Monitoring and Response of Asian Carp in the Ohio River

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Introduction:

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

Assembling information on the 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 in the Ohio River drainage. While some research is available about Asian carps in their native waters, there is relatively little information about their introduced range in the Ohio River. This project provides an ongoing, coordinated approach to monitor relative abundance and determine community impacts of Asian carp in the Ohio River.

Objectives:

- Conduct targeted sampling for surveillance, early detection, and distribution of Asian carp upstream of the McAlpine lock and dam complex to the R.C. Byrd lock and dam complex.
- Monitor Asian carp population dynamics in the Ohio River upstream of the McAlpine lock and dam complex to the R.C. Byrd lock and dam complex.
- States augment protocols for existing annual fisheries surveys as needed to include collection, identification, data gathering and reporting of Asian carps.

Methods:

Asian carp monitoring was conducted over two periods, each intended to be approximately 20 days in length: summer (22nd July – 13th Aug) and fall (19th Oct – 04th Dec). Originally pools were segmented into four macrohabitat types with 48 electrofishing sites (24 random, 24 fixed) and 12 gill netting sites (6 random, 6 fixed) per pool. All sites were remotely selected to evenly distribute sampling effort across habitat types and incorporate suggested sites from previous sampling efforts in 2013 and 2014. Macrohabitat types included island back-channels, embayments, dam tail-waters, and tributaries and were selected in both the upper and lower sections of the Greenup, Meldahl, Markland, and McAlpine pools. This method was amended for the fall sampling season given logistic difficulties during summer sampling. Because sampling efforts took place over a large stretch of the Ohio River, run time between sites and the location of access points played a critical role in the coordination and feasibility of sampling. For the fall sampling period, sites were chosen to maximize sampling effort while still sampling a representative proportion of the available habitat. This reduced electrofishing effort to 24 runs per pool and gill netting effort to 8 sets per pool.

Electrofishing runs were standardized with an output of 6 amperes at 120 pulses per second (pulsed DC) for the duration of a 15-minute run with one dipper. Runs were conducted in a downstream direction from their GPS location. All fish species were collected and held in a live well until the end of a run. In areas where large schools of Clupeiformes or various Cypriniformes species were encountered, as many fish as possible were dipped while maintaining a consistent speed. Fish were identified to species, enumerated, and released during summer monitoring. During fall monitoring, the weight and total length

of each species was collected in addition to their identity and count before release. All small shad-like species were closely examined before release to avoid misidentifying young Asian carps.

Gill nets were up to 100 yards in length, between 10' – 12' in depth, and constructed of large mesh (3"–5" bar mesh). Initially a set consisted of <500 yards of net, set for 20 minutes while creating noise and water disturbance within 150 yards of the set to drive fish into the entanglement. Soak time was altered to a longer 120 – 180 minutes with active noise and disturbance every 30 minutes to promote higher yields. All fish were identified to species, enumerated and released during summer monitoring. During fall monitoring, the weight and total length of each species was collected in addition to their identity and count before release.

Upon capture, all Asian carp (*Hypophthalmichthys spp.*) and grass carp (*Ctenopharyngodon idella*) were examined for the presence of tags (jaw tags and sonic implants attached in 2013 and 2014), identified, geo-located, weighed, and measured. In most cases, Asian carp and grass carp were euthanized and the left pectoral fin ray was collected for aging (Beamish 1981, Schrank and Guy 2002, Williamson and Garvey 2005, Seibert and Phelps 2013). All other carp captured were tagged with a distinct jaw tag and a 95mm VEMCO 69 kHz – V16 acoustic-coded transmitter for tracking purposes and released where captured.

During removal a subsample of lengths, weights, and spines from over 200 euthanized Asian carp were taken for the purpose of assessing population characteristics of carp in the Cannelton and McAlpine pools. Maximum total length in inches was taken along with weight in pounds. Pectoral spines were collected and sectioned on a low speed saw for aging. Cross sections were placed in water with a dark background and aged with reflected light under a dissecting microscope. Each fish was aged blindly by two readers. Spines where ages differed too widely or were damaged were excluded from analyses. Spines that differed to a lesser degree were recounted, and an agreed upon age was assigned to each fish. Age data was used to calculate the mean length (range, 95% confidence interval) at each age, frequency at age, and mortality using a catch curve regression.

Results:

Summer Electrofishing Sampling and Catch – Summer electrofishing throughout McAlpine, Markland, Meldahl, and Greenup pools in 2015 produced a CPUE of 180.62 fish/hour (Table 1). A total of 96 transects yielded a catch of 4,358 fish composed of 46 different species. No bighead carp were sampled via electrofishing in any of the four pools during summer sampling. However, a total of 50 silver carp were obtained in the McAlpine pool. All shad-like fish were closely examined; no YOY fish were detected. Gizzard shad and emerald shiners made up over fifty percent of the total catch by number (Table 2).

Fall Electrofishing Sampling and Catch – Fall electrofishing in McAlpine, Markland, Meldahl, and Greenup pools in 2015 was higher than the total CPUE during the summer (296.65 fish/hour; Table 3). A total of 87 transects were completed to yield 6,290 fish composed of 48 different species. No bighead carp were captured in any of the four pools during summer sampling. A total of five silver carp were obtained from the McAlpine pool. All shad-like fish were closely examined; no YOY fish were detected. Emerald shiner, gizzard shad and smallmouth buffalo dominated the species composition by number (Table 2).

Summer Gill Net Sampling and Catch – Summer gill netting effort was conducted in the McAlpine, Markland, Meldahl, and Greenup pools. Many fish species showed decreased movement during the hot summer months. As a result, we did not expect to catch high numbers of fish in gill nets during the summer. A total of 10,733 yards of net were deployed through 55 sets and yielded 78 fish comprising 10 species (Table 4). One bighead carp was captured in the McAlpine pool while two bighead carp were

caught in the Meldahl pool. No silver carp were captured with the use of nets in any of the pools. Smallmouth buffalo, paddlefish, flathead catfish, and common carp made up approximately 90% of the total summer catch (Table 5).

Fall Gill Net Sampling and Catch – Fall gill netting effort was conducted in the McAlpine, Markland, Meldahl, Greenup and Racine pools. A total of 3,475 yards of net were deployed through 14 sets and yielded 66 total fish comprising 10 species (Table 6). No bighead carp were captured in any of the pools. However, four silver carp were captured in the McAlpine pool. Paddlefish, flathead catfish, bigmouth buffalo, blue catfish, common carp, and smallmouth buffalo made up approximately 90% of the total fall catch (Table 5).

Population Parameters –Fin rays from silver and bighead carp were collected from all euthanized fish during this project, as well as the control and removal project, and compiled for this analysis. Because the sample sizes of bighead and grass carp were small, all further analysis focused on silver carp. Silver carp captured in the McAlpine (N = 78) and Cannelton (N = 105) pools were analyzed separately.

The mean length of silver carp was 31.92in (S.E. = 0.337) from McAlpine pool, and the length frequency distribution was skewed toward larger fish (Figure 1). The majority of silver carp from McAlpine pool was five years of age (N = 20; range = 2-10 years; Table 7). A weight-length regression using LOG10 transformed data produced a regression line of $Log_{10}[grams] = Log_{10}[millimeters](2.94) - 4.79$ ($r^2 = 0.80$). Total annual mortality (A) was calculated to be 48.8% using a weighted catch-curve regression for ages five through ten ($r^2 = 0.83$, $Z = 0.59$). A von Bertalanffy growth curve returned an asymptotic average maximum length of 814.18mm (32.05in) and a growth rate (k) = 3.312.

The mean length of silver carp in Cannelton pool was 32.09in (S.E. = 0.233), and the length frequency distribution appeared to be normal (Figure 2). The dominant age of silver carp from Cannelton pool was four years of age (N = 32; range = 2-8; Table 7). Weight-length regression using LOG10 transformed data produced a regression line of $Log_{10}[grams] = Log_{10}[millimeters](2.92) - 4.73$ ($r^2 = 0.89$). Total annual mortality (A) was also calculated using a weighted catch-curve regression; fish between the ages of four and eight were found to have an annual mortality of 37.5% ($r^2 = 0.93$, $Z = 0.47$). A von Bertalanffy growth curve returned an asymptotic average maximum length of 785.45mm (30.92in) and a growth rate (k) = 0.287.

Discussion:

The monitoring and response of Asian carp in the Ohio River project in 2015 was the greatest effort to date to understand the distribution and abundance of Asian carp above McAlpine Locks and Dam in the Ohio River, the leading edge of invasion. The project was designed to include intensive spring and fall samples in each pool, but the timing of project planning and funding availability delayed spring sampling into the summer. As expected, the total number of fish captured via electrofishing was higher in the fall, likely a result of seasonal changes in water temperature and fish activity. There were 18 (31% of species richness) unique species captured between seasons and 56 species captured in both sampling seasons. Asian carp were only captured in the McAlpine pool, which reflects the higher relative abundance of invasive carps in this pool in comparison to the three pools above it. The majority of Asian carp captured in the monitoring project were encountered in slack water habitats behind islands or in tributaries. Since few Asian carp were captured during this project, it is difficult to draw conclusions on the habitats where Asian carp are found. As additional years of data become available, trends in abundance by habitat will become apparent.

Gill netting in the fall also produced a higher CPUE than in the summer. Out of the 12 species captured, there were four unique species captured between seasons. Although five silver carp were captured in the McAlpine pool, gill nets were not an efficient gear for capturing silver carp in low density areas in either

season; nets are currently the only form of gear that has repeatedly captured bighead carp. Bighead carp were only caught in the summer seasons and were captured in two of the four pools sampled (McAlpine and Meldahl). Specific details of how gill nets are built can affect their ability to capture Asian carp (Ronnie Hopkins, personal communication). As a result, we will incorporate multiple gill net types into 2016 sampling protocols.

The silver carp captured in Cannelton and McAlpine pools show characteristics of a population on the invasion front. All of the fish encountered were large (< 24"), and their corresponding predicted weights suggested that resources are not limiting for this population. Ohio River silver carp show similar condition to those from other locations when looking at length-weight relationships despite a lack of observed lengths under 24" (Table 8). While fish ages ranged from 2-10 in these populations, there was a lot of variation in growth patterns among these fish. Many younger fish appeared to demonstrate rapid growth and quickly reached comparable sizes with much older fish. This was likely the result of changing dynamics within the population. Tracking data suggests that some silver carp are capable of traveling very long distances, which could help explain this variation. Additionally, silver carp spend much of their time in tributaries of the Ohio River. Variation in specific characteristics of each watershed may play a role in the growth of fish between tributaries.

The theoretical maximum calculated ages (10.6-11.6) and maximum ages (8-10) reflected a population with little or no exploitation. Maximum reported ages for silver carp vary by water body and range from 10 – 20 years of age (Kolar et al. 2005). Estimated annual mortality was higher in the McAlpine pool (48.8%) than Cannelton pool (37.5%), but these values are at the low end (42-77%) of mortality estimates from other locations in Midwestern Rivers (Seibert et al. 2015). Asian carp populations are driven by occasional strong year classes. However, the upper Ohio River silver carp population showed relatively consistent representation across year classes, suggesting a less dynamic recruitment source than other systems (Figures 3 and 4).

Data from 2015 marked a baseline on which to measure future trends. When more years of data are available it will be important to compare population parameters of Asian carps between pools and across different habitats. Over time this will inform and provide a measure of the effectiveness in control efforts such as removal and barrier defenses. In addition, monitoring potential community impacts as Asian carp either invade new water or are pushed back down the system will allow a more quantitative measure of the success in managing these invasive species.

Recommendations:

We recommended that monitoring for 2016 continue using the consistent and repeatable design established in 2015. This will allow comparison in future years and help characterize and inform management decisions necessary for the mitigation of Asian carp impacts in the Ohio River drainage. The current design of this project should be retained, but other sampling techniques may be utilized in the future to expand the scope of sampling for more robust monitoring. In addition, summer sampling should be moved up to April so that catch rates more accurately reflect relative abundances of riverine species, which are more active in the spring. It should be mentioned that the current level of Asian carp monitoring is a skeleton project given the size and dynamics of the Ohio River and the Asian carp population therein. With more funding, a more thorough monitoring effort could be conducted, which would increase the geographic range and sampling effort with additional gear types.

Project Highlights:

- This project was an increase in effort to the ongoing "leading edge" project. Since 2013 various sampling efforts have resulted in a minimum of 889 Asian carp removed, 196 Asian carp tagged for tracking purposes and the surveying of over 10,000 fish comprising 58 different species from four pools in the Ohio River Basin.

- A total of 96 electrofishing transects in summer 2015 yielded a catch of 4,358 fish composed of 46 different species. No bighead carp were captured; however, a total of 50 silver carp were obtained out of the McAlpine pool.
- A total of 87 electrofishing transects in fall 2015 yielded 6,290 fish composed of 48 different species. No bighead carp were captured in any of the four pools but five silver carp were obtained from the McAlpine pool.
- A total of 10,733 yards of net were deployed through 55 sets during summer sampling and yielded 78 fish comprised of 10 different species. One bighead carp was captured in McAlpine while two bighead carp were caught in Meldahl. No silver carp were captured with the use of nets in any of the pools.
- A total of 3,475 yards of net were deployed through 14 sets during fall and yielded 66 total fish comprised of 10 different species. No bighead carp were captured in any of the pools. However, four silver carp were captured in McAlpine.
- 62 total Asian carp were captured in the four pools sampled throughout the 2015 monitoring seasons using both gill netting and electrofishing.
- Capture numbers of Asian carp appear to reflect that McAlpine has a much higher density of invasive carps than the three pools above it.
- It is recommended that monitoring for 2016 continue now that a baseline sampling design has been established.

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Tables:

Table 1. Electrofishing effort and summaries of the resulting total catch including the number of fish, number of species, and catch per unit effort (fish per hour) of two species of Asian carp captured in four pools of the Ohio River from 22 July through 13 August, 2015. Standard errors are in parentheses.

	Ohio River Pool				
	McAlpine	Markland	Meldahl	Greenup	Total
Electrofishing Hours	5.43	5.53	5.75	8.04	24.75
Samples (transects)	19	22	23	32	96
All Fish (*N*)	458	1400	1040	1460	4358
Species (*N*)	23	27	31	36	46
Bighead Carp (*N*)	0	0	0	0	0
Silver Carp (*N*)	50	0	0	0	50
CPUE (fish/hour)	91.98 (22.9)	254.09 (31.3)	180.86 (32.7)	182.56 (13.6)	180.62 (13.3)

Table 2. Number of fish captured by species and percent of total catch in four pools of the Ohio River with electrofishing in summer (22 July - 13 August) and fall (19 October - 04 October) of 2015.

	Summer						Fall					
	Ohio River Pool						Ohio River Pool					
Species Captured	McAlpine	Markland	Meldahl	Greenup	Total	Percent	McAlpine	Markland	Meldahl	Greenup	Total	Percent
Alewife					0	0.000%		5			5	0.079%
BigmouthBuffalo	2	3	3		8	0.184%	3	4	3		10	0.159%
BlackBuffalo		2			2	0.046%			1		1	0.016%
BlackCrappie					0	0.000%	13	3	5	18	39	0.620%
BlackRedhorse					0	0.000%				1	1	0.016%
BlueCatfish			1		1	0.023%	2			1	3	0.048%
BluegillSunfish	2	69	20	50	141	3.235%	68	138	81	148	435	6.915%
BluntnoseMinnow				1	1	0.023%					0	0.000%
Bowfin				1	1	0.023%				4	4	0.064%
BrookSilverside	4			22	26	0.597%					0	0.000%
ChannelCatfish	5	15	12	23	55	1.262%	3	19	11	30	63	1.001%
CommonCarp	3	32	7	17	59	1.354%	7	20	26	20	73	1.160%
CrappieSpp				1	1	0.023%					0	0.000%
EmeraldShiner	58	319	289	294	960	22.028%	243	348	220	1525	2336	37.132%
FlatheadCatfish	10	10	6	31	57	1.308%	6	1		5	12	0.191%
FreshwaterDrum	17	38	29	93	177	4.061%	12	26	31	150	219	3.481%
GizzardShad	153	587	371	400	1511	34.672%	99	553	282	236	1170	18.598%
GoldenRedhorse		5	8	23	36	0.826%	19	7	5	36	67	1.065%
Goldeye				1	1	0.023%					0	0.000%
GrassCarp				1	1	0.023%		4	1		5	0.079%
GreenSunfish		1	2		3	0.069%	4	2	3		9	0.143%
HighfinCarpsucker				3	3	0.069%		1		1	2	0.032%
LargemouthBass	4	13	19	11	47	1.078%	48	33	111	71	263	4.181%
Logperch					0	0.000%	1	1			2	0.032%
LongearSunfish	2	10	7	1	20	0.459%	16	20	8	8	52	0.827%
LongnoseGar	31	56	53	163	303	6.953%	8	11	3	19	41	0.652%
MimicShiner					0	0.000%				2	2	0.032%
Mooneye			1	7	8	0.184%	1			6	7	0.111%
Muskellunge			2		2	0.046%			2		2	0.032%
NorthernHogSucker				3	3	0.069%					0	0.000%
OrangespottedSunfish			7		7	0.161%		3	1		4	0.064%
Quillback	6			14	20	0.459%	3	8	3	11	25	0.397%
RedearSunfish				2	2	0.046%	5	6	3	9	23	0.366%
RiverCarpsucker	36	66	53	97	252	5.782%	19	47	11	43	120	1.907%
RiverRedhorse					0	0.000%				9	9	0.143%
RockBass			1		1	0.023%					0	0.000%
Sauger	4	16	5	39	64	1.469%	6	8	12	54	80	1.272%
Saugeye				1	1	0.023%				4	4	0.064%
ShortheadRedhorse	20	1	3	9	33	0.757%	9	10	10	23	52	0.827%
SilverCarp	50				50	1.147%	5				5	0.079%
SilverChub					0	0.000%				3	3	0.048%
SilverRedhorse		3	3	8	14	0.321%	11	10	11	18	50	0.795%
SkipjackHerring	12	12	1	8	33	0.757%	7	12	2	1	22	0.350%
SmallmouthBass	4	5	6	7	22	0.505%	5	4	2	10	21	0.334%
SmallmouthBuffalo	25	94	87	85	291	6.677%	35	97	89	477	698	11.095%
SpotfinShiner		1	15	4	20	0.459%					0	0.000%
SpottedBass	3	12	13	4	32	0.734%	66	18	10	10	104	1.653%
SpottedSucker		9	6		15	0.344%	11	20	7	34	72	1.144%
StripedBass					0	0.000%	1	11	3	2	17	0.270%
ThreadfinShad				1	1	0.023%					0	0.000%
Walleye					0	0.000%				3	3	0.048%
Warmouth		1	1		2	0.046%	6	6	1	2	15	0.238%
White/StipedBassHybrid				12	12	0.275%	1	1		8	10	0.159%
WhiteBass	6	12	4	16	38	0.872%	6	13	4	5	28	0.445%
WhiteCrappie	1	8	5	7	21	0.482%	6	70	16	9	101	1.605%
YellowPerch					0	0.000%				1	1	0.016%
Totals	458	1400	1040	1460	4358		755	1540	978	3017	6290	

Table 3. Electrofishing effort and summaries of the resulting total catch including the number of fish, number of species, and catch per unit effort (fish per hour) of two species of Asian carp captured in four pools of the Ohio River from 19 October through 04 December, 2015. Standard errors are in parentheses.

	Ohio River Pool				
	McAlpine	Markland	Meldahl	Greenup	Total
Sample Dates	19 Oct - 04 Dec				
Electrofishing Hours	5.50	4.73	4.75	6.46	21.44
Samples (transects)	22	18	19	28	87
All Fish (*N*)	755	1540	978	3017	6290
Species (*N*)	34	35	32	39	48
Bighead Carp (*N*)	0	0	0	0	0
Silver Carp (*N*)	5	0	0	0	5
CPUE (fish/hour)	137.45 (29.9)	332.33 (46.3)	205.89 (49.7)	460.38 (79.2)	296.65 (33.0)

Table 4. Gill netting effort and summaries of the resulting total catch including the number of fish, number of species, and catch per unit effort (fish per gill net set) of two species of Asian carp captured in five pools of the Ohio River from 22 July through 13 August, 2015. Standard errors are in parentheses.

	Ohio River Pool				
	McAlpine	Markland	Meldahl	Greenup	Total
Sample Dates	22 July - 13 Aug				
Gill Netting Effort (Yds)	2400	2700	2350	3283	10733
Net Sets	16	12	12	15	55
All Fish (*N*)	30	23	23	2	78
Species (*N*)	5	5	6	2	10
Bighead Carp (*N*)	1	0	2	0	3
Silver Carp (*N*)	0	0	0	0	0
Fish per Set	0.924 (0.368)	0.839 (0.289)	1.083 (0.313)	0.044 (0.044)	0.703 (0.149)

Table 5. Number of fish captured by species and percent of total catch in four pools of the Ohio River with gill netting in summer (22 July - 13 Aug) and fall (19 Oct - 04 Dec) of 20

	2015 Summer Monitoring Gill Netting						2015 Fall Monitoring Gill Netting					
	22 July - 13 Aug						19 Oct - 04 Dec					
	Pool						Pool					
Species Captured	McAlpine	Markland	Meldahl	Greenup	Total	Percent	McAlpine	Markland	Meldahl	Greenup	Racine	Total
BigheadCarp	1		2		3	3.846%						0
BigmouthBuffalo			1		1	1.282%			1		10	11
BlueCatfish	1				1	1.282%		2	1		3	6
BluegillSunfish		1			1	1.282%						0
CommonCarp	2	2			4	5.128%			1		5	6
FlatheadCatfish	1	2	1	1	5	6.410%					12	12
FreshwaterDrum	1				1	1.282%					1	1
LongnoseGar			1		1	1.282%			1			1
Paddlefish	1	7	3		11	14.103%	4				14	18
SilverCarp					0	0.000%	4					4
SkipjackHerring					0	0.000%					1	1
SmallmouthBuffalo	23	11	15	1	50	64.103%	5		1			6
Totals	30	23	23	2	78		13	2	5	0	46	66

Table 6. Gill netting effort and summaries of the resulting total catch including the number of fish, number of species, and catch per unit effort (fish per yard of webbing) of two species of Asian carp captured in five pools of the Ohio River from 19 October through 04 December, 2015. Standard errors are in parentheses.

	Ohio River Pool					
	McAlpine	Markland	Meldahl	Greenup	Racine	Total
Sample Dates			19 Oct - 04 Dec			
Gill Netting Effort (Yds)	1833	397	695	0	550	3475
Net Sets	8	2	3	0	1	14
All Fish (*N*)	13	2	5	0	46	66
Species (*N*)	3	1	5	0	7	10
Bighead Carp (*N*)	0	0	0	0	0	0
Silver Carp (*N*)	4	0	0	0	0	4
Fish per Set	1.146 (0.560)	1.000 (0.000)	1.167 (0.601)	N/A	46.00 (N/A)	4.333 (3.222)

Table 7. Mean length, standard error, and 95% confidence intervals at age for silver carp collected in the Cannelton and McAlpine pools during removal efforts from August - October 2015.

		Age (years)								
		2	3	4	5	6	7	8	9	10
McAlpine	N	1	9	12	20	18	12	5	0	1
	Mean TL (in)	36.00	31.61	30.71	31.34	32.48	32.87	32.38	NA	32.60
	Std Error	NA	0.43	0.97	0.79	0.61	0.78	1.58	NA	NA
	Low 95% CI	NA	30.62	28.57	29.68	31.20	31.16	27.99	NA	NA
	High 95% CI	NA	32.60	32.83	33.00	33.77	34.58	36.76	NA	NA
Cannelton	N	2	17	32	23	16	11	4	0	0
	Mean TL (in)	32.70	32.30	32.34	31.81	32.01	31.83	31.60	NA	NA
	Std Error	2.50	0.52	0.35	0.50	0.64	0.87	2.43	NA	NA
	Low 95% CI	21.95	31.20	31.63	30.78	30.65	29.90	23.88	NA	NA
	High 95% CI	43.45	33.42	33.05	32.84	33.37	33.75	39.32	NA	NA

Table 8. Estimated weights at two lengths for Silver carp from published data collected throughout the Silver carp range in the Mississippi River basin. Amended from Hayer et al. 2014.

System: specific local	Predicted weight for 450mm (g)	Predicted weight for 800mm (g)	Reference
Ohio River: McAlpine Pool	1024	5560	This report
Ohio River: Cannelton Pool	1040	5584	This report
Tennessee River: Kentucky Lake	803	5743	KDFWR data
Missouri River tributary: James River	981	5869	Hayer et al. 2014
Illinois River	972	5856	Irons et al. 2011
Missouri River tributary: Big Sioux River	970	6150	Hayer et al. 2014
Middle Mississippi River	915	5477	Williamson and Garvey 2005
Missouri River: Interior Highlands	900	5453	Wanner and Klumb 2009
Missouri River: Gavins Point	788	6628	Wanner and Klumb 2009
Missouri River tributary: Vermillion River	748	3971	Hayer et al. 2014

Figures:

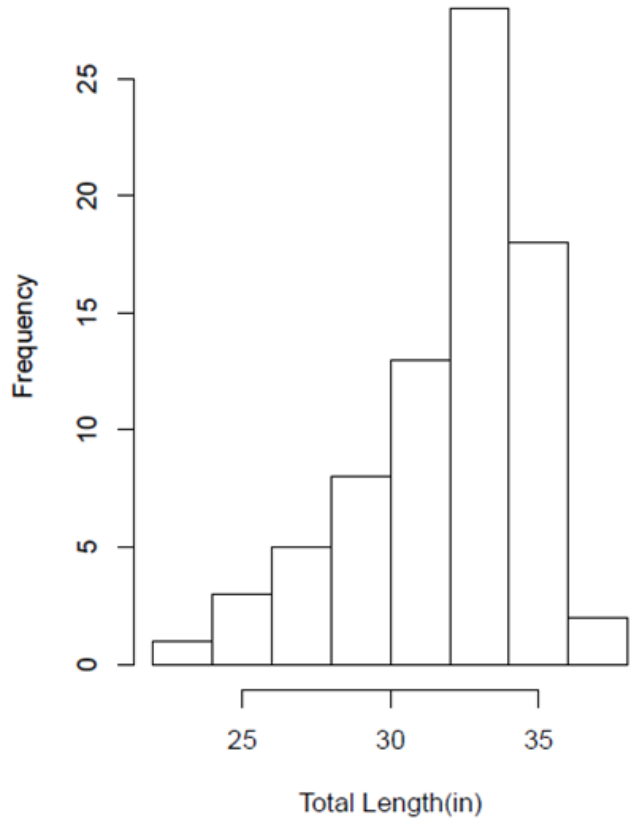

Figure 1. Length frequency of Silver carp captured in the McAlpine pool of the Ohio River in 2015 (N = 78).

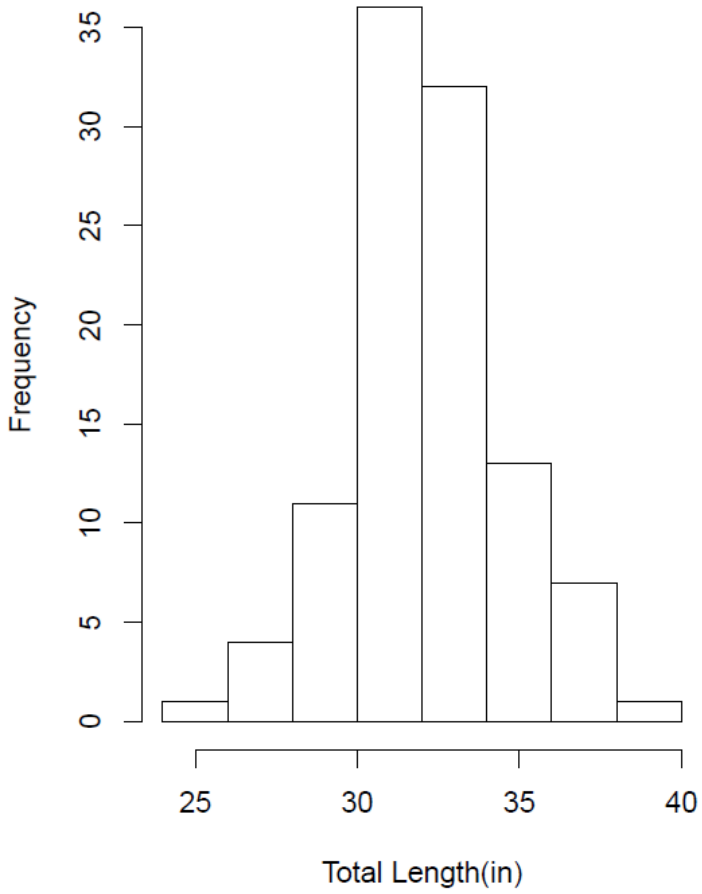

Figure 2. Length frequency of Silver carp captured in the Cannelton pool of the Ohio River in 2015 (N = 105).

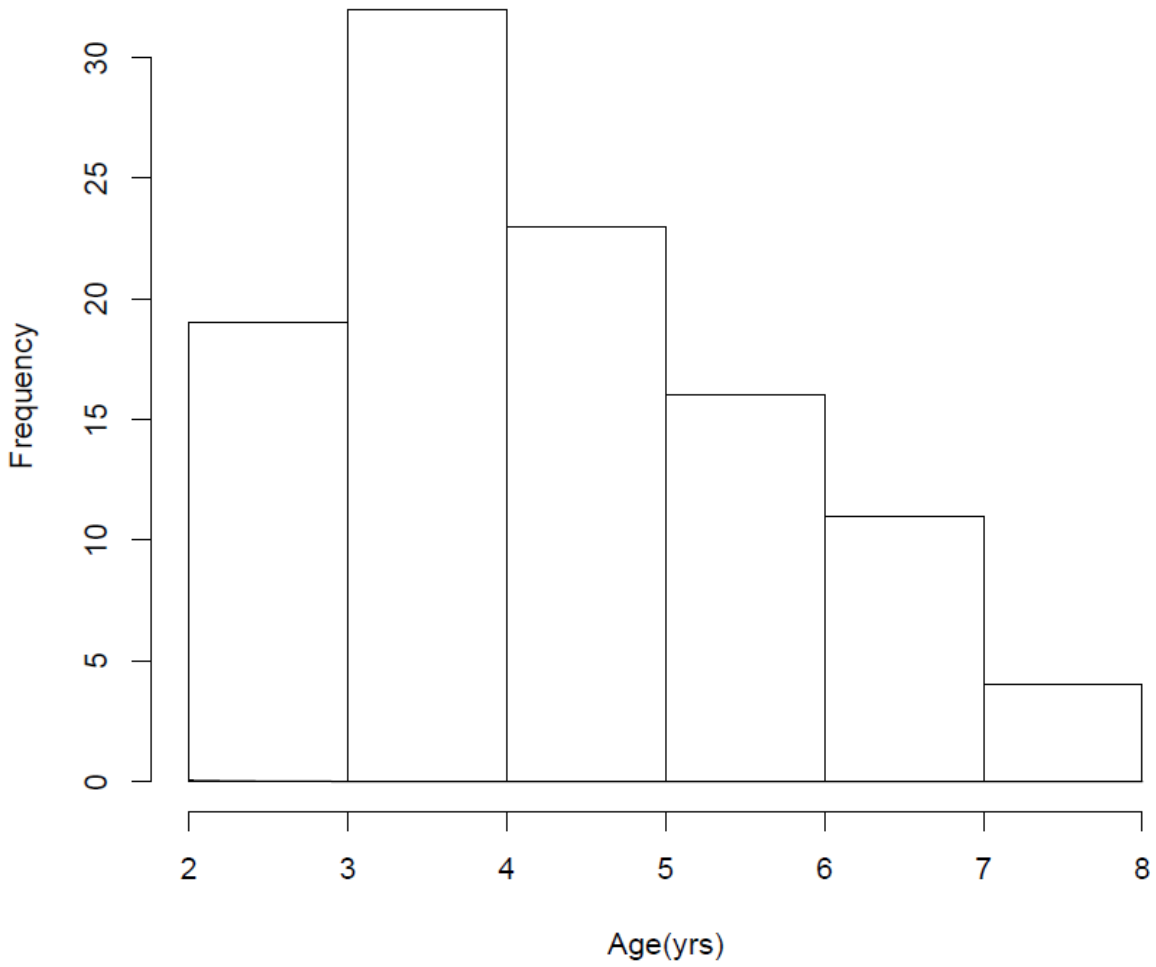

Figure 3. Frequency at age of Silver carp collected in Cannelton Pool of the Ohio River in 2015.

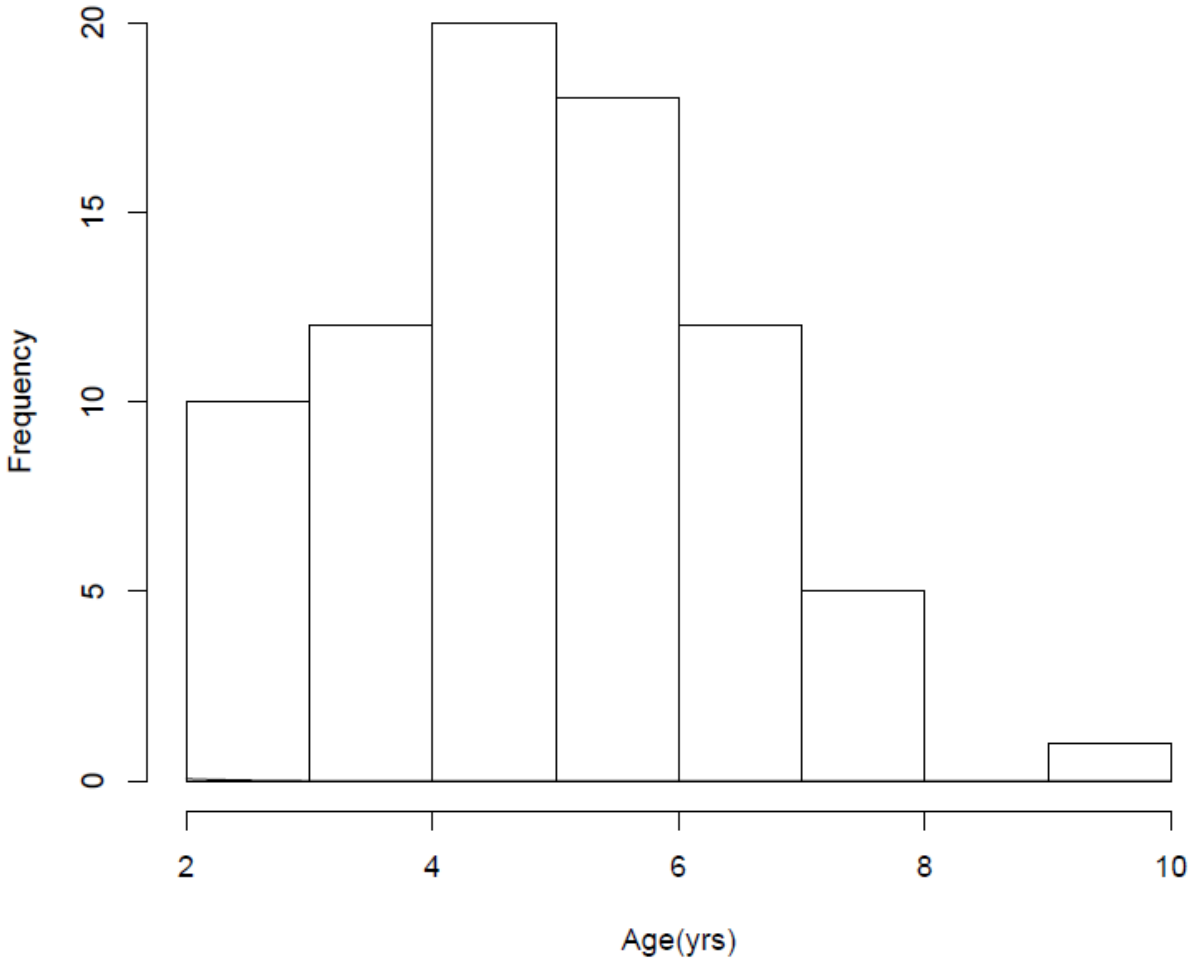

Figure 4. Frequency at age of Silver carp collected in McAlpine Pool of the Ohio River in 2015.