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Entrainment, retention, and transport of freely swimming fish in junction gaps between commercial barges operating on the Illinois Waterway

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ABSTRACT

Large Electric Dispersal Barriers were constructed in the Chicago Sanitary and Ship Canal (CSSC) to prevent the transfer of invasive fish species between the Mississippi River Basin and the Great Lakes Basin while simultaneously allowing the passage of commercial barge traffic. We investigated the potential for entrainment, retention, and transport of freely swimming fish within large gaps (>50 m^3) created at junction points between barges. Modified mark and capture trials were employed to assess fish entrainment, retention, and transport by barge tows. A multi-beam sonar system enabled estimation of fish abundance within barge junction gaps. Barges were also instrumented with acoustic Doppler velocity meters to map the velocity distribution in the water surrounding the barge and in the gap formed at the junction of two barges. Results indicate that the water inside the gap can move upstream with a barge tow at speeds near the barge tow travel speed. Water within 1 m to the side of the barge junction gaps was observed to move upstream with the barge tow. Observed transverse and vertical water velocities suggest pathways by which fish may potentially be entrained into barge junction gaps. Results of mark and capture trials provide direct evidence that small fish can become entrained by barges, retained within junction gaps, and transported over distances of at least 15.5 km. Fish entrained within the barge junction gap were retained in that space as the barge tow transited through locks and the Electric Dispersal Barriers, which would be expected to impede fish movement upstream.

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Introduction

During the last century, introductions of non-indigenous species to the Great Lakes Basin have caused substantial ecological and economic harm (Mills et al., 1994; Pimentel et al., 2005). These introductions have occurred through a variety of mechanisms including accidental release, intentional release, movements through canals, movement along highways and railroads, and ship-related introductions (Mills et al., 1993). The Chicago Area Waterway System (CAWS), including the Chicago Sanitary and Ship Canal (CSSC), is a combination of natural and manmade channels that form an interconnected navigable waterway of approximately 90 miles at the most upstream end of the Illinois Waterway (Duncker and Johnson, 2015) (Fig. 1). As the only navigable connection between the Mississippi River Basin and the Great Lakes Basin (Rasmussen et al., 2011), the CAWS has garnered great attention since the invasion of the Mississippi River Basin by bigheaded carps (Bighead Carp (Page et al., 2013) *Hypophthalmichthys nobilis* and Silver Carp *Hypophthalmichthys molitrix*, collectively) in the late 20th century (Kolar et al., 2007).

Under authorization of the Invasive Species Act of 1996, the U.S. Army Corps of Engineers (USACE) constructed a large electric fish deterrent system (Demonstration Barrier) at river mile (RM) 296 of the Illinois Waterway near Romeoville, IL. This system was intended to prevent the inter-basin transfer of invasive fish species while simultaneously preserving continuity of this important shipping route (Moy et al., 2010). The Demonstration Barrier came online in 2002 and produced peak electrical gradients at the surface of the canal of 0.39 V/cm. Two additional electric barriers came online in 2009 (Barrier IIA) and 2011 (Barrier IIB). The newer barriers are each composed of high voltage narrow electrode arrays and lower voltage wide electrode arrays that were configured so that fish approaching from downstream would be subjected to a gradually increasing electrical field. These barriers produce greater peak electrical gradients (0.79 V/cm–0.91 V/cm over the narrow array) than the Demonstration Barrier, and typically operate in tandem for the purpose of redundancy in case of a mechanical

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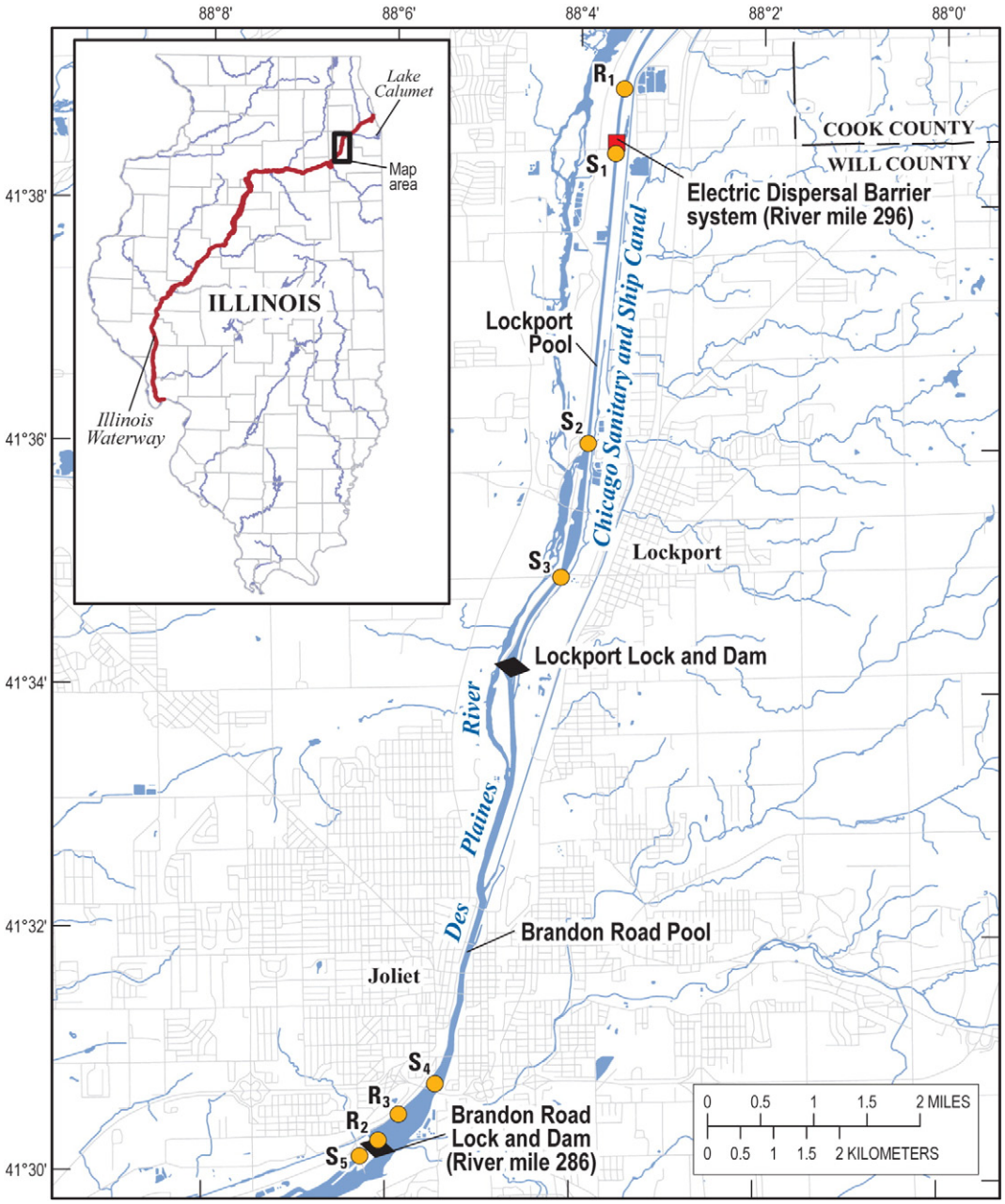

Fig. 1. Map of the study reach of the Illinois Waterway, from Brandon Road Lock and Dam (River mile 286, black diamond), to the Electric Dispersal Barrier system (River mile 296, red square). Lockport Lock and Dam is near the midpoint of the study reach and is indicated with a black diamond. Orange circles indicate fish stocking sites (S) and capture sampling sites (R). Inset shows regional context of the study reach.

failure of one barrier (U.S. Army Corps of Engineers, 2012). Individual Barriers IIA, IIB, and the Demonstration Barrier together make up the Electric Dispersal Barrier system (EDBS) in the CSSC.

Results of intensive monitoring efforts suggest that adult bigheaded carp are commonly present within the Dresden Island Pool of the Illinois Waterway, approximately 26 km below the EDBS (Asian Carp Regional Coordinating Committee Monitoring and Rapid Response Workgroup, 2015a). Since 2010, only one bigheaded carp has been captured above the EDBS (in Lake Calumet). However, environmental DNA samples positive for bigheaded carp DNA are routinely observed above the barrier system in the CAWS (Asian Carp Regional Coordinating Committee Monitoring and Rapid Response Workgroup, 2015a). Juvenile Silver Carp (<175 mm total length (TL)) were detected in the Marseilles Pool of the Illinois Waterway near RM 256.5, or approximately 63.5 km below the EDBS, during sampling conducted in 2015; this is the furthest upstream detection of juvenile bigheaded carps in the Illinois Waterway to date (Asian Carp Regional Coordinating Committee Monitoring and Rapid Response Workgroup, 2015b).

Given that detectable populations of adult and juvenile bigheaded carps have been observed in close proximity to the EDBS, several studies have focused on testing and monitoring the efficacy of the EDBS. During a series of trials, all the caged fish placed adjacent to non-conductive hulled vessels were incapacitated during passage through the Demonstration Barrier (Dettmers et al., 2005). In contrast, caged fish placed adjacent to a steel-hulled barge tow either were not incapacitated or took significantly longer to become incapacitated, leading to the hypothesis that the conductive hull of the barge distorted the electric field of the Demonstration Barrier (Dettmers et al., 2005). Following the implementation of Barriers IIA and IIB, the USACE showed that electrical field distortion did occur when a barge tow traversed the barrier system, such that the electric field in the rake-to-box junction gap (the junction where the front of a rake-style barge is lashed to the