Biological Fish Injury and Survival Evaluation of American Eel after Passage through the Archimedes Screw Turbine at Hanover Pond, Connecticut

Final Summary Report

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1.0 Introduction and Background

The condition of silver-phase American Eel *Anguilla rostrata* after passage through the Archimedes screw turbine at Hanover Pond was evaluated using the HI-Z Tag recapture technique in November of 2018. This technique allows for the immediate recapture of fish after downstream passage through turbines, spillways, and bypasses (Heisey et al. 1992). New England Hydropower Company owns and operates the screw turbine at Hanover Pond, which was the first of its kind installed within the United States and began operation in 2017.

The dam at Hanover Pond was built in 1855 with a hydraulic head of 14.7 ft. and is located at river mile 22 on the Quinnipiac River in Meriden, CT. It is the second dam on the Quinnipiac River and consists of a concrete spillway (approximately 300 ft. in length) with the intake for the turbine located at river right. The screw turbine has three blades with a runner diameter of 139.75 inches. During this evaluation, the approximate discharge through turbine was 152 cfs and the rotation rate of the runner was 14.7 rpm. The fish obtained for this study were obtained from the adult eel collection facility at the Groton Utilities Water Treatment Plant near the mouth of the Poquonnock River in Groton, CT.

This study was conducted with coordination and assistance from New England Hydropower Company and the Connecticut Department of Energy and Environmental Protection.

2.0 Methods

Approximately 50 American Eels were transported to the dam in an oxygenated transport tank on the day of the study remained in the same tank prior to being tagged (Figure 1). Water quality (temperature and dissolved oxygen) was monitored throughout the day. Eels were randomly selected from this group to be tagged, however, any fish that displayed previous injuries or abnormal swimming behavior were not selected. To aid in tagging efforts, each eel was placed into an ice slurry for three to five minutes to reduce movement during tagging procedure.

A uniquely-numbered Floy tag was inserted into the dorsal musculature of each eel to allow for individual identification of eels during post-passage assessment. Four to six HI-Z (balloon) tags were attached along the dorsum of each eel via stainless steel pins or cable ties. A miniature radio tag was attached in combination with one of the pairs of HI-Z tags. Prior to being released into the turbine, eels were allowed to recover from tagging stress in a 50-quart cooler filled with ambient river water until they were actively swimming (Figure 2).

The transit time of water passing through the turbine was determined to be approximately 15 seconds and was measured by releasing buoyant objects into the turbine. After activation, the HI-Z tags that were used inflate in approximately two to four minutes. Due to the relatively quick transit time through the turbine, each eel was held for 90 seconds prior to release into the

turbine after all HI-Z tags were activated. This allowed the eels to become buoyant within 30 seconds to two minutes after release, which aided in the immediate recapture of eels in the tailrace. Treatment eels were individually released by hand into an area located immediately upstream of the turbine to ensure each was committed to passing through the turbine (Figure 3). The same handling and tagging procedures were used for a group of control eels which were released directly into the tailrace downstream of the turbine.

Eels were recaptured with dip nets and transported to shore by five personnel that waded in the tailrace (Figure 4). Holding the eels for 90 seconds prior to release helped to prevent eels from getting too far downstream of the dam, which would have made recapture difficult due to fast-flowing water. Each eel was examined for immediate (1 hour) survival status and injuries prior to being placed into a holding facility. All eels were held for 48 hours in a circular holding tank (approximately 300 gallons) which was maintained with a continuous supply of ambient river water. At the end of the 48 h holding period, each eel was reassessed for delayed survival and injuries that were not detected immediately after recapture.

3.0 Results

3.1 Eel Size and Recapture

The length of treatment eels (n = 25) ranged from 270 to 528 mm with a mean of 325 mm. Only 2 of those fish were longer than 350 mm. Control eels (n = 5) ranged in length from 287 to 354 mm with a mean of 329 mm (Figure 5). A total of 26 treatment eels were tagged and released into the turbine and another five were released as controls. One treatment eel drifted or swam downstream into swift water quickly and could not be recaptured; this eel was removed from the sample. All other eels were recaptured within six minutes of being released, therefore the recapture rates for both the treatment and control groups were 100%.

3.2 Survival and Injury

All treatment and control eels were alive upon recapture (1 h survival = 100%) and there were no injuries observed for any fish. None of the eels died during the 48 hour holding period, resulting in a 48 h survival estimate of 100%. No other injuries were observed after the 48 hour holding period (Table 1).

4.0 Discussion and Conclusions

4.1 Comparison to other anguillid survival studies

Eleven other turbines at eight hydropower stations have been previously evaluated for downstream passage injury and survival of European Eel *Anguilla anguilla* and American Eel using the HI-Z tag recapture technique; 6 of these were propeller turbines and five were Francis turbines (Normandeau Associates, Inc. 2010, 2011a, 2011b, 2016, and 2017; Normandeau

Associates Inc. and J. R. Skalski 1998). An Archimedes screw turbine has not been previously tested using this methodology.

Although the design, characteristics, and power production of this Archimedes screw turbine differ greatly from conventional propeller and Francis turbines, it is noteworthy that this is the only turbine that has been tested in which no eels were injured and survival was 100% (Tables 2 and 3). The size of the eels used in previous evaluations were also significantly larger than those used for this study (325 mm compared to 636-1020 mm average length), however, based on downstream monitoring performed in 2017, as recommended by CT DEEP, the size of eels used for this evaluation are representative of those naturally migrating downstream of Hanover Pond (Table 3).

In general, estimated survival rates for downstream passage of American Eel are higher for Francis turbines compared to propeller turbines; this trend is unique to this species. Other trends for American Eel turbine passage survival that are similar to those observed with other fish species are an increase in survival with a decrease in fish length, the number of buckets/blades, and turbine runner speed (rotation rate), and an increase in survival with an increase in runner diameter and turbine discharge. Characteristic of this Archimedes screw turbine that likely produced such a high estimate of passage survival and low injury rates are the low number of blades (3), very slow runner speed (14.7 rpm), and a moderate runner diameter (139.75 inches).

Literature Cited

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Tables

Table 1 Summary of tag-recapture data: 1 and 48 h survival estimates for American Eel after passage through the Archimedes screw turbine at Hanover Pond, CT in 2018.

	Treatment	Control
No. Released	25	5
No. Recaptured Alive	25	5
No. Recaptured Dead	0	0
Survival 1 h	100%	100%
No. Held	25	5
Alive 48 h	25	5
Survival at 48 h	100%	100%
No. Examined	25	5
No. of Visible Injuries	0	0

Table 2. Comparison of the hydro turbines studied to determine turbine passage survival and injury estimates of adult Eels.

Station	No. blades/buckets	Runner diameter (in)	Hydraulic head (ft)	Discharge (m^3/s)	Runner speed (rpm)
Propeller turbines					
Beaucaire	4	245.7	45	11,057	94
Fessenheim	4	262.6	50	12,783	88.2
Ottmarsheim	5	246	51.5	11,160	93.75
Moses Saunders	6	240	82	9,100	99.2
Wilder	5	180	53.4	4,748	112.5
Vernon (Unit 8 at 1,000 cfs)	5	122	32	1,236	144
Vernon (Unit 8 at 1,700 cfs)	5	122	32	1,681	144
Francis turbines					
Bellows Falls	15	174	57	3,229	85.7
Cabot Station Unit 2*	15	136	60	2,304	97.3
Station 1, Unit 1*	13	54	44	651	200
Vernon (Unit 4)	13	62.5	35	992	133
Vernon (Unit 9)	12	110	34	1308	75
Archimedes screw turbine					
Hanover Pond	3	139.75	15.9	152	14.7

* Part of the Turners Falls complex.

Table 3. Comparison of survival and injury rates for downstream passage of European and American Eels from previous evaluations using the HI-Z Tag methodology.

Station	Eel size (mm)	48 h survival (%)	Visible injury rate (%)
Propeller Turbines			
Beaucaire	686	93.0	7.2
Fessenheim	704	92.4	11.5
Ottmarsheim	750	78.6	26.5
Moses Saunders	1020	73.5	36.7
Wilder	820.7	66.0	42.6
Vernon (Unit 8 at 1,000 cfs)	813	87.5	28.3
Vernon (Unit 8 at 1,700 cfs)	795	74.0	27.3
Francis Turbines			
Bellows Falls	816	98.0	14.0
Cabot Station Unit 2*	683	96.0	4.1
Station 1, Unit 1*	636	90.0	0.0
Vernon (Unit 4)	818	93.5	35.6
Vernon (Unit 9)	796	97.9	8.7
Archimedes screw turbine			
Hanover Pond	325	100.0	0

* Part of the Turners Falls complex.

Figures

Figure 1. Transport and holding tank for eels held prior to being tagged.

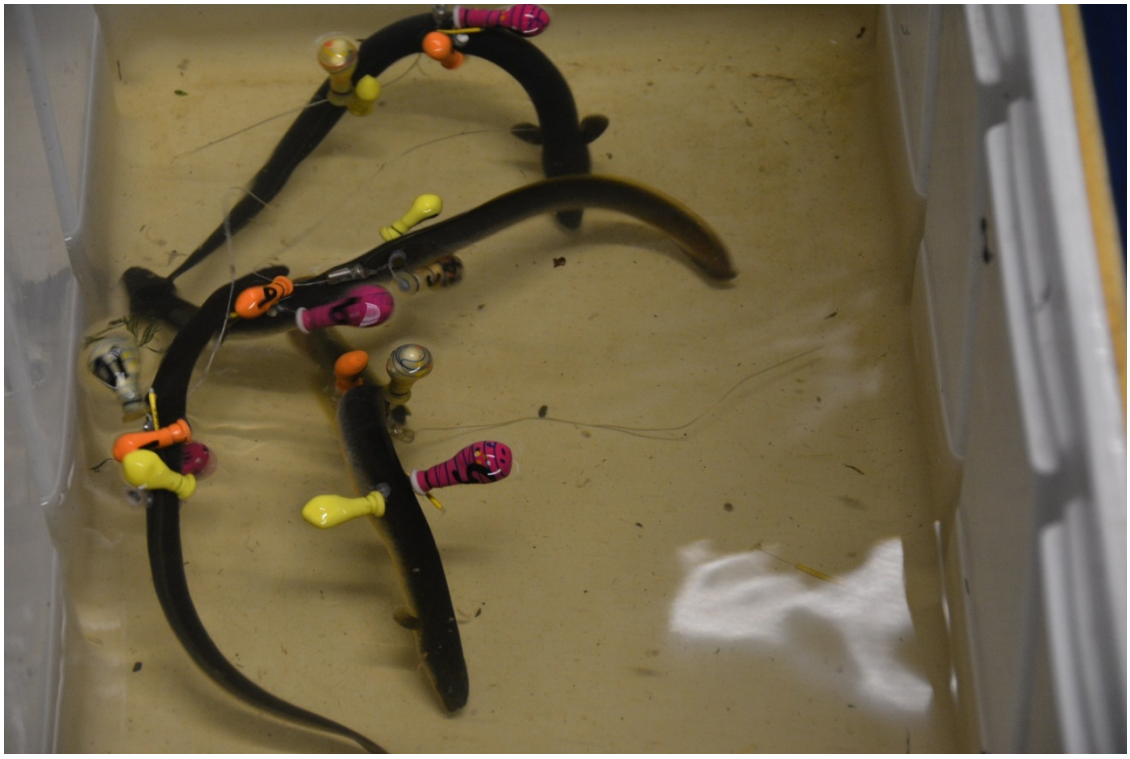

Figure 2. Eels recovering in a cooler with 4 HI-Z tags, a radio tag, and a uniquely numbered Floy tag attached to each fish.

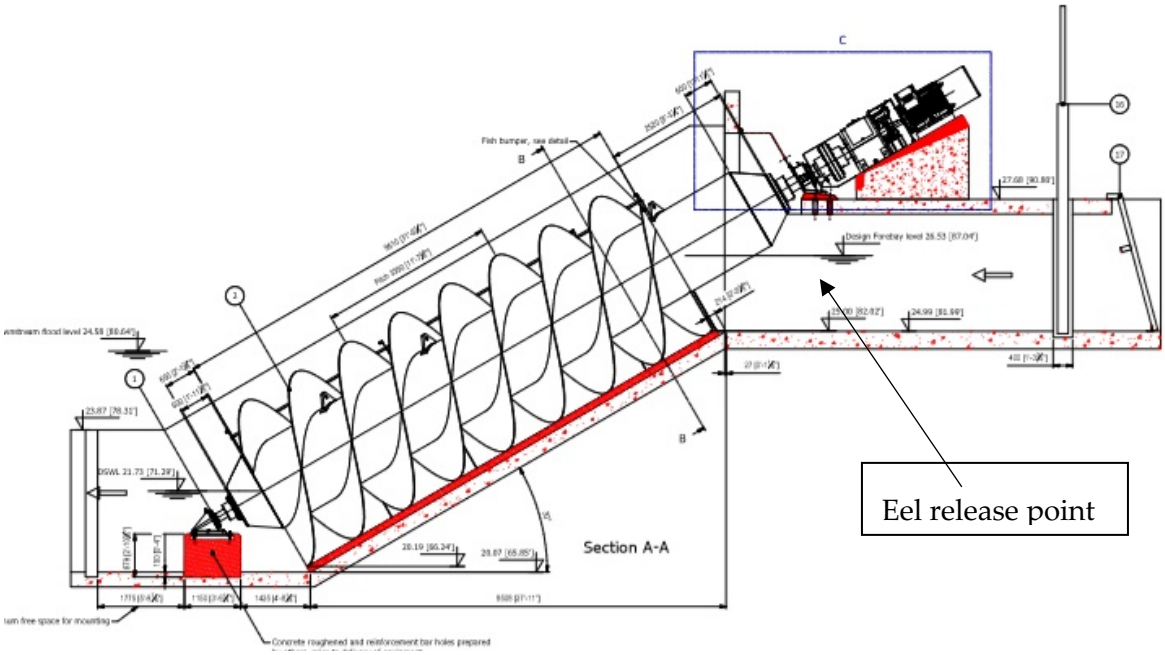

Figure 3. Cross section of the Archimedes screw turbine at Hanover Pond with the eel release point shown just upstream of the turbine runner and downstream of the trash racks.

Figure 4. Eel with inflated balloons being recovered by a dip net in the tailrace of the dam.

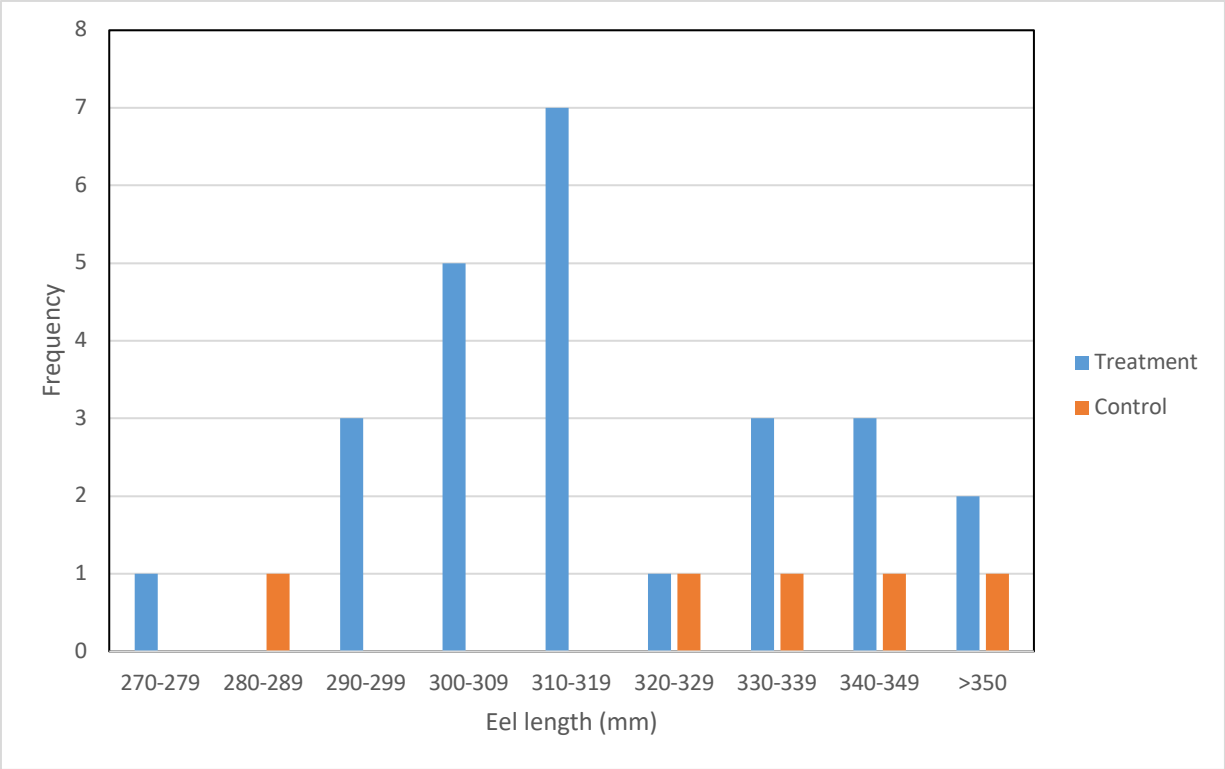

Figure 5. Length-frequency distribution for treatment and control groups of American Eels released.