Evaluation of controls on density and behaviors of Asian carp in the UMR: Hydroacoustic Surveys in UMR Pools 16-19, fall 2019.

Fiscal Year: 2020

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Cooperating Agencies: Illinois Natural History Survey, and ILDNR (Western Illinois University)

Background:
In support of the Asian Carp National Plan and to meet expectations from our partners and Congress to serve a lead role in control and evaluation of Asian carp populations, the U.S. Fish and Wildlife Service initiated a mobile hydroacoustics survey program in the Upper Mississippi River (UMR) during the fall of 2019. Hydroacoustic surveys can provide data on the relative abundance, size distribution, and spatial distribution of fishes. When paired with physical capture data, hydroacoustics can also estimate biomass of fishes, and provide species specific estimates for these metrics. Hydroacoustic surveys in the UMR have a goal of providing spatial distribution, abundance and biomass estimates of Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*), in order to 1) guide contracted harvest efforts, 2) inform potential selection of optimal location(s) for deterrents to upstream movement, and 3) more accurately evaluate the long-term and basin-wide efficacy of management strategies such as harvest and deterrents.

Hydroacoustics is among the least size-biased sampling gears currently available to fisheries professionals, thereby providing more accurate relative abundance and size distribution information for stock assessment purposes. Furthermore, the large spatial coverage capabilities of hydroacoustics compared to traditional gears, can provide more precise and accurate relative abundance estimates, particularly for patchily distributed fish such as Asian carp. However, hydroacoustics is not a stand-alone gear, and requires physical sampling with traditional or non-traditional fisheries gears to separate the overall fish community size distribution into species-specific distributions. Hydroacoustic surveys are one component of a comprehensive stock assessment of Asian carps in the UMR that will be necessary to evaluate control and containment actions, to efficiently allocate resources, and to guide future management decisions.

Methods:
In the fall of 2019, the USFWS conducted hydroacoustic surveys on pools 16-19 of the UMR. Hydroacoustics data were collected similar to that described in MacNamara et al. (2016) and Coulter et al. (2018). Surveys were conducted using two horizontally oriented split-beam transducers (200 kHz; BioSonics, Inc.) offset in angle to maximize water column coverage (Figure 1). Population assessment surveys were conducted at select areas of the main channel, side channels, bays, and backwaters of the UMR (Appendix 1). The fall time period was selected because water levels are typically lower, concentrating fish in main channel border and side channel habitats where they are more easily surveyed with hydroacoustic equipment. Secondly, fish are generally less motile at this time period, reducing chances of double counting fish within or among pools, compared to the spring, when spawning cues can increase fish movement. Thirdly, the fall time period aligns with other comparable hydroacoustic surveys in neighboring river basins (IL River, Ohio River).

UMR transects on the main channel / main channel border consisted of two transects along each bank (Figure 2). The first set of transects was conducted near shore at the 1 to 1.5 m depth contour with the transducers pointed out towards the thalweg. In areas where wing dams extended out into the channel, the first transect followed along the tips of the wing dams (Figure 3). The next set of transects were located farther from shore, picking up where the beams from the first transect would have hit the bottom and viable data collection would have stopped. Side channels only require one transect on each shoreline, backwater lakes, marinas, and other off-channel habitats were sampled with one transect that followed around the perimeter of the entire shoreline (Figure 2).

We sampled 35-40% of main channel habitats in each pool. Main channel transects ranged from 2-5 miles in length, were evenly distributed throughout the pool and included the areas directly downstream of the lock and dam at the head of the pool and the areas directly upstream of the lock and dam at the bottom of the pool (Appendix 1). In addition, a minimum of 40% of accessible backwater and side channel habitats were surveyed in each pool (Appendix 1). No physical fish capture data was available for tributaries in 2019 so these areas were not surveyed.

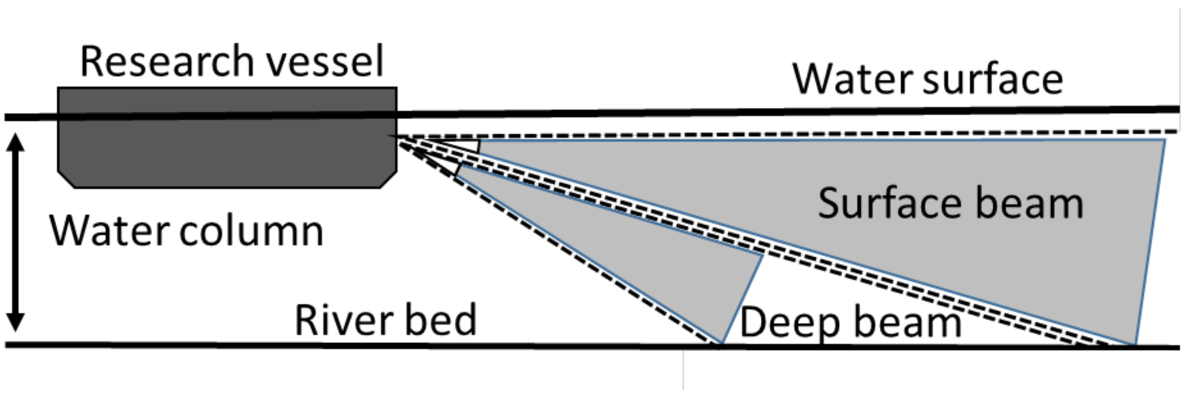

Figure 1. Diagram showing the approximate orientation of the hydroacoustic beams during a mobile survey. The data that can be used in analysis is collected within the gray area.

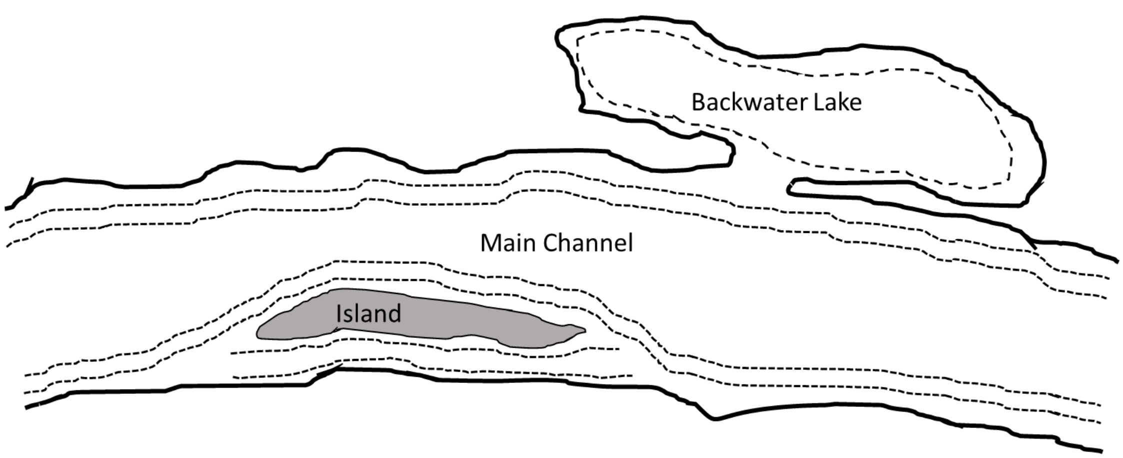

Figure 2. Example of survey transects (represented by dotted lines) in the Upper Mississippi River; two transects for each bank along the main channel, transducers pointing toward the thalweg; one transect on each bank for island side-channels and a one transect that follows the perimeter of the shoreline for backwater lakes.

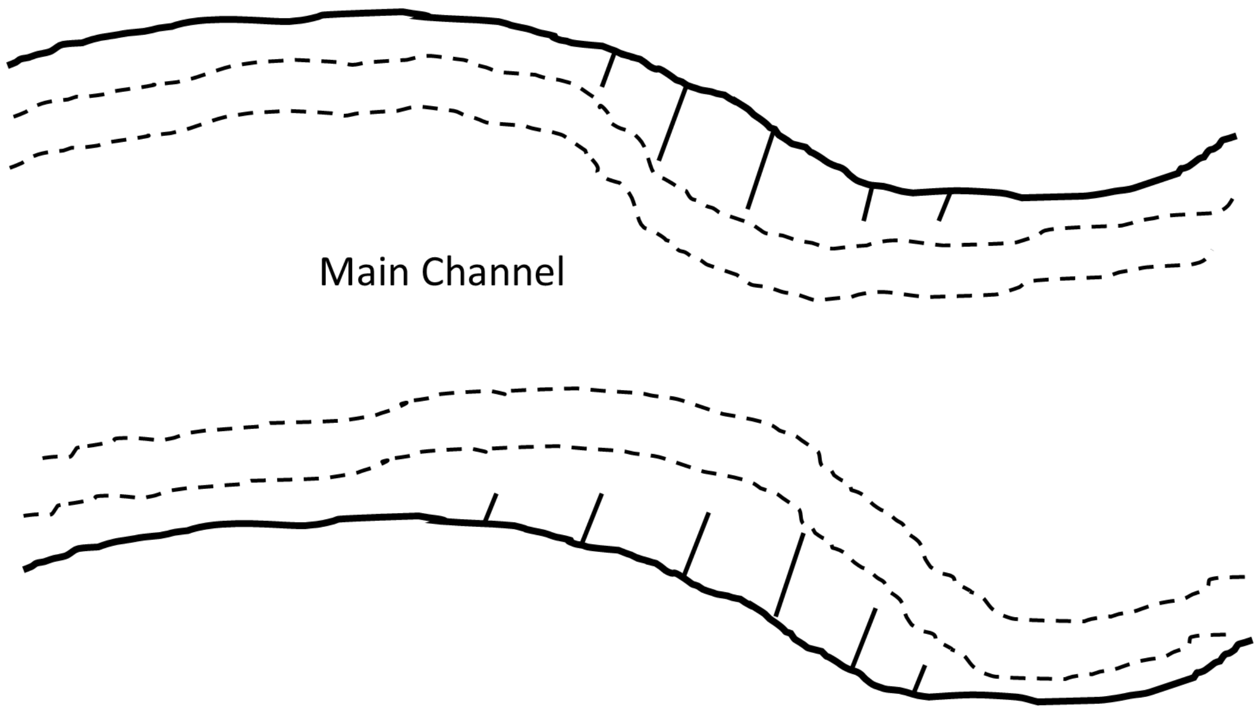

Figure 3. Example of survey transects (represented by dotted lines) in Upper Mississippi River where wing dikes are present. Two transects for each bank along the main channel, transducers pointing toward the thalweg. Transects run along the outside tips of dikes and as close to shore as depth allows.

Physical Sampling

Fishery-independent data was provided by the Illinois Natural History Survey's (INHS) Illinois River Biological Station, through an extensive standardized electrofishing program called the Long-term Survey and Assessment of Large River Fishes in Illinois or the Long-term Electrofishing Program (LTEF). The program uses pulsed-direct current (DC) electrofishing to sample fish communities at randomly selected locations throughout pools 16-21 of the Mississippi River. The program operates on an annual sampling schedule but typically limits sampling to main channel border habitats. The USFWS provided additional funding to the LTEF program to include additional sites at backwater and side channel habitats in pools of interest during their third and final sampling period (mid-September thru October), to provide a more accurate assessment of the overall fish community in the UMR and to increase the amount of data available for use by the hydroacoustic survey. Sites are selected through a stratified random sampling (SRS) design, with effort proportionally allocated among macrohabitat types based on availability. Across all pools combined, INHS sampled 23 main channel border sites, 23 backwater sites, and 37 side channel sites with pulsed-direct current electrofishing, with each electrofishing sample being 15 minutes in duration.

Paired Sampling and Analysis

Hydroacoustics data were analyzed following MacNamara et al. (2016) using Echoview 10.0, and the program "R". Single targets were detected using parameter values from Parker-Stetter et al. (2009). Multiple targets from a single fish were grouped using Echoview's fish tracking algorithm to reduce the potential of over counting fish targets. We instituted a length threshold to examine only fish targets $\geq$ 10" or 254 mm to reduce the number of false targets sometimes caused by bubbles and other disturbance. The size of fish targets (total length; mm) was estimated from mean acoustic target strength (dB) using a function specific to side-looking hydroacoustics (Love 1971). Hydroacoustics data was informed by pool/reach or habitat-specific fish community data (backwater fisheries data informs backwater hydroacoustic surveys; fisheries data from all habitats within a pool inform the pool-wide hydroacoustic estimate).

Length-frequency histograms and cumulative length-frequency plots were constructed and examined for acoustically detected fish by pool and by habitat type. Kruskal-Wallis rank sum tests were used to determine whether length-frequency distributions differed among habitat types and pools based on rank scores, and non-parametric multiple comparison tests (Zar 1996) with a significance level set at p= 0.05, were used to determine where these differences, if any, were occurring. All analyses were conducted using the data analysis program "R".

Results:

The fall of 2019 was characterized by abnormal flooding and high water, which made river access and physical fish collection difficult. The USFWS performed over 317 miles of hydroacoustic surveys across main channel, side channel, and backwater habitats of Pools 16-19 of the UMR (Appendix 1). A total of 36,613,872 cubic meters of water were ensonified and 5,559 fish $\geq$ 10 inches (254 mm) TL, were identified and counted (Appendix 2).

During the ILNHS LTEF third sampling period which aligned with hydroacoustic surveys, electrofishing surveys captured 495 fish $\geq$ 10 inches (254 mm) TL, and comprising 28 different species, all pools and habitats combined. However, none of these fish were Asian carp. Because no Asian carp were collected, reported hydroacoustic densities and abundance estimates were not species specific, rather just length specific (e.g. # fish $\geq$ 10"/1,000 m^3 of water sampled). Physical sampling data was essentially just used to calculate overall fish biomass estimates (Appendix 2).

Across all pools, large-bodied fish ($\geq$ 10" or 254 mm TL), were least abundant in main channel habitats (0.060 fish/1,000 m^3), followed by side channel habitats (0.113 fish/1,000 m^3), and were most abundant in backwaters (1.578 fish/1,000 m^3; Table 2). For pool-wide density estimates, Pool 17 had the highest overall observed densities (0.384 fish/1,000 m^3), while Pool 19 had the lowest observed densities (0.083 fish/1,000 m^3; Table 1). In general, across pools and among habitat types, biomass estimates tracked closely with abundance estimates (Appendix 2).

Summary statistics of length-frequency data were calculated by habitat type (Table 2). The Kruskal-Wallis rank sum test determined the differences in the length-frequency distribution among habitats was significant (χ^2 =260.4, df = 2, p < 0.0001), and nonparametric multiple comparison tests, showed acoustically detected fish were significantly larger in backwaters compared to other habitats, and larger in side channel habitats compared to main channel habitats (Figures 4 and 5).

Summary statistics of length-frequency data were next calculated by navigation pool (Table 3). The Kruskal-Wallis rank sum test determined the differences in the length-frequency distribution among pools was significant (χ^2 =178.21, df = 3, p < 0.0001), and nonparametric multiple comparison tests, showed acoustically detected fish were significantly larger in pool 17 compared to all other pools, while pools 16, 18, and 19 did not differ from one another (Figures 6 and 7).

Table 1. Number of fish $\geq$ 10" (254 mm) total length, detected per 1,000 m^3 of water in the Upper Mississippi River, fall 2019, by pool and macrohabitat type (MC = main channel; SC = side channel; BW = backwater).

	Number of Fish $\geq$ 10" (254 mm) TL /1,000 m^3			
Pool	MC	SC	BW	Total
16	0.051	0.132	2.276	0.128
17	0.049	0.121	2.834	0.384
18	0.065	0.125	0.728	0.131
19	0.063	0.089	0.699	0.083
Total	0.060	0.112	1.575	0.152

Table 2: Length-frequency summary statistics (mm TL) for acoustically detected fishes by habitat type, from pools 16-19 of the Upper Mississippi River, fall 2019 (MC = main channel; SC = side channel; BW = backwater).

Habitat	n	mean	sd	min	Q1	median	Q3	max
BW	3088	376.54	125.86	254	291	339	419	1396
MC	1564	330.73	94.74	254	274	303	351.25	1191
SC	928	339.25	95.55	254	275	311.5	366	1083

Table 3: Length-frequency summary statistics (mm TL) for acoustically detected fishes by pool, from pools 16-19 of the Upper Mississippi River, fall 2019.

Pool	n	mean	sd	min	Q1	median	Q3	max
16	738	334.84	101.46	254	277	305	362	1314
17	2346	377.85	125.88	254	292	340.5	421	1396
18	1166	344.07	105.54	254	279	315	368	1382
19	1330	345.95	104.38	254	276	313	376	1191

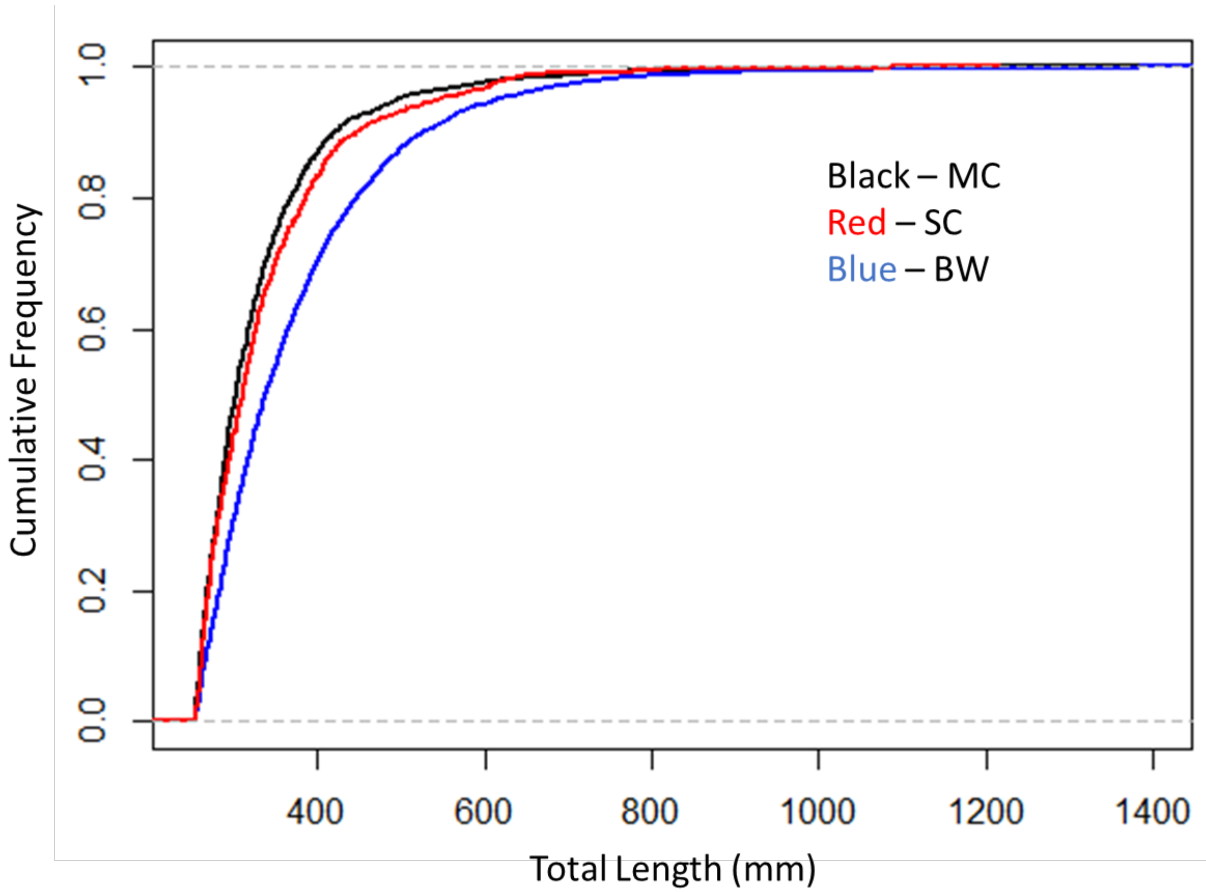

Figure 4. Cumulative frequency by total length (mm) for acoustically detected fish in pools 16-19 of the Upper Mississippi River, fall 2019, by macrohabitat type (MC = main channel; SC = side channel; BW = backwater).

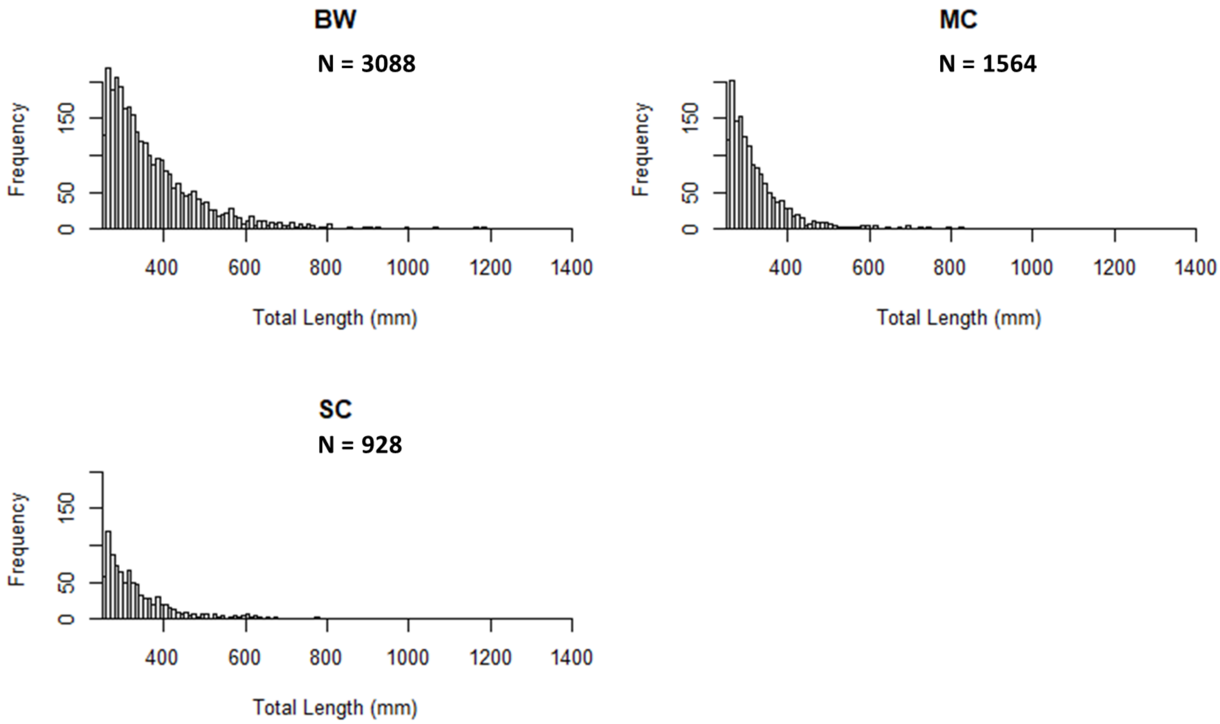

Figure 5. Length-frequency histograms for acoustically detected fish in pools 16-19 of the Upper Mississippi River, fall 2019, by macrohabitat type (MC = main channel; SC = side channel; BW = backwater).

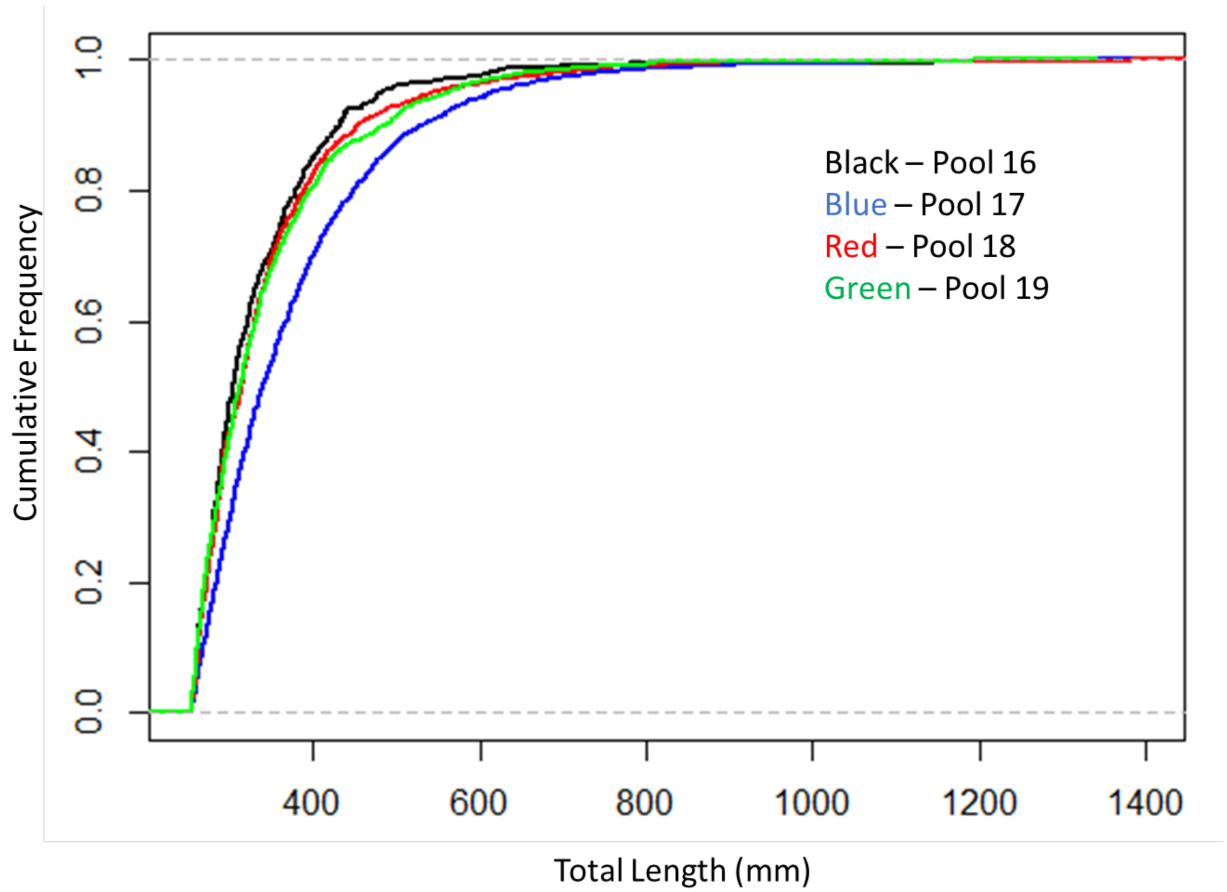

Figure 6. Cumulative frequency by total length (mm) for acoustically detected fish in pools 16-19 of the Upper Mississippi River, fall 2019, all habitats combined.

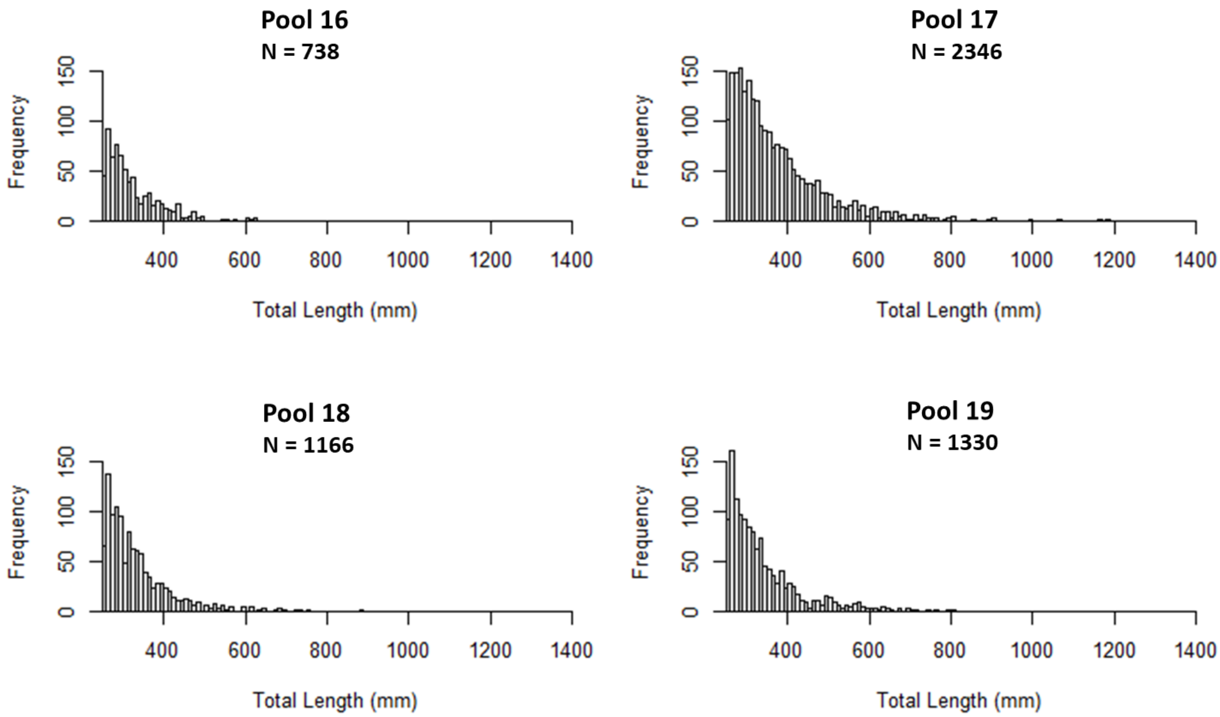

Figure 7. Length-frequency histograms for acoustically detected fish in pools 16-19 of the Upper Mississippi River, all sampled habitats combined, fall 2019.

Conclusion:

Hydroacoustic surveys in UMR pools 16-19 found that pool 17 had the highest densities of fish $\geq$ 10" (254 mm) TL and that across pools, backwaters had higher densities than main channel or side channel sites. Acoustically detected fish within pool 17 were also significantly larger compared to other pools, and across pools, were largest at backwater habitats. Considering the high water and discharge that was observed during surveys, it is possible that fish may have been selecting these off channel habitats for flow refugia. Fish densities observed at individual sites, although not species specific, may still provide clues for directing contracted harvest efforts. While many of the high density backwater sites within each pool were often also the sites of regular contracted removal efforts, and in some cases, home to real-time receivers (e.g. Credit Island in Pool 16, Cleveland Slough Pool 17, Boston Bay Pool 18, Carthage Pool 19), there were other backwater sites at which high densities of large-bodied fish were observed that could be investigated for future removal efforts. These sites include Lake Potter in Pool 16, the Muscatine Municipal Harbor in Pool 17, Gun Slough and Benton Bay in Pool 18, and Rabbit Island and Fish Lake in Pool 19 (Appendix 1).

Although flooding conditions likely contributed to low electrofishing catch rates, future surveys will require more robust fishery-independent data to inform the hydroacoustics sampling. In addition to LTEF electrofishing, future fishery-independent surveys in the UMR will also include comparable sampling effort to be conducted by the USFWS using gears known to be more effective at capturing Asian carps (e.g. the electrified dozer trawl). We may also draw upon additional data collected by state partner agencies (IL DNR, MDC, IA DNR) where available. Fishery-dependent data from the Asian carp contracted removal program, administered by Dr. James Lamer of the INHS, may also be used in the future. It is our goal that the increased combination of sampling efforts by the aforementioned sources will provide the data necessary to inform future hydroacoustic surveys in the UMR and to develop species specific estimates of abundance, biomass, and spatial distribution.

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Appendix 1. Location of hydroacoustic survey sites on the Upper Mississippi River, fall of 2019.

Pool	Sites	Habitat	NRM	Length	Transects	Total Dist. (nmi)
16	Lake Potter	BW	480	1.25	1	1.25
16	Credit Island	BW	479	4	1	4
16	Main Channel	MC	479-483	4	4	12
16	Andalusia Slough	SC	465-475.5	10.5	2	21
16	Main Channel	MC	470-473	3	4	12
16	Main Channel	MC	457.2-460.2	3	4	12
17	Towhead Island	SC	453-455	2	2	4
17	Main Channel	MC	453-457	4	4	16
17	Blanchard Island Chute	SC	448-452	4	2	8
17	Kilpeck Island	SC	446-447	1	2	4
17	Barkis Island	SC	445-446	1	2	4
17	Main Channel	MC	445-447	2	4	8
17	Big Timber/Coolegar	BW	443-445	8	1	8
17	Coleman Slough	SC	441.5-442	1.5	2	3
17	Cleveland Slough	BW	439-440	2	1	2
17	Main Channel	MC	437-439	2	4	8
18	Main Channel	MC	433-437	4	4	16
18	Keg Island	SC	435.5-436.5	1	2	2
18	Boston Bay	BW	433	8	1	8
18	Blackhawk Chute	SC	426-429	3	2	6
18	Main Channel	MC	426-428	2	4	8
18	Huron Chute	SC	420-425	5	2	10
18	Gun Slough	BW	422	2	1	2
18	Benton Bay	BW	419.5-421.5	4	1	4
18	Main Channel	MC	417.8-420	2.2	4	8.8
18	Benton Slough	SC	417.5-419.5	2	2	4
18	Main Channel	MC	411-413	2	4	8
19	Main Channel	MC	406-410	4	4	16
19	O'Connell Slough	SC	405-408	3	2	6
19	Shokokun Slough	SC	398-402	4	2	8
19	Two Mile Island	SC	398-400	2	2	4
19	Fish Lake	BW	398-400	1	4	4
19	Carthage Lake	BW	401.5-403	3	1	3
19	Skunk R. Bottoms	BW	396.5	3	1	3
19	Main Channel	MC	392-397	5	4	20
19	Grape Chute	SC	391-394	3	2	6
19	Lead Island	SC	386-388	2	2	4
19	Rabbit Island	BW	380	3	1	3
19	Main Channel	MC	378-383	5	4	20
19	Main Channel	MC	365-369	4	4	16

Appendix 2. Results from hydroacoustic surveys for main channel (MC), side channel (SC) and backwater (BW) sites in Pools 16-19 of the Upper Mississippi River, fall 2019, including number of fish detected ≥ 10" (254 mm) total length, total volume of water sampled (m^3), and number and biomass of fish by volume.

Pool	Habitat	Site	# Fish ≥ 10"	Water volume sampled (m^3)	Fish/1,000 m^3	95% CI ±	kg/1,000 m^3	95% CI ±
16	SC	Andalusia	200	1515775	0.132	0.025	0.069	0.013
16	BW	Credit	211	74282	2.837	0.702	1.166	0.289
16	BW	Lake Potter	114	68333	1.667	0.453	0.699	0.190
16	MC	457-460	117	1287261	0.091	0.017	0.076	0.014
16	MC	470-473	40	1264430	0.032	0.017	0.018	0.010
16	MC	479-483	49	1514898	0.033	0.010	0.035	0.010
Total	All	Combined	732	5724979	0.128	0.092	0.072	0.076

Pool	Habitat	Site	# Fish ≥ 10"	Water volume sampled (m^3)	Fish/1,000 m^3	95% CI ±	kg/1,000 m^3	95% CI ±
17	SC	Coleman	20	263738	0.077	0.049	0.045	0.029
17	SC	Barkus	38	323189	0.117	0.021	0.061	0.011
17	SC	Blanchard	124	859231	0.145	0.020	0.072	0.010
17	SC	Kilpeck Island	22	185945	0.120	0.066	0.056	0.031
17	SC	Towhead Island	29	301974	0.095	0.040	0.040	0.017
17	BW	Cleveland	951	228356	4.164	0.725	4.446	0.774
17	BW	Coolegar Slough	896	440425	2.035	0.543	1.457	0.389
17	BW	Muscatine Harbor	81	11583	6.964	2.180	4.985	1.561
17	MC	437-439	20	848349	0.024	0.007	0.009	0.003
17	MC	445-447	63	985064	0.064	0.060	0.030	0.029
17	MC	453-457	85	1615252	0.053	0.016	0.021	0.006
Total	All	Combined	2329	6063105	0.384	0.097	0.314	0.097

Pool	Habitat	Site	# Fish ≥ 10"	Water volume sampled (m^3)	Fish/1,000 m^3	95% CI ±	kg/1,000 m^3	95% CI ±
18	SC	Benton Slough	107	188399	0.567	0.225	0.339	0.134
18	SC	Blackhawk Chute	49	350163	0.139	0.055	0.060	0.024
18	SC	Keg Island	40	415370	0.095	0.058	0.071	0.043
18	SC	Huron Chute	37	911593	0.041	0.017	0.015	0.006
18	BW	Boston Bay	378	507901	0.744	0.157	0.534	0.113
18	BW	Gun Slough	120	131628	0.915	0.939	0.632	0.649
18	BW	Benton Bay	44	105256	0.418	0.131	0.291	0.091
18	MC	411-413	84	1314699	0.064	0.023	0.032	0.011
18	MC	418-420	18	844335	0.021	0.014	0.039	0.026
18	MC	426-428	41	969085	0.043	0.018	0.018	0.008
18	MC	433-437	287	3488264	0.082	0.020	0.068	0.017
Total	All	Combined	1205	9226692	0.131	0.085	0.091	0.085

Pool	Habitat	Site	# Fish ≥ 10"	Water volume sampled (m^3)	Fish/1,000 m^3	95% CI ±	kg/1,000 m^3	95% CI ±
19	SC	O'Connell Slough	35	684377	0.051	0.009	0.024	0.004
19	SC	Shokokon Slough	103	1264908	0.082	0.024	0.055	0.016
19	SC	Two Mile Island	43	238187	0.179	0.054	0.103	0.031
19	SC	Grape Chute	13	624116	0.021	0.010	0.015	0.007
19	SC	Lead Island Chute	71	140593	0.502	0.221	0.539	0.237
19	BW	Rabbit Island	6	6947	0.927	0.674	0.217	0.158
19	BW	Carthage	165	230347	0.718	0.420	0.681	0.399
19	BW	Skunk R. Bottoms	31	57353	0.544	0.274	0.670	0.338
19	BW	Fish Lake	56	76642	0.736	0.213	0.496	0.144
19	MC	365-369	253	2939050	0.086	0.029	0.050	0.017
19	MC	378-383	68	2825215	0.024	0.011	0.013	0.006
19	MC	392-397	184	3099766	0.059	0.012	0.044	0.009
19	MC	406-410	266	3411595	0.078	0.012	0.037	0.006
19	All	Combined	1293	15599096	0.083	0.057	0.056	0.057