

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 14-20, special emphasis on Locks and Dams 19, 15, and 14

Lead Agency: United States Geological Service, Upper Midwest Environmental Science Center, Andrea Fritts

Participating Agencies: Illinois Natural History Survey (INHS), Missouri Dept of Conservation (MDC), 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 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 six years (i.e., 2017–2022) of fish passage data that have been collected by the UMR Invasive Carp Team. 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 LD19 with much greater

frequency than fish collected and tagged downstream from LD19 (Fritts et al. 2024). In addition, the partnership has gained insights into behavior of invasive carps tagged with depth-sensitive transmitters. Data from these tags provided 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 four years (Fritts et al. 2022, Turney et al. 2022). Locks and Dams 14 and 15 have both been considered as potential locations for deterrents, and baseline information on behavior of both native and invasive fish species would be important to inform management decisions including the potential deployment of deterrents at these sites (Upper Mississippi River Asian Carp Partnership 2018).

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) 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, plus refining passage data for native and invasive species at LD 14 and LD 15.

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. 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:

- An Open File Report on the first two years of the UADS study was published in 2023 (Brey et al. 2023)
- During 2023, 488 invasive carps and 236 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 April 2023
 - Operated on an 80-hour ON/80-hour OFF cycle from April – November 2023
- During 2023, 52 Paddlefish, and 36 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 April – May 2023 led to prolonged open-river condition at 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). At LD 19, six receivers were deployed in the downstream lock approach, three additional receivers were deployed in the lock chamber, and one additional receiver was deployed upstream from the upper lock gates at LD 19 to enhance vertical position monitoring in the lock chamber and to supplement the existing receivers maintained by MDC. An additional fine-scale telemetry system (307-kHz) was installed at LD 19 concurrent with the installation of the UADS (Figure 3). The 69-kHz telemetry arrays at Locks and Dams 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). 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-UMESC, MDC, and Minnesota Department of Natural Resources. 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, 2022, and 2023. 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. This was done 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. 2024). Native fish species (i.e., Bigmouth Buffalo, Paddlefish, 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*)) 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, 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.

Results

UADS at LD 19

The UADS system construction and installation was completed in early 2021. A maintenance event occurred in March 2022 and April 2023 to conduct maintenance and replace a subset of speakers within the soundbar (Figure 3). The UADS was operated on an 80-hour *on-off* cycle during the navigation season (i.e., March – November) of 2021 – 2023.

From March through May 2023, 488 invasive carps and 236 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.

Depth transmitters (69-kHz) were deployed in Bighead Carp and Silver Carp in 2019 and a subset of these tagged carps are still being detected near LD 19. Bigmouth Buffalo, Paddlefish, Lake Sturgeon, and Flathead Catfish were tagged with depth transmitters in spring 2021 and spring 2022. The depth sensor transmitters are providing information on the position of invasive carps and native fish species in the water column at LD 19 and how fish are responding to the UADS.

Table 1. Upstream and downstream passages at LD 19 during 2023 for fish tagged with 69-kHz transmitters, separated by route of passage (lock chamber or dam gates). Includes data from fish tagged for the UADS study, as well as fish released upstream from LD 19 for fish passage studies at upriver locations.

Lock and Dam 19	Upstream	Downstream
Lock chamber		
Silver Carp	13	0
Grass Carp	1	0
Paddlefish	3	0
Freshwater Drum	1	0
Striped Bass/White Bass hybrid	1	0
Smallmouth Buffalo	1	0
Bigmouth Buffalo	9	0
Dam gates		
Silver Carp	0	2
Paddlefish	0	1
Lake Sturgeon	0	1
Bigmouth Buffalo	0	2

Fish passage at LD 14 and LD 15

Locks and Dams 14 and 15 were in open-river condition for 20-25 days during a spring flood in 2023. During this window of open-river conditions, substantial numbers of native and invasive species undertook upstream passage through the gated portion of LD 14 (Table 2) and LD 15 (Table 3). Tagged Bighead Carp, Silver Carp, Paddlefish, and Bigmouth Buffalo made upstream passage. Of the 163 tagged Silver Carp, Bighead Carp, and Silver/Bighead carp hybrids detected in Pool 16 (downstream of LD 15) during 2023, 46% (75 individuals) passed upstream through LD 15. Paddlefish displayed a similar percentage of the available tagged Paddlefish undertaking upstream passage, with 53% (17 of 32 individuals) completing upstream passage through LD 15. Most upstream passages were through the gated portion of the dam during open-river conditions, with a small number of passages of native species occurring through the lock chamber at LD 15. Many of the fish that completed upstream passage through LD 15 subsequently completed upstream passage through LD 14 in 2023. Downstream movements occurred through the gated portion of LDs 14 and 15.

Table 2. Upstream and downstream passages at LD 14 during 2023, separated by route of passage (lock chamber or dam gates).

Lock and Dam 14	Upstream	Downstream
Lock chamber		
Paddlefish	2	0
Dam gates		
Bighead Carp	6	0
Silver Carp	55	5
Silver/Bighead hybrid	2	0
Paddlefish	11	4
Bigmouth Buffalo	6	1

Table 3. Upstream and downstream passages at LD 15 during 2023, separated by route of passage (lock chamber or dam gates).

Lock and Dam 15	Upstream	Downstream
Lock chamber		
Paddlefish	2	0
Dam gates		
Bighead Carp	8	1
Silver Carp	65	20
Silver/Bighead hybrid	2	0
Paddlefish	15	9
Bigmouth Buffalo	4	4

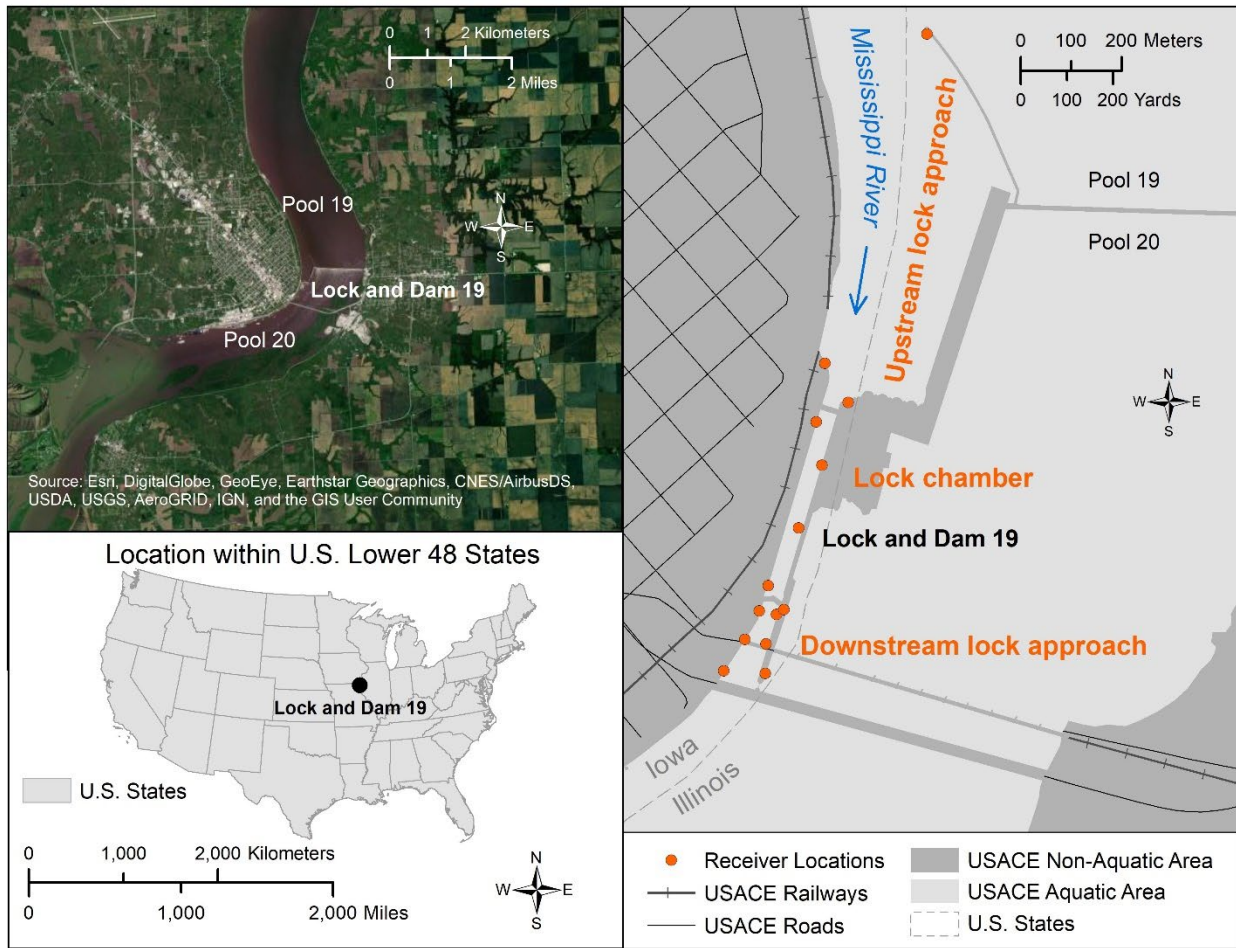


Figure 1. Location of receivers comprising the 69-kHz telemetry array in the lock approach at Lock 19. There are 6 receivers in the downstream approach, 4 receivers in the main lock, and 3 receivers in the upstream lock approach.

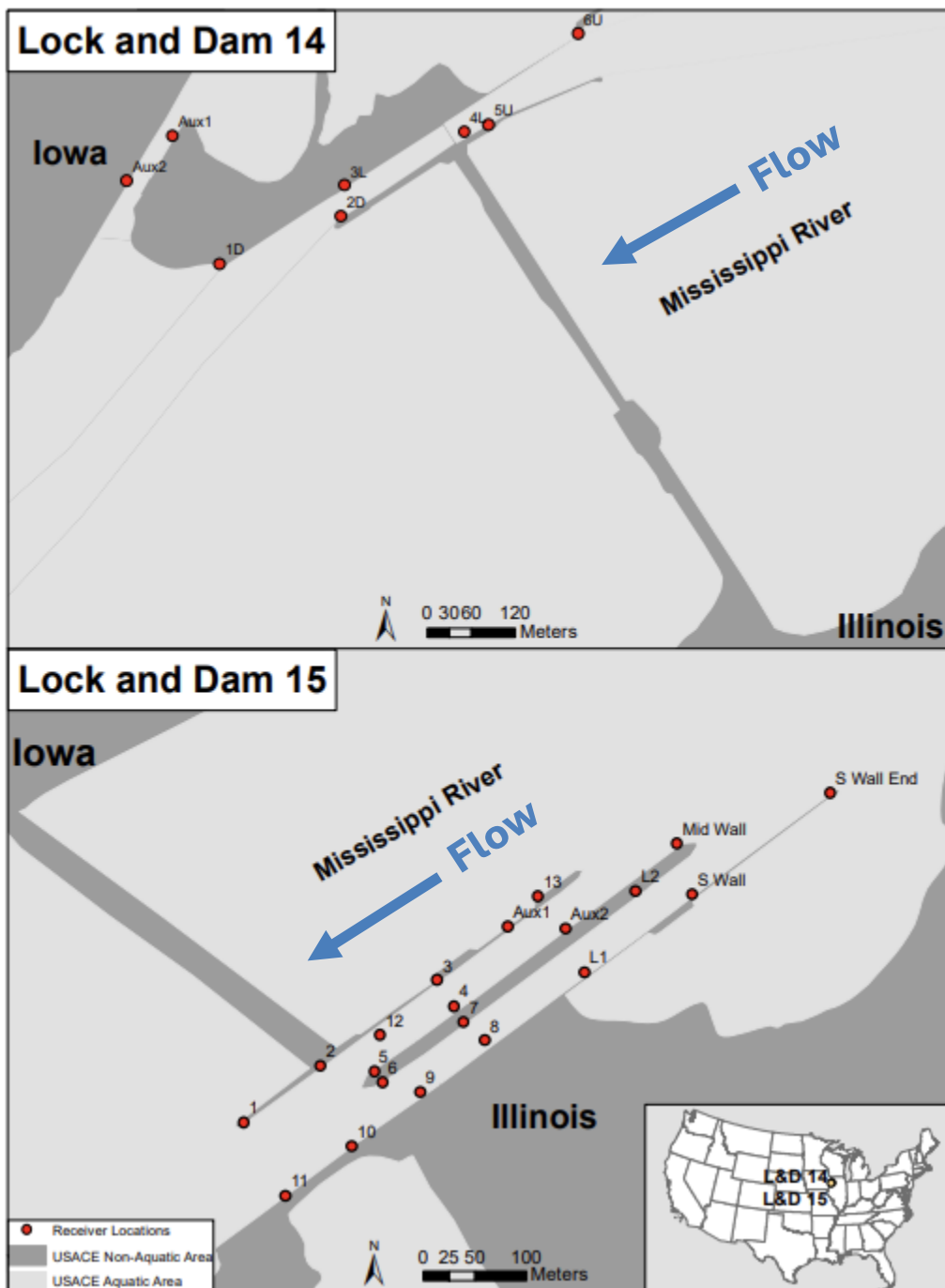


Figure 2. The 69-kHz telemetry arrays at Lock and Dam (LD) 14 in Le Claire, IA, and LD 15 located in Davenport, IA. The receiver locations are displayed by the red dots and are dispersed throughout the main and auxiliary locks. At LD 14 (top) there are 2 receivers in the downstream approach (1D, 2D), 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).

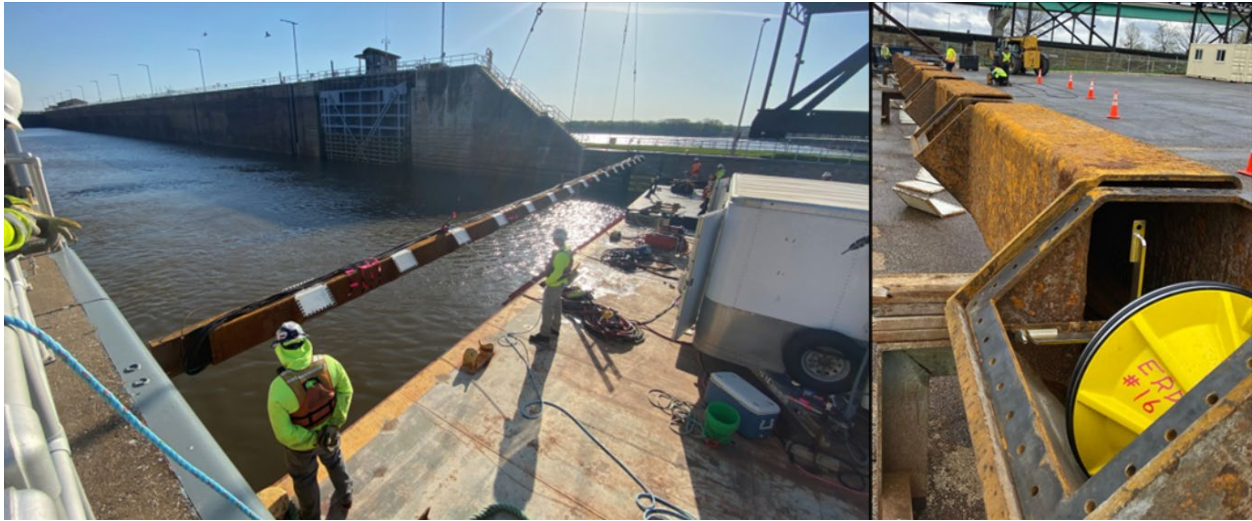


Figure 3. Photograph of the UADS speaker soundbar re-deployment after maintenance at Lock 19 (Photograph by Marybeth Brey, USGS).

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 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.

Presentations and Publications

The following presentations on invasive carp and native fish behavior at LD 19 were provided at conferences during FY23:

- Brey, M.K., Woodley, C.M., Stanton, J.C., Fritts, A.K., Sholtis, M., Castro-Santos, T., Vallazza, J.M., and Albers, J.L., 2023, Lock 19 underwater acoustic deterrent system study. Invited Oral Presentation, 153rd American Fisheries Society Annual Meeting, Grand Rapids, MI, August 20-24, 2023.
- Fritts, A., Gibson-Reinemer, D., Milde, A., Appel, D., Lamer, J., Fritts, M., Tripp, S., Herzog, D., and Brey, M. 2023, Techniques for evaluating fish passage and deterrents at navigation dams: Oral Presentation, National American Fisheries Society 2023 conference, Grand Rapids, Michigan, August 20-24, 2023.
- Brey, M.K., Woodley, C., Stanton, J.C., Fritts, A.K., Sholtis, M., Albers, J., and Castro-Santos, T. Year-2 Update: Underwater Acoustic Deterrent System (uADS) at Mississippi Lock No. 19. Partner presentation.
- Published interim report on initial results from the first two years of the UADS evaluation
 - Report: Brey, M.K., Woodley, C.M., Stanton, J.C., Fritts, A.K., Sholtis, M., Castro-Santos, T., Vallazza, J.M., and Albers, J.L. 2023. Lock 19 underwater acoustic deterrent system study—Interim project update, through 2022: U.S. Geological Survey Open-File Report 2023–1058, 11 p., <https://doi.org/10.3133/ofr20231058>.
 - Data Release: Brey, M.K., Woodley, C.M., Stanton, J.C., Fritts, A.K., Sholtis, M.D., Vallazza, J.M., Appel, D.S., Castro-Santos, T.R., and Albers, J.L., 2023, Data Release for Lock 19 Underwater Acoustic Deterrent System (UADS) Study: Interim Project Update: U.S. Geological Survey data release, <https://doi.org/10.5066/P9PGL147>.
- 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>

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

References:

- Bouska, K.L. 2021. Percentage of annual days that river stage exceeds “open river” conditions for lock and dams on the Upper Mississippi River, 1985-2015. <https://doi.org/10.5066/P9J8BBQ3>.
- Brey, M.K., Woodley, C.M., Stanton, J.C., Fritts, A.K., Sholtis, M., Castro-Santos, T., Vallazza, J.M., and Albers, J.L. 2023. Lock 19 underwater acoustic deterrent system study—Interim project update, through 2022: U.S. Geological Survey Open-File Report 2023–1058, 11 p., <https://doi.org/10.3133/ofr20231058>.
- Brey, M.K., Woodley, C.M., Stanton, J.C., Fritts, A.K., Sholtis, M.D., Vallazza, J.M., Appel, D.S., Castro-Santos, T.R., and Albers, J.L., 2023, Data Release for Lock 19 Underwater Acoustic Deterrent System (UADS) Study: Interim Project Update: U.S. Geological Survey data release, <https://doi.org/10.5066/P9PGL147>.
- Fritts, A.K. and B.C. Knights. 2020. 2017-2018 Telemetry data for Asian carp and native fish species at Lock and Dam 19 in the Upper Mississippi River Basin: U.S. Geological Survey data release, <https://doi.org/10.5066/P9HOPS3O>.
- Fritts, A.K., B.C. Knights, J.C. Stanton, A.S. Milde, J.M. Vallazza, M.K. Brey, S.J. Tripp, T.E. Devine, W. Sleeper, J.T. Lamer, and K.J. Mosel. 2021. Lock operations influence upstream passages of invasive and native fishes at a Mississippi River high-head dam. *Biological Invasions* 23(3):771–794. Springer International Publishing.
- Fritts, A.K., Turney, D.D., Lamer, J.T., Knights, B.C., Vallazza, J.M., and Appel, D.S. 2022. 2017-2019 Telemetry data for invasive carp and paddlefish surrounding Lock and Dam 15 in the Upper Mississippi River Basin: U.S. Geological Survey data release, <https://doi.org/10.5066/P9CHJ8OG>.
- 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>
- 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>
- Murchy, K.A., A.R. Cupp, J.J. Amberg, B.J. Vetter, K.T. Fredricks, M.P. Gaikowski, and A.F. Mensinger. 2017. Potential implications of acoustic stimuli as a non-physical barrier to silver carp and bighead carp. *Fisheries Management and Ecology* 24(3):208–216.
- Turney, D.D., Fritts, A.K., Knights, B.C., Vallazza, J.M., Appel, D.S., Lamer, J.T. 2022. Hydrological and lock operation conditions associated with paddlefish and bigheaded carp dam passage on a large and small scale in the upper Mississippi River (Pools 14–18). PeerJ. DOI: 10.7717/peerj.13822
- Upper Mississippi River Asian Carp Partnership. 2018. Potential use of deterrents to manage Asian carp in the upper Mississippi River basin. http://www.micrarivers.org/wp-content/uploads/2019/08/Potential-Use-of-Deterrents_Final.pdf.
- Vetter, B.J., A.F. Casper, and A.F. Mensinger. 2017. Characterization and management

implications of silver carp (*Hypophthalmichthys molitrix*) jumping behavior in response to motorized watercraft. *Management of Biological Invasions* 8(1):113–124.

Vetter, B.J., A.R. Cupp, K.T. Fredricks, M.P. Gaikowski, and A.F. Mensinger. 2015. Acoustical deterrence of silver carp (*Hypophthalmichthys molitrix*). *Biological Invasions* 17(12):3383–3392. Springer International Publishing.

Wilcox, D.B., E.L. Stefanik, D.E. Kelner, M.A. Cornish, D.J. Johnson, I.J. Hodgins, S.J. Zigler, and B.L. Johnson. 2004. Improving fish passage through navigation dams on the upper Mississippi River system. U.S. Army Corps of Engineers.