

**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:** USGS, Andrea Fritts, afritts@usgs.gov, 608-797-9793

**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. To date, 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 five years (i.e., 2017–2021) 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 and evaluated 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. 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, bigmouth buffalo) 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. VEMCO 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 VEMCO acoustic receivers at LD 19, LD 15, and LD 14. 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 VEMCO 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.

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:**

- Experimental uADS and HTI telemetry system deployed at LD 19 in spring 2021
  - uADS operated on an 80-hour ON/80-hour OFF cycle from March – November 2021
- Maintenance for the uADS sound bar completed in March 2022
  - Operated on an 80-hour ON/80-hour OFF cycle from April – November 2022
- During 2021, 401 invasive carps and 208 native fish were internally implanted with acoustic transmitters to monitor passage through and behavior around the uADS during on and off conditions
  - A subset of these fish were tagged with VEMCO depth transmitters
- During 2022, 501 invasive carps and 234 native fish were internally implanted with acoustic transmitters to monitor passage through and behavior around the uADS during on and off conditions

**Methods:** USGS maintained a VEMCO telemetry receiver array at LD 19 (Figure 1). 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 (HTI) was installed concurrent with the installation of the uADS.

A large fish-tagging event occurred during spring 2021 and spring 2022. 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 (*Ictiobus cyprinellus*) were collected in locations upstream from LD 19 and translocated, tagged with HTI 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. Native fish species (i.e., Bigmouth Buffalo, Paddlefish (*Polyodon spathula*), Lake Sturgeon (*Acipenser fulvescens*), Flathead Catfish (*Pylodictis olivaris*), Blue Sucker (*Cycleptus elongatus*), American Eel (*Anguilla rostrata*), White Bass (*Morone chrysops*), Freshwater Drum (*Aplodinotus grunniens*), Walleye (*Sander vitreus*), Sauger (*Sander canadensis*)) were collected and tagged with a combination of HTI and VEMCO transmitters in Pool 20 (i.e., downstream from LD 19).

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.

**Results:** The uADS system construction and installation was completed in early 2021 (Figure 2). A maintenance event occurred in March 2022 to replace a subset of speakers within the soundbar. The uADS was operated on an 80-hour *on-off* cycle from March to November 2021 and April to November 2022.

From March through May 2022, 501 invasive carps and 234 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., VEMCO and HTI) are being used for the uADS evaluation.

VEMCO depth transmitters 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.

The following presentations on invasive carp behavior at LD 19 were provided at conferences during FY22:

- Andrea Fritts, Brent Knights, Amanda Milde, Jessica Stanton, Marybeth Brey, Doug Appel, Kyle Mosel, James Lamer, Mark Fritts, Sara Tripp, Dave Herzog, Jessica Morris. 2022. Evaluating invasive carp water-column use to inform deterrents and control. Midwest Fish and Wildlife Conference, Des Moines, IA. Feb 2022
- Andrea Fritts, Brent Knights, Amanda Milde, Jessica Stanton, Marybeth Brey, Doug Appel, Kyle Mosel, James Lamer, Mark Fritts, Sara Tripp, Dave Herzog, Jessica Morris. 2022. Invasive carp and native fish water-column use: informing deterrents, control efforts, and fish passage. Mississippi River Research Consortium, La Crosse, WI. April 2022
- Andrea Fritts, Jon Vallazza, Jessica Stanton, Marybeth Brey, Dominique Turney, James Lamer. 2022. Invasive Carp and Paddlefish Passage at Mississippi River Navigation Locks and Dams. American Fisheries Society conference, Spokane, WA, August 2022
- Marybeth Brey, Christa Woodley, Matthew Sholtis, Andrea Fritts, Jessica Stanton, Theodore Castro-Santos, and Aaron Urbanczyk. 2022. Underwater Acoustic Deterrent System (uADS) at Lock No. 19: Year-1 Update. Presentation to the Invasive Carp Regional Coordinating Committee (ICRCC) and Mississippi River sub-basin partners. July 2022
- Marybeth Brey, Christa Woodley, Andrea Fritts, Brent Knights, and Jessica Stanton. 2022. Collaborative Efforts to Evaluate Underwater Acoustic Deterrent Systems to Control Invasive Carps. Joint Aquatic Sciences Meeting, Grand Rapids, MI. May 2022
- Marybeth Brey, Christa Woodley, Matthew Sholtis, Andrea Fritts, Jessica Stanton, Theodore Castro-Santos, and Aaron Urbanczyk. 2022. Feasibility of Using an Underwater Acoustic Deterrent System for Invasive Carp Control. American Fisheries Society conference, Spokane, WA, August 2022

## Publications

- Published manuscript on the invasive species control strategies.
  - Cupp, A., Brey, M., Calfee, R., Chapman, D., Erickson, R., Fischer, J., Fritts, A., George, A., Jackson, R., Knights, B., Saari, G., and Kocovsky, P. 2021. Emerging control strategies for Integrated Pest Management of invasive carps. *Journal of Vertebrate Biology*. 70(4):21057. DOI:10.25225/jvb.21057
- Published manuscript on upstream fish passage.
  - 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
- Published manuscript on upstream fish passage

- Fritts, A.K., Knights, B.C., Stanton, J.C., Milde, A.S., Vallazza, J.M., Brey, M.K., Tripp, S.J., Devine, T.E., Sleeper, W., Lamer, J.T., Mosel, K.L. 2021. Lock operations influence upstream passages of invasive and native fishes at a Mississippi River high-head dam. *Biological Invasions* 23: 771–794.

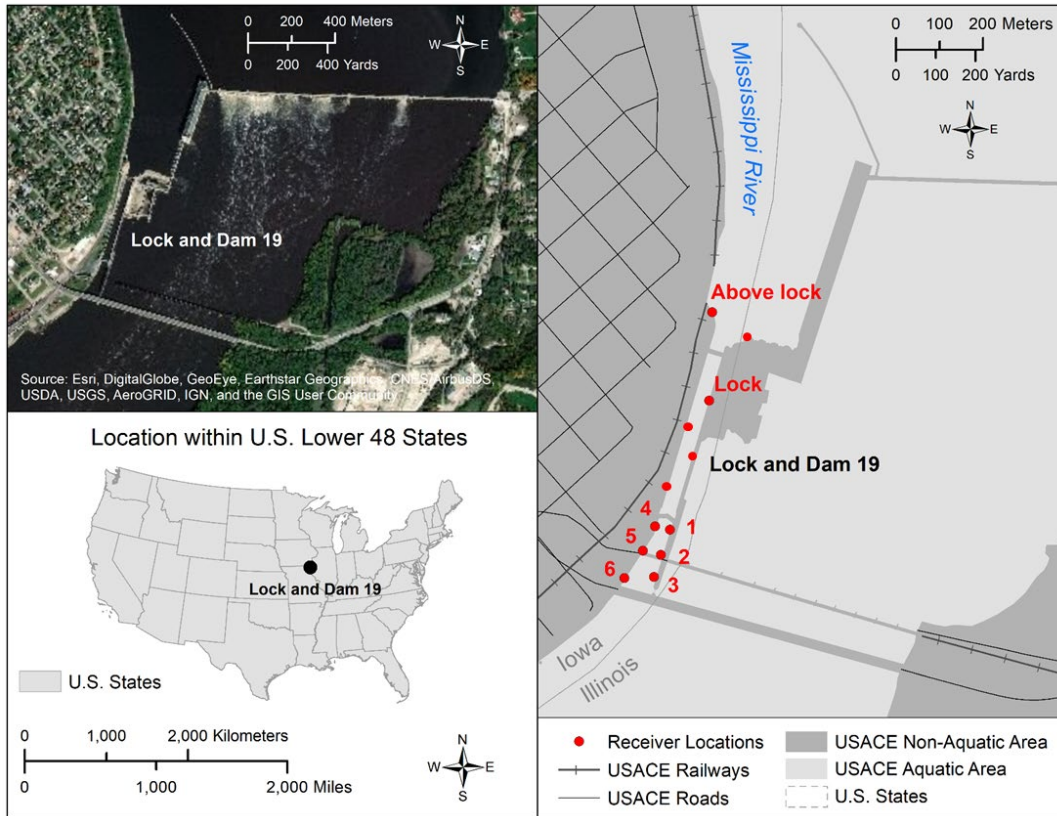


Figure 1. Location of receivers comprising the fine-scale array in the lock approach at Lock 19.



Figure 2. Photograph of the uADS speaker soundbar during deployment at Lock 19 (Photograph by Mark Cornish, USACE).

**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).

**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>.
- 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>.
- Murphy, 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](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.