

# Downstream Fish Passage at Hanover Pond Dam Through the Use of an Archimedes Screw Generator

**Michael E. Steeves**

Kleinschmidt Associates <https://orcid.org/0000-0003-4447-1106>

**Alex Malvezzi** (✉ [Alex.Malvezzi@kleinschmidtgroup.com](mailto:Alex.Malvezzi@kleinschmidtgroup.com))

Kleinschmidt Associates

**Kevin Nebiolo**

Kleinschmidt Associates

---

## Telemetry case report

**Keywords:** Telemetry, Archimedes Screw Generator, Downstream, Passage, Survival, American Shad, Renewable Energy, Hydropower

**Posted Date:** August 5th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-774875/v1>

**License:**   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

---

# Abstract

**Background:** In 2016, an Archimedes Screw Generator (ASG) was installed at the Hanover Pond Dam located in Meriden, CT on the Quinnipiac River to support hydroelectric operations for New England Hydropower Company, LLC (NEHC). The ASG is the first of its kind implemented in the United States, and while they are largely described as ‘fish-friendly’, adequate scientific literature evaluating fish passage is lacking at these facilities. The Connecticut Department of Energy and Environmental Protection (CT DEEP) with consultation from U.S. Fish and Wildlife Service (USFWS) and Kleinschmidt Associates designed and implemented a study to evaluate American Shad downstream fish passage at Hanover Pond Dam. The objective of this study was to document whether American Shad would enter the darkened penstock, pass beneath the downward closing sluice gate, and utilize the ASG for safe downstream passage. A radio telemetry study was designed with three fixed monitoring stations; including one station upstream of the dam, another station within the intake structure, and a third station downstream of the dam. Twenty adult American Shad were collected from Holyoke Dam Fish lift, transported to Hanover Pond, and radio-tagged. Fish were released upstream of the dam and monitored from May 30 to July 15, 2019.

**Results:** In total, 16 fish were detected upstream of the dam, and 8 of those fish passed downstream. Seven of the eight fish that passed through the project (87.5%) utilized the intake of the ASG before being detected at the downstream receiver. One fish passed downstream via the spillway and/or use of a notch in the dam. All fish that passed downstream were detected with subsequent 2-second tag bursts at the downstream monitoring station, suggesting a 100% survival rate through the ASG.

**Conclusions:** These results support the suggestion that the Archimedes Screw Generator is a ‘fish friendly’ operation.

## Background

Archimedes Screw Generators (ASG) have been increasing in abundance, as they can operate at low-head sites where larger hydropower operations would not be feasible. ASG’s consist of 2 to 5 spiral blades connected to a central shaft similar to a screw. The ASG is contained by a fixed trough, which allows the screw to freely rotate. The central shaft of the ASG is connected to a gearbox and a generator to deliver electricity (Simmons and Lubitz, 2017). Also, they can operate at run-of-river mode. Run-of-river operations have little or no water storage facility and operate entirely based upon seasonal river flows. When compared to conventional ASG turbines are typically described as ‘fish-friendly’ (Piper et al., 2018). This ‘fish-friendly’ claim is supported by the slower turbine rotation speed, lower force, and smaller pressure changes (Piper et al., 2018; Spah, 2001).

The first ASG installed in the United States was at Hanover Pond Dam on the Quinnipiac River in Meriden, CT. While some studies have evaluated fish passage at ASG’s in England (Piper et al., 2018), Germany

(Haven et al., 2017), and Scotland (Brackley et al., 2015), this would be the first conducted in the United States and the first of any fish in the Clupeidae family.

During the spring of 2019, a downstream fish passage study was conducted by New England Hydropower Company, LLC (NEHC) in consultation with the Connecticut Department of Energy and Environmental Protection (CT DEEP) and the U.S. Fish and Wildlife Service (USFWS). The objective of the study was to understand the effects of downstream passage through the ASG. This study quantified the proportion of fish that passed via various routes (entrainment, through the fishway, and over the dam or spillway) and their survival.

## Methods:

**Shad Passage Monitoring:** Three radio telemetry stations in the Hanover Pond Dam Project area were deployed at the beginning of the study. These stations were installed upstream of the Dam (T01), within the intake structure (T02), and downstream of the Dam (T03). A list of these monitoring stations and equipment is provided in Table 1. The stations were calibrated to ensure complete coverage of the study area.

**Table 1: Shad monitoring locations and equipment for Hanover Pond Dam**

Station Location	Station ID	Receiver Station Equipment
Upstream of Hanover Dam	T01	An Orion <sup>1</sup> receiver with two 3-element Yagi antennas
ASG Intake	T02	An Orion receiver with a dipole antenna
Downstream of Hanover Dam	T03	An Orion receiver with a 3-element Yagi antenna

**Shad Collection and Tagging:** Fish were tagged and released on May 30, 2019, and the study concluded on July 15, 2019. This period coincides with the end of the seasonal shad migration. The study was concluded when no more tagged fish were detected in the study area. American Shad were collected from the fish lift at Holyoke Dam on the day of the release and were transported by CT DEEP to Hanover Pond Dam.

A total of 20 American Shad were tagged and released during the study. TX-PSC-I-80-M Pisces transmitters manufactured by Sigma Eight were used for each fish during the study. The tags were 9.6mm by 26 mm and operated on a frequency of 149.440 MHz. Tags were programmed with a two-second burst rate, that switched to an eleven-second burst to indicate mortality. The mortality burst was activated by a motionless period of 15 minutes.

Fish selected for release were evaluated for overall condition (minimal scale loss, and vigor) before release. Additionally, only fish that were greater than 400 mm in total length were tagged and released during the study.

**Telemetry Analysis:** Studies that assess movement of anadromous fish through telemetered river-reaches are complex in nature. Analysis is made difficult with the presence of false positive signals and receivers with potential for overlapping detection zones. False positive and overlapping detections were removed with the assistance of BIOTAS (Nebiolo and Castro-Santos 2021).

We evaluated the rate of movement through the project area with a Nelson Aalen cumulative hazard function. Movement occurred over the network of receivers depicted in Figure 2. The initial state for this model was the upstream station (T01). The counting process style data were arranged so that the first detection for every fish was always in the initial state (i.e., upstream of the Dam where the tagged shad were released). Once a fish is detected at any other site, movement has occurred. A fish with a detection history beginning upstream (T01), then through the intake (T02), followed by detection downstream of the Dam (T03), indicates passage through the ASG. If a fish was detected upstream of the Dam (T01), then subsequently downstream of the Dam (T03) without recapture at T02, the fish either spilled over the Dam or utilized the notch (Figure 2).

Operations and flow data used in this evaluation were available in an hourly format. Therefore, flow reported at the time of passage through the ASG is the nearest hourly average flow at the last detection upstream, detections within the intake, and the first detections downstream. If the duration of passage occurred over multiple hours, then the two nearest hourly flows were averaged to calculate passage flows. Similarly, for fish that passed using the notch or via the spillway, passage flow reported represents the average of the flows at the time of last detection upstream and the first detection downstream.

## Results

### Downstream Shad Passage:

Of the 20 shad that were tagged and released in Hanover Pond, 16 shad (80%) were detected at Station T01. Eight of these shad detected upstream of the dam (50%), passed downstream, and were detected at Station T03. Of the eight fish that passed downstream, seven of these fish (87.5%) utilized the intake (T02), passing through the ASG before being detected at the downstream Station T03. The one fish that passed downstream without being detected at Station T02, passed downstream either over the spillway or the notch.

All 20 shad remained upstream for over 100 hours post-release (Fig. 3). Between 100 to 200 hours post release, over 50% of the Shad made a downstream movement to Station T03. There was then a lull in downstream movement from 200 to 300 hours post-release. At 320 hours post-release, another 15% of fish moved downstream to Station T03. A Kaplan-Meier Survival Analysis curve demonstrates the probability of downstream movement of shad through the telemetry network over time since release (Fig. 3).

The four fish that were not detected upstream of the dam at Station T01, either did not migrate, expelled their tag outside of the telemetry network, or experienced mortality outside of the telemetry network. The

fate of the eight fish that were detected at the dam but did not pass downstream is unknown. The eight fish passed downstream between June 2, and June 13 of 2019. All fish that passed downstream, maintained a 2-second burst rate suggesting complete survival. Table 2 displays the frequency and unique ID code of each fish that passed downstream, including the route, and discharge (cfs) at the time of passage.

During downstream passage events, the average flow through the project was 169.9 cfs. The ASG averaged 76.8 cfs while the spillway was 93.2 cfs. The one fish that passed via spill did so when discharge through the ASG was at its greatest (195 cfs) and spill over the Dam (86.6 cfs) at its lowest. The seven other fish passed through the ASG when spillway flows were greater than ASG flows (Table 2). The telemetry equipment continued monitoring fish until June 15, 2019.

Table 2  
Description of conditions for fish that passed downstream at Hanover Pond Dam

Frequency & Code	Route of Passage	Date & Hour of Passage	Project Discharge at Passage (cfs)	Flow Through ASG at Passage (cfs)	Spill/Notch Flow at Passage (cfs)
149.440 21	ASG	6/8/2019 2100	142.5	50.8	91.7
149.440 28	ASG	6/13/2019 0700	163.3	71.1	92.2
149.440 31	ASG	6/4/2019 0400	176.5	79.9	96.6
149.440 33	ASG	6/7/2019 2000	150.5	55	95.5
149.440 36	ASG	6/5/2019 0300	165.5	68.7	97.7
149.440 38	ASG	6/3/2019 2100	183.5	91.4	92.1
149.440 39	ASG	6/3/2019 2200	182.5	89.1	93.4
149.440 35	Spill or Notch	6/2/2019 2100	195	108.4	86.6

## Conclusion

This study demonstrated efficient and safe passage of American Shad through an ASG. These findings support the claim that the ASG is a ‘fish friendly’ method of passage (Piper et al., 2018). Out of the eight

fish that passed downstream at the project, seven (87.5%) of these fish passed successfully via the ASG turbine. 100% survival was demonstrated, as all downstream fish maintained a 2-second burst rate through their residency at the downstream most telemetry site (T03). This downstream passage method demonstrated fish entering a darkened penstock, passing below a sluice gate, and then successfully through the ASG turbine.

## Declarations

**Ethics approval and consent to participate:** Not Applicable

**Consent for publication:** Not Applicable

**Availability of data and materials:** The data that support the findings of this study are available from New England Hydropower Company, LLC but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data may be available from the authors upon reasonable request and with permission of New England Hydropower Company, LLC

**Competing interests:** The authors declare that they have no competing interests.

**Funding:** This study was funded by New England Hydropower Company, LLC.

**Authors' contributions:** MS was involved with the data collection, analysis and writing of this case report. KN was involved with the data analysis and review of this report. AM was involved with the data collection, writing and review of this report.

**Acknowledgements:** Not Applicable.

## References

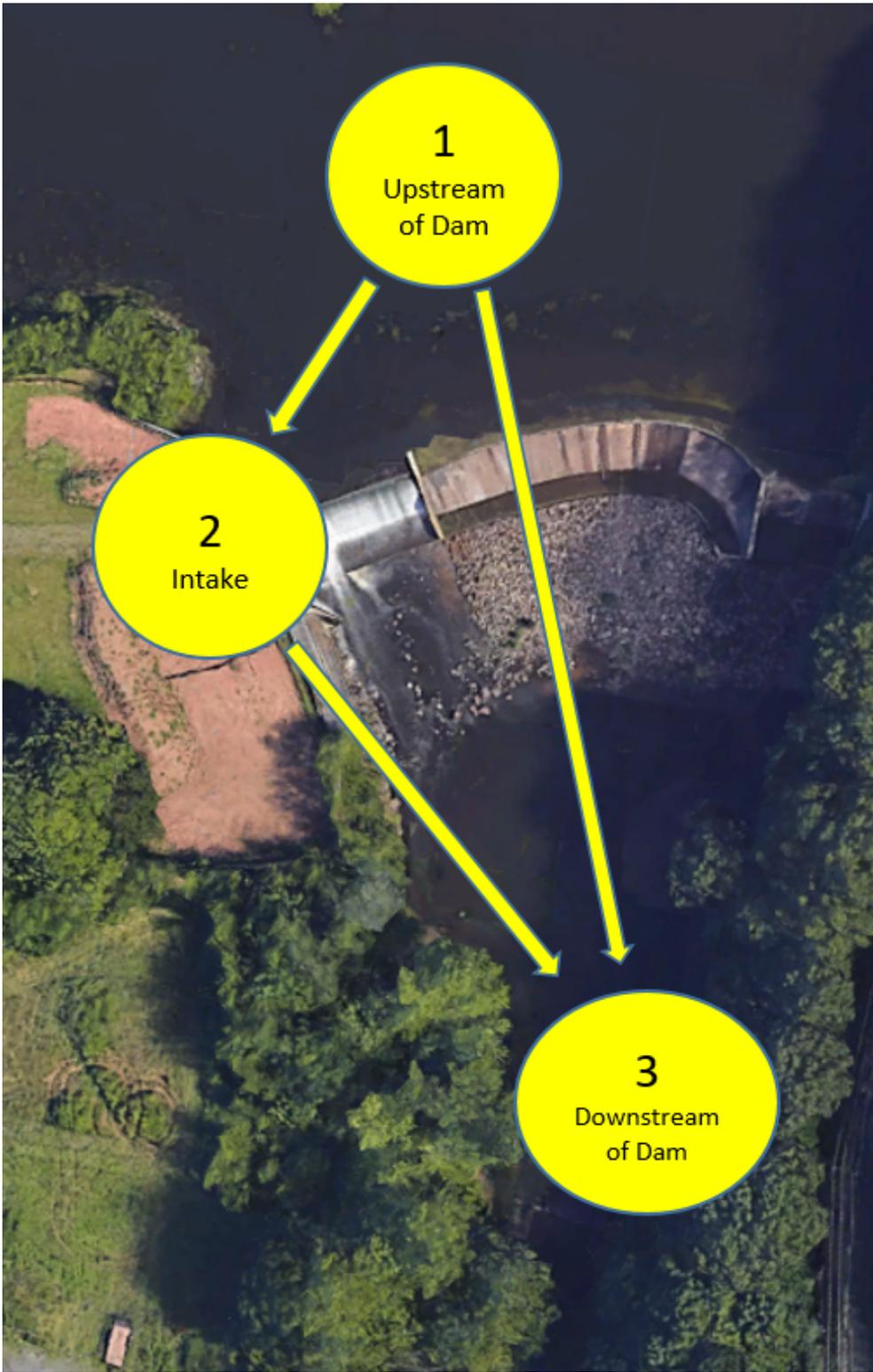
1. Brackley, R., Bean, C., Thomas, R., 2015. Session E9: Migration of Atlantic Salmon (*Salmo Salar*) at Low-Head Archimedean Screw Hydropower Schemes.
2. Havn, T. B., Sæther, S. A., Thorstad, E. B., Teichert, M. A. K., Heermann, L., Diserud, O. H., Borchering, J., Tambets, M., & Økland, F. (2017). Downstream migration of Atlantic salmon smolts past a low head hydropower station equipped with Archimedes screw and Francis turbines. *Ecological Engineering*, 105, 262–275. <https://doi.org/10.1016/j.ecoleng.2017.04.043>
3. Nebiolo, K. P., & Castro-Santos, T. (2021). In Press - BIOTAS: BIO Telemetry Analysis Software, For the Automated Removal of False Positives from Radio Telemetry Data. *Animal Biotlemetry*, 22.
4. Piper, A. T., Rosewarne, P. J., Wright, R. M., & Kemp, P. S. (2018). The impact of an Archimedes screw hydropower turbine on fish migration in a lowland river. *Ecological Engineering*, 118, 31–42. <https://doi.org/10.1016/j.ecoleng.2018.04.009>

5. Simmons, S.; Lubitz, W. Archimedes screw generators for sustainable energy development. In Proceedings of the 2017 IEEE Canada International Humanitarian Technology Conference (IHTC), Toronto, ON, Canada, 21–22 July 2017; pp. 144–148.
6. Spah, H., 2001. Fishery biological opinion of the fish compatibility of the patented hydraulic screw from Ritz Atro. Bielfield, Germany.
7. Therneau, T., Crowson, C., & Atkinson, E. Multi-state models and competing risks. (2016, October). <https://cran.r-project.org/web/packages/survival/vignettes/compete.pdf>. Accessed 22 March 2020.
8. Therneau, T., Crowson, C., & Atkinson, E. Using Time Dependent Covariates and Time Dependent Coefficients in the Cox Model. 2017.

## Figures

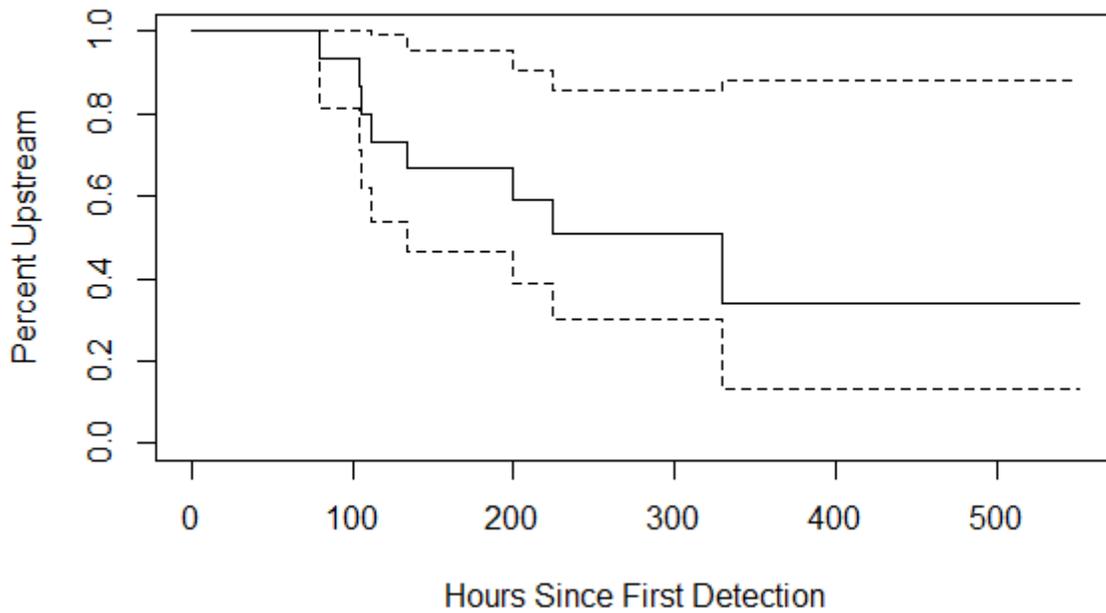


**Figure 1**  
 Map of the project area and the coverage of the three fixed telemetry monitoring stations



**Figure 2**

Competing risk model network for Hanover Pond Dam, showing routes of passage



**Figure 3**

Kaplan-Meier Survival Analysis Curve Displaying Downstream Movement over Time with 95% Confidence Intervals

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AppendixAStatisticalMethodsAppendix.docx](#)
- [Photograph1.png](#)
- [Photograph2.png](#)
- [Photograph3.png](#)
- [Photograph4.png](#)