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Asian Carp Survivability Experiments and Water Transport Surveys in the Illinois River, Volume I

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16. Abstract (MAXIMUM 200 WORDS)

This report combines two earlier reports regarding investigations into the potential for barges and towboats to transport Asian carp upstream across the United States Army Corps of Engineers' electronic dispersal barrier and release them on the Lake Michigan side of the barrier. It summarizes a series of experiments conducted during June 2011 to evaluate the potential for Asian carp larvae to be entrained into and survive in barge ballast tanks on the Illinois River. It also describes investigations in 2010 and 2012 to determine the amount of water normally carried in barge ballast tanks.

Experiments were conducted in the LaGrange Reach of the Illinois River. Results indicated few Asian carp larvae were entrained and the majority of entrained fish were non-Asian carp, primarily gizzard shad. Survival of Asian carp larvae in test cages in tanks was high, even when water quality conditions were not favorable (low dissolved oxygen concentrations). A very small percentage (0.56%) of Asian carp survived for 30 minutes after being pumped through either a 2-inch or 3-inch pump. Although long-term survival following pumping was not determined, this extremely low survival rate translates to a minimal risk.

Visual inspections of ballast tanks and voids on 132 barges (empty and loaded) and 14 towboats were completed in the Chicago Sanitary and Ship Canal (CSSC) in August 2010. An additional tank survey was conducted in July 2012 on barges operating locally near the electronic dispersal barriers. Overall, only 5 percent of the more than 1000 tanks surveyed contained a measurable amount of water. Dissolved oxygen (DO) in tanks ranged between 0.44 - 7.80 mg/L. Although the water quality conditions were not optimal and water depth was very shallow, tanks could support early developmental stages of Asian carp.

Volume I of this report contains the descriptions, results, and conclusions from the experiments and surveys as well as a description of barge design and normal operating procedures. Volume II is comprised of the appendices containing a test plan for experiments and field and laboratory data sheets from the original reports.

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In 2010

- Illinois Marine Towing (IMT)
- American River Transportation Company (ARTCO)
- Hanson Material Services
- Kindra Lake Towing
- American Commercial Lines

In 2012

- Illinois Marine Towing (IMT)
- American River Transportation Company (ARTCO)
- Hanson Material Services
- Midwest Generation, LLC

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EXECUTIVE SUMMARY

The overall purpose of this project was to investigate the potential for Asian carp early life stages to be entrained into and survive in barge ballast tanks which might allow these fish to bypass the United States (U.S.) Army Corp of Engineers (USACE) electrical dispersal barriers in the Chicago Sanitary and Ship Canal (CSSC). Asian carp are non-native, invasive fish that have been steadily migrating up the Mississippi River and its tributaries since the mid-1990s. A self-sustaining population of Asian carp exists in the Marseilles pool and Asian carp have been identified proximate to the Lockport Lock and Dam. Environmental deoxyribonucleic acid (e-DNA) from Asian carp has been found on the lake side of the USACE electric dispersal barriers. There is concern that Asian carp eggs, larvae, and fry entrained in towboat and barge ballast tanks could be transported upstream past the dispersal barriers, released above the barriers, then possibly move into Lake Michigan and eventually into the rest of the Great Lakes.

In the early 1960s and 1970s, Asian carp (bighead, silver, grass, and black) were brought to the United States from Asia to control submersed aquatic vegetation, algae, and mollusks, and also to improve water quality of aquaculture ponds and at wastewater treatment facilities. Through pond escapement or by deliberate introductions, these species now occur in many of the rivers and back waters throughout the Upper Mississippi River System (UMRS).

USACE has constructed electrical barriers to keep invasive fish from moving between the Illinois River and Lake Michigan (and the rest of the Great Lakes). The CSSC Dispersal Barrier now consists of three barriers comprised of Barrier I (the Demonstration Barrier) and Barrier II containing a set of two independent barriers (IIA and IIB). Each barrier has electrode arrays spanning the entire width of the canal. The electrodes pulse direct current into the water, which causes fish to turn back rather than pass through the electric current. The barriers currently operate as part of an effort to keep Asian carp from passing through the CSSC and into the Great Lakes, but little information exists on potential transport mechanisms for early life stages of Asian carp, including eggs and larvae.

The project required two separate efforts: evaluation of the potential for early life stages of Asian carp to survive in barge ballast tanks and a determination of the volume of water being transported across the barriers during normal barge operations.

The survivability study was designed to assess the potential for early life stages of Asian carp to be entrained into barge ballast tanks through either cracks or holes in the hull and then survive there. A hopper barge was modified by installing valves on 3-inch holes cut into the exterior of its four ballast tanks to simulate a barge with a ruptured hull. Valves were opened at set times to entrain water and potentially Asian carp larvae. Survival was investigated by placing caged larvae into the flooded tanks for known periods of time. In addition, an experiment to assess pump effects was conducted to determine whether early life stages of Asian carp could survive a single pass through the type of portable pump normally used during barge and towboat ballasting operations. Water quality parameters, including temperature, dissolved oxygen (DO), conductivity, potential hydrogen (pH), and ammonia were recorded in the Illinois River, as well as in the barge ballast tanks during each experimental trial.

At selected time intervals, tanks were pumped out and the contents retained in a plankton net were examined to determine whether larvae had been entrained. Only three Asian carp larvae were found in the pump-out

material during the entrainment trials. However, because the entrainment and survival experiments ran concurrently, and because some of the mesh used in the experimental cages was damaged during the study, it is possible that these Asian carp larvae escaped from the damaged cages rather than having been entrained. The majority of the fish entrained into the tanks and later pumped out were non-Asian carp (mainly gizzard shad), which were present in relatively high abundances during some of the river plankton tows prior to the initial tank flooding. Results of the survival experiment indicated high survival (low mortality) rates for containment periods as long as 144 hours in the flooded tanks.

The pump effects portion of this study indicated that if entrained, a very small percentage (0.56 percent) of Asian carp larvae could survive a single pass through either a 2-inch or 3-inch portable ballasting pump. During normal tank deballasting, no hose is attached to the pump discharge and the discharged water falls several feet from the barge deck level to the river surface. During this study, however, a discharge hose was attached from the pump to below the waterline to allow the pumped water to be directed into and filtered through a submerged plankton net. It is uncertain what additional mortality (if any) might have taken place had no hose been used on the pump's discharge and the larvae fell directly from the pump discharge and impacted the river surface. Likewise it is not possible to determine the effects of impact with the hose wall.

Water quality parameters measured during the experiments showed that Asian carp larvae were able to withstand a wide range of water quality parameters. The most variable water quality parameter was DO, which decreased in the tanks from a maximum of 5.51 milligrams per liter (mg/L) to a level as low as 0.86 mg/L in the tanks. However, even at these depressed levels, larval survival was not adversely affected.

It should be noted the study began an estimated 11-13 days after an Asian carp spawning event based on the age of the larvae collected in the river at the beginning of the study. Consequently, no eggs or larvae younger than this age were available for testing. It is possible that had the experiments been conducted in the midst of an Asian carp spawning event (both time and location), entrainment of their eggs and young larvae may have been higher through the 3-inch test openings since their avoidance reaction would be less developed.

The water transport study used visual inspections of barge ballast tanks and measured water depth, temperature and dissolved oxygen (DO) concentration in tanks and voids of barges and towboats to assess the potential for early developmental stages (eggs and larvae) to survive and potentially be transported above the barrier. Initial surveys conducted in the Illinois River in 2010 indicated that most (95 percent) of the 969 barge and towboat ballast tanks inspected were dry. For those barge and towboats that contained measurable amounts (more than 2 - 3 inches) of water in an individual tank, water temperatures and DO concentrations were within published tolerances for either Asian carp or other carp species.

A follow-on survey of tanks on barges operating in the immediate vicinity of the USACE electric dispersal barriers was conducted in July 2012 to determine whether locally operating barges engaged in different ballasting procedures and frequencies than the barges surveyed in 2010. Initially, the focus was intended to shift from the large barge companies as previously reported to local/small barge providers. It was found that there are no small companies that move barges within the dispersal barrier focus area, but a few of the previously visited large companies do designate many of their barges to work in the local barrier area. The inspection team focused on these local groups of barges to collect data on 39 barges rafted along areas of the river and two tugboats. The barges inspected were usually empty and in generally good condition. Discussions with operators revealed that ballasting procedures and frequencies were nearly the same for the local barges as for the longer distance barges surveyed earlier. Similarly, only 6 percent of the local barge tanks inspected contained water deep enough (about 4 inches) to measure temperature and DO. Temperature and DO readings were at the upper ranges of those measured in 2010. Results from this survey of barge tanks suggest that water quality conditions in barge and towboat ballast tanks during one season (summer) would be able to sustain juvenile to adult Asian carp.

Results of the overall study indicate that while it may be possible for early life stages to be transported in a barge ballast tank for long periods, there is a very low probability that those life stages will survive passage through the pump when the tanks are deballasted. Additionally, early life stages are available for entrainment or active pumping for a limited time each year. Therefore, barge ballast tanks present a minimal risk vector for incidental transport and introduction of Asian carp.

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LIST OF ACRONYMS, ABBREVATIONS, AND SYMBOLS

µS/cm	microSiemens per centimeter
ARTCO	American River Transportation Company
ºC	degrees Centigrade
CAWS	Chicago Area Waterway System
CSSC	Chicago Sanitary and Ship Canal
DNA	deoxyribonucleic acid
DO	dissolved oxygen
e-DNA	Environmental deoxyribonucleic acid
EPA	Environmental Protection Agency
ft	feet
GIS	Geographic Information System
GLRI	Great Lakes Restoration Initiative
IDNR	Illinois Department of Natural Resources
IMT	Illinois Marine Towing
in	inch
INHS	Illinois Natural History Survey
KLT	Kindra Lake Towing
LTRMP	Long Term Resources Monitoring Program
m^3	cubic meter
mg/L	milligrams per liter
mm	millimeter
nc	not collected
NIS	Non-indigenous species
pH	potential hydrogen
R	river
RDC	Research & Development Center
TAN	total ammonia nitrogen
ULT	Upper lethal temperature
U.S.	United States
UMRS	Upper Mississippi River System
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USGS	U.S. Geological Survey
YSI	Yellow Springs Instrument

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1 INTRODUCTION

This report is a combination of two earlier reports to ensure that all information from the effort to assess the potential risk for early life stages of Asian carp to be transported across the U. S. Army Corps of Engineers electronic dispersal barrier is available in one consolidated report. These efforts included experiments to determine the likelihood of early life stages being entrained into and survive in barge ballast tanks as well as surveys of barge ballast tanks to determine the amount of non-potable water being transported across the barriers in tanks. Due to the size of data appendices, this report consists of two volumes.

Volume I contains the full text from “Survivability of Asian Carp in Barge Tanks in the Illinois River” as the primary report and that from “Water Transport during Normal Operations of Towboats and Barges in the Illinois River” as supporting information. Sections 2 – 5 are the complete text from “Survivability of Asian Carp in Barge Tanks in the Illinois River”. Sections 7 – 12 are the complete text from “Water Transport during Normal Operations of Towboats and Barges in the Illinois River”. Appendix F, “Towboat and Barge Design and Operation”, provides a description of barge design and operating procedures used on commercial barges.

Volume II is comprised of appendices to the two earlier reports that are now consolidated in Volume I. Volume II includes the test plan for the entrainment experiments described in “Survivability of Asian Carp in Barge Tanks in the Illinois River” as Appendix A. The field and laboratory data sheets from the survivability experiments are Appendices B1-B9. Field data sheets from the tank surveys are Appendices C and D.

2 SURVIVABILITY OF ASIAN CARP IN BARGE TANKS IN THE ILLINOIS RIVER

The purpose of this study was to investigate the potential for early life stages (eggs, larvae, or juveniles) of Asian carp to be entrained into and survive in barge ballast tanks. Specifically, this study was designed to address the question of whether barges and towboats can potentially provide a means for these stages to bypass the United States (U.S.) Army Corp of Engineers (USACE) electrical dispersal barrier in the Chicago Sanitary and Ship Canal (CSSC). A previous survey of 969 ballast tanks on barges and towboats showed that only five percent of the tanks contained more than a few inches of water.

Asian carp (bighead, silver, grass, and black) were brought to the United States in the early 1960s and 1970s and now inhabit the waters of the Upper Mississippi River System (UMRS). These species were used to control submersed aquatic vegetation, algae, and mollusks in ponds thereby improving water quality of aquaculture ponds and in wastewater treatment facilities (Chapman & Hoff, 2011) and “to develop nonchemical and environmental friendly control mechanisms” (Kelly et al., 2011). Asian carp invaded nearby rivers through pond escapement or by deliberate release. Asian carp reproduce rapidly when the conditions are favorable. All four species of Asian carp are now well established in the Mississippi River basin (Chapman & Hoff, 2011). Biologists, policy makers, and citizens are deeply concerned about the prospects of Asian carp entering Lake Michigan through the Chicago Area Waterway System (CAWS). Sparks et al. (2011) stated that if bighead and silver carp enter Lake Michigan, they will directly compete for food resources with a number of well-established sport fishes.

The United States Army Corps of Engineers constructed a permanent electrical barrier (the CSSC Aquatic Nuisance Species Dispersal Barrier) to protect Lake Michigan and the other Great Lakes from invasive species movements between the Mississippi River and lakes. This electric barrier was originally conceived as a method to prevent the movement of non-native fishes through the CAWS. The round goby was the first target species but it moved out of Lake Michigan and through the proposed barrier location into the Illinois River before construction of the original barrier was complete. The CSSC Dispersal Barrier consists of three electric barriers (formally Barrier I and II) with Barrier II having two independently operating barriers (IIA and IIB), each consisting of 42 electrodes spanning the width of the canal. The electrodes pulse direct current into the water at a strength and frequency that causes fish to turn back rather than pass through the electric current. The barriers are operating in an effort to keep Asian carp from moving upstream and possibly entering Lake Michigan.

Bighead and silver carp have recently been found downstream of the CSSC and environmental deoxyribonucleic acid (e-DNA) from these species has been found upstream of the barrier (Moy et al., 2011; Jerde et al., 2011). Although the actual source of the positive e-DNA hits has not been found, experiments have shown that e-DNA can persist in water up to 48 hours (Jerde et al., 2010). Towboat operators have reported that Asian carp will occasionally land on the towboat or barge and either die there or leave blood and mucous on the deck until the boat crew hoses down the deck. Thus, it is possible that Asian carp e-DNA could be carried across the barriers by vessel traffic.

There is also concern that Asian carp eggs, larvae, and juveniles may be taken up in ballast or leakage water of towboats and barges and potentially be transported through the dispersal barrier. If the fish are discharged upstream of the dispersal barrier, there is concern that Asian carp could advance into Lake Michigan. While the barrier operates to keep Asian carp from continuing to move upriver, little information exists on potential transport mechanisms for early life stages of Asian carp (Moy et al., 2011).

Irons et al. (2011) reporting on sampling in the La Grange Reach of the Illinois River from 1990 through 2006 stated that the catch of adult silver and bighead carp began in 2000. The peak in abundance of bighead carp was in 2000 followed by a decline to very low levels in 2005 and 2006. Silver carp abundance peaked in 2004 and then decreased between 2004 and 2006 in the La Grange Reach, however Irons et al. (2011) stated that the sampling equipment was ineffective in the collection of the largest individuals, with individuals being observed swimming away from the capture boat. They also observed good recruitment of both bighead and silver carp (based on catch of fish less than about 200 millimeter [mm]) during 2000 and 2003. However, recruitment of both species was poor in 2001, 2002, and 2005. Sass et al. (2010) reported that the La Grange Reach of the Illinois River had a conservative estimate of 2,544 silver carp with a biomass of 5.5 metric tons per river kilometer during 2007-2008. They estimated that silver carp made up about 51 percent of the total fish collected by the Long Term Resource Monitoring Program (LTRMP) in the La Grange Reach. No estimate of bighead carp abundance was presented in this paper.

Papoulias et al. (2006) found that bighead and silver carp can have a long annual spawning season each year in the Missouri River and appear to be able to spawn more than one time during each year. They found that from 2003 through 2005, silver carp spawned as early as late March when the water temperature had reached about 14 ºC while bighead carp did not begin spawning until about early May when the temperature was about 19-20 ºC. Irons et al. (2011) stated that the critical spawning temperature for bigheaded carp was 18 ºC. Coulter & Goforth (2011) found Asian carp eggs in the Wabash River, Indiana, from May through July during 2011. Several studies, including Jennings (1988), DeGrandchamp et al. (2007), Kolar et al.

(2007), Lohmeyer & Garvey (2009), and Irons et al. (2011) also stated that Asian carp spawning is positively correlated to increasing river flow. DeGrandchamp et al. (2007) also stated that high river flow does not appear to be critical for reproduction to take place but may aid in egg and larval survival.

Yi et al. (1988, as translated in Chapman, 2006) described the characteristics of the 48 early developmental stages of the eggs and larvae of the four species of Asian carp in the Yangtze River. These stages begin with egg fertilization and end with the larvae transition into a juvenile. Egg development to hatching takes place quickly. Yi et al. (1988) reported that bighead carp in the field hatch about 39 hours after fertilization while Chapman & George (2011) found hatching in the laboratory after 31 to 45 hours depending on incubation temperature. Silver carp hatch between 26 to 45 hours after fertilization in the laboratory (Chapman & George, 2011) while Yi et al (1988) reported hatching in the Yangtze River after about 38 hours. Development to the juvenile stage in silver and bighead carp was estimated to take about 60-70 days after fertilization (Yi et al. 1988).

Chapman & George (2011) reported that newly hatched bighead and silver carp larvae immediately begin a vertical swimming motion when they were not resting; this swimming motion changes to a horizontal direction near the water surface at larval Stage 36 (when the eyes become pigmented) which is about 100 hours after fertilization. By Stage 38 at about 146 hours after fertilization (referred to as the one-chamber-gas-bladder stage), larvae swim horizontally at varying depths between resting periods. These authors also reported that larvae began to move out of the river channel into the slower water near shore about 100+ hours post hatching (about Stage 37 when the gas bladder forms).

The current study was designed to evaluate the potential for entrainment of early life stages of Asian carp into barge tanks via leaking hulls and to assess their survival in barge ballast water. Another aspect of the study was to assess survival of these life stages after being pumped through a portable pump. This study was not designed to directly address the question of survival of early life stages being transported across the electric barriers while in a ballast tank.

3 SURVIVABILITY TEST METHODS

3.1 Overview

Two experimental trials, each lasting approximately 7 days, were conducted from June 11-24, 2011, within the La Grange Reach of the Illinois River, just down river (south) of Peoria, IL. River plankton sampling began June 9 in an attempt to locate high concentrations of Asian carp eggs and young larvae. With few exceptions, all field and laboratory methods followed an approved Study Plan (Volume II, Appendix A). Details concerning minor changes to the approved Study Plan are presented below. Modifications ranged from changes in the experimental locations to changes in cage holding times.

The decision to begin in early June was based on the suggestion of Dr. Greg Sass (pers. comm., June 1, 2011, Director, Illinois Natural History Survey (INHS), Havana Biological Field Station). He felt that the river water temperature was right for spawning and the river was rising due to thunderstorms in the region. He also mentioned that there had been reports of Asian carp swimming at the surface with possible spawning having already taken place. By June 9 when sampling began, the river was 6-8 feet above its average height for that time of year and was considered to be in flood conditions, which had a direct impact on both sampling and testing locations (see Section 4).

3.1.1 Barge Location and Setup

All experiments took place on a hopper barge secured to the outboard side of a deck barge. The barges were provided by American River Transportation Company (ARTCO) and were moored at the ARTCO Fleeting Services dock in Pekin, IL (Figure 1). ARTCO modified the four ballast tanks of the hopper barge by drilling one 3-inch diameter hole below the waterline in the side of each tank and fitting each with a gate valve to allow tank flooding. The modification was intended to simulate a leak for potential entrainment of larvae. Each of the four ballast tanks on the modified barge was filled by opening the valve and then emptied using a Honda WB20X (2-inch hose) or WB30X (3-inch hose) pump. These types of pumps are used by most barge operators during normal operations to fill or empty their ballast tanks. The ballast water was pumped out of each tank and into a plankton net suspended in the river water in a spud well on the adjacent deck barge. The pump's discharge hose emptied below the waterline inside the plankton net..

3.1.2 River Collections and Results

Plankton tows were used to identify areas where Asian carp eggs and larvae could be found in the La Grange Reach of the Illinois River. Tows were conducted on 9-10 June prior to Trial 1, on 18 June prior to Trial 2, and on a few days during both trials. The majority of the tows were conducted using a plankton net attached to a wood frame (Figure 2) lowered off the bow of a boat supplied by the INHS, Havana Biological Field Station. In general, tows were run diagonally across the channel from one shore to the other.

Results of these tows and visual observation indicated that no Asian carp eggs and very low concentrations of their larvae were present in the channel location; however, larval Asian carp were present in significantly higher abundances in shallow water habitats along the shoreline, generally between the flooded tree trunks. Consequently, larvae were collected using small dip nets from shallow water locations along the shoreline and were used during both trials for the survival and pump effects studies. All Asian carp larvae collected in the larger nets in the main river channel were generally of the same size as those collected in higher numbers along the shoreline near the flooded tree line.

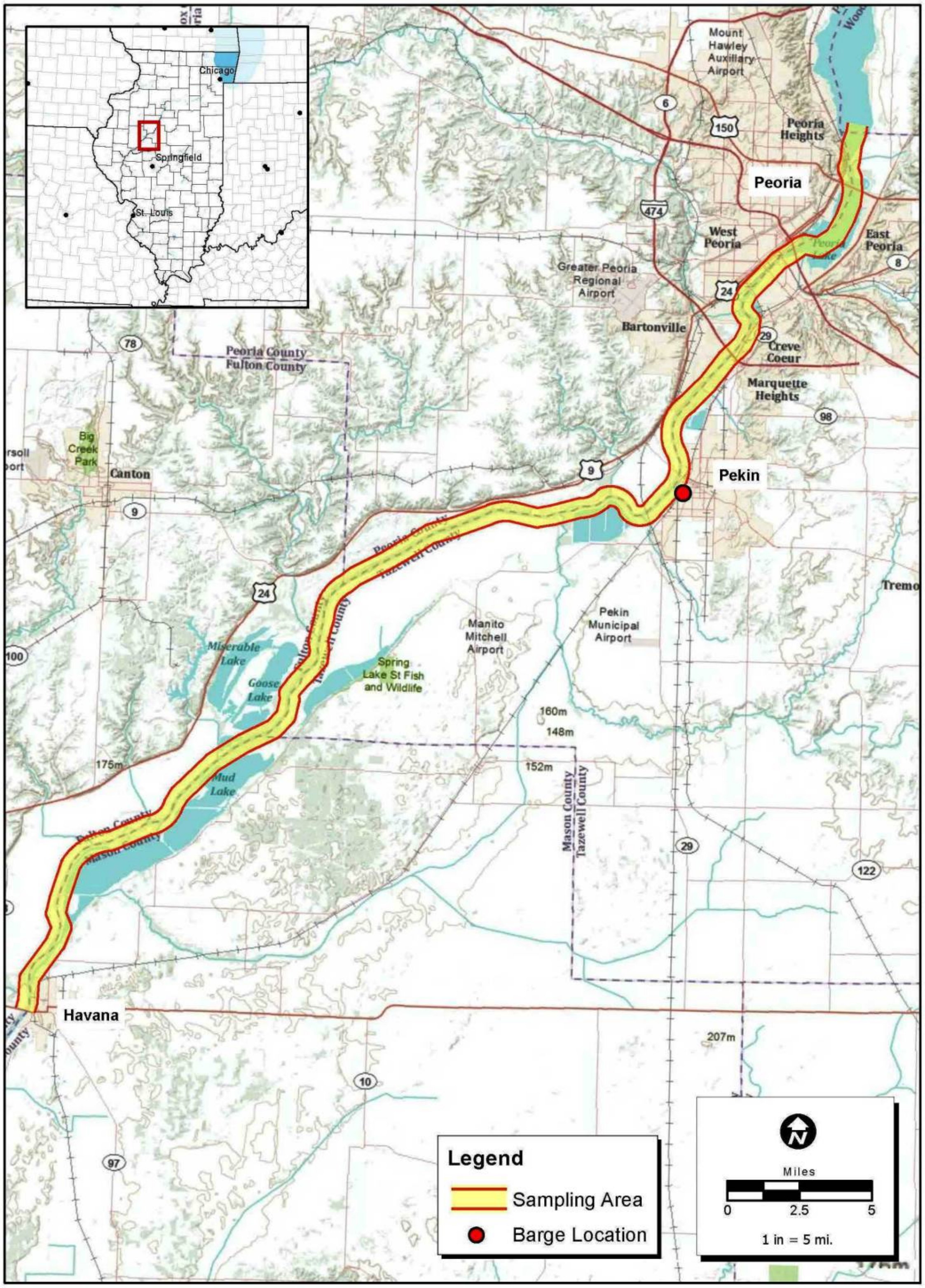


Figure 1. Sampling area and barge location on Illinois River during Trials 1 and 2, June 2011.

Plankton net frame construction

Plankton net on frame

Plankton net being lower into the water

Identifying organisms collected in plankton net using headband magnifier

Figure 2. Photos of the push plankton net frame construction and sampling during river plankton tows.

A second result of finding few to no larvae in the main channel was that it would not be possible to follow one cohort of larvae as they drifted downriver as was initially planned. It was therefore decided to moor the experimental barge and an additional deck barge at the ARTCO facility in Pekin with the valve openings at the edge of the channel thereby allowing river water to flow freely past the openings.

Table 1 presents a summary of the plankton net tow dates, locations, and the main species of fish larvae found on each collection day. For the first two collections (9-10 June), a 500 micron mesh net was towed from the side of the boat in the upper 3-6 ft (feet) of the water column for about 5 minutes. Generally, the rest of the tows were about 5-10 minutes long using a 500-micron mesh net suspended off the front of the boat while it was motored upstream either into or across the river flow. This net setup filtered water from approximately the upper 30 inches (in) of the water column. The majority of the tows were across the river from bank to bank. The volume of water was not determined during the first series of tows, as the emphasis was to try to locate high concentrations of Asian carp eggs or larvae in the main channel and along the shoreline. If a high density had been found, a flowmeter would have been attached to the net to determine volume filtered to find the actual egg or larval concentration. During the 22-23 June tows, a flowmeter was added to the net to generate an estimate of the water volume filtered. The volume per tow ranged from about 100 to 235 cubic meters (m^3) (~26,000 to 62,000 gallons). As can be seen in the table, no Asian carp eggs and only low abundances of their larvae were found.

Table 1. Date, location, and larval fish in river collections.

Note: The total number of all larvae collected during each tow was not determined*.

Date	Location	Number of Tows	Larval Fish
6/9/11	ARTCO's launch ramp to Pekin Landing. Tows were conducted within the upper 6 ft of the water column either across the channel or along the shore just outside of the tree line.	6	Mainly gizzard shad. Four Asian carp total in all six tows.
6/10/11	ARTCO's launch ramp to Kickapoo Creek and in Copperas Creek area. Main tows were within upper 3-6 ft of the water column either across the channel or along the shore just outside of the tree line.	5	Asian carp found along shoreline in rock rubble and in water around trees. River and creek tows collected mainly gizzard shad, with about 50 Asian carp total for all tows.
6/15/11	Up and down river from Havana (estimate covered 15 miles of river while sampling). Main tows within about the upper 30 inches of the water column either across the channel or along the shore just outside of the tree line.	9	5-50 Asian carp per tow with most of the larvae being gizzard shad. Highest number of Asian carp was near Liverpool.
6/16/11	Sampled from Pekin to Upper Peoria Lake. Main tows within about the upper 30 inches of the water column either across the channel or along the shore just outside of the tree line.	6	2-20 Asian carp per tow with most of the larvae being gizzard shad.
6/22/11	Sampled from Pekin to Peoria Lock and Dam (estimate covered 4-5 river miles while sampling). Main tows within about the upper 30 inches of the water column either across the channel or along the shore just outside of the tree line. Volume per tow varied from about 110 to 235 m^3 (~29,000-62,000 gallons).	5	0-5 Asian carp per tow with most of the larvae being gizzard shad.
6/23/11	Up and down river from Havana (estimate covered 6-8 miles of river while sampling). One sample conducted at Toehead Island which historically has been area with high spawning activity. Main tows within about the upper 30 inches of the water column either across the channel or along the shore just outside of the tree line. Volume per tow varied from about 100 to 130 m^3 (~26,000-34,000 gallons).	5	No Asian carp. Larvae mainly gizzard shad.

*Total number of all larval fish for tows presented in this table ranged from 0 to an estimated 500 per tow. The highest numbers were due mainly to gizzard shad collected between upper and lower Peoria Lakes.

3.2 Entrainment Experiment Methods

To evaluate potential entrainment of larval Asian carp into barge ballast tanks, four experimental tanks on the hopper barge were flooded, emptied, and contents analyzed during Trials 1 and 2 according to the timing presented in Table 2 (see Volume II, Appendix A, Table 2 for planned timing). Asian carp entrainment experiments ran concurrently with the survival experiments (see Section 3.3 below). A plankton net (500 micron mesh) was suspended in river water inside a spud well on the adjacent deck barge while each tank was emptied into the net using a portable pump and discharge hose positioned below the water surface inside the net (Figure 3). A 2-inch pump was used during the first pump-out only; a 3-inch pump was used to empty the tanks during all other pump-out events. The pump operated at full throttle during pump out process until the tank water level reached approximately 6 inches remaining. The pump rate was then reduced to about half-throttle to avoid losing suction. (Such rate reduction is common practice during normal barge operations.) The plankton net cod ends were emptied and analyzed twice during each tank pump-out. All entrained larvae, live or dead, were removed and placed in labeled vials for subsequent laboratory identification and staging. The volume of water pumped from each tank was estimated using the dimensions of the tanks supplied by ARTCO and the depth of water prior to and after pumping.

Table 2. Summary of filling/emptying dates and times plus water depths of varying tank fills during Trials 1 and 2.

Start Date	Location	Tank	Fill	Date Filled	Time Filled	Date Emptied	Time Emptied	Filled Water Depth (in.)
Trial 1								
6/11/11	Pekin Dock	T1	F1	6/11/11	9:25	06/11/11	17:30	51
6/11/11	Pekin Dock	T1	F2	6/11/11	21:23	06/17/11	9:30	48
6/11/11	Pekin Dock	T2	F1	6/11/11	9:25	06/12/11	9:30	54
6/11/11	Pekin Dock	T2	F2	6/12/11	12:00	06/17/11	9:15	50.5
6/11/11	Pekin Dock	T3	F1	6/11/11	9:37	06/13/11	9:30	44
6/11/11	Pekin Dock	T3	F2	6/13/11	12:12	06/17/11	10:45	47
6/11/11	Pekin Dock	T4	F1	6/11/11	9:30	06/14/11	9:35	41
6/11/11	Pekin Dock	T4	F2	6/14/11	11:50	06/17/11	11:45	48
Trial 2								
6/18/11	Pekin Dock	T1	F1	6/18/11	11:20	06/24/11	11:45	56
6/18/11	Pekin Dock	T1	F2	No Fill #2				
6/18/11	Pekin Dock	T2	F1	6/18/11	10:35	06/19/11	10:30	59
6/18/11	Pekin Dock	T2	F2	6/19/11	13:32	06/24/11	9:45	45
6/18/11	Pekin Dock	T3	F1	6/18/11	11:00	06/20/11	10:45	48
6/18/11	Pekin Dock	T3	F2	6/20/11	13:10	06/24/11	10:00	48
6/18/11	Pekin Dock	T4	F1	6/18/11	11:10	06/21/11	10:55	49
6/18/11	Pekin Dock	T4	F2	6/21/11	13:00	06/24/11	11:30	48

Due to the low concentration of larvae found during river tows prior to Trial 1, additional plankton tows were not conducted during tank flooding. However, a plankton net was deployed alongside the barge while the ballast tanks were being flooded for the entrainment experiment during Trial 2. The 500 mm mesh plankton net (Figure 3, lower right) was deployed to a depth similar to the tank valve depth to determine if

Asian carp or other species of larval fish were present in the water column and could potentially be entrained.

Pumps for emptying tanks

Pump and hose setup

Emptying tank into plankton net in spud well

Plankton net

Figure 3. Photos from the entrainment experiment.

3.3 Survival Experiment Methods

As mentioned above, plankton tows were used to identify areas in the La Grange Reach where Asian carp eggs and larvae could be obtained. Results of these tows indicated that eggs were absent and larvae were not present in high enough numbers to conduct the survival study in the channel location itself. Larval Asian carp but not eggs were present in shallow water habitats along the shoreline, therefore larvae used in the survival experiments were collected with dip nets from shallow water locations along the shore. For Trials 1 and 2 approximately 30 larvae were placed in each of three cages in each ballast tank (Figure 4) for a range of exposure times as shown in Table 3 and Table 4, respectively. In addition, control cages were deployed in the river during both trials for various exposure times, as indicated in Table 3 and Table 4.

Example cage used in survival experiment

Example of larvae collected for survival experiment

Preparing cages for survival experiment

Cages suspended in ballast tank

Control cages in river (strong current area)

Control cages in river (weak current area)

Figure 4. Photos from the survival experiment.

Table 3. Proposed and actual exposure times (hours) for survival experiment Trial 1 test cages.

Cage Set	Proposed Exposure Times (hrs)	Actual Exposure Times (hrs)
1	8	8
2	24	24
3	48	48
4	72	72
5	80	72*
6	92	94*
7	104	117*
8	108	132*
Control 1	8	8
Control 2	24	24
Control 3	48	65*
Control 4	72	72
Control 5	96	118*

*Times changed from Final Test Plan (**Error! Reference source not found.**)

Table 4. Proposed and actual exposure times (hours) for survival experiment Trial 2 test cages.

Cage Set	Proposed Exposure Times (hrs)	Actual Exposure Times (hrs)
1	8	144*
2	24	144*
3	48	144*
4	72	144*
Control 1	24	143*
Control 2	48	143*
Control 60**	72	120*
Control 90**	72	120*

*Times extended over Final Test Plan (Volume II, Appendix A**Error! Reference source not found.**)

**The 60 and 90 indicate the total number of larvae that were initially placed in these control cages.

Cages were 5-gallon plastic buckets with lids. Openings cut in the bucket sides and lids were covered with 500-micron mesh netting to allow water circulation (Figure 4). Keeping the mesh attached over the cage opening was a problem once the trials began. Initially, aquarium-grade silicone was used but it was determined that this did not bond securely enough to the bucket walls. Hot glue used along the edge of the mesh generally secured the mesh adequately for the testing. A few cages required repair to the mesh covering more than once.

3.4 Pump Effects Experiment Methods

The pump effects experiments assessed whether larvae were able to survive the pumping process that occurs during ballasting operations. This study occurred in conjunction with the entrainment and survival studies. Larvae for this experiment were collected at shore locations using similar methods to those described above for the survival experiment (Section 3.3). The pump intake hose was placed in the river and a large number of larvae were released from a 5-gallon bucket into the water near the intake hose while the pump was operating. Larvae were sucked through the hose and pump and were discharged into a plankton net suspended in a spud well, similar to methods used for the entrainment study (Figure 5). Two-inch and 3-inch water pumps (Honda WB20X and WB30X pumps, respectively) were tested during both trials. No count was made in the field of the number of larvae initially released near the hose intake or collected in the plankton net cod end during each test run. The number of larvae collected during one pump test was estimated by counting the number of larvae in a photo taken following collection. This estimate of the number of larvae passing through the pump was used for all the other pump effects tests.

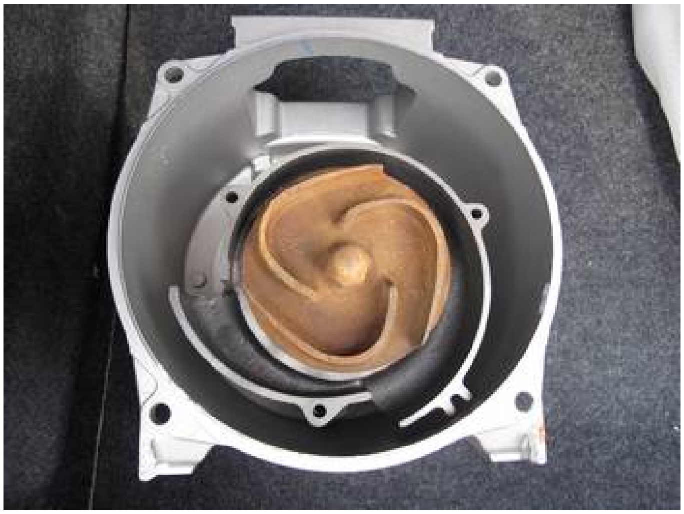
Samples collected in the plankton net were placed in water in small plastic containers and the number of live larvae recorded immediately after collection. The sealed containers were then placed in a bucket of water to keep the samples' water temperature stable during a 30-minute holding period. After 30 minutes the number of live larvae was recorded to assess potential effects of pumping on their viability after passing through the pump assembly.

3.5 Lab Analysis

Labeled vials containing the live and dead larvae from the entrainment and survival experiments and the river-collected larvae were returned to the lab for identification, staging, and enumeration. All larvae that survived passing through the pump in the pump effects experiments were also placed in labeled vials and returned to the laboratory for processing. The stage number of each Asian carp larvae (Table 5) was determined based on Yi et al. (1988). Data from the entrainment, survival, and pump effects samples were recorded on laboratory datasheets. The stage and status (live or dead) of each Asian carp larva was recorded for the entrainment and survival trials. The number and status was also recorded for each non-Asian carp larva collected during these experiments. All recorded data were entered into a Microsoft® Office Access® database and verified for completeness and accuracy prior to the development of summary tables.

3.6 Water Quality Analysis

Water quality parameters from the flooded tanks and the Illinois River were recorded during the entrainment and survival experiments based on the filling and emptying schedule (Table 2). Water quality data included tank water depth, water temperature, dissolved oxygen (DO), potential hydrogen (pH), and total ammonia nitrogen (TAN). All water quality samples were collected at the water surface in the ballast tanks and the river. A Yellow Springs Instrument (YSI) water quality probe was used to collect temperature and DO. During Trial 1, total ammonia was measured using an API® Freshwater Ammonia Test Kit. No pH testing was conducted during Trial 1. During Trial 2, ammonia and pH were measured using API Freshwater Ammonia and pH Test Kits, respectively.



Impeller from 3-inch portable water pump

Hose location for pump effects experiment

Example of larvae used for pump effects experiment

Releasing larvae into river near pump intake

Larvae and juvenile fish (approximately 3 inches) condition after going through pump

Figure 5. Photos from pump effects experiment.

Table 5. Summary of stage number, stage name, length, and days post-fertilization for silver carp larvae from translation of Yi et al. (1988) by Chapman (2006). Stages 1-30 were egg development stages.

Stage #	Stage Name	Length (mm)	Hours or Days Post-Fertilization
31	hatching	6.1	38 hours
32	rudimentary-pectoral-fin	6.3	48 hours
33	gill-arch	6.8	53 hours
34	xanthic-eye	7.2	63 hours
35	gill-filament	7.6	74 hours
36	melanoid-eye	8.0	92 hours
37	gas-bladder-emergence	8.2	106 hours
38	one-chamber-gas-bladder	8.5	146 hours
39	yolk-absorption	8.7	168 hours
40	dorsal-fin-differentiation	9.0	212 hours
41	notochord-tip-lifting	9.4	240 hours
42	two-chamber-gas-bladder	10.3	279 hours
43	pelvic-fin-bud	11.2	312 hours
44	dorsal-fin-formation	14.1	19 days
45	anal-fin-formation	15.7	22 days
46	pelvic-fin-formation	17.0	25 days
47	squamation	20.0	34-55 days
48	juvenile	34.0	60-90 days

4 SURVIVABILITY TEST RESULTS

4.1 Entrainment Experiment Results

The volume of water pumped out of each ballast tank was determined using the dimensions of the tanks provided by ARTCO. The depth of water in the ballast tanks varied from 41 to 59 inches with a mean depth of 49 inches. In spite of splitting the ballast tank pump out into two collection periods, the net's cod end captured a significant amount of rust. To avoid damage to captured larvae from additional rust particles, pumping was halted when an estimated average of 4.5 inches of water remained in each tank. The average volume pumped from the tanks during the two trials was calculated to be 9,092 gallons with a minimum of 8,183 gallons and a maximum of 10,203 gallons (Table 6). The water depths used to estimate the volume of water pumped from each tank are provided on field data sheets in Appendix B1 (See Volume II for appendices.) All other field and laboratory datasheets are presented in Volume II, Appendices B2 through B9.

The number and type of larvae found in the material pumped out of the ballast tanks during the entrainment studies are also presented in Table 6. In all instances the pump-out material included a large amount of rust particles (Figure 6). All larvae, regardless of species, were found dead when they were removed from the pump-out material from the tanks. It could not be determined if the larvae died in the tanks, were killed by passing though the pump and hose, or were killed by being hit or smothered by rust while in the cod end. Only three Asian carp larvae, one each of stage 41, 44, or 45, were found during these collections. It is not certain if these Asian carp larvae were entrained into the ballast tanks during flooding or if they escaped from a damaged cage from the survival study. The majority of the fish collected during the entrainment study were non-Asian carp, mainly gizzard shad. Gizzard shad were found in relatively high abundance during some of the river tows in the days leading up to the initial flooding for Trial 1. A few damaged larvae that could not be visually identified were also collected. The laboratory datasheets for the entrainment experiment are presented in Volume II, Appendices B3 and B6.

Table 6. Number of fish larvae collected after pump-out of ballast tanks following different exposure periods during Trials 1 and 2. Note that all larvae were dead. Blank cells mean no larvae found.

Tank #	Fill #	Hours Exposed	Asian Carp Larvae by Stage			Non-Asian Carp Larvae	Damaged Larvae	Volume Pumped from Tank (gallon)
			41	44	45			
Trial 1								
1	1	8				2		9,305
2	1	24				1		9,642
3	1	48				13		8,519
4	1	72	1			3	14	8,183
4	2	72				1		8,968
3	2	94				1		8,856
2	2	117						9,249
1	2	132			1			8,968
Trial 1 Total			**1**	**0**	**1**	**21**	**14**	**71,690**
Trial 2								
1	1	144				1		9,866
2	1	24				1	1	10,203
3	1	48				5		8,968
4	1	72		1		2	1	9,080
4	2	70.5				2		8,968
3	2	96						8,968
2	2	115						8,632
1	2	Tank 1 only filled one time during this trial						
Trial 2 Total			**0**	**1**	**0**	**11**	**2**	**64,685**

Figure 6. Example of material (mainly rust) pumped out of ballast tank during Trial 1.

During Trial 2, icthyoplankton samples were collected in the river alongside the tug and barge while the ballast tanks were being filled. Two to three samples were collected each day during each of the four filling events (at 0, 24, 48, 72 hours). The volume of water filtered through the plankton net varied from 6,399 to 16,970 gallons with a per sample average of 8,366 gallons. (Scanned field datasheet example is shown in Volume II, Appendix B). The density of larval fish collected during these alongside collections was calculated at 33 to 48 individuals per 9,000 gallons (the approximate average volume of water pumped from each ballast tank). No Asian carp larvae were found in any of these river samples. The larval fish concentration in the river was higher than that found in the water pumped from the ballast tanks during this trial. The actual reason for the difference is unknown but could be due to a number of causes including, but not limited to, larval patchiness, avoidance activity by the advanced stage of larvae, and the difference in the capture efficiency of the open plankton net versus the suction created by the 3-inch hole in the ballast tanks.

4.2 Survival Experiment Results

Survival tests were conducted from 11-24 June 2011 using fish larvae collected from near the shoreline, generally from around submerged trees. The larvae were of the same general size as the few found in the channel.

The larvae used for the testing were a mixture of both Asian carp and non-Asian carp larvae. Initial attempts to separate the larval species with the aid of a dissecting microscope subjected the larvae to too much handling and damaged them. Therefore, both Asian carp and non-Asian carp were placed into the test cages to minimize handling of the collected larvae. A higher proportion of Asian carp larvae made up the larval mixture collected during Trial 2 than Trial 1 due to the decrease in the abundance of non-Asian carp larvae in shoreline collection areas.

The target initial count was 30 larvae per test cage. As indicated in Section 3.3, some of the mesh on several cages became loose during the testing due to failure of the adhesive. This potentially allowed some larvae to escape, causing a reduction in the total number of larvae remaining in a cage at the conclusion of the test interval for that cage.

Control cages were placed in two areas in the river near the barge. During the first two days in Trial 1, the control cages were lowered into the river alongside the tug, but the fast river flow and large amount of floating debris in this location caused extensive damage to the mesh of the cages, allowing larvae to escape.

Therefore, the location of the control cages was changed to a more "protected" area for the remainder of the survival experiment. All control cages for most of Trial 1 and all of Trial 2 were located in the same protected area where the river current was substantially reduced and there was less large floating debris such as logs and branches. (See Figure 4.)

The control cages in both locations experienced higher sediment loads than cages in the tanks, thus the control larvae were not subjected to the same water conditions as those in cages placed in the ballast tanks. Once the water entered the ballast tanks, there was little water movement and the suspended sediment tended to settle to the bottom of the barge with only a small amount of sediment going into each cage. The control cages in the river, however, had a constant supply of new sediment that could enter the cage through the mesh and then settle out due to the decreased water movement within the cage. Upon inspection, the higher sediment load in the control cages at both locations did not appear to affect larval Asian carp survival.

The number of larvae at the conclusion of each test interval for each set of three cages in the tanks or as controls are presented in Table 7 and Table 8. The tables show the number of each type of larvae that were alive and dead at the end of each exposure interval. In addition, Table 7 tables present the percent of Asian carp that were alive after these exposures. Larvae from all three cages in each tank were combined and are presented as the total for each exposure interval. Likewise, the numbers in Table 8 are the combined results from three control cages except as noted. Asian carp survival rates during the study ranged from 92 percent to 100 percent in the ballast tank cages and 89 percent to 100 percent in the control cages. The mean percent survival of Asian carp larvae during all test intervals was 97.0 percent in the test cages and 97.6 percent in the control cages. Scanned laboratory datasheets for the survival experiments are presented in Volume II, Appendices B4, B5, B7, and B8.

During Trial 1, longer exposure intervals did not significantly decrease survival. The lowest survival was after a 48-hour exposure period. Prior to pumping the water out of and then refilling each of the ballast tanks during Trial 2, the test cages were removed from the tanks and a visual assessment was made of the status of the larvae in each cage. Larval survival was always high, therefore the larvae were not removed from the cages. The cages were kept on the deck in the shade during pump out and flooding and were replaced into the ballast tanks once the tank was refilled. This allowed all caged larvae to be submerged in the tanks for about 144 hours. The average survival of Asian carp larvae was slightly lower during Trial 2 (95.7 percent) than during Trial 1 (98.3 percent), which might have been due to the longer exposure interval.

No statistical difference was found between survival of Asian carp larvae in the test versus control cages during Trial 1 ($P=0.622$). Some larvae could not be identified to species, including one live larva that was damaged while being transferred to a storage vial at the end of the cage's test interval (Table 7) and a few dead larvae that had begun to deteriorate. The percent of Asian carp that were alive in control cages after these exposures are presented in Table 8.

During Trial 2, the effect of higher densities of larvae was assessed by stocking higher numbers of larvae into two control cages exposed for 119 and 120 hours. Survival at these higher densities was still high (94-97 percent). No statistical difference was found between survival of larval Asian carp in the ballast tanks or in control cages during Trial 2 ($P=0.293$). No attempt was made to determine the density of larval Asian carp in the river locations where the test larvae were collected.

Table 7. Ballast tank cages: number of alive and dead Asian carp, non-Asian carp, and damaged larvae after varying exposure periods in cages during Trials 1 and 2. The percent alive is based on the number of larvae in the cages at the end of the exposure period. A blank cell means no larvae in that category were found.

Tank #	Fill #	Hrs Exposed	Number in cages after exposure	Asian Carp Larvae				Non-Asian Carp Larvae		Damaged Larvae	
				Total Alive	Total Dead	Grand Total	% Alive	Total Alive	Total Dead	Total Alive	Total Dead
Trial 1											
1	1	8	97	39	2	41	95.1	52	4		
2	1	24	90	24		24	100.0	57	9		
3	1	48	85	30	2	32	93.8	40	13		
4	1	72	65	26		26	100.0	26	12		1
4	2	72	80	66		66	100.0	2	3		9
3	2	94.5	76	32		32	100.0	16	18		10
2	2	117	77	39		39	100.0	28	7	1	2
1	2	132	82	36	1	37	97.3	39	6		
Trial 1 Total			**652**	**292**	**5**	**297**	**98.3**	**260**	**72**	**1**	**22**
Trial 2											
1	1	144	77	72	4	76	94.7	1			
2	1	144	68	60	5	65	92.3	2	1		
3	1	144	75	66	3	69	95.7	5	1		
4	1	144	74	70	1	71	98.6	2			1
Trial 2 Total			**294**	**268**	**13**	**281**	**95.4**	**10**	**2**	**0**	**1**
Average for Asian carp per Trial				**280**	**9**	**289**	**96.8**				

Table 8. Control Cages: Number of alive and dead Asian carp, non-Asian carp, and damaged larvae after varying exposure periods during Trials 1 and 2. The percent alive is based on the number of larvae in the cages at the end of the exposure period. A blank cell means no larvae in that category were found.

Hrs Exposed	Number in cages after exposure	Asian Carp Larvae				Non-Asian Carp Larvae		Damaged Larvae	
		Total Alive	Total Dead	Grand Total	% Alive	Total Alive	Total Dead	Total Alive	Total Dead
Trial 1									
8	90	21	2	23	91.3	47	20		
24	63	2		2	100.0	40	16		
48	49	16	2	18	88.9	31			
72	69	47		47	100.0	12	10		
72	81	39		39	100.0	35	7		
Total	**352**	**125**	**4**	**129**	**96.9**	**165**	**53**	**0**	**0**
Trial 2									
143.5	89	87	1	88	98.9	1			
143*	44	42		42	100.0	2			
120**	54	34	1	35	97.1	7	10	2	
119***	63	31	2	33	93.9	12	18		
Total	**249**	**194**	**4**	**198**	**98.0**	**22**	**28**	**2**	**0**
Average for Asian carp (both trials)		**160**	**4**	**164**	**97.6**				

*began with three cages but one lost an entire mesh panel and many larvae lost so data from this cage was not presented
**only one cage with 60 larvae at start
***only one cage with 90 larvae at start

Larvae from the tank and control cages were preserved and later were classified by stage in the laboratory. Table 9 and Table 10 provide a summary of the number of alive and dead caged Asian carp larvae separated by their stage. Asian carp placed in the cages in Trial 1 were generally younger (lower stage number) than those collected and used during the second trial for this study. During Trial 1, more larvae were stage 43, followed by stage 42, while during Trial 2, more larvae were stage 43 followed by stage 44. Based on Yi et al.'s (1988) description of larval stage and number of days post fertilization, the majority of the larvae placed in the cages on 11 June for the first cage filling for Trial 1 were estimated to be about 11-13 days of age. This aligns with field observations of initial spawning by INHS personnel.

Table 9. Ballast tank cages: summary of number of alive and dead Asian carp larvae of each stage for three test cages deployed for different exposure intervals during Trials 1 and 2. A blank cell means no larvae in that category were found.

Tank #	Fill #	Hours Exposed	Number of Asian Carp Larvae by Stage											
			Alive						Dead					
			40	41	42	43	44	45	40	41	42	43	44	45
Trial 1														
1	1	8		1	27	11					2			
2	1	24		2	12	8	2							
3	1	48	1	3	13	13					2			
4	1	72			4	22								
4	2	72		1	5	46	14							
3	2	94.5				28	4							
2	2	117			6	33								
1	2	132		3	7	26					1			
		TOTAL	**1**	**10**	**74**	**187**	**20**	**0**	**0**	**0**	**5**	**0**	**0**	**0**
Trial 2														
1	1	144			1	41	29	1				1	3	
2	1	144				41	19					5		
3	1	144				40	26				1	1	1	
4	1	144				29	41						1	
		TOTAL	**0**	**0**	**1**	**151**	**115**	**1**	**0**	**0**	**0**	**7**	**5**	**0**

Table 10. Control cages: summary of number of alive and dead Asian carp larvae of each stage for three cages deployed for different exposure intervals during Trials 1 and 2. A blank cell means no larvae in that category were found.

Hours Exposed	Number of Asian Carp Larvae by Stage											
	Alive						Dead					
	40	41	42	43	44	45	40	41	42	43	44	45
Trial 1												
8		10	10	1					2			
25		1	1									
65			5	11				1	1			
72			4	38	5							
118			7	31	1							
TOTAL	**0**	**11**	**27**	**81**	**6**	**0**	**0**	**1**	**3**	**0**	**0**	**0**
Trial 2												
143.5			1	22	63	1					1	
143*				17	22	3						
120**			2	15		16				1		
119***				10	21				1	1		
TOTAL	**0**	**0**	**3**	**65**	**106**	**20**	**0**	**0**	**1**	**2**	**1**	**0**

*only two cages
**only one cage with 60 larvae at start
***only one cage with 90 larvae at start

Although nine different taxa of non-Asian carp larvae were used in survival experiments or collected in river sampling, no attempt was made to enumerate the number of individuals of each of these taxa. A list of the non-Asian carp larvae collected during this study is presented in Table 11.

Table 11. List of non-Asian carp larvae used in the survival experiments or collected during river sampling. Note the number of each of these larvae was not determined from either type of collection.

Scientific Name	Common Name
Aplodinotus grunniens	freshwater drum
*Carassius auratus**	goldfish
Catostomidae	sucker
Cyprinidae	minnows and carps
Cyprinus carpio	common carp
Dorosoma cepedianum	gizzard shad
Ictiobus spp.	buffalo
Morone spp.	basses
Notropsis hudsonius	spottail shiner

*Larvae might be a hybrid with the common carp.

4.3 Pump Effects Experiment Results

A summary of the results from the four sets of trials conducted with two different diameter pumps and hoses is presented in Table 12. Only a few larvae (9 Asian carp plus 3 non-Asian carp) were able to survive passage through either the 2- or 3-inch pump and hose. There was no significant difference between Asian carp survival after passage through the 2-inch or the 3-inch pump. Larvae collected for the pump experiments were darkly pigmented before passing through the pump but virtually colorless when removed from the plankton net (See Figure 5). The larvae that were actively swimming immediately after passage through the pump generally survived and continued actively swimming 30 minutes after pumping. This included both Asian carp and non-Asian carp (Table 12). In contrast, those larvae that were swimming erratically after passing through the pump were not alive 30 minutes after pumping. These results indicate that although some Asian carp larvae were able to survive ballast tank pumping, the total percentage of larvae that survived the pumping was extremely low.

No count was made of the number of larvae that passed through the hose and pump for each of the pump tests. However, analysis of a photo of the larvae removed from the cod end estimated approximately 130 individual larva had been collected. For the twelve trials, only 9 Asian carp survived out of an estimated 1,560 (130 times 12) larvae sucked through the pump system for an estimated survival rate of 0.56 percent.

One approximately 3-inch long, relatively intact juvenile fish passed through the 3-inch pump and hose during one of the entrainment studies. It had been cut into two main pieces plus a somewhat mangled center portion probably from contact with the pump impeller (Figure 5).

During observations of normal operations for pumping water from ballast tanks on a barge in use on the river, it was noted that the discharge water is not generally pumped through a hose back to the river. Instead water exits the pump's discharge port with some of it potentially hitting the metal deck of the barge before free-falling directly into the river. For the present testing, the discharge water was pumped through a hose and discharged below water level into the collection net suspended in one of the barge spud wells. It is uncertain what additional mortality, if any, might have taken place if the water had not been directed through the hose but had free-fallen 3-10 feet from the pump into the river surface. Likewise it is not possible to determine the effects of impact with hose walls on the larvae.

Table 12. Summary of observations of larvae following passage through a 2-inch or 3-inch pump and hose. Observation were made immediately and 30 minutes after pumping. Test dates are in parentheses. Stage number refers to larval stage based on Chapman (2006).

Pump Test	Description of Larvae
Trial 1	
2-inch pump (6/13/11)	
Run #1	All larvae were dead when initially removed from the plankton net cod end.
Run #2	All larvae were dead when initially removed from the plankton net cod end.
Run #3	Initially, two non-Asian carp were alive and actively swimming; all other larvae were dead. These two non-Asian carp larvae were still actively swimming after 30 minutes.
Run #4	Initially, two Asian carp (stage 43) were alive and actively swimming and one Asian carp (stage 43) was alive but swimming erratically; remaining larvae were dead. After 30 minutes, the actively swimming larvae were still actively swimming but the erratically swimming larva was no longer swimming and appeared dead.
3-inch pump (6/14/11)	
Run #1	All larvae were dead when initially removed from the plankton net cod end.
Run #2	Initially, one Asian carp (stage 43) was alive and actively swimming; all other larvae were dead. After 30 minutes, the actively swimming Asian carp larvae was still actively swimming.
Run #3	Initially, two Asian carp (stage 43) were alive and actively swimming and two Asian carp (stage 43) were alive but swimming erratically; all other larvae were dead. After 30 minutes, the actively swimming larvae were still actively swimming but the erratically swimming larvae were no longer swimming and appeared dead.
Trial 2	
2-inch pump (6/19/11)	
Run #1	All larvae were dead when initially removed from the plankton net cod end.
Run #2	All larvae were dead when initially removed from the plankton net cod end.
Run #3	All larvae were dead when initially removed from the plankton net cod end.
3-inch pump (6/20/11)	
Runs #1, 2, and 3 (combined*)	Initially, four Asian carp (stage 44) and one non-Asian carp were alive and actively swimming; all other larvae were dead. After 30 minutes, the actively swimming larvae were still actively swimming.

*larvae from these pump tests were accidently combined into a single vial in the field.

4.4 Water Quality Results

Although some water quality data were collected during night hours, most water quality data were collected during daytime sampling events following the ballast tank filling and prior to tank pump-out. Illinois River temperature averaged 23.5 °C (74.3°F), with a high of 25.6 °C (78.1°F) and a low of 22.0 °C (71.6°F). Water temperatures in the ballast tanks of the experimental barge were similar to river conditions and averaged 23.4 °C (74.1°F), with a high of 26.8 °C (80.2°F) and a low of 22.3 °C (72.1°F).

Dissolved oxygen concentrations in the Illinois River averaged 5.30 mg/L, with a high of 5.51 mg/L and a low of 4.90 mg/l (Table 13; Figure 7). In contrast, ballast tank DO concentrations were much lower and more variable, averaging 2.9 mg/L. The highest DO concentration in the ballast tanks during Trials 1 and 2 was 5.51 mg/L, while the lowest DO concentration was 0.86 mg/L. Note that the single very high DO reading (6.55) in the ballast tank (Table 13) was likely an equipment or recorder error and was not included in Figure 7. In all tanks, DO decreased from concentrations near river values to as low as 0.86 mg/L over the 7 days trial periods.

Table 13. Summary of water quality measurement recorded during Trials 1 and 2, June 2011.

Trial	Tank	Date	Time (24-Hr Clock)	Water Temperature (deg C)	DO (mg/L)	Conductivity (µS/cm)	pH	Total Ammonia
1	T1	6/11/11	9:55	25.2	6.55*	628	nc	0.25
1	T2	6/11/11	9:58	24.9	4.53	550	nc	0.25
1	T3	6/11/11	10:01	25.1	4.01	644	nc	0.25
1	T4	6/11/11	10:03	25.0	4.62	614	nc	0.25
1	R	6/11/11	10:10	25.0	4.99	650	nc	0.25
1	T1	6/11/11	17:25	26.8	4.30	637	nc	0.25
1	R	6/11/11	17:25	25.6	5.20	662	nc	0.25
1	T2	6/12/11	9:30	24.2	3.42	576	nc	0.50
1	R	6/12/11	9:30	24.4	5.23	666	nc	0.25
1	T3	6/13/11	9:30	24.1	1.87	612	nc	0.50
1	R	6/13/11	9:30	23.7	4.90	666	nc	0.25
1	T4	6/14/11	9:30	23.1	2.39	589	nc	0.50
1	R	6/14/11	9:30	23.1	5.07	644	nc	0.50
1	T1	6/15/11	9:00	22.4	2.74	610	nc	0.25
1	T2	6/15/11	9:03	22.3	2.50	606	nc	0.25
1	T3	6/15/11	9:06	22.3	2.55	628	nc	0.25
1	T4	6/15/11	9:08	22.5	2.80	613	nc	0.25
1	R	6/15/11	8:50	22.0	5.50	595	nc	0.25
1	T1	6/17/11	9:20	23.6	1.62	615	nc	0.25
1	T2	6/17/11	9:07	22.5	1.68	604	nc	0.25
1	T3	6/17/11	10:48	23.4	0.95	637	nc	0.25
1	T4	6/17/11	11:40	24.1	1.54	609	nc	0.25
1	R	6/17/11	9:05	22.5	5.42	534	nc	0.25
2	T1	6/18/11	10:28	22.8	5.51	546	nc	0.50
2	T2	6/18/11	10:30	22.8	4.70	549	nc	0.50
2	T3	6/18/11	10:32	22.7	4.87	552	nc	0.50
2	T4	6/18/11	10:35	22.7	5.31	546	nc	0.25
2	R	6/18/11	10:25	22.7	5.42	537	nc	0.50
2	T2	6/19/11	10:30	23.2	2.36	nc	7.0	0.50
2	R	6/19/11	10:15	23.0	5.27	nc	7.2	0.50
2	T3	6/20/11	10:45	23.0	3.09	540	nc	0.25
2	R	6/20/11	10:15	23.5	5.51	565	nc	0.25
2	T4	6/21/11	10:45	24.3	1.14	nc	7.6	0.25
2	R	6/21/11	10:30	24.3	5.39	nc	7.6	0.25
2	T1	6/24/11	11:45	22.6	1.14	nc	7.6	0.25
2	T2	6/24/11	9:45	22.2	1.23	nc	7.6	0.25
2	T3	6/24/11	9:55	22.4	0.86	nc	7.6	0.25
2	T4	6/24/11	11:25	22.6	1.15	nc	7.6	0.25
2	R	6/24/11	9:35	22.4	5.27	nc	7.6	0.50

T1, T2, T3, and T4 correspond to ballast tank numbers 1-4, respectively

R = River C = Centigrade

mg/L = milligrams per liter µS/cm = MicroSiemens per centimeter

nc = not collected *possible equipment error; data not included in Figure 7

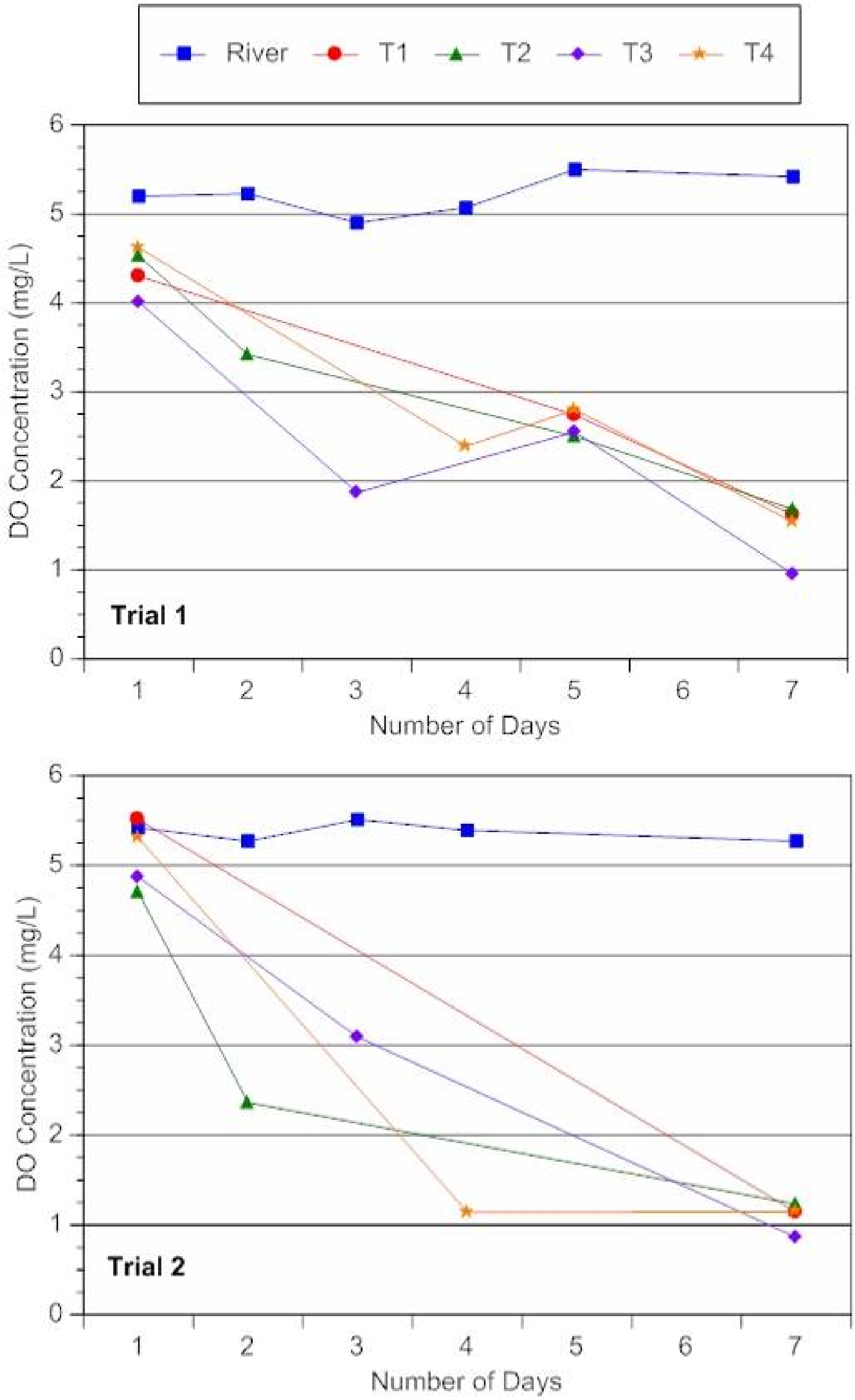


Figure 7. DO concentration in Illinois River and barge ballast tanks during Trial 1 (top) and Trial 2 (bottom). Note: T# refers to the ballast tank number.

Specific conductance (conductivity) is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids (such as salt) in the water (U.S. Geological Survey (USGS) website, accessed September 2011). Specific conductance is an important water quality measurement because it provides an idea of the amount of dissolved material in the water. Conductivity in the Illinois River averaged 613 micro-Siemens per centimeter (µS/cm), with a high of 666 µS/cm and a low of 534 µS/cm (Table 13). Conductivity in the ballast tanks during Trials 1 and 2 were similar to river conditions and averaged 595 µS/cm, with a high of 644 µS/cm and a low of 540 µS/cm.

Due to equipment problems, pH was only measured during Trial 2. pH values in the Illinois River averaged 7.5, with a high of 7.6 and low of 7.2 (Table 13). pH values in the ballast tanks closely tracked natural conditions in the Illinois river, with an average of 7.5, high of 7.6, and low of 7.0.

TAN values in the Illinois River and barge ballast tanks were steady, ranging between 0.25 and 0.50 mg/L. No differences in ammonia concentration were observed between river and ballast tanks samples.

5 SURVIVABILITY TEST DISCUSSION/CONCLUSIONS

This study was conducted to determine if Asian carp eggs and larvae could 1) be entrained into barge ballast tanks, 2) survive while in these tanks, and 3) survive a single passage through a pump. The Study Plan (Test Plan in Volume II, Appendix A) proposed experiments be conducted first in the river channel using Asian carp eggs and young larvae by keeping the barge positioned within the highest concentrations of these individuals during flooding of the tanks while the larvae and possibly new eggs move down the river with the water current. After completing work in the river channel, the plan called for testing with older larvae from the same cohort while the experimental barge was positioned in quieter, slower moving waters. Because initial plankton tows in the river channel showed that no eggs and low larval concentration were available, testing with the eggs and younger larvae in the study could not take place as planned. This was due primarily to a major Asian carp spawn occurring prior to the initiation of these studies and apparently no subsequent spawning taking place in the area. Therefore, no Asian carp eggs or larvae younger than about 11-13 days were available during these tests. By this stage, the larvae had moved out of the main channel towards quieter water. Therefore the experiments were conducted with the barge moored just outside the main channel.

Spawning of Asian carp is known to take place after the river water temperature reaches 14-18 °C along with an increasing river flow (Papoulias et al., 2006; Jennings, 1988; DeGrandchamp et al., 2007; Lohmeyer & Garvey, 2009; and Irons et al., 2011). Asian carp have also been reported to spawn from as early as March until July (Papoulias et al., 2006) when river temperatures and flow increase, typically from spring and early summer rains. Figure 8 presents the river gage height of the Illinois River at Kingston Mines (about 7.4 miles downriver from Pekin) and Copperas Creek (approximately 16 river miles south of Pekin) from early May through late August 2011. It also shows the 5-year average gage height for these locations between 2005 and 2010. As the figure shows, the Illinois River was in flood-like conditions during the time of this study, with gage heights nearly 6-8 feet over the 5-year (2005-2010) average. The study (shaded area) started shortly after the peak flow in late May. Based on the stage and assumed age (based on Yi et al., 1988) of the Asian carp collected during this study, it was estimated that these larvae were spawned during the period of increasing river (gage) height from May 25 until about June 3.

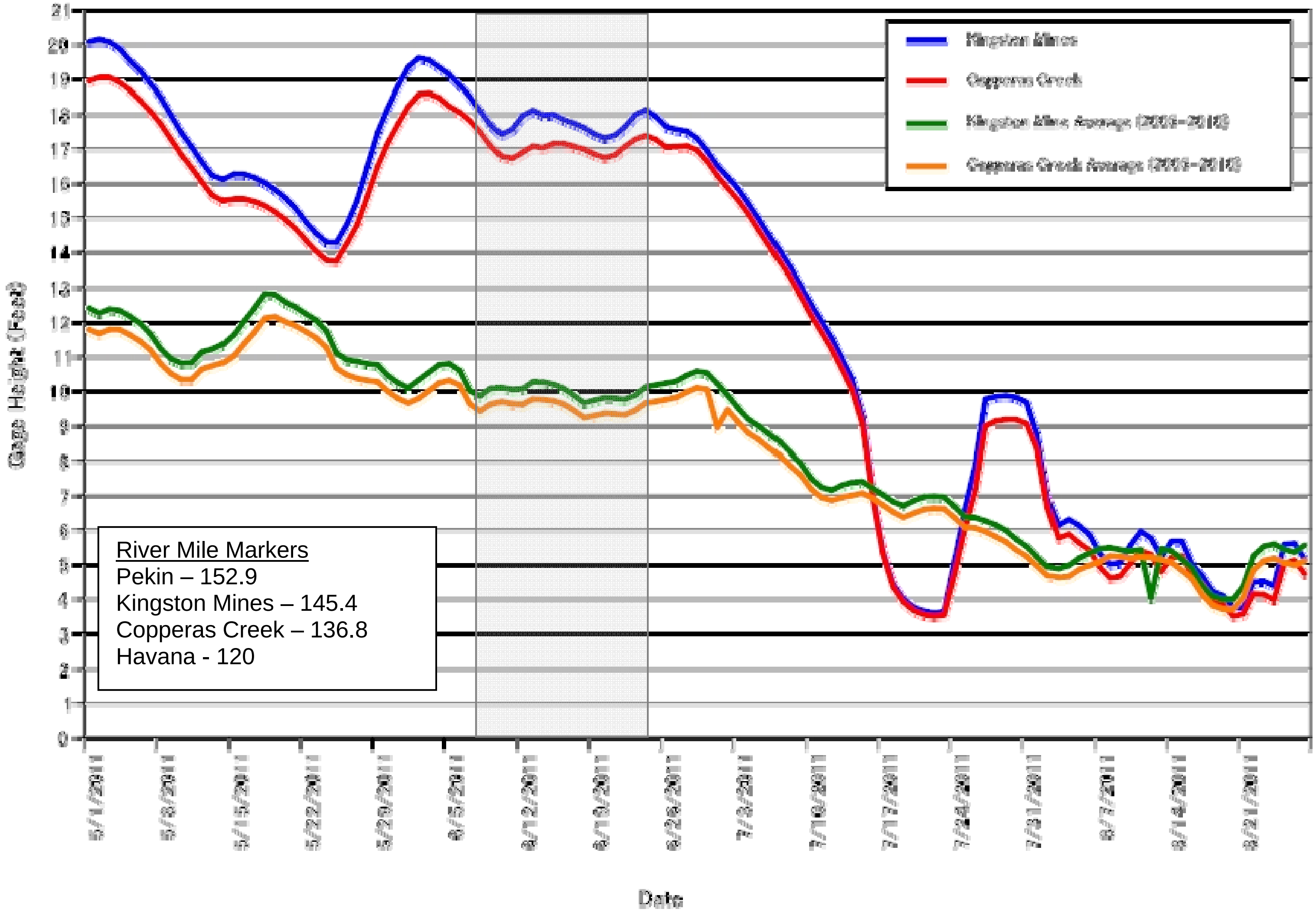


Figure 8. Illinois River Gage Height at Kingston Mines and Copperas Creek. The shaded area represents the time period that this study was conducted. The average river gage height from 2005-2010 for each location is also provided. Data provided by U.S. Geological Survey, WRD, Urbana, IL.

Papoulias et al. (2006) also stated that Asian carp might be able to spawn more than one time per season. Alison Coulter (pers. comm., September 2011; Coulter & Goforth, 2011) stated that during 2011 they found Asian carp eggs in the Wabash River from May through the end of July even though the river flow continued to decrease during this period. They confirmed their visual field egg identifications with DNA analysis. Although there were small increases in the Illinois River flow during this study, secondary spawning did not appear to happen in the La Grange Reach as no eggs or younger larvae were found during any of the collections.

During the entrainment portion of these studies, it was determined that larvae of a variety of taxa could be entrained into the ballast tanks through the experimental valves installed in the tanks. The 3-inch valve penetrations were intended to simulate a break in a tank seam or a hole in the barge hull. Discussions with barge operators and Coast Guard personnel indicated that the 3-inch opening was considerably larger than most cracks occurring during normal barge operations. A hole as large as 3 inches would fill a tank to about 50 inches in approximately 90 minutes and would probably be noticed by the crew as a change in handling or during inspections. However, if the penetrations do represent naturally occurring breaks in barge walls, then fish larvae could be entrained into ballast tanks. It is expected that if eggs had been available and had been entrained from the swift moving current, they would settle to the bottom of the quiet water in the tanks and survival would be low. Thus there is some potential, though very slight, that eggs or larvae could be inadvertently moved across the barriers during normal barge operations in a damaged barge. It is important to note that this would occur only during the spawning season (late spring – summer).

The pump effects experiments showed that if Asian carp larvae were entrained and then pumped out, only a very small percentage of them (0.56 percent) could survive being pumped through either a 2-inch or 3-inch pump. If tanks were actively ballasted (i.e., pumped) and then deballasted, it is highly unlikely that larvae could survive two passages through a pump. This could be readily tested by using the methods of the pump experiments of this study and collecting the pumped water and larvae in a portable tank after the first pass. The larvae and tank water could be pumped once more and collected in a submerged plankton net. Active swimming of larvae for more than 30 minutes would indicate survival potential. A barge or barge-size tank would not be necessary since the volume of water pumped would be small. During the pump effects testing, a hose was used to pump ballast water from the tanks directly into a suspended plankton net. This is different from normal barge operations when no hose is used on the pump's discharge. These studies could not determine whether Asian carp larvae that survived passage through a pump would then survive free fall into the river if a discharge hose were not used.

Kolar et al. (2007) and King et al. (2010) stated that bighead and silver carp have hybridized in the wild and produced fertile offspring. Blake Ruebush (pers. comm., June 2011, Illinois River Biological Station, Havana, IL) stated that many hybrids of bighead and silver carp have been collected during the Long Term Resources Monitoring Program (LTRMP) in the La Grange Reach of the Illinois River. All individuals referred to in this report as larval Asian carp visually appeared to be silver carp based on figures presented in Yi et al. (1988) and Chapman & George (2011), but some might have been hybrids that showed the same pigmentation patterns characteristic of silver carp.

The original survival study plan (See Volume II. Appendix A) called for fish in early developmental stages to be suspended in cages in the ballast tanks to document whether larval Asian carp could survive for a maximum of 108 hours in a ballast tank. Based on high (98%) larval survival in Trial 1 (up to 132 hours exposure), all Trial 2 exposure intervals were increased to 144 hours for all tanks. Asian carp larvae in

Trial 2 also had a high (95.7%) survival rate suggesting that entrained larvae could survive in tanks for at least 6 days. The average Asian carp (stages 40-45) survival in the control cages during both trials was also high (97.7%).

Water quality parameters measured during the trials showed that Asian carp larvae were able to withstand a wide range of the measured water quality parameters, including temperature and DO. The most variable water quality parameter was DO, which decreased to a level of 0.86 mg/L inside one of the ballast tanks but was not low enough to substantially affect survival. It has been reported that grass, bighead, and silver carp can tolerate oxygen levels as low as 0.5 mg/l (Oregon Sea Grant website, accessed August 2011). In addition, Jennings (1988) reported that juvenile bighead carp (average weight = 73 mg) survived DO concentrations of 0.33 mg/L, while smaller individuals (average weight = 23 mg) survived DO concentrations of about 0.40 mg/L. Although the current study used younger individuals, it appears that Asian carp larvae collected in the Illinois River are also able to tolerate low DO levels. Because the DO concentrations in ballast tanks vary, even on a single barge, the actual tolerance level of Asian carp egg and larvae for low DO is not necessary for assessing survival during normal barge operations.

Other investigations related to the potential transport of Asian carp early life stages include surveys to determine the amount of water carried by barges and towboats. A 2010 survey of 969 ballast tanks on 132 barges and 14 towboats found measurable water in only 5.2 percent (50 tanks) of tanks. With the exception of three tanks with depths over 36 inches, the average depth of those tanks with water was 7.2 inches (Heilprin et al, 2011). A similar survey was conducted for barges operating in the immediate vicinity of the USACE dispersal barriers in 2012. Tanks on 39 barges and 2 towboats were checked with only 6 percent of the tanks containing measurable water. Heilprin et al (2011, updated October 2012 (See Sections 7-12 of this report) provide a description of barges and the standard operating procedures used by towboats operators. Operators interviewed during the 2012 survey also indicated they used these procedures. The ballasting procedures call for the use of portable pumps on the rare occasions when ballasting is necessary.

A final question is whether Asian carp eggs or larvae that were present in barge or towboat ballast tanks could survive passage across the USACE electrical barriers. When a barge or towboat passes through the electrical field generated by the dispersal barriers, the hull acts as a Faraday cage to prevent any electrical potential from crossing into a partially filled tank (Dr. N. Yankielun, pers. comm., October 2012). Essentially the electrical currents in the canal water are conducted along the highly conductive metal hull without creating a potential difference anywhere along that hull. Since there is no potential difference, the current cannot pass into the tanks. Thus the hull effectively insolates the ballast water from the electrical field, so any eggs or larvae present in the ballast water would not be affected by transiting across the barriers.

In summary, this study showed that Asian carp larvae could potentially be entrained into ballast tanks through hull cracks and can survive the conditions in these tanks for up to 144 hours. But, if these larvae are then pumped out of the tanks using standard commercial methods, their survival rate is extremely low (less than 1 percent). Survival following intentional ballasting and deballasting (i.e., two passages through a pump) is even less likely. Finally, it is important to note that the potential transport of eggs and larvae would occur only during the spawning season (late spring – summer). Based on the results of this study, it is concluded that the risk of transport of eggs or viable larvae through barge ballast tanks is very low. While additional research of this matter may be undertaken, it is not warranted at this time.

6 WATER TRANSPORT DURING NORMAL OPERATIONS OF TOWBOATS AND BARGES IN THE ILLINOIS RIVER

The United States Coast Guard (USCG) is tasked by the National Aquatic Nuisance Prevention and Control Act (1990) and National Invasive Species Act (1996) with eliminating as much as possible the introduction of non-indigenous species (NIS) via ballast water. Under the Great Lakes Restoration Initiative (GLRI) Act, the Coast Guard has been funded by the U.S. Environmental Protection Agency (EPA) to investigate the potential for towboats and barges to transport Asian carp and other species within the Chicago Shipping and Sanitary Canal (CSSC) and across the electrical dispersal barrier constructed by the U. S. Army Corps of Engineers (USACE) as a preventive measure to keep fish from migrating into and out of the Great Lakes.

Ballast tanks and voids of towboats and barges were initially investigated in August 2010 to determine the volume of water being transported across the U. S. Army Corps of Engineers' electric dispersal barriers in the Chicago Sanitary and Ship Canal. A second survey of ballast tanks of barges and towboats operating in the immediate vicinity of the Barriers was conducted in July – August 2012. Results from those surveys were initially presented in the report "Water Transport During Normal Operations of Towboats and Barges in the Illinois River" updated in October 2012. The main body of that report is presented here as a supplement to "Survivability of Asian Carp in Barge tanks in the Illinois River". Data sheets from this effort are available in Volume II, Appendixes C and D, of this report.

Results of a second survey conducted on barges operating around and across the barrier are included as an update in Section 12 of this report.

7 SURVEY METHODS

Visual inspections of barge and towboat ballast tanks and voids (hereafter called ballast tanks) were conducted along the CSSC in the vicinity of Lemont, IL (Figure 9) between 18 and 26 August 2010. Barge companies in this area were contacted for access to available barges and towboats. In addition to barges in the Lemont, Channahon, and Romeoville areas, barges owned and operated by Kindra Lake Towing (KLT) in Chicago were also inspected. KLT occasionally moves barges/towboats through the Lemont area. Table 14 indicates the locations of vessels inspected during this study.

Figure 9. Barge and towboat ballast tank sampling locations (red dots) along CSSC (red line), August 2010.

Table 14. Vessel company and location of barge and towboat sampling, August 2010.

Vessel Company	Location
American River Transportation Company (ARTCO)	ARTCO Shipyard (Lemont)
Illinois Marine Towing (IMT)	Channahon, IL
IMT	Heritage Storage Yard
IMT	IMT (Channahon)
IMT	Lemont, IL
American Commercial Lines	Lemont, IL
ARTCO	Lemont, IL
ARTCO	Morris, IL
ARTCO	Ottawa, IL
ARTCO	Power Plant (Romeoville, IL)
Hanson Material Services	Romeoville, IL
Hanson Material Services	Romeoville/Loading area
ARTCO	Seneca, IL
Kindra Lake Towing	South Chicago, IL
Kindra Lake Towing	Walsh Slip (Chicago, IL)

Ballast tanks from barges, either rafted along the river bank or at the operator's shipyards, were visually inspected for the presence of condensation and/or measureable amounts of water. Three types of barges were sampled: tank barges, deck barges, and hopper barges. The number of ballast tanks per barge ranged from 6 to 18, depending on the type of barge. Tank barges had separate port and starboard wing tanks with a bow and stern tank, while deck barges had separate port and starboard tanks separated by a bulkhead at the keel creating separate port/starboard ballast tanks. Several of the deck barges were found to have port, center, and starboard tanks per section resulting in a high number of ballast tanks present. Ballast tanks ran side to side on hopper barges.

Data for all barges and towboats inspected was recorded on data sheets in the field. Data included: barge type, number of ballast tanks, location of ballast tank inspected, hatch type and condition, condensation presence, and whether hatch was sealed. Water depth was determined using a weighted measuring tape that was lowered into the ballast tank. Depth was determined from deck level by measuring the point where the weight was observed hitting the surface of the water to the point the weight reached bottom of the tank. If the water level in an individual ballast tank was measurable (defined as greater than or equal to 2 inches, as determined with a tape measure), a Yellow Springs Instrument (YSI) Model 550A Temperature-Dissolved Oxygen probe was then used to record temperature and dissolved oxygen (DO).

Information regarding the number of barges and towboats passing through the CSSC annually (2007 data) was also obtained from the USACE and is presented below in Section 8.4. This information does not necessarily reflect the actual number of vessels transiting over the dispersal barrier as some local vessels cross the barrier but do not transit the full CSSC.

8 SURVEY RESULTS

8.1 Water Depth

8.1.1 Barges

Between August 16 and 25, 2010 a total of 969 individual ballast tanks were inspected on 132 barges and 14 towboats. Data obtained during the survey is described in Appendix E and provided as a table in Volume II. The photographs in Appendix C show several barge types, hatch arrangements, and clearances under bridges. Barges sampled included 19 deck barges, 99 hopper barges, and 14 tank barges. Of the 969 ballast tanks inspected, 50 ballast tanks (5.2 percent), all of which were on barges, had measurable levels of water. Water depths in these ballast tanks ranged from a low of 2 inches to a high of 117 inches (Figure 10). Water depth in deck barges ranged between 4.5 – 24 inches, while hopper barges ranged between 2 – 117 inches (Figure 10). No measurable water was found on tank barges.

For all barges with measurable water in their ballast tanks, overall average water depth was just over 11.0 inches. When three hopper barge tanks with depths of 42, 76, and 117 inches are excluded, water depth averaged 7.2 inches. No information was available to determine why these three tanks contained more water than the remaining 47 tanks with measurable water.

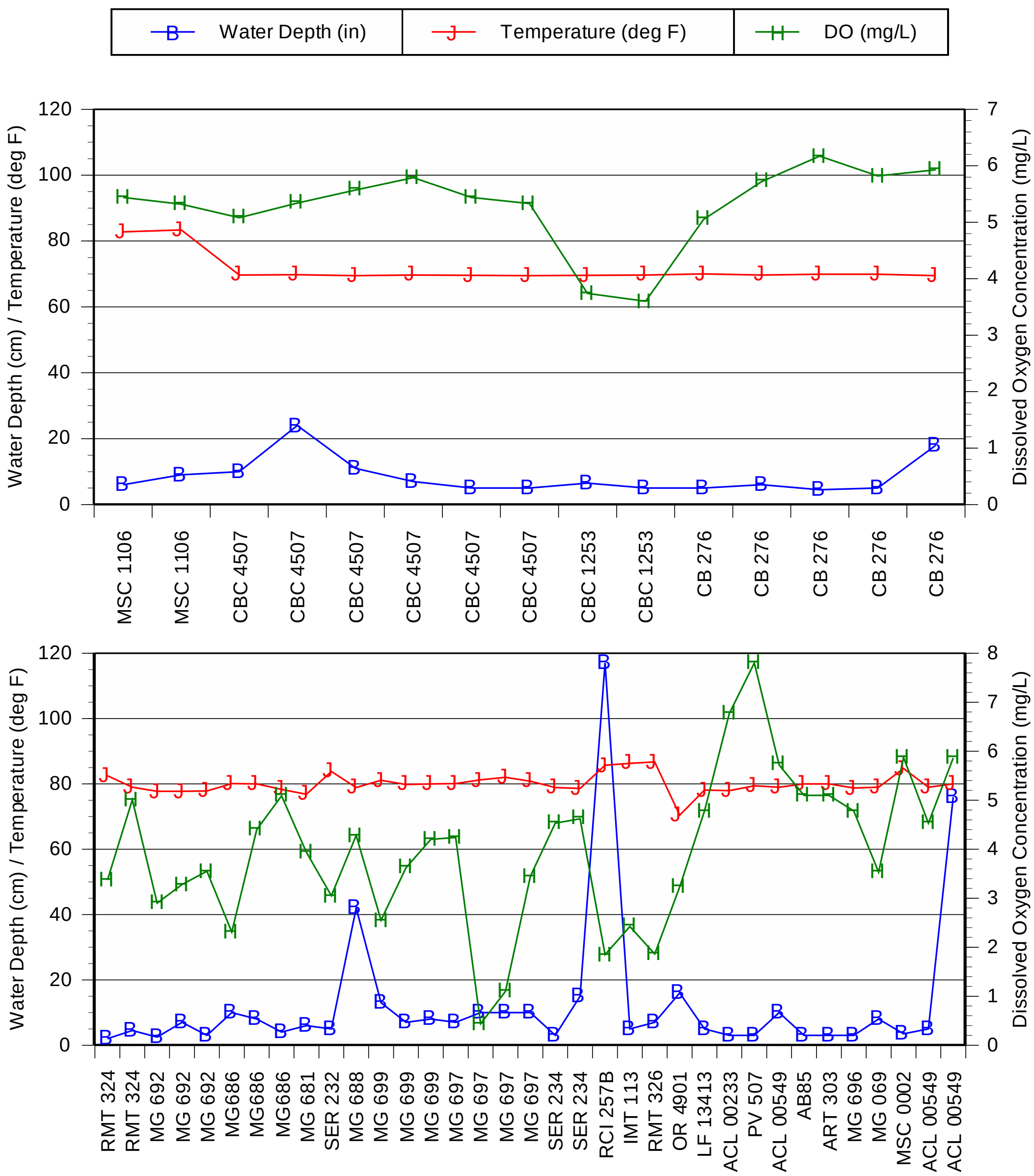


Figure 10. Water depth (inches), water temperature (°F), and DO concentration (mg/L) for deck barge (top) and hopper barge (bottom) ballast tanks sampled in August 2010.

8.1.2 Towboats

Of the 14 towboats inspected in August 2010, only four had measurable amounts of water in their ballast tanks. Water depths for towboats ranged from a low of 18 inches to a high of 72 inches (Figure 11). Average water depth for towboats was 50.5 inches. No information regarding the ballasting of the towboats was available. Towboat operators indicated that ballasting is not routinely conducted.

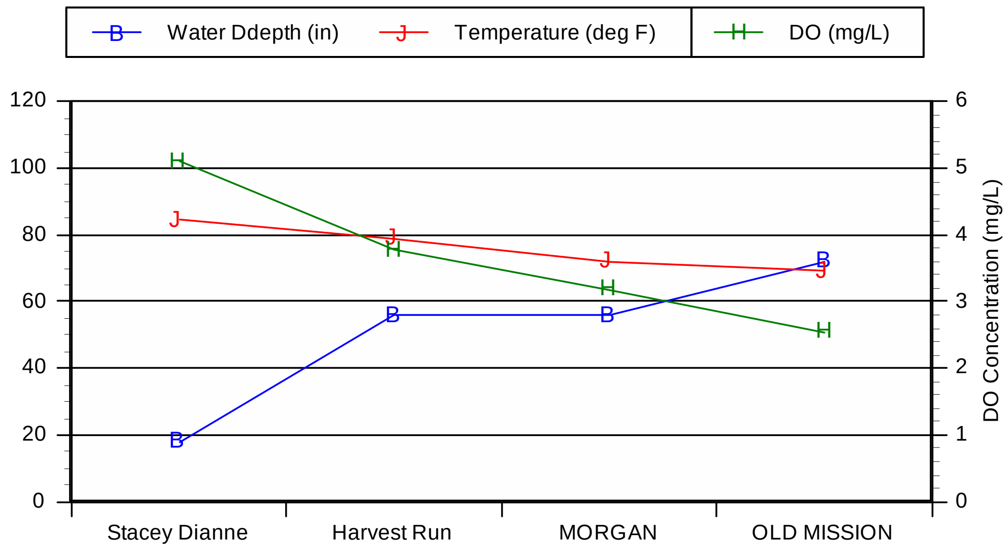


Figure 11. Water depth (inches), water temperature (°F), and DO concentration (mg/L) for towboat ballast tanks sampled in August 2010.

8.2 Water Temperature

8.2.1 Barges

Water temperature (°F) was recorded for the 50 barge ballast tanks that contained measurable amounts of water and ranged between 69.5 - 86.7 °F. Water temperature was relatively consistent in most ballast tanks. For deck barges, water temperature ranged between 69.5 - 83.4 °F, with an average of 71.5 °F (Figure 10). Water temperatures for hopper barges ranged between 70.4 - 86.7 °F (Figure). Average water temperature in hopper barges was 80.0 °F. For all hopper and deck barges combined, average water temperature was 77.4 °F. As mentioned above, there was no measurable water in tank barges.

8.2.2 Towboats

Water temperature in towboat ballast tanks ranged between 69.2 - 84.5 °F (Figure) with higher temperatures found in those tanks with less water. Similarly, the ballast tank with the most water (72 inches) had the lowest temperature. Average water temperature in towboat ballast tanks was 76.2 °F.

8.2.3 Ambient Conditions

Ambient water temperature was measured at approximately 1 meter depth alongside the barges twice during the survey. Water temperature at the IMT Channahon facility on August 17 was 86.3 °F. Water temperature of 70.0 °F was recorded at the Kindra Lake Towing facility near Chicago on August 19. In general, one can expect higher water temperatures in summer in the Lemont area (average = 80 °F) than in those areas closer to Lake Michigan (average = 71.5 °F).

8.3 Dissolved Oxygen (DO)

8.3.1 Barges

DO concentrations in the water of the 50 ballast tanks ranged between 0.44 - 7.80 mg/L and were highly variable. For deck barges, DO ranged between 3.60 - 6.17 mg/L, with an average of 5.29 mg/L (Figure). For hopper barges DO concentrations ranged between 0.44 - 7.80 mg/L. Average DO in hopper barges was 3.98 mg/L. No apparent trends in DO concentration were observed between barges with more water compared to those with less water in their ballast tanks. Tank barges did not contain sufficient water to measure DO. This is not unexpected since tank barges are inspected by Coast Guard after collisions, elisions, etc and, if leaks are found, are removed from service until repairs are made.

8.3.2 Towboats

DO concentrations in ballast water from towboats ranged from 2.54 - 5.10 mg/L (Figure 10). Average DO in towboats was 3.65 mg/L.

8.3.3 Ambient Conditions

As was done with water temperature, ambient DO was also measured twice during the survey at approximately 1 meter depth alongside the barge. DO at the IMT Channahon facility on August 17 was 2.76 mg/L, while DO at the Kindra Lake Towing facility near Chicago on August 19 was 8.46 mg/L. This large difference could potentially be an artifact of sampling since the KLT sample was taken in the morning and the IMT sample was recorded in the afternoon.

8.4 Vessel Traffic

Annual vessel traffic across the electric fish barrier was obtained from USACE for 2007 and is presented in Figure 12. A total of 5,792 vessels crossed the electric fish barrier in Romeoville in 2007, including 2,246 liquid hazardous cargo barges, 2,650 commercial vessels, and 896 recreational vessels. A variety of barge types cross the electric barrier each year, including hopper, tank, and deck barges similar to those inspected in this study.

Figure 12. Annual vessel traffic across the electric fish barrier in 2007 (Source USACE/OMNI).

9 SURVEY DISCUSSION/CONCLUSIONS

It is widely accepted that water temperature, flow conditions, food, and predation are important factors influencing larval survival and growth. Little information exists on water quality tolerances such as temperature and DO for Asian carp, especially the early stages of development such as eggs and larvae. Most of the existing literature focuses on common carp (*Cyprinus carpio L)* and grass carp (*Ctenopharyngodon idella*), which is also an Asian carp species.

Opuszynski et al. (1989) found the upper lethal temperature (ULT) for silver carp was 43.5 - 46.5 °C (110-116 °F) and also found no significant differences in survival of fish reared at lower and higher temperatures when proper food was used. Golovanov and Smirnov (2007) used the chronic lethal impact method with a water heating rate of 1 °C/day or 0.04 °C/h (1.8 °F/day or 0.07 °F/hr) to determine ULT for common carp. At 1 °C/day, (1.8 °F/day) fish successfully acclimated to temperature increases.

Silver carp are also quite tolerant to low water temperatures and have been reported to feed at water temperatures of 10 to 19°C (50-66 °F) in Israel (Leventer 1979, cited in Wrigley et al. 1988). When the water temperature dropped below 15°C (59 °F), the appetite of silver carp was reduced, and below 8-10°C (46-50 °F), feeding almost ceased (FAO 1980; Tripathi 1989). At water temperatures below 18°C (64 °F) or higher than 31°C (88 °F), rates of ovulation and hatching of silver carp have been reported to be low with high rates of abnormal embryonic development (FAO 1980).

Grass carp tolerate a wide range of water temperatures from 0 - 33 °C (32 - 91 °F), with temperatures greater than 38 °C (100 °F) being lethal for adults (Fedorenko and Fraser, 1978). ULT for grass carp fry ranges from 33 - 41 °C (91 - 106 °F), and for yearlings the range is 35 - 36 °C (95-97 °F), depending on season (Chilton and Muoneke, 1992). Grass carp also appear to tolerate moderately rapid changes in temperature. Shireman and Smith (1983) found fingerlings (5 - 7 cm or 2 - 3 inches) could tolerate temperature increases from 4 - 22 °C (39 - 72 °F) over a relatively short amount of time (~2 - 3 hours).

Bighead carp can tolerate extremes in water temperature, from cold temperate to tropical (Kolar, et al. 2007). In their native range in China, bighead carp can spawn at temperatures as low as 18°C (64 °F) in the Han River (Chunsheng, et al. 1980). Negonovskaya (1980) reported bighead carp fingerlings feeding activity continued at 10 °C (50 °F) in lakes in Russia's Pskov Region, but most active feeding activity occurs at 20 - 22 °C (68 - 72 °F). Experiments with thermal preferences conducted in Texas (Bettoli, et al. 1985) indicated that young bighead carp (56 - 73 mm) acclimated to temperatures at 23.0 ºC (73 °F), selected a mean temperature of 25.4 ºC (78 °F), and had their critical thermal maximum at 38.8 ºC (102 °F). Although little information exists on lower water temperature lethal limits for this species, the presence of bighead carp in rivers and reservoirs in the Manchurian Plain that remain frozen 4 to 6 months out of the year suggests that the species is quite cold tolerant.

The vast majority of ballast tanks sampled (919 of 969; 95 percent) were dry; water in the ballast tanks sampled in the current study had little variability in temperature and ranged between approximately 70 - 87 °F (21 - 30 °C) which was similar to the two ambient river temperatures measured. Comparison of temperature ranges in the barge ballast tanks with values found in the literature suggests that Asian carp larvae could potentially tolerate the range of temperatures found in the tanks and probably the fairly rapid changes in temperature in both the barge and towboat ballast tanks.

Information on carp (adult, juvenile, or larvae) tolerances to DO is extremely limited. Cudmore and Mandrak (2004) found DO levels below 3 mg/L can cause stress in grass carp. Shireman and Smith (1983) reported that the same species could tolerate oxygen concentrations as low as 0.2 mg/L and fingerlings survived in DO levels between 0.41 - 28 mg/L. Other studies have also found that young grass carp are more susceptible to low oxygen concentrations than older fishes and that vulnerability varies with season (Chilton and Muoneke, 1992) with less tolerance for lower DO concentrations in colder (winter) water compared to more tolerance for lower DO concentrations in summer, when the waters are warmer (Versar, Inc., 1999).

DO concentrations in barge and towboat ballast tanks measured in this study ranged between 0.44 - 7.80 mg/L. This is well within the range of tolerances for other carp species and is likely within the range for bighead and silver carp. This suggests that water quality conditions with ballast tanks, although not optimal, could support early life stages of Asian carp.

Of the 969 tanks and voids inspected during August 2010, 50 barge tanks (5.2 percent) had measurable levels of water. In April 2010, a visual ballast tank inspection was conducted (no water quality sampling) and found that of the 127 ballast tanks inspected, only 4 tanks (3.1 percent) had greater than approximately 3 inches of water (visual inspection). A worst case scenario can be constructed by assuming that no barge has more than one ballast tank with measurable water (2 inches or more) and that the roughly 5 percent rate for tanks with measurable water is representative. Applying this 5 percent rate to the USACE 2007 data for the number of cargo vessels passing through the electric barrier (see Section 8.4), it can be estimated that approximately 112 barges with water in their ballast tanks could potentially pass through the electric barrier each year.

10 SURVEY RECOMMENDATIONS

Information collected during this study is useful in understanding volumes and water quality conditions in barge and towboat ballast tanks and voids and is useful as a baseline for the development of additional studies to test whether ballast tanks are a viable vector for Asian carp transport. Although the existing literature is sparse on the tolerances of Asian carp, information on other species of carp suggests these species would be able to tolerate a wide range of water quality conditions, including high water temperature and low DO concentrations. It must be noted that the current study only provides a "snapshot" of what ballast water conditions are during a summer event and that no barge history was recorded for those tanks that contained substantial amounts of water. It is possible that those barges had leaks and had remained rafted in place rather than being kept in use. Additional sampling events and barge information during other time periods may be warranted to look at possible seasonal variability within barge and towboat ballast tanks and voids.

Larval fish survivability within a barge or towboat ballast tank has never been studied. In determining whether ballast tanks are to be considered a possible vector for larval transport, the next step should be to determine whether early developmental stages of Asian carp (eggs and larvae) are able to tolerate/survive in these tanks. In addition, other studies should be performed to help evaluate transport mechanisms for Asian carp. These should include sampling barge tanks for different life stages of Asian carp, evaluating the effects that tank leakage has on the potential transport of Asian carp, and investigating the effect of deliberate ballasting via pumps on early life stages.

11 UPDATE FROM 2012 SURVEY OF LOCAL BARGES

The November 2010 Towboat/Barge Sampling Study focused on large barge companies that move hundreds of barges across the electric dispersal barrier. The July 2012 survey addressed localized barges and towboats that regularly work within 10 miles of and regularly transit over the USACE dispersal barrier. The study examined the condition and amount of measurable water found in ballast tanks of those local vessels.

Initially, the intent was to shift from the large barge companies previously surveyed to local/small barge providers. Research revealed there are no small companies that move barges within the dispersal barrier focus area, but a few of the large companies previously visited do designate some of their barges and tow boats to work in the local barrier area. Therefore the inspection team focused on these local groups of barges operating in the immediate vicinity of the dispersal barrier.

11.1 Methods Used in 2012 Survey

The methods used in the previous survey were again used in this survey. Locally operating barge companies provided towboat transportation for the inspection team to locally operating barges along the CSSC in the vicinity of Lemont and Romeoville, IL (Table 15) between 30 July and 1 August 2012. Barges were located near the USACE electrical dispersal barrier indicated in Figure 9.

Table 15. Vessel Company and Location of Barge and Towboat Sampled, July-August 2012.

Vessel Company	Location
IMT	Lemont, IL
ARTCO	Romeoville, IL (Power Plant)
Midwest Generation, LLC	Romeoville, IL (Power Plant)
Hanson Material Services	Romeoville, IL (Loading area)

Ballast tanks of barges either rafted along the river bank or at the operator's facilities on the CSSC were visually inspected for the presence of condensation and/or measureable amounts of water. Hopper barges were the only type of barges available during the inspections. Cargos were either construction materials (sand, gravel) or coal. The barges inspected were double-hull construction with single or double-raked ends. On most of the barges ballast tanks run from side-to-side without obstructions. Eleven older barges had a bulkhead in the center which separated port and starboard tanks. Barges additionally had a stern tank, bow tank, or both which ran from side to side. The number of tanks per barge ranged from 6 to 13 depending on the construction, although 70 percent had 10 tanks each.

Data for all barges and towboats inspected was recorded on data sheets in the field, which were then transferred to the tables included in Volume II, Appendix E. Barge location, barge type, number of tanks, location of tank inspected, condensation/water presence, and if hatch was found sealed were recorded for each barge inspected. If water was present in a tank, a sounding device (tape measure/sounding stick/string and weight) was used to determine if the water level was greater than 4 inches. Four inches of water allowed use of a Yellow Springs Instrument (YSI) Model 550A Temperature-Dissolved Oxygen probe to measure temperature and dissolved oxygen (DO). Ambient river temperature and DO in the vicinity of the barges were also recorded twice a day for a baseline comparison. Photographs of tanks and barge configurations seen during the survey are provided in Appendix D.

11.2 Results of 2012 Survey

Only two towboats were available for transportation and inspection. Both crews reported that they rarely adjust the ballast water in their tanks. A crewman from the towboat STACY DIANE (Hanson Material Services) reported the ballast water in the towboat stern tank was at least 4-6 months old.

Of the 39 barges inspected, the majority were in generally good condition. Most were empty and all were rafted along various portions of the CSSC. Barge ballast tanks were typically accessible through a hinged manhole type hatch (Figure 13) with a rubber seal and edge hatch dogs to latch securely. All hatches were closed but none were found latched. A few barges used a round removable tank manhole cover (Figure 14). A small number of these covers were found loosely sitting over the access hole and not mated tightly closed.

Figure 13. Ballast tank hinged manhole hatch.

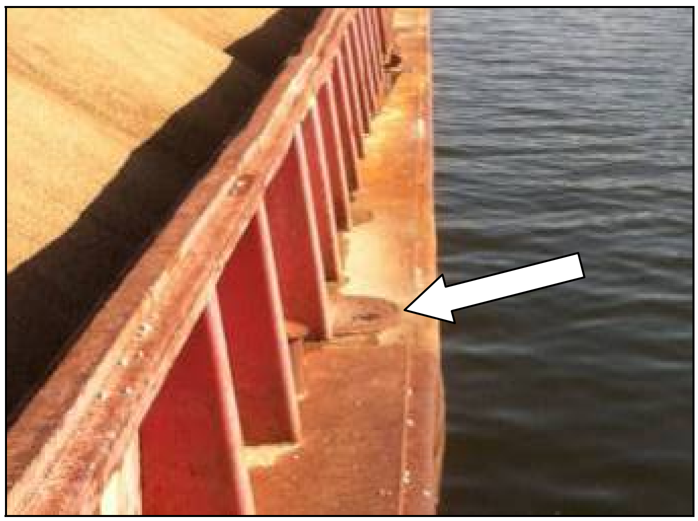


Figure 14. Ballast tank removable manhole cover.

Some barges also incorporated 7-inch tank access tubes (Figure 15). This type of access tube was not reported in the 2010 survey and appeared to be on older barges. These tubes are covered with a hinged cap and are used to conveniently insert pump hoses when needed. The barge crewmen stated these tubes were used as a primary access to the tank when sounding or when pumping into/out of the tanks. Because the crewmen prefer to regularly use these smaller tank accesses, many of the associated larger tank hatch covers were rusted shut from lack of use. The inspection team was able to evaluate the tank water level and perform measurements using these tube accesses.

Figure 15. Ballast tank access tubes.

Barge ballast tanks were approximately 10 feet deep. Typically only a small amount of water was found in the tank and the bottom 4-inch cross-members were usually visible (Figure 16).

Figure 16. Typical tank inspection view.

11.2.1 Water Depth in Tanks from 2012 Survey

A total of 288 barge tanks were inspected; however, three hatches were not accessible due to covers that could not be opened for inspection resulting in 285 barge tanks evaluated for water content**.**

As shown in Table 16, results of the barge inspection indicated 44 percent of all tanks were completely dry and 50 percent had only a trace amount of water. Only 6 percent of the tanks held water above the 4-inch measurable threshold that allowed the use of the YSI meter.

Table 16. Barge Tank Water Content, July-August 2012.

	Number of Tanks	Percent of Total Tanks
Dry	126	44%
Less than 4"	141	50%
Equal to or greater than 4"	18	6%
Total	**285**	**100%**

Of the two towboats accessible to inspect, both had a bow and stern tank. The STACY DIANE (Hanson Material Services) had an empty bow tank and held 32 inches of ballast water in the stern tank. The WINDY CITY (Illinois Marine Towing) had an empty stern tank and held 24 inches of ballast water in the bow tank.

11.2.2 Water Temperatures and Dissolved Oxygen from 2012 Survey

Water temperature in barge and towboat tanks ranged between 81.1 - 86 °F. DO in tanks ranged between 2.85 - 7.07 milligram per liter (mg/L) (Figure 17). Tank water in the STACY DIANE was 90 °F and had a DO reading of 3.11 mg/L when measured during mid-morning. The WINDY CITY bow had a temperature of 84.5 °F and DO was 6.65 mg/L when the water was measured in the afternoon. River baseline measurements of temperature and DO were 82.1 to 90 °F and 3.11 to 7.55 mg/L, respectively.

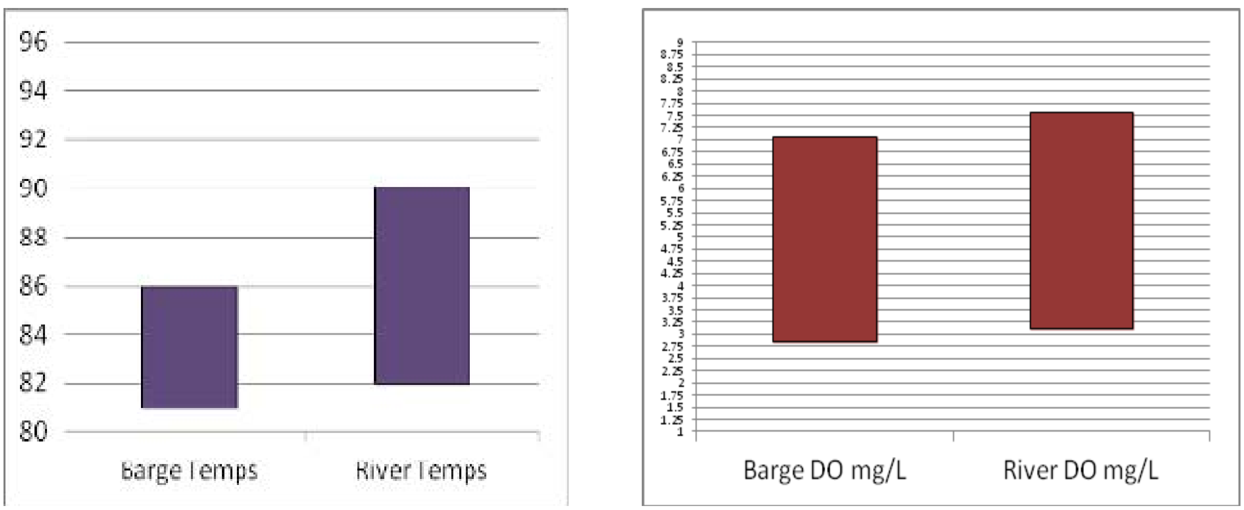


Figure 17. Water Temperature and Dissolved Oxygen Comparisons.

11.3 Conclusions from 2012 Survey

The overall findings of this survey of local barge traffic near the dispersal barrier compares closely to the condition and water content/levels of the larger initial barge study of 2010. The percentage of tanks with measurable amounts of water (5 percent versus 6 percent) and the temperature and DO in those tanks are very similar. Due to lack of availability, only two tow boats were inspected. Each tow boat contained 2 feet or more of ballast tank water; at least one tank had been filled for several months. Because towboat tanks are actively filled more frequently than barge tanks, additional tow boat inspections may be warranted. Due to the extended period of time the towboat tanks remain filled, long-term survival of Asian carp larvae in them is unlikely.

The team was able to collect data on 39 barges rafted along areas of the river. The barges inspected were usually empty and in generally good condition. One crewmember commented that most barges sit uncovered the majority of the time so there is a potential for rainwater to seep through small weld cracks or holes contributing to the trace amounts of water that were found. One barge manager reported that the empty barges moored along the river are not checked regularly for water in ballast tanks, but are inspected anytime they are moved. He said barges are also monitored for water in the ballast tanks every 6 hours while in use, which is the same schedule reported by operators of longer distance barges in 2010.

The barge companies have experienced a recent slowdown in activity around the dispersal barrier focus area and consequently fewer barges/tugboats were available for access. A local barge company representative from the area mentioned that his company was one of the main barge providers that traverse the dispersal barrier. He informed the team that regular coal deliveries will end by mid-September 2012, and his barges will no longer be used to transport coal through the barrier and up to the Chicago area. This slowdown will dramatically reduce the total number of barges that cross through the dispersal barrier.

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APPENDIX A TEST PLAN

The study plan was developed for use during entrainment and survival experiments to be conducted with Asian carp on the Illinois River in June 2011. As noted in the report, high river stage and lack of Asian carp eggs resulted in modifications to the study plan.

The full study plan is available in Volume II, Appendix A, of this report. Distribution of the plan was limited to U.S. Coast Guard and their contractors prior to the experiments.

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APPENDIX B ASIAN CARP FIELD AND LABORATORY DATA SHEETS

The data sheets from the survivability experiments conducted in 2011 are available in Volume II, Appendix B, of this report. They are arranged as follows.

Appendix B1: Times for Fill and Empty of each Tank during Entrainment and Survival Testing

Appendix B2: Water Quality Measurement Datasheets

Appendix B3: Trial 1. Asian carp entrainment/leakage (Task 3.4) laboratory datasheet

Appendix B4: Trial 1. Asian carp survival (Task 3.5) laboratory datasheets – in tank cages

Appendix B5: Trial 1. Asian carp survival (Task 3.5) laboratory datasheets – control cages

Appendix B6: Trial 2. Asian carp entrainment/leakage (Task 3.4) laboratory datasheets

Appendix B7: Trial 2. Asian carp survival (Task 3.5) laboratory datasheets – in tank cages

Appendix B8: Trial 2. Asian carp survival (Task 3.5) laboratory datasheets – control cages

Appendix B9: Trial 2. Plankton Tow Datasheets during Tank Filling

NOTE: The word "Survey" in the datasheets is referred to as "Trial" in the report text. Two (2) trials were conducted for the entrainment, survival, and pump effects experiments.

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APPENDIX C SURVEY PHOTOS, AUGUST 2010

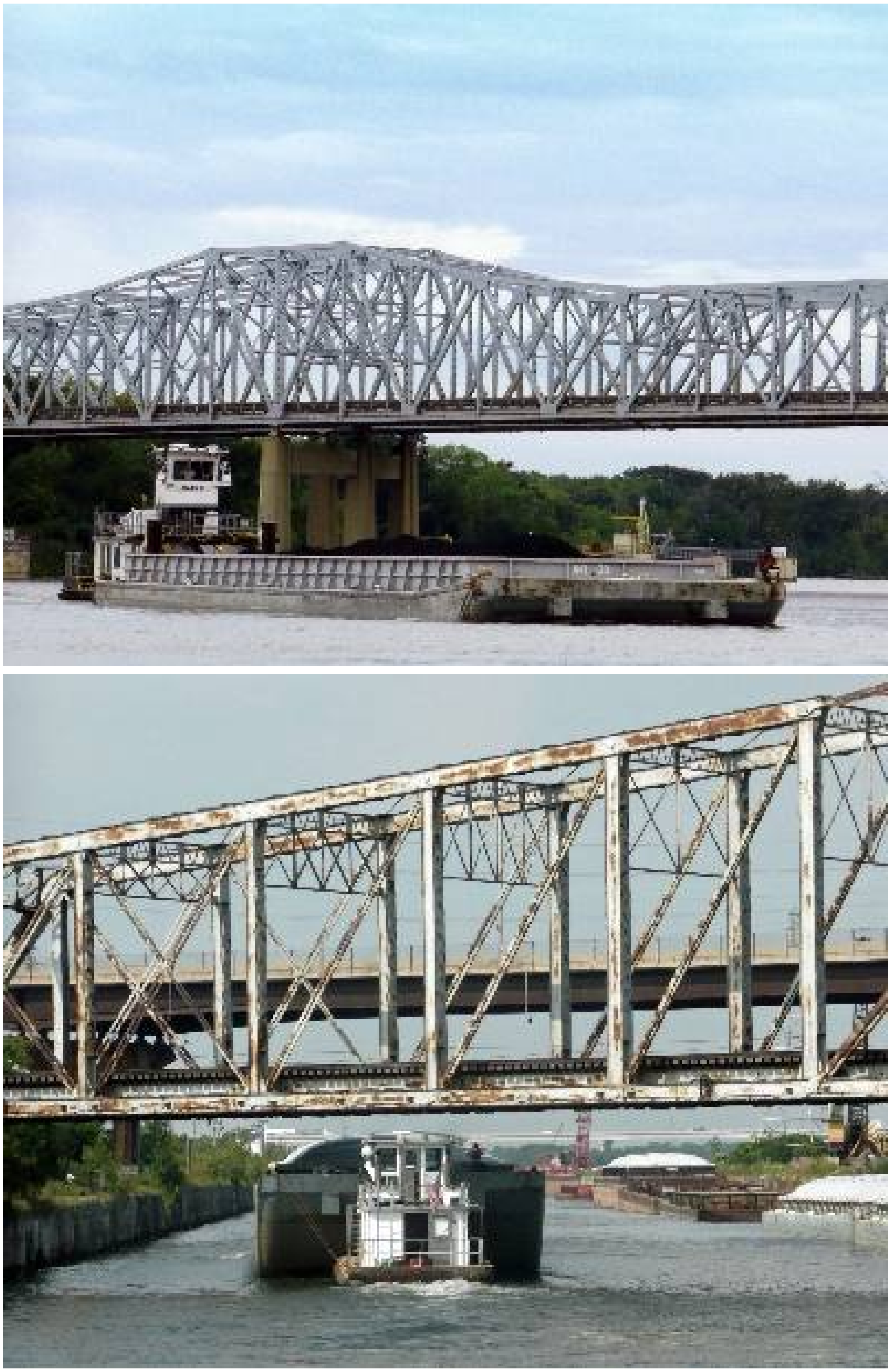

Figure C-1. Loaded (upper) and unloaded (lower) barges. Note minimal clearance under bridge.

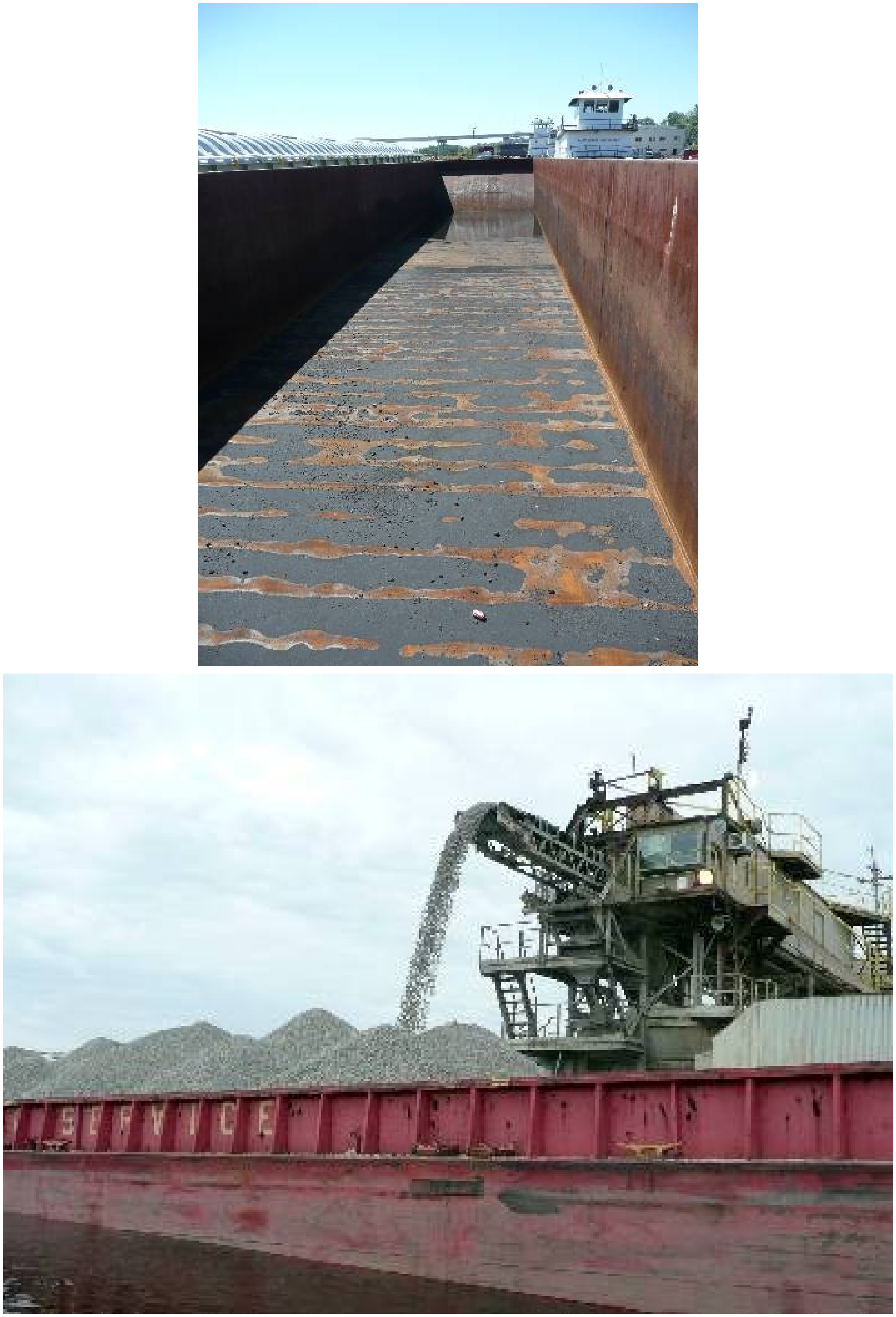

Figure C-2. Interior of empty hopper barge (upper). Loading hopper barge (lower).

Figure C-3. Raised and flush hatch covers on rafted barges (Upper). Raised access hatch (lower).

Figure C-4. Measuring temperature and dissolved oxygen on rafted barge (upper). Interior of barge void space (lower). Water depth approximately 3 inches.

APPENDIX D SURVEY PHOTOS, JULY-AUGUST 2012

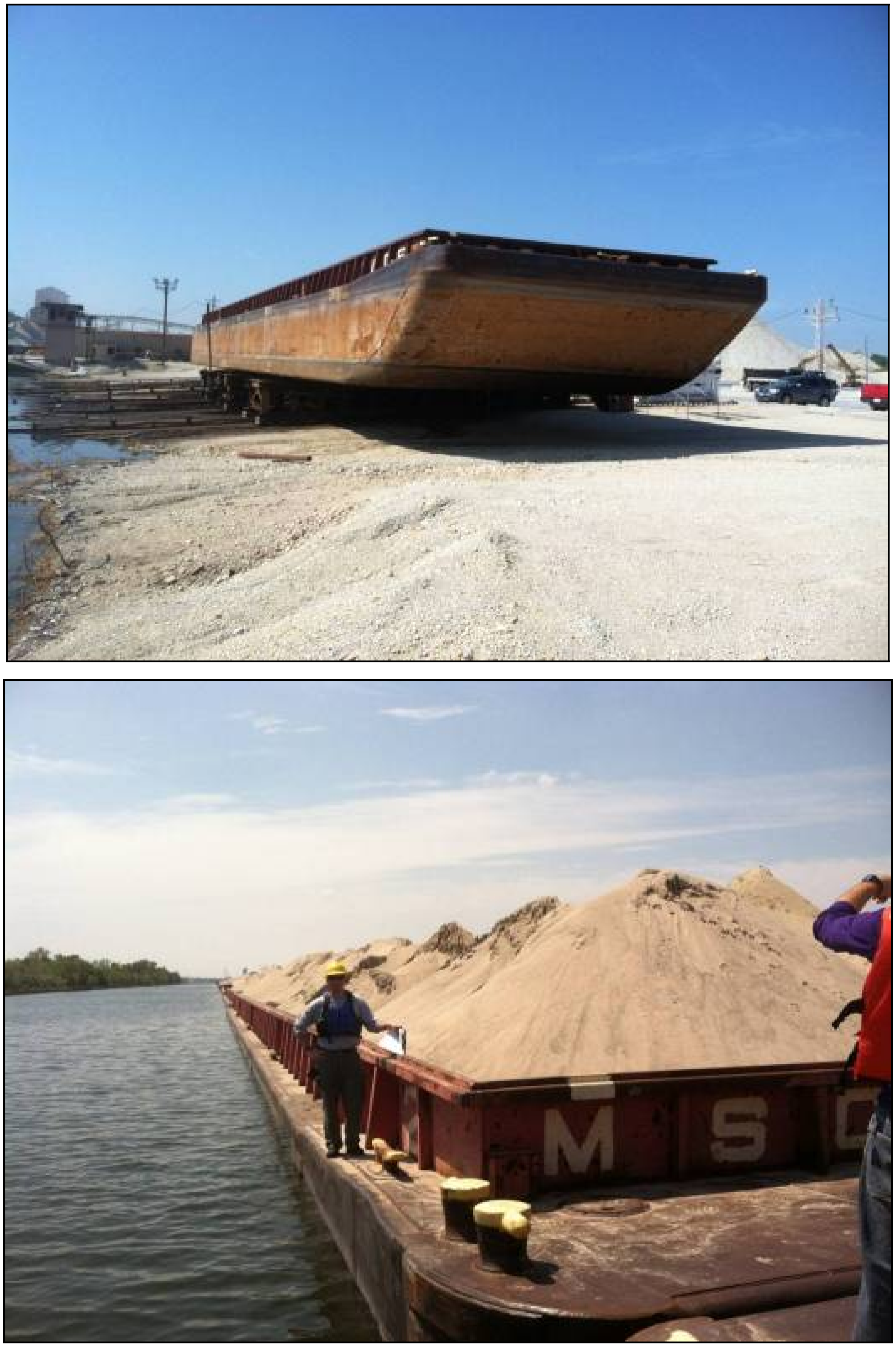

Figure D-1. Hopper barge dry-docked for repair, note hull depth to freeboard (upper). Hopper barge fully loaded with construction grade sand (lower).

Figure D-2. Loaded barges rafted at construction materials site (upper). Covers being installed to protect cargo on hopper barge; note added height (lower).

Figure D-3. Barge being loaded with loose material near dispersal barrier (upper). Empty hopper barge at Midwest Generation on CSSC (lower).

Figure D-4. Recording data aboard towboat in CSSC (upper). Warning sign on CSSC near dispersal barrier (lower).

APPENDIX E 2010 WATER TRANSPORT FIELD DATA SHEETS

The data sheets from the 2010 survey of barge ballast tanks are available in Volume II, Appendix C, of this report. Sheets include barge number, location, and amount of water in tanks. Temperature and dissolved oxygen content are provided for tanks with more than 2-4 inches of water.

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APPENDIX F 2012 WATER TRANSPORT FIELD DATA SHEETS

The data sheets from the 2012 survey of barge ballast tanks are available in Volume II, Appendix D, of this report. Sheets include barge number, location, and amount of water in tanks. Temperature and dissolved oxygen content are provided for tanks with more than 2-4 inches of water.

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APPENDIX G TOWBOAT AND BARGE DESIGN AND OPERATION

Towboats:
Towboats have void tanks, normally located at the bow or stern of the vessel, which are used for ballasting operations. Ballast water is pumped into a void tank (not the bilge area) by an onboard pump through permanent piping. The discharge of this ballast water is done usually through an onboard pump and permanent piping. Some towboats, however, are not equipped with onboard pumps and therefore use portable pumps. Typical portable pumps are 2-inch or 3-inch trash pumps that require suction and discharge hoses.

Towboats may take on ballast water as fuel is consumed and before refueling takes place. This ballasting is necessary to keep the towboat trimmed to the operating draft required or desired for that particular vessel. The ballast water is discharged immediately before refueling or during refueling. Occasionally ballast may be taken onboard to improve handling and remain in the tanks for months before being discharged.

Barges:
There are several types of barges: dry cargo hopper barges, tank barges and deck barges.

Dry cargo hopper barges are the most common barges. They measure 200 feet long by 35 feet wide by 12 to 14 feet tall. These barges look like giant empty shoe boxes with the cargo down in the box. These barges are built such that there is one bow tank, 4 or 5 wing (or side) tanks and one stern tank. The wing tanks go from one side of the barge, under the cargo hopper, and to the other side of the barge. At the side of the cargo hopper, the wing tanks are about 3 feet wide. Under the cargo hopper, the tanks are about 18 inches deep. By design, water is free to flow from side to side because there is no centerline bulkhead (or wall) to prevent this flow of water.

Tank barges have more varied sizes. A 10,000 barrel capacity barge measures 200 feet by 35 feet by 12 feet. Larger capacity barges measure 296 feet long by 54 feet wide by 12 feet. The tank barges have cargo boxes like the dry cargo barges although they are cargo tanks. There are usually 3 cargo tanks or compartments per barge. Similar to dry cargo barges, tank barges have a bow tank, 4 or 5 wing tanks and a stern tank. Some tank barges may have a center bulkhead resulting in separate port and starboard tanks.

Deck barges are constructed to carry the cargo on the deck of the barge and not down in a cargo box. There are few standard sizes for deck barges and they come in many sizes. Deck barges usually have one, if not more, centerline bulkheads. This means that the water cannot flow from one side of the barge to the other side. Deck barges usually have more individual void tanks because of the centerline bulkhead(s). The centerline bulkhead may or may not dissect the bow and stern tanks into two or more separate tanks. Unlike dry cargo barges, deck barges do not have wing tanks but rather void tanks that are much larger than wing tanks. These void tanks can be 12 – 14 feet deep since they reach from the barge hull to the deck.

Barges do not have permanent piping to pump water into or out of their tanks, portable pumps are used. Barges may be ballasted to clear low bridges such as the low railroad bridge in Lamont. Barge tanks are inspected regularly. Operators questioned about standard ballasting practices for this study indicated that tanks are inspected once per 6-hour watch when active or once per day if rafted and inactive.

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