report.

Conclusions

Of all gear types used to capture Asian carp in 2018, gill nets remain the most dependable and available 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 have begun recruiting to gill nets used by commercial fishermen. 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 2019. 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.

Collins, S. F., S. E. Butler, M. J. Diana, and D. H. Wahl. 2015. Catch rates and cost effectiveness of entrapment gears for Asian carp: a comparison of pound nets, hoop nets, and fyke nets in backwater lakes of the Illinois River. North American Journal of Fisheries Management 35:1219-1255.

Table 1. Capture rates (number of fish) of Asian carp and bycatch in gill nets by mesh size during targeted sampling efforts in Western Kentucky waters in 2018.

	1.5"		2"		3"		4"		5"	
Water Body	Asian Carp	Bycatch	Asian Carp	Bycatch	Asian Carp	Bycatch	Asian Carp	Bycatch	Asian Carp	Bycatch
Kentucky Lake					171	53	20	34	5	23
Lake Barkley	0	1	4	11	578	182	97	140	22	114
Lower Cumberland River					11	19	4	10	4	2

Table 2. Electrofishing effort and resulting catch during Asian carp removal efforts from Lake Barkley tailwaters, Clarks River, and tributaries of the lower Cumberland River in 2018.

Date	Location	Effort (hours)	Water Temperature (˚F)	Pounds of Asian Carp Removed	CPUE (fish/hr)
3/22/2018	Lower Cumberland River	2.17	49.8	1921	140
5/18/2018	Barkley TW	0.77	79	4662	UNK*
5/21/2018	Lower Cumberland River	1.03	81	1731	218
8/2/2018	Barkley TW	UNK**	85	2149	UNK**
8/8/2018	Barkley TW	0.61	85	539	254
8/14/2018	Barkley TW	0.86	85	983	113
8/15/2018	Clarks River	1.41	82	904	159
8/23/2018	Lower Cumberland River	0.19	81.5	106	132
8/23/2018	Barkley TW	0.50	81.5	563	236
9/27/2018	Lower Cumberland River	2.38	74	3238	229
10/22/2018	Lower Cumberland River	0.13	61	1560	962

* = Individual fish were not counted

** = Electrofishng box timer did not work properly

Table 3. 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
Novemeber 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
October 2018	4.72	1,496	308.3	61.0	1	2

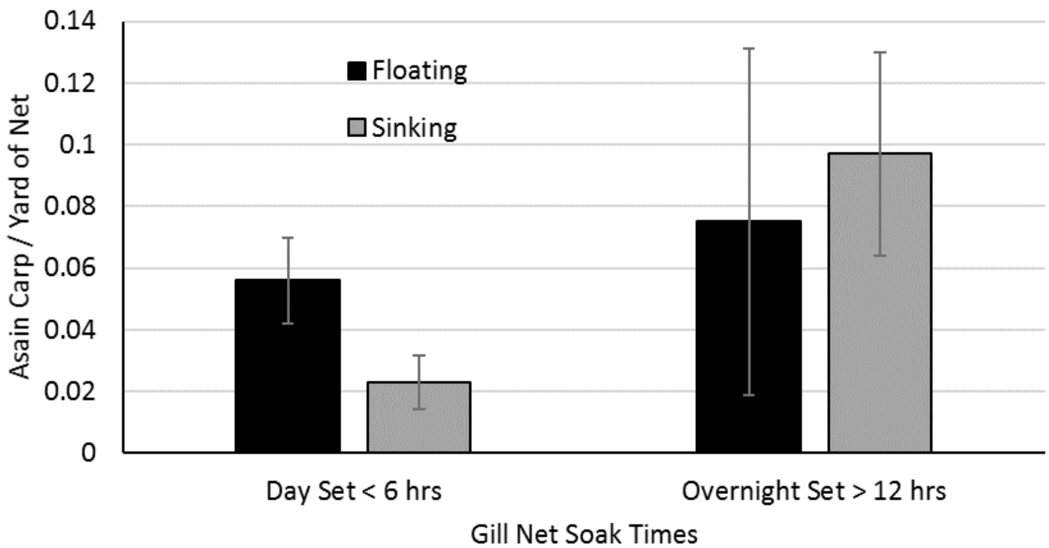

Figure 1. Comparison of floating to sinking gill net catch rates (fish / yard of net) for Asian carp between day sets and overnight sets in 2018.

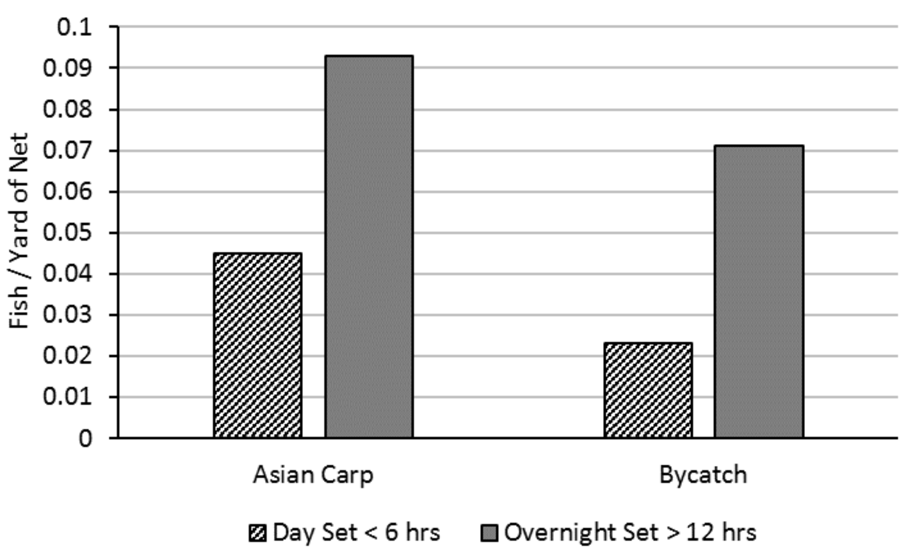

Figure 2. Comparison of Asian carp to bycatch catch rates (fish / yard of net) in gill nets between day sets and overnight sets in 2018.

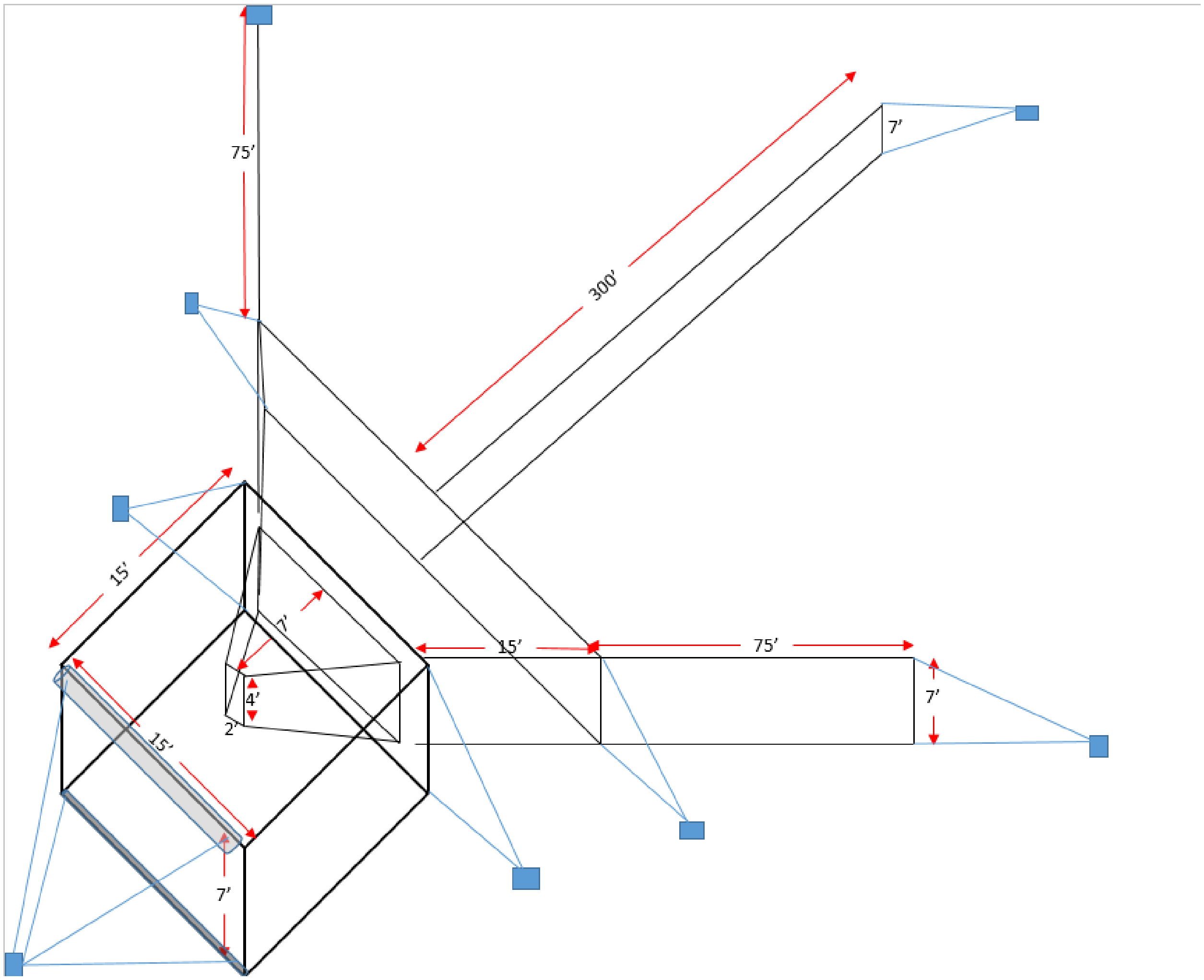

Figure 3. Diagram of Merwin net that was deployed by the USGS in Lake Barkley in October of 2018.

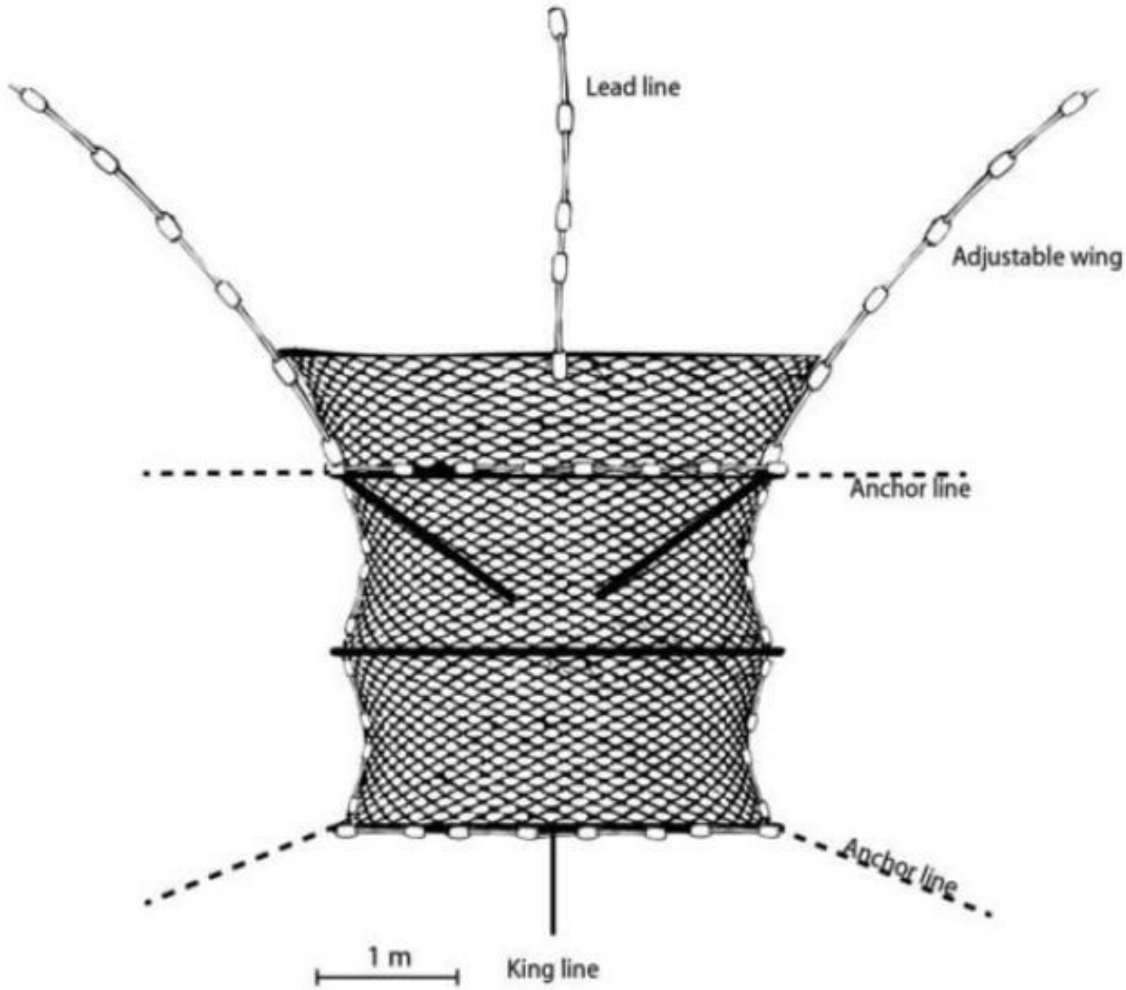

Figure 4. Diagram of pound net similar to the one deployed in Lake barkley by the USGS in October of 2018 (Collins et al. 2015).

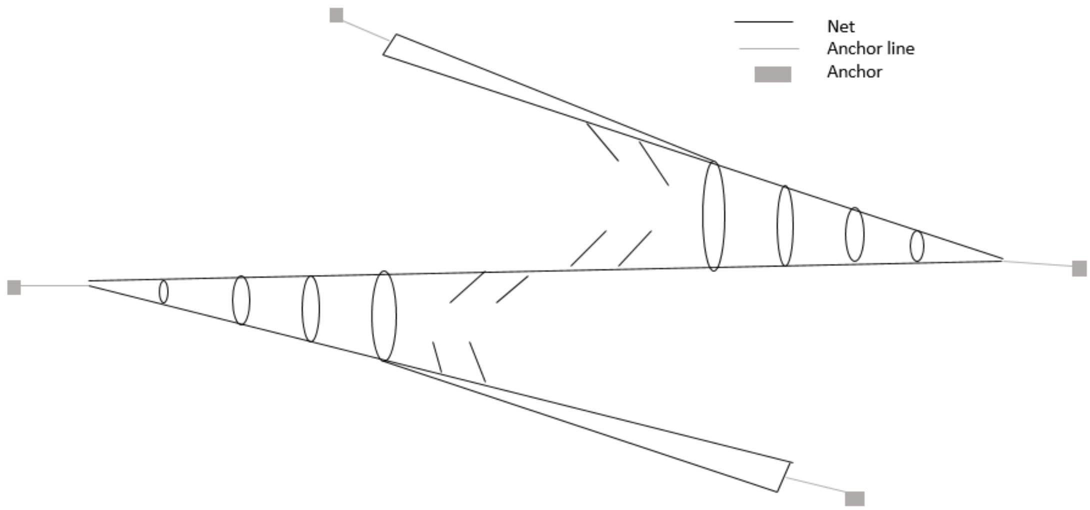

Figure 5. Approximate diagram of net design created by Two River Fisheries, and tested by KDFWR staff in Lake Barkley. Specific dimensions were unavailable.

STATE: Kentucky

GRANT NO: F-95-5

GRANT TYPE: Research and Survey

GRANT TITLE: Asian Carp Research and Monitoring

PERIOD COVERED: April 1, 2018 – March 31, 2019

Research and Survey Section

Project 6: Assessment of Bowfishing as a Tool for Asian Carp Removal

Project Objectives:

1. Estimate Asian carp harvest by bow anglers through tournaments and recreational fishing.
2. Determine if bowfishing is a viable large-scale removal method for Asian carp.
3. Obtain bow angler demographics to improve management strategies for this user group.
4. Determine potential solutions for the dumping of fish harvested by bow anglers and identify opportunities to utilize harvested fish.

A. ACTIVITY

Carp Madness II Bowfishing Edition

Kentucky Department of Fish and Wildlife Resources hosted its first ever bowfishing tournament on June 23-24, 2018 at Kentucky Dam State Park. The tournament was deemed "Carp Madness II: Bowfishing Edition" as a sequel to the first Carp Madness tournament held in March of 2013. Carp Madness II was created to harvest as many Asian carp as possible, generate media attention, and to highlight the ongoing Asian carp issues in Kentucky and Barkley Lakes. Bow anglers traveled from 11 different states (AR, GA, IL, IN, KY, MO, MS, OH, SC, TN, MI) to participate in the bowfishing tournament. There were a total of 81 teams that participated in the tournament, which weighed in over 16,823 lbs of Asian carp. This tournament also allowed KDFWR to take a deeper look at the potential effects bow anglers may be having on Asian carp numbers in Western Kentucky waters.

Bowfishing Angler Attitude Survey

Kentucky Department of Fish and Wildlife Resources (KDFWR) administered an angler attitude survey to 365 bow anglers fishing in Western Kentucky. The surveys were conducted 1 March 2018 – 31 October 2018, at the Kentucky Lake Tailwaters, Lake Barkley Tailwaters, and bowfishing tournaments attended by KDFWR staff. The 2018 bowfishing angler attitude survey was initiated to collect baseline data on the demographics and harvest rates of bow anglers in the state of Kentucky. A total of 365 bow anglers were surveyed, with 164 being bank bow anglers, and 149 boat bow anglers. Bow anglers surveyed represented 16 different states and 151 different zip codes.

Bowfishing Tournament Data

In Kentucky, bowfishing is becoming a popular sport, especially on larger lakes and rivers such as the Ohio River, Kentucky Lake, Lake Barkley, and their respective tailwaters. The increased interest in bowfishing for many Kentucky anglers is due in part to the growing Asian carp (bighead carp, *Hypophthalmichthys nobilis* and silver carp, *Hypophthalmichthys molitrix*) populations in Kentucky waters. In recent years, bowfishing clubs have become popular and the number of bowfishing tournaments held in Western Kentucky is increasing yearly. In 2018 alone, there were 12 tournaments recorded in Western Kentucky. KDFWR staff have reached out to tournament hosts to collect information on harvest rates, with emphasis on Asian carp and the number of bow anglers participating in each tournament. KDFWR found that 'Asian carp only' tournament participation varies widely and can produce average team weights from as little as 200 lbs to over 1100 lbs of harvested fish. Tournament participation and harvest data is relatively easy to gather and can continue to be useful tool in evaluating the impact of bow fishing on both invasive carps and native fisheries.

B. TARGET DATES FOR ACHIEVEMENT AND ACCOMPLISHMENTS

Planned achievement date - 31 March 2019

Work accomplished - 31 March 2019

C. SIGNIFICANT DEVIATIONS

None

D. REMARKS

None

Project VI: Assessment of Bowfishing as a Tool for Asian Carp Removal

FINDINGS

Carp Madness II Bowfishing Edition

Kentucky Department of Fish and Wildlife Resources (KDFWR) hosted its first ever bowfishing tournament on June 23-24, 2018 at Kentucky Dam Village State Park. The tournament was deemed "Carp Madness II: Bowfishing Edition" (Figure 1) as a sequel to the first Carp Madness tournament held in March of 2013. Carp Madness II was created to highlight the ongoing Asian carp issues in Kentucky and Barkley Lakes and harvest as many pounds of Asian carp as possible from the Tennessee and Cumberland River systems. This tournament also provided KDFWR the opportunity to take a deeper look at the potential impacts that bow anglers might be having on Asian carp numbers in Western Kentucky waters.

Bow anglers traveled from 11 different states (AR, GA, IL, IN, KY, MO, MS, OH, SC, TN, MI) to participate in the bowfishing tournament. There were a total of 81 boats that competed for $23,000 in awards. Entry fee to participate in the tournament was $150.00 per boat (2-4 participants per boat), and an optional entry for Big Fish of $25.00. The tournament was broken down into two divisions; lakes (Kentucky and Barkley Lakes), or rivers (lower Cumberland River and lower Tennessee River). First through third places were awarded prize money for their division in the allotments of: $10,000, $1,000, $500 respectively. Big fish payout was based upon the number of teams that participated in that pot. The tournament was a total weight tournament for all Asian carp species (silver carp, bighead carp, grass carp: *Ctenopharyngodon idella*, and black carp: *Mylopharyngodon piceus*) and was sanctioned by the Bowfishing Association of America (BAA).

The rivers division was comprised of 48 teams, which harvested a total of 8,453 pounds of Asian carp. A team from Kentucky named "Descalin" won first prize with 1,007 lbs, the second place team was "Hydrophilic Bowfishing" with 585 lbs, and third was "All-Around Outdoors" with 546 lbs. Rivers division big fish was won by team "Grizz Fish" with a bighead carp that weighed 48 lbs. The Lakes division had 33 teams, which brought in a total of 8,370 pounds of Asian Carp. First place was won by a team from Indiana named "Making Moves" with 1,104 lbs, team "PMA" came in a close second with 1,093 lbs, and team "Spinal Tap" took third with 689 lbs. Lakes division big fish was won by team "AMS" with a 34 lb bighead carp. The total weight of Asian carp weighed in by bow anglers participating in the tournament was 16,823 lbs. These harvest results were lower than expected due to thunderstorms that created a tornado, and a large mayfly hatch that lasted hours on the lakes. There were an estimated 3,000-5,000 lbs of Asian carp brought to the weigh-in that jumped into participants' boats during the tournament, this brought the total pounds of Asian carp removed during the tournament to over 20,000 lbs. Asian carp harvested during the event were donated to Fin Gourmet and Schafer processing facilities to be used as fertilizer or fish meal products.

"Carp Madness II: Bowfishing Edition" was a multi-state and multi-agency effort including the Kentucky Fish and Wildlife Foundation, Tennessee Wildlife Resources Agency (TWRA), Kentucky State Parks, U. S. Fish and Wildlife Service (USFWS), Fishing League Worldwide (FLW), Bowfishing Association of America (BAA), and bowfishing enthusiast Joe Nichols. This tournament was a huge public relation success creating news coverage from at least 3 television news stations (out of Paducah and Louisville), one radio station, a Kentucky Afield episode, multiple social media platforms, and coverage from the "War on Carp" campaign. Carp Madness II was so successful that it was deemed one of the top 5 bowfishing tournaments of 2018 by “bowhunting.com”. TWRA plans to host their own bowfishing tournament for Asian carp in May 2019 at Camden, Tennessee.

Bowfishing Angler Attitude Survey (AAS)

In Kentucky bowfishing is a legal method for harvesting rough fish (except alligator gar) year-round by long bow, crossbow, compound bow, recurve bow or pneumatic air arrow launching device (Appendix 1). No sport fish may be harvested by bowfishing in Kentucky, and only 5 catfish and 2 paddlefish per day are allowed (Appendix 2). KDFWR administered an angler attitude survey to bow anglers fishing in Western Kentucky in order to estimate Asian carp harvest and gather baseline demographics data. Historically, bowfishing effort has been very limited, consequently there is very little information on fish harvested by bow anglers. Additionally, there are no known publications in peer-reviewed literature that effectively describe bow angler practices and demographics (Bennett et al. 2015). Traditional creel surveys typically underestimate or completely miss bowfishing effort since most bowfishing occurs after dark. Individual bowfishing participation nationwide is normally not reported in national fishing surveys (USFWS and U.S. Census Bureau 2016). However, over the past decade, bow fishing has become an increasingly popular sport throughout the United States, including Kentucky. The increased interest in bowfishing for many Kentucky anglers is due in part to the growing Asian carp populations in Kentucky waters. Therefore, understanding bowfishing harvest rates of Asian carp is critical in determining the potential impact that this sport may be having on Asian carp populations.

To gain an understanding of the impacts of bowfishing on Asian carp KDFWR conducted an angler attitude survey targeting bow anglers from 1 March 2018 – 31 October 2018. Anglers were interviewed at Kentucky Lake Tailwaters, Lake Barkley Tailwaters, and bowfishing tournaments attended by KDFWR staff (Figure 2). The days and time periods surveyed were selected during the peak season for bowfishing in order to survey as many bow anglers as possible. All surveys were done in late evening time periods approximately 5pm-11pm. A total of 365 bow anglers were surveyed, with 164 being bank bow anglers, and 149 boat bow anglers. Bowfishing anglers were chosen at random and an attempt was made to interview all anglers observed. The 2018 bowfishing angler attitude survey was the first attempt to collect baseline data on the demographics, harvest rates, and attitudes of the growing bowfishing participation in Western Kentucky. During data analysis surveys were reviewed aggregately (Appendix 3) and by user groups: bank only (Appendix 4), and boat only (Appendix 5).

During the survey 45.0% of bow anglers were surveyed while bank fishing and 40.8% of bow anglers surveyed were fishing from a boat. Due to recording errors, 14.2% of the surveys did not have information on whether bow anglers were fishing from the boat or bank. Bow angler ages’ ranged from 9 to 65 years of age with the average age being 26 years old. Bow anglers surveyed were primarily males 92.6% (Appendix 3). Zip codes of the anglers’ home towns were also recorded which comprised of 151 different zip codes located in 16 different states in the United States (Figure 3). When asked how long bow anglers have been engaged in bowfishing 84% of bank bow anglers had begun participating in the sport within the last 5 years compared to 41.1% of boat bow anglers (Appendix 4 and 5). This difference in years of experience between bank and boat bow anglers could be due to beginning bow anglers starting out shooting from the bank because it is a cheaper option than buying a boat. The average number of days fished per year that all bow anglers reported during the survey fish was 49.4 days (Appendix 3). This number is similar to the findings of a survey conducted by Texas Parks and Wildlife Department where an average of 46 days per year were reported (Bennett et al. 2015). The average time a bow angler from the survey actively bowfished was 5.76 hours per trip. The average distance traveled to the boat ramp location for all bow anglers was 40.6 miles (Appendix 3). When bow anglers were asked about their average cost per trip, bank users averaged $30.80 per trip, while boat users averaged $67.04 (Appendix 4 and 5). This difference in average cost is likely due to increased costs of operating vessels. Yearly expenditures of all bow anglers was also estimated from the survey since 365 bow anglers were surveyed that averaged 49.4 days of bowfishing a year with an average cost per trip of $49.26. Using this information, the total estimated expenditures of bow anglers surveyed was $888,207.06.

During the 2018 survey 62.4% of bow anglers listed Kentucky and Barkley Tailwaters as their primary bowfishing location. This is most likely due to the high density of Asian carp combined with the plentiful bank access for bow anglers. The majority of bow anglers surveyed selected Asian carp (bighead, silver, and grass carp) as the most targeted species (Appendix 3). Of bow anglers that consistently shot silver carp, bank anglers (n=103) reported that they shot an average of 11 silver carp per trip that weighed an average of 9.9 lbs per fish. Boat bow anglers (n=126) reported shooting an average of 21 silver carp per trip that weighed an average of 10.9 lbs per fish. Of bow anglers that consistently shot bighead carp, anglers fishing from the bank (n=56) reported an average of 5 bighead carp shot per trip that weighed on average 20.8 lbs; while boat bow anglers (n=105) averaged 8 per trip that weighed 21.7 lbs per fish. Of bow anglers that consistently shot grass carp, bank bow anglers (n=42) reported that they averaged 2 grass carp per trip that weighed 12.7 lbs per fish, while boat bow anglers (n=98) averaged 4 grass carp per trip that weighted 19.6 lbs per fish (Appendix 4 and 5). Boat bow anglers reported a higher average harvest of Asian carp than bank bow anglers, this may be due to the increased mobility and experience from boat bow anglers. The estimated average size of silver carp harvested by bow anglers appears to be inflated compared to mean weights of silver carp sampled during KDFWR electrofishing in the Kentucky Tailwaters (3.1 lbs) and Barkley Tailwaters (11.0 lbs) (KDFWR 2017 A).

Bank bow anglers (n=72) harvested on average 9 paddlefish per year compared to boat users (n=81) who averaged 3 per year (Appendix 4 and 5). A total of 940 paddlefish were reported to be harvested by the 186 bow anglers who reported shooting paddlefish. The average estimated weight for paddlefish harvested was 19.2 lbs per fish (Appendix 3) year. In comparison, in 2017 commercial fishermen statewide reported harvesting 8,977 paddlefish with a flesh weight of 157,457 lbs (KDFWR 2017 B). However, these results must be interpreted with care as the design of the survey relies on anglers estimating both the average weight and quantity of fish caught over the past year, leaving a potential for significant recall bias.

Using the information from the survey we estimate that a boat bow angler on average harvests 373 lbs of Asian carp per trip. In tournaments that KDFWR has observed the highest average weight of a team (4 bow anglers) was in 2016 where the average was 1122 lbs. This means that these bow anglers would have harvested 281 lbs per person, which is a much lower average than the estimated 373 lbs from the 2018 bowfishing survey. This indicates that, as expected, the survey weights reported are likely significantly inflated. Nonetheless, even if these estimates are inflated, the impact that bow anglers could have on Asian carp may be significant.

During the 2018 bowfishing survey 59.2% of bow anglers said they keep their harvested fish, 26.5% sink the fish, and 14.3% dispose of the fish in the trash. The top 3 reasons bow anglers kept their fish were compost/fertilizer (35.6%), consumption (29.8%), and bait (12.5%). Due to illegal dumping of harvested fish a question about other disposal options was included in the 2018 bowfishing survey. 93.6% of bow anglers surveyed answered they would be willing to transport their fish to designated dump stations. The bow anglers that answered yes to transporting their fish were then asked how far they would be willing to travel and 66.7% answered less than 10 miles from the ramp (Appendix 3). KDFWR acknowledges that the majority of bow anglers are willing to travel minimal distances to properly dispose of their fish and is exploring disposal opportunities. KDFWR is also looking for possible solutions to illegal dumping such as informative signs and education on proper disposal methods.

Many bow anglers surveyed that recreationally bowfish also compete in tournaments (29.8% of bank bow anglers and 71.6% of boat bow anglers: Appendix 4 and 5). The higher tournament participation from boat bow anglers is due to most bowfishing tournaments requiring boats for competition. The number one reason for not competing in bowfishing tournaments was due to lack of equipment (39.1%) (Appendix 3). Of the bow anglers that responded “yes” to competing in tournaments in 2018, 78.2% indicated they competed in less than 9 tournaments. Bow anglers were also asked if they participated in other fishing tournament events and 15.7% of them responded “yes”. Of those tournaments 85% were bass, 6.7% crappie, 6.7% catfish, and 1.7% steelhead. Bow anglers were also asked if they belonged to any bowfishing clubs or organizations and only 26.7% answered yes. During the survey bow anglers were asked what initiated their interest in bowfishing, 57.7% listed “friends” and 22.3% listed “family” as their primary reason for starting bowfishing. Household income was also included in the survey. The majority of bow anglers fishing from the bank listed a household income of less than $35,000 (70.6%), and the majority of boat bow anglers listed their household income as $35,000 to $75,000 (43.6%) (Appendix 3). The higher household income for boat bow anglers was expected due to the increased cost of equipment in order to participate in the sport using that mode. The last question on the 2018 bowfishing survey asked for comments or suggestions for KDFWR. The top 3 answers that were received included need of dump stations in place, issue of dumping harvested fish, and increase of law enforcement and tickets (Appendix 3).

The 2018 bowfishing angler attitude survey was the first of its kind in capturing specific bow fishing information for KDFWR. Since this is the first bowfishing angler attitude survey to be administered, it is unknown if recreational bowfishing participation, harvest rates, and participation in tournaments are changing. It will be important to monitor trends during other angler attitude surveys conducted throughout the state to identify impacts of bow fishing on species harvested, particularly Asian carp.

<u>Bowfishing Tournament Data</u>

In recent years, local bowfishing clubs have become popular and both regional and national tournaments are being held throughout Kentucky. The increased interest in bowfishing for many Kentucky anglers is due in part to the growing Asian carp (bighead carp, and silver carp) populations in Kentucky waters. In Kentucky, bowfishing is a popular sport, especially on large lakes and rivers such as the Ohio River, Kentucky River, Kentucky Lake, Lake Barkley, and their respective tailwaters. The number of tournaments held in Western Kentucky specifically on the Ohio River, Tennessee River, Cumberland River, Kentucky Lake, and Lake Barkley are increasing yearly. In 2016 there were 8 tournaments recorded by KDFWR in western Kentucky, in 2017 there were 11 tournaments, and 12 tournaments in 2018. With this increase in tournament numbers, KDFWR staff have reached out to tournament hosts to collect more information and attended several of them. When KDFWR staff are unable to attend a tournament, the tournament host is contacted and sent a tournament form to fill out and return to KDFWR (Appendix 6). Information that KDFWR collects from tournaments is used to determine the overall harvest rates of Asian carp and the number of bow anglers participating in these tournaments. Since bowfishing tournaments are not required to have a permit or registration, little is known about the effects of bowfishing tournaments on fish populations in Western Kentucky. These tournaments are sometimes difficult to find due to the lack of public information. Tournaments are typically found through social media platforms and bowfishing clubs or forums. As of now, KDFWR only requires tournaments with over 100 boats to register. Bass fishing tournaments are listed on KDFWR's online website, which makes it easy to find tournaments to fish. Creating a public tournament database for bowfishing tournaments would give bow anglers a place to easily find tournaments, and allow KDFWR to more accurately monitor tournament participation and harvest.

Bowfishing tournaments are typically seasonal, being conducted typically in the spring and summer months due to water temperatures. Bowfishing success is dependent on the targeted fish being visible and close to the surface of the water (Bennett et al. 2015). Bowfishing tournaments in Western Kentucky are typically numbers tournaments (most fish wins the tournament) or Big 20 (heaviest 20 fish wins). Most tournaments are restricted to common carp, gar, buffalo, and Asian carp. Tournaments are typically 12 hours starting just before dark and going until daylight the following morning. Tournament teams are normally 2-4 individuals per boat. Teams are allowed to trailer their boats to any public ramp that is on the water body specified by that tournament. Tournament entry fees are paid per boat and typically range from $150.00-$300.00, most tournaments also have several side pots with the most frequent being biggest fish.

KDFWR staff have collected data from the annual "Unlimited Asian Carp Only" tournament hosted by James Story at Kuttawa, KY for the past 5 years (Table 1). This bowfishing tournament is solely an Asian carp tournament that awards the teams that bring in the most pounds of Asian carp. Participation for this tournament varies yearly, but always takes place in the late spring or early summer. Over the past 5 years' participation for the "Unlimited Asian Carp Only" tournament has decreased overall. However, the average lbs of Asian carp per boat has not decreased (Table 1). Bowfishing teams for the tournament have averaged 494 lbs to 1122 lbs of Asian carp in the past 5 years (Table 1). In the 2018 "Unlimited Asian Carp Only" tournament it took 2,036 lbs to win first place. These average team weights are comparable to a single night's harvest from some commercial fishermen. In 2018 commercial fishermen fishing on the KDFWR Asian Carp Harvest Program subsidy averaged 1,279 lbs of Asian carp per trip. This raises the question of what impact bow anglers are on Asian carp populations. Further investigation is needed to better understand total harvest rates of bow anglers. Increasing the sample size of tournaments in the future would be desirable to more accurately determine harvest numbers.

Final Discussion

Through bow angler surveys KDFWR gained a more comprehensive understanding of the impact that bow fishing may be having on Asian carp. KDFWR understands that bowfishing is becoming a more widespread sport that continues to draw anglers from hundreds of miles away to target Asian carp here in Western Kentucky. KDFWR created baseline demographics for bow anglers that can be referenced in the future. This bow angler survey has also shown that it is in fact plausible for bow anglers to harvest Asian carp and other species in high numbers. Additional bowfishing data will be gathered during the upcoming Kentucky and Barkley Tailwaters Sport Fish Assessment creel survey being completed in 2019.

Literature Cited:

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Kentucky Department of Fish and Wildlife Resources. 2017. Annual performance report for Asian Carp Research and Monitoring. 77-85. A

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USFWS (U.S. Fish and Wildlife Service) and U.S. Census Bureau. 2016. 2016 National survey of fishing, hunting, and wildlife-associated recreation. USFWS and U.S. Census Bureau, Washington, D.C.

Figure 1. Flyer designed by Obie Williams (KDFWR) used to advertise the “Carp Madness II: Bowfishing Edition” Tournament held on June 23-24, 2018.

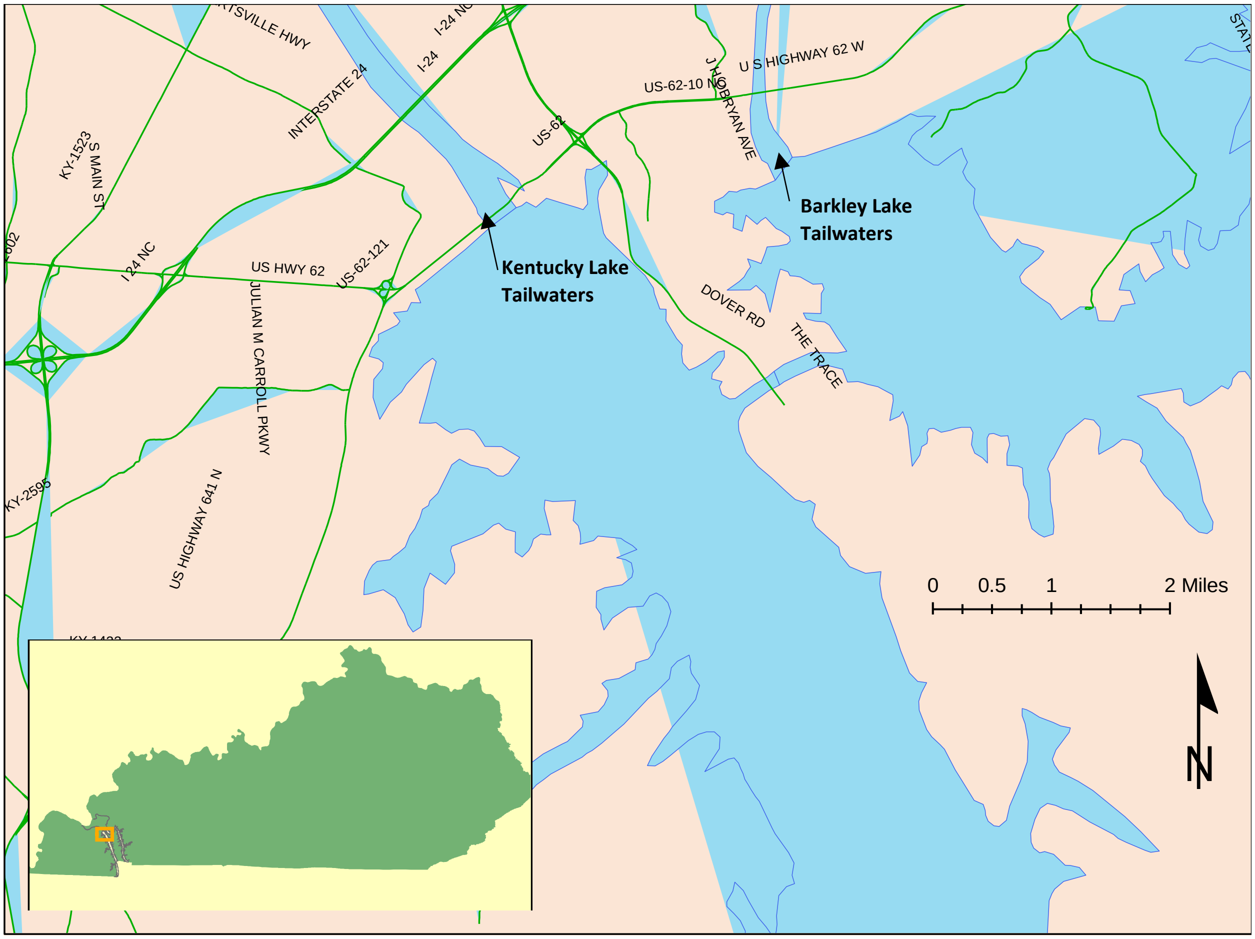

Figure 2. The bowfishing angler attitude survey conducted at Kentucky Lake Tailwater, and Lake Barkley Tailwaters.

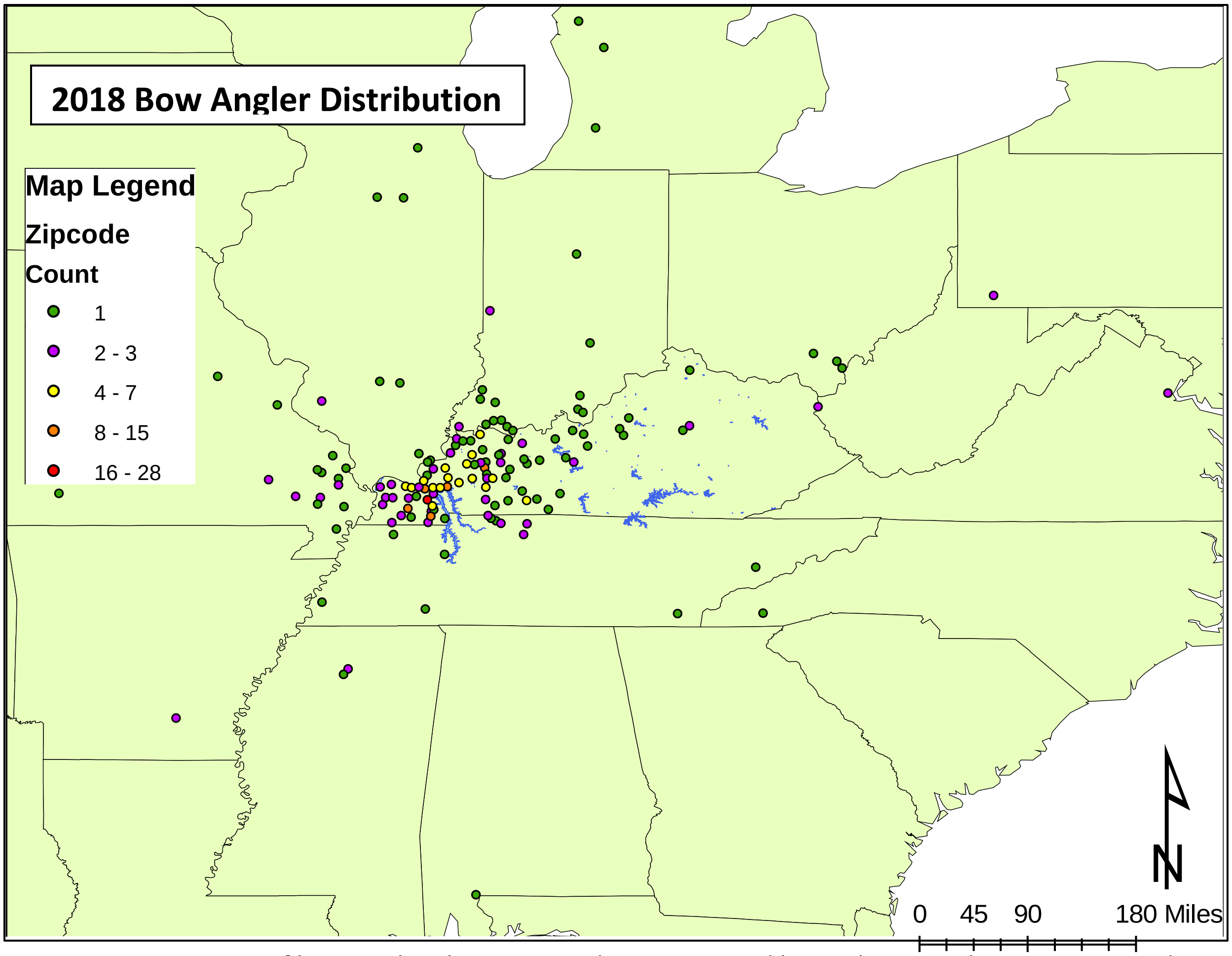

Figure 3. A range map of bow anglers home zip codes as captured by angler attitude surveys. Map does not illustrate one location in both Maine and Utah.

Table 1. Reported harvest of "Unlimited Asian Carp Only" bowfishing tournaments targeting only Asian carp species (bighead, silver, and grass).

"Unlimited Asian Carp Only" Bowfishing Tournaments			
Date	Number of Boats	Total lbs	Average lbs per boat
5/17/2014	33	16,332	494.9
6/7/2015	26	18,426	708.69
6/11/2016	15	16,844	1122.93
8/19/2017	6	6,283	1047.2
9/1/2018	8	5,600	700

Appendix 2. (301 KAR 1:410) KDFWR Fishing Regulations

Rough fish (except alligator gar) may be taken year-round by long bow, crossbow, compound bow, recurve bow or pneumatic air arrow launching device. Sport fish may not be taken with this gear. Arrows must have a barbed or retractable style point that has a line attached for retrieval. Catfish have a daily creel limit of 5 (in aggregate) and paddlefish have a daily creel limit of 2. There is no limit on other rough fish. Bow fisherman may fish within 200 yards of a dam, except by boat in boat restricted areas. Bow fishing is prohibited on the Cumberland River below Wolf Creek Dam downstream to the Tennessee line, including Hatchery Creek and all tributaries for ½ mile upstream of their confluence with the Cumberland River.

Persons using a bow and arrow for fishing must have the appropriate fishing license and may take rough fish from bank or boat. Bow anglers cannot sell paddlefish or their roe taken by bow and arrow. Paddlefish and catfish taken by bow and arrow must be taken into immediate possession and cannot be culled. Fish taken by bow must not be discarded on the bank. Bank disposal is littering and subject to a fine.

Appendix 1. 301 KAR 1:410 section 8. Taking of fish by nontraditional fishing methods.

Section 8. Bowfishing

- (1) An angler using archery equipment, a crossbow, or a pneumatic arrow launching device shall not take: (a) Sport fish; (b) Alligator gar; (c) More than five (5) catfish daily; (d) More than two (2) paddlefish daily; or (e) Lake sturgeon.
- (2) Any paddlefish or catfish shot with archery equipment, a crossbow, or a pneumatic arrow launching device shall: (a) Be immediately retained, and not released or culled; and (b) Count toward a person's daily limit.
- (3) Bowfishing shall be open statewide, except: (a) In the Cumberland River below Wolf Creek Dam downstream to the Tennessee line including Hatchery Creek; (b) In any tributary of the Cumberland River below Wolf Creek Dam to the Tennessee line, from the junction of the tributary with the Cumberland River to one-half (1/2) mile upstream; or (c) From a boat in restricted areas below navigation, power generating, or flood control dams. (32 Ky.R. 434; Am. 622; eff. 10-12-2005; 33 Ky.R. 1889; eff. 4-6-07; 34 Ky.R. 374; eff. 10-9-2007; 35 Ky.R. 995; 1448; eff. 1-5-2009; 37 Ky.R. 744; 10-7-2010; 38 Ky.R. 1974; 39 Ky.R. 13; eff. 7-12-2012; 1944; eff. 5-31-2013; 41 Ky.R. 564;p 1048; eff. 12-5-2014; 42 Ky.R. 1322; eff. 1-4-2016; 44 Ky.R. 574; eff. 1-5-2018; 45 Ky.R. 428; eff. 10-5-2018.)

  (301 KAR 1:410)

Appendix 3. Bow Angler Attitude Survey With Combined Users (N=365) (March 2018-October 2018)

2018 Bowfishing Attitude Survey

1. Have you been surveyed this year? ☐ **Yes** - stop survey ☐ **No** – continue
2. Bow angler **Age** 26 **Gende**r (Please **check**) 92.6% - **MALE** or 7.4% - **FEMALE** and **Zip Code**________________
3. How long have you been engaged in bowfishing? (**Please Check**)
   34% - Within the last 2 years 26.6% - Within the last 5 years 21.8% - Within the last 10 years 17.6% - Longer than 10 years
4. Which type of bowfishing do you participate in? (Please check) 21.6% - **Bank** 25% - **Boat** 53.4% - **Both**
5. How **MANY** bowfishing trips do **YOU** make in each season? **March-August** 40.3 **September-November** 7.7 **December-February** 1.4
   Of those trips, average time on the water? **Hours** 5.76
   Of those trips, average distance traveled to the boat ramp? 40.6 **Miles**
   Of those trips, **YOUR** average overall cost of each trip taken? $49.26
6. Where do you primarily bow fish when in Kentucky? (Please **NUMBER** in order of time spent bowfishing with **1-7 being most time spent**, if you don't bow fish at location leave **blank**)
   Barkley Lake Tailwaters ___1___ Kentucky Lake Tailwaters ___2___ Barkley Lake ___3___ Kentucky Lake___4___
   Ohio River North of Owensboro, KY___7___ Ohio River South of Owensboro, KY___5___ Other___6___
7. When bowfishing, what species do you target? (Please **Check** all fish that apply)
   87.9% - Bighead Carp 86.8% - Silver Carp 81.1% - Grass Carp 60.0% - Buffalo 32.6% - Catfish
   56.7% - Common Carp 40.8% - Freshwater drum 74.8% - Gar 50.4% - Paddlefish
8. On average, after one trip of bowfishing how many of these fish do **YOU** shoot? (IF consistently shot)
   Silver carp ___18.4_____ Bighead carp ___8.48_____ Grass carp ___5.02_____ Paddlefish per year___5.05_____
9. On average, what size fish do you shoot?
   Silver carp __10.42___(lbs.) Bighead carp __22.2___(lbs.) Grass carp __17.9___(lbs.) Paddlefish __19.2___(lbs.)
10. After harvesting the fish how do you dispose of them? (Please **Check**) 59.2% - Keep them 26.5% - Sink them 14.3% - Dispose of them in trash
    If you checked **KEEP THEM**, what do you do with them? (**#1)** 35.6% - Compost/Fertilizer (**#2)** 29.8% - Consumption
11. If dump stations were available for harvested fish would you be willing to transport fish to them? (Please check)
    93.6% - **YES** 6.4% - **NO**
    If **YES**, how far would you be willing to drive to utilize them? 66.7% - 0 to 10 miles 25.9% - 10 to 20 miles 5.1% - 20 to 30 miles 2.3% - 30 or more miles
12. Overall satisfaction with bowfishing on:

Kentucky Lake- (**Please check**) 63.4% - Satisfied 21.4% - Neutral 1.5% - Dissatisfied 13.7% - No opinion
Kentucky Lake Tailwaters- (**Please check**) 77.6% - Satisfied 13.3% - Neutral 3.4% - Dissatisfied 5.7% - No opinion
Barkley Lake- (**Please check**) 55.2% - Satisfied 21.6% - Neutral 5.6% - Dissatisfied 17.6% - No opinion
Barkley Lake Tailwaters- (**Please check**) 79.4% - Satisfied 13.4% - Neutral 1.8% - Dissatisfied 5.4% - No opinion
Ohio River North of Owensboro, KY- (**Please check**) 28.6% - Satisfied 18.4% - Neutral 0% - Dissatisfied 53% - No opinion
Ohio River South of Owensboro, KY- (**Please check**) 50.8% - Satisfied 18.5% - Neutral 0% - Dissatisfied 30.7% - No opinion

13. Do you participate in bowfishing tournaments? (Please check) 53.1% - **YES** 46.9% **- NO**

If **YES**, how many tournaments do you participate in each year? 5.48
If **NO**, explain why you do not participate?(**#1)** 39.1% - Lack of Equipment (**#2)** 15.2% - Beginner (**#3)** 8.7% - None Close Enough

14. Do you belong to a bowfishing club? (Please **check**) 26.7% - **YES** 84.3% - **NO**
15. Do you participate in any other fishing tournaments? (Please **check**) 15.7% - **YES** 84.3% - **NO**

If **YES**, what other fishing tournaments do you participate?(Please **check**) 85% - **BASS** 6.7% - **CRAPPIE** 6.7% - **CATFISH** 1.7% - **OTHER**

16. What initiated your interest in bowfishing? (Please **check 1 box**) 22.3% - Family 57.7% - Friends
    5.8% - Increase in Asian Carp Numbers 4.2% - Social Media <1% - Public Outreach <1% - Food Source
    8.8% - Other **(#1)** 42.4% - Archery **(#2)** 9.1% - Shooting
17. Bow angler's household Income? (Please check amount applicable)
    49.9% - Less than $35,000 29.7% - $35,000-$75,000 10.6% - $75,000-$100,000 9.8% - $100,000+
18. Comments or suggestions about bowfishing (**Please respond on back of sheet**)

(#1) 13.6 – Dump Stations Needed **(#2)** 12.5% - Dumping of Fish/Smell **(#3)** 9.1% - Increase Law Enforcement in the Tailwaters **(#4)** 5.7%-Bowfishing Education/awareness **(#5**) 4.5%-Raise Paddlefish Limits

Appendix 4. Bow angler Angler Attitude Survey Only Bank Users (N=164) (March 2018-October 2018)

2018 Bowfishing Attitude Survey

1. Have you been surveyed this year? □ **Yes** - stop survey □ **No** – continue
2. Bow anglers **Age** 22.6 **Gende**r (Please **check**) 94.3% - **MALE** or 5.7% - **FEMALE** and **Zip Code**_______________
3. How long have you been engaged in bowfishing? (**Please Check**)
 50% - Within the last 2 years 34% - Within the last 5 years 8.3% - Within the last 10 years 7.7% - Longer than 10 years
4. Which type of bowfishing do you participate in? (Please check) 48.4% - **Bank** 0.6% - **Boat** 51% - **Both**
5. How **MANY** bowfishing trips do **YOU** make in each season? **March-August** 46.8 **September-November** 7.0 **December-February** 1.1

 Of those trips, average time on the water? **Hours** 4.6
 Of those trips, average distance traveled to the boat ramp? 29.4 **Miles**
 Of those trips, **YOUR** average overall cost of each trip taken? $30.80
6. Where do you primarily bow fish when in Kentucky? (Please **NUMBER** in order of time spent bowfishing with **1-7 being most time spent**, if you don't bow fish at location leave **blank**)
 Barkley Lake Tailwaters ___1___ Kentucky Lake Tailwaters ___2___ Barkley Lake ___5___Kentucky Lake ___6___
 Ohio River North of Owensboro, KY___7___Ohio River South of Owensboro, KY___3___ Other___4___
7. When bowfishing, what species do you target? (Please **Check** all fish that apply)
 86% - Bighead Carp 85.3% - Silver Carp 77.4% - Grass Carp 44% - Buffalo 34.8% - Catfish
 39.6% - Common Carp 34.8% - Freshwater drum 71.3% - Gar 58.5% - Paddlefish
8. On average, after one trip of bowfishing how many of these fish do **YOU** shoot? (IF consistently shot)
 Silver carp ___10.8_____ Bighead carp ___5.02_____ Grass carp ___2.7_____ Paddlefish per year___8.7_____
9. On average, what size fish do you shoot?
 Silver carp __9.9___(lbs.) Bighead carp __20.8___(lbs.) Grass carp __12.7___(lbs.) Paddlefish __18.8___(lbs.)
10. After harvesting the fish how do you dispose of them? (Please **Check**) 69% - Keep them 18.6% - Sink them 12.4% - Dispose of them in trash

If you checked **KEEP THEM**, what do you do with them? (**#1)** 44%- Consumption (**#2)** 28%- Compost/Fertilizer

11. If dump stations were available for harvested fish would you be willing to transport fish to them? (Please check)
 89.6% - **YES** 10.4%-**NO**

If **YES**, how far would you be willing to drive to utilize them? 78.9% - 0 to 10 miles 17% - 10 to 20 miles 2.7% - 20 to 30 miles 1.4% - 30 or more miles

12. Overall satisfaction with bowfishing on:

Kentucky Lake- (**Please check**) 60.9% - Satisfied 13% - Neutral 8.7% - Dissatisfied 17.4% - No opinion
Kentucky Lake Tailwaters- (**Please check**) 85.2% - Satisfied 7.8% - Neutral 5.5% - Dissatisfied 1.5% - No opinion
Barkley Lake- (**Please check**) 47.8% - Satisfied 21.7% - Neutral 4.4% - Dissatisfied 26.1% - No opinion
Barkley Lake Tailwaters- (**Please check**) 85.5% - Satisfied 13% - Neutral 1.5% - Dissatisfied 0% - No opinion
Ohio River North of Owensboro, KY- (**Please check**) 15.4% - Satisfied 0% - Neutral 0% - Dissatisfied 84.6% - No opinion
Ohio River South of Owensboro, KY- (**Please check**) 75% - Satisfied 11.1% - Neutral 0% - Dissatisfied 13.9% - No opinion

13. Do you participate in bowfishing tournaments? (Please check) 29.8% - **YES** 70.2% **- NO**

If **YES**, how many tournaments do you participate in each year? 2.94
If **NO**, explain why you do not participate? (**#1)** 46.2% - Lack of Equipment (**#2)** 19.2% - Beginner (**#3)** 15.4% - Never Tried

14. Do you belong to a bowfishing club? (Please **check**) 17.9% - **YES** 82.1% - **NO**
15. Do you participate in any other fishing tournaments? (Please **check**) 14.2% - **YES** 85.8% - **NO**

If **YES**, what other fishing tournaments do you participate?(Please **check**) 88% - **BASS** 8% - **CRAPPIE** 4% - **CATFISH** 0% - **OTHER**

16. What initiated your interest in bowfishing? (Please **check 1 box**) 14% - Family 61.6% - Friends
 7.9% - Increase in Asian Carp Numbers 4.3% - Social Media 1.2% - Public Outreach 0% - Food Source
 11% - Other **(#1)** 38.9%-Archery **(#2)** 16.7%-Outdoors
17. Bow angler's household Income? (Please check amount applicable)
 70.6% - Less than $35,000 19.6% - $35,000-$75,000 5.5% - $75,000-$100,000 4.3% - $100,000+
18. Comments or suggestions about bowfishing (**Please respond on back of sheet**)

(#1) 28% – Dumping of Fish/Smell **(#2)** 24% - Dump Stations Needed **(#3)** 8% - Raise Paddlefish Limits **(#3)** 8% - Bounty/subsidy on fish

Appendix 5. Bow angler Angler Attitude Survey Boat Only Users (N=149) (March 2018-October 2018)

2018 Bowfishing Attitude Survey

1. Have you been surveyed this year? □ **Yes** - stop survey □ **No** – continue
2. Bow anglers **Age** 29.3 **Gende**r (Please **check**) 89.7% - **MALE** or 10.3% - **FEMALE** and **Zip Code**________________
3. How long have you been engaged in bowfishing? (**Please Check**)
 18.5% - Within the last 2 years 22.6% - Within the last 5 years 32.9% - Within the last 10 years 26% - Longer than 10 years
4. Which type of bowfishing do you participate in? (Please check) 0% - **Bank** 48.3% - **Boat** 51.7% - **Both**
5. How **MANY** bowfishing trips do **YOU** make in each season? **March-August** 34.4 **September-November** 8.5 **December-February** 1.5

   Of those trips, average time on the water? **Hours** 6.7
   Of those trips, average distance traveled to the boat ramp? 42.7 **Miles**
   Of those trips, **YOUR** average overall cost of each trip taken? $67.04
6. Where do you primarily bow fish when in Kentucky? (Please **NUMBER** in order of time spent bowfishing with **1-7 being most time spent**, if you don't bow fish at location leave **blank**)

Barkley Lake Tailwaters 1 Kentucky Lake Tailwaters 2 Barkley Lake 4 Kentucky Lake 3
Ohio River North of Owensboro, KY 6 Ohio River South of Owensboro, KY 5 Other 7

7. When bowfishing, what species do you target? (Please **Check** all fish that apply)
   91.3% - Bighead Carp 89.9% - Silver Carp 84.6% - Grass Carp 70.5% - Buffalo 30.9% - Catfish
   67.8% - Common Carp 43.6% - Freshwater drum 74.5% - Gar 45% - Paddlefish
8. On average, after one trip of bowfishing how many of these fish do **YOU** shoot? (IF consistently shot)
   Silver carp 21.4 Bighead carp 8.4 Grass carp 4.4 Paddlefish per year 2.8
9. On average, what size fish do you shoot?
   Silver carp 10.9 (lbs.) Bighead carp 21.7 (lbs.) Grass carp 19.6 (lbs.) Paddlefish 19.3 (lbs.)
10. After harvesting the fish how do you dispose of them? (Please **Check**) 52.1% - Keep them 33.3% - Sink them 14.6% - Dispose of them in trash

If you checked **KEEP THEM**, what do you do with them? (**#1)** 45.2% - Compost/Fertilizer (**#2)** 22.6% - Consumption

11. If dump stations were available for harvested fish would you be willing to transport fish to them? (Please check)
    96.6% - **YES** 3.4% - **NO**

If **YES**, how far would you be willing to drive to utilize them? 61.3% - 0 to 10 miles 31% - 10 to 20 miles 4.9% - 20 to 30 miles 2.8% - 30 or more miles

12. Overall satisfaction with bowfishing on:

Kentucky Lake- (**Please check**) 69.2% - Satisfied 21.8% - Neutral 0% - Dissatisfied 9% - No opinion
Kentucky Lake Tailwaters- (**Please check**) 72.7% - Satisfied 19.2% - Neutral 1% - Dissatisfied 7.1% - No opinion
Barkley Lake- (**Please check**) 62% - Satisfied 22.5% - Neutral 7% - Dissatisfied 8.5% - No opinion
Barkley Lake Tailwaters- (**Please check**) 75% - Satisfied 14.8% - Neutral 1.9% - Dissatisfied 8.3% - No opinion
Ohio River North of Owensboro, KY- (**Please check**) 32.8% - Satisfied 23% - Neutral 0% - Dissatisfied 44.2% - No opinion
Ohio River South of Owensboro, KY- (**Please check**) 43.8% - Satisfied 21.9% - Neutral 0% - Dissatisfied 34.3% - No opinion

13. Do you participate in bowfishing tournaments? (Please check) 71.6% - **YES** 28.4% **- NO**
    If **YES**, how many tournaments do you participate in each year? 6.55
    If **NO**, explain why you do not participate? (**#1)** 18.2% - Lack of Equipment (**#1)** 18.2% - None Around
    _ (**#1)** 18.2% - Never Got the Chance (**#1)** 18.2%-No Time
14. Do you belong to a bowfishing club? (Please **check**) 34% - **YES** 66% - **NO**
15. Do you participate in any other fishing tournaments? (Please **check**) 16% - **YES** 84% - **NO**

If **YES**, what other fishing tournaments do you participate?(Please **check**) 80% - **BASS** 4% - **CRAPPIE** 12% - **CATFISH** 4% - **OTHER**

16. What initiated your interest in bowfishing? (Please **check 1 box**) 29.5% - Family 52.7% - Friends
    4.8% - Increase in Asian Carp Numbers 5.5% - Social Media <1% - Public Outreach <1% - Food Source
    6.2% - Other **(#1)** 55.6%-Archery
17. Bow angler's household Income? (Please check amount applicable)
    25% - Less than $35,000 43.6% - $35,000-$75,000 15.7% - $75,000-$100,000 15.7% - $100,000+
18. Comments or suggestions about bowfishing (**Please respond on back of sheet**)

(#1) 11.4% – Law Enforcement/write more tickets **(#1)** 11.4% - Bowfishing Education/awareness
(#2) 8.6% - Dump Stations Needed

Appendix 6. KDFWR Bowfishing Tournament Form

Bowfishing Tournament Data Sheet

Date:	
Tournament Name:	
Hours of Bowfishing Tournament:	
Location of Bowfishing Tournament Waters:	
Estimated Lbs of Silver Carp Harvested:	
Number of Silver Carp Harvested:	
Estimated Lbs of Bighead Carp Harvested:	
Number of Bighead Carp Harvested:	
Estimated Lbs of Grass Carp Harvested:	
Number of Grass Carp Harvested:	
Estimated Lbs of All Harvested Fish:	
Fresh Water Drum Harvested:	
Gar Harvested:	
Number of Bow Anglers:	

Comments:

Return Address:

Kentucky Department of Fish and Wildlife
Critical Species Investigation
Attn: Matthew Combs
30 Scenic Acres Dr.
Murray, KY 42071

Matthew.Combs@ky.gov

Early detection and evaluation of Asian carp removal in the Ohio River

Geographic Location: Ohio River basin, extending from the Cannelton pool (RM 720.7) to the Racine pool (RM 237.5) along with the Dashields (RM 13.3), Montgomery Island (RM 31.7), and New Cumberland (RM 54.4) pools of the Ohio River in addition to the Allegheny and Monongahela rivers.

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

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

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

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

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

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.
Invasive Carp – one of four species (i.e. Silver Carp, Bighead Carp, feral Grass Carp, and Black Carp) of carps originating from the continent of Asia, which are currently classified as aquatic nuisance species.
Macrohabitat – One of four habitat types used to categorize fixed sites within a pool (e.g. Tributary/Embayment, Tailwater, Island Back-Channel, Main Stem River).

Presence Front – The farthest upstream extent where invasive carp populations occur, but reproduction is not likely.
Targeted Sampling – sampling that uses gear and/or techniques intended to specifically target one species (i.e. Silver Carp and Bighead Carp) and exclude others (i.e. native species).

Spring Targeted Sampling (Cannelton – R.C. Byrd)
Asian carp targeted sampling was introduced in 2017 to take the place of spring community monitoring, previously conducted in the basin. This adjustment was made in an effort to better reflect the annual change in relative carp abundance and provide a baseline assessment to direct future removal efforts. Targeted sampling was conducted from 16 April – 29 May, 2018, along five pools (Cannelton – R.C. Byrd pools) in the middle Ohio River. This geographic range is significant because it currently represents the upper end of the establishment front through the lower end of the presence front for Silver Carp in the ORB (Figure 1). All fixed sampling sites were selected from a stratified random design in 2015. While randomly selected sites were considered ideal, this study design was found to be prohibitive with many random locations being remote or far from ramp launch sites. Thus, the sampling structure was adjusted in an attempt to offset logistic limitations while maintaining adequate pool coverage. Pools were segmented into four sections (upper, upper-middle, lower-middle, and lower) with six fixed electrofishing sites and two fixed gill netting sites per section (~24 electrofishing runs and 8-12 gill net sets per pool). To ensure coverage of each pool through this fixed sampling design, four major macrohabitat types were identified in each pool in order to compare trends within pools through time. Macrohabitat types included main-stem locations, island back-channels, tributaries/embayments, and dam tailwaters in each pool. In general, tributary or embayment sites comprise the majority of sampling locations (~ 62%). Fish communities tend to accumulate in these locations and tributaries are more frequent in number than islands and dam tailwaters in the Ohio River. The main-stem river is obviously the most frequent habitat available for sampling, but because of span and depth of the river, fisheries gears are limited in their ability to target fish.

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

Gill nets used in targeted sampling were typically 45m (150ft) in length, 3m (14ft hobbled to 10ft) in depth, and constructed of large mesh (either 10cm or 12.5cm bar mesh) with a foam core float line to keep them suspended at top water. An additional 45m net with 7.6cm mesh (3” bar mesh) was included where conditions allowed in order to broaden the size distribution of invasive carp targeted with netting gear. Appropriate conditions were typically where flow was not so great as to sweep nets or push too much debris into the tighter mesh while being fished in the same manner as the other gears. Gill nets were set perpendicular to the shoreline when possible. Sites sampled consisted of at least two net sets, fished for two hours while creating noise and water disturbance every 30 minutes within 300 meters of the set. Regular disturbance was intended to drive or persuade the movements of bigheaded carps into the gear.

Upon capture, all bigheaded carps were examined for the presence of external and/or internal tags (jaw tags and sonic implants attached in 2013-2016 through the Ohio River Asian Carp Telemetry Project), identified, geo-located, weighed, and measured. In most cases, bigheaded carps were euthanized. A subsample of otoliths and spines were collected for aging following established protocols (Beamish 1981, Schrank and Guy 2002, Williamson and Garvey 2005, Seibert and Phelps 2013). Feral Grass Carp (*Ctenopharyngodon idella*) presence was also recorded and fish were euthanized upon capture. Any *Hypophthalmichthys spp*. that were not euthanized were tagged with a distinct jaw tag and a 95mm VEMCO 69 kHz – V16 acoustic-coded transmitter. Tagged fish were released at point of capture to contribute to the Ohio River Asian Carp Telemetry project. All fish tagged during the monitoring project activities are reported in the telemetry project report: Quantifying lock and dam passage, habitat use, and survival rates of Asian carp in the Ohio River.

Fall Standardized Community Monitoring (Cannelton – R.C. Byrd)
From 05 October – 20 November, fish community surveys were repeated along the same pools in the middle Ohio River (Cannelton, McAlpine, Markland, Meldahl, Greenup, and R.C. Byrd) using the same sampling sites as previous years (see above). Pool divisions (upper, upper-middle, lower-middle, and lower reaches) remained the same with six fixed electrofishing sites and two fixed gill netting sites per section (~24 electrofishing sites and 8 gill netting sites per pool). These sites are intended to remain constant throughout consecutive years of monitoring in order to compare trends within and among pools through time.

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

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

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

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

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

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

Incidental sampling for Asian Carp was conducted using baited tandem hoop nets, beach seining, and boat electrofishing. Baited tandem hoop nets (3' diameter, 1.5" bar mesh, 3 nets in tandem) were set in the Emsworth, Pool 2, Pool 3, and Pool 4 of the Allegheny River in June 2018 and were fished for three consecutive nights. All species were identified and enumerated before being released except for Channel and Flathead Catfish, which were retained for aging using otoliths.

Beach seining was conducted in August at six fixed locations in the Montgomery Island Pool of the Ohio River using a 30 m (100') seine with 1 cm (3/8") mesh. One seine haul was conducted at each of the six locations. Species readily identifiable in the field were enumerated and released; all other species were retained for identification and enumeration in the laboratory.

Daytime boat electrofishing was conducted in July on four fixed sites in the Montgomery Island Pool of the Ohio River, four fixed sites on the Charleroi Pool of the Monongahela River, and six fixed sites on Pool 4 of the Allegheny River. Electrofishing was conducted using an ETS MBS electrofishing system operated at 25% duty cycle and 60 pulses per second (pulsed DC) at variable voltages and amperages depending on river conditions. Transects were fixed length (100 – 300 m) and were sampled from 5 to 19 minutes. Black bass were measured and enumerated, and presence/absence of other species was recorded.

Nighttime boat electrofishing was conducted in October in the New Cumberland Pool of the Ohio River and Pool 4 of the Allegheny River and in December in the New Cumberland Pool, the Montgomery Island Pool, and the Dashields pool of the Ohio River. Electrofishing was conducted using an ETS MBS electrofishing system operated at 25% duty cycle and 60 pulses per second (pulsed DC) at variable voltages and amperages depending on river conditions. Three 15 minute transects were sampled in the New Cumberland Pool in the tailwater portion of the Montgomery Dam on each bank in October. All black bass and true bass were collected, and presence/absence of other species was recorded. On the Allegheny River in October, four fixed sites were sampled. Black bass and Sander species were collected, and presence/absence of other species was recorded. In the three pools of the Ohio River in December, the same unit and settings were used. Transects consisted of four 10 minute runs in the tailwater portion of each pool. All Sander species were collected and presence/absence of other species were recorded.

Assessing Asian Carp Population Demographics

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

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

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

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

Where L_t = the estimated length at time t, L_∞ = the estimated average maximum theoretical length, K = Brody growth coefficient, t = time or age in years, and t_0 = is the time in years when fish length would theoretically be zero. For the equation, L_∞ was set to the largest length captured for age and growth. This fixed L_∞ at the 99th percentile for the total lengths of fish captured within the 2018 field season and is likely a good reflection of the theoretical average maximum length for fish in the pool. The model was fitted in R using non-linear modeling procedures outlined by Derek Ogle (2016). In the future, growth coefficients within each pool will be used to obtain tentative annual mortality estimates for Silver Carp populations in the Cannelton and McAlpine pools. For this report, the growth equation was used to obtain an estimate of length at age of Silver Carp captured in the Cannelton pool.

Hydroacoustics Analysis

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

Hydroacoustics surveys were performed using methods similar to those described in MacNamara et al. (2016). Briefly, surveys were conducted parallel to the shoreline on both banks of the Ohio River for 4 miles and up to 2 miles upstream into tributaries. Surveys were conducted using two 200 kHz split-beam transducers (BioSonics, Inc.) aimed in side-looking aspect toward the shoreline on the main channel and away from the shoreline in tributaries and other shallow. The side-looking orientation is important to maximize the volume of water sampled and to reduce the potential of underestimating density of Asian carp that would evade detection of down-looking transducers via behavioral responses to boat disturbance. Transducers had a circular beam pattern of 6.4° and were offset in angle to minimize interference from the surface and maximize water column coverage (i.e., 3.2° and 9.6° below the surface of the water). Angles were adjusted and maintained throughout surveys using a dual-axis rotator. Data were collected at 5 pings/s with a pulse width of 0.4 ms. Temperature was recorded at the time of each survey to compensate for its influence on absorption and the speed of sound in water. An on-axis calibration was conducted after each survey following Foote et al. (1987).

Data are in the process of being analyzed using Echoview 9.0 following MacNamara et al. (2016). After background noise removal, the split-beam single target detection (method 2) algorithm was used to detect fish echoes or single targets. Multiple targets from a single fish were grouped into a fish track using EchoView's fish tracking algorithm to reduce the potential of overcounting fish targets. Size of fish targets (total length; cm) were estimated from a relationship between maximum side-aspect acoustic target strength (dB) and fish size (Love 1971). This function is wavelength- and temperature-dependent and was therefore scaled appropriately for 200 kHz transducers and temperature recorded during the survey. To estimate density of fish (e.g., number/m^3), the volume of water ensonified was estimated using the wedge volume approach.

Individual fish detections cannot reliably be assigned to a particular species using single-frequency hydroacoustics data. Rather, the proportion of fish at each length class determined from community data is applied to the size distribution and frequency of fish echoes. Fish community data from each pool will be apportioned among 3 fish categories (i.e., Silver carp, Bighead carp, and other fish species) for each length class. Finally, pool specific length-weight regressions will be used to estimate length-specific biomass for each species of interest. Density (numeric and mass) will be estimated following MacNamara et al. (2016).

Compilation and Incorporation of Other ORB Data Sources

Regional and national georeferenced databases are ideal for compiling both historical and current Asian carp range data from ORB states and participating basin groups. The Nonindigenous Aquatic Species (NAS) database, currently maintained by United States Geological Survey, was accessed in February 2019 and used to inform the range of Asian carp species captured and reported throughout the ORB. The NAS database provides a unified reporting and reference system where confirmed sightings from all basin partners can be submitted and will be considered when discussing the range and expansion of Asian carps in the ORB and its tributaries. In addition, data from Ohio River Valley Water Sanitation Commission (ORSANCO) were downloaded and compiled to determine the additional occurrences of Asian carps in sampling data taken from 1957 – 2018. Data were sorted and mapped in order to supplement project records and additional upstream detections of bigheaded carps in the Ohio River (Figures 8-9). In addition, with the increase in Black Carp records over the past several years, a new map was generated using these sources to show the current known distribution of those fish in the ORB (Figure 10). Some tributaries of the Ohio River are also included in this search, but are only referenced using their associated pools. Internal reports from other agency and partner projects are also included to expand carp sightings and our knowledge of invasion status within basin states. KDFWR's ichthyology branch has also provided additional counties where Asian carp have been documented in internal state streams, connected to the larger Ohio River system.

Results:

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

Spring targeted electrofishing in 2017 produced a single Bighead Carp capture and an overall catch per unit effort (CPUE) of 3.71 fish/hour (n = 74, SE = 1.31) for Silver Carp with no Grass Carp captures in any of the six pools sampled (Table 5). With spring work shifting towards targeted sampling in instead of community monitoring in 2017, Silver Carp yields were higher than previous seasons. However, previous sampling efforts, produced similar captures within the Cannelton, McAlpine, and Markland pools indicating that the yield were likely not an indication of population increases. In 2018, targeted electrofishing yielded zero Bighead Carp and 61 Silver Carp combined from Cannelton, McAlpine and Markland pools. The overall CPUE for all five pools sampled was of 3.05 fish/hour (n = 61, SE = 0.80) (Figure 11). Efforts also yielded an overall catch rate of 0.20 fish/hour (n = 4, SE = 0.12) for Grass Carp, an increase from previous years. Between both years, catch rates for Silver Carp in the Cannelton pool dropped slightly while occurrences increased in the upriver pools of McAlpine and Markland. However, the detection range where Silver Carp were captured remained consistent with targeted effort in 2017.

Spring gill netting in 2017 produced an overall CPUE of 0.10 fish/set (n = 10, SE = 0.06) for Bighead Carp, 0.70 fish/set (n = 31, SE = 0.34) for Silver Carp, and 0.19 fish/set (n = 17, SE = 0.10) for Grass Carp (Table 6). Eighty-five sets made up 5,822m (19,100ft) of net, yielding a total catch of 197 fish and 11 unique taxa. Asian carp species were caught throughout the sampling range with feral grass carp landings in all pools, but Silver Carp yield ended below Meldahl Locks and Dam (Figure 12). Bighead Carp were also captured throughout the sampling range in 2017, but only in the Cannelton, Markland, and RC Byrd pools. Smallmouth Buffalo and Silver Carp made up over 50% of the total catch by number. Bighead Carp made up ~5% of the total catch. Similarly, in 2018, Smallmouth Buffalo and Silver Carp made up over 50% of the total catch by number for captures in 2018 and were the most represented groups in term of catch by number (Table 7). Seventy-two net sets (3,292m or 10800ft) yielded a total number of 230 fish sampled in spring 2018 with 13 unique taxa identified. Overall catch rates for Bighead (0.07 fish/set, SE = 0.05), Silver (0.57 fish/set, SE = 0.25) and Grass Carp (0.08 fish/set, SE = 0.03) decreased in the four pools sampled in 2018 (Table 6). Captures in 2018 decreased for all invasives observed in the Cannelton and Markland pools, but increased slightly due to single captures of one each Silver and Grass carp in the McAlpine pool in 2018.

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

Fall gill netting in 2017 produced an overall CPUE of 0.10 fish/set (n = 9, SE = 0.53) for Bighead Carp, 0.28 fish/set (n = 26, SE = 1.40) for Silver Carp, and 0.01 fish/set (n = 1, SE = 0.01) for Grass Carp (Table 10). In 2018, Silver Carp were captured only in the Cannelton Pool while Bighead carp were captured in the Cannelton and RC Byrd pools with nets. Eighty-two sets made up 3,749m (12,300ft), yielding a total catch of 152 fish and 10 unique taxa. Smallmouth Buffalo and Silver Carp alone made up the majority of catch as they did in 2017. Together the two species comprised over 86% of the total catch with Longnose Gar and Paddlefish making up an additional 6% (Table 11).

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

Assessing Asian Carp Population Demographics
In total, the number of Bighead Carp captures across all projects in 2018 was 57 fish, a slight increase compared to the 46 fish caught in 2017. Of those two years, males were only slightly more common than females and immature fish were captured during both years. The mean total length of Bighead Carp

across both years was similar, with the 2017 average TL = ~1020mm (n = 46, SE = 31.0) and 2018 average TL = ~1052mm (n = 57, SE = 21.6). The weight-length regression for 2018 produced a more gradual slope and a shallower y-intercept than the ORB regression derived in 2017 (Table 3, Figure 4). Data points from 2018 cluster well, if not only somewhat lower than previous records used to derive the ORB regression, but the range of total lengths for fish taken from that pool in 2018 did not span the full range of total lengths observed in 2016 - 2017. Boxplot comparisons by year for the relative weights (W_r) of Bighead Carp in the Cannelton pool show a slow decline in body condition over the last three sampling seasons (Figure 5).

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

The presence of spawning patches on female fish was also tracked in 2018, which can be viewed as evidence of relatively recent spawning activity. A spawning patch was noted if it was actively hemorrhaging or the flesh was raw, with scales missing along the ventral surface of the body, and there was little to no visible signs of healing. Females captured exhibited fresh spawning patches from May – August. In May, spawning patches showed up by the 15^{th} and 52% of females captured by the end of the month exhibited fresh spawning patches. In June and July, 56% and 41% of females respectively displayed actively bleeding spawning patches. By August, most females captured were either healing or had little sign of damage on their ventral surface with only 8% of females caught showing signs of recent spawning activity. The Cannelton and McAlpine pools during this period of the sampling season typically demonstrate increased CPUE for all gears, but most notably with electrofishing as fish tend to fill tributaries in large numbers and are more accessible to removal crews. This pattern was also seen in 2016 and 2017 and has been used to increase carp capture numbers during population control projects.

In total, otoliths from 68 Silver Carp were examined and used to produce a von Bertalanffy growth curve with a theoretical average maximum length (L_∞) at 986mm. The oldest fish in the sample was 10 years old and the majority of fish were found to be between the ages of four and six. The theoretical average maximum length was fixed using the longest fish in the age and growth sample. This 10 year-old fish was found to be within the 99^{th} percentile of length distributions from 3700 fish harvested from the Cannelton pool in 2018. The Brody growth coefficient (K) was calculated at 0.319, which is relatively steep and indicates fish appear to approach L_∞ rapidly; in fact, predicted ages suggest that fish within their second growing season will likely reach a length of approximately 367mm (Table 12). While this model includes some uncertainty due to data limitations, the maximum age and length at age predictions are consistent or similar to growth parameters reported from other basins (Hayer et al. 2014, Seibert et al. 2015).

Hydroacoustic Analysis

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

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

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

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

Daytime boat electrofishing on the Ohio River Montgomery Island Pool, Monongahela River Charleroi Pool, and Allegheny River Pool 4 was conducted for 2.31 hrs of effort and no Asian carp were captured. Similarly, night boat electrofishing on the Ohio River in the New Cumberland Pool at the Montgomery Dam tailwater for 1.5 hrs of effort and in Pool 4 of the Allegheny River for 1.95 hrs of effort captured no Asian Carp in October. No Asian carp were captured during night electrofishing surveys in December in the New Cumberland, Montgomery Island, or Dashields Pools (1.33 hrs of effort per pool).

Compilation and Incorporation of Other ORB Data Sources
Data taken from ORSANCO records show a similar pattern in presence/absence of Asian carps as seen during standard monitoring sampling and removal efforts conducted between 2015-2018. The farthest up-river accounts of Asian carps by ORSANCO were in the Markland Pool in 2012 and McAlpine Pool in 2014 (Figures 8 – 10). The USGS NAS database expands the range of Silver Carp reports to the farthest upriver detection in Raccoon Creek, a tributary of the R.C. Byrd Pool in 2016 (Figure 9). Recently a Bighead Carp was captured as far up as a tributary of the Pike Island Pool in 2016 and an additional account of a Bighead impinged against the water intake screen at WH Sammis Power Plant in the New Cumberland pool was reported this past season in 2018 (Figure 8). Grass Carp records continue to be sporadic throughout the Ohio River and within all internal waters of the surrounding basin states. This is likely indicative of diploid Grass Carp establishment throughout the ORB. During routine sampling in 2017, the KDFWR ichthyology branch reported Silver Carp sightings at six locations between August and October in McCracken and Ballard counties in 2017. Two of six sites (Massac Creek and Clanton Creek wetland) previously contained juvenile Silver Carp between 69 – 85mm in total length. Both systems are tributaries of the Ohio River close to its confluences with the Mississippi. In 2018, Gar Creek, a tributary below the Tennessee and Cumberland Rivers and above Olmsted Locks and

Dam, was sampled in mid-July and found to harbor large numbers of Bighead, Silver, and Grass Carp YOY. Additionally, one young-of-year Black Carp (~ 23mm TL) was discovered while sorting the sample and officially verified by experts at the USGS Research Center and Missouri Department of Conservation. This finding marked the first location where juvenile Black Carp have been observed outside of the Dutchtown ditch near southeast Girardeau, MO. In addition, reports of adult Black Carp records within the lower part of the Ohio River and surrounding systems have increased in the past few years. In 2018 - 2019 there have been nineteen reports from verified captures in the lower Ohio River and surrounding tributaries, Barkley Lake/Cumberland River, Kentucky Lake/Tennessee River (Figure 10).

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

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

Relative catch rates (CPUE) of Silver Carp over both years continue to support increases in relative abundances from downriver to upriver pools (Figures 15 – 16). This trend among Silver Carp abundance is also apparent during removal efforts and additional observations during projects further up the Ohio River. Increased frequency of larger length-classes of Silver Carp in upriver pools, in addition to more narrow ranges for total lengths overall, suggests that fish captured upriver are likely migrants rather than successfully reproducing populations (Figure 15). This is further reinforced by reported data from additional sources such as the NAS database records, which have few recent records of Silver Carp extending past the R.C. Byrd pool. However, increases in the frequency of smaller length classes of Silvers in Cannelton indicate that fish within that pool may have had a successful spawn and juveniles are now beginning to show up in harvest data. Tributaries where these younger individuals were observed in 2017 are potentially important to recruitment success (primarily Clover Creek/Tug Fork and Oil Creek). No gear types currently seem to be effective at targeting Bighead Carp; however, as mentioned above, focusing on capture known locations (even in low density pools) have proven useful in removing Bighead Carp from the river. Despite our better understanding of how and where to capture Bighead Carp, successful landings are infrequent and take a substantial amount of effort. This has led to relatively little information on Bighead Carp in each pool and makes it difficult to determine if they follow similar abundance patterns as Silver Carp populations. From our experience, Bighead Carp appear more erratic in their distributions and our current assumptions are that pool densities are less dependent on fish age or population densities. Fall gill netting and regular removal efforts in RC Byrd are beginning to show that Bighead Carp can be consistently caught in the stretch of river between RC Byrd Locks and Dam and Raccoon Creek, while pools below don't appear to produce consistent yields of Bighead, despite historical captures at specific locations. Using agency records and reported sightings, their range upriver appears to greatly exceed the presence front currently suggest for Silver Carp populations. In addition, telemetry data supports the postulation that individual Bighead Carp have a higher propensity to migrate upriver when compared to Silver Carp. However, individual Bighead appear to find their preferred habitat and remain in that area for a majority of time.

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

Regressions for both *Hypophthalmichthys spp.* derived in 2017 appear similar to those derived from carp sampled in other watersheds and remain a good estimator for weight at length in the ORB. Previously, an ANCOVA analysis was applied to a multiple linear regression model ($y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \varepsilon$), with weight (g) being determined by total length (mm) with year used as a categorical predictor variable for fish captured after spawning activity. Predicted weights at each length along the regression were used to determine that there was no statistically significant difference in growth of fish between the two years. However, with the length classes of fish caught between 2017 and 2018 differing in range, appropriate use of this analysis would involve recalculating a regression for 2017 using a truncated dataset containing similar total lengths to fish caught in 2018. With annual regressions being reported, adjusted, and then recalculated each successive year, analyses may become confusing and difficult to track. Thus, regressions for Bighead and Silver Carp were plotted against previous data used in determining condition regressions in 2017 and visually compared. Data for Bighead Carp appeared to cluster slightly lower than data from previous seasons and suggest a small decrease in weight at length for fish caught in 2018. In addition, boxplots showing the range and median relative weights for each year were plotted for comparison. While data ranges showed significant overlap between years, Bighead Carp condition appears to have steadily decreased over the past three removal seasons in the Cannelton pool. Although there is not sufficient evidence to attribute any decline in condition to interspecies competition for resources, this may be part of the body of evidence showing that *Hypophthalmichthys* populations in that section of river are beginning to crowd. Silver Carp regression points clustered similarly with previous data and the 2018 regression slope was likely affected by the lack of smaller size fish in the data range. When looking at Silver Carp relative weights across years in the Cannelton and McAlpine pools, it appears that they have been relatively steady over the last three seasons. Conditions between the two pools do differ slightly and suggest that fish in McAlpine (a lower density pool) have consistently maintained a higher condition than fish in the Cannelton pool (a relatively higher density pool).

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

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

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

yields. These areas currently include Clover Creek in the Cannelton pool, Sinking Creek in the Cannelton pool, the mouth of Salt River in the Cannelton pool, and the mouth of the Kentucky River in the McAlpine pool. With fish being more susceptible to netting gears in cooler water temperatures, it is recommended that regular removal targeting these locations be incorporated annually to boost population control efforts. Finally, with results indicating increases in population densities in the Cannelton pool, larger scale control efforts are a primary objective for future efforts considering that Silver Carp populations may be recruiting in this section of river. With Cannelton pool harboring a potential source of upriver migrant fish, contract fishing is recommended to reach the scale of population control necessary to decrease pressure for upriver progression.

Project Highlights:

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

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Figures:

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

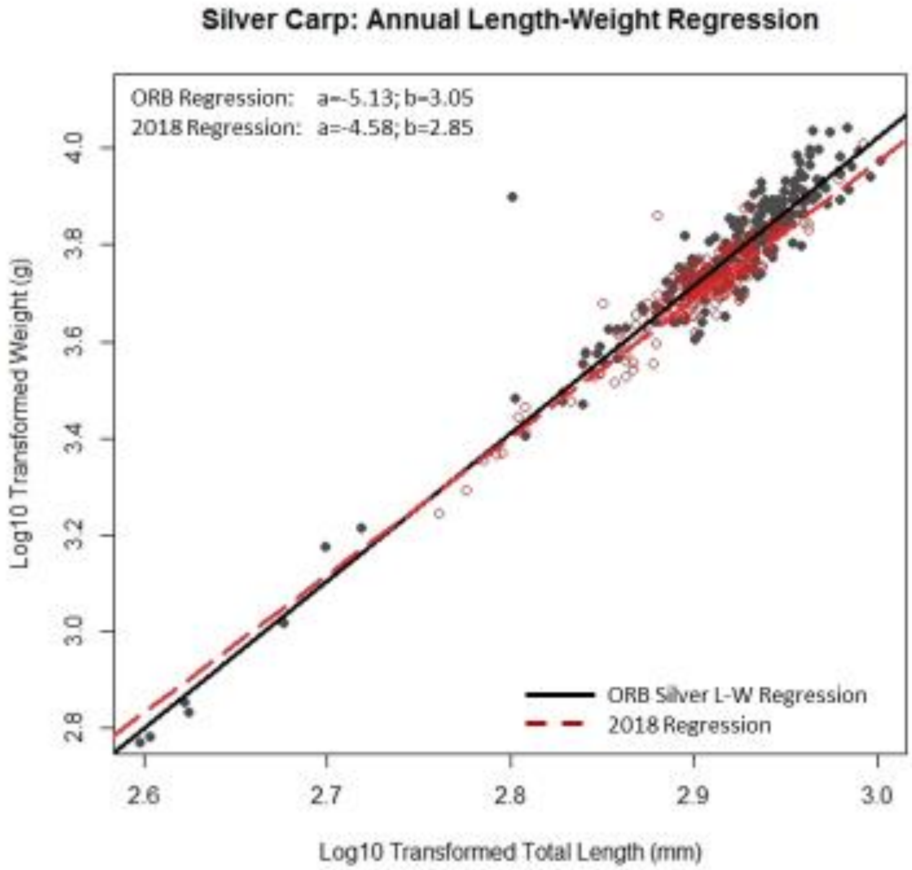

Figure 2. The log-transformed relationship between total length and weight for Silver Carp in the ORB. The black line and data points indicate the cumulative length-weight relationship developed for Silver Carp in the ORB in 2017 (Table 2), while the red line and data points indicate the new 2018 data.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

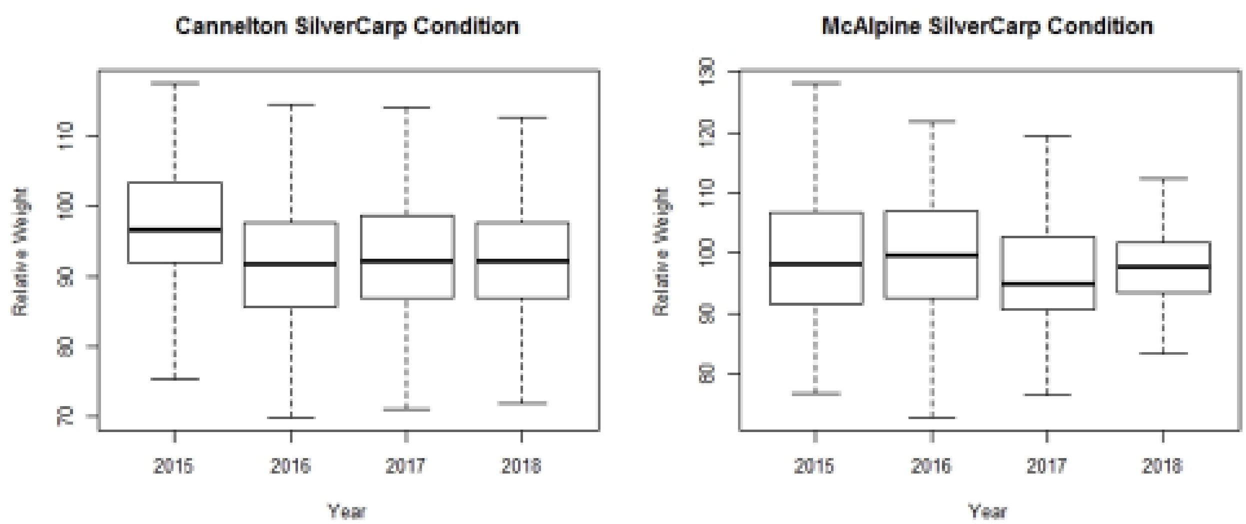

Figure 3. The relative weight (Wr) condition for Silver Carp captured in the Cannelton and McAlpine pools over the past four years. There appears to be little difference in body condition since 2016 across each pool, but fish in McAlpine appear to maintain slightly higher body condition than fish captured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

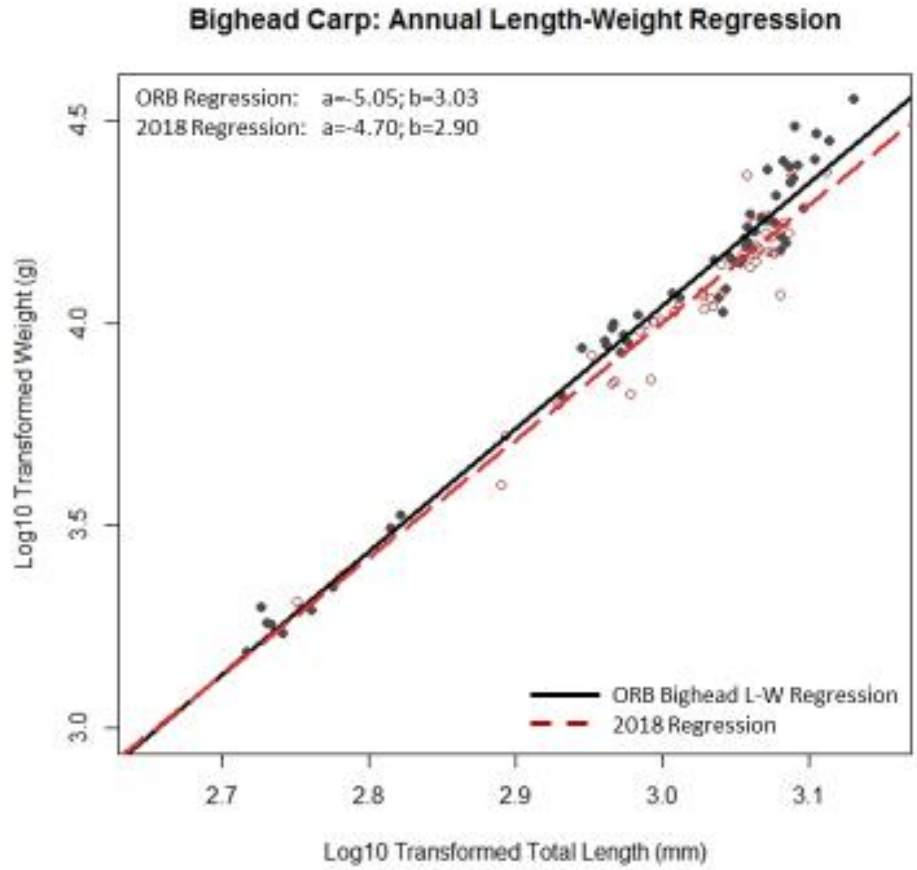

Figure 4. The log-transformed relationship between total length and weight for Bighead Carp in the ORB. The black line and data points indicate the cumulative length-weight relationship developed for Bighead Carp in the ORB in 2017 (Table 3), while the red line and data points indicate the new 2018 data.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

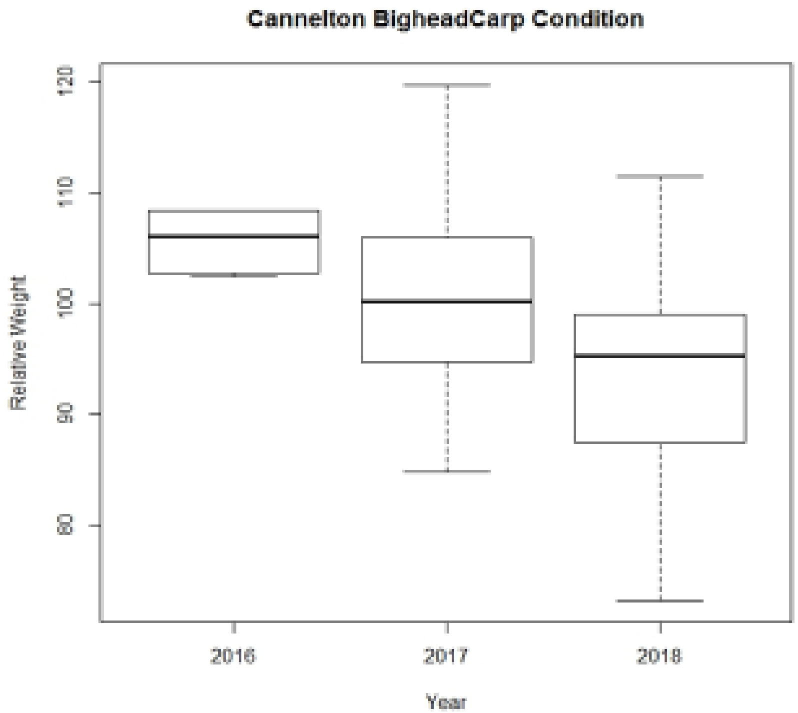

Figure 5. The relative weight (Wr) condition for Bighead Carp captured in the Cannelton pool over the past three years. There appears to be a decline in body condition since 2016.

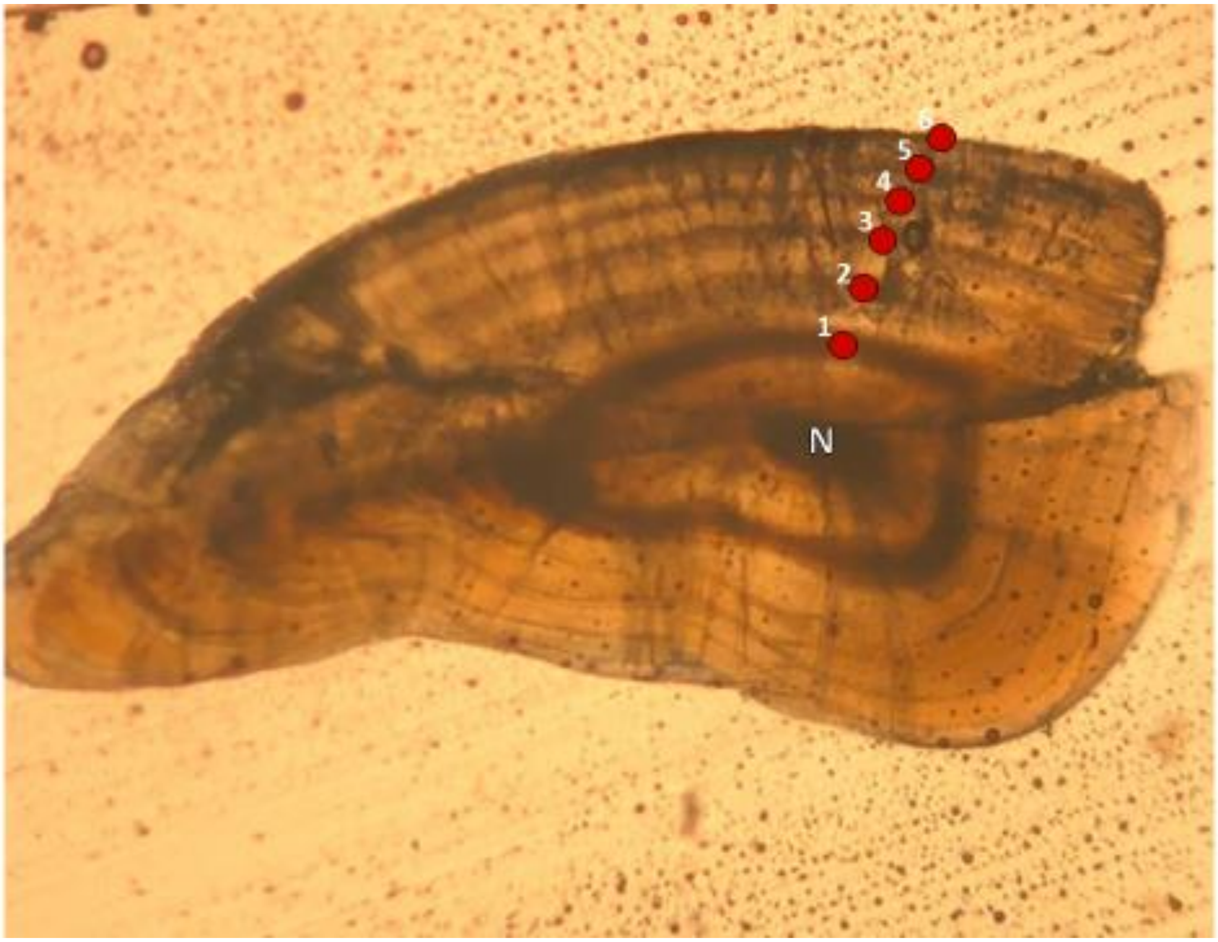

Figure 6. An example of the lapilliar otolith taken from a Silver Carp (age-6) used for age and growth estimation in the Cannelton pool.

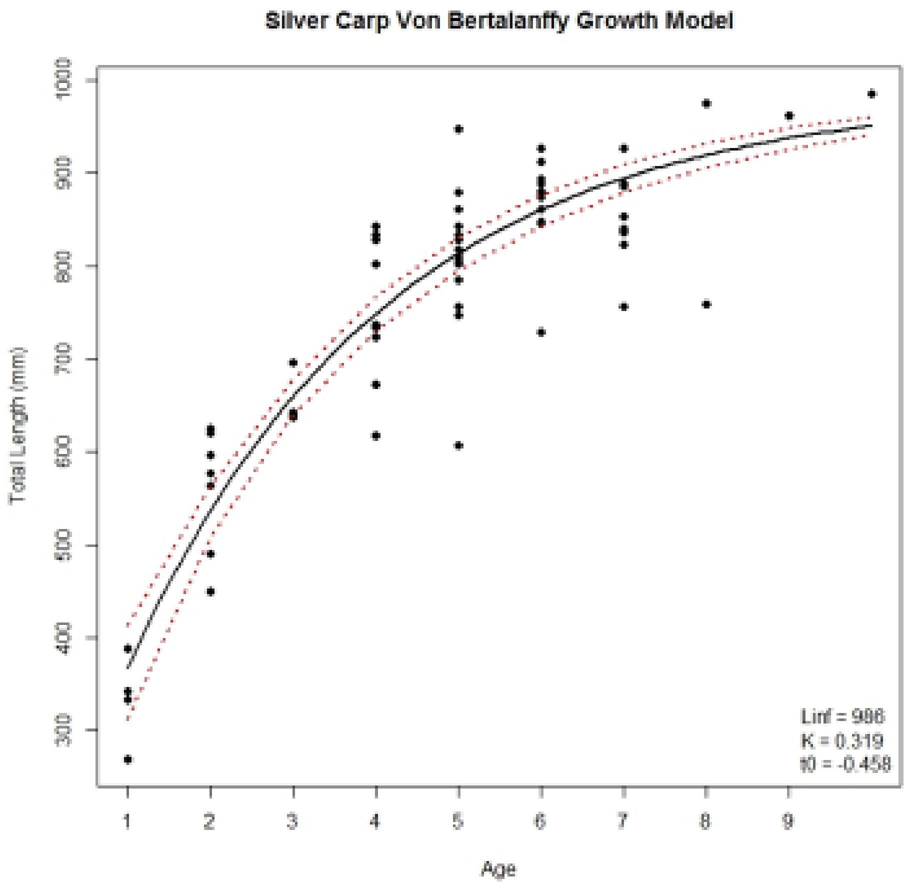

Figure 7. A von Bertalanffy growth curve estimating the age and growth of Silver Carp harvested from the Cannelton Pool in 2018. Age is in years and total length are in millimeters.

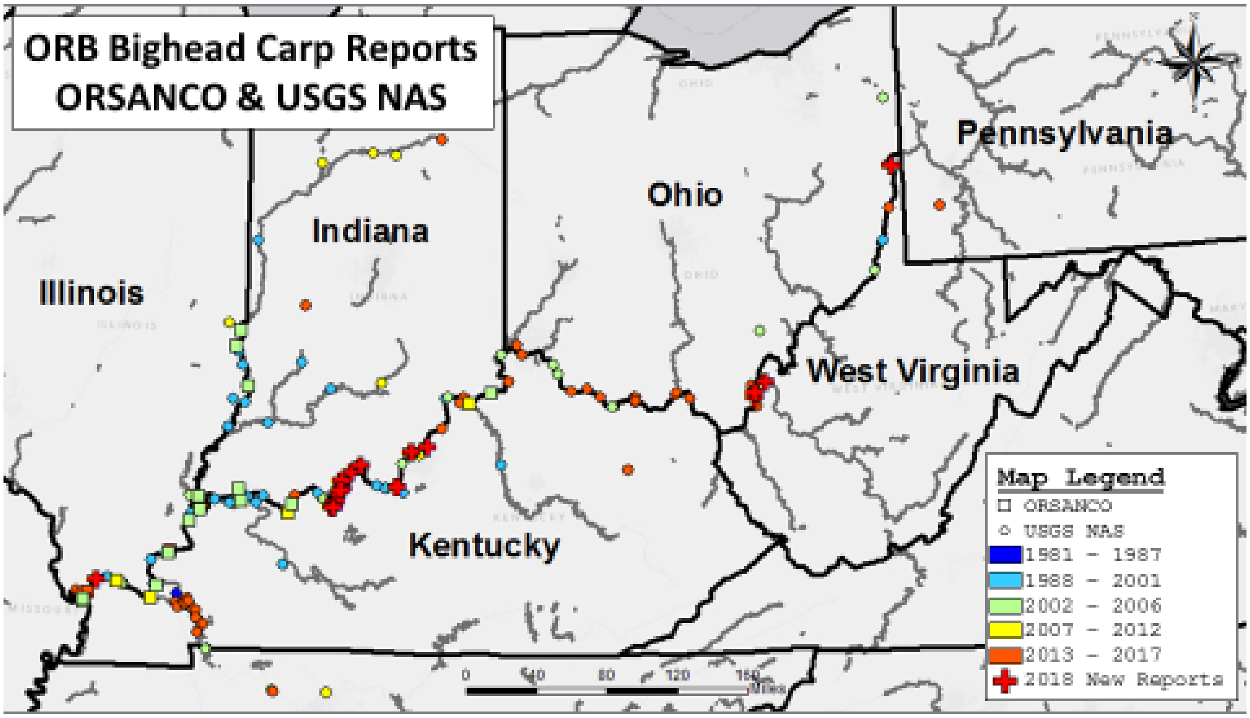

Figure 8. A map depicting the distribution of Bighead Carp throughout the ORB; records were compiled from both ORSANCO and the USGS NAS database and show the range of Bighead, which have been reported by basin states since 1981.

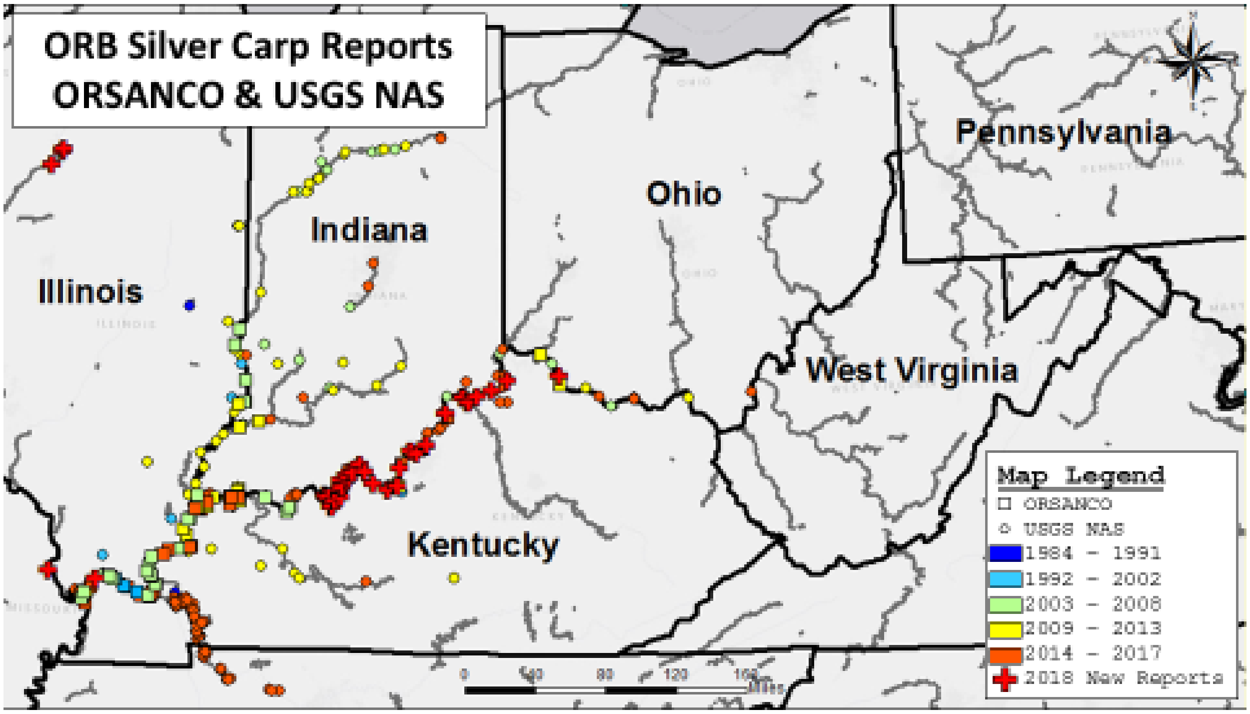

Figure 9. A map depicting the distribution of Silver Carp throughout the ORB; records were compiled from both ORSANCO and the USGS NAS database and show the range of Silver Carp, which have been reported by basin states since 1984.

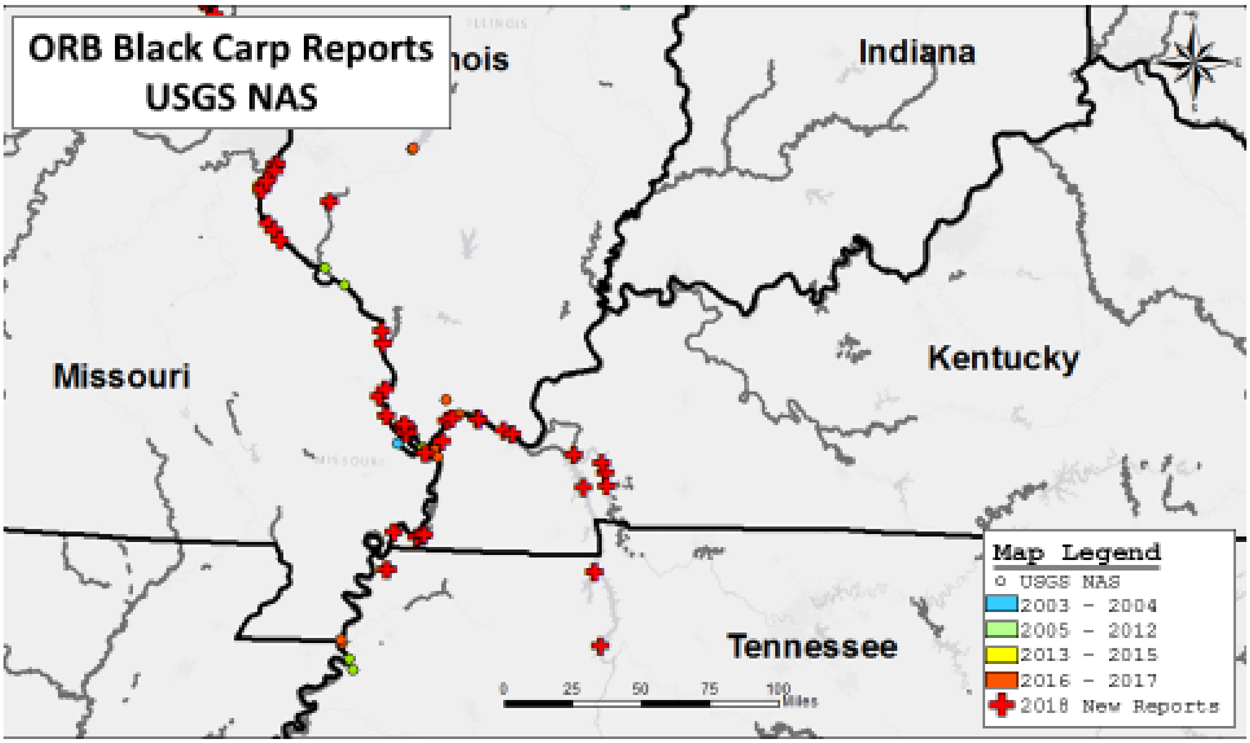

Figure 10. A map depicting the distribution of Black Carp throughout the ORB; records were compiled from both ORSANCO and the USGS NAS database and show the range of Black carp, which have been reported by basin states since 2003.

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

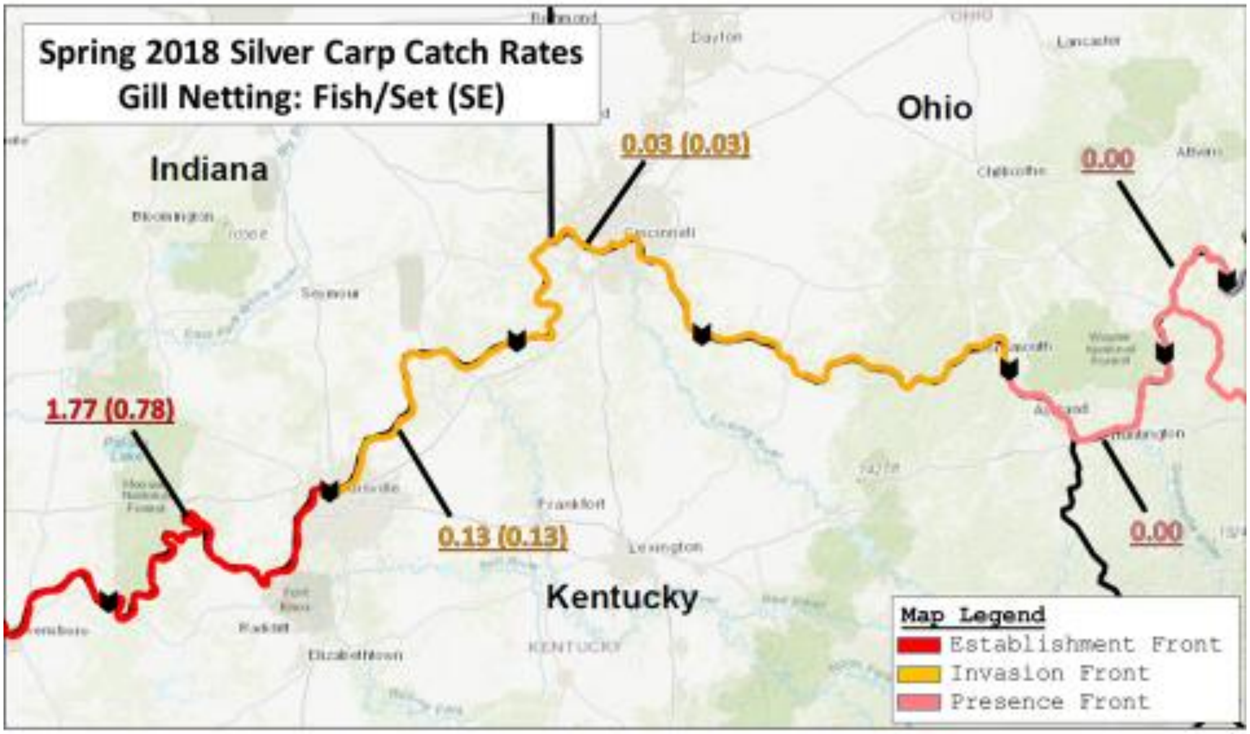

Figure 12. A map of the Silver Carp establishment ranges between Cannelton and RC Byrd pools and the average catch-rates of Silver Carp per pool during targeted sampling using gill netting.

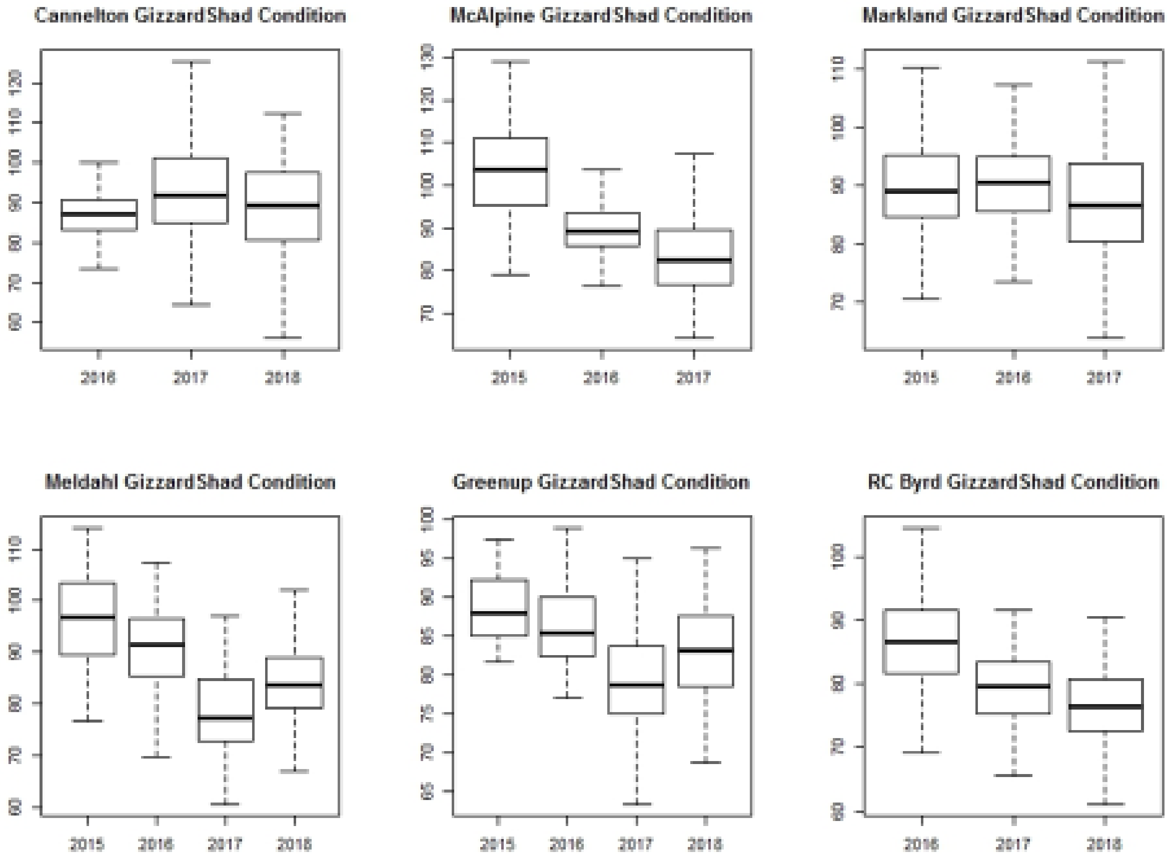

Figure 13. The body condition (Wr) of Gizzard Shad from six of the monitoring pools throughout the Ohio River since 2015.

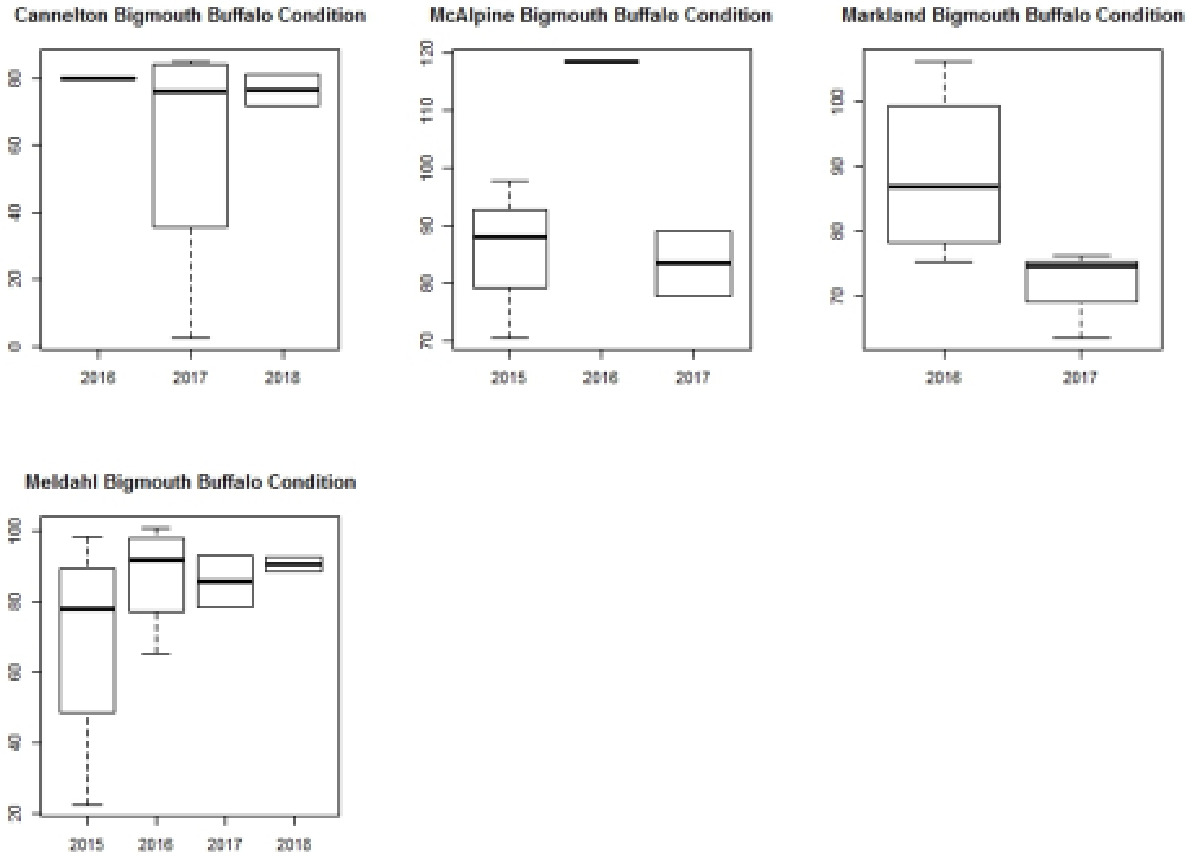

Figure 14. The body condition (Wr) of Bigmouth Buffalo from four of the monitoring pools throughout the Ohio River since 2015. Annually, catches for this species are sporadic and many pools do not have enough occurrences to allow for good trend data.

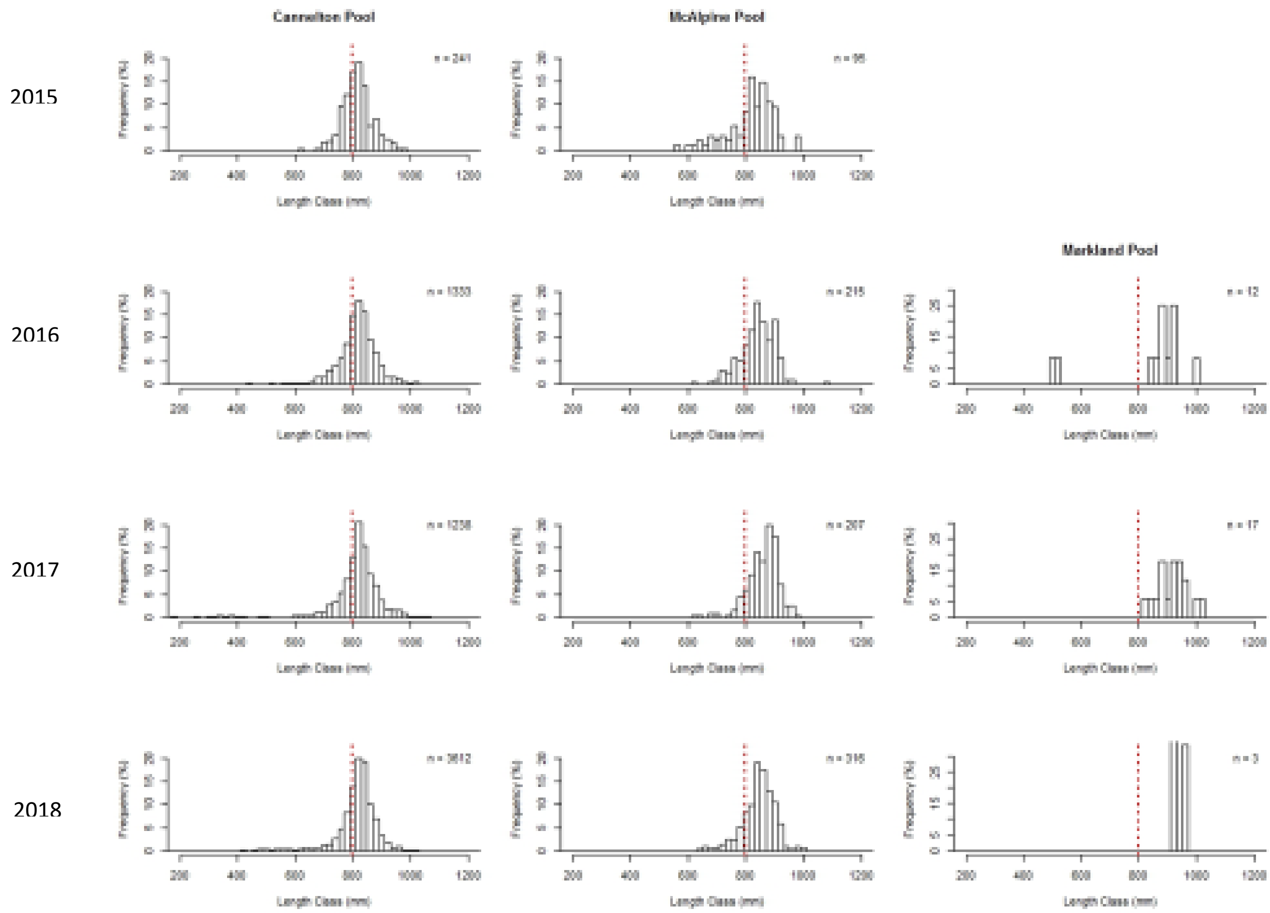

Figure 15. The frequency of total lengths for Silver Carp captured in Cannelton, McAlpine, and Markland pools since 2015. Patterns indicate larger fish occur with higher frequencies and lower numbers as you progress upriver.

Tables:

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

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

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

System: Specific Locale	L-W Regression Equation (metric)	Predicted weight for 450mm (g)	Predicted weight for 800mm (g)	Reference
Ohio River	$\log_{10}$ weight = -5.13 + 3.05($\log_{10}$ length)	917	5302	ORB Technical Report 2017
Illinois River	$\log_{10}$ weight = -5.29 + 3.12($\log_{10}$ length)	972	5856	Irons et al. 2011
Middle Mississippi River	$\log_{10}$ weight = -5.29 + 3.11($\log_{10}$ length)	915	5477	Williamson and Garvey 2005
Missouri River: Gavins Point	$\log_{10}$ weight = -6.92 + 3.70($\log_{10}$ length)	788	6628	Wanner and Klumb 2009
Missouri River: Interior Highlands	$\log_{10}$ weight = -5.35 + 3.13($\log_{10}$ length)	900	5453	Wanner and Klumb 2009
Missouri River tributary: Big Sioux River	$\log_{10}$ weight = -5.53 + 3.21($\log_{10}$ length)	970	6150	Hayer et al. 2014
Missouri River tributary: James River	$\log_{10}$ weight = -5.26 + 3.11($\log_{10}$ length)	981	5869	Hayer et al. 2014
Missouri River tributary: Vermillion River	$\log_{10}$ weight = -4.82 + 2.90($\log_{10}$ length)	748	3971	Hayer et al. 2014

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

System: Specific Locale	L-W Regression Equation (metric)	Predicted weight for 450mm (g)	Predicted weight for 800mm (g)	Reference
Ohio River	$\log_{10}$ weight = -5.05 + 3.03 ($\log_{10}$ length)	976	5577	ORB Technical Report 2017
Illinois River: La Grange	$\log_{10}$ weight = -4.84 + 2.95 ($\log_{10}$ length)	970	5298	Irons et al. 2010
Missouri River (Males)	$\log_{10}$ weight = -5.42 + 3.15 ($\log_{10}$ length)	866	5306	Schrank and Guy 2002
Missouri River (Females)	$\log_{10}$ weight = -5.40 + 3.13 ($\log_{10}$ length)	803	4860	Schrank and Guy 2002
Missouri River: Gavins Point	$\log_{10}$ weight = -4.86 + 2.96($\log_{10}$ length)	985	5409	Wanner and Klumb 2009
Missouri River: Interior Highlands	$\log_{10}$ weight = -4.30 + 2.75($\log_{10}$ length)	991	4825	Wanner and Klumb 2009

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

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

Table 5. Electrofishing effort and the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per hour) of three species of Asian carp captured in six pools of the Ohio River from spring targeted sampling in 2017 and 2018. Standard errors are in parentheses.

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

Table 6. Gill netting effort and summaries of the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per set) of three species of Asian carp captured in six pools of the Ohio River from spring tergeted sampling in 2017 and 2018. Standard errors are in parentheses.

	Spring Gill Netting													
	Ohio River 2017							**Ohio River 2018**						
	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total	Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	Total
Sampling Dates	04 April - 23 May							18 April - 29 May						
Effort (ft)	2400	1800	3900	3300	3050	4650	19100	3300	1200	4800	0	1500	0	10800
Net Sets	8	6	13	11	16	31	85	22	8	32	0	10	0	72
All Fish (N)	46	1	70	57	2	21	197	144	12	69	0	5	0	230
Species (N)	6	1	10	8	2	9	11	10	7	10	0	3	0	13
Bighead Carp (N)	6	0	2	1	0	1	10	5	0	0	0	0	0	5
Silver Carp (N)	27	0	4	0	0	0	31	39	1	1	0	0	0	41
Grass Carp (N)	0	1	13	1	1	1	17	0	1	5	0	0	0	6
Bighead Carp CPUE	0.75 (0.62)	0.00	0.15 (0.15)	0.00	0.00	0.03 (0.03)	0.10 (0.06)	0.23 (0.15)	0.00	0.00		0.00		0.07 (0.05)
Silver Carp CPUE	3.38 (1.58)	0.00	0.31 (0.17)	0.00	0.00	0.00	0.70 (0.34)	1.77 (0.78)	0.13 (0.13)	0.03 (0.03)		0.00		0.57 (0.25)
Grass Carp CPUE	0.00	0.17 (0.17)	1.00 (0.62)	0.09 (0.09)	0.06 (0.06)	0.03 (0.03)	0.19 (0.10)	0.00	0.13 (0.13)	0.16 (0.07)		0.00		0.08 (0.03)

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

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

Table 8. Electrofishing effort and the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per hour) of three species of Asian carp captured in six pools of the Ohio River from fall community sampling in 2017 and 2018. Standard errors are in parentheses.

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

Table 9. The number of fish captured by species and percent of total catch in six pools of the Ohio River with boat electrofishing surveys at fixed monitoring sites in 2017 and 2018. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

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

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

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

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

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

Table 10. Gill netting effort and summaries of the resulting total catch by the number of fish, number of species, and catch per unit effort (fish per set) of three species of Asian carp captured in six pools of the Ohio River from fall community sampling in 2017 and 2018. Standard errors are in parentheses.

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

Table 11. The number of fish captured by species and percent of total catch in six pools of the Ohio River with gill netting surveys at fixed monitoring sites in 2017 and 2018. (Ohio River Pools: Cann = Cannelton; McAlp = McAlpine; Mark = Markland; Meld = Meldahl; Green = Greenup)

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

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

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

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

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

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

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

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

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

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

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

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

Control and Removal of Asian carp in the Ohio River

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

Participating Agencies: Kentucky Department of Fish and Wildlife Resources (KDFWR), Indiana Department of Natural Resources (INDNR), US Fish and Wildlife Service (USFWS), West Virginia Department 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 (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) in addition to disrupting human connections to natural resources (i.e. fishing, boating, navigation, aesthetics, etc). 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. In addition, contingency planning can aid in preparing agencies and many other stakeholder groups for managing changes in invasion status.

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). 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 provides an assessment tool that aids in guiding decisions about monitoring, barrier defense, and population control efforts in future years.

Objectives:

1. Target and remove Asian Carp to suppress populations and reduce propagule pressure in the Ohio River.
2. Develop an Ohio River contingency response plan.

Methods:

Removal efforts in 2018 focused on Cannelton and McAlpine pools with limited effort in the RC Byrd pool (Figure 1). Cannelton pool currently marks the accepted establishment front for Silver Carp populations within the ORB. In previous years, the McAlpine Dam appeared to be a bottleneck for Silver Carp advancement upriver with few fish tagged near the tailwater known to pass the dam. However, with recent evidence indicative of crowding populations in the Cannelton pool in addition to some limited dam passages seen in the past two years, it is likely that fish are beginning to expand upriver in response to density increases.

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 be inconsistent terminology used across the basins when talking about basin-specific invasions. With this in mind, below is 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 four habitat types used to describe the variety of fixed sites within a pool (e.g. Tributary/Embayment, Tailwater, Island Back-Channel, and Main Stem River).
Presence Front – The farthest upstream extent where Asian carp populations occur, but reproduction is not likely taking place.
Targeted Sampling – sampling that uses gear and/or techniques intended to specifically target one species and exclude others (i.e. silver carp and bighead carp).

Targeting and Removal of Asian Carps
Electrofishing and gill netting for removal in 2017 were conducted over approximately 15 weeks from May through September. In 2018, this was expanded while taking advantage of the high water conditions on the river. When fixed monitoring sites could not be accessed due to hazardous conditions, high water tended to force large schools of carp into flooded tributaries and embayments. Those that provided access were used to conduct removal. 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” – 6.0” 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 throughout the season in areas where they did not create hazards to navigation. However, in the warmer months this was avoided to decrease paddlefish by-catch. Often electrofishing crews were paired with netting crews so that they could work in tandem to push large schools of into netting gears

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 discovered from accessing early monitoring sampling sites in 2015 - 2016. Additional sites were identified using map study, recommended by agency biologists, or were in areas that contained characteristics of typical carp habitat. 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 the lowest taxonomic level possible. 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 project. 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).

Contingency Planning Effort and Document
In 2017, a need was identified for a consistent procedure that ORB member agencies and management groups could follow in an effort to respond to changes in the Asian Carp conditions in any of the six pools of the Ohio River. The Upper Illinois Waterway Contingency Response Plan was a major source for template design and many of the components of the current draft mimic that document. The goal of the contingency plan was identified in the context of the ORB and reviewed at the beginning of the document. Information on relevant pool characteristics was accumulated and paired with information on carp population status for two of the four invasive species (i.e. Bighead Carp and Silver Carp) across pools currently being monitored. This information was organized into a “decision matrix” and assigned

an urgency level that would help facilitate a response. Then a “Response Matrix” was designed with possible actions tied to each of the different changes in urgency level. A flowchart showing the process for initiating a response was laid out and provides a general suggestion for initiating any coordinated basin effort. The draft will be introduced to the basin partners for comment, edits, and augmentation.

Results:

Physical Removal of Asian Carps

Approximately 87 hours were spent electrofishing in five pools of the Ohio River and its tributaries between Cannelton and RC Byrd Locks and Dam (Table 1). Four thousand and sixty-nine carp were removed using boat electrofishing over these four pools in 2018. The highest level of effort was expended in the Cannelton pool where a total number of 3,726 carps, weighing approximately 23,446 kg (51,690 lbs), were removed. Electrofishing provided the most success between sampling gears, but is aided with the use of barrier structures such as nets. Thus, many electrofishing efforts were conducted in tandem with gill netting. In addition, some tributaries consistently hold schools of invasive carp and can be regularly targeted and produce yields.

A total of 6,309 meters (20,700 ft) of large mesh (4” – 6” square) gill nets were used in capturing 505 invasive carps in five pools of the Ohio River (Cannelton – RC Byrd) (Table 2). This amounted to 3,281 kg (~7,233 lbs) of Bighead, Silver, and Grass Carp combined. The largest amount of effort was expended in the Cannelton pool with 3,109 meters (10,200 ft) of gill net fished to remove 494 fish, weighing approximately 3,056 kg (~6,737 lbs). Gill netting has been less effective than boat electrofishing, but it is useful in creating structure and obstacles that are difficult for carp to maneuver around. This has aided in increasing capture success when used in addition to boat electrofishing.

By-catch was rarely taken with boat electrofishing. Small minnow and herring species were occasionally dipped to ensure they were not juvenile carp, but were released upon inspection. When gill netting, by-catch was a concern because it usually impacts native fauna and can severely reduce set times. The most common non-target species encountered when gill netting in 2018 were Smallmouth Buffalo (~20% overall catch), Paddlefish (~ 5%), Common Carp (~ 4%), and Blue Catfish (~ 4%) with all other species comprising an additional 7% (Table 3) with accounts of fish rarely being DOA. Targeted invasive carp make up ~ 60% of the total catch by number and it often benefits crews to use short sets and remove them from nets quickly to prevent capture loss.

Total effort and capture numbers accounted for in this report include some time and effort placed into targeted monitoring from the basin’s evaluation project. However, this report does not contain all removal efforts contributing to population control in the basin. For example, some additional work has been conducted by INDNR in the White and Wabash rivers, which are free-flowing tributaries of the Ohio River. In 2018, Indiana removed 39 kg (86.4 lbs) of Bighead Carp and 723 kg of Silver Carp captured as by-catch during paddlefish gill net and catfish hoop net sampling. These fish were used in outreach events where carp fillets were provided for the public to sample and generated interest in the targeting and consumption of the invasive species. Also, through juvenile sampling, adult fish are removed on an annual basis; for more detail on effort and removal conducted during juvenile sampling in 2018, please refer to that report.

Contingency Planning Effort and Document

The contingency document has progressed and is a rough approximation of what an ORB contingency plan should look like. The plan is short, but identifies the known range statuses for Bighead and Silver carp in the ORB. The response matrix currently contains seven potential actions that can be expanded on by additional partners. The draft is currently missing a section that clearly defines a chain of command within the ORB Asian Carp Coordination Committee and a section that includes logistics and resource limitations (i.e. the speed at which state permits could be obtained or how money would be leveraged to complete actions, etc…).

Discussion:

Dams along the Ohio River likely provide some barrier to dispersal for invasive carps migrating up river. Data acquired from monitoring sampling efforts in 2018 show that the average sizes of Silver Carp increase (Figure 2) as you move up river, while catch rates decrease (Figures 3 – 4). This has been a consistent pattern in data gathered since 2015 and is an indication that fish further up river are not only fewer in number, but likely older. Older and larger fish likely have greater ability to disperse in addition to more time to move up the establishment and invasion fronts. With Cannelton being the furthest upriver pool where fish < 400 mm have been observed consistently, it must be prioritized as a major target in terms of population control. Numbers of fish are high enough to suggest that intense, regular fishing pressure is needed at a level higher than current agency crews can maintain. Also, with the presence of juvenile fish that may have been newly recruited in that pool, it is likely the most adjacent 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.

The McAlpine pool itself has several areas where fish accumulate and most fish appear to be mature adults which average 28mm larger than fish caught in the Cannelton pool below. This pattern is more indicative of a migrant population, but with potential increases in population size over the past two years it is important to continue removal efforts in this pool as well to reduce the overall population size and the potential for successful recruitment.

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. Driving the boat in aggressive and sinuous patterns is often used to pin fish against the bank when targeting Silver and Grass Carp and can be effective at getting fish to surface. However, because they are difficult to catch when airborne, CPUE is often highly variable and dependent on the experience of the driver and dipper. Targeting of tributary waters and tributary mouths gives removal crews an advantage because gears are typically more effective in these shallower waters and fish appear to prefer these slower moving waters. In all cases, the use of side-scan imaging can greatly increase success and the ability of a crew to move between multiple tributaries from one launch location increases the likelihood of success. Future removal efforts should be designed to take advantage of periods of increased movement when fish are actively moving in or out of contiguous tributaries to maximize catch. The late 2018 and early 2019 seasons have been very high water periods and have made access to the river challenging, but additional exploratory efforts have led to the discovery of winter aggregations of carp in certain tributaries like Clover Creek. When water is accessible, fish should be targeted during cooler months when they are more susceptible to netting gears.

By-catch is always a concern when considering impacts of targeting and removing bigheaded and grass carps from the Ohio River. Overnight sets during productive sampling months were decreased substantially and only utilized a handful of times. Overnight sets have the potential to produce low increases in Bighead Carp captures, but come at the cost of increased by-catch during warmer water months. Typically paddlefish are found to be dead on arrival (DOA) if caught in nets overnight in warmer conditions and often it has been more effective to target sites known to produce previous Bighead Carp captures. When utilizing short active net sets, by-catch can be dealt with while continuing to fish netting gears and catch rates of native species is rather low.

When compared to previous years, larger yields in 2018 are primarily due to the shifting of effort downstream where densities of Silver Carp are higher. However, there has been no indication that removal efforts have made any measurable impact on carp numbers. In fact, some evidence suggests that numbers have increased in Cannelton (frequent large schools now common, decreasing Bighead Carp body condition, small increases in dam passages, and relatively larger yields anecdotally being reported by removal crews). With Cannelton pool being such a strategic area for removal, additional effort is now necessary to begin placing heavier fishing pressures on carp populations in that pool. Contract fishing planned for 2019 will greatly increase fishing pressure and free up resources for agency personnel to shift additional effort into the McAlpine pool and potentially aid in lowering numbers of fish in that section of the Ohio before they become established in the pool. With the existing monitoring efforts we hope to be able to identify if the increase in pressure does lead to a measurable impact in carp numbers.

The contingency planning document has progressed and provides one possible framework for how agencies can prepare for changes in Asian Carp status and respond to that change in the ORB. Future work should focus on providing logistical and resource assumptions in addition to identifying a chain of command that allows for coordinated approaches between basin partners to be implemented in a responsible manner. In addition, work needs to be placed into expanding both the response action and decision matrices. Decision matrices have gaps in knowledge that need to be addressed and pool characteristics need to be added into consideration of the threat level that initiates each action. Finally, an outline defining what "rapid response" efforts should look like and how they should be incorporated into this document is needed.

Recommendations:
It is imperative that fishing pressure increases substantially in the Cannelton pool as it is the reproductive extent of Silver Carp. Future removal effort in the form of contract fishing should augment removal in that pool during the months of May to August when spawning activity and overall movement in and out of tributaries is common. 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 for continual removal efforts. Outreach and efforts to spur public and commercial interest within the Cannelton pool should continue and will be 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 2018 was altered from removal conducted in 2017 in order to focus removal effort in higher density pools were larger impacts could be made. However, no reductions on population size are evident.
- Approximately 87 hours of boat electrofishing yielded 23,446 kg (51,690 lbs) of invasive carp removed from the Ohio River
- Gill netting effort accounted for the removal of over 3,200 kg of invasive carp removed from the Ohio River but remains a difficult tool to use when targeting Silver Carp. Yields tend to increase when used in tandem with boat electrofishing and are often more effective in cooler water when known aggregations of fish can be targeted.
- Gill netting efforts in 2018 have produced little strain on native populations and the most common by-catch species removed from net sets are Smallmouth Buffalo and Paddlefish. Targeted carp species make up more than 60% of the total catch by number in netting gears.

- It is imperative that fishing pressure increases substantially in the Cannelton pool. Future removal effort in the form of contract fishing should augment removal efforts in that portion of the Ohio River.
- A contingency plan document is included with this report for basin review and comment. This is a draft document and is currently not being implemented in the ORB.

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Figures:

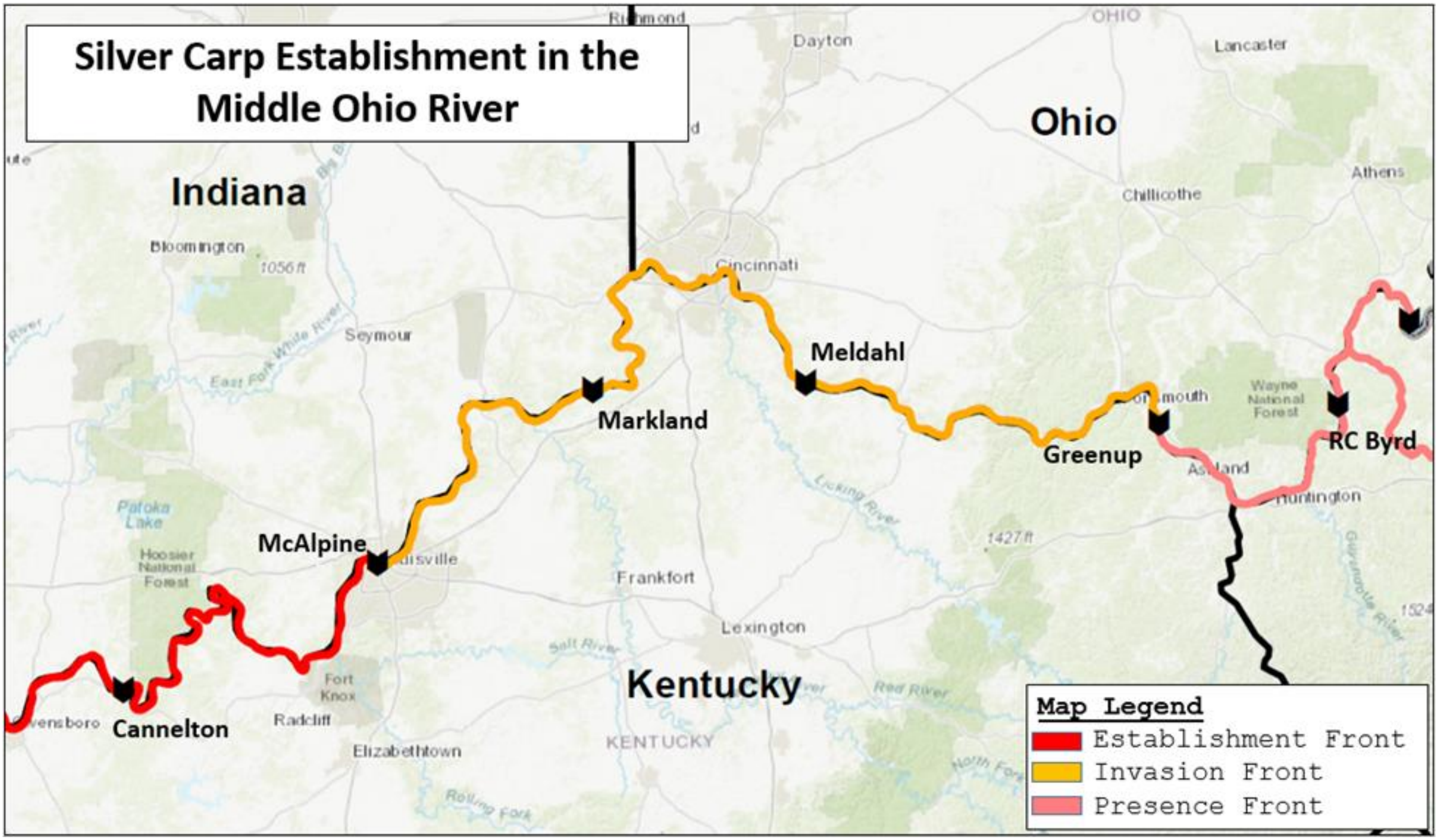


Figure 1. A map depicting the differing levels of Asian carp establishment in the middle Ohio River where targeted sampling and regular suppression is currently being conducted.

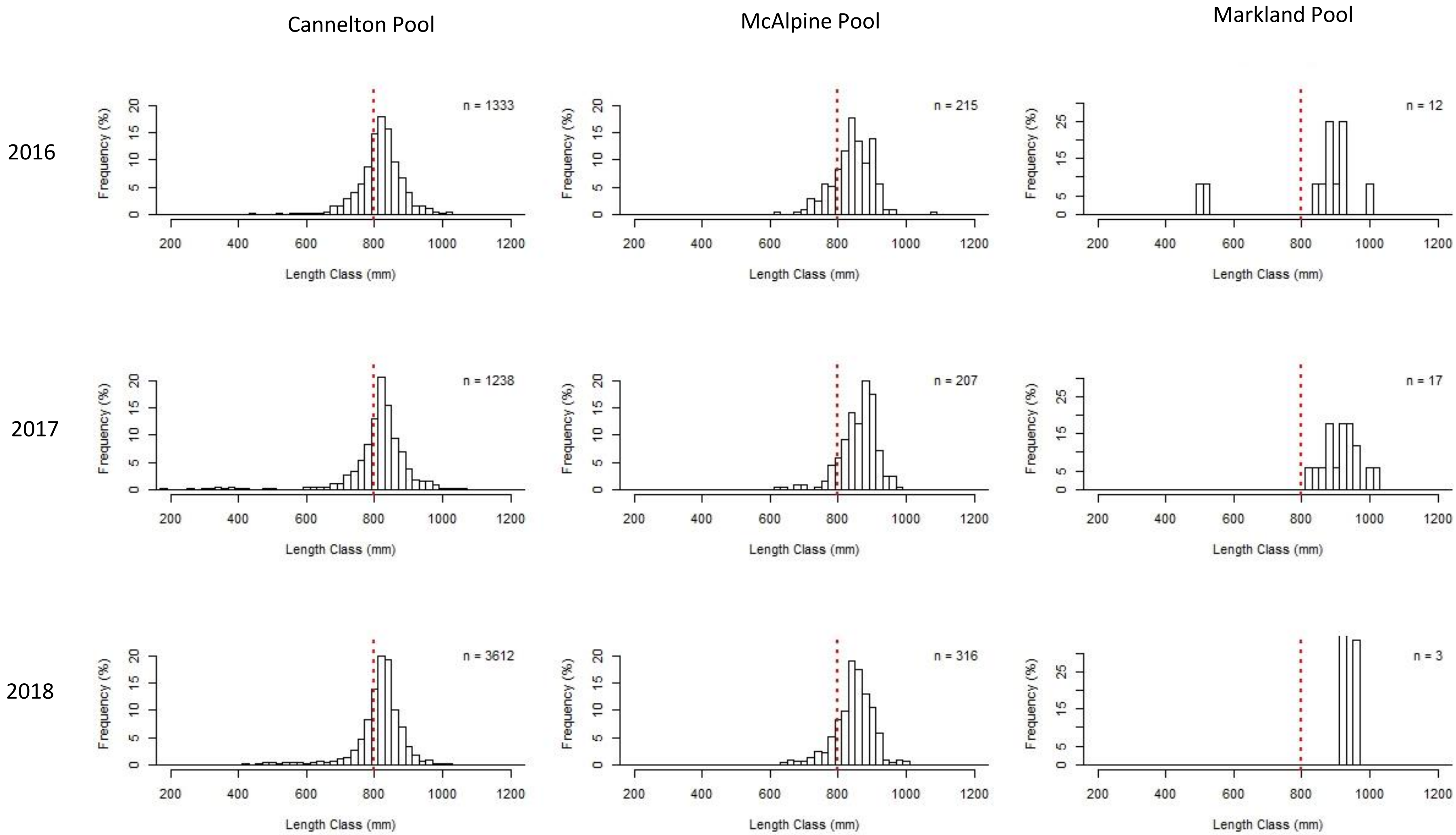


Figure 2. Length frequencies of silver carp captured during sampling efforts in 2016 – 2018. A line at 800mm highlights the change in length-classes from fish captured farther upriver with Cannelton being the farthest pool downstream and Markland the farthest pool upstream.

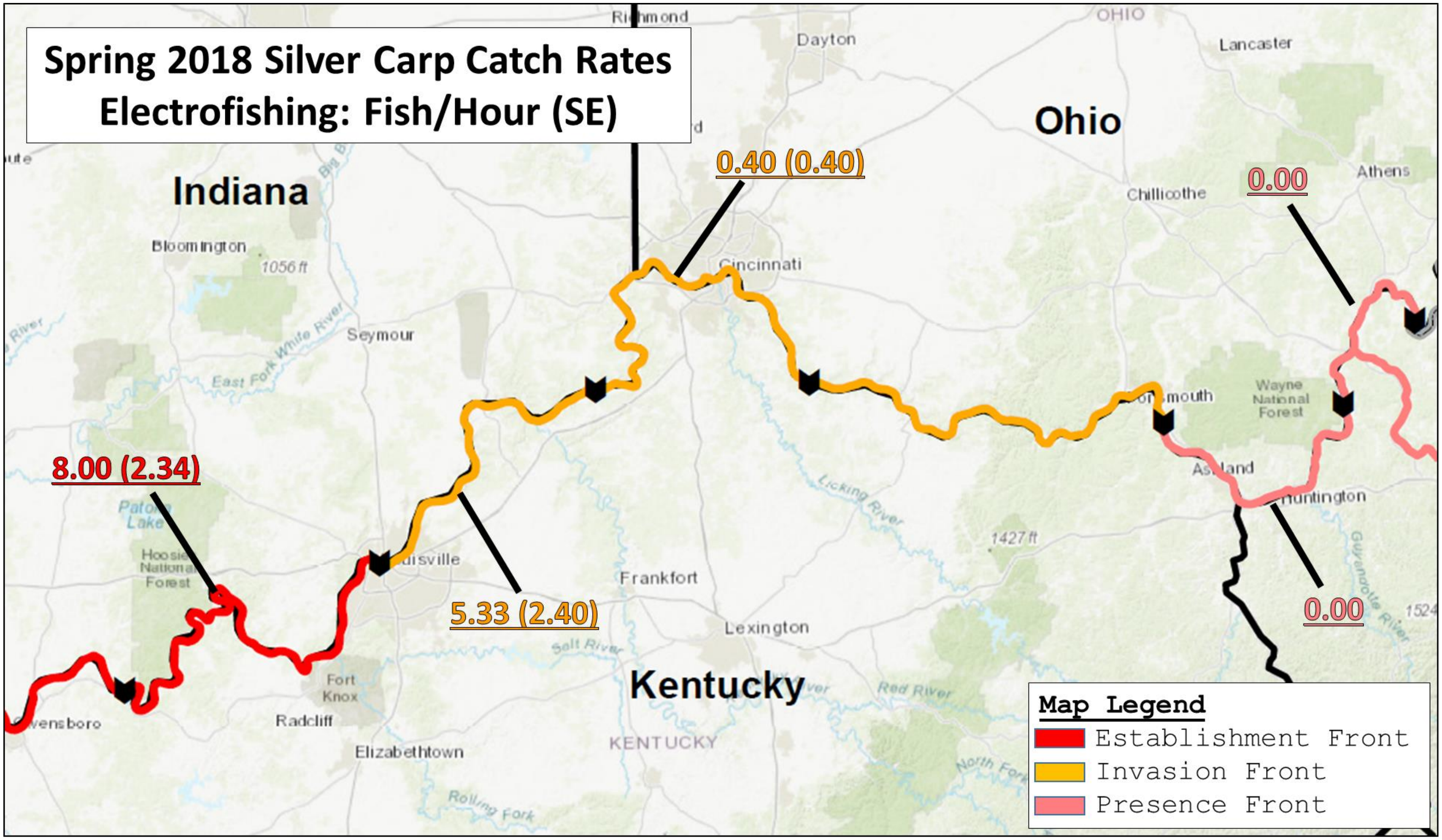


Figure 3. Mean Silver Carp catch rates in fish per hour by navigation pool using boat electrofishing during targeted sampling in 2018. Standard errors are in parenthesis.

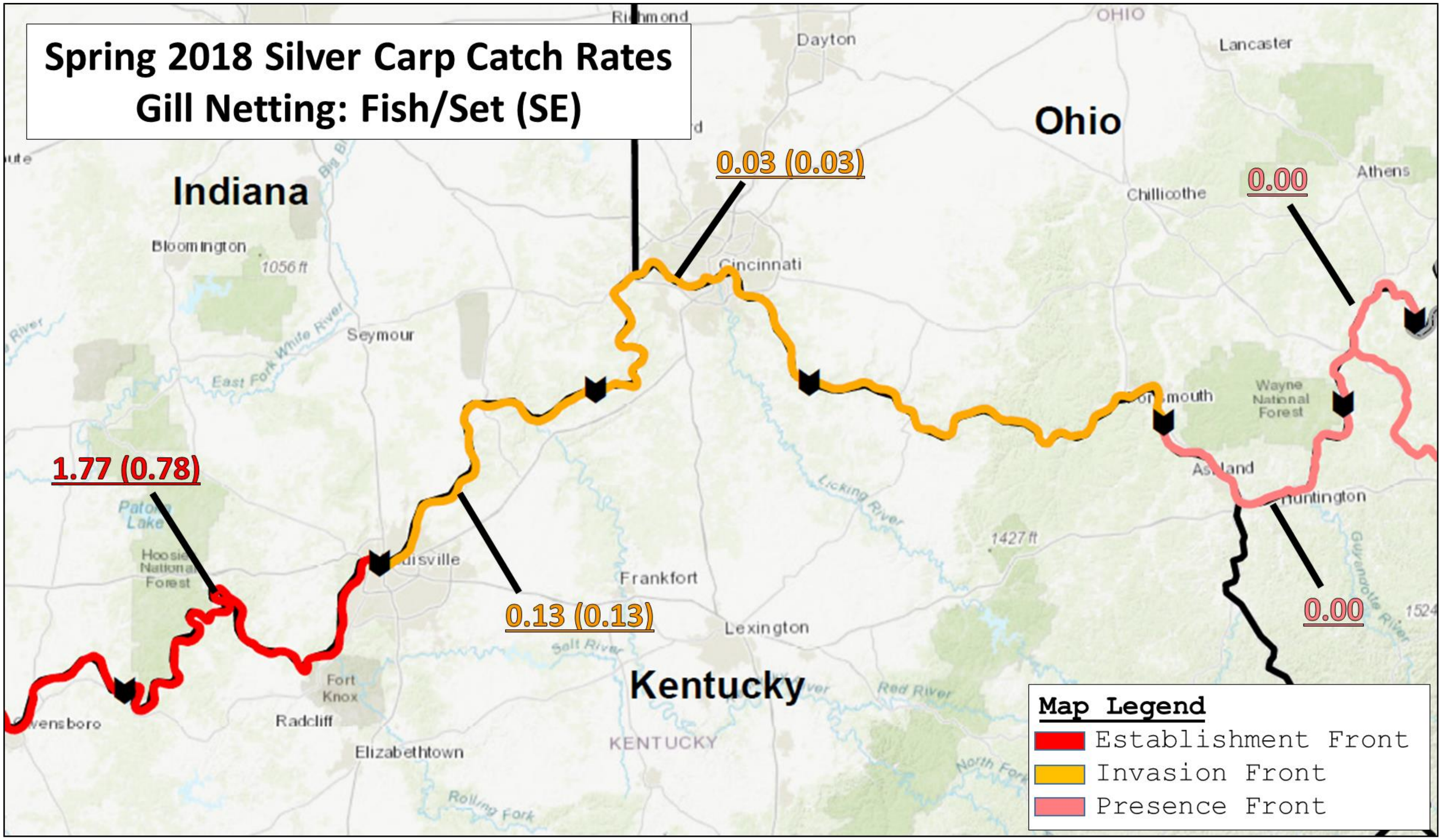


Figure 4. Mean Silver Carp catch rates in fish per net-set by navigation pool using gill netting during targeted sampling efforts in Spring 2018. Standard errors are in parenthesis.

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 2018.

Pool	Electro Hours (hr)	Bighead Carp (N)	Hybrid Bigheaded Carp (N)	Silver Carp (N)	Grass Carp (N)	Total (N)	Bighead Carp (kg)	Hybrid Bigheaded Carp (kg)	Silver Carp (kg)	Grass Carp (kg)	Total (kg)
Cannelton	53.70	16	16	3682	12	3726	218.40	108.80	21010.70	108.30	21446.20
McAlpine	18.75	1	5	330	0	336	13.65	34.00	1894.20	0.00	1941.85
Markland	6.00	0	0	3	2	5	0.00	0.00	17.20	17.00	34.20
Greenup	4.50	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
RC Byrd	3.85	0	0	0	2	2	0.00	0.00	0.00	24.00	24.00
Total	86.8	17	21	4015	16	4069	232.05	142.80	22922.10	149.30	23446.25

Table 2. Gill netting effort (meters) 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 2018.

Pool	Total Net Length (m)	Bighead Carp (N)	Hybrid Bigheaded Carp (N)	Silver Carp (N)	Grass Carp (N)	Total (N)	Bighead Carp (kg)	Hybrid Bigheaded Carp (kg)	Silver Carp (kg)	Grass Carp (kg)	Total (kg)
Cannelton	3109	37	2	454	1	494	404.67	39.00	2605.96	6.35	3055.98
McAlpine	366	0	0	1	1	2	0.00	0.00	5.74	12.90	18.64
Markland	1463	0	0	1	5	6	0.00	0.00	5.74	58.90	64.64
Greenup	457	0	0	0	0	0	0.00	0.00	0	0.00	0.00
RC Byrd	914	3	0	0	0	3	142.00	0.00	0	0.00	142.00
Total	6309	40	2	456	7	505	546.67	39.00	2617.44	78.15	3281.26

Table 3. A table indicating by-catch of species during 2018 sampling, excluding records from Community Monitoring samples taken during the fall season. Numbers indicate total catch (n) of fish species. Targeted carp species include Bighead Carp, Silver Carp, and Grass Carp.

	Cann	McAlp	Mark	Green	RCByrd	Total	Percent
TargetedCarpSpecies	389	2	6	0	2	399	60.3%
BigmouthBuffao	7	0	0	0	0	7	1.1%
BlackBuffalo	1	1	1	0	0	3	0.5%
BlueCatfish	22	0	2	2	0	26	3.9%
ChannelCatfish	0	0	0	2	0	2	0.3%
CommonCarp	4	2	17	0	3	26	3.9%
FlatheadCatfish	2	0	7	0	0	9	1.4%
FreshwaterDrum	8	1	1	0	2	12	1.8%
LongnoseGar	5	0	0	0	0	5	0.8%
Paddlefish	32	0	1	0	2	35	5.3%
RiverCarpsucker	2	0	2	0	0	4	0.6%
SmallmouthBuffalo	94	6	32	0	0	132	19.9%
StripedBass	1	0	0	1	0	2	0.3%
Total	567	12	69	5	9	662	

Ohio River Contingency Response Plan

Participating Agencies: KDFWR, WVDNR, INDNR

Introduction and Need:
This contingency plan is intended to develop response protocols for controlling and responding to changes in establishment status for populations of invasive bigheaded carps in the Ohio River Basin (ORB) among basin states and federal agencies. The plan utilizes the current information gathered about invasive carp populations in the middle Ohio River on the reproductive invasion front of Silver Carp and should be updated when substantial changes in status are observed. If no changes in status are observed, the plan should be reviewed every three years to ensure that it remains up to date and takes into consideration changes in policy or protocols implemented by the basin states.

In the event that a change in carp population status is detected, this document is intended to aid basin partners in determining the risk level of the change and help provide a structure for coordinated basin-wide responses. It is acknowledged that actions and responses contained in this document are intended to be recommendations to unite basin efforts to respond to changes in invasion statuses of bigheaded carps and in no way supersedes the authorities of individual state or federal jurisdictions.

Purpose:
The Ohio River Fisheries Management Team (ORFTM) developed a document in 2014 assessing the current status of Bighead and Silver Carp species in the Ohio River. This "Control Strategy Framework" was intended to outline actions the basin should take in order to control, prevent, monitor, and respond to changes in invasive carp expansion in the ORB. This document became the sub-basin's guide in establishing projects to monitor and control Asian carp populations under the greater, national framework: The Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States. The purpose of this document is to fulfil the sub-basin framework goal 2.1; that is to "develop a response plan for the Ohio River basin that identifies risk and return of actions when new information [on Asian carp] emerges." To fulfil this need, this plan must contain three things: 1. Identify pre-planned responses to changes in status, 2. Identify most appropriate actions, 3. Define a communication chain between partner groups and the public.

Background:
Currently, there are six projects being conducted in the Ohio River basin concerning Asian carp. In the Ohio River proper, projects include a population control project, an evaluation and early detection project, a project considering the abundance and distribution of early life stages, and a telemetry project aimed at quantifying dam passage and Asian carp movement. In addition, two other projects involving large tributaries (the Tennessee and Cumberland Rivers) of the Ohio River are intended to understand relative population densities and test Asian carp deterrent measures. These projects together have shaped the ORB's current knowledge on the status of Asian carp populations in the Ohio River.

Management and response protocols are best implemented over discrete units so that response actions remain organized and can be succinctly defined. The Ohio River is a large riverine system running 981 miles from the confluence of the Allegheny and Monongahela rivers in Pittsburgh, PA to its confluence with the Mississippi river near Cairo, IL. It flows directly through or along six basin states (PA, OH, WV, KY, IN, IL) and receives water from several large river systems that expand its watershed into nine additional states. The main stem itself has 20 dams that are managed by the U.S. Army Corps of Engineers which has altered the substrate and flow of the river for the purpose of navigation. With individual pools along the river acting much like flowing reservoirs, pools can to look very different in terms of their biological communities and geomorphology. In addition, dams can provide significant barriers to dispersal for invasive carp populations, relative to other natural or man-made deterrents; in recent years, telemetry efforts have shown limited movement of tagged fish across pool boundaries. Using this information, this document was written with invasion statuses, population life stages, and response actions broken down by pool as regular units of measure.

The invasion status of Bighead and Silver Carp can be broken into four different categories: Establishment front, Invasion front, Presence, and Non-present fronts. Each of these different categories is assigned using a body of evidence about the different life history stages seen from portions of the populations removed or reported in each pool. These fronts are not necessarily the same for each of the two *Hypophthalmichthys spp*. Thus, status changes and response actions must be considered separately for Bighead versus Silver Carp populations. Establishment status is assigned to those pools in which recruitment is verified or suspected. The most upriver pool contained within the Silver Carp establishment front is currently Cannelton pool, below the McAlpine Locks and Dam. The Silver Carp Invasion Front begins in the McAlpine pool and runs up until Greenup Locks and Dam. Fish in this section of river appear to be in numbers high enough to aggregate during annual spawning events and there is evidence of successful spawning in previous years but negligible recruitment. The Silver Carp Presence Front is defined as Greenup pool through RC Byrd pool and has only a few isolated instances of large, likely migrant, adult Silver Carp catches from high amounts of fishing effort.

With relatively little information on Bighead Carp in the middle portion of the basin, it is difficult to define differences in invasion status for populations within pools. To date, there have only been a handful of young-of-year Bighead Carp captured in the lower end of the river. In 2016, x-number of small Bighead Carp were captured amongst some YOY Silver Carp with a surface trawl in Hovey Lake, JT Myers pool. Thus the establishment front for Bighead Carp is a gap in knowledge for ORB partners and defining this range is currently an objective within the Early Life Stages project being led by INDNR. In 2017, several juvenile Bighead carp were captured in the Cannelton pool during regular population control efforts. Additional unverified reports of small (~ 350 – 400mm) Bighead Carp captured at the tailwater of Taylorsville Lake, Salt River, KY (a tributary of the Cannelton pool) indicate that Bighead may be recruiting in this section of the river. For this document's purposes, the current range for Bighead carp establishment is aligned with that of Silver Carp in the Cannelton pool. The invasion front for Bighead Carp is currently defined as the RC Byrd pool, but little data exists above this section of river that would allow for better resolution in status.

Status:

<u>Silver Carp</u>

- Newburgh pool and Below
    - Established
        - Adult and juvenile fish reported regularly
        - Large schools present and frequently seen
        - Evidence of successful spawning
        - Evidence of successful recruitment
- Cannelton pool
    - Established
        - Adults present in number and some juvenile fish captured
        - Large schools (Thousands of Fish) present and occasionally seen
        - Evidence of successful spawning
        - No firm evidence of YOY fish, but small juvenile fish have been captured (**fish** < 400mm)
- McAlpine pool
    - Invading

        - Adults present in number, with an occasional juvenile fish (400mm > **fish** < 650 mm)
        - Large aggregates (~ 100 – 1000 Fish) of fish confined to some specific sections of the river
        - Evidence of successful spawning
        - No evidence of successful recruitment
- Markland pool
    - Invading
        - Adults present
        - Small aggregations (~ 10 – 100 Fish) of fish confined to a few sections of river
        - No evidence of successful spawning, but successful spawning is likely
        - No evidence of successful recruitment
- Meldahl pool
    - Invading
        - Large adults present
        - No aggregations or schools ever reported, only solitary fish ever captured
        - Evidence of successful spawning for *Hypophthalmichthys* genus, but no evidence for Silver Carp
        - No evidence of successful recruitment
- Greenup pool
    - Present
        - Large adults have only been present in data occasionally
        - No aggregations or schools ever reported, only solitary fish ever captured
        - No evidence of successful spawning
        - No evidence of successful recruitment
- RC Byrd pool
    - Present
        - Two large adult reported from ODNR in 2016 and one in Kanawha River by WVDNR
        - No aggregations or schools ever reported
        - No evidence of successful spawning
        - No evidence of successful recruitment
- Racine and Above
    - Not Present
        - No reports of Silver Carp
        - No aggregations or schools ever reported
        - No evidence of successful spawning
        - No evidence of successful recruitment

<u>Bighead Carp</u>

- JT Myers and Below
    - Established
        - Adult and juvenile fish reported regularly
        - Occasional reports of several adult fish captured or conveyed together
        - Evidence of successful spawning
        - Evidence of successful recruitment
- Newburgh pool
    - Established
        - Adult and juvenile fish reported regularly
        - Occasional reports of several adult fish captured or conveyed together
        - Successful spawning unknown

        - Successful recruitment unknown
- Cannelton pool
    - Established
        - Adults reported regularly some juvenile reports and juvenile fish captures from 2017
        - Occasional records where several adult fish were captured together
        - Evidence of spawning with spawning patches visible in spring
        - No evidence of successful recruitment
- McAlpine pool
    - Invasion
        - Adults reported occasionally in some sections of the river
        - Occasional records where several adult fish were captured together
        - Evidence of spawning with spawning patches visible in spring
        - No evidence of successful recruitment
- Markland pool
    - Invasion
        - Adults captured occasionally in some sections of the river
        - Occasional records where several adult fish were captured together
        - Evidence of spawning with spawning patches visible in spring
        - No evidence of successful recruitment
- Meldahl pool
    - Invasion
        - Adults captured rarely in some sections of the river
        - Large adults have only been present in data occasionally, only solitary fish captured
        - Evidence of spawning with spawning patches visible in spring
        - No evidence of successful recruitment
- Greenup pool
    - Invasion
        - Adults rarely reported or captured
        - Large adults have only been present in data occasionally, only solitary fish captured
        - No evidence of successful spawning
        - No evidence of successful recruitment
- RC Byrd pool
    - Invasion
        - Large adults regularly reported or captured
        - Large adults captured annually in ONE section of the lower end of this pool
        - No evidence of successful spawning
        - No evidence of successful recruitment
- Racine and Above
    - Present
        - Adults reported occasionally with some telemetry data on fish movement into and above Racine
        - Adults rarely reported or captured
        - No evidence of successful spawning
        - No evidence of successful recruitment

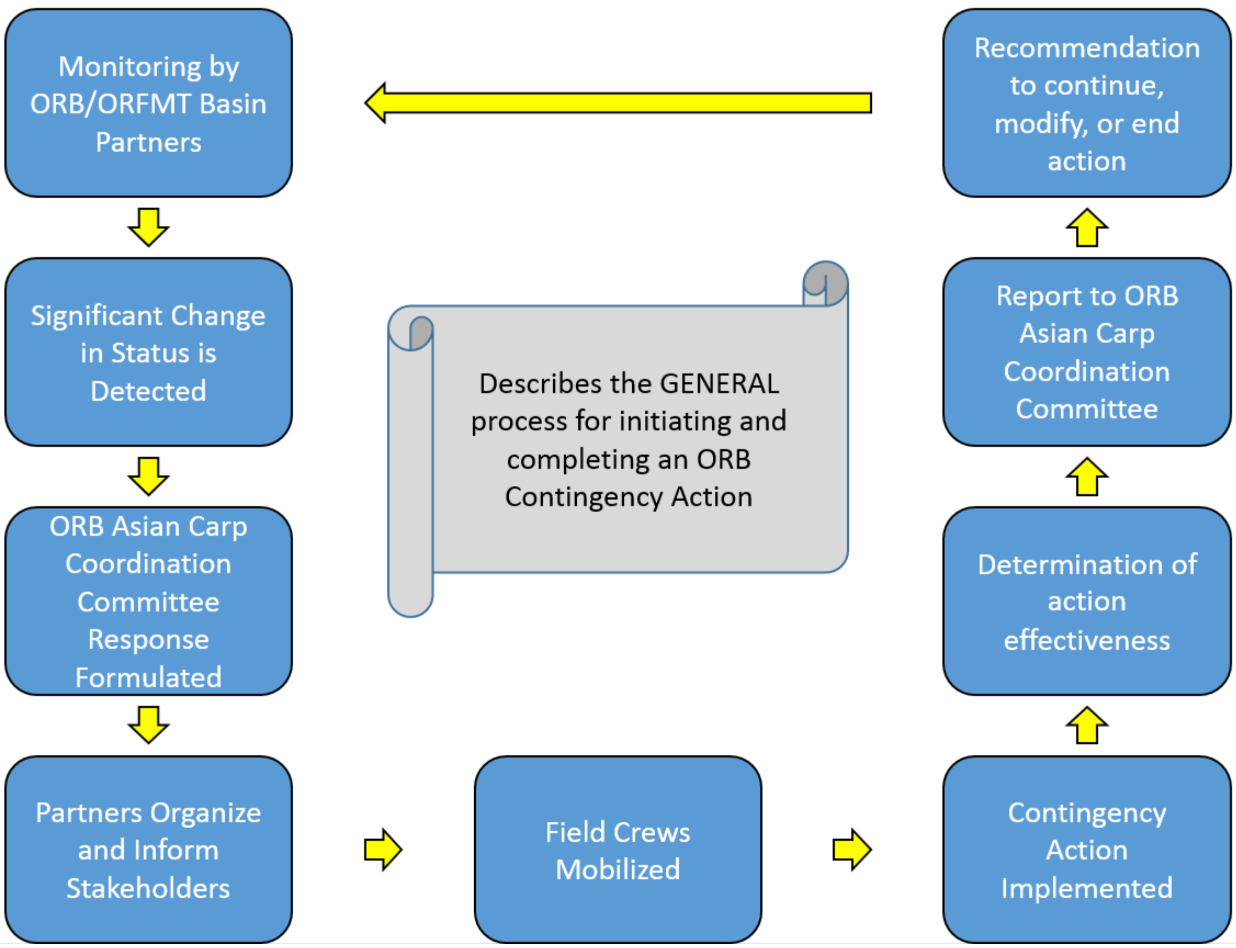
Planning Assumptions and Constraints:

These planning assumptions attempt to anticipate realistic situation, conditions, and possible constraints for partner groups:

Situational Assumptions

- Response to changes in status are important from a basin wide perspective and actions will need participation from all partner groups in order to have the best chance of success.
- Response actions will be discussed as a basin and decisions will be made based on conditions, timing, geographic location, and take into consideration comments from all participating stakeholders.
- Response actions will take place in the Ohio River and contiguous waters
- This plan currently includes contingencies for Bighead and Silver Carp… future invasive carp species may be added to this framework but currently all actions are intended as a response to changes in status of *Hypophthalmichthys spp*.

Chain of Command



Logistics and Resource Assumptions

Decision Matrices:

Silver Carp	Pool	Eggs/Larvae			Small Fish (< 450mm)			Large Fish		
		Rare	Common	Abundant	Rare	Common	Abundant	Rare	Common	Abundant
Direction of Flow	Montgomery Isl									
	New Cumberland									
	Pike Island									
	Hannibal									
	Willow Island									
	Belleville									
	Racine									
	RC Byrd									
	Greenup									
	Meldahl									
	Markland									
	McAlpine									
	Cannelton									
	Newburgh									
	JT Myers									
	Smithland									

Bighead Carp	Pool	Eggs/Larvae			Small Fish (< 450mm)			Large Fish		
		Rare	Common	Abundant	Rare	Common	Abundant	Rare	Common	Abundant
Direction of Flow	Montgomery Isl									
	New Cumberland									
	Pike Island									
	Hannibal									
	Willow Island									
	Belleville									
	Racine									
	RC Byrd									
	Greenup									
	Meldahl	?	?							
	Markland	?	?	?						
	McAlpine	?	?	?						
	Cannelton			?						
	Newburgh									
	JT Myers									
	Smithland									

Response Action Matrix

Urgency Level	Potential Actions	Applicable Locations	Responsible Partners	Estimated Implementation Time	Regulatory or Other Requirements	Relative Cost
Significant Change	Coordinated Rapid Response	All	KDFWR, USFWS	1 day	Unknown	$
	Agency Control Efforts Shifted	All	INDNR, KDFWR, WVDNR	7 days	Sampling Permits; ORB Coordination	$
	Increased Monitoring Effort	All	INDNR, KDFWR, WVDNR, PFBC	14 days	Sampling Permits	$
	Strategic Public Outreach	All	All Agencies	30 days	Unknown	$
	Implementation of Contract Fishing	IN, KY Waters	INDNR, KDFWR	Months	ORB Coordination	$$
	Use of toxicants/chemicals	Non-sensitive Areas	All Agencies	Unknown	Federal and State Regulations	$$$
	Implementation of Barrier	Unknown	All State Agencies, USGS	Years	Unknown	$$$$
Moderate Change	Coordinated Rapid Response	All	KDFWR	1 day	Unknown	$
	Agency Control Efforts Shifted	All	INDNR, KDFWR, WVDNR	7 days	Sampling Permits; ORB Coordination	$
	Increased Monitoring Effort	All	INDNR, KDFWR, WVDNR, PFBC	14 days	Sampling Permits	$
	Strategic Public Outreach	All	All Agencies	30 days	Unknown	$
No Change	Maintain Current Level of Effort	N/A	All	Ongoing through 2021	N/A	$

Abundance and distribution of early life stages of Asian carp in the Ohio River (Assembled by Craig Jansen, INDNR)

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.

Confirmed Asian carp spawning events have been reported in tributaries (i.e. Wabash River) and 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 Meldahl Pool. Successful reproduction of *Hypophthalmichthys* spp. was detected at river mile (RM) 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 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 sampling prior to 2018 determined the extent of recruitment as below Cannelton Lock and Dam, with the majority of young-of-year (YOY) and Juvenile detections below Newburgh Lock and Dam in J.T. Myers Pool (Jansen and Stump 2017, Roth 2018). 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. Determine the extent of Asian carp spawning activity in the Ohio River via sampling for Asian carp eggs, embryos, and larvae.
2. Determine the extent of Asian carp recruitment 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.

Project Highlights:

- As of 2016, Asian carp (*Hypophthalmichthys* spp.) larvae were collected at river mile 405.7 (Meldahl Pool).
- Six sites from RM 546 to RM 773 were sampled via ichthyoplankton tows weekly from late-May through July; Asian carp "type" larvae were collected at all six sites.
- Six sites from RM 497 to RM 260 were not able to be sampled via ichthyoplankton tows in 2018.
- Targeted electrofishing efforts were reduced and refined from previous years to target a few suspected recruitment areas in each pool.
- Sampling in 2018 detected the most upstream juvenile Silver Carp in Newburgh Pool (RM 750).
- Majority of recruitment remains in J.T. Myers Pool, although previous sampling suggests limited recruitment in Cannelton and Newburgh Pools.
- 197 Asian carp were collected for a total of 591 pounds of fish removed.

Methods:

For analysis purposes and for the remainder of this report, both "YOY" and "immature" are collectively referring to "juvenile" Asian carp; "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 more incorporated during the 2018 sampling season to provide an updated delineation of the spawning extent from what EA engineering documented in 2015 and 2016. Ichthyoplankton sampling was conducted weekly at six sites within Newburgh (N=2), Cannelton (N=2), and McAlpine (N=2) Pools from late-May through July. 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. Four tows were conducted during each sampling event at a site; one tow either at the intake structure or within the tributary, and one tow at each the right-descending, middle, and left-descending portions of the Ohio River. 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 seven sites within J.T. Myers (N = 2), Newburgh (N = 1), Cannelton (N = 2), and McAlpine (N = 2) Pools from June to August, 2018. The surface trawl was 3.7 m wide, 0.6 m tall, and 5.2 m deep with 16 mm bar mesh. The last eight feet of the purse had an additional layer of 4.8 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 30.5 cm tall, 61.0 cm long, and each had a 12.7 cm diameter, 27.9 cm long "buoy style" PVC float 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 23rd to August 22nd, 2018. 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 allocate more effort towards larval sampling, the number of sites was reduced from 2017 to only include those locations with the greatest likelihood of producing juvenile Asian carp. 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, only transects shorter than 15 minutes were possible. Specific electrofishing settings were 80 pulses per second at 40% duty cycle, and volts were adjusted based on water conductivity to achieve standard power goals and maximize Asian carp collection. 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. Lapilli otoliths were removed from fish under 600 mm 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 to 2018 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 ($N = 21$) to those locations without ($N = 347$). 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 120, three-minute ichthyoplankton tows were conducted by KDFWR at Mill Creek Plant, Clifty Creek Plant, and Kentucky River sites. Additionally, 108 tows were conducted by INDNR at FB Cully Plant, Anderson River, and Clover Creek sites (Figure 1). A total of 3008 larval fish were collected, the majority of which were unidentified Asian carp (N = 1407; Silver Carp, Bighead Carp, or Grass Carp), Freshwater Drum (N = 771), Gizzard Shad (N = 386), and unidentified cyprinids (N = 227). In addition, eight unidentified eggs were collected. Asian carp were unable to be identified to species. The total number of larvae and Asian carp "type" larvae generally decreased farther upstream, however the proportion of Asian carp "type" larvae was highest in McAlpine Pool (Table 1). In addition, spikes in discharge were typically noticed around the same time as increases in Asian carp "type" larvae in the weekly samples (Figure 2).

Surface trawl:

A total of 24 trawl runs were conducted across seven sites in 2018, totaling 1.93 hours of sampling effort. Catch included 213 YOY *Hypophthalmichthys* spp., all of which were captured in either Hovey Lake (N = 70) or Hovey Lake Drain (142) except for one YOY Silver Carp captured in a borrow pit within Newburgh Pool. The majority of YOY fish were captured in late-June during trial runs of the gear at Hovey Lake Drain; individuals during this time ranged from 14 to 36 mm total length and could only be confidently identified to genus.

Electrofishing:

Electrofishing was conducted at 15 sites; 4 sites were sampled in J.T. Myers Pool, 5 in Newburgh Pool, 3 in Cannelton Pool, and 3 in McAlpine Pool for a total of 2.25, 2.50, 2.50, and 2.08 hours of electrofishing per pool, respectively (Figure 1). A total of 9.33 hours of electrofishing effort were expended. All but one site was sampled twice with at least two weeks between sampling dates; six sites were large enough for multiple transects (left bank/right bank, upper/lower).

Young-of-year Silver Carp were only captured in the lower portion of J.T. Myers Pool at Hovey Lake; eight were captured, ranging in length from 47 to 56 mm. Mean YOY CPUE (fish/hour ± SE) in Hovey Lake was 10.6 ± 3.6. Immature Silver Carp were not captured at any location. A total of 118 adult Silver Carp were collected; one Grass Carp and zero Bighead Carp were captured. Overall catch rates of adult fish were highest in Cannelton Pool (18.0 fish/hour) followed by McAlpine (12.5 fish/hour), Newburgh (12 fish/hour), and JT Myers Pools (7.6 fish/hour).

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 (84.0°F) than those without (79.8°F); $t(22) = 3.77$, $p < 0.001$. Secchi visibility was significantly lower in sites where Asian carp were captured (13.5 in) than those without (17.7 in); $t(24) = -2.58$, $p = 0.008$. Similarly, conductivity was lower in sites with Asian carp (382.1 µS) than those without (464.3 µS), $t(27) = -2.73$, $p = 0.006$. Depths were lower in sites with juvenile Asian carp (max depth: 8.6 ft, avg. depth: 5.2 ft) than sites without (max depth: 12.8 ft ± 0.4, avg. depth: 7.8 ft). 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 $\chi^2(6, N = 364) = 6.47$, $p = 0.373$, presence of woody debris $\chi^2(1, N = 367) = 0.433$, $p = 0.101$, or presence of aquatic vegetation $\chi^2(1, N = 363) = 0.566$, $p = 0.452$.

Discussion:

Results of the third 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. The collective efforts of targeted electrofishing, surface trawls, and ichthyoplankton tows 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* spp., 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 a more thorough ichthyoplankton sampling design to this project in 2018, we hoped to provide the most up-to-date delineation of the extent of Asian carp spawning within the Ohio River. However, due to unforeseen circumstances, the six most upstream sites were unable to be sampled via ichthyoplankton tows. Based off of previous larval data, the upper extent of spawning was presumed to occur somewhere across the gradient of these upstream sampling sites (from RM 497 to RM 260). Therefore it is paramount that these sites be sampled in the near future to accurately define the extent of Asian carp spawning in the Ohio River to inform ongoing projects and prospective management strategies.

Between 37.8% to 69.4% of all larvae captured at six sites in 2018 were identified as Asian carp "type" larvae. The fish were only able to be confidently identified to the family level, meaning that there is a possibility that they could be either Grass Carp, Bighead Carp, or Silver Carp (Black Carp would also be in the same family but hasn't been found in those pools of the Ohio River). We suspect that many of these Asian carp "type" larvae are in fact Silver or Bighead Carp due to these sites being downstream of the areas where *Hypophthalmichthys* spp. were collected in 2015 and 2016. Interestingly, rising water levels were correlated with peaks in Asian carp larvae collected, highlighting the prolonged spawning season of these fish. Throughout the extent of sampling, water temperatures ranged between 68.6 and 85.1 for the Ohio River, which suggests larvae will hatch approximately 20 to 35 hours after a spawning event (Murphy and Jackson 2013). Using this knowledge, managers should target larval sampling during increased flows following a rain event to more efficiently capture Asian carp and further pinpoint specific spawning locations.

As recommended in the 2017 technical report and to address Strategy 2.3 of the basin framework, 2018 sampling was conducted to monitor the extent of Asian carp spawning and recruitment across years and environmental conditions. Results of 2018 sampling largely support the extent of recruitment we defined in 2016 and 2017, with the majority of juvenile carp again 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 collection of several juvenile Asian carp (269-399mm TL) in Cannelton Pool during multiple 2017 Basin Framework projects (Early Life Stages, Monitoring, Removal) suggests the extent of recruitment to be above Cannelton Lock and Dam. Although no juvenile Asian carp were captured in or upstream of Cannelton Pool during 2018 Ohio River Basin Framework projects, it appears that Cannelton Pool provides several areas suitable for Asian carp recruitment and therefore should still be considered the upstream extent of recruitment. There has not been a strong spawning event or year-class since this project was initiated in 2016. Based on the apparent Asian carp spawning in McAlpine Pool, as highlighted by ichthyoplankton data, a highly successful spawning event could quickly shift the current known extent of recruitment to pools farther upstream. Therefore, 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.

The additional utilization of a surface trawl demonstrated its value as an efficient tool for sampling juvenile Asian carp. The surface trawl effectively samples smaller size Asian carp (as small as 14 mm) which allows managers to begin targeted sampling earlier in the season. The small size of trawl allows maneuverability in many of the smaller tributaries of the Ohio River. A multi-gear approach will provide a more accurate picture of Asian carp spawning and recruitment in the Ohio River.

As in previous years, the 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 relatively stable, we suspect recruitment within Cannelton Pool might be occurring more often than our limited sampling is detecting. Therefore, we suggest electrofishing and surface trawling efforts should be consolidated to focus on determining the recruitment potential of Cannelton Pool. A more thorough, multi-gear approach in Cannelton Pool sites where juveniles have been captured or where abiotic factors may promote recruitment is needed. This will allow us to continue to monitor recruitment, upriver of areas that recruitment appears to be consistent and stable (JT Myers Pool).

As our ichthyoplankton sampling was limited in 2018, there is still a lack of information of the true extent of spawning in the Ohio River. We recommend completing weekly ichthyoplankton tows in 2019 at the six upstream sites that were missed in 2018 to determine the extent of spawning. Also, we recommend conducting targeted ichthyoplankton tows following rain events (and subsequent river rises) in tributaries of Newburgh, Cannelton, and McAlpine Pools where Asian carp spawning is suspected to begin identifying specific spawning locations. In addition to these effort, we highly recommend that techniques are utilized to confidently identify larval fish to at least the genus level to rule out the possibility of Grass Carp falsely inflating our estimated extent of spawning *Hypophthalmichthys* species. We recommend working with Whitney Genetics Lab to utilize eDNA and other techniques to confirm the presence of *Hypophthalmichthys* spp. larvae in ichthyoplankton samples. In addition, we suggest field staff from various agencies be trained on larval fish identification to aid in the processing of samples.

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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Table 1. Number of total larvae and Asian carp "type" larvae collected at each Ohio River sampling site from 5/21/18 to 7/23/18.

Sample Site	River Mile	Larvae Sampled (N)	AC-type Larvae (N)	% AC-type
FB Cully Plant	773	884	334	37.8%
Anderson River	731	560	258	46.1%
Clover Creek	711	522	266	51.0%
Mill Creek Plant	626	684	311	45.5%
Clifty Creek Plant	560	193	134	69.4%
Kentucky River	546	165	104	63.0%

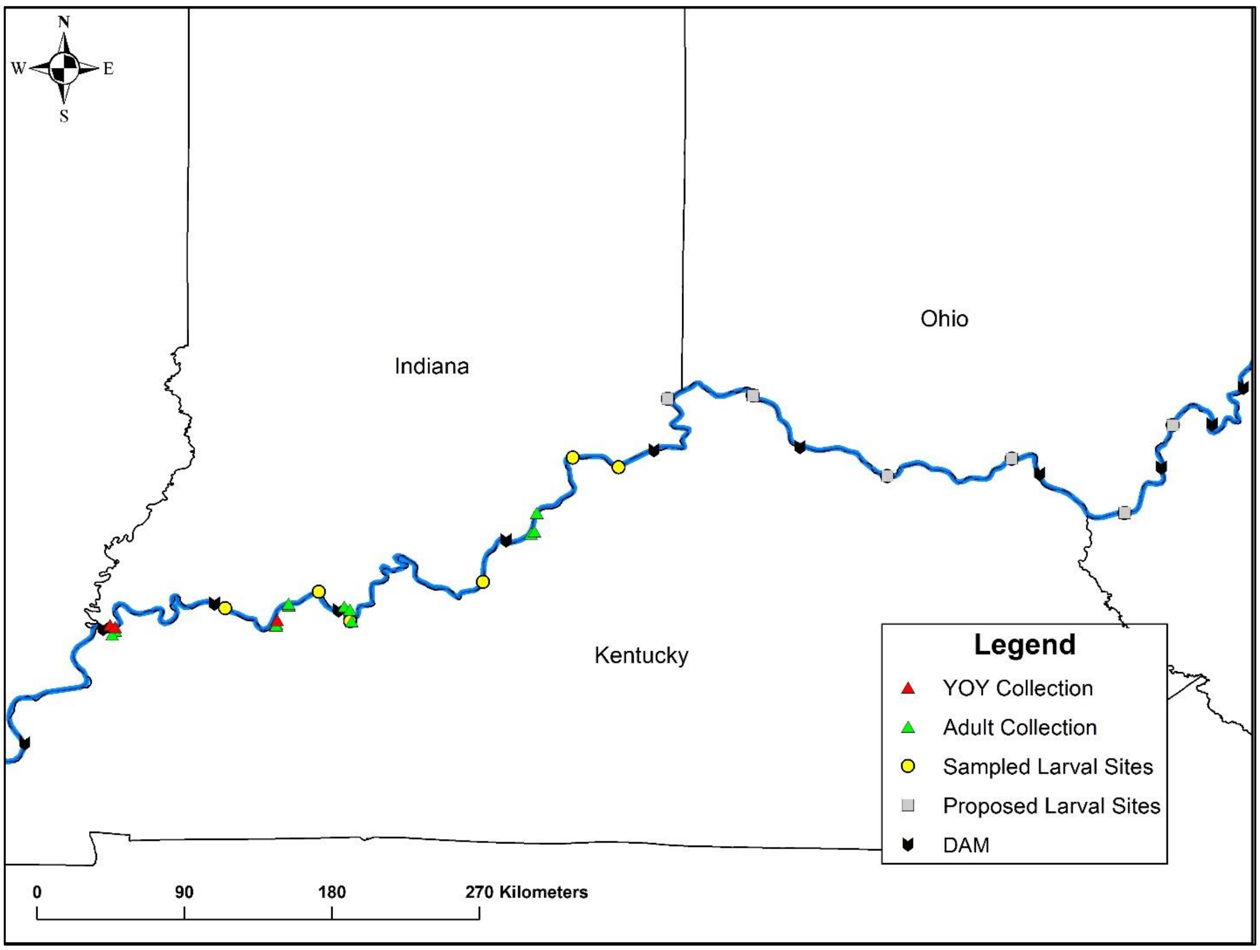


Figure 1. Map of electrofishing, trawling, and larval sites among eight pools of the Ohio River (J.T. Myers, Newburgh, Cannelton, McAlpine, Markland, Meldahl, Greenup, RC Byrd). Red triangles = young-of-year Asian carp collection sites, green triangles = adult only Asian carp collection sites, yellow circles = larval sites that were sampled, grey squares = proposed larval sites that were unable to be sampled.

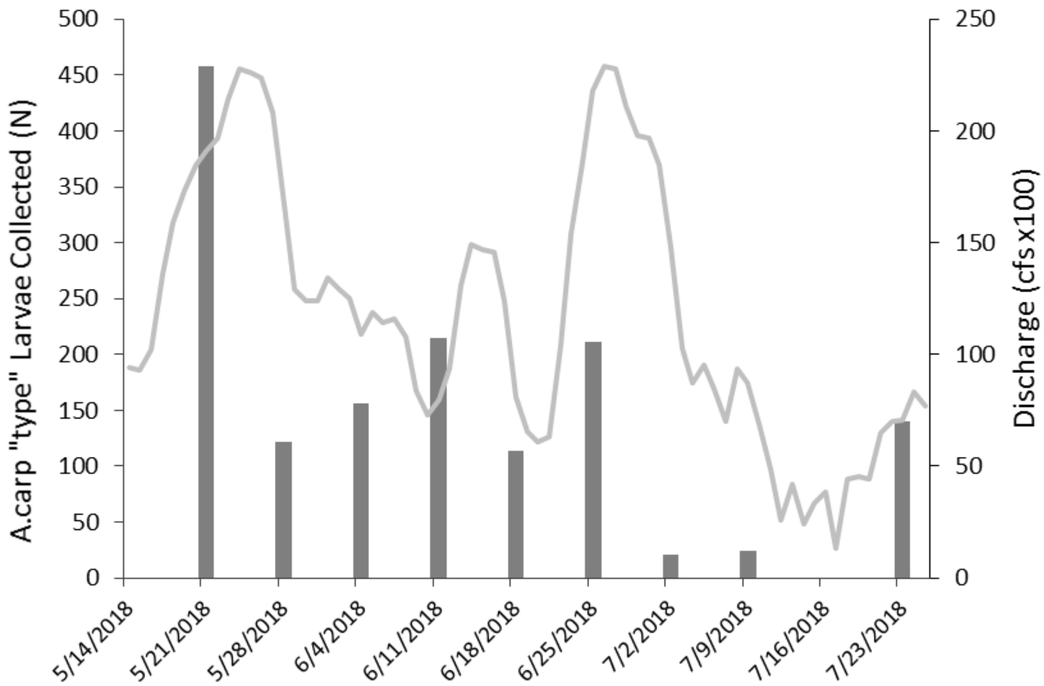


Figure 2. Total number of Asian carp "type" larvae collected weekly at six downstream sites (RM 546 to RM 773) overlaid with mean daily discharge at Cannelton L&D during the sampling timeframe.

Telemetry of Asian Carp in the Ohio River

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

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 circumstances in the lower ORB, there are pools in the middle and upper Ohio River that still lack any self-sustaining populations of Asian Carp. This situation prompted several state and federal agencies to make a cooperative effort towards preventing the Asian Carp from becoming established in specific areas of the upper Ohio River Basin. This collaboration gained additional support from the Great Lakes and Mississippi River Interbasin Study (GLMRIS) that identified some previously unknown connections between the upper ORB and the Great Lakes. The identification of these connections was an important step towards eliminating any alternative pathways that Asian Carp could use to access the Great Lakes, which is the only way to prevent the invasive species from causing irreparable damage to the important commercial and recreational fisheries located within these water bodies.

Fish and Wildlife agencies from neighboring states initially responded to this threat by developing a telemetry study to learn as much as possible about the Asian Carp populations that are trying to make their way into the upper Ohio River Basin. When it began in 2013, this Telemetry Project was one of the first multi-agency efforts that was dedicated towards researching Asian Carp that reside primarily within the mainstem Ohio River. This project uses ultrasonic acoustic telemetry to identify the distribution and movement of the Bighead and Silver carp that currently inhabit the middle Ohio River. Along with its primary objective of identifying the pathways that Asian Carp are using to disperse upriver, this project also attempts to study their movements on a finer scale in order to provide guidance to the ongoing efforts to remove Asian Carp from the high density populations that reside within the middle Ohio River.

As of 2018, the primary objectives for the Ohio River Asian Carp Telemetry Project 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.
5. Estimate probability of survival

Methods

Establishment of the Receiver Array:

A primary component of the Asian Carp Telemetry Project is a relatively large (~500 miles) telemetry array that started taking shape in 2013 with the initial deployment of 60 VEMCO (model VR2W) ultrasonic receivers. Over the next several years, the array expanded as field crews continued to populate adjacent pools with new receiver stations. The KDFWR, USFWS and ODOW have ultimately been responsible for maintaining most of the receiver stations that have been established for the project in 2013-2018.

The new sites established in 2017 and 2018 were often located in areas of the array where existing receiver coverage was lacking, but they still had to include the habitat types that were essential to accomplishing the project's objectives. The three most common types of receiver sites that are required by the Telemetry Project's current objectives are 1) the mainstem of the Ohio River, 2) the larger tributaries suitable for Asian Carp, and 3) the lock chambers/approaches of Lock & Dam (L&D) facilities located within the array. Most of the sites in the mainstem river were established by using 10'-12' steel rods to securely hang receivers to navigational buoys, private/public boat docks and a fishing pier. Because most of the tributaries within the array don't have navigational buoys, the VR2W's associated with these sites were either attached to existing structures (i.e. bridge piers and docks) or secured to metal stands that were deployed to the creek/river bottom. At all L&D sites, receivers were protected by metal sleeves and then lowered into ladder-wells located in the lock chambers and along their approach walls.

As was done previously, those receivers deployed to tributary and L&D sites were allowed to remain active for the entire year in order to continuously record any detections of tagged AC that move within range. However, because of the inherent volatility of the Ohio River, the more vulnerable mainstem receivers were retrieved from the buoys during mid-December 2017 and then replaced in the spring when water levels were conducive. During previous years of the project, the efforts to redeploy the mainstem receivers were typically underway by March or April of the following spring. However, an extremely wet spring in 2018 caused larger systems like the Ohio River to experience some of the highest water levels in over 20 years. When conditions finally improved, the US Coast Guard began to replace all of the missing navigational buoys located throughout the Ohio River Basin, and then by mid-June, KDFWR biologists were able to redeploy the last of the over-wintering receivers to their respective mainstem sites.

In 2013 – 2017, the successful redeployment of over-wintering receivers was typically followed by efforts to establish new sites, which included the extensive effort in 2017 to improve receiver coverage in many tributaries and the upstream approaches of several L&D facilities. However, at the start of 2018, the receiver coverage was considered adequate, so aside from the establishment of new sites at a few key locations, the primary focus of each agency during summer 2018 was to maintain all existing receivers and to complete the efforts to offload any new detections on a monthly basis. For KDFWR field crews in 2018, this included maintaining and offloading telemetry data from 30+ sites established in their section of the receiver array that stretches out over the Cannelton, McAlpine and lower Markland pools of the Ohio River. Since 2017, local crews have also become responsible for obtaining data from the temperature (temp) loggers that were deployed along with receivers that already occupied the upstream sites of the larger tributaries within the array. These loggers are being used to record additional data that could help determine if a tributary's water temperature has any influence on the behavior of Asian Carp.

Implanting Ultrasonic Transmitters

During the late summer and early fall of 2018, biologists with the USFWS, KDFWR and INDNR worked together on several occasions in order to sample Bigheads and/or Silver Carp using a combination of pulsed DC electrofishing. All Asian Carp collected during these efforts were surgically implanted with ultrasonic transmitters. Similar to 2017, most tagging completed during 2018 focused on collecting carp from the lower density populations that reside in the Markland and Meldahl pools. These efforts were necessary to replace the initial group of Asian Carp (n=19) implanted with transmitters during 2013 that were scheduled to run out of power in summer 2018 after reaching the end of their 5-year battery life. The next scheduled shutdown involves an even larger group (n = ~140) of Asian Carp from McAlpine, Markland and Meldahl, which will reach a similar fate during the summer and fall of 2019.

When a healthy Bighead or Silver Carp is captured, a surgical procedure outlined by Summerfelt et al. (1990) is followed in order to implant a VEMCO (model V16-6H) ultrasonic transmitter into the carp's abdominal cavity using an incision (~2" long) that was made posterior to its pelvic fin and anterior to its anus. After a transmitter is carefully implanted into the fish, the incision is closed using 3 - 4 simple interrupted sutures. Upon closure of the incision, specific details about the surgical procedure (i.e. location, crew, transmitter ID #) are recorded along with the length, weight and sex of the fish. Finally, the tagged carp is always released within a mile of its sampling location after being externally marked with an aluminum jaw tag (5/8" wide) bearing a unique ID number that allows for quick identification if the fish happens to be recaptured.

The VEMCO model V16-6H transmitters (.625" diameter & 3¾" long) have been in use during each year of the project from 2013 to 2018, which insures that a tagged AC will always be compatible with the receivers 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. As mentioned previously, these transmitters have an above-average battery life of 5 years, which was the result of using a high-capacity lithium battery without adding extra sensors (i.e. temperature or pressure). For standardization, all transmitters are programmed to shut down upon reaching the end of their 5-year life span, which should occur regardless of any remaining battery power.

Data Collection, Management & Analysis

With the array nearly doubling in size over the past several years, the KDFWR, USFWS and ODOW have worked together to develop a more efficient protocol for maintaining receiver stations and offloading the new data at regular intervals. Since 2016, project biologists have utilized a method that required the array to be divided into 2-3 sections. The first section includes a 170-mile stretch of the river located at the downstream end of the array and it consists of Cannelton, McAlpine, and the first half of the Markland Pool. In 2017 and 2018, KDFWR's project biologist accepted responsibility for as many as 40 receiver sites located throughout this entire 170-mile stretch of the array. The second and sometimes third section of the array cover 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 stretch of the Ohio River.

As previously noted, most receiver work completed by participating agencies (KDFWR, USFWS & ODOW) between June and December 2018 was comprised of monthly efforts to offload new data from any of the VR2W's found in the different 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 agencies via a file transfer protocol (FTP) site. The download and compilation of new detections were completed regularly throughout 2018 to ensure that all parties had access to a database that was as up-to-date as 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 needs to be regularly 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 2018. In order to accomplish this task, KDFWR's project biologist regularly downloaded new telemetry datasets from the 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 detections of tagged Asian Carp and then subsequently imported into the telemetry database. This database eventually contained all 2018 project data, including the total detections, details from each tagged carp and the locations of all active receiver stations.

On multiple occasions in 2018, the telemetry database was reduced in order to create two separate datasets that contained detailed information about carp detections on an hourly or daily time scale. These more manageable datasets could be analyzed using a simple spreadsheet program that could keep track of tagged AC movements on a broader scale (i.e. pool transfers) and over longer time periods (i.e. weeks & months). However, when the complete database (~7.9 mil. detections in 2018) was required, KDFWR's project biologist often analyzed it using R statistics that was loaded with VTrack (v1.11), which is a collection of scripts that enhances the software's ability to manage large telemetry datasets. Finally, ArcMap (v10.5) software was also used to create maps for the annual reports and to complete any other GIS work that was required by the Telemetry Project.

Results and Discussion

Establishment of Project's Receiver Array

In 2018, the project's 500-mile telemetry array consisted of 131 receivers that were distributed over a combination of mainstem, tributary and L&D sites, which are crucial to the project's ongoing efforts to monitor the movements of tagged AC throughout 9 different pools of the Ohio River (Figure 1). Even though poor conditions in late March 2018 led to an initial delay in their redeployment efforts, the KDFWR was ultimately forced to hold onto the overwintering VR2W's for another 2+ months as conditions failed to improve after several weeks of continuous spring rainfall. Some areas of the Ohio River Basin reacted to the spring rainfall totals by producing river levels that were the highest they've been over 20 years. However, once crews were able to access the river again, they encountered additional issues (i.e. missing buoys) that continued to delay the redeployment efforts until the last few overwintering VR2W's could be returned to their mainstem sites in mid-June 2018.

The higher water levels during spring 2018 also led to the loss of many receivers that had remained in the Ohio River throughout the winter. While some areas of the array had fewer issues (i.e. McAlpine Pool), there were others, like the Meldahl Pool, that contained a higher proportion of mainstem sites that relied on buoys, docks and other structures that were much more vulnerable to higher river levels. Ultimately, the total of 131 receivers that the project utilized during 2018 was ~20% drop over previous years (i.e. n = 158 receivers in 2017). However, the Meldahl Pool was the only one to lose 10+ receivers since 2017, and the largest contributor to this was the 37% decline in the total number of active mainstem sites (Table 1). After the 2+ month delay in the reestablishment of the array's full receiver coverage, project biologists had to quickly shift focus towards maintaining the functionality of each functional receivers at each site for as long as possible, and this included making regular monthly efforts to offload any new telemetry data.

Implanting Ultrasonic Transmitters

Since all 2018 tagging efforts conducted by the USFWS, KDFWR and INDNR occurred in pools containing low density populations, the field crews were only able to successfully capture and tag a total of 32 Asian Carp, which included one Bighead and 31 Silver Carp pulled from the Markland (n = 21) and Meldahl (n = 11) pools (Table 2). Each Asian Carp that was tagged in 2018 will continue to be monitored with the receiver array until 2023, which is when each transmitter's battery power is expected run out. From all tagging efforts that were conducted from 2013 to 2018, the Ohio River Telemetry Project had successfully implanted ultrasonic transmitters into 540 Asian Carp. However, since the first group of AC tagged in 2013 (n = 19) have already shut down, there is currently only 521 tagged AC that can still be identified by receivers in the Project's telemetry array. This current group of 520+ tagged AC can be broken down by species to include 489 Silver Carp (93.9%) and 32 Bigheads (6.1%) (Table 2). The tagged carp for this project were sampled from five different pools, but as expected, the majority (81.2%) of these fish 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 32 - 33 in, but those from the Markland and Meldahl pools were slightly larger carp that measured 36 – 38 in long (Table 2). After it was determined that most tagged Bighead Carp were > 40 in long, a simple comparison between their total lengths and those of the tagged Silver Carp quickly indicated that there was a rather large size disparity between these two species (Figure 5). Finally, the Asian Carp that were tagged in 2014 (n = 139), including 115 Silver Carp in the McAlpine Pool, are the next group of tags that are expected to shut down as their transmitters approach the end of their 5-year battery life during the summer and fall of 2019.

Since all 2018 tagging efforts conducted by the USFWS, KDFWR and INDNR occurred in pools containing low density populations, the field crews were only able to successfully capture and tag a total of 32 Asian Carp, which included one Bighead and 31 Silver Carp pulled from the Markland (n = 21) and Meldahl (n = 11) pools (Table 2). Each Asian Carp that was tagged in 2018 will continue to be monitored with the receiver array until 2023, which is when each transmitter's battery power is expected run out. From all tagging efforts that were conducted from 2013 to 2018, the Ohio River Telemetry Project had successfully implanted ultrasonic transmitters into 540 Asian Carp. However, the 19 Asian Carp tagged in 2013 should have already gone quiet after reaching the end of each transmitter's 5-year battery life. Hence, by the end of 2018, there was a maximum of 521 tagged fish remaining in the project's active sample, which, by species, included 489 Silver Carp (93.9%) and 32 Bigheads (6.1%) (Table 2). The telemetry project's tagged carp were sampled from five different pools, but as expected, the majority (81.2%) of these fish originated from the higher density populations found in Cannelton and McAlpine.

Unfortunately, there are numerous ways for a tagged fish to effectively disappear from a telemetry project's active sample, and most of these will have an impact well before the transmitters start have problems with low battery levels. One of the more common ways that this happens is when a tagged AC dies because it never fully recovers from the surgical procedure used to implant the transmitter into its abdominal cavity. This is a factor that project biologists actually expect to some degree, and oftentimes, it already has an influence on the number of carp that are tagged over a specific time period. One of the few remaining situations that has the potential to substantially reduce a telemetry project's active sample is often related to the number of open pathways that the tagged carp can use to emigrate from a large river system like the mainstem Ohio River, or at the very least, remain just out of the reach of the receiver array. A closer examination of the 2013-2018 detection data has allowed for the identification of 30+ tagged carp that have left the mainstem Ohio River for at least 1 full year, and then an additional 32 fish that may still be in the Ohio River even though they are no longer within reach of the project's receiver array (Figure 3).

Detections of Tagged Asian Carp

Throughout 2018, KDFWR's project biologist made numerous efforts to error-check and format the telemetry datasets that were regularly offloaded by field crews from the KDFWR, ODOW, USFWS WVDNR and WVU. After checking each datasets from Jan 1 to Nov 30 and then importing them into the telemetry database, it was determined that only 66, or 50.4%, of the array's 131 active receivers had contributed to the ~7,797,000 detections recorded in 2018 (Table 3), which is a decrease from the ~8,175,000 million detections obtained during 2017 (Table 4). Additional analysis showed that the most recent 2018 dataset contained at least 1 detection of 227 different tagged carp, which was less than half (43.6%) of the 520+ unique AC that were detectable at the start of 2018. However, this total was not very far off from the amount detected during the previous year, including the 263 tagged carp that were identified in the 2017 telemetry database (Table 4). The 7.8 million detections that made up the 2018 telemetry database were eventually reduced to create new hourly and daily datasets the contained 280,901 and 29,203 detections, respectively. These hourly/daily datasets were often much easier to manage than the original database so they were the obvious choice when the analyses started to focus on large-scale movements of the tagged AC (i.e. monthly ranges, pool transfers, etc).

The complete 2018 telemetry database was analyzed using R statistics software that was equipped with the VTrack package. With the help of this specific package, all 7.8 million tagged carp detections in 2018 were divided into groups that were based on the location of the receiver that made the initial detection. The earliest results from both 2017 and 2018 suggested that there were specific receivers located within the bottom half of the array that often detected high numbers of tagged carp. In fact, when a plot of the 2018 results (Figure 4) was compared to that from 2017 (Figure 5), it was apparent that there were similar groups of receivers during both years there regularly recorded the highest numbers of tagged AC detections. For instance, the largest proportion of the 2018 detections were concentrated along both ends of the McAlpine Pool, which was not unexpected given that 21 different receivers were used last year in order to monitor the 237 tagged AC that were released into the 75 mi long pool between 2014 and 2016. All offloads obtained from receivers in the McAlpine Pool were combined to create a dataset with over 5.2 million tagged carp detections, which accounted for 67% of the 7.8 million detections made by the entire receiver array in 2018. Even though the McAlpine Pool results weren't unexpected, there were still some surprises in 2018 that included the receivers in the Markland Pool accumulating more than 1.3 million detections, which easily allowed the pool to become the 2nd most productive area in 2018 (Table 3). Prior to that year, the large group of 30+ receivers that used to be spread throughout the Meldahl Pool (TL= 95+ mi) were often able to record more than enough tagged carp detections to classify it as the 2nd most productive area within the array, which was what happened during 2017 after the Meldahl Pool was able to finish with a total of 573,578 detections (Table 4). However, a substantial decrease in the total number of active receiver stations that were used in 2018, and the subsequent drop in overall tagged carp detections (n = 431,964), is what led Meldahl to be classified as only the 4th most productive pool of the array.

In contrast to the declines exhibited among the Meldahl receiver sites, there were more than enough detections made by receivers in the upper McAlpine Pool to warrant a specific analysis that attempts to identify any seasonal changes in the habitat preferences of Asian Carp. This analysis began by splitting up all of the 2018 detections, and the related numbers of unique carp, into groups based on the season during which they were recorded. For this project, the seasons were defined as winter (Jan - Feb), spring (Mar - May), summer (Jun - Aug) and fall (Sep - Nov). According to the maps of the upper McAlpine Pool that illustrated the distribution of the tag detections that were recorded during the winter (Figure 6), spring (Figure 7), summer (Figure 8) and fall (Figure 9) of 2018, it becomes quite apparent that the Asian Carp residing in this area of the McAlpine Pool have come to rely very heavily on the habitat being provided by the tributaries. When the seasonal influences are removed by mapping an entire year's worth of detections, the Asian Carp still exhibit an obvious preference towards the tributary habitat (Figure 10). One aspect of their behavior that is not entirely evident by this analysis is the likelihood that Asian Carp will often move between tributaries that are in relatively close proximity of each other. However, it can't be understated just how important the mainstem receivers are to learning more about tagged carp movements after they venture out of the tributaries.

KDFWR's project biologists conducted an additional analysis that was only focused on the 2017-2018 data provided by a small group of receiver stations in the upper McAlpine Pool that are known for accumulating large numbers of tagged carp detections. However, the large datasets were not the primary motivation for these efforts. The sites were chosen on the pretense that the data should give biologists the best opportunity to identify any trends that could reliably predict when large numbers of Asian Carp could be present in a specific area or tributary. This new analysis effort initially focused on a group of six VR2W's that had been deployed to one of three different tributaries in the area. However, a second set of four VR2's from nearby mainstem sites were added to the effort to help identify any conditions that may be related to increased carp movements between tributaries by way of the mainstem river. All ten receiver sites were found within a stretch of the upper McAlpine Pool that was only 13.2 miles long. However, the higher tagged carp densities in this area means that these receivers are still very likely to record more than enough tag detections. And finally, another type of data was needed to help describe the conditions of the river at the time that most of the tagged AC detections were being recorded. Hence, for the purpose of this analysis, a USGS gage located below Markland L&D provided the data needed to help describe the environmental conditions (i.e. water levels & temperatures) on the mainstem OHR during 2017-2018. Smaller temperature loggers were also attached to the uppermost site in each tributary, and they were offloaded prior to this analysis in order to provide data on local water temperatures that would only effect the tagged carp in that specific waterway (i.e. creek, stream or small river).

In 2017-2018, the receivers selected for this analysis were able to record as many as 8.5+ million detections of tagged carp, and the majority of these were specifically logged by upper and lower receivers within the tributaries, which included ~3.5 million detections by receivers in the Kentucky River (Figure 11), ~2.0 million from the Little Kentucky River (Figure 12) and another ~2.5 million tagged AC detections made within Indian-Kentuck Creek (Figure 13). In contrast to detections collected around the tributary stations, the four mainstem receiver sites recorded a combined total of ~500,000 tagged AC detections (Figure 14). However, when daily detection totals from these receivers were are graphed over time in order to simplify the site comparisons, there simply weren't that many trends that stood out, especially when incorporating the river levels and water temperatures to help predict where the Asian Carp may be located. A result of this analysis effort that has been fairly consistent with those that were conducted previously, in that the tagged AC in the middle Ohio River have once again demonstrated that they have a much stronger preference towards tributaries than the mainstem river.

Movements of Tagged Asian Carp

In a manner that was similar to what was completed just one year earlier, the 2018 hourly detections were also used to estimate the mean monthly ranges of both the Bighead and Silver Carp. To be certain that only the detections of live fish were used to generate these estimates, all tagged carp that were detected by only one receiver during 2018 were subsequently removed from the dataset before any a range estimates were generated. All hourly detections that were still present at this point were separated into groups according to the month that the detection was made and the pool where the receiver station was located. For the purpose of this analysis, the range of a tagged Asian Carp is defined by the overall number of river miles that exist between its most upstream and most downstream detections that recorded during a specific time period (i.e. month). The mean monthly ranges generated from the 2018 hourly detections were compared for the tagged Bighead and Silver Carp that resided in the most active pools within the receiver array, which in 2018 were McAlpine, Markland and Meldahl (Figure 10). The most active months for both Asian Carp species during 2018 were obviously May, June and July. During these months, Bighead Carp often appeared to cover more of the river than their Silver Carp counterparts. However, there was a single discrepancy to this trend that occurred in the Markland Pool during June 2018 when a handful of Silver Carp were able to extend their ranges by just enough to surpass those efforts made by the tagged Bighead Carp that resided in the same pool (Table 5). Although the Silver Carp did exhibit some smaller movements for a few more months that followed, these were minor compared to the larger areas that both species covered during the previous months.

Additional Asian Carp movements that were closely monitored in both 2017 and 2018, included all recorded attempts that tagged carp made to pass through a L&D in order to access an adjacent upstream or downstream pool. An early prelim analysis of the 2018 data obtained from receivers on either side of a L&D was able to identify 8 tagged carp that initially appeared to have transferred between pools. However, when the movements of these fish were carefully scrutinized, it was determined that only 4 out of the 8 carp (50%) had actually made a "valid" pool transfer at some point during 2018 (Table 6). A closer look at the results indicated that 2 of the valid transfers were made by Silver Carp moving into a downstream pool, which included one that passed through McAlpine L&D and another that actually made it through both Meldahl and Markland within the same year. Other tagged fish that made valid transfers during 2018 were two additional Silver Carp that moved upstream from Cannelton into the McAlpine Pool. The other four carp suspected of moving between pools were nullified after it was determined that each one would've had to complete a nearly impossible task in order for their transfer to be validated (i.e. traveling 175+ miles in <20 hrs while avoiding detection as many as 12 different receivers). Ultimately, the small number of transfers that actually occurred in 2018 continues to reinforce the belief that there may be only a small handful of Asian Carp that actually move freely between pools of the Ohio River.

Additional Asian Carp movements that were closely monitored in both 2017 and 2018, included all recorded attempts that tagged carp made to pass through a L&D in order to access an adjacent upstream or downstream pool. An early prelim analysis of the 2018 data obtained from receivers on either side of a L&D was able to identify 8 tagged carp that initially appeared to have transferred between pools. However, when the movements of these fish were carefully examined, it was determined that only 4 out of the 8 carp (50%) had actually made a "valid" pool transfer at some point during 2018 (Table 6). A closer look at the results indicated that two of the valid transfers were made by Silver Carp moving into a downstream pool, which included one that passed through McAlpine L&D and another that actually made it through both Meldahl and Markland within the same year (Figure 20). Other tagged fish that made valid transfers during 2018 were two additional Silver Carp that moved upstream from Cannelton into the McAlpine Pool. The other four carp suspected of moving between pools were nullified after it was determined that each one would've had to complete a nearly impossible task in order for their transfer to be validated (i.e. traveling 175+ miles in <20 hrs while avoiding detection as many as 12 different receivers).

The small number of transfers that actually occurred in 2018 continues to reinforce the previous results that suggest there are not very many tagged carp moving between pools of the middle Ohio River. Hence, upon closer examination of the small group of ~20 Asian Carp that completed actual pool transfers since 2013, there have been a couple instances where tagged carp have actually been able to complete upstream transfers involving either multiple (Figure 21) or single (Figure 22) pools. However, the vast majority of the pool-to-pool movements being completed by this small group of active fish are still just simple downstream transfers of a single pool.

Table 1. Total amounts and distribution of all Mainstem, Tributary and Lock & Dam (L&D) receiver sites that made up the project's telemetry array in 2016 - 2018.

		2017 Receiver Sites								2018 Receiver Sites							
		Mainstem		Tributary		L&D				Mainstem		Tributary		L&D			
Pool	Length (mi)	N	% of Pool	N	% of Pool	N	% of Pool	Total # of Sites	% of 2017 Sites	N	% of Pool	N	% of Pool	N	% of Pool	Total # of Sites	% of 2018 Sites
Willow Is.	3.0	1	50.0	0	0.0	1	50.0	2	1.3	1	50.0	0	0.0	1	50.0	2	1.5
Belleville	42.2	9	47.4	6	31.6	4	21.1	19	12.0	7	41.2	6	35.3	4	23.5	17	13.0
Racine	33.6	3	33.3	2	22.2	4	44.4	9	5.7	3	33.3	2	22.2	4	44.4	9	6.9
RC Byrd	41.7	4	36.4	3	27.3	4	36.4	11	7.0	1	11.1	4	44.4	4	44.4	9	6.9
Greenup	61.8	9	47.4	6	31.6	4	21.1	19	12.0	6	37.5	6	37.5	4	25.0	16	12.2
Meldahl	95.2	24	63.2	10	26.3	4	10.5	38	24.1	15	55.6	7	25.9	5	18.5	27	20.6
Markland	95.3	10	34.5	15	51.7	4	13.8	29	18.4	9	36.0	12	48.0	4	16.0	25	19.1
McAlpine	75.3	9	40.9	10	45.5	3	13.6	22	13.9	8	38.1	10	47.6	3	14.3	21	16.0
Cannelton	53.7	7	77.8	2	22.2	0	0.0	9	5.7	3	60.0	2	40.0	0	0.0	5	3.8
Totals	501.8	76	48.1	54	34.2	28	17.7	**158**	100.0	53	40.5	49	37.4	29	22.1	**131**	100.0

Table 2. Total counts, species composition and mean total lengths (in) of the Bighead and Silver Carp that were collected from 5 pools of the Ohio River and surgically implanted with acoustic transmitters in 2013 – 2018. All transmitters implanted into Asian Carp during 2013 had gone silent by fall 2018 after surpassing their 5-year battery life.

Year	Status After 2018	Species	Pool						Total
			Cannelton	McAlpine	Markland	Meldahl	Greenup	RC Byrd	
2013	*Inactive*	*Silver Carp*	-	-	*0*	*6*	*0*	-	*6*
	Inactive	*Bighead Carp*	-	-	*0*	*13*	*0*	-	*13*
2014	Active	Silver Carp		115	6	10	0	-	131
	Active	Bighead Carp		4	4	0	0	-	8
2015	Active	Silver Carp	-	22	3	5	0	-	30
	Active	Bighead Carp	-	1	1	5	0	-	7
2016	Active	Silver Carp	92	94	6	0	-	0	192
	Active	Bighead Carp	4	1	4	2	-	3	14
2017	Active	Silver Carp	90	-	12	3	-		105
	Active	Bighead Carp	0	-	2	0	-		2
2018	Active	Silver Carp	-	-	21	10	-	-	31
	Active	Bighead Carp	-	-	0	1	-	-	1
Total (2014-2018)	Active	Silver Carp	182	231	48	28	0	0	489
	Active	Bighead Carp	4	6	11	8	0	3	32
	Active	Total	186	237	59	36	0	3	521
% Species Composition	2014-2018	Silver Carp	34.9	44.3	9.2	5.4	0.0	0.0	93.9
		Bighead Carp	0.8	1.2	2.1	1.5	0.0	0.6	6.1
		Total	35.7	45.5	11.3	6.9	0.0	0.6	100.0
Mean Total Lengths (in)	2013-2018	Silver Carp	32.5	33.8	36.2	38.0	0	0.0	33.9
		Bighead Carp	44.9	46.0	46.3	45.4	0	47.6	45.8

Table 3. Total number of detections (Total Dtxns), and the related amount of unique Asian Carp (AC), that were recorded in JAN - NOV of 2018 by receivers located throughout the mainstem, tributary and L&D sites that had been established across the first 7 pools of the project's telemetry array.

Time of Year	VR2 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	0	0	--	--	9	1	4	1	0	0	0	0	--	--	13	2
	Trib	217,621	11	838,481	81	315,165	10	135,894	10	0	0	23,909	1	0	0	1,531,070	113
	L&D	0	0	0	0	101	1	99	1	0	0	0	0	0	0	200	1
	All	217,621	11	838,481	54	315,275	12	135,997	12	0	0	23,909	1	0	0	1,531,283	116
Spring	Main	0	0	4,389	24	1,509	12	1,621	7	0	0	31	1	31	1	7,581	45
	Trib	188,273	28	1,582,240	115	406,234	12	134,877	11	0	0	26,021	1	0	0	2,337,645	166
	L&D	--	--	3	2	15	3	2,410	2	0	0	0	0	0	0	2,428	7
	All	188,273	28	1,586,632	117	407,758	13	138,908	13	0	0	26,052	1	31	1	2,347,654	171
Summer	Main	31,523	31	292,297	102	3,324	12	73,478	10	0	0	1,169	1	45	1	401,836	155
	Trib	250,142	27	1,590,872	110	172,900	12	70,016	9	0	0	0	0	57	1	2,083,987	159
	L&D	--	--	27	4	8	3	136	1	0	0	0	0	0	0	171	8
	All	281,665	36	1,883,196	120	176,232	12	143,630	12	0	0	1,169	1	102	1	2,485,994	180
Fall	Main	4,740	11	67,809	55	0	0	12,973	14	0	0	0	0	0	0	85,522	80
	Trib	9,738	10	862,823	80	473,722	31	456	1	0	0	0	0	0	0	1,346,739	122
	L&D	--	--	18	1	0	0	0	0	0	0	0	0	0	0	18	1
	All	14,478	11	930,650	92	473,722	31	13,429	14	0	0	0	0	0	0	1,432,279	147
All	Main	36,263	31	364,495	113	4,842	13	88,076	14	0	0	1,200	1	76	1	494,952	170
	Trib	665,774	37	4,874,416	128	1,368,021	32	341,243	12	0	0	49,930	1	57	1	7,299,441	209
	L&D	--	--	48	6	124	4	2,645	4	0	0	0	0	0	0	2,817	13
	All	702,037	46	5,238,959	134	1,372,987	33	431,964	20	0	0	51,130	1	133	1	7,797,210	227

Table 4. Total number of detections (Total Dtxns), and the related amount of unique Asian Carp (AC), that were recorded in JAN - NOV of 2017 by receivers located throughout the mainstem, tributary and L&D sites that had been established across the first 7 pools of the project's telemetry array.

Time of Year	VR2 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 in 2017 - 2018. These ranges were calculated via a comparison of each tagged carps' most upstream (US) and most downstream (DS) detections, so it required the tagged fish to be detected by at least 2 receivers in 2017 and/or 2018. The wavy vertical lines were added to the table to indicate when the results were most likely to be impacted by an incomplete receiver array due to the practice of bringing mainstem receivers in for overwinter storage;

Year	Pool	AC Species	Mean Ranges per Month											
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2017	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*
2018	McAlpine	Bighead Carp	--	--	--	--	--	--	--	--	--	--	--	--
		Silver Carp	*1.38*	*0.51*	*0.61*	*0.54*	9.64	12.27	13.03	4.10	2.09	2.33	1.13	*0.65*
	Markland	Bighead Carp	*0.50*	*0.23*	*0.63*	*0.45*	60.03	45.67	42.07	0.63	0.63	0.48	0.50	*0.00*
		Silver Carp	*0.30*	*0.43*	*0.56*	*0.56*	50.01	52.04	24.72	0.41	4.39	1.70	0.25	*0.75*
	Meldahl	Bighead Carp	*0.00*	*0.00*	*0.00*	*0.00*	38.20	13.07	23.33	5.03	0.33	0.33	0.00	--
		Silver Carp	*0.00*	*0.00*	*0.00*	*0.00*	22.37	6.69	16.13	8.46	3.53	0.00	0.00	*6.60*
	All Pools	Bighead Carp	*0.20*	*0.18*	*0.27*	*0.08*	32.19	19.69	24.53	2.23	0.48	0.41	0.33	*0.00*
		Silver Carp	*1.08*	*0.46*	*0.55*	*0.51*	11.26	12.33	11.95	3.76	2.49	2.06	0.97	*0.79*

Table 6. Pool-to-Pool transfers in 2017-2018 that could be validated once the tagged AC were detected by 1 or more receivers (mainstem and/or tributary) that were located beyond the initial Lock and Dam (L&D) that divided the two pools.

Transfer Year	Tag ID #	*Spp.*	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
Valid Transfers											
2018	A69-1601-56468	SVC	M	Meldahl	2017	Meldahl	McAlpine	Meldahl	McAlpine	DS	Made 2 transfers (Feb & Jun) that were verified by several receivers that made detections as it moved through 3 pools;
2018	A69-1601-58055	SVC	M	McAlpine	2016	McAlpine	Cannelton	McAlpine	Cannelton	DS	A DS transfer into the Cannelton Pool that was supported by the numerous instances when the SVC was recorded by receivers located both above & below McAlpine L&D;
2018	A69-1601-58058	SVC	F	McAlpine	2016	Cannelton	Cannelton	McAlpine	McAlpine	US	A transfer from Cannelton to McAlpine during spring 2018 that was verified once SVC #58058 was detected multiple times within tributaries on both sides of McAlpine L&D;
2018	A69-1601-58064	SVC	M	McAlpine	2016	Cannelton	Cannelton	McAlpine	McAlpine	US	An upstream transfer from Cannelton to McAlpine in July 2018 that was based on the many detections made by 6+ receivers located on both sides of McAlpine L&D;
2017	A69-1601-23996	SVC	M	McAlpine	2014	McAlpine	Cannelton	McAlpine	Cannelton	DS	Downstream transfer into Cannelton occurring in 2017-06 that was verified by detections made above & below McAlpine L&D;
~~2017~~	~~A69-1601-24009~~	~~N/A~~	~~na~~	~~N/A~~	~~na~~	~~RC Byrd~~	~~Greenup~~	~~RC Byrd~~	~~Greenup~~	~~DS~~	Regardless of this transfer's validity, it was recently revealed that Tag #24009 was NOT implanted in an AC and is no longer a part of this Telemetry Project.
2017	A69-1601-27347	SVC	M	Markland	2016	McAlpine	McAlpine	Markland*	McAlpine	DS	SVC stayed in Markland thru 2016 & then detections from 2017-01, show it moving through Markland L&D and into McAlpine.
2017	A69-1601-56475	BHC	F	Markland	2017	Markland	McAlpine	Markland	McAlpine	DS	Detections indicate a transfer into the McAlpine Pool via the 600' lock chamber at Markland L&D in August 2017;
2017	A69-1601-57948	SVC	M	McAlpine	2016	Cannelton	Cannelton	McAlpine	McAlpine	US	Detections indicated that SVC #57948 transferred from Cannelton to McAlpine in June 2017 & then remained through the end of 2017;

Table 6 cont. The remaining transfers from 2017 that were determined to be authentic, and other reports of Pool-to-Pool movements that could not be validated, which were categorized as either 1) "Potential Transfers" of tagged AC that had multiple detections, but from only one station on the receiving side on the transfer, or as 2) "Invalid Transfers" that relied on what were later identified as False detections.

Transfer Year	Tag ID #	*Spp.*	Sex	Tagging Pool	Tag Year	Pool with... First Detection	Most DS Detection	Most US Detection	Last Detection	Transfer Direction	Notes
Valid Transfers cont.											
2017	A69-1601-57962	SVC	F	McAlpine	2015	McAlpine	Cannelton	McAlpine	McAlpine	Both	Initially detected transferring from McAlpine to Cannelton in June 2017, but then came back to McAlpine in August & stayed there until 2017 ended.
2017	A69-1601-57975	SVC	M	McAlpine	2015	McAlpine	Cannelton	McAlpine	Cannelton	DS	Near KY River area of McAlpine until 2017-06 when several receivers detected it transferring downstream into Cannelton;
2017	A69-1601-58058	SVC	F	McAlpine	2016	McAlpine	Cannelton	McAlpine	McAlpine	Both	SVC detected transferring from McAlpine to Cannelton in 2017-05 and then making a return trip to McAlpine just 1 month later;
Potential Transfer											
2018	A69-1601-56472	SVC	F	Markland	2017	Markland	McAlpine	Markland	McAlpine	DS?	SVC #56472 stayed in or near the Great Miami River for 270 days in 2018 until making a surprise 113-mi trip through Markland & McAlpine while avoiding any detections until reaching the McAlpine L&D;
Invalid Transfers											
~~2018~~	~~A69-1601-24016~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~RC Byrd~~	~~McAlpine~~	~~RC Byrd~~	~~RC Byrd~~	~~Both?~~	Regardless of this transfer's validity, it was recently revealed that Tag #24016 was NOT implanted in an AC and is no longer a part of this Telemetry Project.
2018	A69-1601-56550	BHC	M	Markland	2017	Markland	Markland	Meldahl	Markland	Both?	Based on results that required the BHC to travel undetected for 158 mi from mid-Markland to Greenup L&D, and then complete the return trip in 10 hr & without further detections;
2018	A69-1601-57992	BHC	F	Markland	2016	Markland	Markland	Meldahl	Markland	Both?	A valid transfer would've required BHC #57992 to complete an unlikely 24-hr, 175+ mi trip to Greenup L&D without being detected by any of the 12+ receivers located along the way;

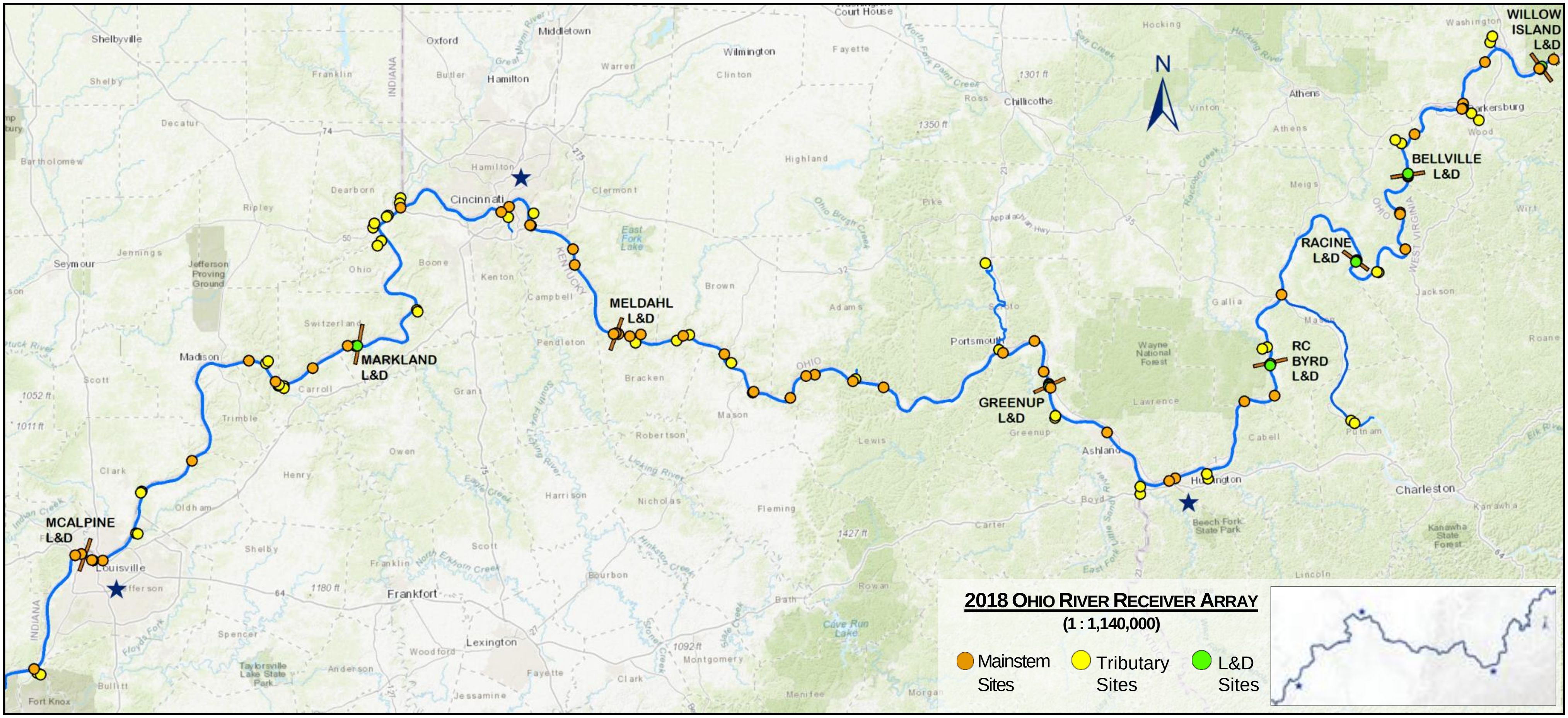


Figure 1. A map of the project's entire 500-mile telemetry array with the eight separate Locks and Dam locations that are monitored for upstream/downstream transfers of tagged Asian Carp. The 2018 array included 158 receiver stations that were distributed across three distinct habitat types, which included the mainstem river, the tributaries, and the L&D's.

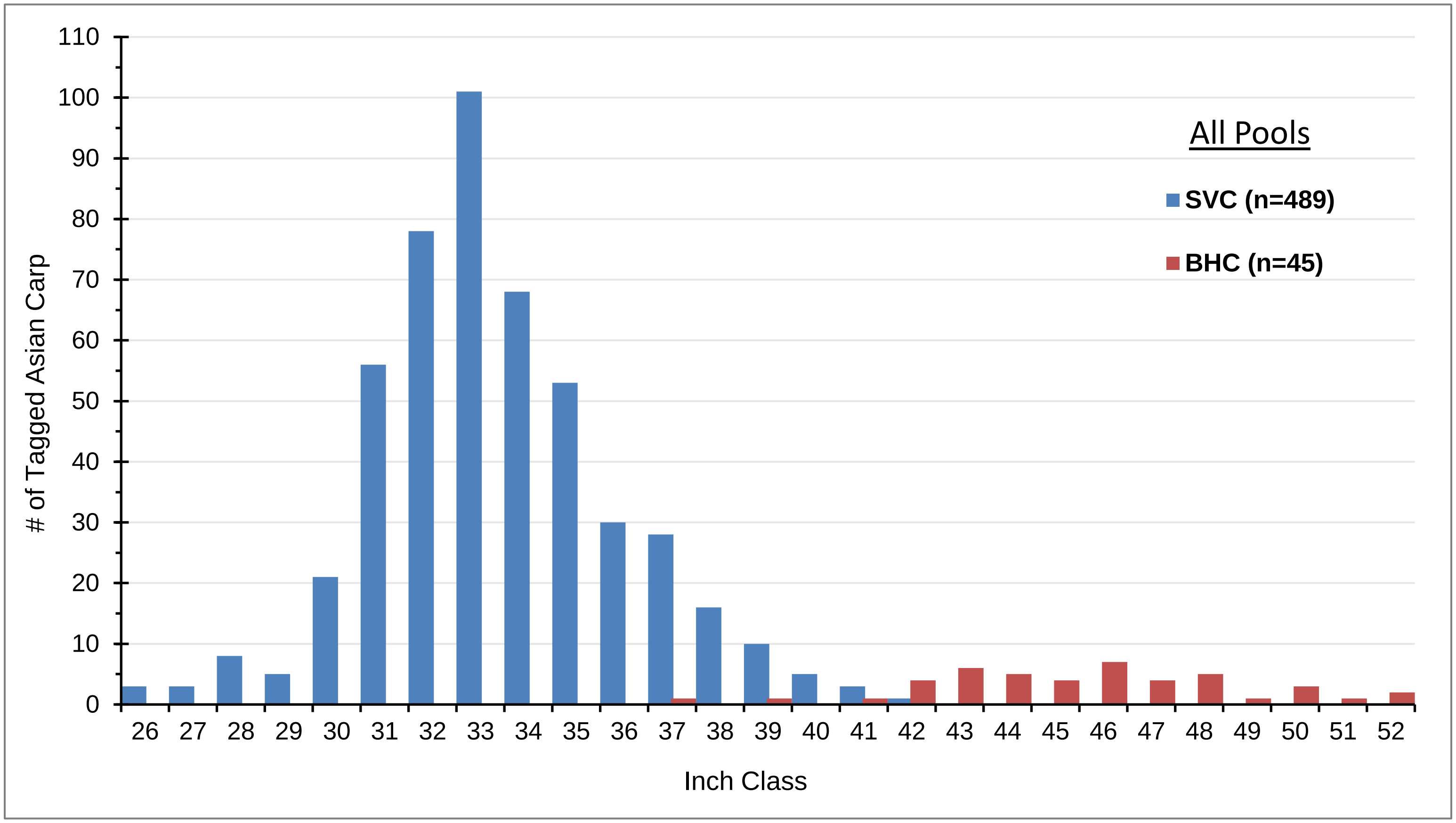


Figure 2. The length frequency of Silver Carp and Bighead Carp that were collected from five different pools during 2013 – 2018 and then ultimately implanted with transmitters.

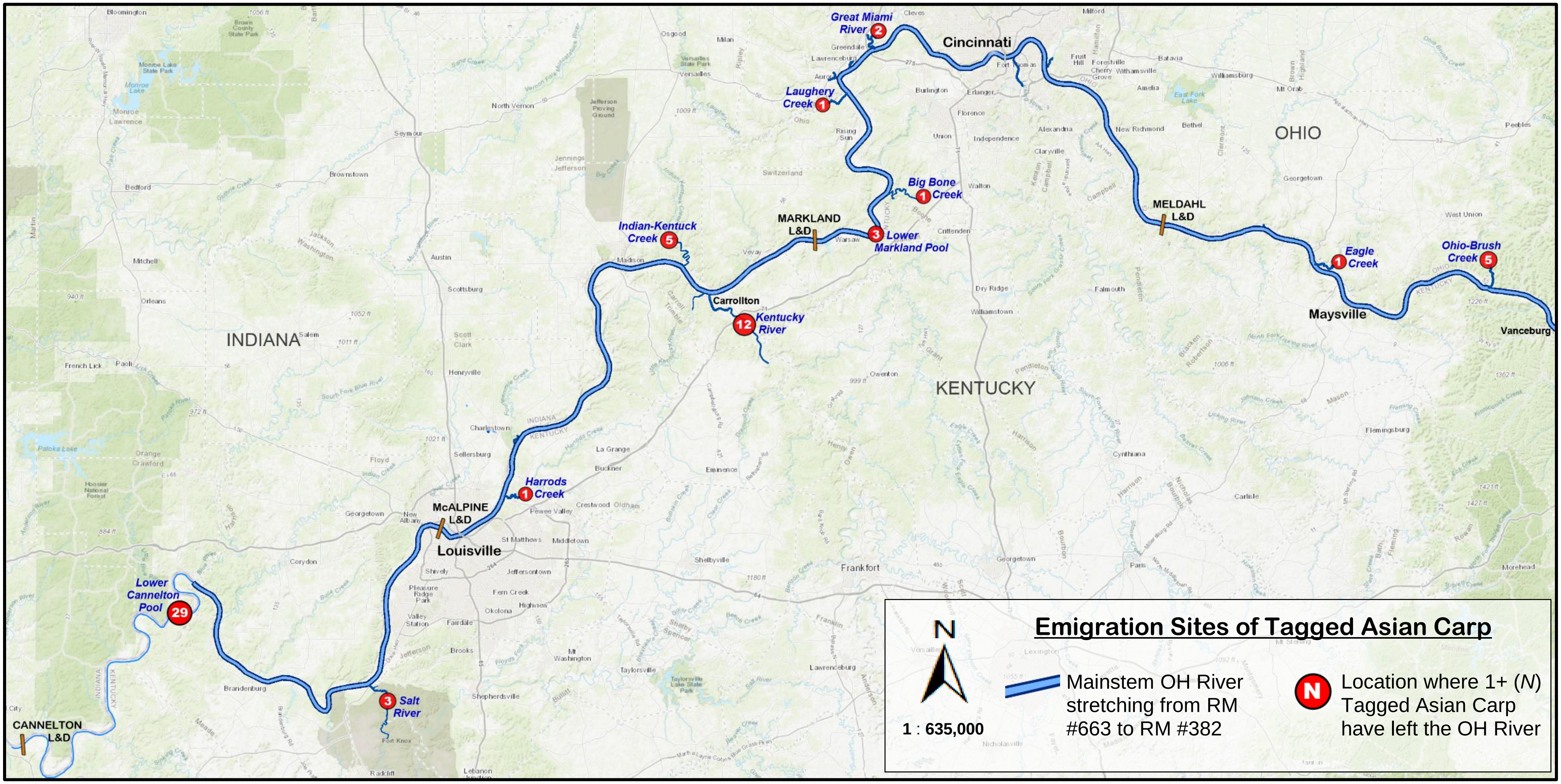


Figure 3. Locations throughout the initial 280 miles of the Telemetry Project's receiver array where 1+ tagged Asian Carp are suspected of leaving the mainstem Ohio River for a duration of at least one full calendar year.

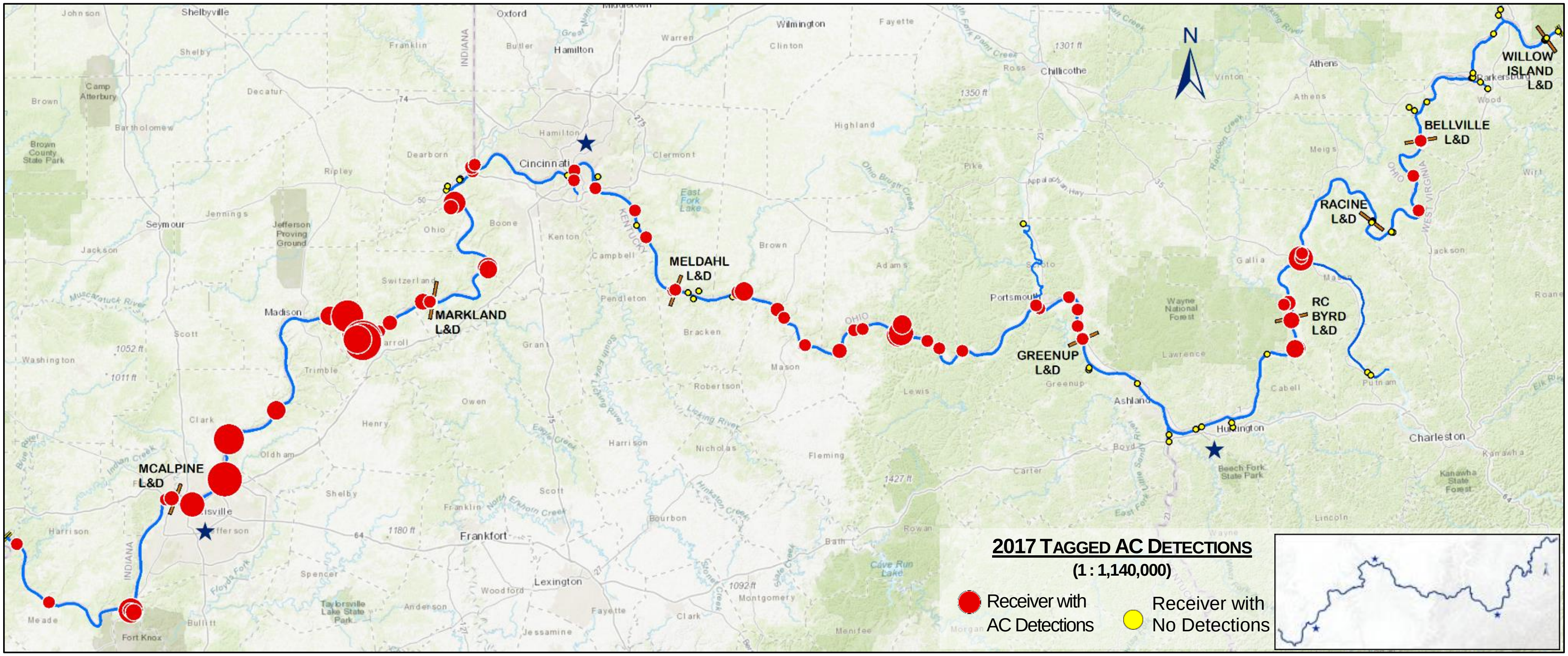


Figure 4. A map showing the distribution of receivers that recorded tagged carp detections during 2017. The amount of detections that a receiver made during the year is correlated to the size of its corresponding red circle, so sites with the highest numbers of tagged carp detections are denoted by the largest red circles.

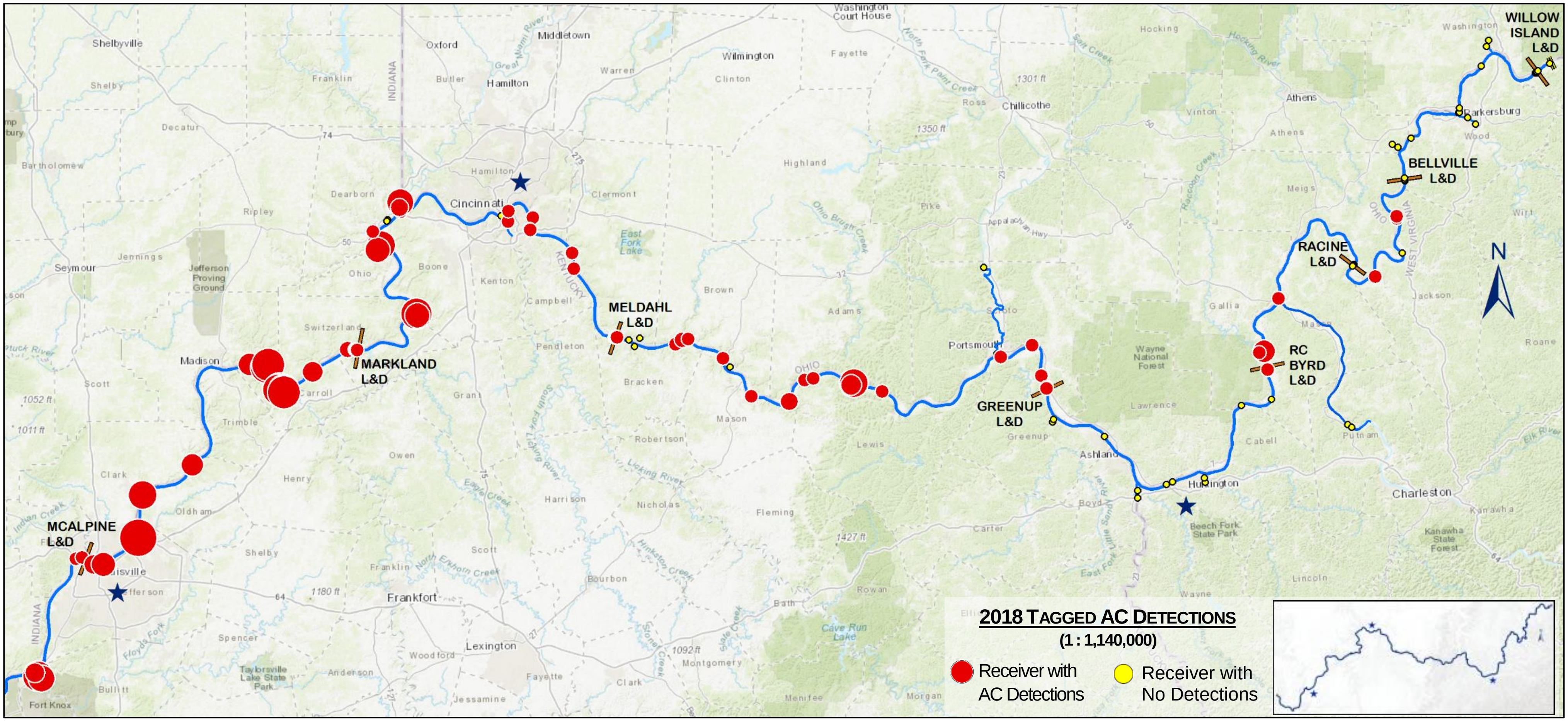
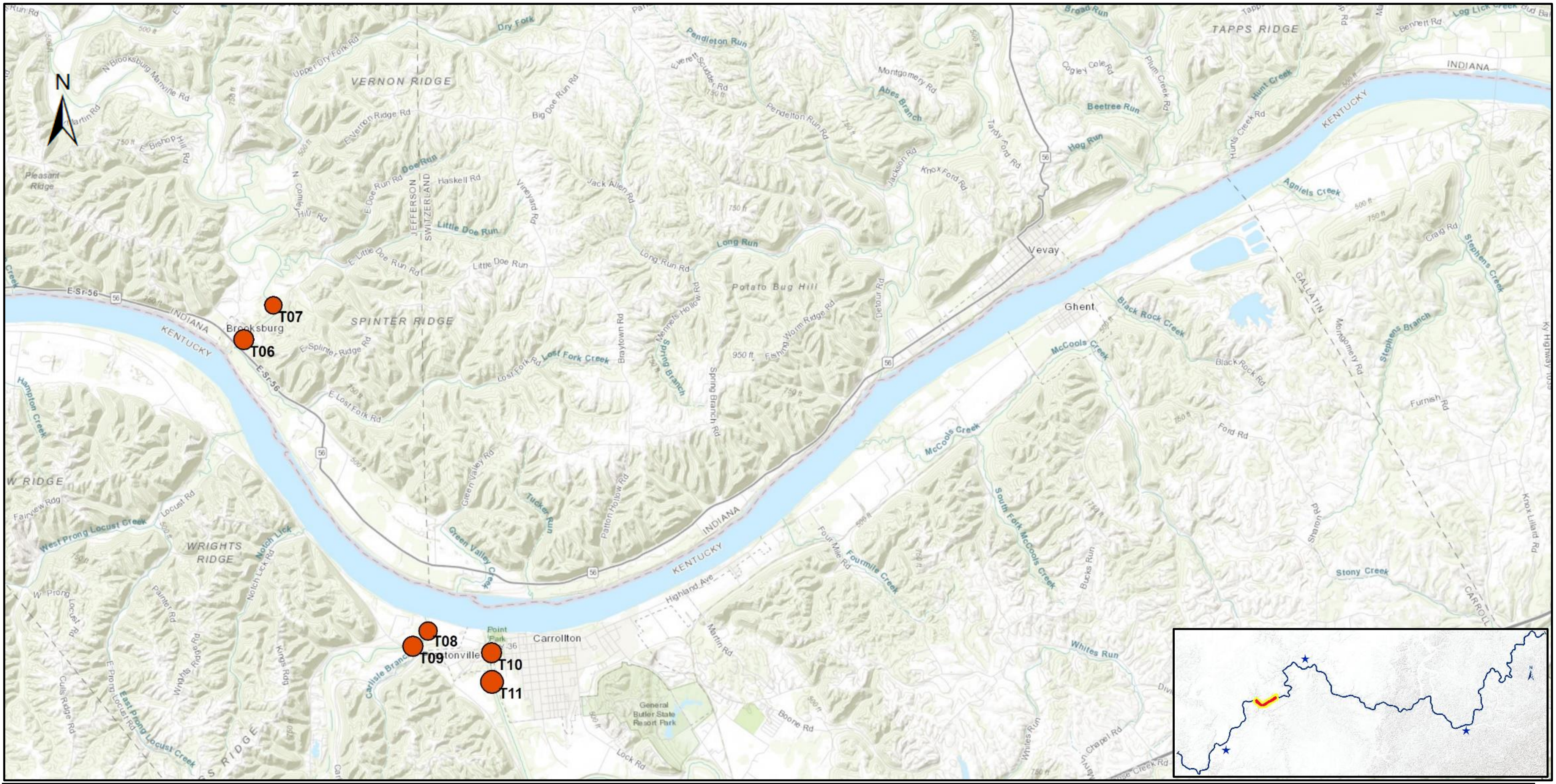
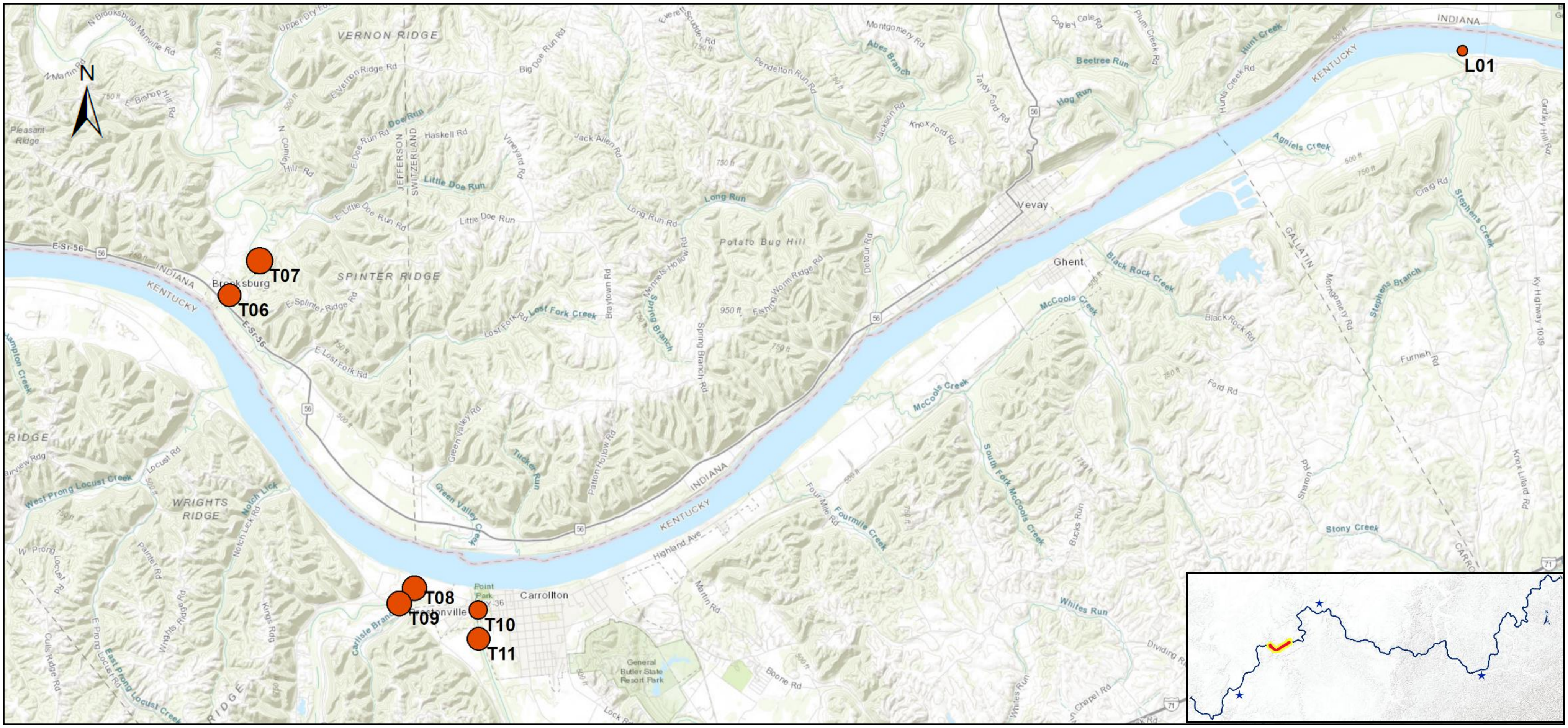


Figure 5. A map showing the distribution of receivers that recorded tagged carp detections during 2018. The amount of detections that a receiver made during the year is correlated to the size of its corresponding red circle, so sites with the highest numbers of tagged carp detections are denoted by the largest red circles.



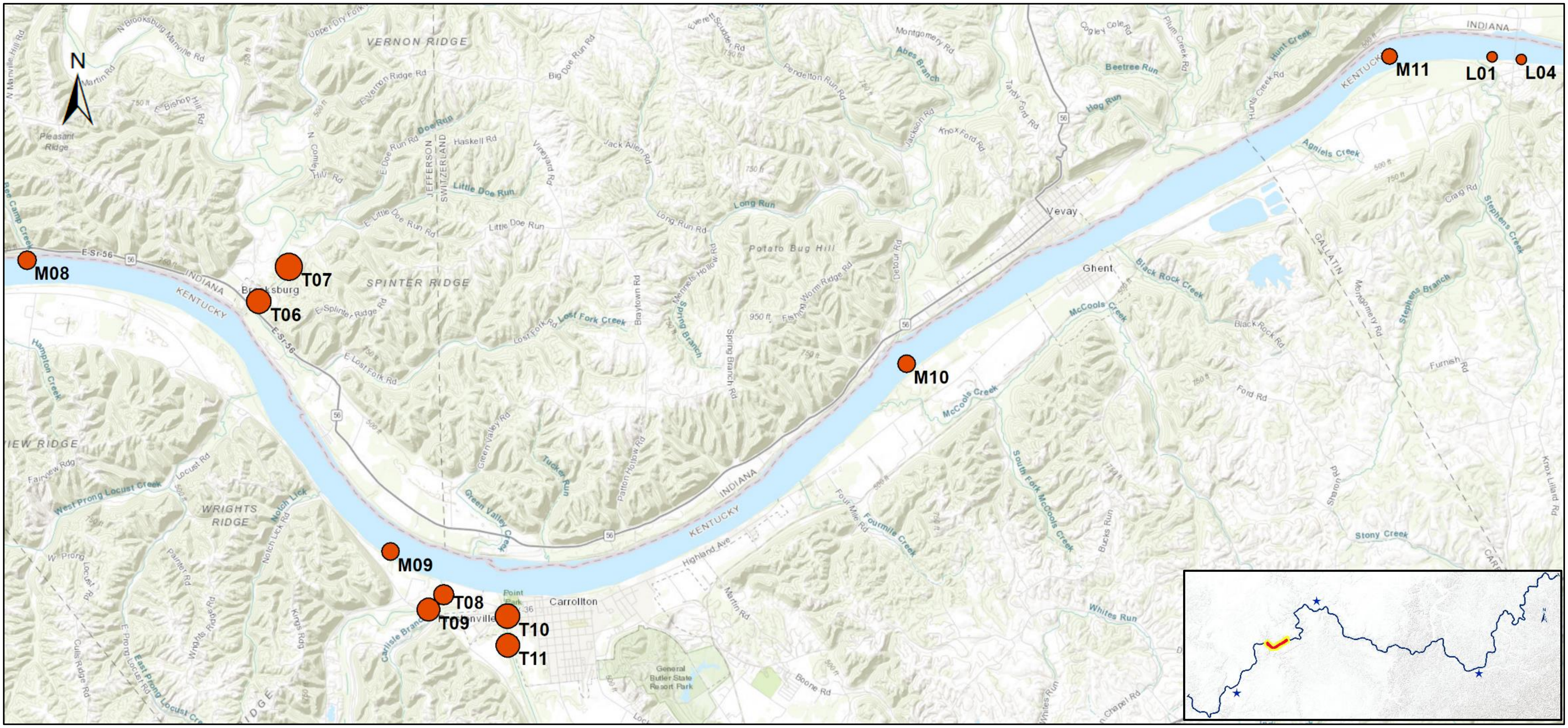
Map ID #	T06	T07	T08	T09	T10	T11
Site Name	Indian-Kentuck Creek (lower)	Indian-Kentuck Creek (upper)	Little KY River (lower)	Little KY River (upper)	KY River (lower)	KY River (upper)
# Winter Detections	105,878	44,452	65,358	120,794	118,955	161,860
# Unique Tags	18	11	38	37	28	32

Figure 6. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during the winter (JAN – FEB) of 2018. 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).



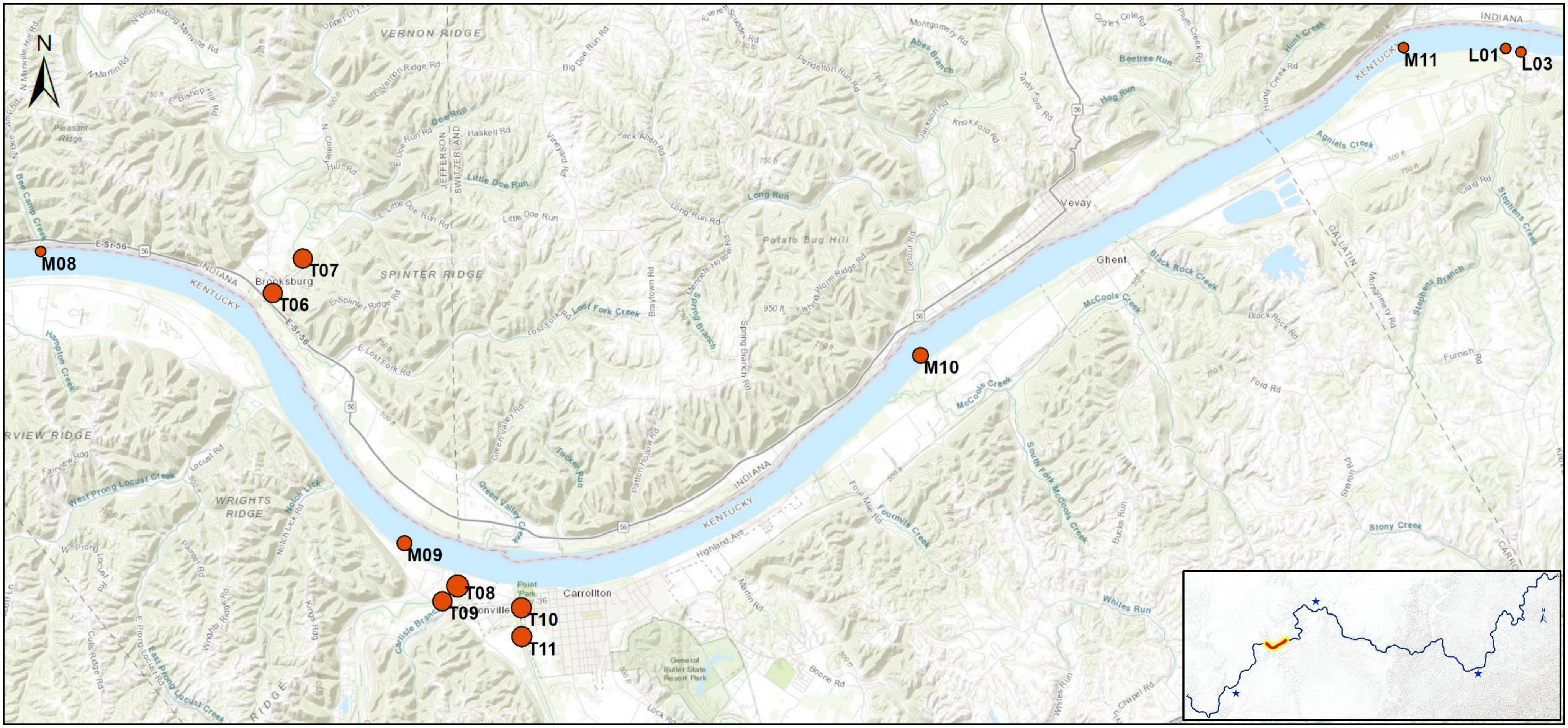
Map ID #	T06	T07	T08	T09	T10	T11	L01
Site Name	Indian-Kentuck Creek (lower)	Indian-Kentuck Creek (upper)	Little KY River (lower)	Little KY River (upper)	KY River (lower)	KY River (upper)	McAlpine L&D (DS Approach)
# Spring Detections	159,215	241,892	201,280	215,094	70,118	151,586	3
# Unique Tags	37	27	50	48	62	86	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 2018. 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).



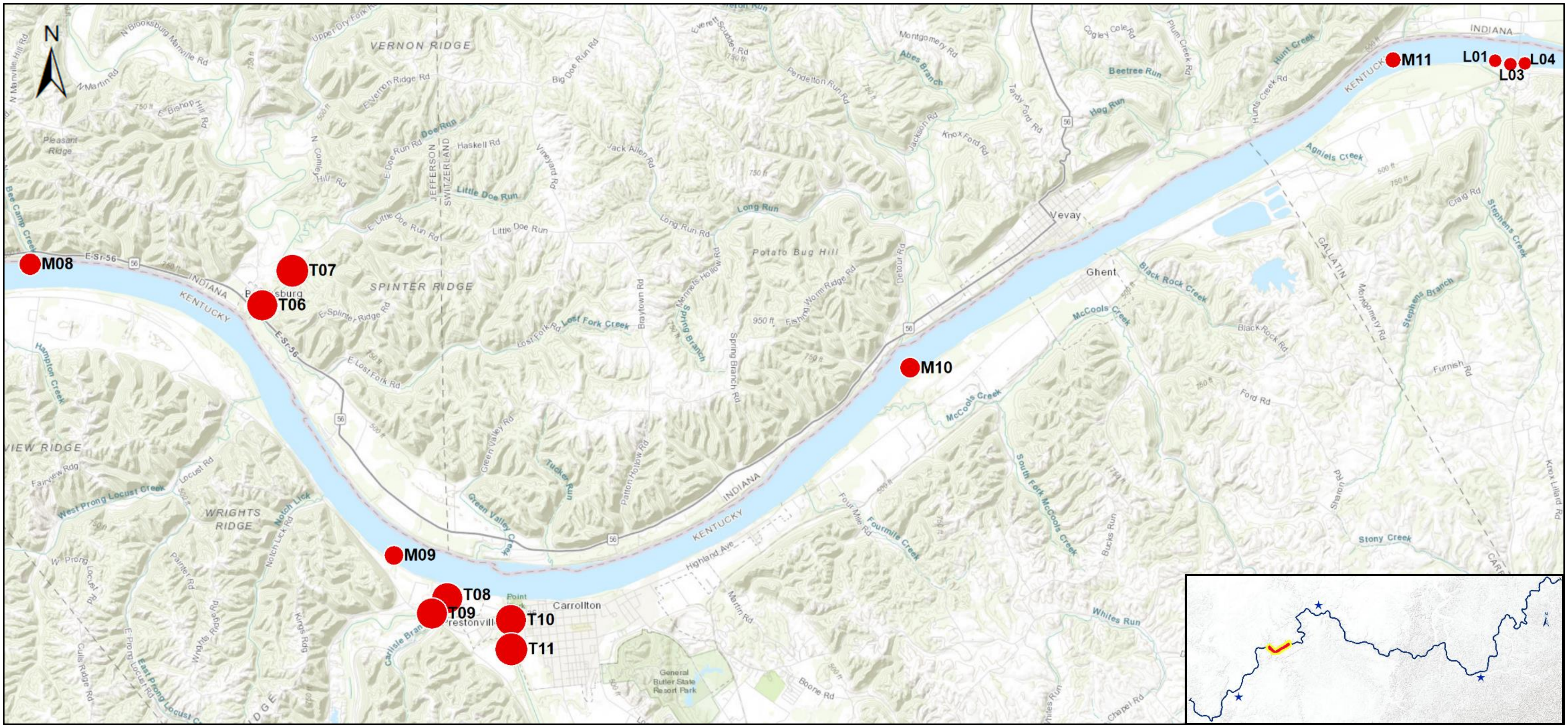
Map ID #	M08	T06	T07	M09	T08	T09	T10	T11	M10	M11	L01	L04
Site Name	Near Bee Camp Creek	Indian-Kentuck Creek (lower)	Indian-Kentuck Creek (upper)	Below Little KY River	Little KY River (lower)	Little KY River (upper)	KY River (lower)	KY River (upper)	Near Indian Creek	DS of Markland L&D	McAlpine L&D (DS Approach)	McAlpine L&D (US Approach)
# Summer Detections	66,536	203,579	270,569	27,811	104,075	161,914	215,421	181,733	30,231	15,109	27	1
# Unique Tags	57	47	30	77	46	40	75	75	51	31	4	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 2018. 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 #	M08	T06	T07	M09	T08	T09	T10	T11	M10	M11	L01	L02
Site Name	Near Bee Camp Creek	Indian-Kentuck Crk (lower)	Indian-Kentuck Crk (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	McAlpine L&D (DS Approach)	McAlpine L&D (600' Lock)
# Fall Detections	227	90,370	95,490	6,417	137,091	86,728	107,792	114,164	22,909	7	17	1
# Unique Tags	5	23	22	39	39	39	46	48	7	1	1	1

Figure 9. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during the fall (SEP – NOV) of 2018. 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 #	M08	T06	T07	M09	T08	T09	T10	T11	M10	M11	L01	L03	L04
Site Name	Near Bee Camp Creek	Indian-Kentuck Crk (lower)	Indian-Kentuck Crk (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	McAlpine L&D (DS Approach)	McAlpine L&D (600' Lock)	McAlpine L&D (US Approach)
Total Detxns	66,763	565,847	653,127	34,228	512,174	587,405	524,849	626,634	53,140	15,116	47	1	1
Unique Tags	57	61	35	81	67	61	88	104	51	31	6	1	1

Figure 10. A map of the receivers that were deployed to Kentucky River area of the McAlpine Pool during 2018 (JAN – DEC). The overall number of tagged AC detections that the receivers recorded throughout 2018 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).

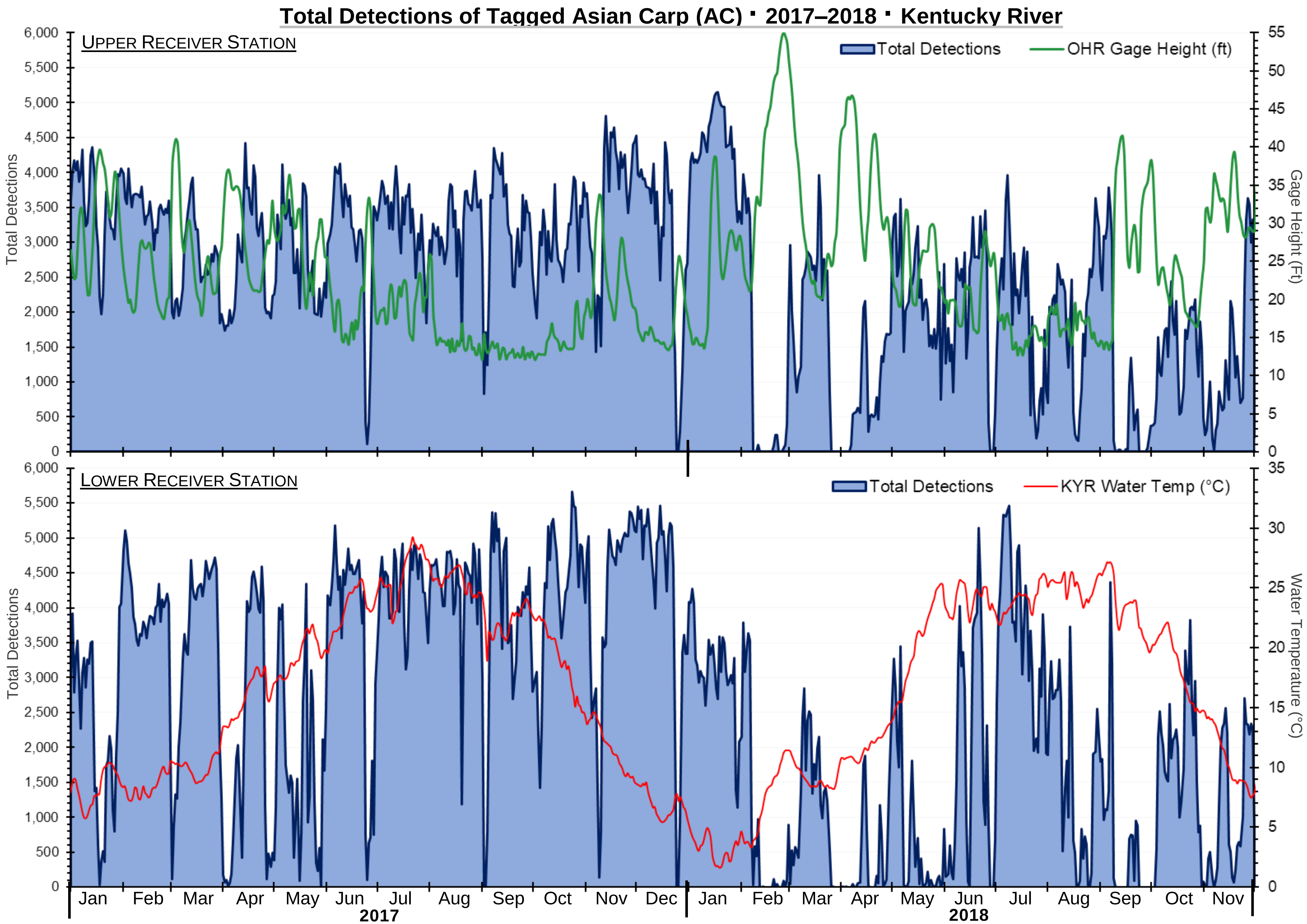


Figure 11. Daily totals of tagged AC detections made by stationary receivers that occupied the upper and lower sites of the Kentucky River in 2017-2018. The secondary line graphs illustrate both the level of the Ohio River and the water temperature recorded around the same time that the detections were made.

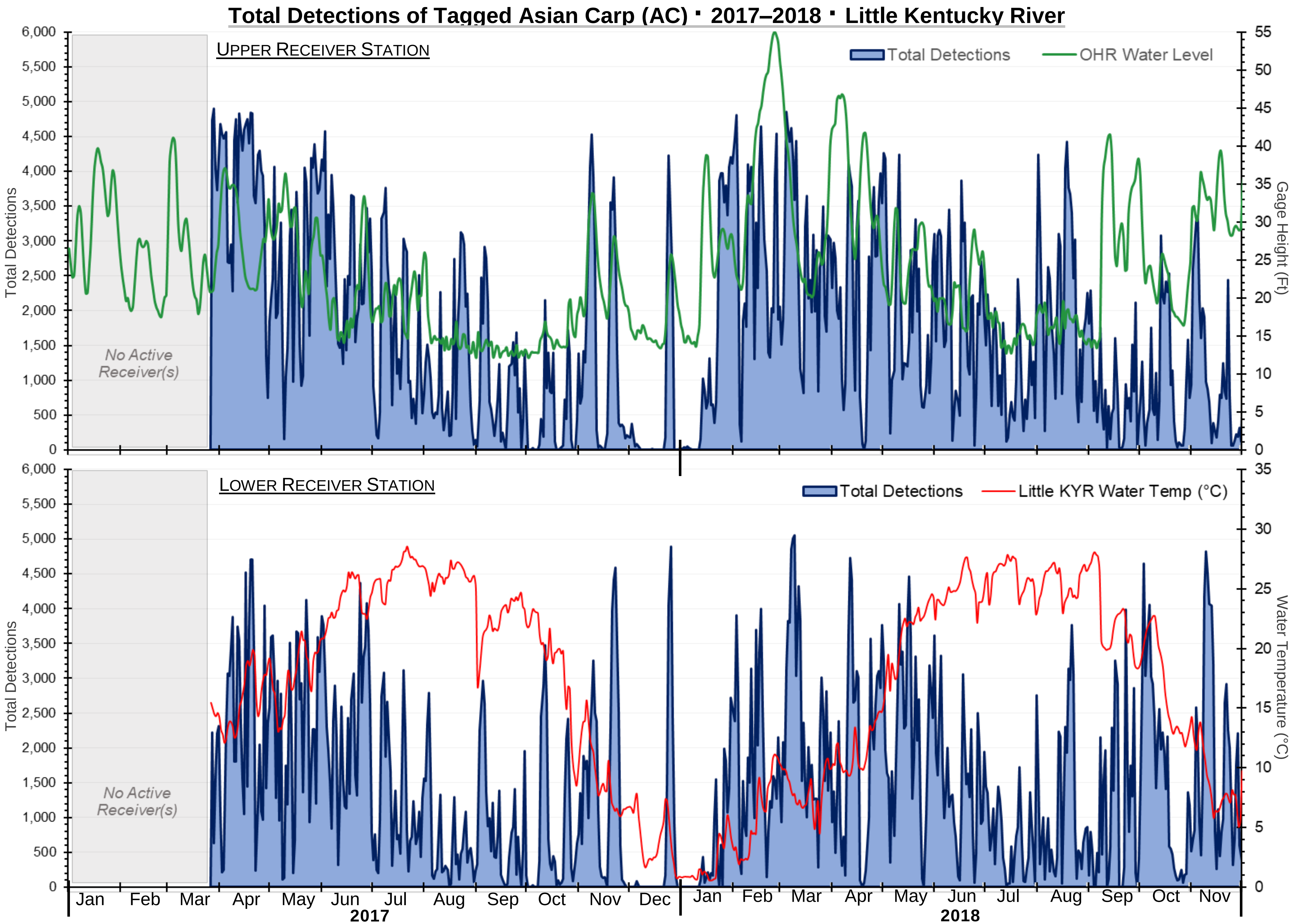


Figure 12. Daily totals of tagged AC detections made by stationary receivers that occupied the upper and lower sites of the Little Kentucky River in 2017-2018. The secondary line graphs illustrate both the level of the Ohio River and the water temperature recorded around the same time that the detections were made.

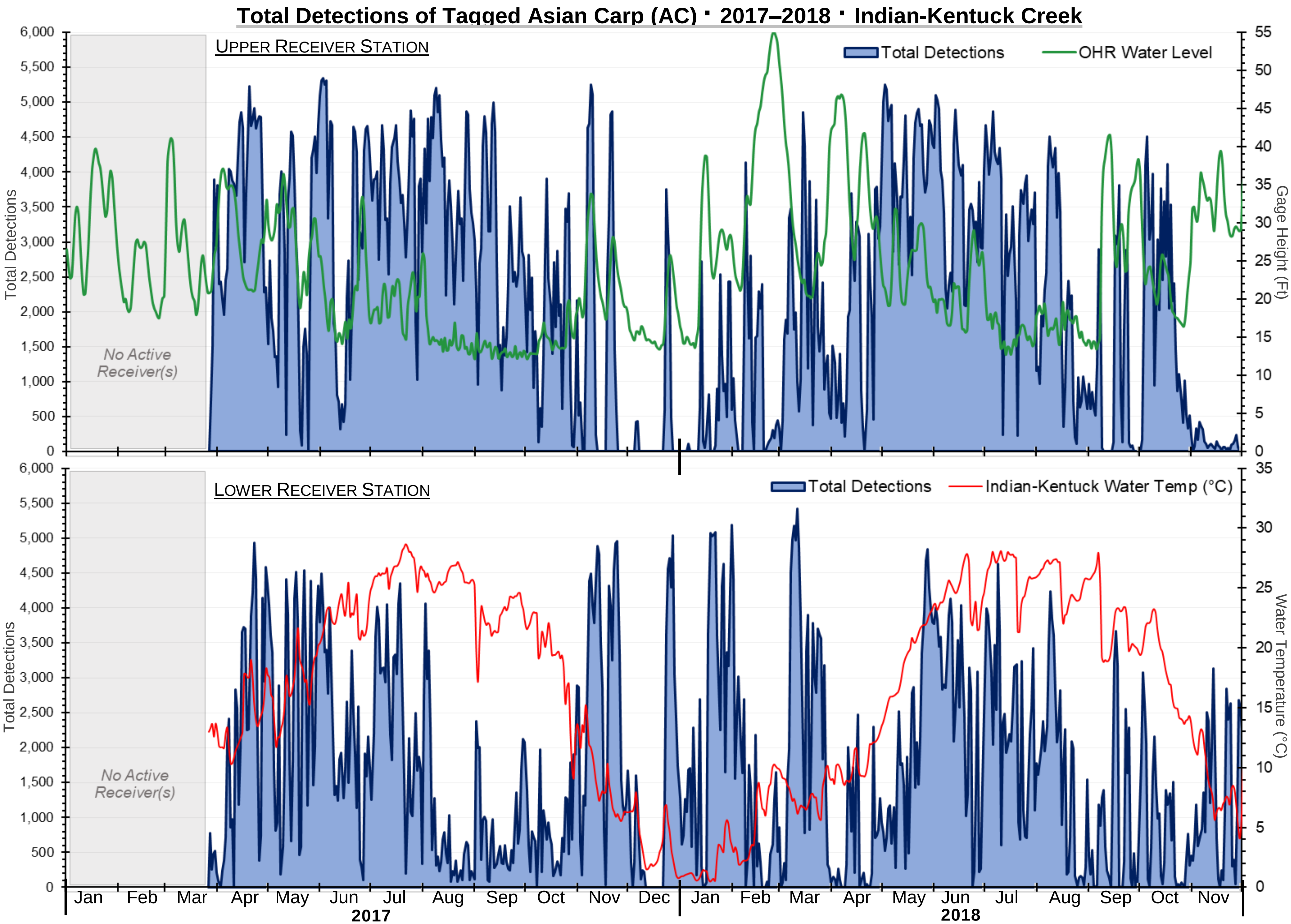


Figure 13. Daily totals of tagged AC detections made by stationary receivers that occupied the upper and lower sites of the Indian-Kentuck Creek in 2017-2018. The secondary line graphs illustrate both the level of the Ohio River and the water temperature recorded around the same time that the detections were made.

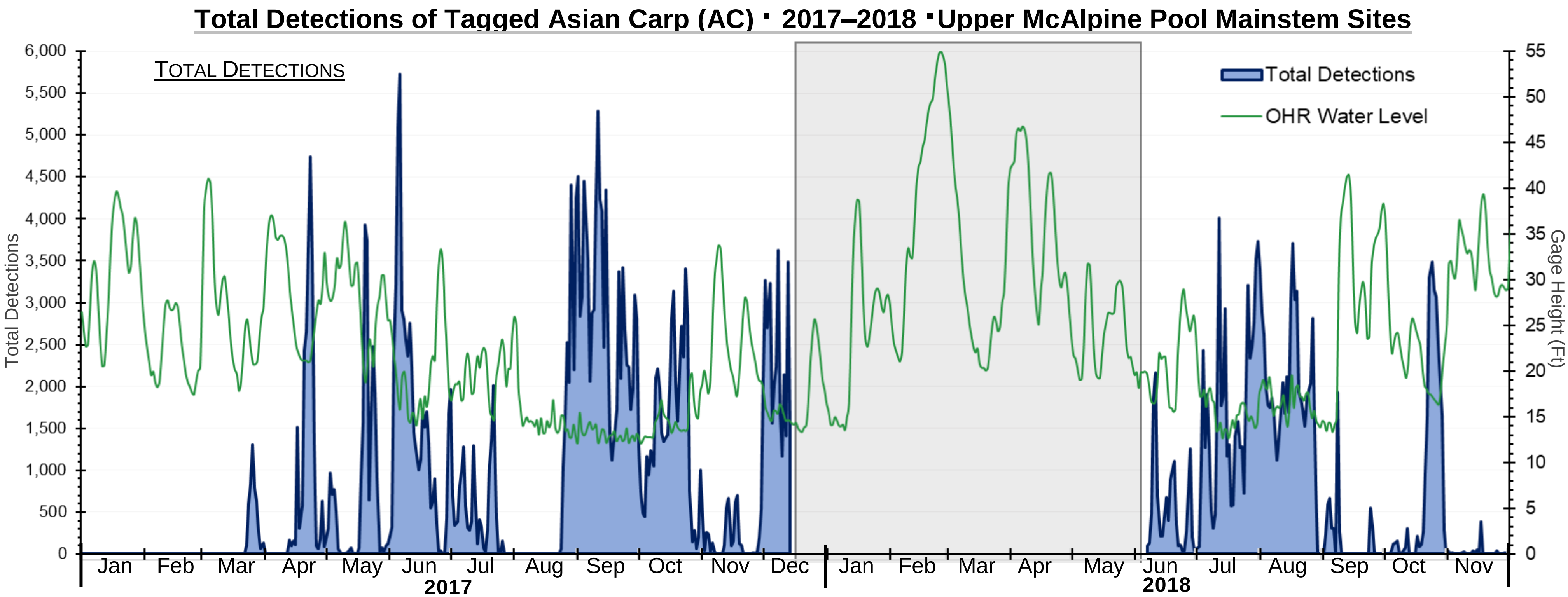


Figure 14. Daily totals of the overall tagged AC detections that were recorded during 2017-2018 by the stationary receivers associated with four mainstem Ohio River sites located near primary tributaries of the upper McAlpine Pool. The secondary line graph illustrates the Ohio River water levels that were measured at the time that these detections were recorded

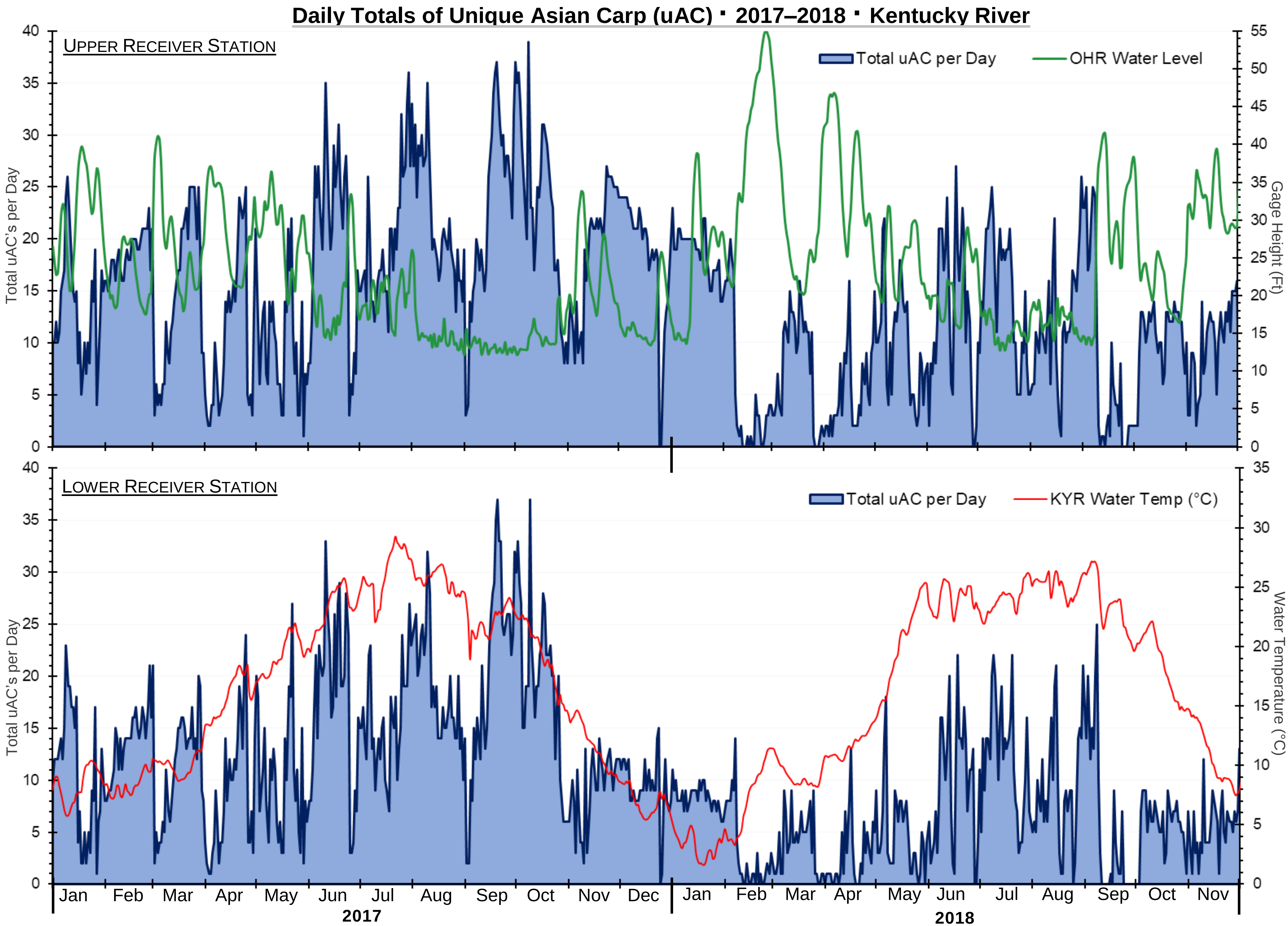


Figure 15. The daily amount of uniquely tagged AC (uAC) detected in 2017-2018 by stationary receivers occupying the upper and lower sites of the Kentucky River. The secondary line graphs illustrate both the level of the Ohio River and the water temperature recorded around the same time that these uAC were detected.

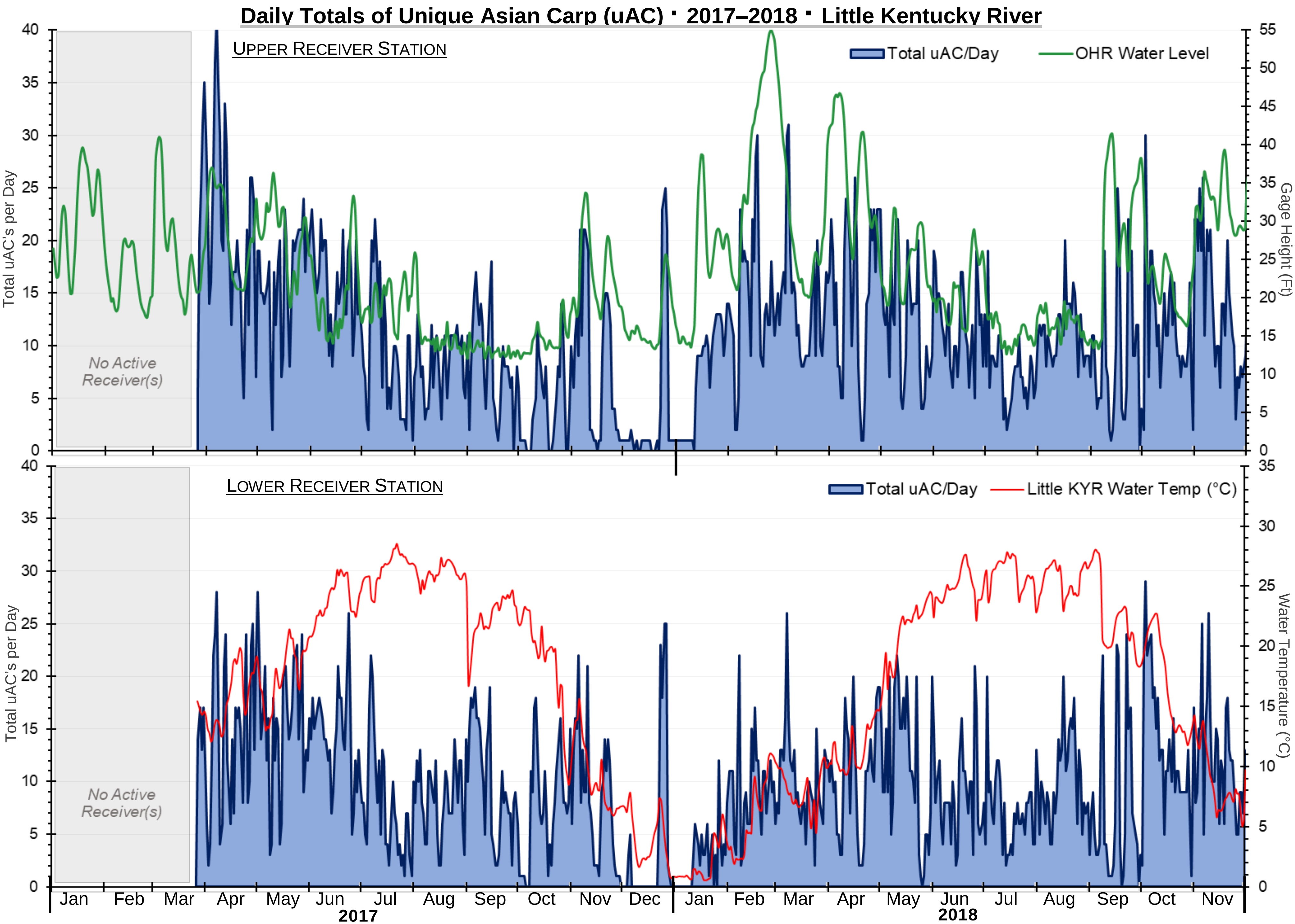


Figure 16. The daily amount of uniquely tagged AC (uAC) detected in 2017-2018 by stationary receivers occupying the upper and lower sites of the Little Kentucky River. The secondary line graphs illustrate both the level of the Ohio River and the water temperature recorded around the same time that these uAC were detected.

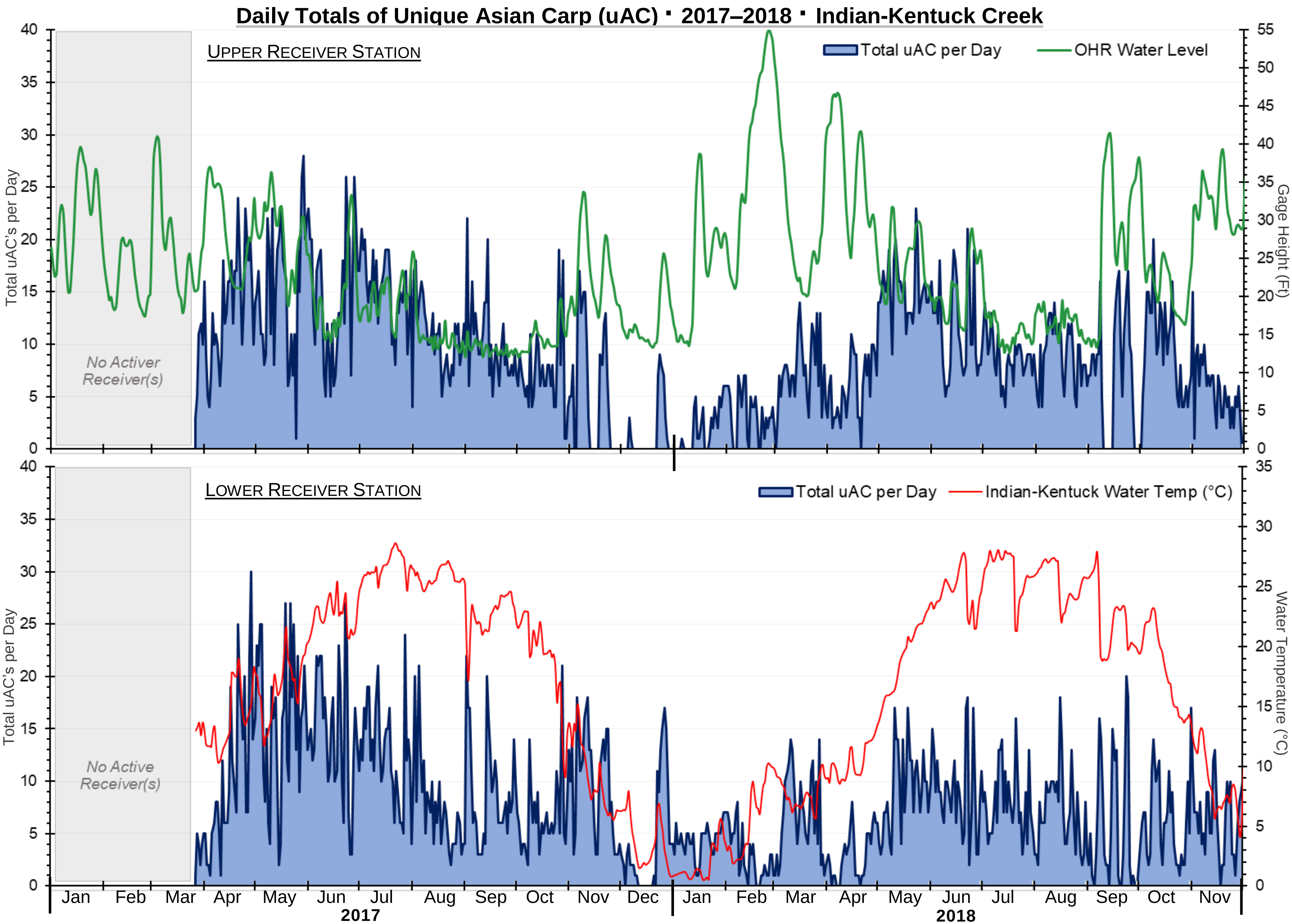


Figure 17. The daily amount of uniquely tagged AC (uAC) detected in 2017-2018 by stationary receivers occupying the upper and lower sites of the Indian-Kentuck Creek. The secondary line graphs illustrate both the level of the Ohio River and the water temperature recorded around the same time that these uAC were detected.

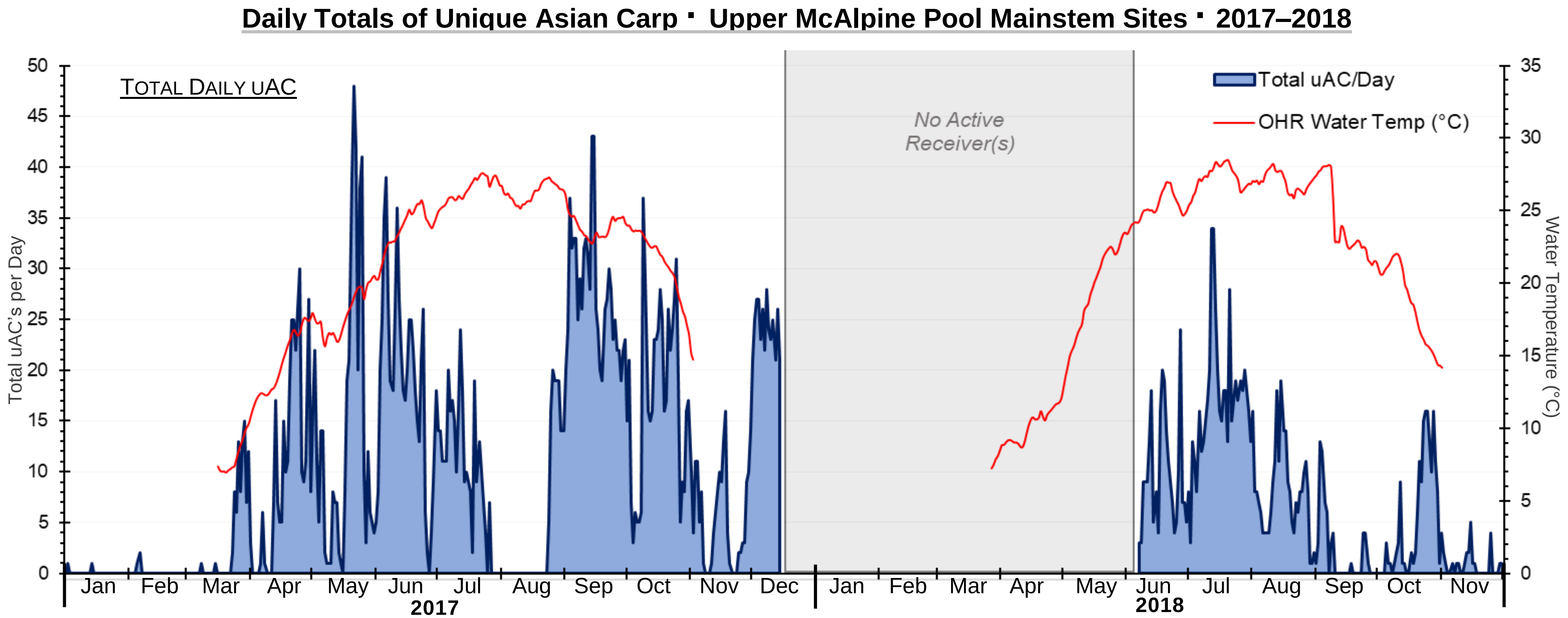


Figure 18. Combined daily totals of the uniquely tagged AC (uAC) that were detected in 2017-2018 by receivers occupying four mainstem Ohio River sites located near primary tributaries of the upper McAlpine Pool. The secondary line graph illustrates the water temperature at the time that the detections were made.

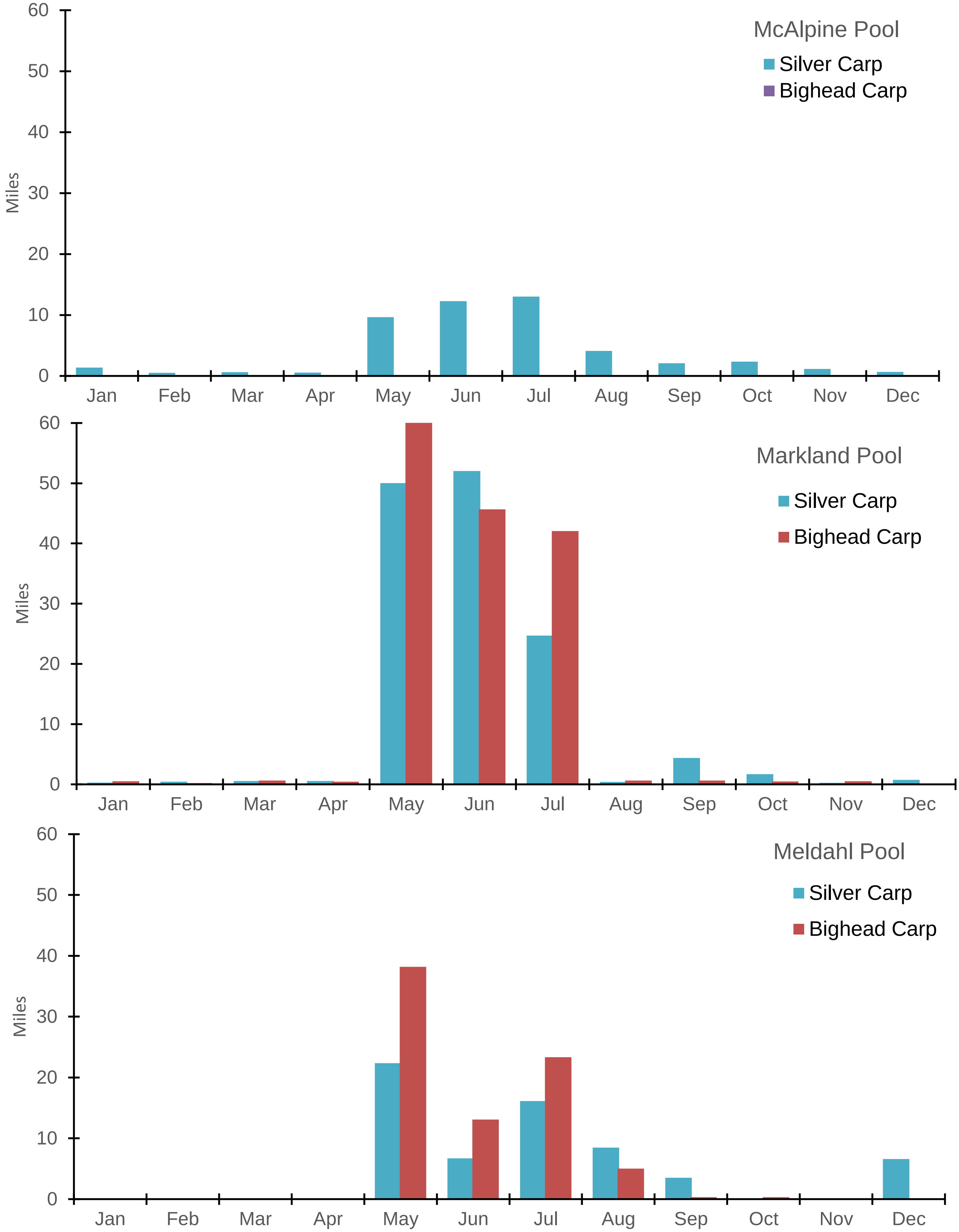


Figure 19.The mean monthly distances (in river miles) between the most upstream and downstream detections for tagged Bighead and Silver Carp in the three most active pools of the Telemetry Project. Only tagged carp that were detected by 2 or more receivers during 2018 were included in the analysis.

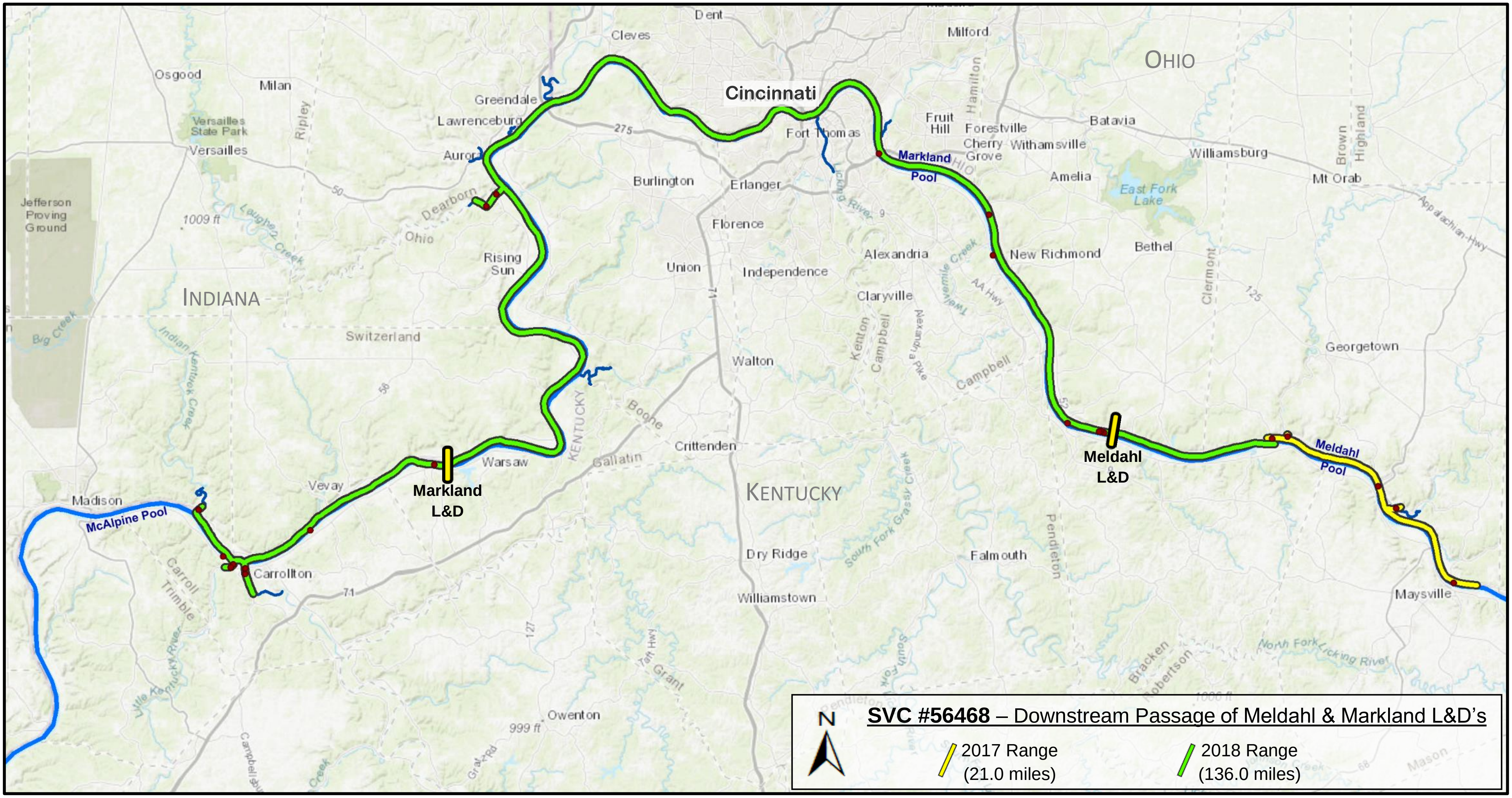


Figure 20. A map of the 2017-2018 estimated ranges for a Silver Carp (SVC) that was implanted with Tag #56468 after being collected from the Meldahl Pool in Spring 2017. Following its tagging procedure, SVC #56468 spent the 2nd half of 2017 within the boundaries of the lower Meldahl Pool. However, in 2018-02, SVC #56468 entered the lock chamber that would eventually allow it to pass through Meldahl L&D and then continue moving downstream through 2018-06, which was when it had successfully gained passage through Markland L&D as well.

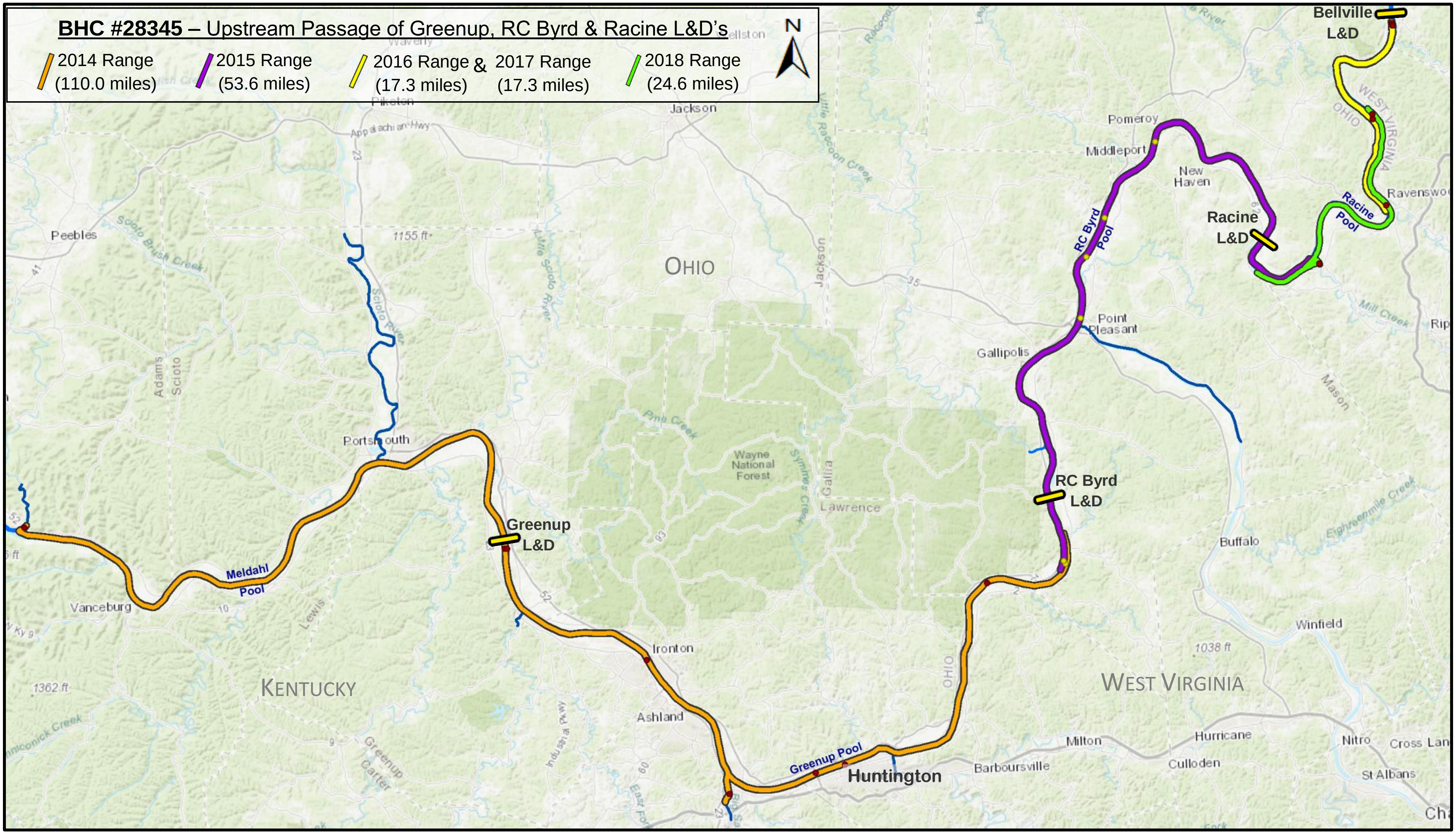


Figure 21. A 192-mile stretch across the four pools of the Ohio River that Bighead Carp (BHC) #28345 travelled during the 5 years (2014 -2018) that immediately followed its initial capture in 2013 by a contract angler. In order to reach its uppermost pool (Racine), BHC #28345 conducted a series of three upstream transfers between May 2014 and July 2015 that allowed it to pass through the dams at Greenup, RC Byrd and Racine L&D.

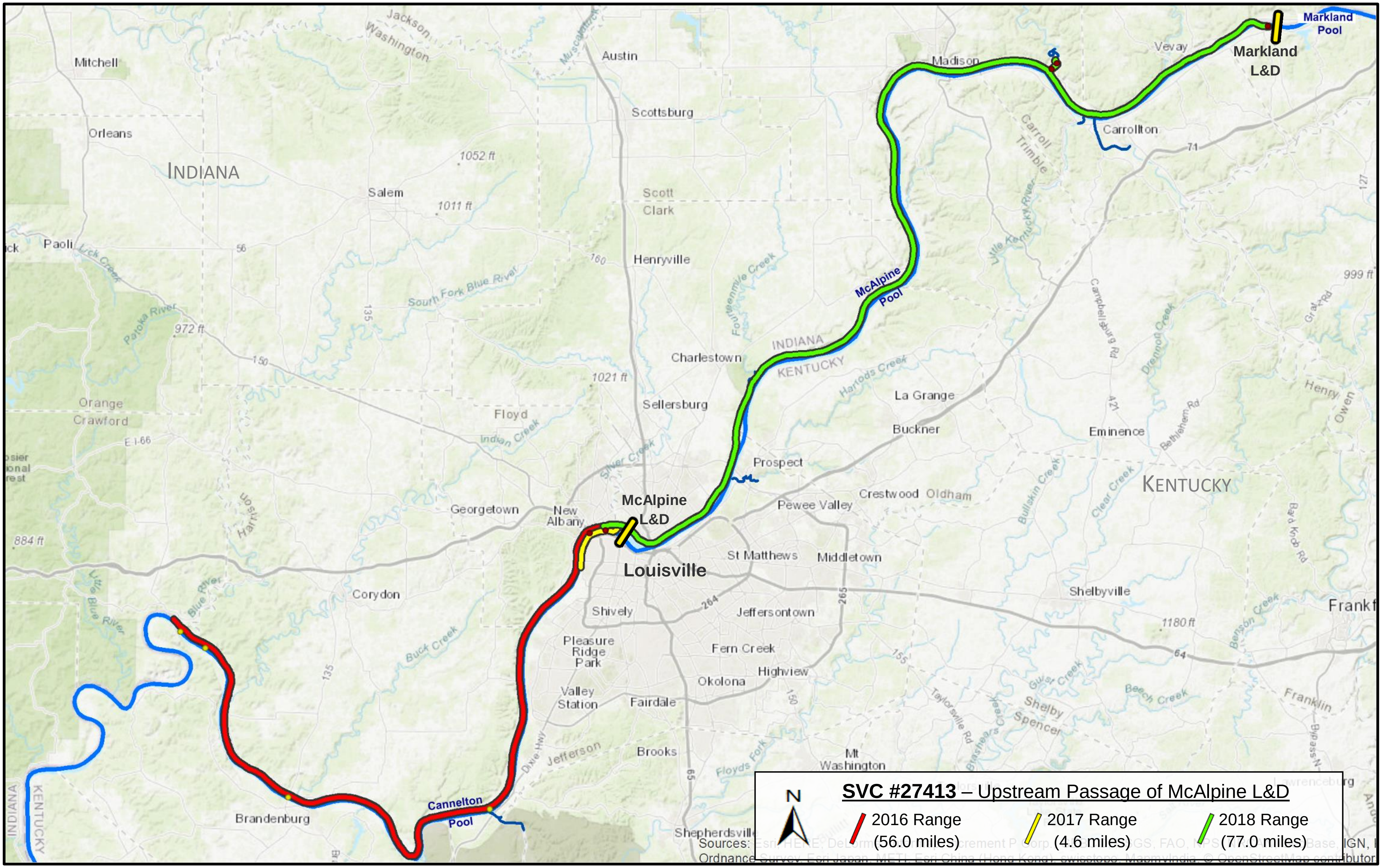


Figure 22. The estimated ranges (2016-2018) for Silver Carp (SVC) #27413 that was initially detected in June 2016 by a receiver in the upper Cannelton Pool. SVC #27413 remained in Cannelton for almost 2 years, but then early in 2018, it gained passage through McAlpine L&D as it continued to move upstream through the McAlpine Pool on its way to Indian-Kentuck Creek. SVC #27413 is one of only two tagged carp that have permanently transferred into an upstream pool.