Effects of barge vessel transit on the efficacy of the Chicago Sanitary and Ship Canal Electric Dispersal Barrier: Preliminary Results from 2016 field trials

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Disclaimer

The results presented herein are preliminary in nature and subject to change. Internal and external peer review processes are underway. The final results of this research will be made available through the peer reviewed literature upon completion of the peer review process.

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Executive Summary

The most 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 (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., 2010).

In 2016, the U.S. Fish and Wildlife Service, U.S. Geological Survey, and U.S. Army Corps of Engineers undertook a large-scale field study to determine the influence of commercial barge vessels on the efficacy of the EDBS in preventing fish passage. This study included sonar-based observations of wild fish as a tow consisting of a tug vessel and six fully-loaded barges traversed the EDBS (Figs. 1 & 2). Additionally, as the tow passed through the EDBS, its effect on flow velocities and voltage gradients were measured (Fig. 3).

Flow velocities were measured using hydroacoustic instruments mounted on the canal wall and the tow. The velocity measurements indicate that loaded tows transiting the EDBS in the downstream direction create a return current between the tow and the canal wall that travels in the upstream direction at an average velocity of 0.18 m/s (n = 21) (Table 1 & Fig. 3, top panel). Additionally, as the tow transited the EBDS, the voltage gradient was measured at Barrier IIB (Fig. 2). These measurements show that the passage of a tow causes a distinct decrease in voltage gradient within the canal (Fig. 3, bottom panel).

Two DIDSON multi-beam sonar systems, mounted on the west canal wall and aimed toward the wall (Figs. 2 & 4), were used to monitor wild fish behavior during the study. Schools of juvenile fish moved upstream and completely crossed the peak electrical field of the EDBS concurrent with the passage of downstream transiting tows in 89.5% (n = 19) of trials (Table 2). These schools were not observed to breach the EDBS under ambient conditions and showed no signs of incapacitation in the barrier field during downstream tow passage. The number of fish passages observed during each downstream tow transit ranged from 0 to 822 (Mean = 120 fish, S.D. = 199). Sonar based size estimates of a sub sample of fish that achieved passage of the EDBS ranged from 37.7 mm to 92.3 mm (Mean = 61.4 mm, S.D. = 7.4 mm, n = 170).

Fish that were physically captured in the area immediately downstream of the EDBS concurrent with tow transit trials were Gizzard Shad (*Dorosoma cepedianum*) (n = 304) and Threadfin Shad (*Dorosoma petenense*) (n = 6). The mean size of physically captured Gizzard Shad was 54.0 mm TL (S.D. = 8.95 mm) with sizes ranging from 33.0 to 94.0 mm.

Based on these study results, the efficacy of the EDBS in preventing upstream passage of small fish is compromised while tows are moving across the barrier system. This observation of upstream fish passage identifies a potential pathway for the movement of invasive fishes through the EDBS and into the Great Lakes. The identification of this pathway does not elevate the risk of invasive fish passage from current levels. Rather, it improves functional understanding of the efficacy of the EDBS, thereby enhancing the ability of invasive species managers to assess risk and implement appropriate actions.

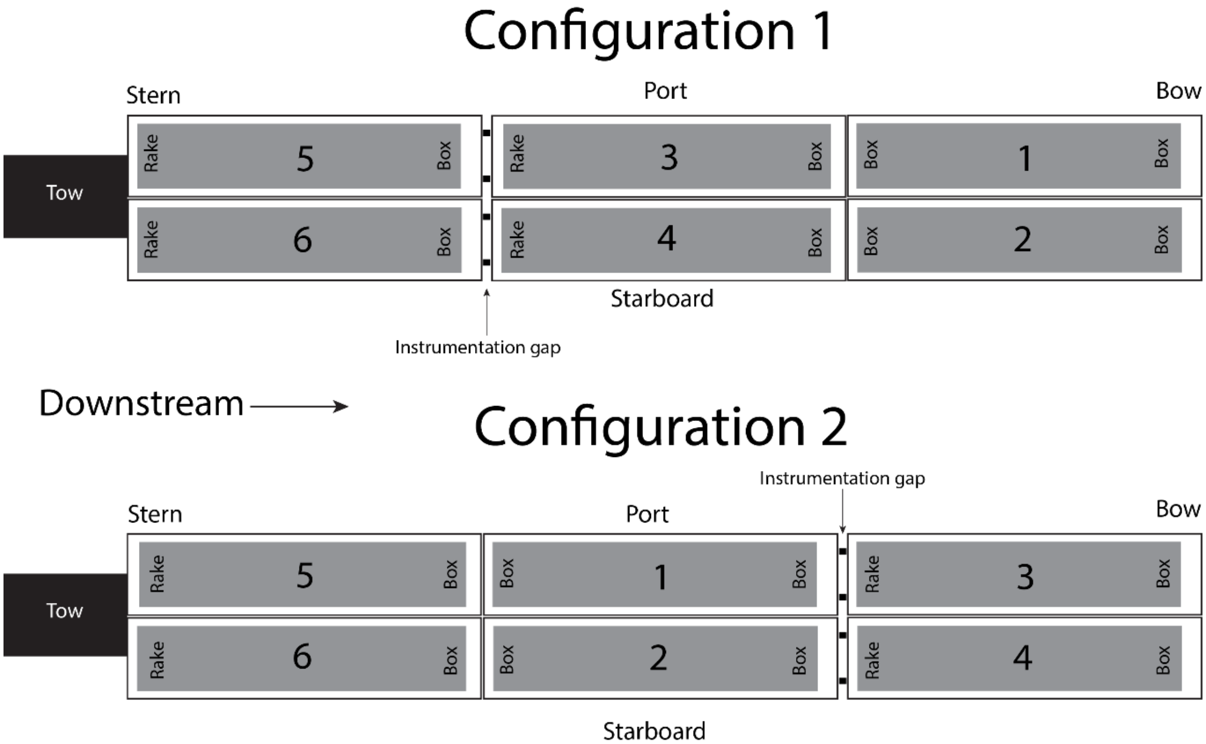

Figure 1*.Tow configurations utilized during downstream transit trials at the Chicago Sanitary and Ship Canal Electric Dispersal Barrier System.*

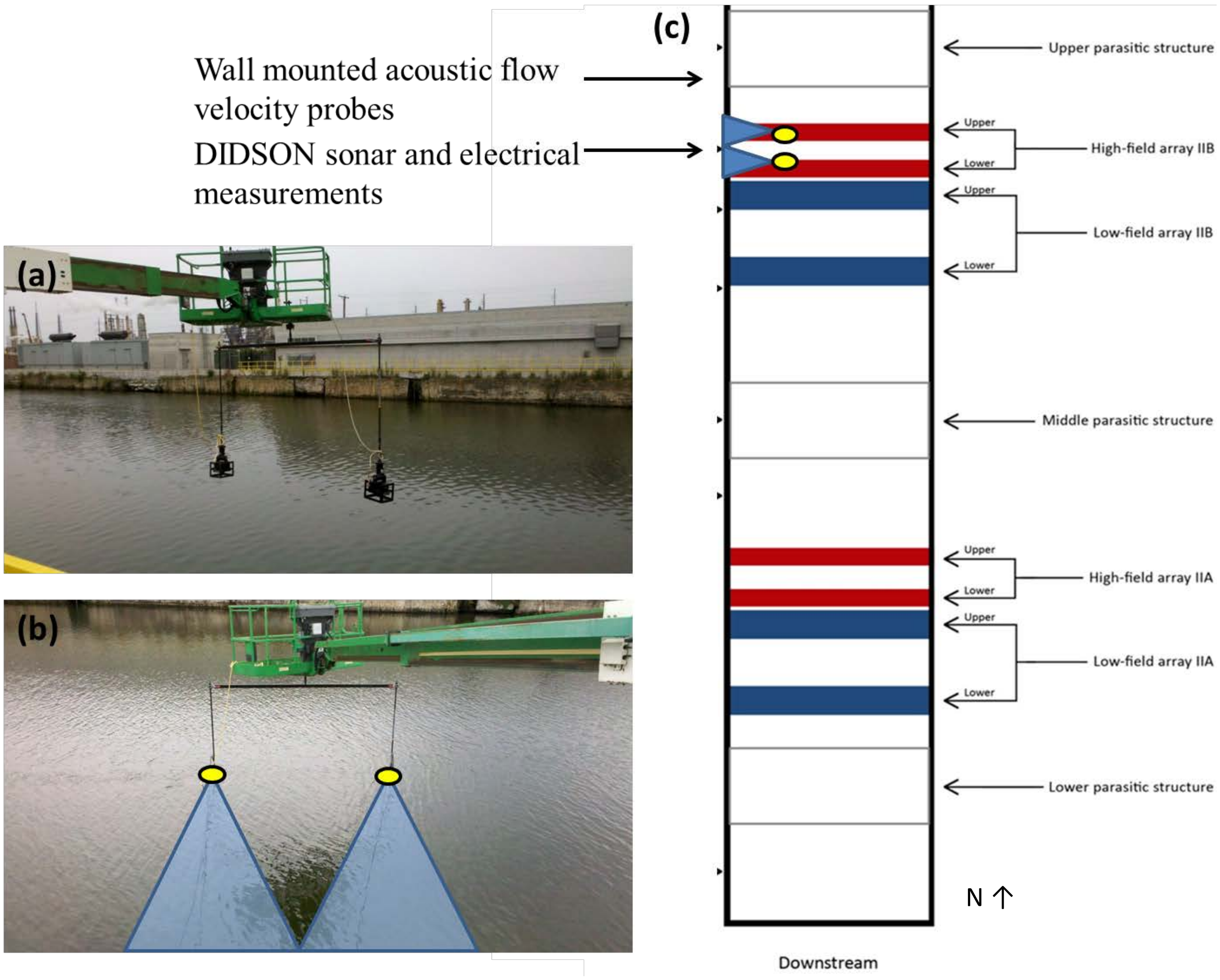

Figure 2. *Telescopic boom lift that was utilized to deploy two DIDSON multi-beam sonar units in parallel at the Chicago Sanitary and Ship Canal Electric Dispersal Barrier System (panels a and b). Blue shading indicates approximate field of view obtained from the sonar system (panel b). The sonar units and electrical field measurement probe were positioned directly over the Barrier IIB narrow array, as shown in panel (c). Wall mounted acoustic flow velocity probes were positioned just upstream of the Barrier IIB narrow array (panel c).*

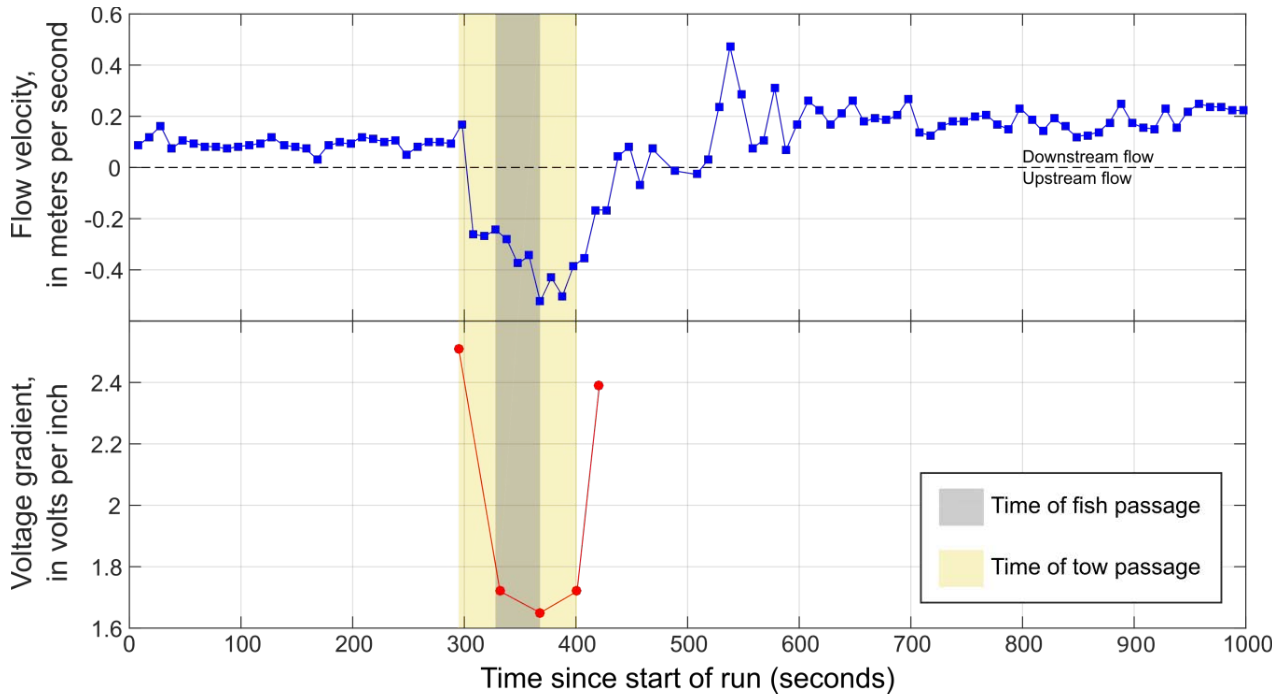

***Figure 3**. This figure shows velocity and voltage gradient data from a downbound tow transit of the Electric Dispersal Barrier System (EDBS) on August 8th, 2016. As the tow transited EDBS Barrier IIB, reverse flows (negative flow velocity, top panel) were initiated concurrent with substantial reductions in voltage gradient (bottom panel). **Top panel:** the streamwise component of velocity was measured 5.3 meters from the west wall of the canal. Positive flow velocity indicates downstream flow and negative flow velocity indicates upstream flow. **Bottom panel:** the voltage gradient during tow passage. The yellow shading indicates the time during which six loaded barges passed the DIDSON multi-beam sonar units. The grey shading indicates the time during which wild fish were observed fully traversing the EDBS Barrier IIB in the upstream direction.*

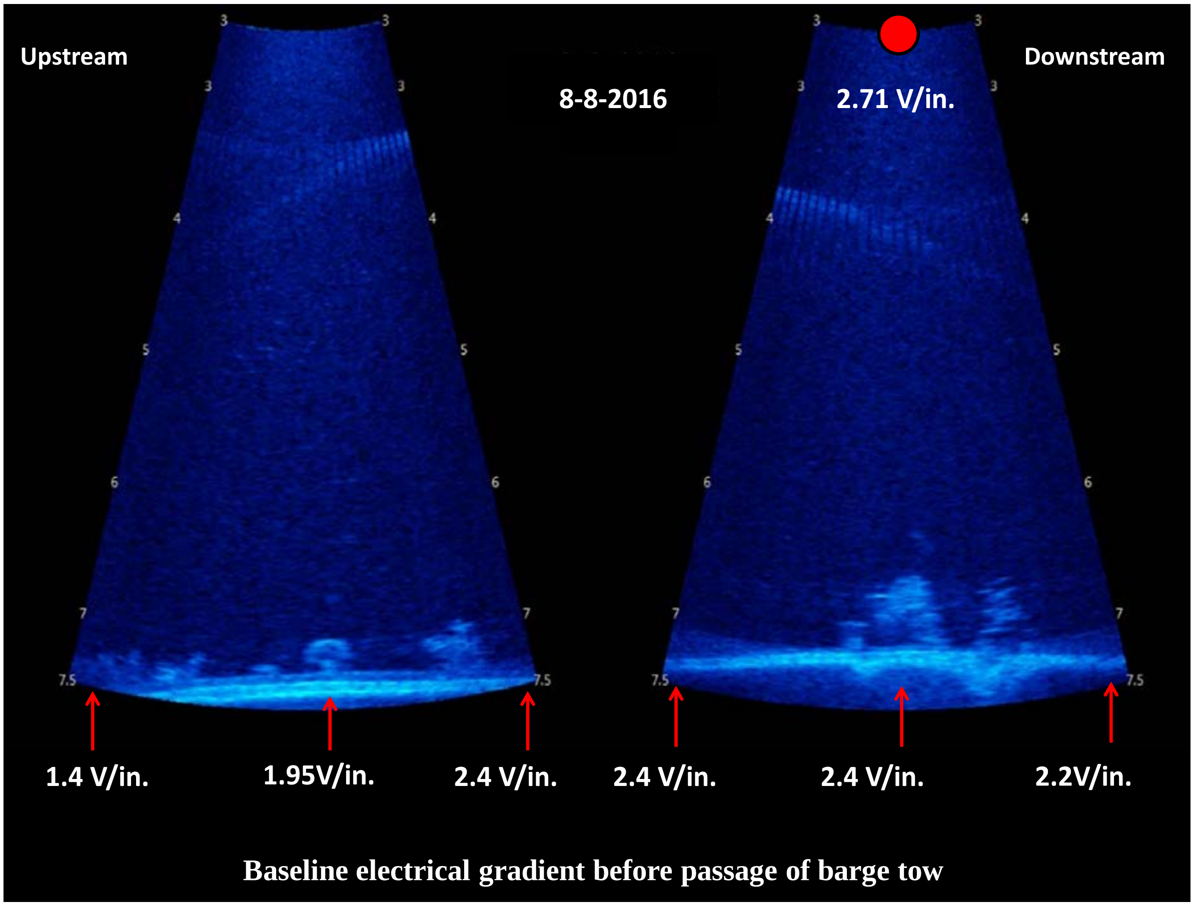

Figure 4A. *Example of two parallel DIDSON multi-beam sonar echograms collected at the Electric Dispersal Barrier System. Red arrows indicate locations of baseline electric voltage gradient measurements at the west canal wall. Red dot indicates the approximate location of baseline electric voltage gradient collected from DIDSON boom with a 3-D electrical probe.*

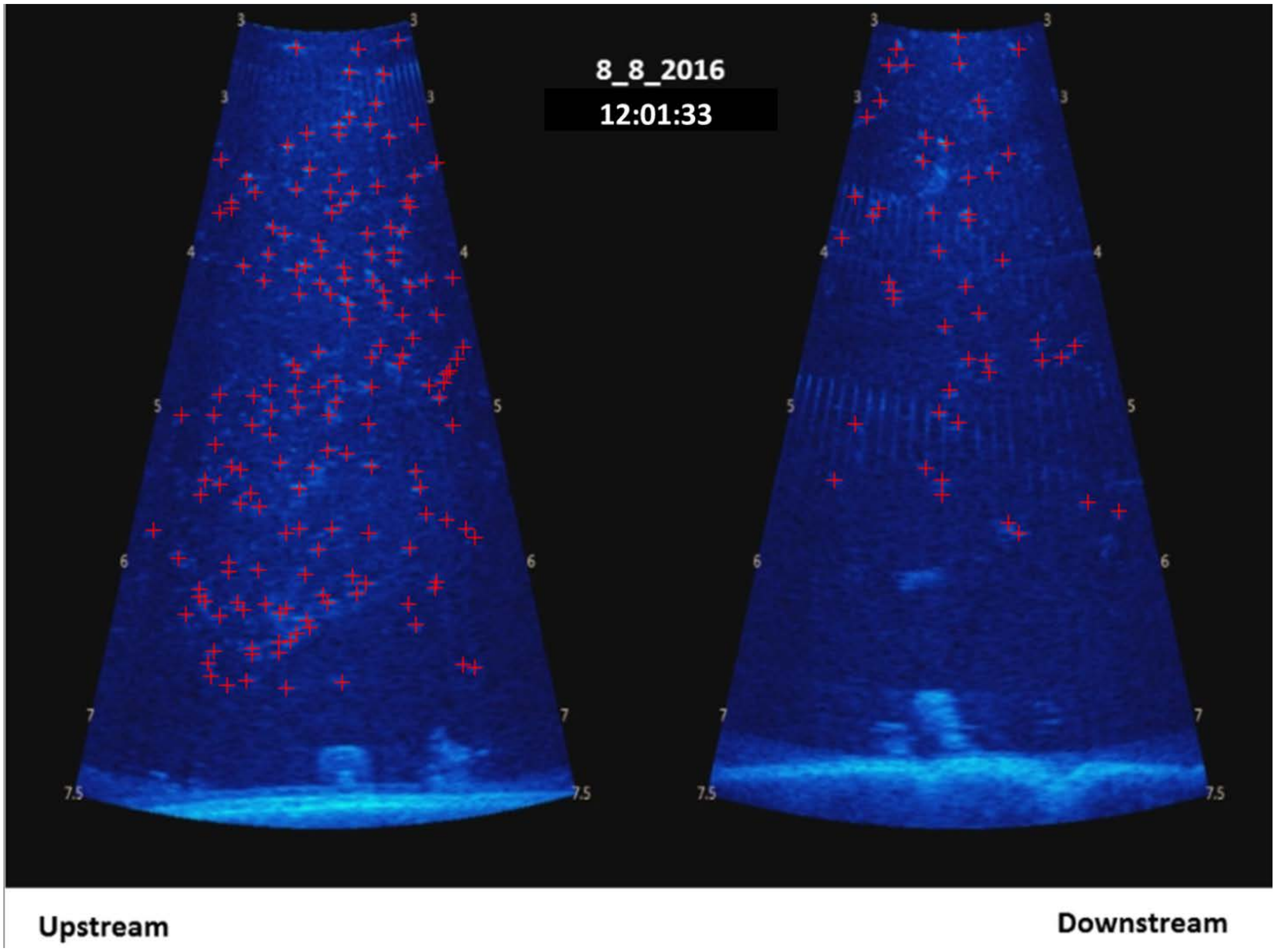

Figure 4B. *Example of two parallel DIDSON multi-beam sonar echograms showing fish passage at the Electric Dispersal Barrier System. Red crosshairs denote fish locations on the echograms.*

	Return current velocity, in meters per second	
	Upstream-bound tows (n = 21)	Downstream-bound tows (n = 21)
Minimum	0.38	0.06
Maximum	0.80	-0.29
Average	0.50	-0.18
Standard Deviation	0.09	0.08

Table 1. *Minimum, maximum, average, and standard deviation of the return current velocity measured by the tow-mounted hydroacoustic velocity meter (statistics computed for all trials with sufficient velocity data;* $n_{downbound} = 21$*,* $n_{upbound} = 21$*). The return current velocity was calculated by averaging the streamwise velocity profile measured by the tow-mounted hydroacoustic velocity meter over the period of time that the tow passed the wall-mounted instruments, which gives a time-averaged velocity profile, then averaging over the time-averaged velocity profile over the distance between 1.8 m from the tow and the furthest measurement cell.*

Date	Direction	Time bow of tow at Barrier IIB	Time first fish Passage	Time Last Fish Passage	Number Fish Passages	S.D.	Mean Length (mm)
8/2/2016	Downstream	16:15:34	N/A	N/A	0	0.00	N/A
8/3/2016	Downstream	15:38:16	15:38:37	15:40:40	66	20.21	61.53
8/3/2016	Downstream	16:43:17	16:44:18	16:45:27	20	6.66	54.96
8/4/2016	Downstream	10:04:59	10:05:36	10:06:52	126	18.68	49.76
8/4/2016	Downstream	11:25:56	11:26:52	11:28:23	29	9.50	48.13
8/4/2016	Downstream	15:14:00	15:15:42	15:16:15	2	1.00	52.93
8/4/2016	Downstream	16:31:45	16:32:08	16:33:53	18	11.93	51.66
8/8/2016	Downstream	12:00:32	12:01:09	12:01:50	427	30.35	69.13
8/8/2016	Downstream	15:44:00	N/A	N/A	0	0.00	N/A
8/8/2016	Downstream	16:50:00	16:50:10	16:51:12	75	3.51	62.66
8/9/2016	Downstream	10:57:42	10:58:07	10:59:49	33	1.53	73.60
8/9/2016	Downstream	14:53:15	14:53:23	14:54:25	39	6.43	68.40
8/9/2016	Downstream	15:59:43	16:00:14	16:01:34	140	16.56	63.60
8/10/2016	Downstream	10:06:42	10:07:03	10:08:23	227	16.65	61.36
8/10/2016	Downstream	11:13:12	11:13:44	11:15:00	822	40.08	67.43
8/10/2016	Downstream	15:00:08	15:00:59	15:02:00	82	10.02	63.58
8/10/2016	Downstream	16:13:53	16:14:30	16:15:46	49	3.21	67.60
8/11/2016	Downstream	11:37:55	11:39:25	11:39:46	3	1.00	63.50
8/11/2016	Downstream	15:39:55	15:40:37	15:41:52	118	9.85	64.16

Table 2*. Average number of upstream fish passages through the Electric Dispersal Barrier System, Barrier IIB narrow array during each downstream tow passage event. Observations were made with DIDSON multi-beam sonar and validated by three independent readers. Mean length is the average of 10 randomly selected fish from each tow transit as measured on sonar echograms.*

Acknowledgments

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