Title: Bigheaded carp monitoring and removal in UMR

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Geographic Location

Pools 14-19 of the Mississippi River

Participating Agencies

Illinois Natural History Survey, Illinois Department of Natural Resources, United States Geological Survey-Upper Midwest Environmental Sciences Center, and United States Fish and Wildlife Services

Statement of Need

Adult silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*), and grass carp (*Ctenopharyngodon idella*), hereafter referred to as Asian carp, are present in varying abundances in the Upper Mississippi River (UMR) in Pools 14 through 19; however black carp have not been collected above Lock and Dam (LD) 19. Bighead and silver carp, collectively referred to as bigheaded carp, have increased in range and abundance throughout the Mississippi River basin, thus increasing their potential for causing ecological and economic damage. Lock and Dam 19 has limited movements of bigheaded carp upstream as all upstream passage is restricted to the lock chamber, effectively slowing progression and establishment of bigheaded carp in the UMR. A combination of containment and control measures are thought to be the most effective tools for managing Asian carp in the UMR. The Upper Mississippi River Asian Carp Team (UMRACT) is an interagency group across five states that is concerned with minimizing the impacts of bigheaded carp in the UMR. Commercial harvest effort programs, funded through the UMRACT, are aimed at capturing and removing bigheaded carp in the UMR to prevent establishment of incipient populations. We propose that targeted commercial harvest at the established and invasion front (Pool 16) will be effective in reducing populations and help alleviate the pressure invasive species elicit at dams.

Project Objectives

1) Targeted removal of 400,000-500,000 lbs of Asian carp species in UMR Pools 14-19 using commercial fishers and intensive netting protocols.
2) Acoustically tag and monitor, collectively, 300 Bighead Carp, Silver Carp, and Bigmouth Buffalo within the study area to assess frequency and timing of fish passage at Lock and Dam 14 and 15.

Project Highlights

- Commercial removal efforts resulted in 171,299 lbs of Asian carp removed from 01/01/2020 – 12/31/2020
- Since the project started in 2015 a total of 715,695 lbs of Asian carp have been removed, with 528,264 lbs coming from 2018, 2019, and 2020
- 473 bighead carp (BHCP), 7,175 silver carp (SVCP), 27 hybrid silver carp x bighead carp (SCBC), and 1,876 grass carp (GSCP) were harvested and removed in 2020

- The use of multiple crews (more than one fisherman) tended to increase catch per unit effort, specifically the increase to two fishermen in 2019 and 2020

Methods

Study site

Data were collected from September 2015 through December 2020 on Pools 14-20 of the UMR. The UMR is classified as the portion of the river above Cairo, Illinois to St. Anthony Falls near Minneapolis, Minnesota. The UMR consists of 29 locks and dams that vary in size and passage capability. The UMR has a drainage basin of 490,000 km^2 and at the mouth has a discharge of 5,796 m^3/s. Pools 14-19 of the Mississippi River are the border waters between Illinois and Iowa, while Pool 20 is the border water between Illinois and Missouri. Pool 14 is 47.0 km long and has an area of 41.6 km^2. It extends from Lock and Dam 13 near Clinton, IA to Lock and Dam 14 in Le Claire, IA. Pool 15 is 16.7 km long and covers an area of 14.7 km^2, extending from Lock and Dam 14 in Le Claire, IA to Lock and Dam 15 in Rock Island, IL. Pool 16 is 41.4 km long and occupies an area of 52.6 km^2. It extends from Lock and Dam 15 in Rock Island, IL to Lock and Dam 16 in Muscatine, IA. Pool 17 is 32.3 km long and covers 30.7 km^2 between Lock and Dam 16 in Muscatine, IA and Lock and Dam 17 near New Boston, IL. Pool 18 is 42.8 km long and covers 53.8 km^2. It is located between Lock and Dam 17 near New Boston, IL and Lock and Dam 18 in Gladstone, IL. Pool 19 extends 74.5 km and covers 123.3 km^2 from Lock and Dam 18 in Gladstone, IL to Lock and Dam 19 in Keokuk, IA. Pool 20 is approximately 34 km long and has an area of approximately 28.3 km^2 (Jahn and Anderson 1986). It extends from Lock and Dam 19 in Keokuk, IA to Lock and Dam 20 near Canton, MO. Pools 14-18 and 20 have similar aquatic habitats, while Pool 19 shows more similarities to pools further upriver (Pools 4-13), characterized by a higher average size of contiguous impounded and shallow aquatic areas than downstream pools (Koel 2001). Pools can be split into three distinct groups based on dominant aquatic habitat types: Pools 14, 18, and 20, Pools 15 and 17, and Pool 16. Pools 14, 18, and 20 have no contiguous impounded area, contiguous floodplain shallow aquatic area, or tertiary channel. Pools 15 and 17 have a small portion of the tertiary channel and contain a larger floodplain area than other pools. Pool 16 has more secondary channels than other pools (Koel 2001). Tributaries that contribute to Pools 14-19 of the Mississippi River include Wapsipinicon River (converges at Pool 14), Rock River (converges at Pool 16), Iowa River (converges at Pool 18), and Skunk River (converges at Pool 19).

Sample Collection

Fish were collected using nylon filament gillnets provided by Illinois Natural History Survey (INHS) biologists and contracted removal effort personnel. Net mesh sizes used were 3.5, 4, 4.25, 4.5, 5, 5.25, and 6-inch bar gillnets. Gillnets were set in a range of habitat areas (backwater, side channel, main channel border, and tributaries) to target bigheaded carp. Bigheaded carp were located using side-scan sonar, acoustic receivers (manual, stationary, and real-time), visual cues, and fishing areas that have had historically high catch rates. The time nets were set and removed was recorded, along with mesh size, net height, length, color, and twine size. Dissolved oxygen, specific conductivity, and water temperature were measured at net locations using a YSI Pro 2030 meter (Yellow Springs, Ohio, USA), and GPS coordinates were taken using a Vemco VR-100 receiver (Bedford, Nova Scotia, Canada). Once set, the

nets were either left overnight to fish ("dead set") or a method called "pounding" was employed which included driving fish towards the nets to scare them into the nets (Butler et al. 2019). Nets were then removed from the water, and fish were removed from the net. Fish collected from nets were identified to species, the number of fish per species was recorded, and the bulk weight of Asian carp by species was measured and recorded. To collect additional bycatch data, on certain days all collected fish were weighed to the nearest 10 g and measured to the nearest mm. Asian carp were removed from the system and bycatch were released back into the water at the capture location.

Statistical analyses

Relative weight (Wr) was calculated based on the available standard weight equation for each species. Grass carp could not be included in these analyses because standard weight equations do not exist for this species. Relative weight for a species was compared between years, and between pools per year. Box plots were constructed to display the Wr for each species between years, and between pools per year. Analysis of Variance (ANOVA) tests were performed to determine if Wr of species were statistically, significantly different (α=0.05) between years both in all pools combined, and in each pool separately. A Tukey's Post Hoc test (α=0.05) determined between what years in each pool any difference in Wr existed.

Results and Discussion

Contracted Commercial Removal

Drought river conditions and COVID-19 restrictions majorly impacted our fishing efforts in 2020. Due to COVID restrictions effective mid-March, we were unable to conduct our intensive harvest event for the entire month of April. During intensive harvest, we contract 3-4 fishermen crews during the peak period when bigheaded carp occupy backwater areas which can account for 1/3 of our yearly catch. Fishing efforts were resumed at the start of June with social distancing restrictions in place.

Despite delayed fishing efforts and the inability to conduct our intensive harvest, we removed 9,551 Asian carp, weighing 171,299 lbs, from Pools 14-19 of the Mississippi River (Table 1, Table 2). Silver carp were the most abundant Asian carp species removed from the UMR (7,175 fish; 121,708.3 lbs), followed by grass carp (1,876 fish; 36,020.2 lbs), bighead carp (473 fish; 13,148.8 lbs), and hybrid carp (27 fish; 421.67 lbs). A total of 13,721 bycatch fish were captured in gill nets and released, with the highest amount of bycatch caught in Pool 19 (7,915 fish; Table 3).

Contracted commercial efforts have been successful in removing large quantities of biomass annually from the UMR. Catch per unit effort (CPUE) has steadily risen from 2018 to 2020 (Fig. 1). As contracted fishing moved upstream, the total CPUE decreased. The exception for this was Pools 16 and 17, where Pool 16 CPUE was higher than Pool 17. Pools 18 and 19 had the highest CPUE, and Pool 14 had the lowest CPUE. One silver carp was removed from Pool 14 in 2020 (Fig. 2). These results suggest that Pools 18 and 19 are key focal points for removing pressure from upstream movement and contain the highest densities.

The effectiveness of using one versus 2+ fishing crews was analyzed using data from 2018-2020, which showed that CPUE generally increased with additional fishing crews (Fig. 3). However, results may be slightly biased because crews of 3 fishermen in 2020 were generally used when the harvest was the lowest for the year. Comparison of CPUE between crews of 1-4 fishermen across years showed that in 2018, 2019, and 2020, a positive trend generally exists between the number of fishermen and CPUE (Fig. 3).

Total removed weight was higher in 2020 (171,299 lbs) than 2019 (168,912 lbs), but lower than 2018 (174,781 lbs). The lack of intensive harvest likely attributed to our harvest weight being lower in 2020 than 2018. We had the highest number of Asian carp removed (9,551 fish) in 2020 compared to 2015-2018 data (Table 1, Table 2). The total removed Asian carp and CPUE calculations show the benefits of using additional fishermen to increase harvest efforts. This effort is further supported by better prediction tools, such as real-time receivers deployed by our federal partners, and using telemetry data to help guide our efforts.

Table 1. Total weight (lbs) of Asian carp removed from Pools 14-19 on the Upper Mississippi River from 2015-2020. Asian carp are broken down by bighead carp (BHCP), silver carp (SVCP), grass carp (GSCP), and bighead x silver carp (Hybrid). Unsorted weight is an accumulated weight of all species weight when there was no ability to sort by species.

Year	BHCP	SVCP	GSCP	Hybrid	Unsorted	Total
2015	205.87	1167.94	192.33	0	0	1566.14
2016	18797.05	38267.88	12486.72	1509.26	0	71060.92
2017	15396.33	33131.58	19617.70	404.97	27102.29	68550.58
2018	25987.17	98433.36	49879.08	481.89	13071.87	174781.49
2019	24303.83	90264.64	53730.11	613.68	1785.74	168912.25
2020	13148.79	121708.33	36020.25	421.68	0	171299.05
Totals	97839.04	382973.73	171926.19	3431.48	41959.90	**656170.43**

Table 2. Total number of Asian carp captured and removed using gill nets in Pools 14-20 of the Upper Mississippi River from 2015-2020.

Year	Pool	Bighead Carp	Silver Carp	Hybrid Carp	Grass Carp	Total
2015	17	1	3	0	0	4
	18	0	6	0	0	6
	19	6	56	0	9	71
	20	3	4	0	0	7
Total		**10**	**69**	**0**	**9**	**88**
2016	16	0	0	0	8	8
	17	22	66	1	54	143
	18	95	136	3	119	353
	19	180	1781	18	450	2429
	20	57	255	1	44	357
Total		**354**	**2238**	**23**	**675**	**3290**
2017	16	13	33	1	51	98
	17	106	342	3	37	488
	18	19	64	0	14	97
	19	70	395	0	347	812
	20	0	0	0	0	0
Total		**208**	**834**	**4**	**449**	**1495**
2018	14	2	0	0	0	2
	16	64	330	2	127	523
	17	119	531	4	157	811
	18	266	1061	2	690	2019
	19	305	3078	22	1275	4680
Total		**756**	**5000**	**30**	**2249**	**8035**
2019	15	2	36	0	4	46
	16	116	364	2	115	597
	17	44	240	1	27	306
	18	372	1556	5	379	2313
	19	302	3637	19	2113	6056
Total		**836**	**5843**	**27**	**2638**	**9318**
2020	14	0	1	0	0	1
	15	2	8	0	2	12
	16	77	626	2	92	797
	17	83	819	2	75	979
	18	65	1139	4	161	1369
	19	246	4582	19	1546	6393
Total		**473**	**7175**	**27**	**1876**	**9551**
Total		**2637**	**21159**	**111**	**7896**	**21803**

Table 3. Total number of bycatch species captured using gill nets in Pools 14-20 of the Upper Mississippi River from 2015-2020.

Family/Species	2015	2016	2017	2018	2019	2020	Total
Acipenseridae							
Lake Sturgeon			1	1		2	4
Shovelnose Sturgeon				1	2		3
Amiidae							
Bowfin		7	3	16	6	15	47
Catostomidae							
Bigmouth Buffalo	79	822	2134	2417	1985	2470	9907
Black Buffalo		226	1019	953	859	1247	4304
Golden Redhorse				1			1
Quillback		6	2		7	3	18
River Carpsucker	16	89	64	143	82	43	437
River Redhorse				1			1
Shorthead Redhorse		2			2		4
Smallmouth Buffalo	19	321	3237	1183	974	2502	8236
Centrarchidae							
Black Crappie				1	4	2	7
Bluegill					2		2
Largemouth Bass	1	5	1	7	11	7	32
Smallmouth Bass					1	2	3
White Crappie		1	6	3	2		12
Clupeidae							
Gizzard Shad	4	8	11	11	8	5	47
Cyprinidae							
Common Carp	83	1460	2273	3819	3964	3457	15056
Goldfish			1		2	2	5
Hiodontidae							
Mooneye			3	13	13	1	30
Ictaluridae							
Brown Bullhead						1	1
Channel Catfish	1	55	34	102	91	72	355
Flathead Catfish		4	37	145	90	87	363
Lepisosteidae							
Longnose Gar	21	33	27	124	111	138	454
Shortnose Gar	37	33	28	109	179	267	653
Moronidae							
Striped x White Bass	1		2	24	52	31	105
White Bass	1	5	3	7	3	1	20
Sciaenidae							
Freshwater Drum	68	350	806	1847	3108	2009	8188
Esocidae							
Northern Pike		17	28	64	67	28	204
Polyodontidae							
Paddlefish	5	1010	2077	2989	2087	1319	9487
Percidae							
Sauger			1	3	7		11
Walleye	3	1	1	21	14	10	50
Total	339	4455	11799	14005	13733	13721	**58052**

Table 4. Total Asian carp gill netting effort in Pools 14-19 of the UMR in 2019. Asian carp are broken down by bighead carp (BHCP), silver carp (SVCP), grass carp (GSCP), and bighead x silver carp (HYBRID). Unsorted weight is an accumulated weight of all species weight when there was not an ability to sort by species.

2019	Pool 19	Pool 18	Pool 17	Pool 16	Pool 15	Pool 14	Total
Netting Effort							
Total Yards of Net	190,610	83,025	34,200	40,560	4,400	3,950	356,745
Catch Effort (Removed)							
Total AC (N)	6,071	2,322	312	597	42	0	9,344
Total AC Weight (kg)	48,131	19,605	2,794	5,763	323	0	76,617
Average AC Weight (kg)	7.9	8.4	9.0	9.7	7.7	0	8.2
Total Unsorted AC Weight (kg)	0	810	0	0	0	0	810
Total BHCP (N)	302	372	44	116	2	0	836
Total BHCP Weight (kg)	3,129	5,794	639	1,424	38	0	11,024
Average BHCP Weight (kg)	10.4	15.6	14.5	12.3	19.0	0	13.2
Total SVCP (N)	3,637	1,566	240	364	36	0	5,843
Total SVCP Weight (kg)	25,254	10,831	1,836	2,771	253	0	40,943
Average SVCP Weight (kg)	6.9	6.9	7.7	7.6	7.0	0	7.0
Total HYBRID (N)	19	5	1	2	0	0	27
Total HYBRID Weight (kg)	198	55	17	8	0	0	278
Average HYBRID Weight (kg)	10.4	11.0	17.0	4.0	0	0	10.3
Total GSCP (N)	2,113	379	27	115	4	0	2,638
Total GSCP Weight (kg)	19,551	2,926	303	1,561	32	0	24,372
Average GSCP Weight (kg)	9.3	7.7	11.2	13.6	8.0	0	9.2
Catch per unit of effort							
CPUE (BHCP/100 yds of net)	0.16	0.45	0.13	0.29	0.05	0	0.23
CPUE (SVCP/100 yds of net)	1.91	1.89	0.70	0.90	0.82	0	1.64
CPUE (HYBRID/100 yds of net)	0.01	0.006	0.003	0.005	0	0	0.008
CPUE (GSCP/100 yds of net)	1.11	0.46	0.08	0.28	0.09	0	0.74
CPUE (Total AC/100 yds of net)	3.19	2.80	0.91	1.47	0.95	0	2.62

Table 5. Total Asian carp gill netting effort in Pools 14-19 of the UMR in 2020. Asian carp are broken down by bighead carp (BHCP), silver carp (SVCP), grass carp (GSCP), and bighead x silver carp (HYBRID). Unsorted weight is an accumulated weight of all species weight when there was not an ability to sort by species.

2020	Pool 19	Pool 18	Pool 17	Pool 16	Pool 15	Pool 14	Total
Netting Effort							
Total Yards of Net	164680	39830	41130	34590	8050	5060	293340
Catch Effort (Removed)							
Total AC (N)	6393	1369	979	797	12	1	9551
Total AC Weight (kg)	52569	10578	8339	6126	80	8	77700
Average AC Weight (kg)	8.5	7.7	8.5	7.7	6.7	8.0	8.3
Total Unsorted AC Weight (kg)	0	0	0	0	0	0	0
Total BHCP (N)	246	65	83	77	2	0	473
Total BHCP Weight (kg)	2908	852	1272	906	25	0	5964
Average BHCP Weight (kg)	11.8	13.1	15.3	11.8	12.5	0	12.7
Total SVCP (N)	4582	1139	819	626	8	1	7175
Total SVCP Weight (kg)	36180	8257	6447	4271	43	8	55206
Average SVCP Weight (kg)	7.9	7.2	7.9	6.8	5.4	8.0	7.8
Total HYBRID (N)	19	4	2	2	0	0	27
Total HYBRID Weight (kg)	137	30	25	0	0	0	191
Average HYBRID Weight (kg)	7.2	7.5	12.5	0	0	0	7.1
Total GSCP (N)	1546	161	75	92	2	0	1876
Total GSCP Weight (kg)	13344	1439	596	949	11	0	16339
Average GSCP Weight (kg)	8.6	8.9	7.9	10.3	5.5	0	9.0
Catch per unit of effort							
CPUE (BHCP/100 yds of net)	0.15	0.16	0.20	0.22	0.025	0	0.16
CPUE (SVCP/100 yds of net)	2.78	2.86	2.00	1.81	0.10	0.02	2.45
CPUE (HYBRID/100 yds of net)	0.01	0.01	0.01	0.01	0	0	0.01
CPUE (GSCP/100 yds of net)	0.94	0.40	0.18	0.27	0.025	0	0.64
CPUE (Total AC/100 yds of net)	3.88	3.44	2.40	2.30	0.15	0.020	3.26

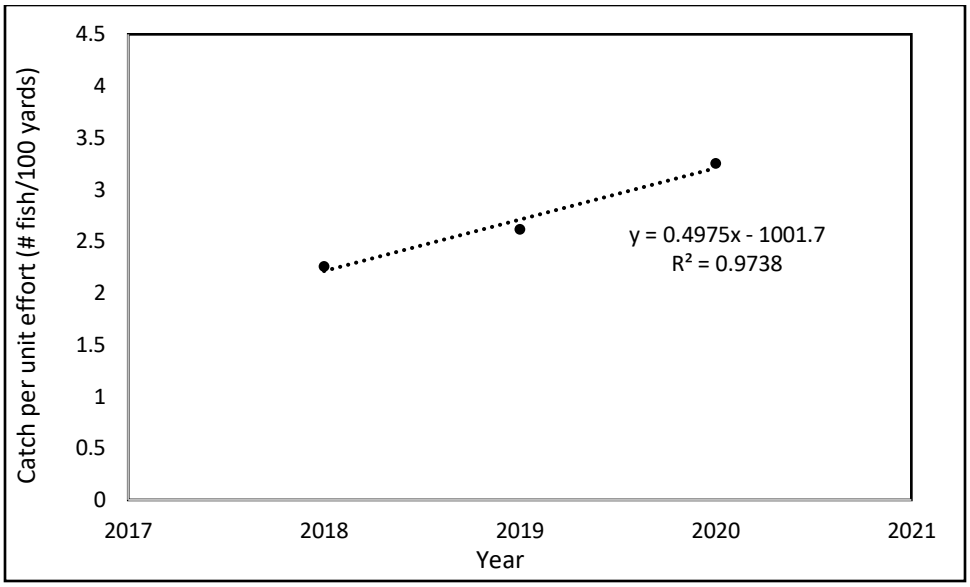

Figure 1. Total catch per unit effort per year for Asian carp removed from the Upper Mississippi River Pools 14-19 using gill nets from 2018-2020.

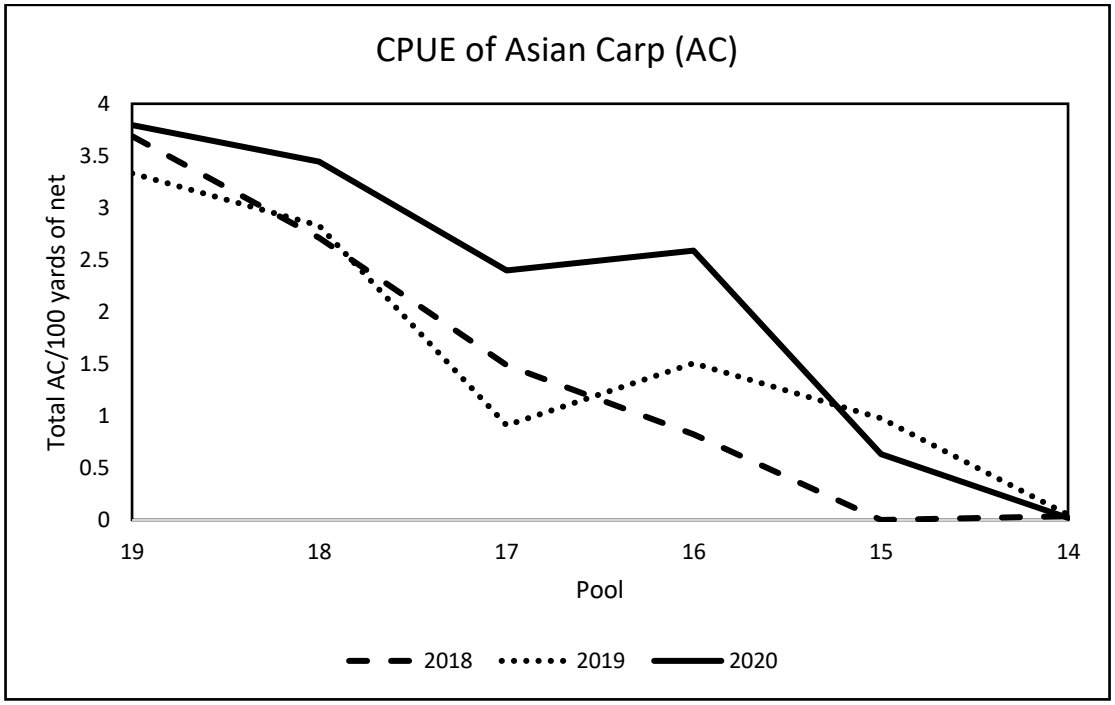

Figure 2. Catch per unit effort for Asian carp contracted commercial removal using gill nets by Upper Mississippi River reach in 2018 and 2020. The dashed line represents 2018, the dotted line represents 2019, and the black line represents 2020.

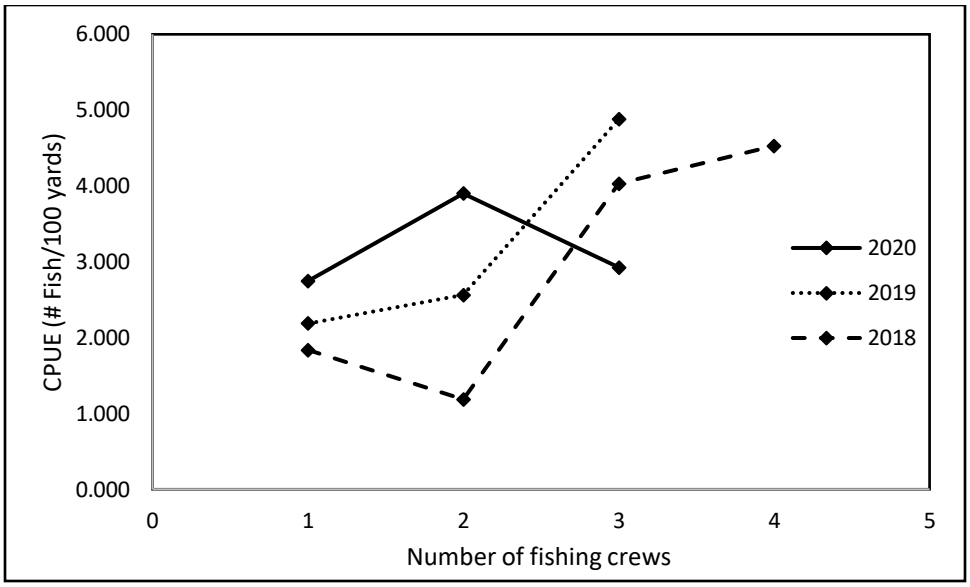

Figure 3. Total catch per unit effort (CPUE) per number of fishermen across years for Asian carp removed from the Upper Mississippi River Pools 14-19 using gill nets from 2018-2020. The dashed line represents 2018, the dotted line represents 2019, and the black line represents 2020.

Acoustic Monitoring

We monitored acoustically tagged fish through three methods in Pools 14-19: Vemco VR100 detections during harvest, recaptures of acoustically tagged individuals in nets during harvest, and active tracking. These data were used to monitor movements of Asian carp to assist in commercial harvest efforts.

Active Tracking

We acoustically-tagged 150 bigmouth buffalo and 132 bigheaded carp from 6/10/2020 – 6/23/2020 in Pools 14, 15, and 19. In Pool 15, we tagged 18 bigmouth buffalo and 38 silver carp. In Pool 16, we tagged 132 bigmouth buffalo, 87 silver carp, 6 bighead carp, and 1 bighead x silver hybrid carp. In Pool 19, we tagged 30 bigmouth buffalo. We actively tracked in Pools 14-16 from July to August resulting in 404 detections (Table 6). We observed three silver carp and one bigmouth buffalo moving from Pool 15 to Pool 16. One silver carp and one bigmouth buffalo tagged in Pool 15 moved to Pool 17.

The combination of extended efforts of commercial removal crews along with acoustic telemetry data can provide great opportunities at removing congregated schools of bigheaded carp. Increasing acoustically transmitted bigheaded carp and stationary real-time receivers could benefit during increased removal events and help establish better population estimates in the UMR.

Acoustic tag recaptures

We recaptured 10 unique telemetered individuals during our commercial removal efforts in 2020. Five individuals were bighead carp, three individuals were silver carp, one individual was a bigmouth buffalo, and one individual was unknown (Table 7). Most fish were recaptured in Pool 16, primarily in Sunset Marina.

All fish besides two were released after capture in 2020. We removed one bighead carp (A69-9001-17389, jaw tag #1083) on 7/14/2020 in Sunset Marina, Pool 16. This fish did not possess a jaw tag and was detected by a metal detector when fish were weighed after commercial fishing. This fish weighed 15000 g and measured 1090 mm. The other bigheaded carp (A69-9001-17425, jaw tag #1429) was captured on 7/15/2020 in Big Timber, Pool 17. This fish was found dead in our net. This fish weighed 25000 g and measured 1350 mm. Hard structures for aging and a fin clip were removed from this individual.

Commercial fishing VR 100 detections

Our Vemco VR100 receiver was equipped with a portable omni-directional hydrophone (Vemco Model VH165) to detect the presence of acoustically tagged fish in areas where commercial removal efforts occurred. In 2020, we had 19 detections among five different species: bighead carp, silver carp, bighead x silver hybrid carp, bigmouth buffalo, and paddlefish. There were 4 bighead carp individuals, 5 silver carp individuals, 1 bighead x silver hybrid carp individual, 5 bigmouth buffalo individuals, and 3 paddlefish individuals captured from VR100 receiver (Table 8). Most of our bigheaded carp detections were captured in Pools 16 and 17, primarily in Sunset Marina (Pool 16) and Big Timber (Pool 17). We suspect that there were fewer detections of fish in 2020 than previous years due to the underutilization of the VR100 during contracted removal efforts.

Table 6. Detections of fish species from active tracking in Pools 14-16 in the Upper Mississippi between July-August 2020 using a VR100.

Active Tracking Detections	
Species	Detections
BMBF	162
SVCP	124
BHCP	3
SCBC	2
PDFH	92
Unknown	38
Total	404

Table 7. Number of tagged bigheaded carp captured (release/killed) from commercial removal efforts in Pools 16-19 in the Upper Mississippi River from 2018 to 2020.

USFWS/USGS Acoustically Tagged Fish Recaptures																
	2018					**2019**					**2020**					**Total Removed**
Pool	**15**	**16**	**17**	**18**	**19**	**15**	**16**	**17**	**18**	**19**	**15**	**16**	**17**	**18**	**19**	
BHCP	0	1	8	6	2	0	1	1	3	0	0	3	1	0	1	10
BMBF	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
SCBC	0	0	1	4	0	0	0	0	0	1	0	0	0	0	0	0
SVCP	0	1	12	7	4	0	0	0	2	1	0	2	1	0	0	5
Unknown	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total Detections	0	2	21	17	6	0	1	1	5	2	2	5	2	0	1	15

Table 8. Number of fish detections from the VR100 receiver during commercial removal efforts in Pools 16-19 in the Upper Mississippi River from 2018 to 2020.

VR100 Detections															
	2018					**2019**					**2020**				
Pool	**15**	**16**	**17**	**18**	**19**	**15**	**16**	**17**	**18**	**19**	**15**	**16**	**17**	**18**	**19**
BHCP	0	1	2	3	7	0	1	3	6	2	0	3	1	0	0
BMBF	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0
GSCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PDFH	0	15	0	0	1	0	3	3	0	1	0	2	0	0	1
SCBC	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
SVCP	0	4	4	5	8	0	0	3	4	10	0	2	2	0	1
Total Detections	0	20	7	8	16	0	4	9	10	13	0	12	4	0	2

Relative Weight of 4 Common Species Caught During Commercial Efforts

Bighead Carp

Bighead carp Wr decreased from 2015 to 2016, slightly decreased from 2016 to 2017, slightly increased from 2017 to 2018, held steady from 2018 to 2019, and slightly increased from 2019 to 2020 (Fig. 7). There was not a statistical difference among years shown using an ANOVA ($p=0.001$, $\alpha = 0.05$).

In Pool 16, Wr appeared to increase from 2016 to 2017 (Fig. 8). Relative weight held steady in 2017-2019. There were no data available for Pool 16 in 2015, and there were no statistically significant differences detected. In Pool 17, Wr dropped from 2015 to 2017, and increased again in 2018, then dropped in 2019; there was limited data for 2020 (Fig. 8). No statistically significant differences were detected. In Pool 18, there were limited data for 2015. Wr was relatively steady in Pool 18 throughout the years (Fig. 8). There was a significant difference detected between 2016 and 2017 ($p=0.03$, $\alpha = 0.05$). In Pool 19, Wr remained relatively stable across time and there were no significant differences found in the data. We have discontinued fishing in Pool 20 for bighead and silver carp.

There were low amounts of data associated with bighead carp due to low capture success using gill nets or abundance in these pools. More data are needed to analyze the effects of bighead carp in the UMR.

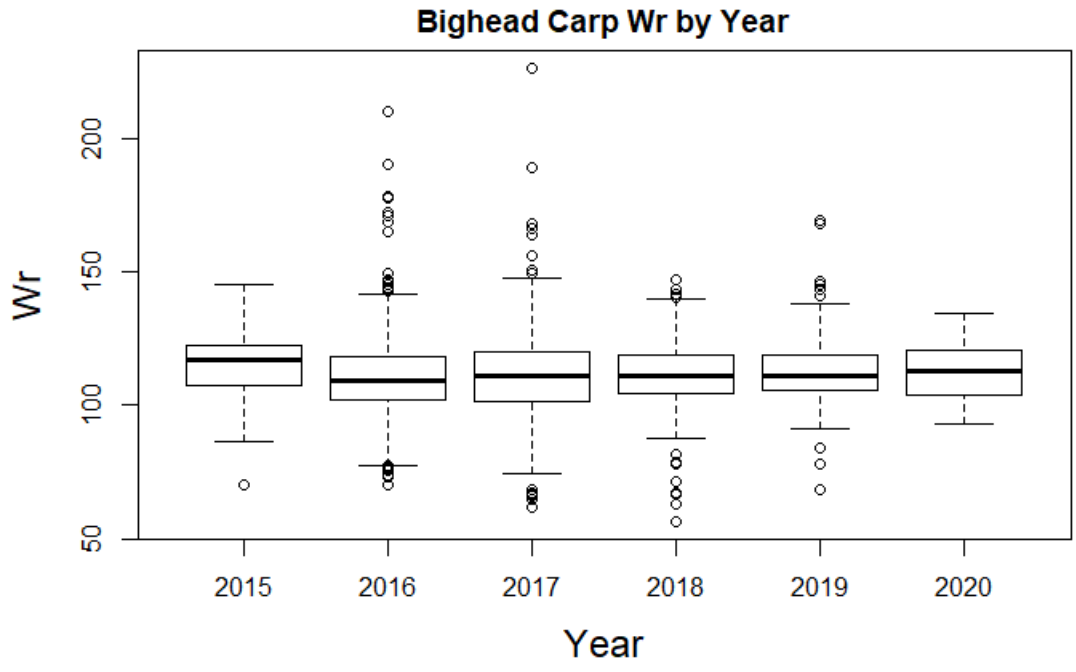

Figure 7. Bighead Carp Wr by year in Pools 16-20 of the Upper Mississippi River from 2015 to 2020.

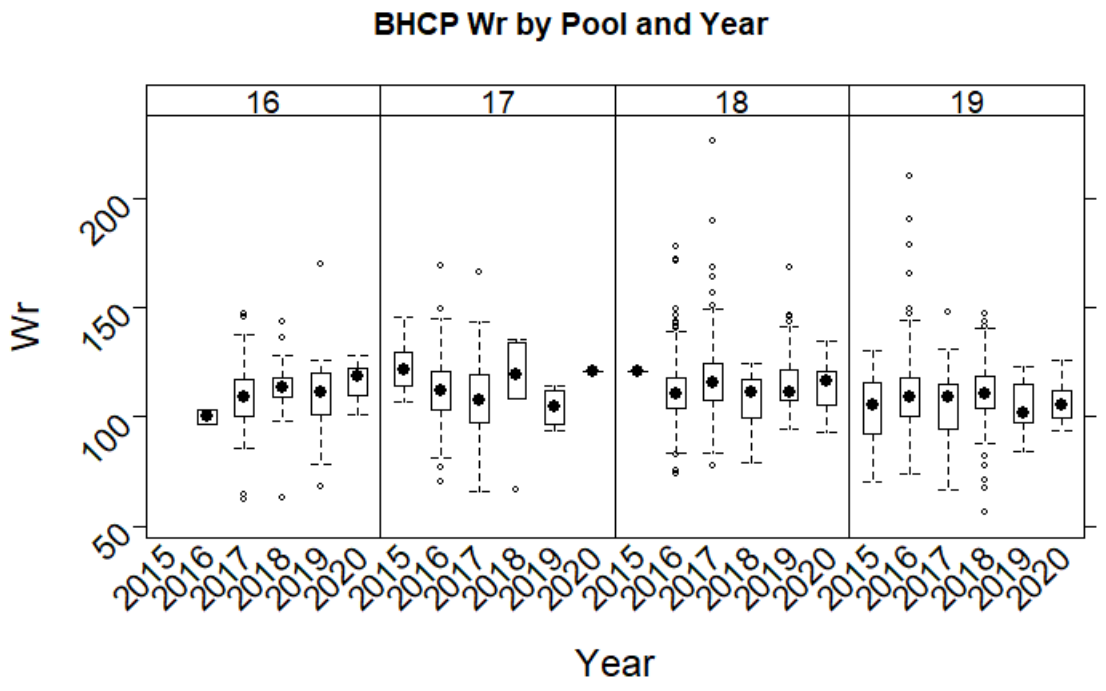

Figure 8. Bighead Carp Wr by year and by pool in Pools 16-20 of the Upper Mississippi River from 2015 to 2020.

Silver Carp

Silver carp Wr (Fig. 9) has a steady trend throughout the years with little interannual variability. However, an ANOVA indicated significant differences in the data ($p \leq 0.001$, $\alpha = 0.05$). A Tukey's test revealed a significant difference between 2015 and 2017 ($p \leq 0.001$), 2015 and 2019 ($p \leq 0.001$), 2016 and 2018 ($p \leq 0.001$), 2017 and 2018 ($p \leq 0.001$), and 2018 and 2019 ($p \leq 0.001$).

In Pool 16, there were no data available for Pool 16 in 2015, but a steady trend exists in silver carp Wr from 2017 to 2019 (Fig. 10). An ANOVA indicated no significant difference in the data. In Pool 17, silver carp Wr remained steady throughout all years, but a significant difference was found between 2016 and 2017 ($p=0.03$). In Pool 18, silver carp Wr was variable throughout the years. An ANOVA revealed significant differences in the data between 2016 and 2019 ($p=0.01$), and 2017 and 2019 ($p=0.003$). In Pool 19, silver carp Wr was variable between 2015 and 2019 with no apparent trend in the data. The ANOVA revealed a significant difference ($p=0.09$). A Post Hoc Tukey's test showed a significant difference between 2015 and 2019 ($p \leq 0.001$), 2016 and 2018 ($p \leq 0.001$), 2017 and 2018 ($p \leq 0.001$), 2018 and 2019 ($p \leq 0.001$), and 2019 and 2020 ($p \leq 0.001$).

Data are lacking in several areas of this data set. To continue to monitor Wr, data must be taken diligently and at appropriate times. Continued collections are needed to continue to monitor silver carp Wr and the effects they have on other species.

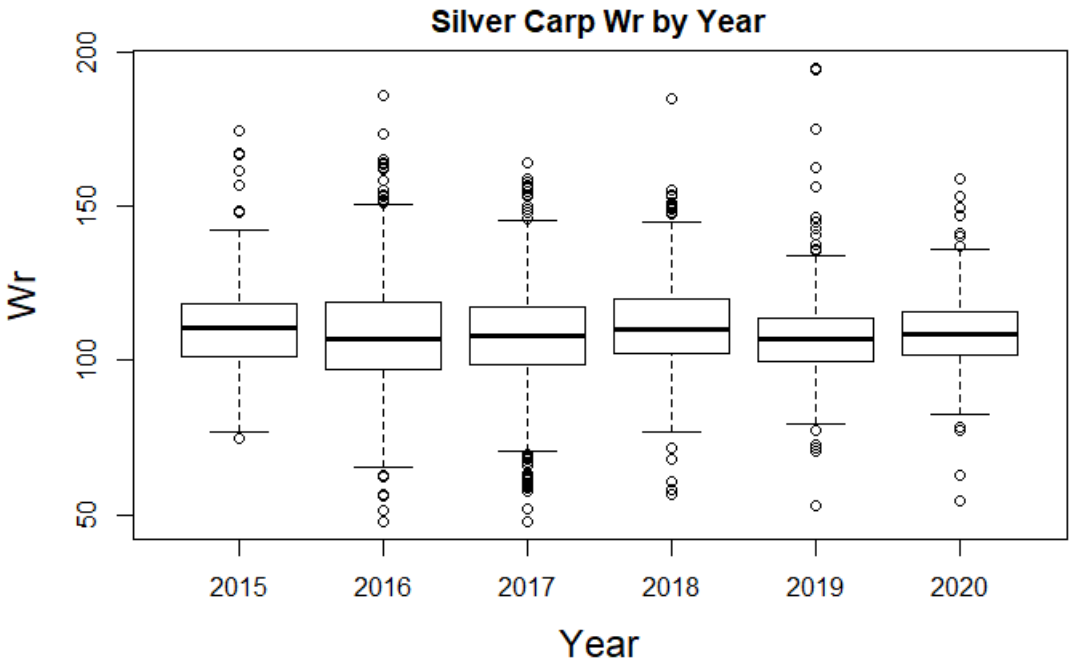

Figure 9. Silver Carp Wr by year in Pools 16-20 of the Upper Mississippi River from 2015 to 2020.

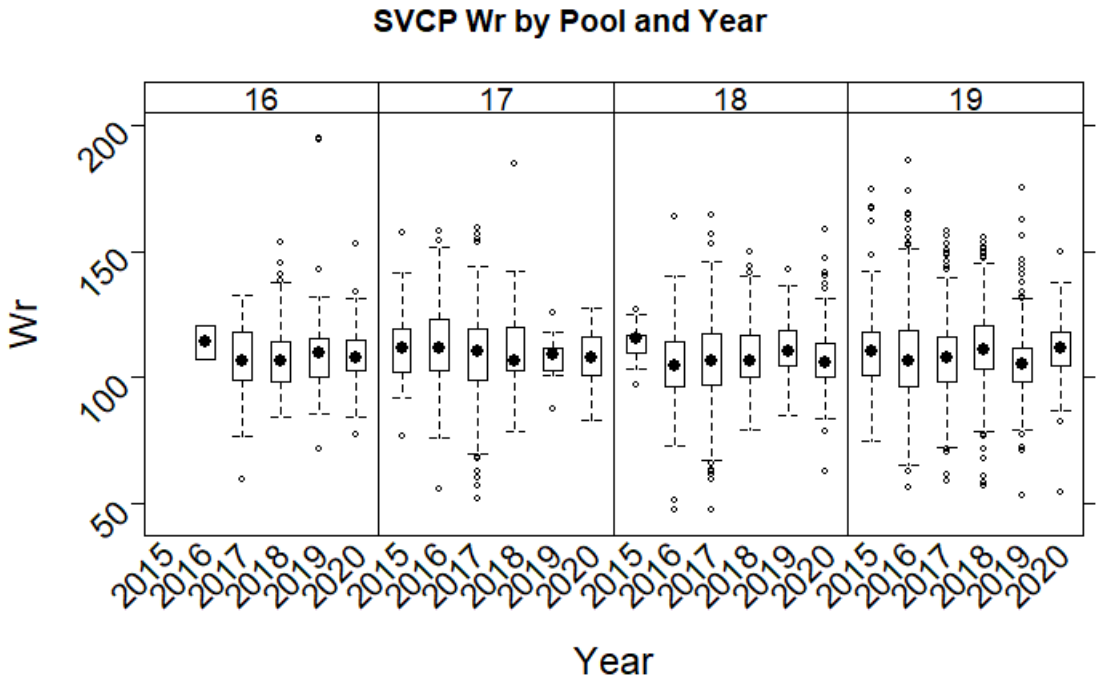

Figure 10. Silver Carp Wr by year and by pool in Pools 16-20 of the Upper Mississippi River from 2015 to 2020.

Bigmouth Buffalo

Bigmouth buffalo show relatively stable Wr throughout all years of sampling (Fig. 11). There were no significant differences found in the data with an ANOVA ($p=0.51$, $\alpha = 0.05$).

When examining the data between pools and years, Wr appeared variable. In Pool 16, there were no data from 2015 or 2020. A slight upward trend in Wr existed from 2016 to 2019 in Pool 16, and there was a significant difference shown in the ANOVA ($p=0.001$). Post-Hoc Tukey's test showed a significant difference between 2016 and 2019 ($p=0.02$), and 2017 and 2019 ($p=0.02$). In Pool 17, the Wr of bigmouth buffalo appeared variable throughout the years (Fig. 12). The ANOVA indicated a significant difference in the data ($p\leq0.001$), and the Post Hoc Tukey's test showed a significant difference between 2015 and 2016 ($p=0.044$), 2015 and 2017 ($p=0.03$), 2016 and 2018 ($p\leq0.001$), and 2017 and 2018 ($p\leq0.001$). There were no data available for 2020. In Pool 18, there were no data available for 2015. Throughout 2016, 2017, and 2018, Wr appeared to be stable (Fig. 12). The ANOVA showed no significant difference between any of the years in Pool 18 ($p=0.307$). In Pool 19, Wr was variable (Fig. 12). The ANOVA ($p\leq0.001$) and Post Hoc Tukey's test ($p=0.001$) indicated a difference between 2017 and 2018 ($p=0.005$) and 2018 and 2019 ($p=0.004$).

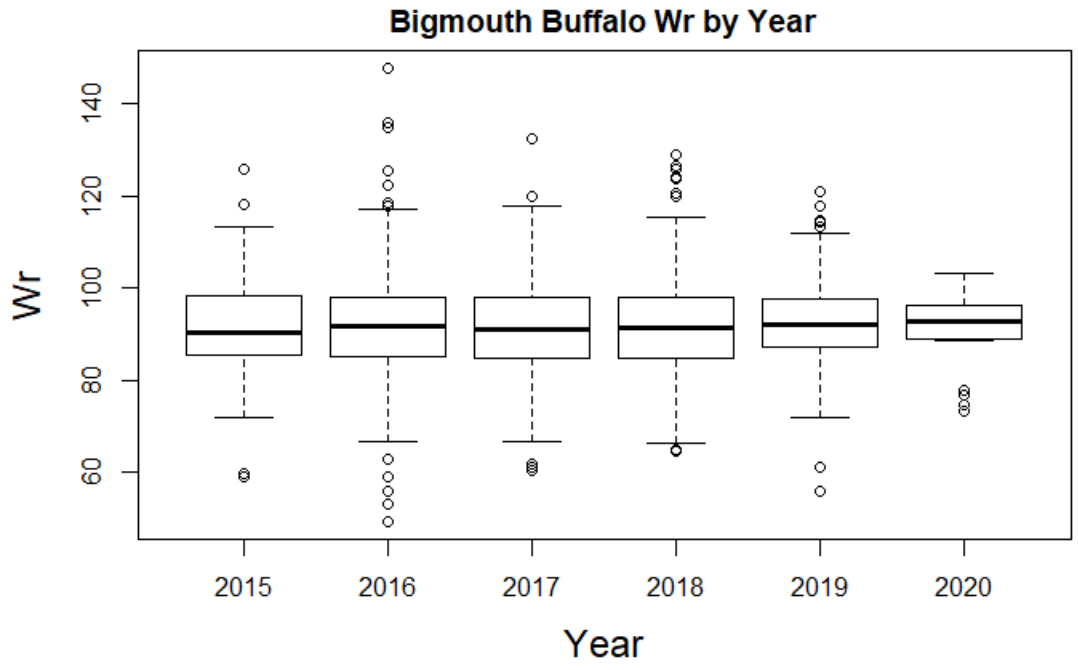

Figure 11. Bigmouth buffalo Wr by year in Pools 16-19 of the Upper Mississippi River from 2015 to 2020.

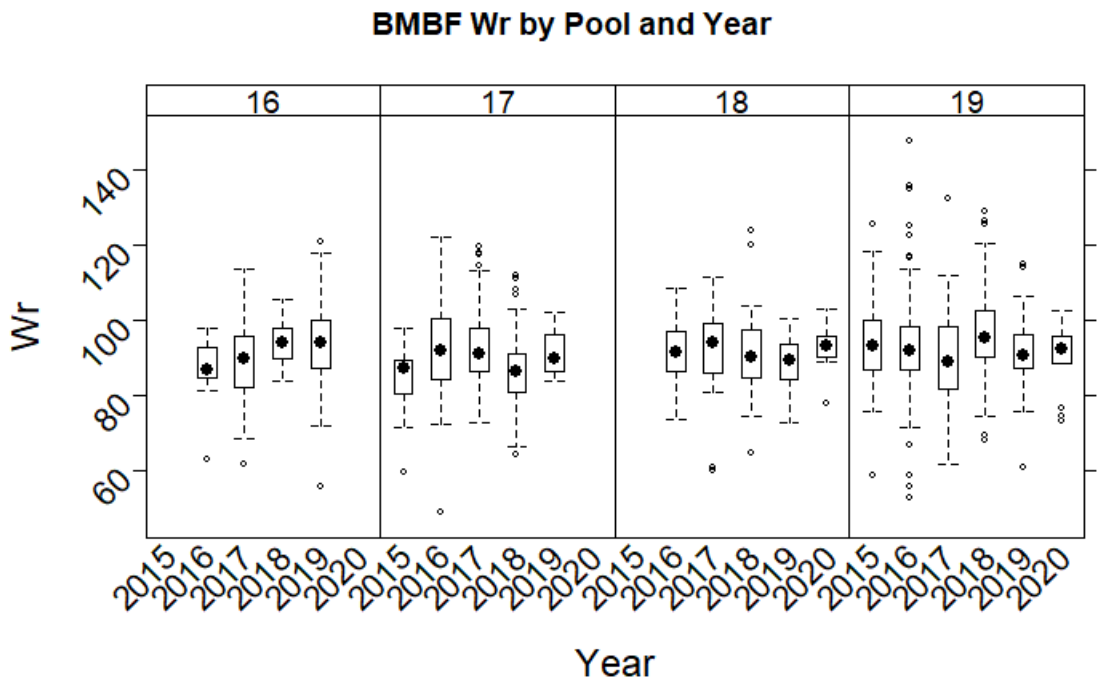

Figure 12. Bigmouth buffalo Wr by year and by pool in Pools 16-19 of the Upper Mississippi River from 2015 to 2020.

Paddlefish

Paddlefish data was only collected in Pool 17 in 2015 and was limited for 2020 due to COVID restrictions. Paddlefish showed a slightly decreasing trend in Wr from 2015 to 2017 and an increasing trend from 2017 to 2019 when all the Pools were combined (Fig. 13). The ANOVA showed significant differences ($p<0.001$, $\alpha = 0.05$) between 2016 and 2017 ($p=0.01$), 2016 and 2018 ($p<0.001$), 2016 and 2019 ($p<0.001$), 2017 and 2018 ($p<0.001$), and 2017 and 2019 ($p<0.001$).

In Pool 16, paddlefish Wr was variable throughout the years (Fig. 14). An ANOVA indicated a significant difference between years in Pool 16 ($p=0.05$), specifically between 2017 and 2018 ($p=0.04$). In Pool 17, paddlefish Wr appeared steady. However, an ANOVA showed a significant difference in the data ($p<0.001$). A Tukey's test revealed a significant difference between 2016 and 2017 ($p<0.001$), 2017 and 2018 ($p<0.001$), and 2017 and 2019 ($p<0.001$). In Pool 18, there were no data for 2015 and limited data for 2018. An ANOVA ($p<0.001$) showed a significant difference in the data, and a Tukey's test revealed a difference between 2016 and 2019 ($p<0.001$), and between 2017 and 2019 ($p=0.01$), showing 2019 Wr was higher than previous years. In Pool 19, a significant difference was detected between 2016 and 2018 ($p=0.004$).

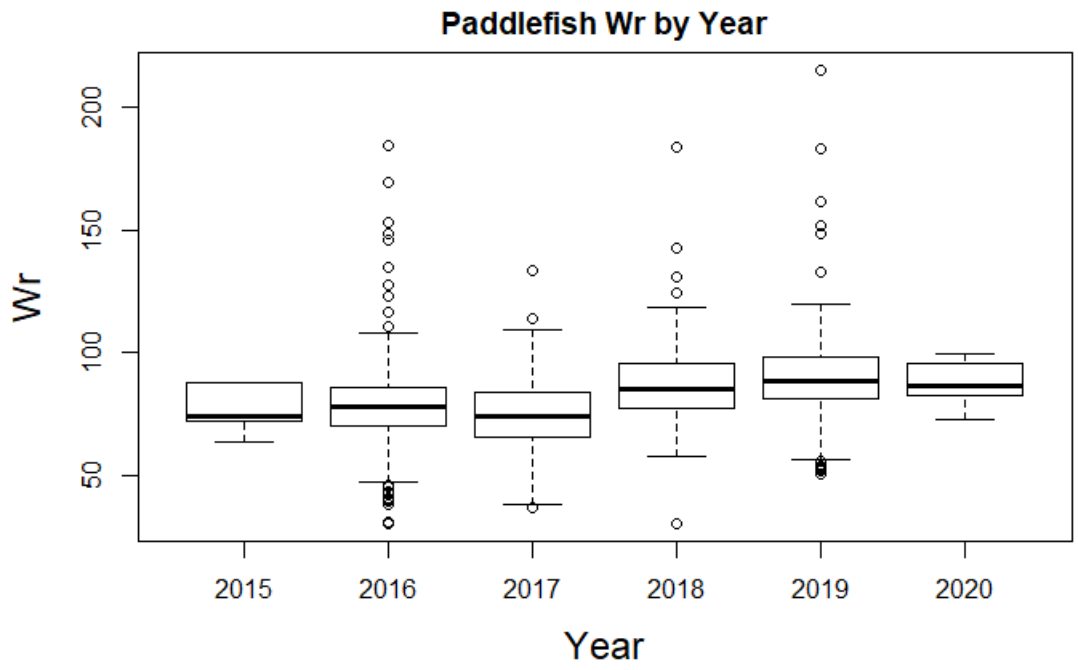

Figure 13. Paddlefish Wr by year in Pools 16-19 of the Upper Mississippi River from 2015 to 2020.

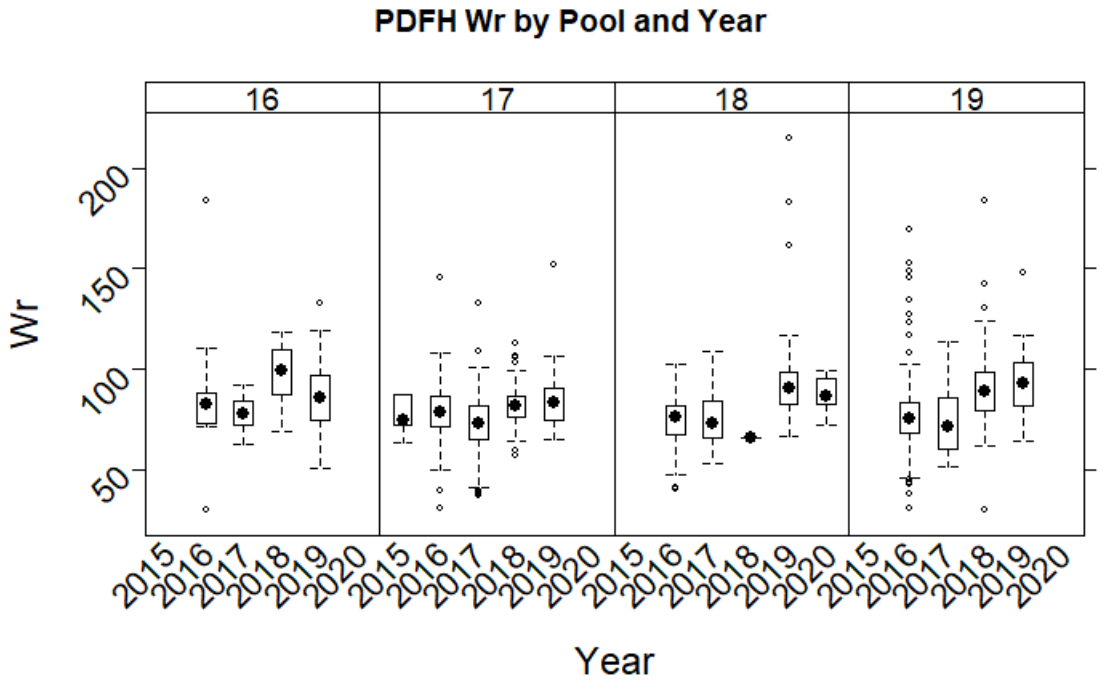

Figure 14. Paddlefish Wr by year and by pool in Pools 16-19 of the Upper Mississippi River from 2015 to 2020.

Recommendation

It is recommended that commercial removal efforts continue to reduce the number of bigheaded carp in Pools 16-19 in the Upper Mississippi River (low-density management zone). It is also recommended that efforts continue to determine the relationship between bigheaded carp and commonly encountered bycatch. This information is important to collect to target bigheaded carp more effectively and efficiently while trying to avoid harming other ecologically and commercially important species.

It is recommended to continue contracting commercial fishermen and increase the number of fishermen per sampling event to increase the total likelihood of bigheaded carp captured. Having additional acoustically tagged bigheaded carp and real-time receivers can offer greater capture success by identifying where schools of bigheaded carp are daily and provide better population estimates.

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