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Effects of tow transit on the efficacy of the Chicago Sanitary and Ship Canal Electric Dispersal Barrier System

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ABSTRACT

In 2016, the U.S. Fish and Wildlife Service, U.S. Geological Survey, and U.S. Army Corps of Engineers undertook a field study in the Chicago Sanitary and Ship Canal near Romeoville, Illinois to determine the influence of tow transit on the efficacy of the Electric Dispersal Barrier System (EDBS) in preventing the passage of juvenile fish (total length < 100 millimeters (mm)). Dual-frequency identification sonar data showed that large schools of juvenile fish (mean school size of 120 fish; $n = 19$) moved *upstream* and crossed the electric field of an array in the EDBS concurrent with downstream-bound (downbound) loaded tows in 89.5% of trials. Smaller schools of juvenile fish (mean school size of 98 fish; $n = 15$) moved *downstream* and crossed the electric field of an array in the EDBS concurrent with upstream-bound (upbound) loaded tows in 73.3% of trials. Observed fish passages through the EDBS were always opposite to the direction of tow movement, and not associated with propeller wash. These schools were not observed to breach the EDBS in the absence of a tow and showed no signs of incapacitation in the barrier during tow passage. Loaded tows transiting the EDBS create a return current of water flowing between the tow and the canal wall that typically travels opposite the direction of tow movement, and cause a decrease in the voltage gradient of the barrier of up to 88%. Return currents and decreases in voltage gradients induced by tow passage likely contributed to the observed fish passage through the EDBS. The efficacy of the EDBS in preventing the passage of small, wild fish is compromised while tows are moving across the barrier system. In particular, downbound tows moving through the EDBS create a pathway for the upstream movement of small fish, and therefore may increase the risk of transfer of invasive fishes from the Mississippi River Basin to the Great Lakes Basin.

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Introduction

A substantial pathway for the movement of invasive fishes between the Mississippi River Basin and the Great Lakes Basin is the Chicago Area Waterways System (CAWS), including the Chicago Sanitary and Ship Canal (CSSC) in the Upper Illinois Waterway (Asian Carp Regional Coordinating Committee (ACRCC) Monitoring and Rapid Response Workgroup, 2013; U.S. Army Corps of Engineers, 2014). An Electric Dispersal Barrier System (EDBS) was constructed in the CSSC to prevent the movement of invasive fish species between the Mississippi River Basin and the Great Lakes Basin while maintaining the continuity of this important shipping route (Moy et al., 2011). The recent finding of juvenile bigheaded carps (bighead carp *Hypophthalmichthys nobilis*, and silver carp *Hypophthalmichthys molitrix*) further upstream in the Illinois Waterway in the Marseilles Pool near River Mile (RM) 256.6 (ACRCC Monitoring and Response Workgroup, 2015 underscores the need for a complete understanding of the mechanisms that potentially allow fish passage across the EDBS. Therefore, the purpose of this study is to build on existing research addressing the impact of commercial barge traffic (hereafter referred to as tows) on the efficacy of the EDBS in preventing fish passage through a series of field experiments carried out by a multidisciplinary team of scientists and engineers from the U.S. Fish and Wildlife Service (USFWS), the U.S. Geological Survey (USGS), and the U.S. Army Corps of Engineers (USACE).

Previous studies designed to test the efficacy of the EDBS in preventing fish passage have primarily focused on the entrainment and transport of fish in the interstitial spaces between barges. Laboratory experiments in a scaled physical model of the EDBS (Bryant et al., 2016), and field trials conducted at the EDBS (Davis et al., 2016), both

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showed that small fish may be entrained within the gap space formed at the junction between the curved bow of a rake-style barge and the square stern of a box-style barge (rake-to-box junction gaps), and transported in the direction of tow travel. During the field trials, freely-swimming golden shiners (*Notemigonus crysoleucas*) (total length (TL) < 123 mm) in the rake-to-box junction gap showed no signs of harm or incapacitation as the tow transited distances up to 15.5 kilometers (km), through locks, and across the EDBS (Davis et al., 2016). Other research has highlighted the influence of loaded, steel-hulled barges on the voltage gradient in the EDBS, following early suggestions that barges may distort the barrier's electric field (Dettmers et al., 2005). Field tests indicated that the subaqueous electric field within the rake-to-box junction gap between barges was reduced to the point of being "barely measurable" (0.06 volts per centimeter (V/cm) (U.S. Army Corps of Engineers, 2013).

It is well established that loaded tows transiting through confined channels, such as the CSSC, generate a flow of water that moves opposite to the direction of tow travel, hereafter referred to as a "return current" (e.g. Constantine, 1960; Bhowmik et al., 1995; Hochstein and Adams, 1989; Stockstill and Berger, 2001; Das et al., 2012; Bryant et al., 2016). However, the combined effects of tow-induced return currents and electric field distortion on the efficacy of the EDBS in preventing fish passage have not previously been examined in a comprehensive manner at the field scale. The present study addresses this research gap through synchronized sonar observations of wild freely-swimming fish, measurements of flow velocity, and measurements of voltage gradient during upstream-bound (upbound) and downstream-bound (downbound) transits of a loaded tow through the EDBS.

Methods

Study site

This study was conducted during August 2016 in the CSSC at the USACE EDBS, located at RM 296 of the Illinois Waterway, near Romeoville, Illinois, USA (Fig. 1). The CSSC is a confined channel at this location, with a depth of approximately 7.5 meters (m) and width of approximately 48.8 m. The EDBS comprises the Demonstration Barrier (constructed in 2002), Barrier IIB (constructed in 2011), and Barrier IIA (constructed in 2009), listed in order from upstream to downstream (Fig. 1). Barriers IIA and IIB are composed of a high voltage gradient narrow electrode array and a low voltage gradient wide electrode array

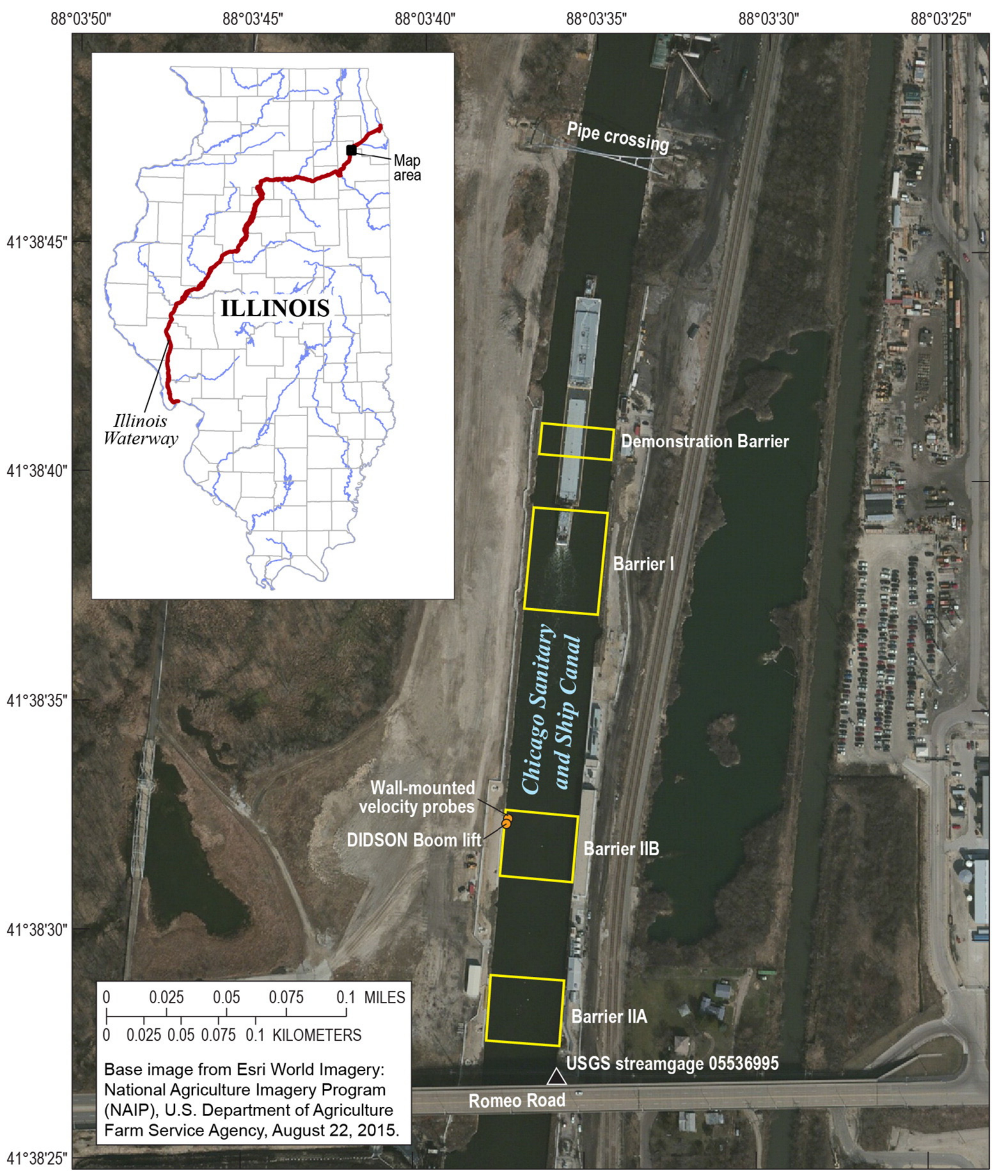

Fig. 1. Location map with annotations showing details of the Electric Dispersal Barrier System.