Distribution, movement, and lock and dam passage of Asian carp in the Ohio River through acoustic telemetry 2018 Report

Geographic Location: The Ohio River from Cannelton pool near Leavenworth, IN, to 2.5 miles upstream of the Willow Island Lock and Dam near Eureka, WV.

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

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

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

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

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

Project Objectives:

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

Project Highlights:

- An extensive array of 158 stationary receivers was deployed during 2018, which recorded nearly 8 million detections of 231 Silver and Bighead carp throughout five Ohio River pools.
- Most of the fish tagged during the course of this study remained in the Ohio River pool where they were tagged. Nearly 73% of Bighead Carp and over 78% of Silver Carp have made net movements of five miles or less both upstream and downstream from first to last detection of this year.
- Preliminary pool-to-pool transition probabilities for each species have been estimated.

- Annual survival for Silver Carp was estimated to be nearly 65%, while Bighead Carp survival was over 68%, but with greater confidence interval margins.

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

Ultrasonic Transmitter Tagging: Adult Bighead and Silver carp were surgically implanted with ultrasonic transmitters (Vemco, Model V16-6H; 69 kHz) which provide individual identification. The V16-6H coded transmitters are nominally programmed to transmit a signal every 40 seconds yielding a battery life of 1,825 days. Fish being tagged were collected by Agency personnel from the Cannelton, McAlpine, Markland, and Capt. A. Meldahl pools. Prior to surgery, fish were measured for total length (mm) and weight (g), and visually or manually sexed (if possible). Previously, tagged fish were fitted with an external jaw tag applied around the dentary bone (lower jaw) (National Tag Co. #1242 F9). However, due to some evidence of these jaw tags negatively affecting the jaws of tagged fish, lock-on tags inserted posterior to the dorsal fin were used for all fish tagged in 2018 (Floy Tag & Manufacturing, Inc. FT-4 Lock-on tag with clear over-tubing). Gill nets and Direct Current (DC) boat electrofishing were used to capture Asian carp for tagging. Efforts were concentrated in areas that are attractive to Asian carp such as side channels, backwaters, and tributary creeks and rivers.

Ultrasonic receiver array: An array of VR2W and VR2AR receivers was redeployed in the river in spring 2018. Receivers were placed above and below lock and dams, in the lower portions of major tributary streams, and at regular intervals between lock and dams. Receiver data were downloaded monthly or as often as possible. Mainstem Ohio River VR2W receivers were removed from the river over the winter months to avoid loss of equipment to ice flows.

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

Statistical Analyses: Pool-to-pool transition probabilities, mainstem river to tributary transition probabilities, annual survival, and detection probabilities were estimated using the “Multi-state with Live Recaptures” analysis in Program MARK (G.C. White, Dept. of Fish, Wildlife, and Cons. Bio., Colorado State University, Fort Collins, CO). Encounter histories were constructed for each individual by determining the pool of last known detection for each month for each year (June 2013 through December 2018). Because individuals were tagged throughout the duration of this study, not all individuals have a complete encounter history (maximum of 67 possible time periods). Encounter histories of tagged carp whose tag’s battery had expired were right censored and removed from the estimation procedures. Known harvested fish were coded as having transitioned into a “dead” state in which detection and survival probabilities were fixed at one and transition probabilities out of the “dead” state were fixed at zero (Coulter et al. 2018). These encounter histories were then used to construct models to estimate pool transition, survival, and detection probabilities for each species by pool and month. Numerous models were constructed that tested whether data supported more complex models beyond time-invariant parameter estimates (e.g., survival constant across all months vs variable across months) and spatially invariant parameter estimates (e.g., survival is constant across all pools vs variable across pools). The best models for each species were selected based on the Akaike’s information criterion corrected for small sample size (AIC_c); a difference in AIC_c values exceeding two was taken as evidence that a model outperformed a competing model, with smaller values being better.

Results and Discussion:
Receiver Array Placement - Mainstem and tributary VR2W receivers were installed from late March through early May, as well as two newly deployed receivers above McAlpine Locks and Dam in June to help determine dam passage (Figure 1). The sole mainstem VR2AR acoustic release receivers deployed above Belleville Dam was never recovered during the spring of 2018, resulting in the discontinuation of mainstem VR2AR use. An attempt to retrieve the VR2AR receiver from Ohio Brush Creek in the spring of 2018 was initially unsuccessful, however, it was later recovered and returned to USFWS by a private citizen. Plans are in place to redeploy the receiver in Ohio Brush Creek in the spring of 2019. The VR2AR receiver in the Big Sandy River was successfully offloaded and redeployed in both the spring and fall of 2018. Figure 1 illustrates the locations of VR2W and VR2AR receivers deployed in 2018. The receiver array covered over 500 river miles (RM) of the Ohio River from Leavenworth, IN upstream to Eureka, WV.

Receivers were generally concentrated within the Capt. A. Meldahl pool during 2015 through 2018 due to a concurrent catfish telemetry study being conducted by the Ohio Department of Natural Resources Division of Wildlife (ODNR DOW) within that pool. By using the same telemetry equipment, both studies were able to share the fish detection data. Recorded detections were downloaded on a monthly schedule and data uploaded to an FTP site maintained by ODNR DOW. Similarly, West Virginia Division of Natural Resources was conducting a catfish telemetry study within the R. C. Byrd pool, which will lead to a greater number of receivers and constant monitoring within the pool in the coming years.

Receivers were offloaded or removed in the winter of 2018 to avoid loss due to winter flooding, ice flows, and commercial barge strikes. Due to extensive flooding in the fall of 2018, many of the mainstem and tributary receivers throughout the entire stretch of the array were lost. All but one receiver within the lock chambers and approaches were offloaded and replaced.

Fish Tagging Efforts– To date 537 Asian carp have been surgically implanted with acoustic transmitters from the Cannelton, McAlpine, Markland, Capt. A. Meldahl, and R. C. Byrd pools of the Ohio River (Table 2). Of the 537 tagged carp, three have been found deceased and 19 have tags that were set to expire during the fall of 2018. During 2018, 30 fish were tagged over two weeks of tagging effort within the Markland and Meldahl pools consisting of gill netting and boat DC electrofishing. These two pools were targeted due to the relatively low number of tagged fish within them, which will be further exacerbated by the 19 expiring tags within the Meldahl Pool.

Fish Detections – Between 01 January 2018 and 12 December 2018 receivers recorded nearly eight million individual Asian carp detections. Of the 537 fish tagged in this study, 231 (43%) were detected in 2018. The total number of fish, however, includes 90 Silver Carp tagged in October 2017 in the lower portion of Cannelton pool, nearly 50 miles downstream of the closest receiver. This could reduce the detection percentage until more receivers are placed in the lower portion of the pool or until the recently tagged fish move upstream into the receiver array. Plans are being made to increase the number of receivers in the lower Ohio River in order to quantify downstream movement and movement into connected basins.

Fish Movements – During 2018 the majority of tagged fish in this study remained close to the area in which they were initially detected at the start of the year. Nearly 73% of the tagged Bighead Carp and over 78% of Silver Carp detected during this study had a net upstream or downstream movement of five miles or less (Figure 2). Mean monthly movement distances by each species in each pool were calculated, showing peak movements between May and July (Figure 3).

Model Selection – The best model selected for Silver Carp, as in 2017, provided pool and time invariant survival estimates, probability of detection estimates that varied over space and time, and movement estimates that varied for each pool. The closest competing model of the remaining 51 models that have been currently tested had a ΔAIC_c of 309 while estimating for four more parameters by including survival estimates that varied by pool.

Pool-to-pool transition probabilities, survival, and detection probabilities were estimated for Bighead Carp using the same methods in Program MARK that were used for the Silver Carp data set. As with Silver Carp, Bighead Carp model selection had survival that was time and state invariant, probabilities that varied by state and time, and transition probabilities that varied between pools.

Tributary Use – At the time of release of this report, tributary use had not yet been analyzed due to the extra time dedicated to pool-to-pool movement models and problems arising in Program MARK. Analysis of tributary use versus mainstem Ohio River use will be completed and released at a later date.

Dam Passage – Throughout this study, there have been 54 dam passage events by eight Bighead Carp (one female, two males, five unknown sex) and 23 Silver Carp (nine females, ten males, four unknown sex). Thirty-two of the 54 (56%) passage events were in a downstream direction by seven Bighead Carp (ten passes) and 18 Silver Carp (22 Passes). The remaining 22 passes (44%) were in an upstream direction and consisted of two Bighead Carp (five passes) and 12 Silver Carp (17 passes). Of the tagged Bighead and Silver Carp, 17.8% and 4.7% were found to pass through dam structures, respectively. During 2018, eight Silver Carp (four females, three males, and one unknown sex) passed through dams on 11 occasions with five being in an upstream direction. Two pool transitions in 2018 are thought to be through the lock chambers including one upstream pass at McAlpine L&D and the other in a downstream direction at the Meldahl L&D, both by male Silver Carp. The remaining nine pool transitions are suspected as being through the dams themselves, as there are no detections within the lock chambers.

Preliminary pool to pool transition probabilities were found to be highest for Silver Carp from Cannelton Pool to McAlpine Pool (0.066 ± 0.006) and from McAlpine Pool back to Cannelton Pool (0.053 ± 0.005) (Table 3). Movement probabilities were highest for Bighead Carp from McAlpine to Markland Pool (0.455 ± 0.128), from Greenup to R.C. Byrd Pool (0.192 ± 0.126), and from Markland to McAlpine Pool (0.095 ± 0.029). For both Silver Carp and Bighead Carp in any navigation pool along the Ohio River, staying within the same pool accounted for the most likely observation.

Survival – The annual survival estimates of tagged Asian carp were calculated in Program MARK using a multi-state live-capture model. Silver Carp survival was estimated to be 64.9% (95% C.I. = 61.4 – 68.1%) throughout all pools. Bighead Carp annual survival rate was calculated to be 68.1% (95% C.I. = 57.4 – 76.6%). Given that only two of these fish were known to have been harvested, we believe that this estimate provides a robust estimate of natural mortality (e.g., 95% CI = 31.9% - 38.6% for Silver Carp; 95% CI = 23.4% - 42.6% for Bighead Carp).

Recommendations:

Although tributary use has yet to be analyzed for this year, past analysis has provided evidence to the importance of tributaries to Asian carp versus the relatively structureless mainstem Ohio River. Continued monitoring of tributaries will provide a more in depth understanding of the importance of this habitat type to Asian carp in the Ohio River basin. Similarly, continued monitoring of dam passage and inter-pool movement will not only strengthen current passage estimates, but also increase the accuracy of survival and detection probabilities, which will help inform receiver placement and densities within each pool. Movement estimates will also need to be formatted for incorporation into the spatially explicit population model being developed for the Ohio River. Finally, upstream movement estimates appear to be very low whereas downstream movement below Cannelton pool is not well known. Previous detections of a tagged Asian carp in Lake Barkley originating from Cannelton pool begs the question as to if and how Kentucky Lake or Lake Barkley serve as a population sink for the Ohio River population, thereby reducing upstream range expansion on the Ohio River. With the proposed deterrent technologies at Barkley Lock, one hypothesis that should be considered is whether blocking a potential population sink of the Ohio River population will increase upstream movement rates.
Continued evaluation of the movement of Asian carp through Kentucky and Barkley Dams, as well as movement downstream of Cannelton Locks and Dam will help evaluate what effects these barriers will have on the upper pools of the Ohio River. Increasing receiver coverage in the lower Cannelton Pool, as well as into the lower Ohio River will help to understand larger-scale movement patters of Asian carp, as well as the importance of those downstream source populations to the upstream movement of Asian carp. Modeling simulations will help us better understand how management decisions affect the Asian carp population at much larger scales.

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Figures and Tables –

Table 1. Distribution of telemetry receivers in 2017 (Rec. = receivers, RM = river miles)

Ohio River Pool	# of Rec. in Mainstem	RM in Pool	RM/Rec.	Rec. in Locks/Approach Walls	Rec. in Tribs.
Cannelton	3	55	18.3	0	2
McAlpine	8	75	9.38	3	21
Markland	9	95	10.56	4	12
Capt. A. Meldahl	15	95	6.33	5	7
Greenup	6	62	10.33	4	6
R. C. Byrd	1	42	42	4	4
Racine	3	31	10.33	4	2
Belleville	7	42	6	4	6
Willow Island	1	35	35	4	0
Totals	53			32	60

Table 2. Bighead Carp and Silver Carp tagged from 2013 - 2018

	Cannelton	McAlpine	Markland	Capt. A. Meldahl	R. C. Byrd	Total
2013						
Silver Carp				6		6
Bighead Carp				13		13
2014						
Silver Carp		115	6	10		131
Bighead Carp		4	4			8
2015						
Silver Carp		22	3	5		30
Bighead Carp		1	1	5		7
2016						
Silver Carp	92	94	6			192
Bighead Carp	4	1	4	2	3	14
2017						
Silver Carp	90		11	3		104
Bighead Carp			2			2
2018						
Silver Carp			19	10		29
Bighead Carp				1		1
Totals	186	237	56	55	3	537

= Tags set to expire Fall 2018

Table 3. Pool-to-pool transition probabilities of Silver Carp in the Ohio River through acoustic telemetry – 2013 to 2018 (preliminary results). The best model ($\Delta AIC_c > 2$) for Silver Carp provided state and time invariant survival, probability of detection estimates that varied over space and time, and movement estimates that varied for each pool. Note that transition probabilities were not estimated in Greenup Pool or above due to the lack of movement data within these reaches of the river.

	Destination pool			
Departure pool	Cannelton	McAlpine	Markland	Meldahl
Cannelton	0.934	0.066	0.000	0.000
McAlpine	0.053	0.947	0.000	0.000
Markland	0.016	0.019	0.965	0.000
Meldahl	0.000	0.000	0.004	0.996

Table 4. Pool-to-pool transition probabilities of Bighead Carp in the Ohio River through acoustic telemetry – 2013 to 2018 based on the best model. The best model ($\Delta AIC_c > 2$) for Bigheaded Carp provided time and pool invariant survival estimates, probability of detection estimates that varied over space and time, and movement estimates that varied for each pool.

	Destination pool						
Departure pool	Cannelton	McAlpine	Markland	Meldahl	Greenup	R. C. Byrd	Racine
Cannelton	1.000	0.000	0.000	0.000	0.000	0.000	0.000
McAlpine	0.000	0.545	0.455	0.000	0.000	0.000	0.000
Markland	0.000	0.095	0.897	0.008	0.000	0.000	0.000
Meldahl	0.000	0.000	0.043	0.94	0.017	0.00	0.00
Greenup	0.000	0.000	0.000	0.000	0.808	0.192	0.000
R. C. Byrd	0.000	0.000	0.000	0.000	0.000	0.925	0.075
Racine	0.000	0.000	0.000	0.000	0.000	0.000	1.000

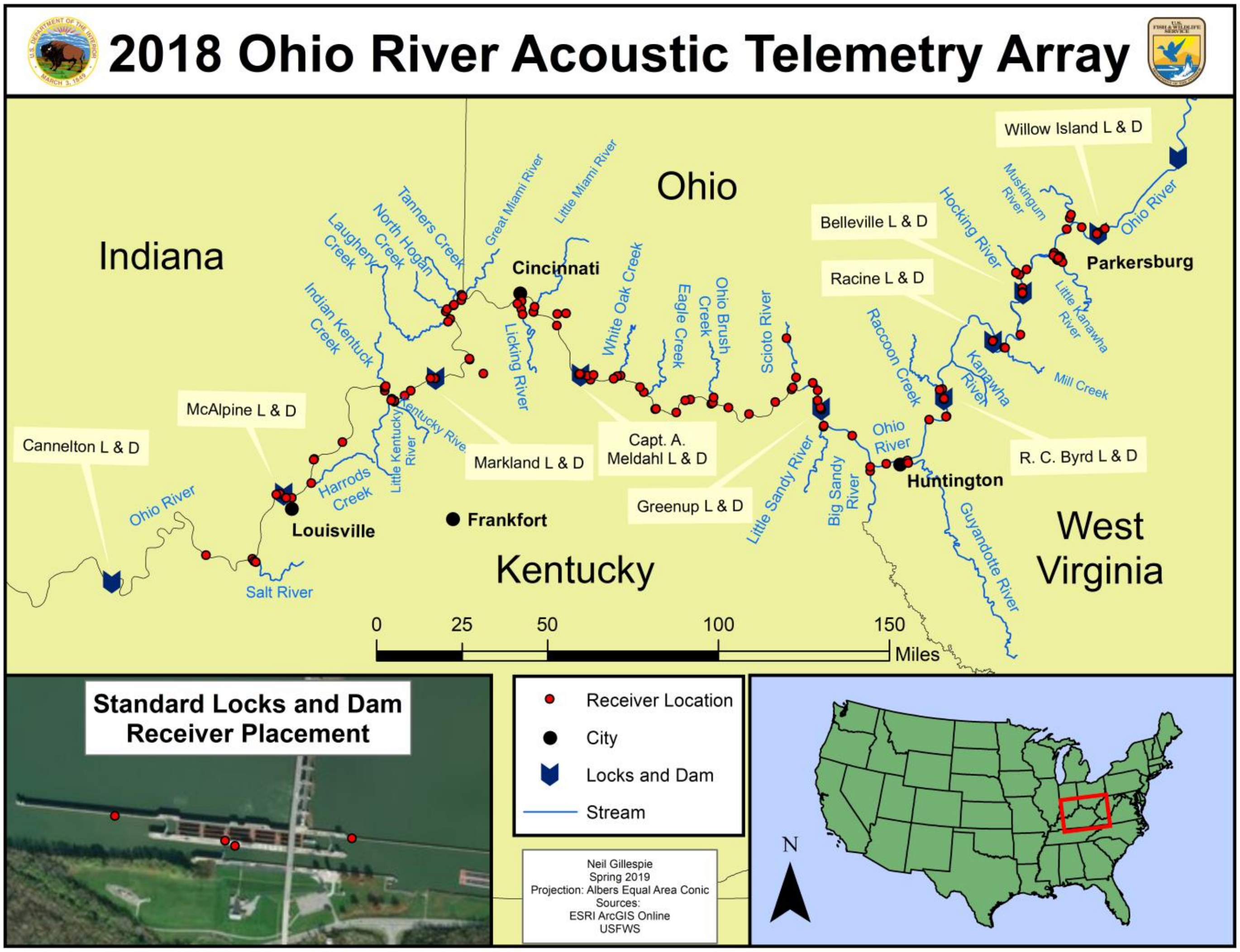

Figure 1. Locations of stationary VR2W and VR2AR receivers in 2018. Individual points may represent more than one receiver at this scale.

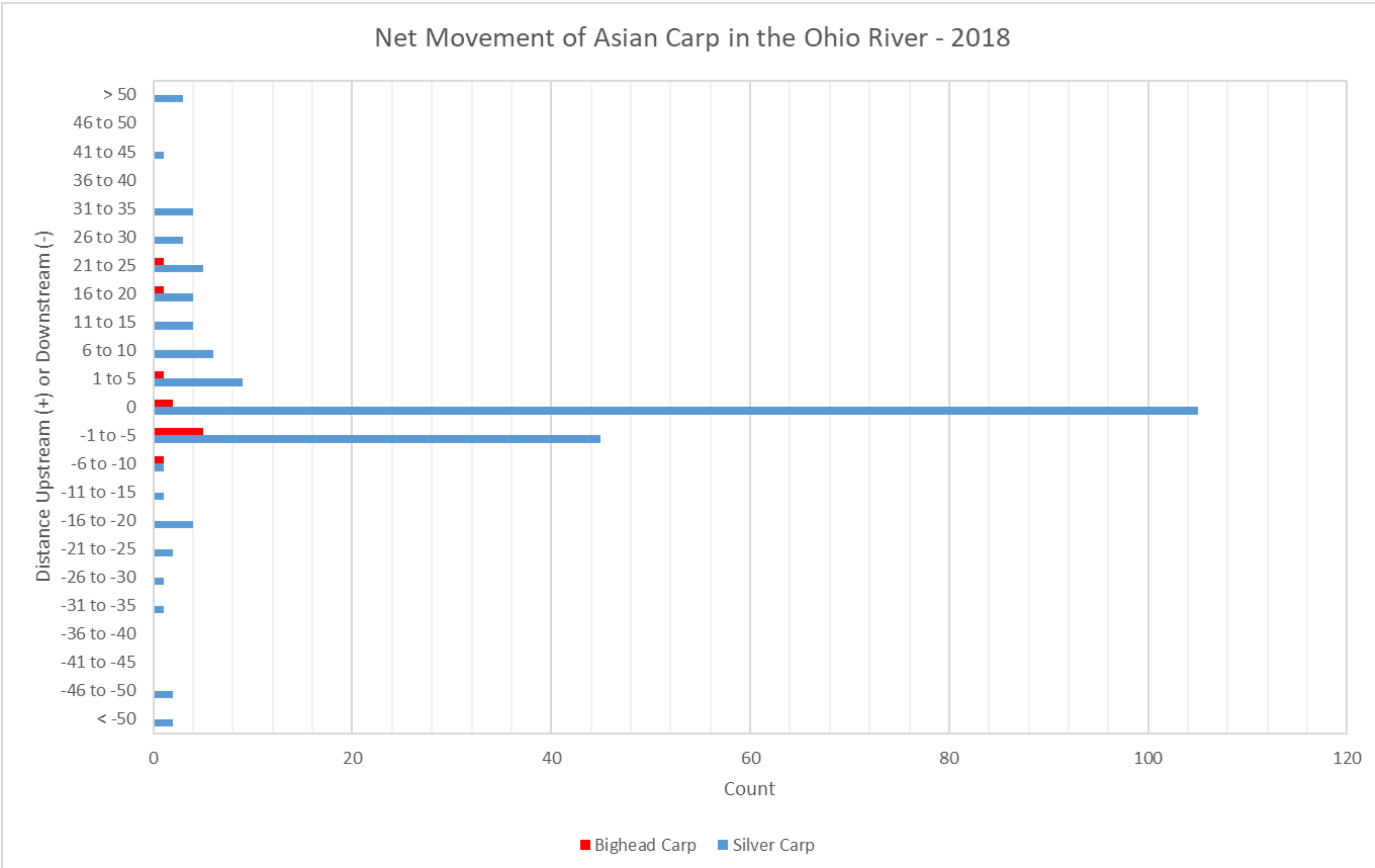

Figure 2. Net upstream (+) and downstream (-) movement (in miles) of Asian carp in the Ohio River between first and last detection - 2018.

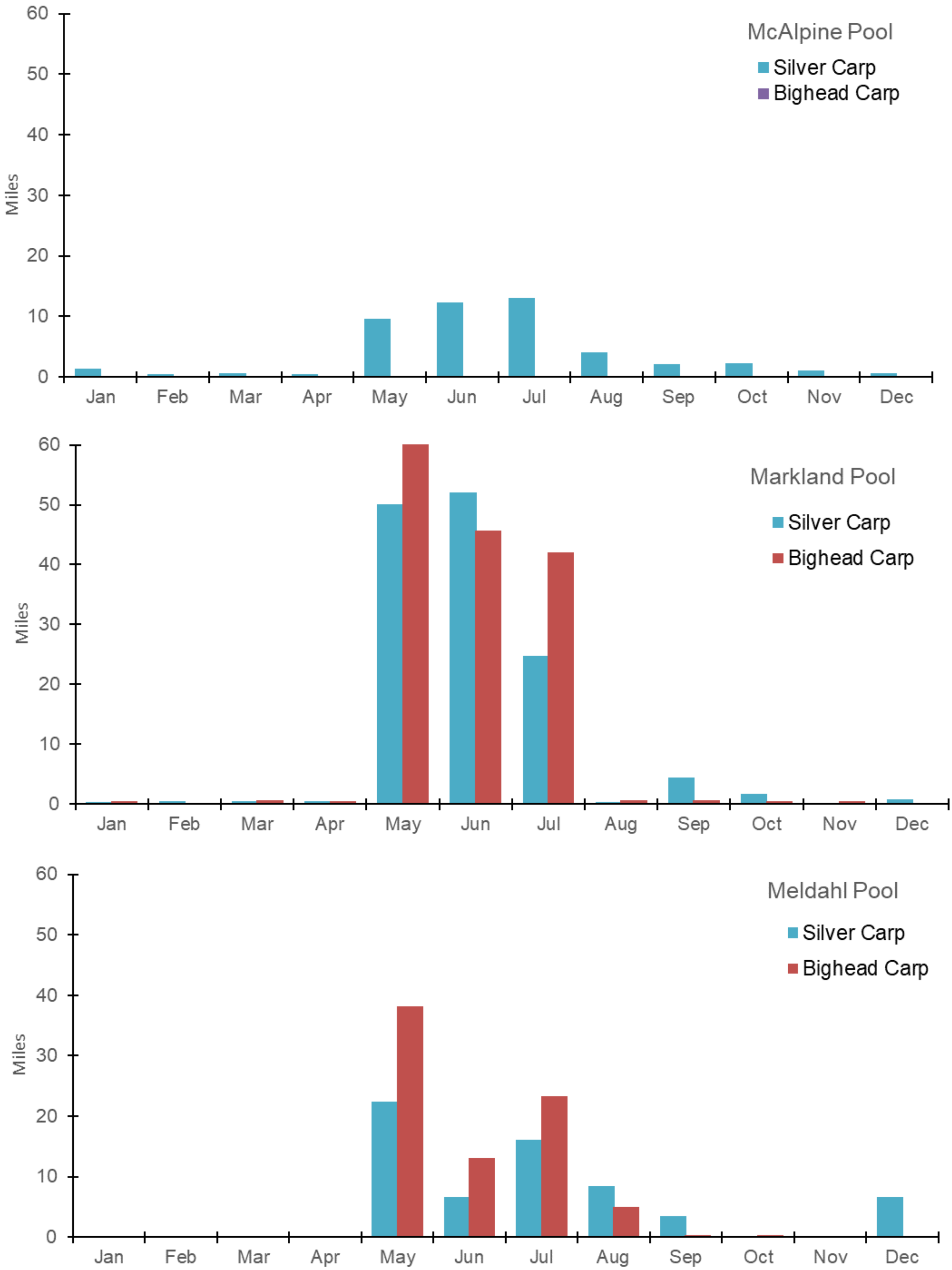

Figure 3. Mean monthly distances (in river miles) between the most upstream and downstream detections for Bighead and Silver carp that were detected by two or more receivers during 2018 – Chris Hickey, KDFWR.