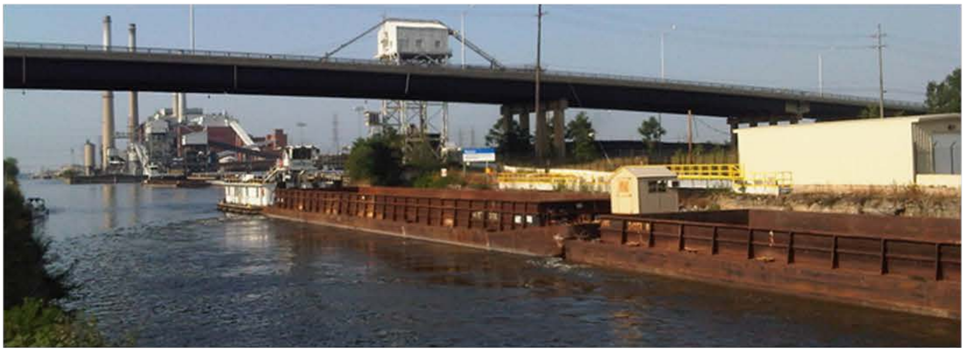
U.S. Fish & Wildlife Service - Midwest Region

Fisheries Program

Fish Entrainment, Retention, and Inadvertent Transport by Barge Traffic in the Illinois Waterway: 2015 Preliminary Results



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Executive Summary

The U. S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office has been undertaking large scale, field based, evaluations of fish-barge interactions at the Electric Dispersal Barrier system in the Chicago Sanitary and Ship Canal (CSSC) since 2012. The findings from these preliminary studies suggested that upstream passage of the Electric Dispersal Barrier system by barge traffic could potentially provide an opportunity for the simultaneous passage of fish within barge junction gap spaces. During 2015, the U.S. Fish and Wildlife Service conducted a more advanced set of experimental trials that utilized freely swimming (non-caged/non-tethered) fish. These fish (hatchery reared Golden Shiners (*Notemigonus crysoleucas)* 63-122 mm TL) were marked and then released at various locations near a moving barge tow. The behavior of the freely swimming fish was monitored with a high resolution underwater acoustic camera as the barge tow traversed the Electric Dispersal Barrier system, navigated through various portions of the Illinois Waterway below the barrier system, and underwent upstream lockage operations at Brandon Road and Lockport locks. Attempts were then made to recapture the marked fish at the conclusion of these trials.

Results suggested that small (< 123 mm) freely swimming fish that encounter a barge tow moving upstream, can become inadvertently entrained by the barge tow. Once entrained within a rake-to-box junction gap, a substantial portion of fish (32.0%) were transported across the entire Electric Dispersal Barrier system and subsequently recaptured unharmed above the barrier system. Additional trials also demonstrated that entrained fish could remain within the barge rake-to-box junction gap during upstream lockage operations and continue to move upstream with the barge tow following lockage. Several trials examined upstream transport of fish over long distances while navigating real world obstacles within the Illinois Waterway. These obstacles included other traffic, lockage operations, and the Electric Dispersal Barrier. In one trial that incorporated all of these obstacles, fish were transported upstream over 15 km.

Introduction

The Bigheaded carps, herein referred to as Asian carp, include the Silver Carp (*Hypophthalmichthys molitrix)* and Bighead Carp (*H. nobilis)* as well as hybrids between these species. Populations of these two introduced aquatic nuisance species (ANS) are spreading throughout the Mississippi River Basin (Conover et al. 2007; Chapman and Hoff 2011; O'Connell et al. 2011). Kolar et al. (2007) rated the probability of Silver and Bighead Carp spreading to previously uncolonized areas as "high" and assigned this rating a "very certain" degree of certainty. Asian carp are highly invasive fishes that have been expanded their range in the U.S. since they first began to appear in public waters (Freeze and Henderson 1982; Burr et al. 1996). Populations of Asian carp have grown exponentially because of their rapid growth rates, short generation times, and dispersal capabilities (DeGrandchamp 2003; Peters et al. 2006; DeGrandchamp et al. 2008). Populations of Asian carp have become well established in the lower and middle reaches of the

Illinois River and successful reproduction has been documented as far upstream as the Peoria reach (Asian Carp Regional Coordinating Committee Monitoring and Rapid Response Workgroup, 2015).

The Great Lakes Mississippi River Inter-basin Study (GLMRIS) was released in January of 2014 and presents a comprehensive range of options and technologies available to prevent the inter-basin transfer of ANS between the Great Lakes and Mississippi River Basins through aquatic pathways. The most substantial of these pathways is the Chicago Area Waterways System and the Upper Illinois Waterway. If Asian carp become established in the Great Lakes they could pose a significant threat to established fisheries by competing with economically and recreationally important fishes for limited plankton resources (Sparks et al. 2011). They could also pose a danger to recreational boaters. Although predictions of the effects of Asian carp on the Great Lakes ecosystem vary widely, negative impacts on the fishery and recreational use of these resources are anticipated.

The Electric Dispersal Barrier system in the CSSC was designed and is operated to prevent the transfer of invasive fish species between the Mississippi River Basin and the Great Lakes Basin while simultaneously allowing the passage of commercial barge traffic. A demonstration barrier that has been operational since 2002 operates at 0.39 V/cm., 5 Hz, 4 ms. Sparks et al. (2010) and Dettmers et al. (2005) were the first to directly test the effectiveness of the Demonstration Barrier. Sparks et al. (2010) recorded a radio-tagged Common Carp breaching the barrier in April 2003. This breach was later determined to have coincided with the passage of a barge. During November 2003, Dettmers et al. (2005) passed encaged fish alongside a barge through the Demonstration Barrier. Results from that study showed that the effects of the electrical field were delayed when fish traversed the barrier alongside the conductive (steel) barge hulls. Some fish were never incapacitated as they moved through the barrier. Those authors attributed the delayed incapacitations and non-incapacitations to a distortion of the electrical field by the steel hulled barges. Following the Dettmers et al. (2005) study, design modifications were made to two additional electrical barriers that were constructed to account for the barge-induced electrical warping. Barriers IIA and IIB were implemented in 2009 and 2011, respectively. The newer barriers cover a much larger area than the Demonstration Barrier and are capable of generating electrical fields of much higher intensity.

During 2012 and 2013, the U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers performed a series of laboratory and field based experiments to determine if there was a potential for commercial barge traffic to facilitate fish passage beyond the newer more powerful electric barriers. The U.S. Army Corps of Engineers collected a series of electrical field strength measurements from an instrumented rake style barge tow as it traversed the Electric Dispersal Barrier system in a variety of configurations. Results showed that when barges traversed the barrier in a rake-to-box junction configuration the electrical field in the water within the junction gap space between barges is reduced to the point of being “barely measurable” (U.S. Army Corps of Engineers 2013). Researchers at the U.S. Army Corps of Engineers-Coastal Hydraulics Laboratory conducted simulations of barge fish interactions in a flume system modeled to represent a scaled down version of the CSSC Electric Dispersal Barrier system. These trials showed that the dominant transport method in the direction of vessel travel is entrainment within the junction gap space between rake and box barges. Greater than fifty percent of model fish in that study were entrained past both Barrier IIA and Barrier IIB by barges in rake-to-box configurations (Bryant et al. 2016). Field trials conducted by the U.S. Fish and Wildlife Service using caged and tethered fish corroborated the results of the U.S. Army Corps of Engineers studies with live fish. Fish were placed in non-conductive cages at different locations around rake barges as they traversed the Electric Dispersal Barrier system. In most locations fish were incapacitated as the barge entered the electric field produced by the barrier. However, when fish were placed within the junction gap space between a rake-to-box configured barge tow, they were not incapacitated as the barge traversed the Electric Dispersal Barrier system (Parker and Finney 2013). Additionally, wild mosquitofish (*Gambusia affinis*) were observed being transported past the active barrier in the rake-to-box junction without being incapacitated. The findings from these studies suggested that entrainment of fish through the Electric Dispersal Barrier system by rake-to-box configured barges presents a risk of fish passage.

In an attempt to gain further understanding about the potential risk of fish passage associated with barge traffic at the Electric Dispersal Barrier system the U.S. Fish and Wildlife Service conducted a series of experimental trials during 2015 which utilized a contracted commercial barge tow. Those studies investigated the potential for entrainment, retention, and transport of freely swimming fish within the large gaps created at junction points between barges. Modified mark and capture trials were employed to assess fish entrainment, retention, and transport by barge tows. A multi-beam sonar system enabled estimation of fish abundance within barge junction gaps. Results of mark and capture trials showed direct evidence that small Golden Shiners (< 123 mm) can become entrained by barges, retained within junction gaps, and transported over distances of at least 15.5 km. Fish entrained within the barge junction gap were also retained in that space as the barge tow transited through locks and across the Electric Dispersal Barrier system.

Materials and Methods

Study sites

The study presented here was conducted during August 2015 in the Illinois Waterway between the U.S. Army Corps of Engineers Electric Dispersal Barrier system at RM 296 near Romeoville, IL, and the Brandon Road Lock and Dam at RM 286 near Rockdale, IL. Observed water temperatures varied between 22.5 and 27.8 degrees C during the experimental trials. Entrainment, retention, and transport trials occurred at the Electric Dispersal Barrier system, in the Lockport Pool, at Lockport Lock, in the Brandon Road Pool, and at the Brandon Road Lock. Lockport Lock is located within the study reach at Illinois Waterway RM 291. The lock chamber dimensions are 182.9 m by 33.5 m and the change in water surface elevation at maximum vertical lift is 12.8 m. The Brandon Road Lock and Dam is the next navigational and flood control structure downstream of Lockport Lock on the Illinois Waterway, located at RM 286. The Brandon Road

Lock has the same size chamber as Lockport Lock but has a vertical lift of 10.4 meters. These navigational structures and the Electric Dispersal Barrier system act as impediments to upstream fish movements on the Upper Illinois Waterway.

Barge Configuration

A barge tow consisting of a towing vessel typical for use on the Illinois Waterway and four fully loaded barges was utilized during all trials (Figure 1). The tow vessel was 32.0 m long, had a 9.1 m beam, and drafted 2.3 m. Each 59.4 m by 10.7 m barge held approximately 1,360 metric tons (MT) of non-hazardous material and drafted 2.7 m. The barges were lashed together in a configuration that was two barges long by two barges wide. The two starboard side barges were hopper barges with boxed ends on both the bow and the stern. The port side barges consisted of one hopper barge with a raked bow and a boxed stern and one tank barge with a raked bow and a boxed stern. The connection between the port side barges in the middle of the tow represented a typical rake-to-box junction (Figure 1) with the exception that the connection junction was modified by placing two 38.0 cm spacers between the barges, at the push knees, to allow access for installation of instrumentation and fishing gear. All sonar and fish capture data were collected from this rake-to-box junction gap. The barge tow was pushed upstream with the rake end of the port side barges facing in an upstream direction at normal operating speeds (1.6–5.6 km/h) during all trials.

Figure 1. Conceptual model of 2015 barge tow configuration. Red oval shows the location of the rake-to-box junction.

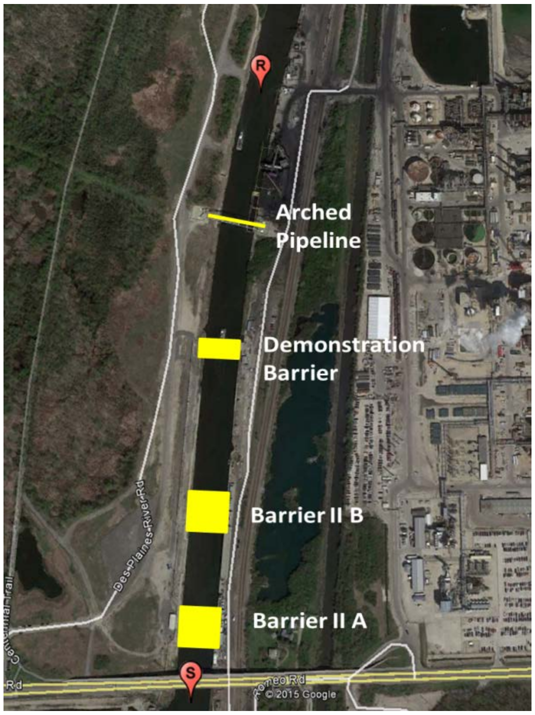

Figure 2. Map showing locations of fish stocking (S) and recapture (R) areas utilized during barge entrainment and retention trials at the Electric Dispersal Barrier.

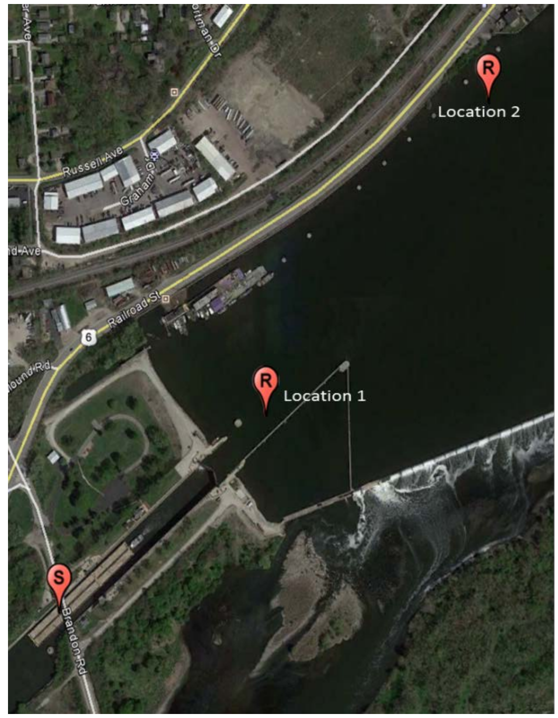

Figure 3. Map showing locations of fish stocking (S) and recapture (R) areas utilized during barge transport trials at the Brandon Road Lock

Mark and capture trials

Direct evidence of fish entrainment into barge junction gaps and subsequent retention and transport was acquired through a series of mark and capture trials. Hatchery-reared Golden Shiners (63 to 122 mm TL, subsample (n=100)) were marked by applying fin clips to anal, dorsal, upper caudal, and lower caudal fins in combination to provide positive identification of captured individuals. Unique combinations of fin clips were used for each trial during each week. These marked fish were subsequently stocked either in front of the leading barge (entrainment trials) or directly within the rake-to-box junction gap (retention and transport trials). At the conclusion of each trial, the barge tow stopped and attempts to capture fish remaining inside the junction gap were accomplished by deploying a Betts Tyzac™ cast net; 1.2 m diameter with 0.95 cm monofilament mesh. The capture attempts were aided by the use of a multi-beam sonar system (Sound Metrics ARIS Explorer 3000™) that allowed personnel to determine the locations of fish within the junction gap. Attempts to capture fish were terminated once movement of the barge tow commenced or sonar evidence suggested that no targets remained within the junction gap. Due to the limitation that capture attempts could not take place while the barge was moving, the number of capture attempts conducted during each trial was not standardized. The number of individual net casts taken at the conclusion of each trial varied from three to twelve (mean = 6.1, SD = 2.7, n=21).

The multi-beam sonar system was mounted inside the center tow rake-to-box junction gap on the port side of the tow facing in towards the center of the tow and was operated at low frequency setting (1.8 MHz), with wide pulse width, and data were collected at 6 frames per second. Receiver sensitivity was 22 dB and maximum range was 9.94 m. This system utilized 128 acoustic beams that provided a total field of coverage of 30 degrees x 14 degrees with 4.4 mm resolution. The unit was submerged 0.4 m below the water surface and rotated on its axis remotely using a Sound Metrics AR2™ rotator. Tilt and pan angle of the sonar unit was optimized during trials to track moving schools of fish. Typical tilt values ranged between -12.0 degrees and -3.0 degrees. This system enabled monitoring of schools and individual fish during trials and allowed targeted capture sampling to occur at the completion of each trial. The recording capability of the system was used to perform *post hoc* enumeration of fish that were present within the rake-to-box junction gap at different periods during each trial.

Entrainment trials (n=6, where hereafter n is the number of trials) were designed to determine if it is possible for a fish that encounters a moving barge tow to become entrained into the rake-to-box junction gap of the barge tow. Golden Shiners (n_S=300/trial, where n_S is the number of stocked fish) were stocked directly in front of the moving barge tow (1.9 to 5.3 km/h). This was accomplished by stocking fish directly in front of the moving barge from the bow deck of the forward barge in the tow. The barge tow was approximately 80 m downstream of Electric Dispersal Barrier IIA when stocking occurred (Figure 2). The tow then traveled upstream and crossed both Barrier IIA and Barrier IIB before continuing upstream to the mooring area. During our trials, Barrier IIA was operated with only the narrow array active, producing peak electrical gradients of 0.79 V/cm to 0.91 V/cm at the surface. Barrier IIB was operated with both the narrow and wide arrays active, producing peak electrical gradients at the surface of 0.31 V/cm over the center of the wide array and 0.79 V/cm to 0.91 V/cm over the narrow array. During entrainment trials the total distance traveled between the stocking location and the capture location was approximately 1.0 km. Upon stopping forward progress, capture attempts using the cast net were conducted within the rake-to-box junction gap at the center of the tow.

Retention and transport trials were designed to quantify the potential retention within the rake-to-box junction gap for entrained fish and the potential for upstream transport of those fish. Trials were conducted at the Electric Dispersal Barrier system (n=6), at Brandon Road Lock (n=6), and within the Lockport (n=2) and Brandon Road Pools (n=1) of the Illinois Waterway. Golden Shiners were stocked directly into the center of the rake-to-box junction gap while the barge tow was underway during all retention and transport trials. Retention and transport trials conducted at the Electric Dispersal Barrier system (n=6) utilized the same stocking and capture locations as the entrainment trials and a total travel distance of 1.0 km. Golden Shiners (n_S=300/trial) were stocked directly into the center of the rake-to-box junction gap in the middle of the tow downstream of the Electric Dispersal Barrier system. The tow then travelled upstream to a mooring location upstream of the entire barrier system.

Retention and transport trials were also conducted at the Brandon Road Lock (n=6) to determine the likelihood that fish could be transported through the upstream lockage process in barge junction gaps. During those trials, Golden Shiners (n_S=300/trial; except n_S=238 during one trial due to a hole in the holding net) were stocked into the rake-to-box junction gap of the moving barge tow (0.3-0.6 km/h) approximately 50 m downstream of the Brandon Road Lock. The tow then entered the lock and underwent normal upstream lockage operations (filling of the lock to lift the barge 10.4 m over approximately 20 minutes). Upon completion of the lockage operations the barge tow exited the lock and traveled either 100 m (n=3) or 700 m (n=3) upstream out of the lock before capture attempts took place (Figure 3).

Three retention and transport trials were conducted to examine fish retention and transport over longer distances. In two of these long distance (5.4 km and 7.6 km) retention and transport trials, Golden Shiners (n_S=1,000/trial) were stocked directly into the rake-to-box junction gap of the moving barge tow (1.9–3.0 km/h) in lower Lockport Pool. Capture attempts took place above the Electric Dispersal Barrier system at the same location utilized during previous trials. One additional long distance (15.5 km) retention and transport trial began in the Brandon Road Pool, approximately 1.0 km upstream from the Brandon Road Lock. Golden Shiners (n_S=2,000/trial) were again stocked directly into the rake-to-box junction gap at the center of the moving barge tow (5.6 km/h). During this trial the barge tow traveled upstream for approximately 6.5 km, entered the Lockport Lock, underwent a normal upstream lockage operation, traveled an additional 9.0 km upstream through Lockport Pool, and traversed the entire Electric Dispersal Barrier system before capture attempts took place at the same capture area utilized during previous trials. Different numbers of fish were stocked during the various trial types to allow a reasonable probability of detection of entrainment and transport events.

Data Analyses

All fish that were captured at the conclusion of each trial were identified to species, enumerated, measured, and examined for the presence of fin clips (Smith 2002). The number of marked fish captured after each trial were counted in the field and sonar data were reviewed and analyzed in the laboratory to determine the number of fish remaining in the gap after capture attempts. Timestamps on sonar data were used to identify data collection periods that corresponded to the time period after capture attempts had been completed for each trial. Ten frames of sonar data were selected from the data collection period for each trial for further analysis. Selection criteria included visual clarity, the presence of the entire school of fish within the frame, and the distance that fish targets were from the sonar system. Three readers independently counted all remaining fish on each of the ten frames selected from each trial. The fish counts from each of the ten frames were averaged for each reader. The grand mean of the three reader averages was then calculated to provide an estimate of the number of fish remaining in the barge junction gap after capture attempts were completed. The sonar data did not provide information that would allow the determination of species or whether or not individual fish possessed the mark that was applied before each stocking event. Because a small number of fish (wild juvenile Gizzard Shad and Golden Shiners with a different mark) which were not stocked during that trial were captured at the conclusion of some trials, a by-catch correction factor for each trial type was calculated (number of fish remaining in the gap minus the average percentage of non-target catches observed in each trial type). A total fish entrainment/retention estimate was calculated by adding the number of marked

Golden Shiners that were physically captured at the conclusion of the trial to the by-catch corrected number of fish estimated to remain within the barge junction gap. Descriptive statistics including mean, range, minimum, maximum, and standard deviation of fish capture and retention estimate data were tabulated for each trial type.

Results

See Appendix for a summary of results table.

Fish Entrainment

Golden Shiners stocked in front of the moving barge either passed to the side of or under the leading barge. A fraction of the stocked fish became entrained into the rake-to-box junction gap. Of those fish that were stocked in front of the barge tow (n_S=300/trial), a mean of 6.8% (Standard Deviation (SD)=4.5%) were captured in the rake-to-box junction gap after passing over the entire Electric Dispersal Barrier system (68-100 mm TL). Capture rates ranged from 3.0% to 12.7% (n=6). Estimates of total entrainment and retention beyond the Electric Dispersal Barrier system based on capture data plus by-catch corrected sonar evidence of additional non-captured fish ranged from 3.1% to 17.2% (n=6). The mean total entrainment and retention estimate for this series of trials was 8.6% (SD=5.6%; n=6). These trials provided evidence that freely swimming small fish that come in contact with a barge traveling upstream can become entrained into the rake-to-box junction gap, subsequently retained within the gap, and transported upstream through the Electric Dispersal Barrier system with no evidence of incapacitation due to the electric field.

Fish Retention and Transport Across the Electric Dispersal Barrier System

Golden Shiners stocked directly into the rake-to-box junction gap downstream of the Electric Dispersal Barrier system (n_S=300/trial) were retained within that junction gap as the barge tow traveled upstream through the Electric Dispersal Barrier system. A mean of 32.0% (SD= 21.8%; n=6) of stocked fish were captured after the barge tow traversed the entire Electric Dispersal Barrier system. The mean total retention was estimated to be 51.1% (SD=13.3%; n=5; no sonar data was available for one trial). Marked Golden Shiners captured at the completion of these trials ranged in size from 66-101 mm TL. No evidence of incapacitation of the fish by the electric field was observed.

Fish Retention and Transport Through Navigation Locks

The complex and dynamic flow characteristics of an upstream lockage did not flush all stocked fish from the barge rake-to-box junction gap. A portion of the Golden Shiners stocked directly into the barge junction gap below the Brandon Road Lock were retained within the junction gap throughout lockage operations and after the barge tow exited the lock chamber and traveled upstream during all trials. Marked Golden Shiners captured at the completion of these trials ranged in size from 62-122 mm TL. During three of the trials the barge tow proceeded out of the lock chamber and stopped approximately 100 m upstream of the lock to allow capture attempts.

The mean capture rate after these trials was 39.7% (SD=17.1 %; n=3) and the total retention estimate was 52.3% (SD=22.8%; n=3). During the remaining three trials the barge tow was not able to moor at that location because southbound traffic was staged in that area awaiting downstream lockage. Instead, the barge tow traveled upstream approximately 700 m upstream and moored. The total retention estimate of stocked Golden Shiners after the completion of lockage operations for these trials was estimated at 20.4% (SD=16.3%; n=3). However, capture rates obtained during the trials that utilized the alternate mooring location were greatly reduced from those observed during trials at the primary mooring location (3.4%; SD=5.1%; n=3). During these trials the barge tow was required to utilize a hard reverse maneuver to position the tow correctly against the mooring cells. The total retention estimates were made with sonar data collected before the utilization of the hard reverse maneuver. The capture attempts were made after the hard reverse maneuver. Sonar data collected during this maneuver indicated that the currents and/or sediment suspension produced by the tow vessel operating in reverse flushed debris and fish from the rake-to-box junction gap at the center of the tow.

Long Distance Fish Retention and Transport

Several trials were conducted which examined the transport of juvenile Golden Shiners over much longer distances. A mean of 26.9% (SD=13.6%; n=2) of stocked fish were captured after the barge tow traveled northwards from near the Lockport Lock and Dam, through the Lockport navigation pool, and traversed the entire Electric Dispersal Barrier system (total distance traveled of 5.4 km and 7.6 km, respectively). Marked Golden Shiners captured at the completion of these trials ranged from 70-106 mm TL. The mean total retention estimate for these trials was 35.1% (SD=5.8% n=2).

One long distance transport trial incorporated multiple elements encountered by barge traffic during typical barge operation on the Illinois Waterway (passage through a lock chamber, through constrictions and broad open channels, passage of working tows and moored barges, multiple changes in heading and speed over a long distance, and passage through the Electric Dispersal Barrier system). A total of 3.8% (76 fish; 66-115 mm TL) of the 2000 Golden Shiners that were stocked into the rake-to-box junction in the Brandon Road navigation pool were captured at the mooring area upstream of the Electric Dispersal Barrier system after traveling 15.5 km and undergoing upstream lockage at Lockport Lock. The total retention estimate during this trial was 5.6%.

Wild Fish Entrainment

Throughout the study, during initial setup of the sonar system on each morning of each trial, wild fish were observed within the rake-to-box junction gap with the sonar system. A sample of the wild fish population present within the rake-to-box junction gap was obtained by capture with the cast net system before trials began each day. The wild fish observed and captured were identified as juvenile Gizzard Shad (41–110 mm TL). During post-trial capture attempts following entrainment and retention trials at the Electric Dispersal Barrier, small numbers (mean=4.5 fish/trial; SD=7.0; n=12) of wild juvenile Gizzard Shad were captured as by-catch along with the marked Golden Shiners in 58.3% of the trials. During trials conducted at the Brandon Road Lock, wild Gizzard Shad were captured at the conclusion of 66.6% of trials (mean=1.8 fish/trial; SD = 3.1; n=6). Since these wild fish were not marked in any way, it is unknown whether the wild Gizzard Shad captured at the conclusion of the trials were the same individuals present in the rake-to-box junction while the barge tow was moored before the onset of each trial or if those individuals may have become entrained into the rake-to-box junction at some unknown point during the course of the trial.

Additional Observations

During a second set of retention and transport trials conducted at the Brandon Road Lock, we observed marked decreases in capture rates at the conclusion of trials. Sonar evidence collected after the barge tow initially left the lock chamber indicates that substantial numbers of fish remained within the rake-to-box junction after the tow exited the lock. However, many fish were lost from the gap before capture attempts took place. During these trials, when the barge tow maneuvered to the mooring location the pilot utilized a hard reverse maneuver to direct the stern of the tow into the mooring cell. This maneuver caused large amounts of sediment to become suspended in the water column which was visually observed inside the rake-to-box junction and along the barge. This observation holds promise that management recommendations could reduce the risk of barge mediated upstream fish transport in high priority areas and warrants further study to quantify the impacts of tow maneuvering on the hydraulic forces in rake-to-box junction gaps. Future work may provide insight into development of protocols or practices which may be effective at flushing undesirable fish, eggs, and larvae from the water column near barges and in rake-to-box junctions.

Conclusions

This study has shown that when loaded moving barges with a rake-to-box junction encounter juvenile fish there is a possibility that they will become inadvertently entrained into the barge junction gap, retained within the gap, and transported upstream. Juvenile fish that have been entrained into barge junction gaps may pass navigational structures and breach the Electric Dispersal Barrier system unhindered. Despite the steady commercial traffic on the Illinois Waterway (USACE data reports 236,171 barges transited through Brandon Road Lock between 1999 and 2015 [USACE 2015]); there is currently no direct evidence of entrainment and upstream transport of Asian carp by barges. However, there are currently no known studies that have monitored barge gap spaces for upstream transport of Asian carp. This study has identified a key vulnerability at the present Electric Dispersal Barrier system, which may allow small fish (potentially including Asian carp) to breach the barrier system in the future. The results of the study presented here and the implications for potential inter-basin transport of invasive fish species predicate that management actions intended to mitigate such risks are required.

Photograph of recaptured marked Golden Shiners on the deck of the barge tow following recapture during a transport trial at the Brandon Road Lock 8-20-2015.

Acknowledgments

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Disclaimer

The results presented herein are preliminary in nature and subject to change. Internal and external peer review processes are underway. The final results of this research will be made available through the peer reviewed literature upon completion of the peer review process.
Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Appendix

Summary of results from 2015 barge entrainment, retention, and transport trials.

Trial Type	Number of Trials	Physical Location	Distance Traveled (km)	Recapture %	Total Retention Estimate %
Entrainment	6	Electric Dispersal Barrier	1.0 km	6.8%	8.6%
Retention	6	Electric Dispersal Barrier	1.0 km	32.0%	51.1%
Retention	3	Brandon Road Lock Location 1	0.1 km	39.7%	52.3%
Retention	3	Brandon Road Lock Location 2	0.7 km	3.4%	20.4%
Transport	2	Lockport Pool and Electric Dispersal Barrier	5.4 km 7.6 km	26.9%	35.1%
Transport	1	Brandon Road Pool, Lockport Lock, Lockport Pool, Electric Dispersal Barrier	15.5 km	3.8%	5.6%

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