

Project Title: Evaluation of fish passage for assessment of invasive carp deterrents at locks in the upper Mississippi River

Geographic Location: Upper Mississippi River, Pool 5-20, special emphasis on Locks and Dams 19, 15, 14, and 5

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Participating Agencies: Illinois Natural History Survey (INHS), Missouri Dept of Conservation (MDC), Minnesota Department of Natural Resources, U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE)

Statement of Need: Invasive carps are established in the upper, middle, and lower Mississippi River and their expansion upstream threatens a variety of aquatic ecosystem services including fishing and recreational boating. The physical and operational characteristics of Lock and Dam (LD) 19 restrict upstream movement of fishes because the only upstream fish passage route is through the lock chamber. This restriction might be hindering consistent reproduction and recruitment of invasive carps enough to reduce their abundance upstream from LD 19. Locks and Dams 5, 14, and 15 (upriver from LD 19) are infrequently at open-condition and may also be limiting the continued upstream expansion of invasive carps. Upstream passage of fishes at these locations would be limited to the lock chamber for the majority of the year (Wilcox et al. 2004; Bouska 2021).

Acoustic deterrents have been developed to deter fish movement through restricted passage points, and those systems show promise in deterring invasive carps. Small-scale acoustic deterrents have been tested on many native fishes and invasive carps in laboratories, outdoor ponds, and small rivers (Vetter et al. 2015, 2017; Murchy et al. 2017). Federal, state, and local partners approved the opportunity to test an experimental underwater acoustic deterrent system (UADS) at LD 19. This system, composed of 16 underwater speakers, was installed during January–March 2021. Testing of a UADS at a pinch-point dam, such as LD 19, will help managers understand the effects of a management deployment of a UADS at this site and other large river locations.

Lock and Dam 19 is an advantageous location to test an experimental UADS because fish can only move upstream through the lock chamber and because this location has seven years (i.e., 2017–2023) of fish passage data that have been collected by the UMR Invasive Carp Partnership. The partnership has successfully evaluated the seasonal timing of passages of invasive carps and native fish species, as well as the relation of fish upstream passages with the operation of the lock for river vessels (Fritts et al. 2021). A pivotal discovery from the ongoing work has been the identification of a differential motivation of invasive carps to complete upstream passage at LD 19. Invasive carps that were originally tagged upstream from LD 19 and moved downstream on their own volition were much more likely to complete upstream passage than invasive carps tagged downstream from LD 19 in Pool 20 (Fritts and Knights 2020, Fritts et al. 2021). This observation prompted an experimental translocation effort in 2019, which confirmed that fish with upstream experience complete upstream passage through LD 19 with much greater frequency than fish collected and tagged downstream from LD 19 (Fritts et al. 2024a). In

addition, the partnership has gained insights into behavior of invasive carps tagged with depth-sensitive transmitters. Data from these tags provides information about the position of a fish within the water column at LD 19 and how fish interact and respond to river vessel presence in the downstream lock approach and the lock chamber.

Passage data for invasive carps and native species (i.e., Paddlefish *Polyodon spathula* and Bigmouth Buffalo *Ictiobus cyprinellus*) have also been studied at LD 15 over the past five years (Fritts et al. 2022, Turney et al. 2022). Locks and Dams 5, 14, and 15 have been considered as potential locations for deterrents, and baseline information on behavior of both native and invasive fish species is important to inform management decisions including the potential deployment of deterrents at these sites (Upper Mississippi River Asian Carp Partnership 2018). These locks and dams all have the potential to enter open-river conditions during floods, so it is critical to evaluate the pathways of upstream passage (i.e., lock chamber versus gated portion of the dam) during variable flow conditions (Wilcox et al. 2004, Fritts et al. 2024b).

State and federal partners have identified evaluating the effects of a UADS on native species as a high priority. Acoustic telemetry data are currently being collected by Missouri Department of Conservation (MDC), Illinois Natural History Survey (INHS), U.S. Fish and Wildlife Service (USFWS), Minnesota Department of Natural Resources (MN DNR), and U.S. Geological Survey (USGS) from previously tagged fish (invasive carps and native species) moving through longitudinal and fine-scale arrays of 69-kHz acoustic receivers at LD 19, LD 15, and LD 14. (Innovasea, Nova Scotia). Many of the previously tagged fishes will continue to be tracked in addition to the newly tagged fishes. Our project involves the continued collection of movement data using acoustic receiver arrays and acoustically tagged fish in the UMR to evaluate the effects of the UADS at LD 19 on invasive carps and native species, refining passage data for native and invasive species at LD 14 and LD 15 and establishing a new array of 69-kHz receivers at LD 5.

This project directly addresses multiple aspects of the UMR sub-basin framework, including providing information on evaluating and implementing deterrent measures at strategic pinch points to prevent dispersal of invasive carps and supporting research to develop new containment technologies. This project also closely aligns with the goal of containing expansions of invasive carps in the UMR while minimizing effects to native fish species movement.

Project Objective:

- 1.1. Assessment of fish behavior and passage at lock and dam structures on the Upper Mississippi River to evaluate passage rates, movement probabilities, and behavior in and around locks to inform and evaluate deterrent testing

Project Highlights:

- During 2024, 353 invasive carps and 289 native fish were internally implanted with acoustic transmitters (combination of 69-kHz and 307-kHz) to monitor passage through and behavior around the UADS during on and off conditions
- Maintenance for the UADS sound bar completed in March 2024
 - Operated on an 80-hour ON/80-hour OFF cycle from April – November 2024

- During 2024, 4 Bighead Carp, 11 Silver Carp, 37 Paddlefish, and 39 Bigmouth Buffalo were internally implanted with 69-kHz acoustic transmitters to monitor passage through LD 14 and LD 15 to refine understanding of baseline passage rates at locations that may be considered for invasive carp deterrents
- Flooding during June and July 2024 led to prolonged open-river condition at LD 5, LD 14, and LD 15 and resulted in substantial upstream passage through these dams for native fish species and invasive carps

Methods:Telemetry arrays

USGS maintained a 69-kHz telemetry receiver array at LD 19 (Figure 1), LD 15 and LD 14 (Figure 2). A new telemetry receiver array was deployed at LD 5 during 2024 (Figure 3). At LD 19, receivers are deployed in the downstream lock approach, lock chamber, and upstream lock approach. An additional fine-scale telemetry system (307-kHz) was installed at LD 19 concurrent with the installation of the UADS (Figure 4). The 69-kHz telemetry arrays at Locks and Dams 5, 14, and 15 are designed to detect upstream and downstream fish passages through the lock chamber as well as passages through the gated portion of the dam (Figure 2, Figure 3). Data from the telemetry arrays at the focal locks and dams were coupled with the 69-kHz large-scale longitudinal telemetry array maintained by INHS, USFWS, USGS, MDC, Iowa State University, and MN DNR. Stationary receivers in the longitudinal array were placed throughout different aquatic areas including the main navigational channel, backwaters, tributaries, and side channels, and provided confirmation of dam passages at our focal locks and dams.

Large fish-tagging events occurred during the spring of 2021—2024. All animal procedures were reviewed and approved by the U.S. Geological Survey's Upper Midwest Environmental Sciences Center Institutional Animal Care and Use Committee, under IACUC protocol number ESB-19-LD19CARP-01 and AEH-20-LD19ADS-01. Silver Carp (*Hypophthalmichthys molitrix*), Bighead Carp (*Hypophthalmichthys nobilis*), Grass Carp (*Ctenopharyngodon idella*), and Bigmouth Buffalo were collected in locations upstream from LD 19 and translocated, tagged with 307-kHz transmitters, and released downstream into Pool 20; a subset of fish were also dual tagged with 69-kHz transmitters. The translocation of fishes originating upstream from LD 19 to downstream from LD 19 was intended to increase the sample size of invasive carps that would approach and challenge the UADS, thereby increasing the amount of data available to assess the efficacy of this experimental deterrent (Fritts et al. 2024a). Native fish species (i.e., Paddlefish, Bigmouth Buffalo, Smallmouth Buffalo (*Ictiobus bubalus*), Black Buffalo (*Ictiobus niger*), Lake Sturgeon (*Acipenser fulvescens*), Flathead Catfish (*Pylodictis olivaris*), Blue Sucker (*Cycleptus elongatus*), White Bass (*Morone chrysops*), Freshwater Drum (*Aplodinotus grunniens*), Walleye (*Sander vitreus*), Sauger (*Sander canadensis*), Northern Pike (*Esox lucius*), River Carpsucker (*Carpionodes carpio*)) were collected and tagged with a combination of 69-kHz and 307-kHz transmitters in Pool 20 (i.e., downstream from LD 19). Additional Silver Carp, Bighead Carp, Paddlefish, and Bigmouth Buffalo were tagged in Pools 13 – 15 to provide data on baseline passage rates at LD 14 and LD 15 under varying hydrologic conditions.

Lock Queue Reports were obtained from the U.S. Army Corps of Engineers Lock Performance Management System to evaluate the relation between fish passage, operation of the UADS, and operation of the lock for river vessels at LD 19, plus relation of fish passage with vessels at LD

14 and LD 15. Hydrologic data and lock and dam operational data were obtained from the U.S. Army Corps of Engineers St. Paul District and Rock Island District.

Results:

UADS at LD 19

The UADS system construction and installation was completed in early 2021. Maintenance events occurred in March 2022 and April 2023 to conduct maintenance and replace a subset of speakers within the soundbar (Figure 4). During both events, the sound bar was removed from the river for the necessary maintenance. During 2023, the connections for the speakers were changed to “wet-connect” options that allowed for future maintenance events to occur underwater. During 2024, a speaker was replaced while still in the water because of the new “wet-connect” upgrade. A full dive survey of all equipment was also completed. The UADS was operated on an 80-hour *on-off* cycle during the navigation season (i.e., March – November) of 2021 – 2024.

From March through May 2024, 353 invasive carps and 289 native fish were internally implanted with acoustic transmitters to monitor passage through and behavior around the UADS during on and off conditions. Two telemetry systems (i.e., 69-kHz and 307-kHz) are being used for the UADS evaluation.

Fish passage at LD 5, 14 and 15

During 2024, 4 Bighead Carp, 11 Silver Carp, 37 Paddlefish, and 39 Bigmouth Buffalo were internally implanted with 69-kHz acoustic transmitters to monitor passage through LD 14 and LD 15 to refine understanding of baseline passage rates at locations that may be considered for invasive carp deterrents. Locks and Dams 5, 14, and 15 were in open-river condition for >17 days during a summer flood in 2024. During this window of open-river conditions, substantial numbers of native and invasive species undertook upstream passage through the gated portion of the UMR navigation dams. Most upstream passages were through the gated portion of the dams during open-river conditions, with a small number of passages occurring through the lock chambers.

Communication and information dissemination

The following presentations on invasive carp and native fish behavior in relation to Mississippi River locks and dams were provided at conferences during FY24:

- Stanton, J.C., Brey, M.K., Woodley, C.M., Fritts, A.K., Sholtis, M. and Castro-Santos, T., 2024, Underwater acoustic deterrent effects on invasive carp behavior downstream of a navigation lock, Oral Presentation, 23rd International Conference on Aquatic Invasive Species, Halifax, Nova Scotia, Canada, May 12-16, 2024.
- Brey, M.K., Woodley, C., Stanton, J.C., Fritts, A.K., Sholtis, M., Swyers, N.M., Albers, J., and Castro-Santos, T., 2024, Invasive carp underwater acoustic deterrent system at Mississippi River Lock 19, Oral Presentation, 23rd International Conference on Aquatic Invasive Species, May 12-16, 2024, Halifax, Nova Scotia, Canada.
- Gibson-Reinemer, D., Fritts, M., Henderson, C., Lieder, K., Appel, D.S., Milde, A.S., Brey, M.K., and Fritts, A.K., 2023, Flooding allows rapid long-distance movements by

native and invasive species in the Mississippi River: Oral Presentation, The 15th International Symposium on Ecohydraulics (ISE 2024) and Fish Passage, Québec City, May 5-9, 2024.

- Appel, D.S., Kao, Y., Fritts, M., and Fritts, A., 2024, Invasive carp on the move: deciphering longitudinal movement patterns in the upper Mississippi River: Oral Presentation, Mississippi River Research Consortium Annual Meeting, La Crosse, Wisconsin, April 16-18, 2024.
- Fritts, A.K., Gibson-Reinemer, D.K., Milde, A., Brey, M.K., Appel, D.S., Lamer, J., Fritts, M., Lieder, K., Henderson, C., Turney, D., Witzel, Z., Szott, E., Loppnow, G., Stiras, J., Zankle, K., Oliver, D., and Hoxmeier, J., 2024, Flooding allows rapid long-distance movements by native and invasive fish, Oral Presentation, 154th American Fisheries Society Annual Meeting, September 15-19, 2024, Honolulu, HI.
- Jarabica, J., Martin, F., Kumagai, K., Laber, C., Urbanczyk, A., Brey, M.K., and Woodley, C., 2024, Aerial acoustic impacts on local community from an underwater acoustic deterrent system (UADS) Lock No. 19, Oral Presentation, 154th American Fisheries Society (AFS) Annual Meeting, September 15-19, 2024, Honolulu, HI.

Publications

- Published manuscript on experimental translocation
 - Fritts, A.K., Gibson-Reinemer, D.K., Knights, B.C., Milde, A.S., Stanton, J.C., Brey, M.K., Appel, D.S., Cupp, A.R., Tripp, S.J., Lamer, J.T. and Fritts, M.W., 2024. Upstream experience and experimental translocation of invasive bigheaded carps results in increased upstream passage success at a navigation lock in a large river. *River Research and Applications*. <https://doi.org/10.1002/rra.4253>
 - Data release: Fritts, A. K., Gibson-Reinemer, D. K., Knights, B., Stanton, J. C., Milde, A. S., Brey, M. K., Lamer, J., Appel, D. S., Cupp, A. R., Tripp, S., & Fritts, M. 2024. Data release for an experimental translocation of invasive bigheaded carps and upstream passage success at a navigation lock. U.S. Geological Survey Data Release. <https://doi.org/10.5066/P9ACWTGK>
- Published manuscript on large-scale fish migrations through 16 UMR locks and dams
 - Fritts, M., Gibson-Reinemer, D.K., Appel, D.S., Lieder, K., Henderson, C., Milde, A.S., Brey, M.K., Lamer, J., Turney, D., Witzel, Z., Szott, E., Loppnow, G., Stiras, J., Zankle, K., Oliver, D., Hoxmeier, J., and Fritts, A.K., 2024, Flooding and dam operations facilitate rapid upstream migrations of native and invasive fish species on a regulated large river. *Sci Rep* 14, 20609. <https://doi.org/10.1038/s41598-024-70076-4>
 - Data release: Fritts, M., Gibson-Reinemer, D.K., Appel, D.S., Lieder, K., Henderson, C., Milde, A.S., Brey, M.K., Lamer, J., Turney, D., Witzel, Z., Szott, E., Loppnow, G., Stiras, J., Zankle, K., Oliver, D., Hoxmeier, J., and Fritts, A.K., 2024, Data release associated with research that describes how major flooding and

dam operations in the Upper Mississippi River contribute to large upstream migrations of native paddlefish and invasive bigheaded carp: U.S. Geological Survey data release, <https://doi.org/10.5066/P14GQIVU>

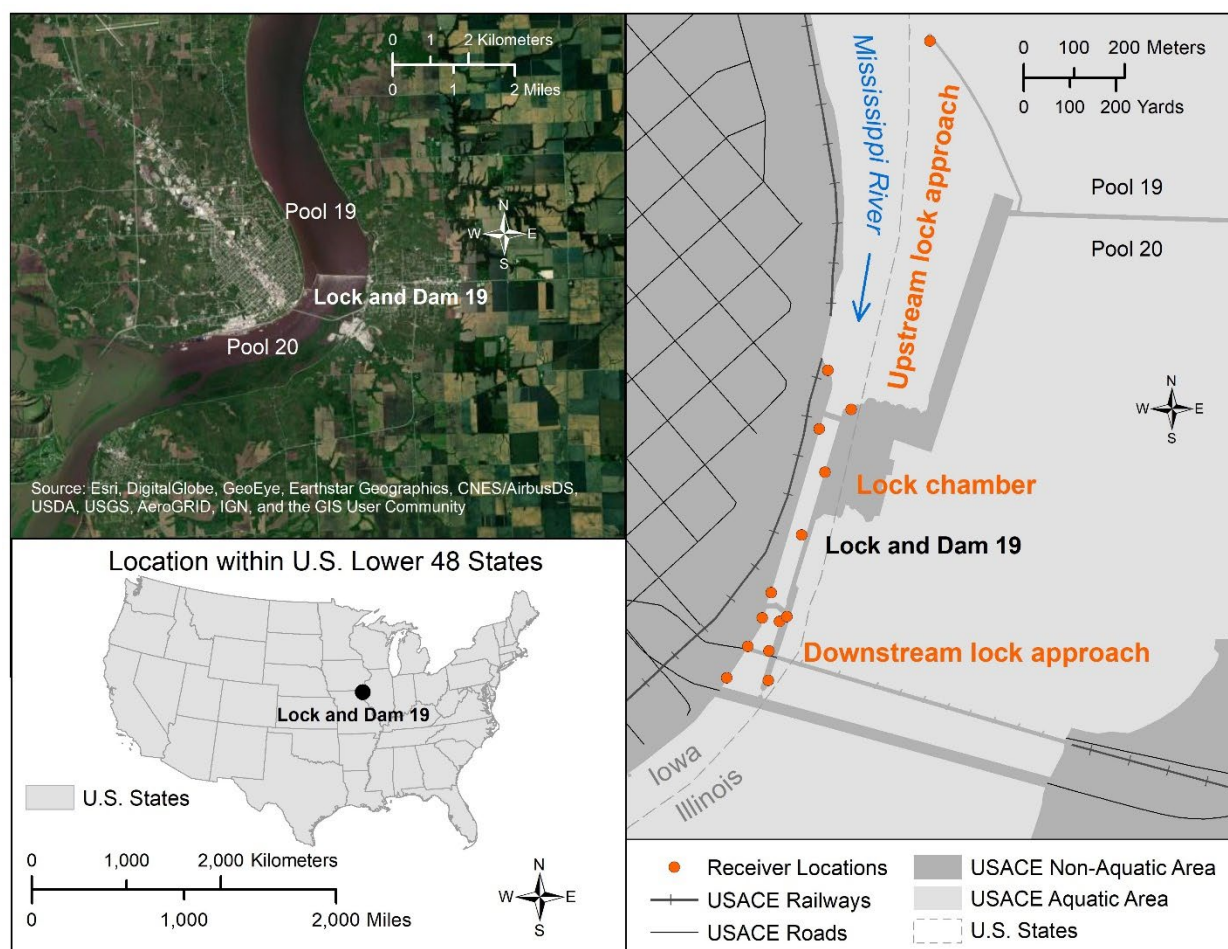


Figure 1. Location of receivers comprising the 69-kHz telemetry array in the vicinity of Lock No. 19.

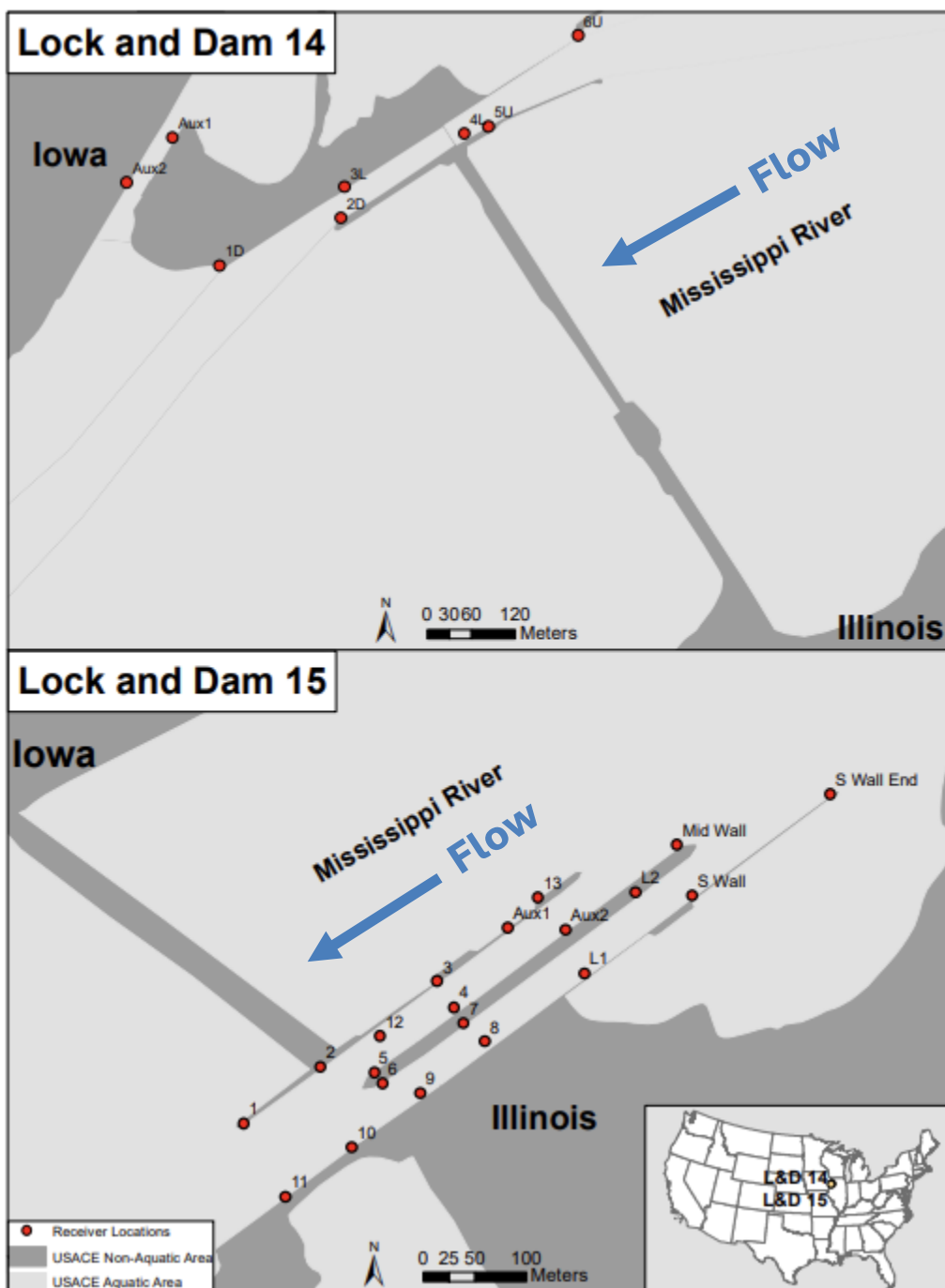


Figure 2. The 69-kHz telemetry arrays at Lock and Dam (LD) 14 in Le Claire, IA, and LD 15 located in Davenport, IA. The receiver locations are displayed by the red dots and are dispersed throughout the main and auxiliary locks. At LD 14 (top) there are 2 receivers in the downstream approach (1D, 2D), 2 receivers in the main lock (3L, 4L), 2 receivers in the auxiliary lock (Aux1, Aux2), and 2 receivers in the upstream lock approach (5U, 6U). At LD 15 (bottom) there are 12 receivers in the downstream approach (1-12), 2 receivers in the main lock (L1, L2), 2 receivers in the auxiliary lock (Aux1, Aux2), and 4 receivers in the upstream lock approach (S.Wall, MidWall, S Wall End, 13).



Figure 3. The 69-kHz telemetry arrays at Lock and Dam (LD) 5 in Minnesota City, MN. The receiver locations are displayed and provide coverage of the downstream lock approach, lock chamber, upstream lock approach, and areas overlooking the tailwaters and headwaters of LD 5.



Figure 4. Updated speakers that are equipped with wet-connections to facilitate replacement underwater (Photograph by Marybeth Brey, USGS).

Recommendation: Understanding how sound affects invasive carps and resident native fish species at LD 19, where invasive carps are abundant, can help further develop methods that limit invasive carp movement. The deployment and evaluation of a UADS at LD 19 is integral to determining if underwater sound is an effective deterrent for upstream migrating invasive carps at strategic locks and dams. In addition, we will gain valuable information on freshwater soundscapes and native and invasive fish behavior to develop a framework for evaluating deterrents at locks and dams and other locations in large rivers. Information will help managers and other researchers (e.g., USACE Engineer Research and Development Center) make decisions for deterrent usage at other locations (e.g., Brandon Road Lock and Dam; UMR LDs 5, 14 and 15; locks and dams in other basins).

An improved understanding of fish passage dynamics at pinch-point dams helps to inform decisions on the potential or utility to implement invasive species deterrents at these locations. Understanding how fish species behave at these navigation dams is critical information for river researchers as they evaluate potential tools or technologies to slow or cease the progress of bigheaded carp expansion in the UMR.

Acknowledgement: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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