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December 29, 2017
VIA E-FILING

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N. E.
Washington, DC 20426

Ellsworth Hydroelectric Project FERC No. 2727-086
2017 Downstream Passage Studies – Final Study Reports

Dear Secretary Bose:

Black Bear Hydro Partners, LLC (Black Bear), licensee for the Ellsworth Hydroelectric Project (Project), filed an Application for New License (Application) for the Project on December 30, 2015. The Application detailed the plan and timeline for conducting several continuing studies necessary to inform the Commission's license decision.[1] Three[2] of the study reports were filed in December, 2016, and two[3] additional study reports are being filed herewith.

In 2017, in accordance with the approved study plan, Black Bear conducted a second year of downstream smolt passage studies at the Project to continue to evaluate the performance of, and to test certain refinements to, the downstream passage facilities at both the Graham Lake Dam development and the Ellsworth Dam development. The resulting study report, an *Evaluation of Atlantic Salmon Smolt Passage*, was distributed to the applicable agencies on October 11, 2017 for a 30 day review and comment period. The National Marine Fisheries Service (NMFS or NOAA Fisheries) submitted comments on October 31, 2017 which are addressed in the attached final report. Additionally, in accordance with an approved study plan, Black Bear completed a salmonid release and recapture study at the Ellsworth Dam and powerhouse to assess salmon smolt survival or injury (using trout as a surrogate) at specific passage routes through the facilities. The resulting study report, an *Evaluation of Survival and Injury Occurrence Associated with Downstream Passage for Juvenile Salmonids*, was submitted to the agencies on November 17, 2017 for a review and comment period ending on December 15, 2017. The NMFS submitted comments dated December 7, 2017 which are addressed in the attached final report. No other entity commented on either report.

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[1] This relicensing is being conducted under the Commission's Integrated Licensing Process. During the course of reviewing and commenting on the Updated Study Report and Draft License Application, and in its Determination on Requested Study Modifications (December 8, 2015) the Commission authorized, or required the continuance of, several studies post-filing of the Application.

[2] See December 22, 2016 filing of the 2016 Tributary Access Study Report, the 2016 Atlantic Salmon Smolt Downstream Passage Study and a status report for the Adult American Eel Downstream Passage Study.

[3] The 2017 *Evaluation of Atlantic Salmon Smolt Passage* and the 2017 *Evaluation of Survival and Injury Occurrence Associated with Downstream passage for Juvenile Salmonids*.

In summary, Black Bear has conducted a second year of downstream smolt passage study (passage routes and survival) for the overall Project along with a separate Ellsworth development route specific injury and survival study in 2017. The draft reports have been reviewed by the appropriate agencies and the final reports, revised to address agency comments as applicable, are attached hereto.[4]

If you have any questions regarding this filing, please contact me by phone at (207) 755-5603 or by email at Frank.Dunlap@BrookfieldRenewable.com.

Sincerely,

Frank H. Dunlap
Licensing Specialist
Brookfield Renewable

cc: Distribution List
N. Palso, FERC
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[4] In addition, by letter dated December 8, 2017, Black Bear respectfully requested an extension of time until May 31, 2018 to submit a revised Draft Biological Assessment and Species Protection Plan in order to consider the information provided by these studies and continue agency consultation and consideration of potential enhancements of both upstream and downstream fish passage at both project developments.

DISTRIBUTION LIST
Ellsworth Hydroelectric Project (FERC No. 2727)
2017 Downstream Passage Study Reports

I, Frank H. Dunlap, Licensing Specialist, Brookfield Renewable, hereby certify that a link to the foregoing documents on the Commission website has been transmitted to the following parties on December 29, 2017.

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1.0 Introduction and Background

Black Bear Hydro Partners, LLC (BBHP or Black Bear) owns and operates the Ellsworth Hydroelectric Project (Federal Energy Regulatory Commission [FERC] No. 2727) (Ellsworth Project or Project) on the Union River pursuant to the license issued by FERC on December 28, 1987. Black Bear is in the process of relicensing the existing Ellsworth Project. On December 30, 2014, FERC issued a determination on requests for study modifications and new studies for the Ellsworth Project. In that determination, FERC recommended that Black Bear conduct a field study to evaluate downstream Atlantic salmon smolt passage at the Project. As requested, Black Bear developed a study plan, in consultation with the resource agencies, to evaluate the effectiveness of downstream passage of Atlantic salmon smolts. The final study plan was filed with FERC on March 31, 2015. A draft report, providing a summary of the methods and results of the 2016 Atlantic salmon smolt evaluation at Ellsworth was submitted to the National Marine Fisheries Service (NMFS), United States Fish and Wildlife Service (USFWS), Maine Department of Marine Resources (MDMR), and the Maine Department of Inland Fisheries and Wildlife (MDIFW) on October 19, 2016. A supplemental examination of downstream passage events at Graham Lake Dam was provided to the resource agencies on November 9, 2016. Written comments were received from NMFS and MDMR and responses to each comment were provided in the final 2016 study report which was filed with FERC on December 22, 2016.

Based on observations made during the first year of study, the release and monitoring approaches for evaluation of downstream passage at the Ellsworth Project were modified and a draft study plan for 2017 was submitted to NMFS, USFWS, MDMR, and MDIFW on November 11, 2016. Following receipt and response to agency comments, a final study plan for the evaluation of downstream smolt passage at the Graham Lake and Ellsworth dams during spring 2017 was submitted to FERC on January 31, 2017. A draft report, providing a summary of the methods and results of the 2017 field evaluation was submitted to NMFS, USFWS, MDMR, and MDIFW on October 11, 2017. The transmittal correspondence along with written comments provided by NMFS is included in Appendix E. Responses to comments received are provided in Appendix F and where appropriate, this final study report has been updated to reflect the content of those comments.

1.1 Study Objectives

The objective of the 2017 study was to further evaluate downstream passage routes and survival for outmigrating Atlantic salmon smolts at both the Graham Lake and Ellsworth facilities. Based upon the results of the 2016 study, Black Bear temporarily modified the existing passage measures (i.e., those evaluated during the 2016 study) to evaluate whether the selected modifications may improve passage success. At Graham Lake Dam, Black Bear modified the approach to the existing downstream passage weir by adding a floor and two side panels to create an Alden weir and a bell-shaped approach to smooth approach velocities and subsequently improve attraction (Figure 1-1). At the Ellsworth facilities Black Bear temporarily removed three seven-foot-wide sections of flashboards adjacent to the existing downstream passage weir to provide additional passage flow and to evaluate a potential additional route for downstream passage (Figure 1-2). In addition, the section of the Ellsworth Dam spillway below the removed flashboards was resurfaced to eliminate potential sources of injury or mortality (Figure 1.3).

The design of the 2017 study also allowed for collection of additional information including residence time immediately upstream of the facilities, temporal distribution of arrival and passage at the project dams, downstream bypass effectiveness, transit times and rates through defined sections of interest within the study reach, as well as background or natural mortality through non-impounded reaches of the Union River.

1.2 Project Description

The Ellsworth Project is located on the lower reach of the Union River in the City of Ellsworth and the towns of Waltham and Mariaville in Hancock County, Maine. The project consists of an upper dam with a large storage reservoir (Graham Lake) and a lower dam (Ellsworth Dam) located about 4 miles downstream, with a small reservoir (Leonard Lake). The Graham Lake Dam consists of three 20-foot-wide tainter gates, and an 8-foot-wide bay with a 4-foot-wide overflow weir (controlled with stoplogs) used for downstream fish passage. This weir empties into a plunge pool which subsequently discharges into the river below the dam structure. The Ellsworth Dam consists of an integral dam and intake structure with four short penstocks; the spillway of the dam is approximately 275 feet long. The existing downstream fish passage system at Ellsworth consists of three downstream passage surface weirs that deliver migrants to the sluice located on the western end of the spillway adjacent to the powerhouse. The Ellsworth Dam forms the upper limit of the tidal influence of the Union River. The Union River flows into the Union River Bay approximately 3.5 miles downstream from the project.

Ellsworth Dam is approximately 377 feet long, including a 275-foot-long spillway, and is 65 feet high with 26-inch-high flashboards on the spillway. Leonard Lake extends approximately 1 mile upstream of Ellsworth Dam and has a surface area of 90 acres at normal water surface elevation 66.67’ USGS datum. The Ellsworth powerhouse contains four turbines which have a total rated capacity of 8,900 kW. Units 1 and 4 are vertical shaft propeller turbines, and Units 2 and 3 are vertical shaft Kaplan turbines. Ellsworth Dam is equipped with a vertical slot upstream fishway and trap. The downstream fish passage facilities consist of stop-log-controlled surface weirs and a transport pipe and sluice leading to a plunge pool immediately downstream of the dam. The downstream fishway is operated from April 1 to December 31 each year, as river conditions allow.

Graham Lake Dam is a flood control and storage facility that does not contain a powerhouse or hydroelectric turbines. Graham Lake Dam is 30 feet high and consists of a 670-foot-long non-overflow earth dike and an 80-foot-long concrete gate structure. The concrete gate structure contains three 20-foot-wide radial gates and an eight-foot-wide bay with a four-foot-wide sluice that is used for downstream fish passage.

The Project is operated with a continuous minimum flow requirement of 105 cubic feet per second (cfs) from the Graham Lake Dam and Ellsworth Dam from July 1 through April 30, and a continuous minimum flow requirement of 250 cfs from May 1 through June 30. The flows can be temporarily modified if required by operating emergencies beyond the control of the Licensee, and for short periods upon agreement among the Licensee, the U.S. Fish and Wildlife Service (USFWS), and the Maine Department of Environmental Protection (MDEP).

Figure 1–1. Alden weir installed into the downstream sluice at Graham Lake Dam. Photo on top left shows unit in build shop (oriented with the upstream entrance towards the shop floor and the weir floor facing the viewer),photo on top right shows the unit installed (as viewed from the downstream side of the sluice) and photo on bottom shows weir as viewed from upstream looking down through.

Figure 1–2. Approximately 20 feet of opened flashboards (three sections) at the Ellsworth Dam to provide additional passage opportunity for tagged Atlantic salmon smolts, spring 2017.

Figure 1–3. Ellsworth spillway face showing condition prior to study (top), concrete repair work (lower left), and final surface prior to opening of downstream bypass and additional flashboard spill during the 2017 study (lower right).

2.0 Telemetry Methodology

2.1 Overview

Smolt passage during the 2017 outmigration period was assessed using a combination of radio and acoustic telemetry at the Ellsworth Project. Detection information collected for radio-tagged Atlantic salmon smolts was used to inform on passage and survival through freshwater portions of the Ellsworth Project area. Given the physical location of the Ellsworth Dam relative to the upstream extent of saltwater intrusion into the lower Union River, acoustic-telemetry was used to inform on survival through that reach. Attenuation of radio signals due to dissolved salts reduces the signal range to near zero in brackish or salt water which can render the use of radio-telemetry ineffective. As a result, the survival of Atlantic salmon smolts passing Ellsworth dam during 2017 was estimated based on passage of acoustically tagged individuals. The feasibility of also evaluating survival during 2017 using radio-tagged smolts at Ellsworth dam was evaluated through the downstream drift patterns of freshly-dead, radio-tagged pseudo "smolts" (i.e., brown trout) released to mimic individuals killed during passage.

Hatchery-reared Atlantic salmon smolts were obtained from the Green Lake National Fish Hatchery (GLNFH) in Ellsworth, Maine. Releases of surgically-tagged, hatchery-reared individuals were initiated in mid-May and were completed prior to water temperatures reaching 18°C. Releases were conducted at three locations (Figure 2-1):

- Release Site 1 - Upstream of Graham Lake Dam at a point along the western shoreline approximately 0.75 miles upstream of the dam;
- Release Site 2 - Downstream of Graham Lake Dam at a point along the western bank downstream of bypass sluice discharge; and
- Release Site 3 - Downstream of Ellsworth Dam from the deck of the upstream fishway.

A total of four release events were conducted during the study. Each release event consisted of 75 tagged study smolts, including 30 radio-tagged smolts released upstream of Graham Lake Dam, 15 radio-tagged and 15 acoustic-tagged smolts released downstream of Graham Lake Dam and 15 acoustic-tagged individuals released downstream of Ellsworth Dam.

The downstream progression of radio-tagged smolts was monitored via a series of stationary telemetry stations installed at selected locations to inform on passage rates and passage success through the lower portion of Graham Lake, Graham Lake Dam, Leonard Lake, and Ellsworth Dam. In addition to the stationary telemetry data collected during the study period, mobile tracking was conducted following each smolt release in an effort to determine the interim and final locations of radio-transmitters not passing the entire array. The downstream progression of acoustic-tagged smolts was monitored via a series of moored underwater receivers located in the headpond of the Ellsworth Dam and at three locations in the lower Union River prior to its entry into Union Bay.

2.2 Telemetry Equipment

The presence of radio-tagged outmigrating Atlantic salmon smolts was recorded on the Union River using a combination of Lotek (SRX_400 and SRX_600) and Sigma Eight (Orion) radio telemetry receivers. Radio-telemetry receivers were placed following consideration of the detection requirements for the intended area of coverage as well as the attributes of the receiver model. The Sigma-Eight Orion receiver is a broadband receiver capable of monitoring multiple channels simultaneously within a 1-MHz band and was used for monitoring radio-tagged fish in areas where movement through the detection field can occur quickly (e.g., turbine units and downstream bypasses). Although Lotek receivers have a greater detection range they can only monitor a single frequency at a time and as a result are required to toggle through each study frequency. This switching can decrease detection efficiency in areas where fish are passing at a higher rate of speed. As a result, Lotek receivers were used at locations requiring longer range and where the intended detection field can be characterized by relatively slow transit speeds for tagged fish. Several types of antennas were used for this study including four-element and six-element Yagi antennas as well as custom-made underwater antennas. Yagi antennas provided directional coverage and were utilized in open areas (e.g., cross-river locations or tailrace). Custom built dropper antennas were placed at appropriate depths within structures and were used to determine points of passage (i.e., downstream bypass and turbine units).

Radio transmitters were purchased from Lotek Wireless (model NTC-3-2) and were digitally encoded on one of three unique frequencies (149.100, 149.300 or 149.340 MHz). Each transmitter measured 6.0 mm x 16.0 mm, weighed 1.1 g in air, and was programmed by the manufacturer to propagate a signal once every 2.0 seconds. Transmitters used during this study had a manufacturer's warranty for battery life of 31 days.

Downstream movements of acoustic-tagged outmigrating salmon smolts were recorded upstream and downstream of Ellsworth using Vemco VR2W 69 kHz receivers. Acoustic receivers were secured to mooring blocks and deployed by boat for the duration of the study period (Figure 2-2). Acoustic transmitters were purchased from Vemco (model V9-6L) and operated on a frequency of 69 kHz. Transmitters were programmed by the manufacturer for a 20-40 second ping rate for 45 days and a 60-80 second ping rate for the remainder of the operating period. Each acoustic transmitter measured 9.0 mm x 21.0 mm and weighed 2.9 g in air.

2.3 Monitoring Stations and Antenna Arrangements

Radio telemetry antennas and data logging receivers were installed at both Graham Lake and Ellsworth Dams, as well as at selected locations upstream and downstream of both facilities to monitor downstream passage of the radio-tagged smolts. A total of fifteen stationary radio-telemetry receivers were installed on the Union River during 2017 (identified in this report as U1-U15). Three monitoring stations were associated with the Graham Lake Dam (U1-U3) and eight monitoring stations with the Ellsworth Dam (U6-U13). A total of five stationary acoustic-telemetry receivers (identified in this report as stations U16-U19) were installed on the Union River during 2017. Two units were moored in the Ellsworth headpond and provided redundant coverage to ensure that no smolts approaching the dam were missed. Three acoustic units were installed at locations downstream of Ellsworth Dam. These three acoustic receivers were placed at locations further downstream of Ellsworth Dam during 2017 than they were installed at during 2016. A description of each monitoring station is provided below, and locations are shown graphically in Figure 2-3.

Monitoring Station U1: This station was located on the upstream face of Graham Lake Dam and was intended to inform on radio-tagged smolts approaching the upstream side of the tainter and stop-log gates at that facility. Monitoring station U1 consisted of a single radio-receiver and aerial antenna. For the purposes of this study, it was assumed that coverage by this receiver extended from the upstream face of the dam to a point approximately 200 m upstream into Graham Lake.

Monitoring Station U2: This station was installed for the purpose of determining downstream passage of radio-tagged smolts through the overflow weir (equipped with the Alden weir) used for downstream fish passage at Graham Lake Dam. Monitoring station U2 consisted of a single radio-receiver and an aerial antenna.

Monitoring Station U3: This station was located on the downstream side of Graham Lake Dam and was intended to inform on radio-tagged smolts having passed that facility. Monitoring station U3 consisted of a single radio-receiver and aerial antenna oriented to cover the width of the river channel.

Monitoring Station U4: This station was located on the western bank of the Union River at a point approximately 3.4 km (2.1 miles) downstream of Graham Lake Dam and provided passage information on radio-tagged smolts moving downstream following passage at that facility. Monitoring station U4 consisted of a single radio-receiver and an aerial antenna oriented perpendicular to the river channel.

Monitoring Station U5: This station was located on the western bank of the Union River and near the upper extent of Leonard Lake. Monitoring Station U5 was located at a point approximately 4.2 km (2.6 miles) downstream of Graham Lake Dam and 2.4 km (1.5 miles) upstream of Ellsworth Dam. It consisted of a single radio-receiver and aerial antenna oriented perpendicular to the river channel.

Monitoring Station U6: This station was located on the western bank at a point approximately 200 m upstream of Ellsworth Dam. Monitoring Station U6 consisted of a single radio-receiver and aerial antenna, which was oriented perpendicular to the river channel. This station provided information on radio-tagged smolts as they entered the Ellsworth Dam project area.

Monitoring Station U7: This station consisted of a single receiver and two custom-made underwater drops. Dropper antennas were positioned within the vent tubes of Ellsworth unit 1 at a point inside of the trash racks and towards the upstream end of the penstock.

Monitoring Station U8: This station consisted of a single receiver and two custom-made underwater drops. Dropper antennas were positioned within the vent tubes of Ellsworth unit 2 at a point inside of the trash racks and towards the upstream end of the penstock.

Monitoring Station U9: This station consisted of a single receiver and two custom-made underwater drops. Dropper antennas were positioned within the vent tubes of Ellsworth unit 3 at a point inside of the trash racks and towards the upstream end of the penstock.

Monitoring Station U10: This station consisted of a single receiver and two custom-made underwater drops. Dropper antennas were positioned within the vent tubes of Ellsworth unit 4 at a point inside of the trash racks and towards the upstream end of the penstock. Note that Unit 4 did not operate during the duration of the study.

Monitoring Station U11: This station consisted of a single receiver and a pair of custom-made underwater drops and was intended to detect radio-tagged smolts passing Ellsworth Dam via one of the two surface weirs located adjacent to Units 2 and 4. The two drop antennas were installed within the concrete chamber located immediately upstream of its confluence with the pipe leading to the sluice located at the western end of the spillway adjacent to Unit 1. Drop antennas were installed at this location to ensure that any radio-tagged individuals detected had committed to passage via that route and were not being detected from areas within the adjacent headpond.

Monitoring Station U12: This station consisted of a single receiver and a custom-made underwater drop antenna, and was intended to detect radio-tagged smolts passing Ellsworth Dam via the surface weir located adjacent to Unit 1, which exits directly into the sluice located at the western end of the spillway.

Monitoring Station U13: This station was located on the western bank at a point approximately 40 m (131 feet) downstream of Ellsworth Dam. Monitoring Station U13 consisted of a single radio-receiver and aerial antenna, which was oriented perpendicular to the river channel. This station detected radio-tagged smolts as they passed the Ellsworth facilities and provided validation of passage via the turbine and bypass routes. In the presence of spill, detection information at this location (coupled with lack of detection information at Stations 7-12) was used to infer the occurrence of passage via spill through the three open sections covering approximately 20 feet of the flashboards along the spillway.

Monitoring Station U14: This station was located on the eastern bank of the Union River at a point approximately 0.4 km (0.25 miles) downstream of Ellsworth Dam. It consisted of a single radio-receiver and an aerial antenna oriented perpendicular to the river channel.

Monitoring Station U15: This station was located on the eastern bank of the Union River at a point approximately 0.6 km (0.4 miles) downstream of Ellsworth Dam. It consisted of a single radio-receiver and an aerial antenna oriented perpendicular to the river channel.

Monitoring Stations U16: This station consisted of a pair of underwater Vemco receivers located approximately 200 m (656 feet) upstream of Ellsworth Dam. Monitoring station U16 was intended to detect acoustic-tagged smolts as they entered the Ellsworth Dam project area.

Monitoring Stations U17: This station consisted of an underwater Vemco receiver located approximately 3.0 km (1.9 miles) downstream of Ellsworth Dam. Monitoring station U17 was intended to provide passage information on acoustic-tagged smolts moving downstream following release in the tailrace or passage at the Ellsworth facility. This station was placed in the vicinity of the furthest downstream acoustic monitoring station deployed during the 2016 study.

Monitoring Stations U18: This station consisted of an underwater Vemco receiver located approximately 4.4 km (2.8 miles) downstream of Ellsworth Dam and 1.4 km (0.9 miles) downstream of monitoring station U17. Monitoring station U18 was intended to provide passage information on acoustic-tagged smolts moving downstream following release in the tailrace or passage at the Ellsworth facility.

Monitoring Stations U19: This station consisted of an underwater Vemco receiver located approximately 5.2 km (3.3 miles) downstream of Ellsworth Dam and 0.8 km (0.5 miles) downstream of monitoring station U18. Monitoring station U19 was intended to provide passage information on acoustic-tagged smolts moving downstream following release in the tailrace or passage at the Ellsworth facility.

Each radio-telemetry monitoring station consisted of a data-logging receiver, one or more antennas, and a power source. The monitoring stations were configured to receive signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receiving stations to maximize detection efficiencies at each of the routes and locations, while minimizing the degree of overlap among adjacent monitoring stations. The operation of the radio-telemetry system as a whole was confirmed throughout the study period by the use of beacon tags. Beacon tags were stationed at strategic locations within the detection range of either multiple or single antennas, and were programmed to emit a signal at scheduled time intervals. These signals were detected and logged by the receivers and used to record the functionality of the system throughout the study period. Although each monitoring station was installed in a manner which limited its ability to detect transmitters from unwanted areas, the possibility of such detections did still exist. As a result, behavioral data collected in this study (i.e., duration at a specific location or passage route) was inferred based on the signal strength, duration and pattern of contacts documented across the entire detection array.

2.4 Transport, Holding, Tagging and Release Procedures

Hatchery-reared Atlantic salmon smolts were obtained from GLNFH in Ellsworth, Maine. Smolts were transported by Normandeau personnel in an oxygenated hauling tank to a holding facility installed at Ellsworth Dam. Transport personnel followed the criteria specified by GLNFH with regards to hauling densities and water quality standards. Water quality parameters were recorded at periodic intervals during transit to ensure that tank conditions were appropriate for the smolts (Appendix A). Once on site, smolts were maintained in covered 300 gallon tanks supplied with flow-through river water. A low flow of oxygen was provided to all tanks holding smolts as a safety precaution in the event that power was lost to the water supply pump.

Prior to tagging, the main anesthetic container and a gravity-fed drip bucket were prepared. Smolts were anesthetized using buffered tricaine methanesulfonate (MS-222) at a concentration of 80 milligram per liter (mg/L) of fresh water. The MS-222 was buffered using sodium bicarbonate in a 1:1 ratio. A gravity-fed bucket containing fresh river water was equipped with rubber tubing leading to an in-line valve. Smolts placed in the main anesthetic container were visually monitored and were removed from anesthesia 15-30 seconds following the loss of equilibrium. While immobile, the smolt was weighed to the nearest gram (g) and measured to the nearest millimeter (mm). The smolt was placed ventral side up and supported by a soft, moist towel. The gravity-fed supply line was inserted into its mouth to provide a continuous supply of fresh river water during the procedure.

Both acoustic and radio-transmitters were surgically implanted. Prior to insertion into the body cavity, the transmitter was activated and its unique ID code verified. An incision was made on the left side of the fish, adjacent to the ventral mid-line and just anterior to the pelvic girdle. For insertion of radio-tags, a hollow needle was inserted into the incision and was pushed through the body wall just off of the ventral mid-line, at a point posterior to the incision and between the pelvic girdle and anal fin. The radio antenna was fed through the needle and gently pulled so that the transmitter entered the body cavity. The needle was then removed from the antenna. The transmitter was positioned by pulling the antenna so that the transmitter lay directly under the incision. Acoustic transmitters did not have an antenna and were simply inserted into the body cavity. The incision was closed with two to three interrupted sutures (chromic gut with a 4-0 cutting needle) evenly spaced across the incision. A small amount of antibacterial ointment was applied to the incision site to prevent infection. The smolt was immediately transferred to an aerated freshwater holding tank for observation during a 5-minute recovery period. Following recovery from anesthesia, tagged smolts were placed in a larger holding tank and maintained in circulating river water for a minimum of 24 hours to evaluate short-term tagging effects, tag retention, and post-tagging mortality.

Radio and acoustic-tagged smolts were transported in the same holding tanks into which they were placed following tagging. Smolts were moved by truck to the selected release sites. All releases were conducted after sunset. Smolts were placed in the water directly by submerging the holding/transport tank and allowing the smolts to volitionally exit the container. This was done to prevent any additional netting or direct handling prior to release.

2.5 Tag-life, Retention, Delayed Mortality Assessment

During the first trial period, a randomly selected group of five transmitters were activated and then held for the duration of the study in order to assess transmitter battery life. These active tags were checked daily in order to determine the time span for which each of the tags remained operational.

A total of 30 smolts were tagged with dummy radio tags to evaluate retention of the radio tags as well as long-term tagging/handling effects. Tagging procedures for these fish were identical to those used for fish being released into the river. Following tagging, individuals being assessed for retention and latent injury/mortality were maintained for the duration of the monitoring period in a separate holding tank equipped with flow through river water and supplemental oxygen to maintain quality conditions in the event of a pump failure. While a careful tagging procedure can minimize the potential for tag expulsion, tag loss is still a possibility as fish move through the river. In this situation, a fish can continue downstream, but the tag will become stationary, and that fish will be falsely assigned as a mortality. Should the results indicate potential introduction of bias into survival estimates based on prematurely failing transmitters or poor tag retention, the results of these tag life and tag retention studies will be factored into the survival estimates for the study fish in the river.

2.6 Downstream Drift Assessment

Prior to the use of downstream detection information from radio-tagged Atlantic salmon smolts to evaluate passage survival at Ellsworth Dam, it was necessary to understand the downstream settlement pattern for smolts killed during dam passage. To accomplish this, four[1] "smolts" (Note: hatchery-reared brown trout were used as a surrogate) were euthanized, internally radio-tagged following the same approach detailed in Section 2.4, and released into the Ellsworth tailrace (via the downstream bypass sluice located at the western end of the spillway that discharges directly into outflow from the project turbine units). This was the same route of introduction into the tailrace as was used during 2016 and was done so in order to ensure that these tagged "smolts" were injected into the project flow and did not become hung up during turbine passage. These individuals transmitted on a separate frequency than those used for test fish. The frequency for the drift test individuals were programmed for detection by the downstream monitoring stations. In addition, the stretch of the Union River downstream of Ellsworth was manually checked on a periodic basis to determine if smolts killed during passage would drift to or beyond the nearest radio-telemetry monitoring station under given 2017 flow conditions. Detection of these tagged individuals at the downstream monitoring station(s) was used as an indicator to determine if use of passage data for live releases of radio-tagged smolts would likely produce overestimates of project survival biased by the downstream drift of individuals killed during passage.

2.7 Data Analysis

2.7.1 Data Collection and Processing

Data were downloaded from radio-receivers on a near daily basis throughout the study period. Back-up copies of all data files were immediately saved to a dedicated flash drive and checked prior to re-initialization of the downloaded receiver. Data were stored in receivers as a single event, which included date, time, channel, code, and signal strength. Downloaded radio-telemetry files were processed using custom programs developed in-house at Normandeau using SAS (statistical analysis software, Version 9.3; SAS Institute Inc., Cary, North Carolina). Tag detections in each downloaded data file were validated and filtered based on a series of site-specific and logical criteria: These criteria included:

1. Power threshold level of the signal,
2. Frequency of the radio-tag signals per unit of time, and

[1] Note that the 2017 FERC approved study plan called for the use of five radio-tags to evaluate downstream drift. One of the five purchased tags could not be activated and as a result the test was conducted with four fish.

3. Spatial and temporal distribution of the radio signals detected at monitoring stations both at and between the dams.

Information related to the power threshold for a valid tag signal versus power levels associated with background noise were determined at each monitoring station prior to the release of any radio-tagged smolts. These "false" signals were typically at relatively low power levels and were removed from the analysis using a series of data filters. The frequency of the signal detections for an individual radio-tag was examined at each monitoring station, such that over a period of time adequate number of detections were available to rule out an isolated false detection (e.g., at least 3 detections within 1 minute). Finally, the spatial and temporal distributions of detections across multiple monitoring stations for each individual smolt were examined to verify that the pattern of detections was not unreasonable (i.e., for a fish to have relocated within the time between the detections).

Acoustic receivers were collected at the end of the monitoring period and downloaded a single time. Information included the transmitter ID and date-time of the detection. Similar to radio-telemetry data, the acoustic data files were processed in SAS and valid detection information was exported for the evaluation of passage survival at Ellsworth Dam.

In addition to the telemetry data collections, information on river flow and project operational data was obtained for Graham Lake and Ellsworth Dams. Water temperature in the Union River was collected using a HOBO data logger installed in the headpond above Ellsworth Dam and set to record at one hour intervals for the duration of the study.

2.7.2 Determination of Passage Route, Travel Times and Movement Rates

Following the completion of file processing using SAS, a complete record of all valid detections for each tagged salmon smolt was generated. The time series of detections for individual smolts equipped with radio-tags were evaluated to determine a route of passage at Graham Lake and Ellsworth Dams. At Graham Lake Dam, detection at Monitoring Station U2 prior to detection at Monitoring Station U3 was used to confirm passage via the modified downstream sluice. At Ellsworth Dam, an arrival time into the upstream project area was determined based on detections recorded by Monitoring Station U6. The subsequent pattern of detections was then reviewed and the time and route of passage determined. In the event a route could not be clearly determined from the collected data, the passage event for that particular smolt was classified as "unknown".

Where data were available, residence times in the nearfield area upstream of Graham Lake and Ellsworth Dams, as well as downstream transit times, were calculated for smolts. Residence times were calculated as the duration of time from the initial upstream (Monitoring Station U1 at Graham Lake Dam and Monitoring Station U6 at Ellsworth Dam) until the final detection at one of the monitored passage routes (e.g., bypass, turbine) or initial detection in the tailrace (e.g., spill). Residence times were calculated for radio-tagged smolts at Graham Lake Dam and for both radio and acoustic-tagged smolts at Ellsworth Dam. Downstream transit times were calculated as the duration of time from the peak signal strength of detection at an upstream location to the peak signal strength of detection at a downstream location.

In addition to travel times, rates of movement (ROM) for tagged smolts moving through river segments between monitoring stations were calculated using the formula:

$$ROM_{ab} = D_{ab} / (T_b - T_a)$$

where: ROM_{ab} = the rate of movement between stations *a* and *b*

D_{ab} = the distance (miles) between stations *a* and *b*

T_b = the date/time detected at station *b*

T_a = the date/time detected at station *a*

Rates of movement were calculated for radio-tagged Atlantic salmon smolts within the following study reaches (approximate distance):

Release Site 1 to Graham Lake Dam (0.75 miles)

Graham Lake Dam (Release Site 2) to Monitoring Station U4 (2.1 miles)

Monitoring Station U4 to Monitoring Station U5 (0.5 miles)

Monitoring Station U5 to Ellsworth Dam (1.5 miles)

Rates of movement were calculated for acoustic-tagged Atlantic salmon smolts within the following study reaches (approximate distance):

Release Site 2 to Ellsworth Dam (4.1 miles)

Ellsworth Dam (Release Site 3) to Monitoring Station U17 (1.9 miles)

Monitoring Station U17 to Monitoring Station U18 (0.9 miles)

Monitoring Station U18 to Monitoring Station U19 (0.5 miles)

2.7.3 Parameter Estimation

Survival (*S*) and detection (*p*) probabilities were estimated using a Cormack-Jolly Seber (CJS) model constructed in Program MARK (White and Burnham 1999). Parameter estimates for *S* and *p* were obtained using the individual encounter histories constructed for each smolt and were based on their unique series of detections as they move past adjacent detection locations. For this analysis, a suite of CJS models were evaluated and differed from one another based on whether survival, recapture (i.e., detection), or both varied or were held constant among stations. These models included:

- *S*(t)*p*(t);
- *S*(t)*p*(.);
- *S*(.)*p*(t); and
- *S*(.)*p*(.).

Where;

- *S* = probability of survival
- *p* = probability of detection
- (t) = parameter varies
- (.) = parameter is constant

Prior to comparison among models, goodness of fit testing was conducted for the 'starting model' (i.e., the fully parameterized model) using the function RELEASE within Program MARK. Within RELEASE, output from Test 2 and Test 3 combine to provide goodness of fit information for the fully time dependent model. If the resultant χ^2 results from Test 2, Test 3, or the overall result (Test 2 + Test 3) are significant, then the test assumptions are violated and the fully parameterized model does not provide adequate goodness of fit. To accommodate for the lack of fit, a measure of how much extra binomial noise (i.e., variation) exists in the data is needed. This value, the variance inflation factor ($\hat{c}$), can be estimated within MARK and used to correct for any minor over-dispersion. To estimate $\hat{c}$, the bootstrap (observed full model deviance / mean deviance among 200 simulated deviances) and median $\hat{c}$ procedure (logistic regression) were performed. To be conservative, the larger of the two values was used for adjusting variance (if required).

Akaike's Information Criterion (AIC) was used to rank the models as to how well they fit the observed mark-recapture data. Lower AIC values denote a more explanatory yet parsimonious fit than higher AIC values. Assuming the assumptions of the model with the lowest AIC value were reasonable with regards to this study, it was selected for the purposes of generating MARK-derived reach-specific estimates of survival and detection probability. Estimates of survival were determined for radio-tagged smolts moving through the following reaches:

- Graham Lake release site to upstream of Graham Lake Dam (Stn U1)
- Upstream of Graham Lake Dam (Stn U1) to downstream of Graham Lake Dam (Stn U3)
- Downstream of Graham Lake Dam (Stn U3) to Monitoring Station U4
- Monitoring Station U4 to Monitoring Station U5
- Monitoring Station U5 to Ellsworth approach (Stn U6)
- Ellsworth approach (Stn U6) to Ellsworth passage

Estimates of survival were determined for acoustic-tagged smolts moving through the following reaches:

- Downstream Graham Lake Dam release site to Ellsworth approach (Stn U16)
- Ellsworth approach (Stn U16) to Monitoring Station U17
- Monitoring Station U17 to Monitoring Station U18

Detection probabilities (*p*) were determined for radio-tagged smolts passing the following locations:

- Monitoring Station U1
- Monitoring Station U3
- Monitoring Station U4

- Monitoring Station U5
- Monitoring Station U6
- Ellsworth facilities
- Monitoring Station U14

Detection probabilities (p) were determined for acoustic-tagged smolts passing the following locations:

- Ellsworth approach (Stn U16)
- Monitoring Station U17
- Monitoring Station U18

Asymmetric ranges of the 95% and 75% CIs around the survivorship probabilities were calculated. The 95% CIs around mean parameter estimates resultant from CJS models in MARK are based on the assumption of an asymptotically normal distribution on the logit scale. By default, MARK uses α=0.05 for calculation of CIs. As a result, the 95% CIs were calculated as:

$$\beta_i \pm 1.96(SE)$$

where β_i is the mean parameter estimate on the logit scale, SE is the standard error of $\bar{x}$, and 1.96 is the critical t-value containing 95% of a normal distribution.

After the calculation of the upper and lower 95% confidence limits, all estimates were back transformed from the logit scale to the original scale of the data (0.00-1.00). The mean and confidence limits were back-transformed from the logit scale as:

$$\bar{x} = Logit(\beta_i)^{-1} = \frac{e^{\beta_i}}{1 + e^{\beta_i}}$$

where $\bar{x}$ is the mean parameter estimate or the confidence limit on the original scale of the data, and β_i is the mean parameter estimate or confidence limit on the logit scale. The back-transformed values are referred to as “real parameter estimates” in MARK. In order to calculate the 75% CI for survival estimates in MARK, the same procedure was used. The only difference between the calculations of 95% and 75% CI values was that the critical t-value used for calculating 75% CIs on the logit scale was 1.15 (the critical t-value containing 75% of a normal distribution).

2.7.4 Determination and Incorporation of Background Mortality

Survival estimates for reaches containing the Graham Lake and Ellsworth Dams obtained following the methodology presented in Section 2.7.3 are reflective of mortality due to a combination of both project and background effects. To allow for the separation of these two components from the CJS-derived survival estimates for the Graham Lake and Ellsworth facilities, an estimate of background mortality was required. Based on observations made during the 2016 field season, it is suspected that predation rates for the Union River in the vicinity of Graham Lake and Ellsworth Dams may not be equal (potential impacts include observed avian densities, tidal cycle, etc.). As a result, background mortality was estimated both upstream and downstream of Ellsworth Dam during 2017 with the upstream value used to correct passage survival at Graham Lake Dam and the downstream value used to correct passage survival at Ellsworth Dam.

Two CJS-derived survival estimates between Monitoring Stations U4 and U5 for radio-tagged smolts were used to determine the background mortality correction for use at Graham Lake Dam. The first of these estimates was based on the set of radio-tagged smolts released immediately downstream of Graham Lake Dam (i.e. release location 2) with no potential for delayed effects from previous dam passage events and the second was based on the set of radio-tagged smolts released immediately downstream of Graham Lake Dam as well as individuals released upstream of the dam into lower Graham Lake (i.e. release locations 1 and 2). Both groups were allowed ample distance between their release location and the upstream extent of the "background mortality reach" for any potential tagging or handling effects to be expressed prior to reach passage. The CJS-derived survival estimates between Monitoring Stations U17 and U18 for (1) acoustic-tagged smolts released immediately downstream of Ellsworth Dam (i.e., release location 3) and (2) acoustic-tagged smolts released downstream of Graham Lake Dam and downstream of Ellsworth Dam (i.e. release locations 2 and 3) were used to adjust for background mortality at that facility.

The estimates of background survival obtained from the CJS model for the two reference reaches were converted to instantaneous rates of background mortality and scaled for length of reach using the equation:

$$r = \frac{lnS}{l}$$

where r = the instantaneous rate of mortality, S = the CJS-derived survival estimate from MARK, and l = the reach length (in kilometers). A dam reach-specific mortality rate (M) was then calculated using r and the length of the reaches monitored from the approach to first downstream receiver using the equation:

$$M = 1 – S = 1 - e^{rl}$$

The dam reach-specific mortality rate (M) was then added to the CJS-derived survival estimates for each dam to calculate the background mortality adjusted survival rate.

At Graham Lake Dam, a dam reach survival estimate for radio-tagged smolts was calculated as the product of the independent, background mortality adjusted reach estimates from the approach receiver to dam passage and from dam passage to the first downstream receiver.

- **Graham Lake Dam (radio)**: [Stn U1 to Stn U3] * [Stn U3 to Stn U4]

At Ellsworth Dam, a dam reach survival estimate for acoustic-tagged smolts was calculated as the independent, background mortality adjusted reach estimate from the approach receiver to the first downstream receiver.

- **Ellsworth Dam (acoustic)**: [Stn U16 to Stn U17]

Finally, the error around the estimates for both the background and dam reach survival was propagated through addition in the quadrature:

$$ll = \sqrt{(m_{ll})^2 + s_{ll})^2}$$
$$ul = \sqrt{(m_{ul})^2 + s_{ul})^2}$$

where *ll* is the estimate of the lower confidence limit, m_{ll} is the difference between the expected background mortality rate and its lower confidence limit, s_{ll} is the difference between the expected reach-specific survival rate and its lower confidence interval, *ul* is the upper confidence limit, m_{ul} is the difference between the expected background mortality rate and its upper confidence limit, and s_{ul} is the difference between the expected reach-specific survival rate and its upper confidence interval. In the instance of Graham Lake Dam where the reach-specific survival estimate is a product of the survival estimate for the reach from the approach receiver to the dam and from the dam to the first downstream receiver a bootstrap procedure was used to generate confidence intervals around that estimate. Program MARK was used to generate 10,000 simulated parameter estimates and the output was imported into SAS software where a beta distribution was fit to the distribution of bootstrap replicates using the PROC UNIVARIATE procedure. Quantile values were obtained from the fitted beta distribution for an estimate of the lower and upper confidence limits (e.g. 75% or 95%) for the project reach survival estimate.

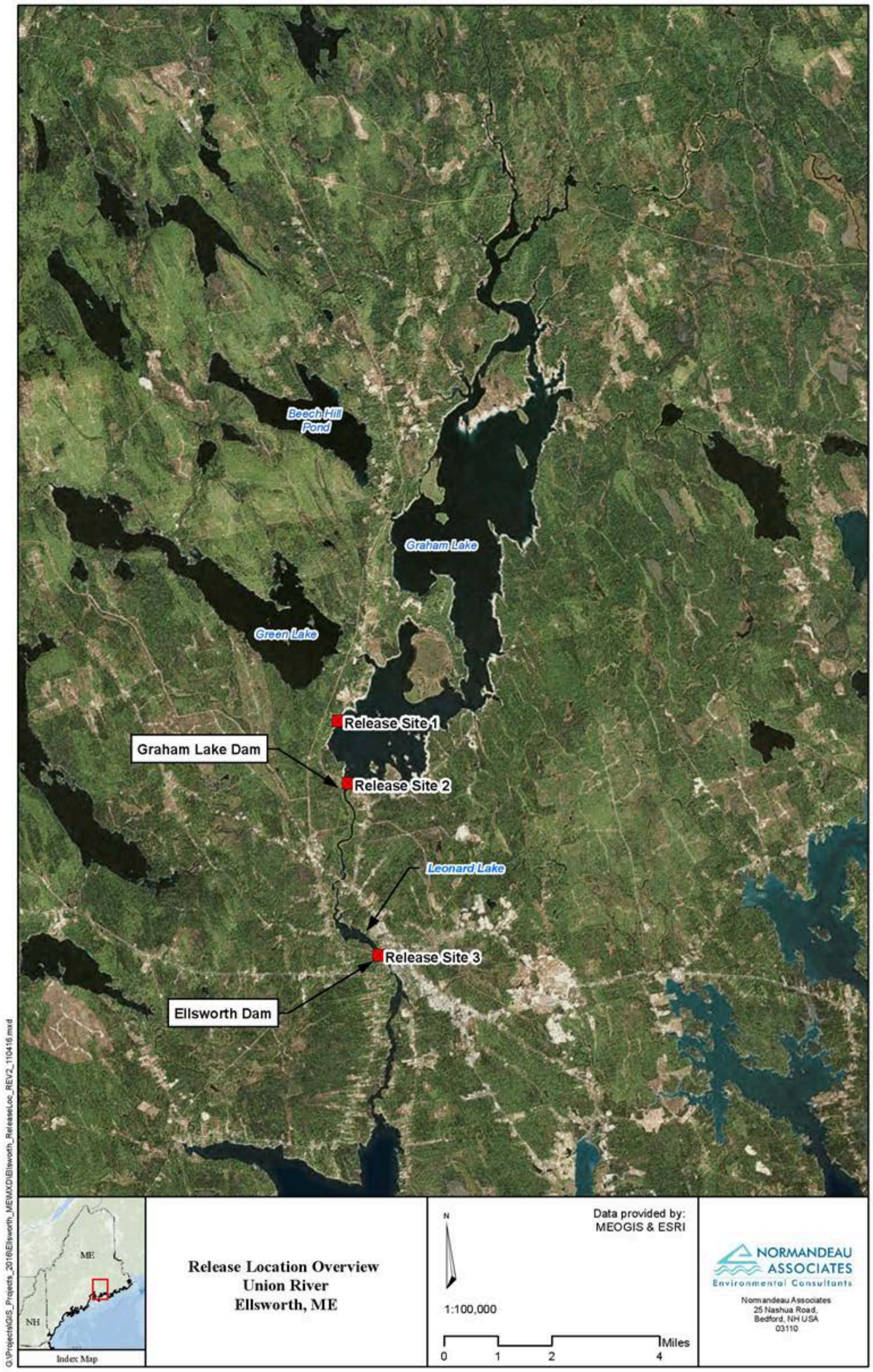

Figure 2–1. 2017 Ellsworth Project Atlantic salmon smolt release locations.

Figure 2-2. Vemco VR2W acoustic receiver and mooring platform deployed in the Union River during the 2017 downstream smolt passage evaluation.

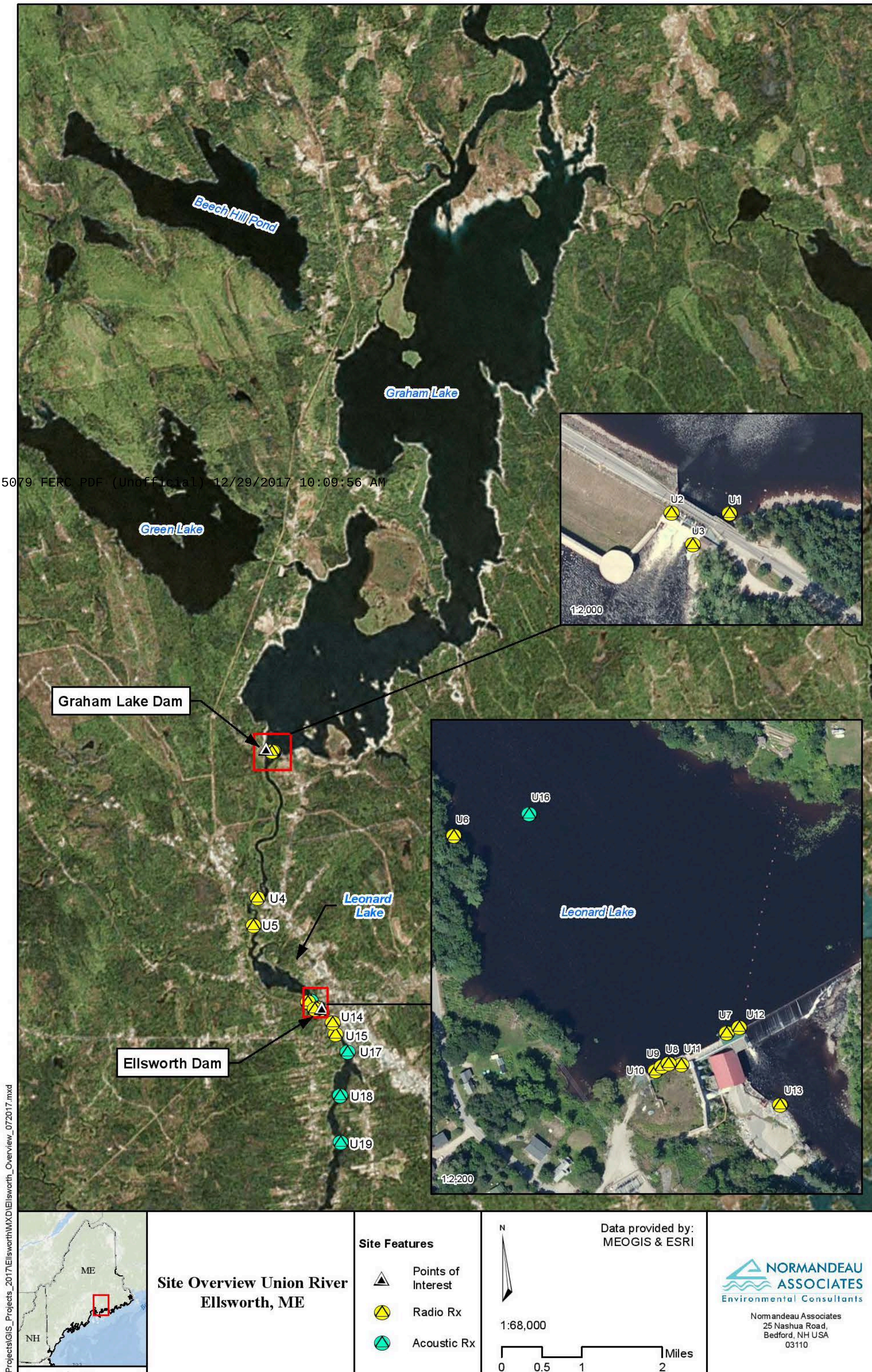

Figure 2-3. 2017 Ellsworth Project radio and acoustic-telemetry monitoring stations.

3.0 Tag-life, Retention, Delayed Mortality Assessment

3.1 In-River Test Smolts

All salmon smolts tagged for release at Ellsworth during 2017 were held for a minimum of 24 hours to assess tag retention and handling-induced mortality. Following radio-tagging, smolts (n=178) were held an average of 33.1 hours (range = 28.4-36.2 hours). Atlantic salmon smolts receiving acoustic transmitters (n=120) were held for an average of 29.1 hours (range = 26.9-31.0 hours) prior to release downstream of Graham Lake or Ellsworth Dam. There were no observed mortality events among radio or acoustic-tagged smolts during the post-tagging (or pre-release) evaluation during the 2017 study.

3.2 In-Tank Test Smolts

In addition to assessing the tag retention and delayed mortality of surgically-tagged smolts prior to their release into the Union River, an additional group of 30 smolts were radio-tagged with dummy NTC-3-2 transmitters and maintained in a holding tank at Ellsworth to assess study-duration effects. Tagging took place on May 17, 2017. Randomly selected individuals ranged in fork length from 172-210 mm (mean = 192 mm) and in weight from 47-92 g (mean = 69 g). All tank-test smolts were held for a total of eight days and during that period there were no observations of tag loss or post-tagging mortality. Following holding, individuals were transported to the Ellsworth marina downstream of the project and released into the lower portion of the Union River.

3.3 Transmitter Battery Evaluation

A total of five NTC-3-2 transmitters were randomly selected prior to the tagging of any Atlantic salmon smolts. These transmitters were activated on May 14, 2017 and were allowed to run continuously until their battery expired. Lotek Wireless states that the NTC-3-2 transmitter will operate for approximately 31 days when set to a 2.0 second burst rate. Each of the five transmitters operated for a minimum of 31 days (range = 31.9-37.8 d).

3.4 Downstream Drift Assessment

Hatchery-reared brown trout were obtained for use in evaluating downstream drift patterns of dead "smolts" at the Ellsworth Dam during 2017. A total of four individuals (mean FL = 205 mm; mean W = 97 g) were euthanized, radio-tagged, and then released into the Ellsworth Dam tailrace via the downstream bypass. The release of drift "smolts" took place at 2010 on May 18, 2017. Discharge at the time of release included Units 1, 2 and 3, the downstream bypass system, and the additional spill flow passing via the three open sections of flashboards. Overall, a total of 1,774 cfs (1,704 cfs via the project units and 332 cfs via waste) was passing the project at the time of release. Each of the four "smolts" was confirmed to have entered the tailrace, and their tags were active immediately following release. All four dead "smolts" were confirmed to have passed the downstream monitoring station. Peak signal strength occurred at 20 minutes, approximately 10 hours, approximately 13 hours and approximately 32 hours following release. Three of the four "smolts" passed the downstream monitoring location quickly. The fourth "smolt" remained within the detection field of the downstream receiver for approximately 2 days prior to disappearing. Its presence during that period was also confirmed during a manual tracking event. None of the four drift tags were detected within the reach from Ellsworth Dam downstream to the Ellsworth marina during the final manual tracking event which took place on May 31. As a result of the drift evaluation, downstream detection information for radio-tagged individuals passing Ellsworth Dam was not considered reliable to estimate project survival due to the likely bias of false positive detections (i.e., a smolt which was killed during passage but drifted and was detected at the downstream monitoring stations suggesting it was alive). This finding is opposite of that observed during 2016 when all five test "smolts" associated with the drift evaluation settled in the immediate tailrace following release through the downstream bypass system and remained stationary in the tailrace for the duration of the study period. The greatly lower total flow at time of release during the 2016 of only 461 cfs (398 cfs via Unit 3 and 63 cfs via waste) is likely responsible for the observed difference between the two study years.

4.0 2017 Study Findings

4.1 Ellsworth Operations and Union River Conditions

Hourly Union River discharge values at Ellsworth Dam are presented graphically in Figure 4-1. The mean Union River discharge for the entire study period (May 16 – June 3, 2017) was 1,190 cfs. Based on the long-term monthly flow duration curve (Figure 4-2), the normal monthly median flow for the site is approximately 900 cfs during May. Relative to the May long-term flow duration curve for the Union River at Ellsworth, river flows observed during the 2017 study period were 290 cfs greater than the median condition.

Flow discharges through Units 1-4 are presented in Figure 4-3. These values were obtained using recorded megawatt (MW) values for each unit and a station conversion factor. Unit 4 (one of two vertical shaft propeller turbines) was offline for the duration of the 2017 smolt study. Units 1 (vertical shaft propeller turbine) and 2 (vertical Kaplan turbine) operated intermittently during the study period, with Unit 1 operating on 11 of 19 study dates and Unit 2 operating on 10 of 19 study dates. Unit 3 operated over all 19 of the study dates (May 16-June 3, 2017). Non-unit discharge at Ellsworth was provided via (a) three stoplog-controlled surface weirs leading to a common sluice passing downstream on the western side of the spillway and (b) three opened approximately seven-foot-wide sections of flashboards adjacent to the existing downstream passage weir. Discharge via the downstream bypass system and adjacent flashboard opening was near constant at 262 cfs for the duration of the study period (Figure 4-4).

Downstream passage at Graham Lake Dam was provided via a 4-foot wide overflow weir controlled by stoplogs and outfitted with the Alden weir intake. The downstream sluice was open full (i.e., all stop logs removed) for the duration of the 2017 smolt monitoring period. The crest elevation for that sluice is 96.7',the long-term average pond elevation for the study period is approximately 104.16' and the licensed full pond elevation of Graham Lake is 104.2'. Figure 4-5 presents hourly lake level values for Graham Lake along with the calculated depth of spill through the downstream sluice. The mean lake level in Graham Lake for the study period was approximately 1.3 feet lower than the licensed full pond elevation for the study period. Spill depths through the downstream sluice ranged between 4.9 to 5.6 feet (approximately 130 and 158 cfs, respectively). In addition to the downstream sluice, the three bottom opening radial gates at Graham Lake Dam were in operation throughout the study period. Gates 1 and 2 were operated as needed to pass flows from Graham Lake and Gate 3 was opened to provide the required minimum flow for the duration of the study (Figure 4-6).

Union River water temperatures were recorded at Ellsworth for the duration of the study and are presented in Figure 4-1. Mean daily water temperature ranged between 11.3 and 18.0°C during the study period.

4.2 Monitoring Coverage

Figure 4-7 presents the coverage provided by each of the fourteen stationary radio-telemetry receivers installed in the vicinity of Graham Lake and Ellsworth Dams during 2017[2]. Station coverage was determined by beacon transmitter detections and by field personnel observations while conducting the near daily receiver checks and data downloads. The majority of monitoring stations operated with no issues for the duration of the study period (May 17 – June 5).

Inconsistencies in coverage occurred at two monitoring locations:

- Coverage was lost at Station U2 (Graham Lake downstream bypass) from soon after receiver initialization on May 17th until 1400 on May 18th. A review of arrival and passage times for radio-tagged smolts released into Graham Lake indicates that only two individuals passed Graham Lake Dam during that period. As a result of the missing coverage, use of the downstream bypass could not be confirmed for those two individuals.
- Coverage was lost at Station U7 (Unit 1 at Ellsworth Dam) from 0900 of May 24 until 0700 on May 25 due to an apparent interruption to the power supply. A review of arrival and passage times for radio-tagged smolts released upstream of Ellsworth Dam indicated that a total of 6 smolts arrived and passed during that time period. Two of those individuals had definitive passage routes. Four individuals had an initial detection in the tailrace following their detection at the approach receiver suggesting either passage via spill or undetected through Unit 1. Due to the inability to differentiate the passage route for these four fish, the route was classified as “unknown”.

4.3 Transport, Tagging, and Release

A total of 383 Atlantic salmon smolts were obtained from GLNFH on two dates (May 15 and 19, 2017) and were transported to holding facilities located at Ellsworth Dam. Smolts were surgically tagged at that location, held for at least 24 hours for post-surgery observation, and were then transported by truck to release sites. A total of 178 radio-tagged and 120 acoustic-tagged smolts were released over four dates (298 total tagged smolts; May 17, 19, 21 and 23).

[2] Station U10 (Unit 4) not included in Figure 4-7 as unit was offline for duration of monitoring period

Each release consisted of 30 radio-tagged smolts at release location 1 (i.e., point located upstream of Graham Lake Dam), 15 radio and 15 acoustic-tagged smolts at release location 2 (i.e., point located immediately downstream of Graham Lake Dam), and 15 acoustic-tagged smolts at release location 3 (i.e., immediately downstream of Ellsworth Dam).

Fork length for hatchery-reared Atlantic salmon smolts released at Ellsworth in 2017 ranged between 168-229 mm (mean = 191 mm), and their weight ranged between 45 - 118 g (mean = 68 g; Table 4-1).

4.4 Smolt Movements and Passage

Stationary telemetry data collected at radio-telemetry stations U1-U15 and acoustic-telemetry stations U16-U19 were used to identify travel times and rates of movement through various river reaches, as well as to provide passage route information at Ellsworth Dam.

4.4.1 Graham Lake Dam: Arrival, Residence and Downstream Passage

Passage through Graham Lake Dam was assessed using the set of 120 radio-tagged smolts released into lower Graham Lake at release location 1, approximately 0.75 miles upstream of the dam. Of the 120 radio-tagged smolts stocked at release location 1, 104 (87%) were determined to have approached the upstream face of Graham Lake Dam based on detection by Monitoring Station U1. The minimum, maximum, mean and median transit times for radio-tagged smolts with available detection data at Graham Lake Dam are presented in Table 4-2. Of individuals from release location 1 detected at the upstream side of Graham Lake Dam, 24% arrived within 24 hours of release and 76% arrived within 48 hours of release (Figure 4-8).

Residence time at Graham Lake Dam was calculated for radio-tagged smolts as the duration from their initial time of arrival (Monitoring Station U1) to their determined time of downstream passage (Monitoring Station U3). When radio-tagged smolts with available detection data were considered, the median residence time was 5.6 hours (Table 4-3; range 0.1 – 118.1 hours). Residence time from arrival until passage was less than 24 hours for the majority (67%) of radio-tagged smolts at Graham Lake Dam during 2017 (Figure 4-9).

A total of 104 radio-tagged smolts were available for evaluation of downstream passage at Graham Lake Dam during 2017 (Table 4-4). Of that total, 86 (83%) passed downstream of Graham Lake Dam with the majority of those (73%; 63 of 86) confirmed passing via the modified downstream bypass. The remainder of radio-tagged smolts passing Graham Lake Dam either did so (1) undetected via the modified downstream bypass or (2) via one of the bottom opening gates in operation for the duration of the study period.

Figure 4-10 presents the timing (by hour of the day) for the arrival and downstream passage of radio-tagged smolts at Graham Lake Dam by release group. The timing of downstream passage events at Graham Lake Dam did not appear to be influenced by time of day as events occurred across the full range of day and night time hours.

4.4.2 Union River and Leonard Lake Passage

Passage of Atlantic salmon smolts moving downstream from the Graham Lake Dam tailrace and approaching the Ellsworth Dam was monitored for both radio and acoustically-tagged individuals. Movement of radio-tagged smolts through the Union River reach downstream of

Graham Lake Dam and Lake Leonard was evaluated for (1) the subset of smolts from release location 1 which successfully passed at Graham Lake Dam, and (2) an additional 58 smolts released immediately below Graham Lake Dam (i.e. release location 2). Of the 58 radio-tagged smolts stocked at release location 2, 56 (97%) of those were determined to have arrived at the first receiver downstream of the dam (i.e., Station U4). The two radio-tagged smolts released in the tailrace and not reaching the first downstream receiver were part of release groups 1 (May 17) and 4 (May 23).

The minimum, maximum, mean and median transit times for radio-tagged smolts from those groups between (a) monitoring station U3/release location 3 (i.e., Graham Lake Dam tailrace) to monitoring station U4, (b) monitoring station U4 to U5, and (c) monitoring station U5 to U6 (i.e., Ellsworth Dam headpond) are presented in Table 4-5. When radio-tagged smolts from both release locations are considered, transit times through the three reaches downstream of Graham Lake Dam and delineated by stationary radio-telemetry equipment were relatively quick. The majority of radio-tagged smolts moved from the Graham Lake Dam tailrace to Monitoring Station U4 in under 12 hours, from Monitoring Station U4 to U5 in under 2.5 hours, and from Monitoring Station U5 to Ellsworth Dam in under 15 hours (Figures 4-11, 4-12, and 4-13, respectively).

Movement of acoustic-tagged smolts through the Union River reach downstream of Graham Lake Dam and Lake Leonard was evaluated for a total of 60 smolts released immediately below Graham Lake Dam. Of the 60 acoustic-tagged smolts stocked at release location 2, 53 (88%) of those were determined to have arrived at Ellsworth Dam based on their detection at monitoring station U16. The minimum, maximum, mean and median transit times for acoustic-tagged smolts from the Graham Lake Dam tailrace to the Ellsworth Dam are presented in Table 4-6. The median transit time for an acoustically-tagged smolt to move from the Graham Lake Dam tailrace to a point just upstream of Ellsworth Dam (a distance of ~ 4.1 miles) was 25.4 hours. The frequency distribution of transit times from Graham Lake Dam to Ellsworth for the set of acoustic-tagged smolts is presented in Figure 4-14.

4.4.3 Ellsworth Dam: Arrival, Residence and Downstream Passage

Upstream residence time and passage at Ellsworth Dam were examined using (1) the subset of radio-tagged smolts arriving at Ellsworth dam from release locations 1 and 2, and (2) the subset of acoustic-tagged smolts arriving at Ellsworth dam from release location 2. Of the radio-tagged smolts released upstream, 63% (76 of the 120) stocked at release location 1 and 93% (54 of the 58) stocked at release location 2 reached Ellsworth Dam (Table 4-7). Of the acoustic-tagged smolts released upstream, 88% (53 of the 60) reached Ellsworth Dam (Table 4-7).

Residence time in the project area immediately upstream of Ellsworth Dam was calculated for radio-tagged smolts as the duration from their initial time of arrival (monitoring station U6) until their determined time of downstream passage. For acoustic-tagged smolts, the residence time was calculated as the duration from their initial to final detections at monitoring station U16. When all radio-tagged smolts arriving at Ellsworth Dam were considered, the median residence time was 1.5 hours (Table 4-8; range = 0.2-39.5 hours), while for acoustic-tagged smolts the median residence time was 5.7 hours (range = 0.1 – 104.2 hours). Residence time from arrival to passage was less than 10 hours for the majority of surgically-tagged smolts at Ellsworth Dam (Figure 4-15).

A total of 130 radio-tagged individuals were available for the evaluation of passage route selection at Ellsworth. Table 4-9 presents the observed distribution of route selection among individuals approaching Ellsworth. Of the radio-tagged smolts determined to have approached Ellsworth Dam, 93% (121 of the 130) passed the dam. Of the 121 individuals passing, 30.6% (37 of the 121) utilized the spill through the sections of flashboards opened prior to the 2017 monitoring period. An additional 72 individuals passed via the turbine units (26.4% of total via Unit 1, 19.8% of total via Unit 2 and 13.2% of total via Unit 3). The downstream bypass system was utilized by 6.6% of all smolts passing Ellsworth. The majority of those individuals (6 of 7) utilized the surface entrances adjacent to Units 2 and 3.

Figure 4-16 presents the timing (by hour of the day) of smolt arrival and downstream passage at Ellsworth Dam by release group. Similar to that observed at Graham Lake Dam, the timing of downstream passage events at Ellsworth Dam did not appear to be strongly influenced by time of day as events occurred across the full range of day and night time hours.

4.4.4 Lower Union River Passage

Transit times in the lower Union River were evaluated for (1) the subset of acoustically-tagged smolts from release location 2 which successfully passed at Ellsworth Dam, and (2) an additional 60 acoustically-tagged smolts released immediately below Ellsworth Dam (i.e. release location 3). The minimum, maximum, mean and median transit times for acoustic-tagged smolts for the river reaches between Ellsworth Dam and monitoring station U17, monitoring stations U17 and U18, and monitoring stations U18 and U19, are presented in Table 4-10. Acoustically-tagged smolts moved relatively quickly through the lower river with median passage times of 6.1, 1.5, and 0.4 hours through the three acoustic-receiver defined reaches. The frequency distribution of observed transit times for acoustic-tagged smolts for the full stretch of the lower Union River from Ellsworth Dam downstream to the lowest acoustic monitoring station (U19) is presented in Figure 4-17. The majority of acoustic-tagged smolts (67%) moved through the 3.3 mile reach of the lower Union River downstream of Ellsworth in 24 or fewer hours.

As described in Section 3.4 downstream detection information for radio-tagged individuals passing Ellsworth Dam was not considered reliable to estimate project survival due to the likely bias of false positive detections (i.e., a smolt which was killed during passage but drifted and was detected at the downstream monitoring stations suggesting it was alive). Due to the inability to differentiate live versus dead/drifting individuals, transit times for radio-tagged smolts in the lower Union River were not calculated.

4.4.5 Rate of Movement

In addition to the transit time information presented in Sections 4.4.1 through 4.4.4 above, rates of movement (ROM) were calculated for radio and acoustic-tagged salmon smolts moving through defined reaches (See Section 2.7.2). Appendix B provides the minimum, maximum, mean and median ROM for surgically-tagged smolts out-migrating through the Union River and Ellsworth Project area during 2017.

4.5 Smolt Survival

4.5.1 Radio-tagged Smolt Survival

4.5.1.1 Parameter Estimates

Survivorship probabilities were estimated for five discrete Union River reaches defined by fixed radio-telemetry monitors using a CJS model run in Program MARK. The model $S(t)p(.)$ provided the best fit for the mark-recapture data collected for the 120 radio-tagged smolts released in the lower portion of Graham Lake (approximately 0.75 miles upstream of Graham Lake Dam; Table 4-11). Reach-specific survival estimates for this group of smolts from their release location downstream to the face of Ellsworth Dam are presented in Table 4-12. Estimates for the two components comprising the Graham Lake Dam reach (dam approach (U1) to passage (U3) and passage (U3) to first downstream receiver (U4)) were 0.824 and 0.903, resulting in an uncorrected survival estimate for the Graham Lake Dam project reach of 0.744 (0.824*0.903 = 0.744). This value represents smolt losses attributable to both background mortality (i.e., predation) as well as project effects.

4.5.1.2 Background Mortality Adjustment: Upper Union River

The Graham Lake Dam reach-specific survival estimate presented in Section 4.5.1.1 is reflective of mortality due to a combination of both project and background (or natural) effects. To allow for the separation of these two components an estimate of background mortality was required. During the 2017 study, this background mortality estimate was obtained from (1) a CJS-derived survival estimate for the group of radio-tagged Atlantic salmon smolts released into the Graham Lake Dam tailrace (release location 2), and (2) a CJS-derived survival estimate for the group of radio-tagged Atlantic salmon smolts released into the Graham Lake Dam tailrace combined with those released into Lower Graham Lake (release locations 1 and 2). The latter estimate provided a larger sample size with which to evaluate background mortality and was included following verification that the survival estimate through the representative reach for radio-tagged smolts originally released upstream of Graham Lake Dam was not lower than that observed for smolts released into the tailrace (and therefore presumably not negatively biased by previous exposure to dam passage). Passage of radio-tagged smolts through the 0.8 km riverine reach between radio monitoring stations U4 and U5 was considered representative of natural conditions in the upper portion of the Union River. The representative reach for the upper Union River did not include the impounded portion of the river upstream of Ellsworth (i.e., Leonard Lake).

To facilitate the return of background mortality to the Graham Lake Dam reach estimate, the CJS-derived survival fraction for the Graham Lake tailrace release group was converted to an instantaneous mortality rate (r = -0.023; 75% CI = -0.072 – 0.007; Table 4-13). Using the calculated instantaneous mortality rate for radio-tagged smolts released into the Graham Lake Dam tailrace and the known project reach length (3.6 km from monitoring station U1 to U4), a reach-specific mortality rate adjustment for the upper Union River was calculated as 0.078. The CJS-derived survival fraction for the full set of radio-tagged smolts released upstream of the upper Union River representative reach was also converted to an instantaneous mortality rate (r = -0.010; 75% CI = -0.044 – 0.002; Table 4-13). Using the calculated instantaneous mortality rate for all radio-tagged smolts released upstream of the representative reach (i.e., those from release locations 1 and 2) and the known project reach length (3.6 km from monitoring station U1 to U4), a second reach-specific mortality rate adjustment for the upper Union River was calculated as 0.035.

4.5.1.3 Graham Lake Dam Reach Survival

The CJS-derived survival estimate for Graham Lake Dam from the point approximately 200 m upstream of the gates (monitoring station U1) to the first downstream receiver (monitoring station U4) was 0.744. This estimate was adjusted for estimated losses due to background mortality (as measured in the representative reach between monitoring stations U4 and U5; Section 4.5.1.2) for (1) the set of radio-tagged smolts released directly into the Graham Lake Dam tailrace and (2) the set of all radio-tagged smolts released into lower Graham Lake and the Graham Lake Dam tailrace. When adjusted using radio-tagged smolts from the tailrace release location, the corrected Graham Lake Dam reach survival estimate is 82.2% (95% CI = 68.4-98.2%; Table 4-14). When adjusted using radio-tagged smolts from both the lower Graham Lake and tailrace release locations, the corrected Graham Lake Dam reach survival estimate is 77.9% (95% CI = 74.3-93.8%; Table 4-14).

Passage opportunities at Graham Lake Dam were limited to the modified downstream bypass or one of the bottom opening gates. To evaluate route-specific survival, separate CJS models were run for the groups of radio-tagged salmon smolts passing at Graham Lake Dam via the two potential downstream routes. As noted above in Section 4.4.1, 63 of the 86 radio-tagged smolts passing downstream of Graham Lake Dam were confirmed to have done so via the modified downstream bypass. Based on the lack of detections within the modified downstream bypass it can be assumed that the 23 remaining radio-tagged smolts utilized one of the bottom opening gates for passage. Table 4-14a presents the estimated dam survival rates for radio-tagged smolts determined to have passed via the modified downstream bypass and bottom opening gates. When adjusted for background mortality losses through the Graham Lake Dam reach, survival of radio-tagged smolts utilizing the modified downstream bypass was calculated at 92.4% (95% CI = 83.8-98.7%) when the full set of tagged fish were considered for determination of background mortality. Similarly, survival of radio-tagged smolts utilizing the bottom opening gates was calculated at 100% (95% CI = 95.3-100%).

4.5.1.4 Upper Union River Reach Specific Survival Estimates

CJS model results presented in Sections 4.5.1.1 and 4.5.1.2 provide reach-specific survival estimates generated for specific groups of radio-tagged smolts for the purpose of providing an estimate of survival related solely to downstream passage at Graham Lake Dam (Section 4.5.1.3). An additional CJS model was run which utilized the detection information for all radio-tagged smolts (regardless of release location) to provide a series of robust reach–specific survival estimates for (a) lower Graham Lake, (b) the Union River downstream of Graham Lake Dam, and (c) Lake Leonard.

The model $S(t)p(t)$ provided the best fit for the mark-recapture data collected for the full set of radio-tagged smolts released during 2017 (Table 4-15). Detection probabilities (Table 4-16) and reach survival estimates (Table 4-17) for radio-tagged smolts were obtained from that model. Calculated detection probabilities ranged from 91-100% among the six locations evaluated. Individual reach survival estimates were highest for smolts passing through upper Leonard

Lake (98%) and the adjacent section of the Union River located upstream (99%). Individual reach survival estimates were lowest for radio-tagged smolts passing through Graham Lake Dam (83%) and lower Graham Lake (87%).

Encounter histories used in the generation of detection and survivorship probabilities for radio-tagged smolts released at Ellsworth can be found in Appendix C.

4.5.2 Acoustic-tagged Smolt Survival

4.5.2.1 Parameter Estimates

Survivorship probabilities were estimated for the Union River reaches defined by fixed acoustic monitors using a CJS model run in Program MARK. The model $S(t)p(t)$ provided the best fit for the mark-recapture data collected for the 60 acoustic-tagged smolts released in the tailrace of Graham Lake Dam (Table 4-18). Reach-specific survival estimates for this group of smolts varied among the three reaches evaluated (release location 2 to monitoring station U16, monitoring station U16 to U17 and monitoring station U17 to U18) (Table 4-19). The estimate for the reach from monitoring station U16 to U17 (0.623; Table 4-19) represents the uncorrected survival estimate for the Ellsworth Dam project reach. This value represents smolt losses attributable to both background mortality (i.e., predation) as well as project effects.

4.5.2.2 Background Mortality Adjustment: Lower Union River

The Ellsworth Dam reach-specific survival estimate presented in Section 4.5.2.1 is reflective of mortality due to a combination of both project and background (or natural) effects. To allow for the separation of these two components an estimate of background mortality was required. During the 2017 study, this background mortality estimate was obtained from (1) a CJS-derived survival estimate for the group of acoustic-tagged Atlantic salmon smolts released into the Ellsworth Dam tailrace (release location 3) and (2) a CJS-derived survival estimate for the full group of acoustic-tagged Atlantic salmon smolts released into the Ellsworth Dam tailrace combined with those released into the Union River downstream of Graham Lake Dam (release locations 2 and 3). The latter estimate provided a larger sample size with which to evaluate background mortality and was included following verification that the survival estimate through the representative reach for acoustic-tagged smolts originally released upstream of Ellsworth Dam was not lower than that observed for smolts released into the tailrace (and therefore presumably not negatively biased by previous exposure to dam passage). Passage of these individuals through the 1.4 km reach between acoustic monitoring stations U17 and U18 was considered representative of natural conditions in the lower portion of the Union River.

To facilitate the return of background mortality to the Ellsworth Dam reach estimate, the CJS-derived survival fraction for the Ellsworth tailrace release group was converted to an instantaneous mortality rate (r = -0.068; 75% CI = -0.113 – 0.040; Table 4-20). Using the calculated instantaneous mortality rate for acoustic-tagged smolts released into the Ellsworth Dam tailrace and the known project reach length, a reach-specific mortality rate adjustment for the lower Union River was calculated as 0.185. The CJS-derived survival fraction for the full set of acoustic-tagged smolts (i.e., those from release locations 2 and 3) released upstream of the lower Union River representative reach was also converted to an instantaneous mortality rate (r = -0.042; 75% CI = -0.070 – 0.025; Table 4-20). Using the calculated instantaneous mortality rate for all acoustic-tagged smolts released upstream of the representative reach and the known project reach length (3.0 km from monitoring station U16 to U17), a second reach-specific mortality rate adjustment for the lower Union River was calculated as 0.117.

4.5.2.3 Ellsworth Dam Reach Survival

The CJS-derived survival estimate for Ellsworth Dam from the point 200 m upstream of the intakes (monitoring station U16) to the first downstream receiver (monitoring station U17) was 0.623 (Table 4-19). This estimate was adjusted for estimated losses due to background mortality (as measured in the representative reach between monitoring stations U17 and U18; Section 4.5.2.2) for (1) the set of acoustic -tagged smolts released directly into the Ellsworth Dam tailrace (i.e., release location 3) and (2) the set of all acoustic-tagged smolts released upstream and downstream of Ellsworth Dam (i.e., release locations 2 and 3). When adjusted for estimated losses due to background mortality as measured for smolts from only release location 3, the corrected Ellsworth Dam reach survival estimate is 80.8% (95% CI = 64.4-93.6%; Table 4-21). When adjusted for estimated losses due to background mortality as measured for smolts from release locations 2 and 3, the corrected Ellsworth Dam reach survival estimate is 74.0% (95% CI = 60.3-86.4%; Table 4-21).

4.5.2.4 Lower Union River Reach Specific Survival Estimates

CJS model results presented in Sections 4.5.2.1 and 4.5.2.2 provide reach-specific survival estimates generated for specific groups of acoustic-tagged smolts for the purpose of providing an estimate of survival related solely to downstream passage at Ellsworth Dam (Section 4.5.2.3). An additional CJS model was run which utilized the detection information for all acoustic-tagged smolts (regardless of release location) to provide a series of robust reach–specific survival estimates for the lower portion of the Union River.

The model $S(t)p(.)$ provided the best fit for the mark-recapture data collected for the full set of radio-tagged smolts released during 2017 (Table 4-22). Detection probabilities were estimated at 100% for monitoring stations U16, U17, and U18. Individual reach survival estimates were highest for acoustic-tagged smolts passing through the lower Union River (94%) and from the Graham Lake Dam tailrace to Ellsworth Dam (88%; Table 4-23).

Encounter histories used in the generation of detection and survivorship probabilities for acoustic-tagged smolts released at Ellsworth can be found in Appendix C.

4.5.3 Cumulative Passage Survival

A cumulative estimate of survival for the full study reach (i.e., from the release location in lower Graham Lake to monitoring station U18 located 2.8 miles downstream of Ellsworth Dam) was calculated as the product of reach-specific estimates for consecutive river reaches. Survival estimates obtained from radio-tagged smolts were considered representative for the study area section from lower Graham Lake downstream to arrival at Ellsworth Dam (Table 4-22) and estimates obtained from acoustic-tagged smolts were considered representative for the study area section from passage at Ellsworth Dam downstream to station U18 (Table 4-23). The cumulative estimate of survival for tagged Atlantic salmon smolts moving through the Union River study reach during 2017 was 38.1%. It should be noted that this estimate represents losses attributable to both background (i.e., natural) and project effects. When only project related effects are considered, the cumulative survival estimate for smolts passing through the Graham Lake and Ellsworth project reaches (i.e. excluding natural mortality through river reaches) is

66.4% (0.822 x 0.808 = 0.664) when relying on the background mortality correction derived from the subset of tagged smolts unexposed to prior dam passage and 57.6% (0.779 x 0.740 = 0.664) when relying on the background mortality correction derived from all tagged smolts.

The CJS models presented in Sections 4.5.1.4 (radio-tagged smolts) and 4.5.2.4 (acoustic-tagged smolts considered detection information for the full set of tagged individuals, regardless of location and generated a series of reach-specific survival estimates for the upper Union River (based on radio-telemetry data) and lower Union River (based on acoustic-telemetry data). Table 4-24 provides a complete summary of the reach-specific survivorship probabilities (by release date) for the study area from the release location upstream of Graham Lake Dam to a point approximately 4.4 km downstream of Ellsworth Dam.

4.6 Additional Movement Data

In addition to the stationary telemetry data, manual tracking was conducted at regular intervals during the 2017 study period. Manual tracking efforts consisted of land-based (i.e., foot and truck) and boat tracking. Tracking covered all accessible portions of the study reach including lower Graham Lake, the Union River and Leonard Lake upstream of Ellsworth Dam, and the Union River downstream of Ellsworth Dam to the public marina. Manual tracking was conducted on six dates during the study period (May 19, 21, 23, 24, 30, and 31). During that effort, a total of 148 manual detections were made representing 106 individual smolts.

The majority of manual detections (90 of the 148; representing 64 individuals) were collected for smolts within Graham Lake. Most of those detections (60%) were from the lowest portion of the lake, within a distance of approximately 1.25 miles upstream of the dam facility. However, radio-tagged individuals were detected as far as 8.25 miles upstream of Graham Lake Dam. In general, the likelihood of subsequent downstream passage at Graham Lake Dam (and eventually Ellsworth Dam) was greater for smolts whose manual detections prior to downstream passage were restricted to the lower portion of Graham Lake. A total of 37 detections (representing 29 individuals) were made of smolts within the portion of the study area from the Graham Lake tailrace downstream to the approach area at Ellsworth Dam. Of the 29 individuals detected between Graham Lake and Ellsworth Dams, 16 eventually passed Ellsworth Dam and moved beyond the two downstream stationary receivers (U14 and U15). The final 21 detections (representing 13 individuals) were from the reach stretching from the Ellsworth tailrace to a point just downstream of the public marina. It should be noted that a number of individuals had multiple detections from the same location at or immediately downstream of monitoring stations U14 and U15. These observations support the findings of the drift test which indicated smolts killed during passage would likely reach the downstream stationary receivers, biasing any effort to estimate passage survival using radio-tagged individuals under 2017 river conditions. A listing of manual tracking detections collected during 2017 is provided in Appendix D.

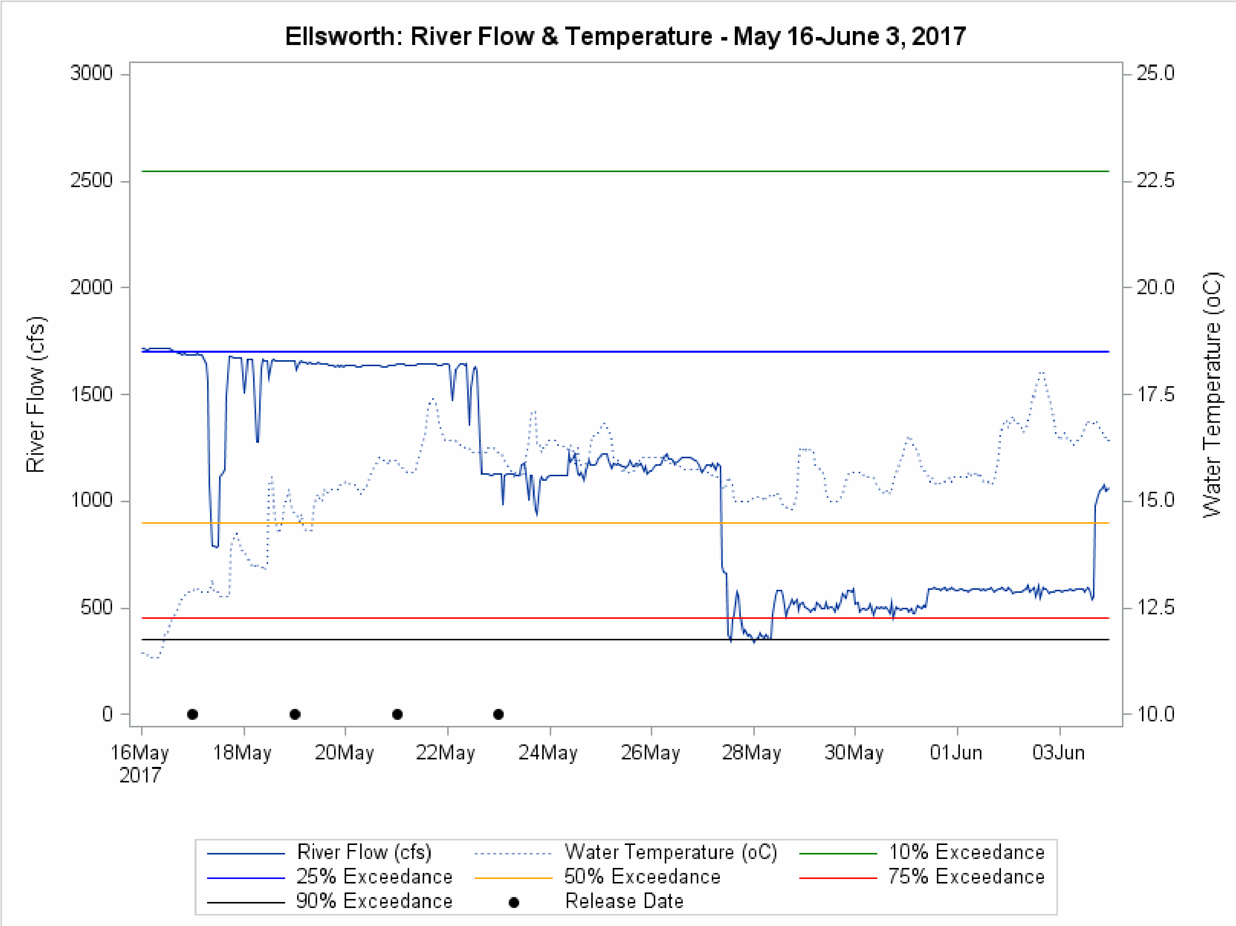

Figure 4-1. Hourly Union River flow (cfs) and daily water temperature (°C) as measured at Ellsworth for the time period May 16-June 3, 2017. The 10, 25, 50, 75, and 90% flow exceedance conditions based on historic Union River flow data (for May) as well as tagged fish release dates are included for reference

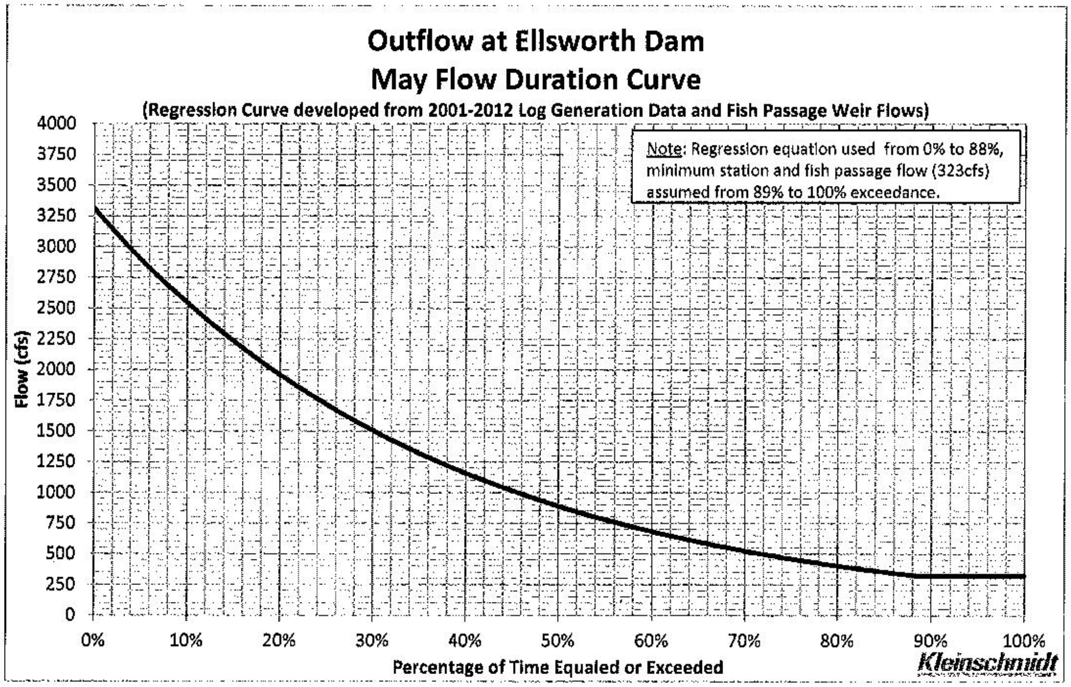

Figure 4–2. Long-term flow duration curve for May at Ellsworth Dam

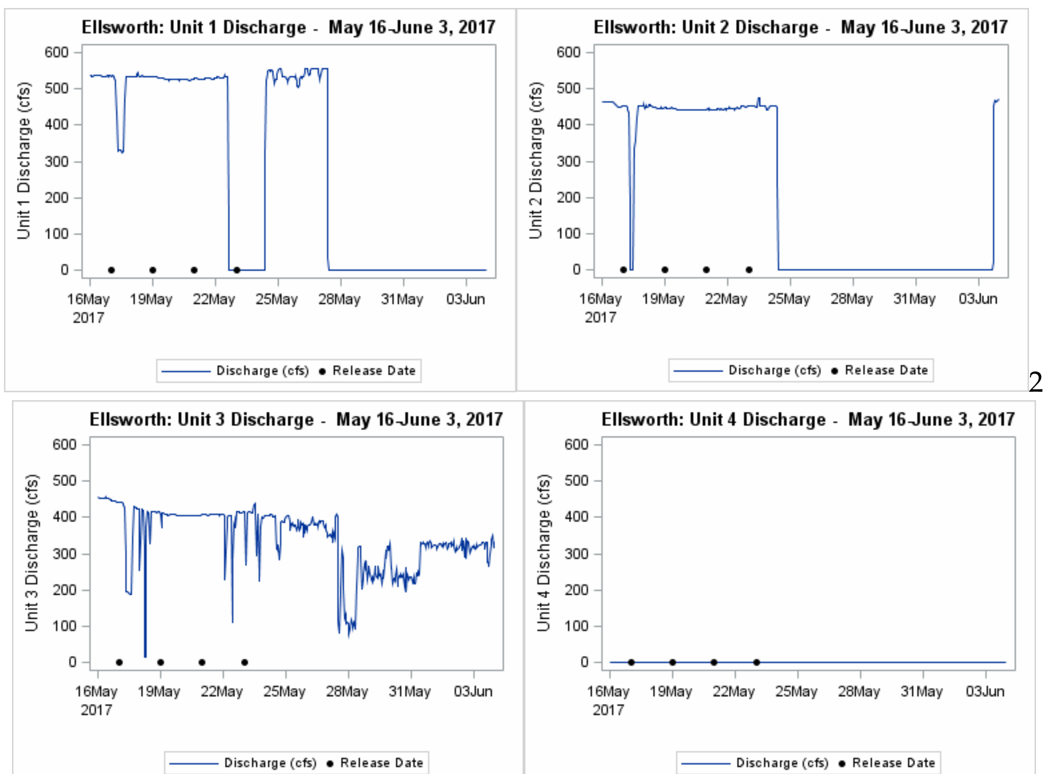

Figure 4–3. Ellsworth unit discharges (cfs) for the time period May 16-June 3, 2017. Tagged fish release dates included for reference

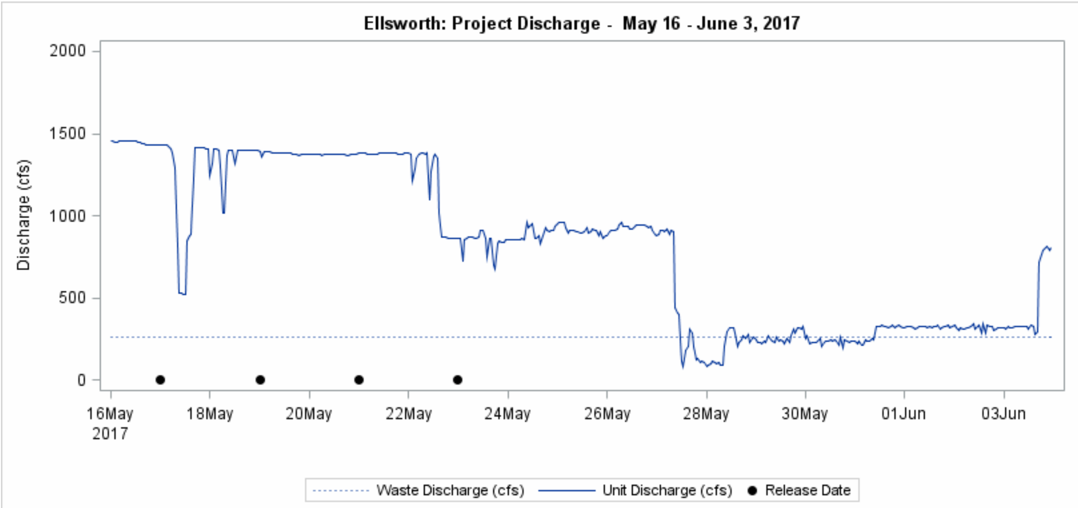

Figure 4–4. Ellsworth project discharge (generation and non-generation values; cfs) for the time period May 16-June 3, 2017. Tagged fish release dates included for reference

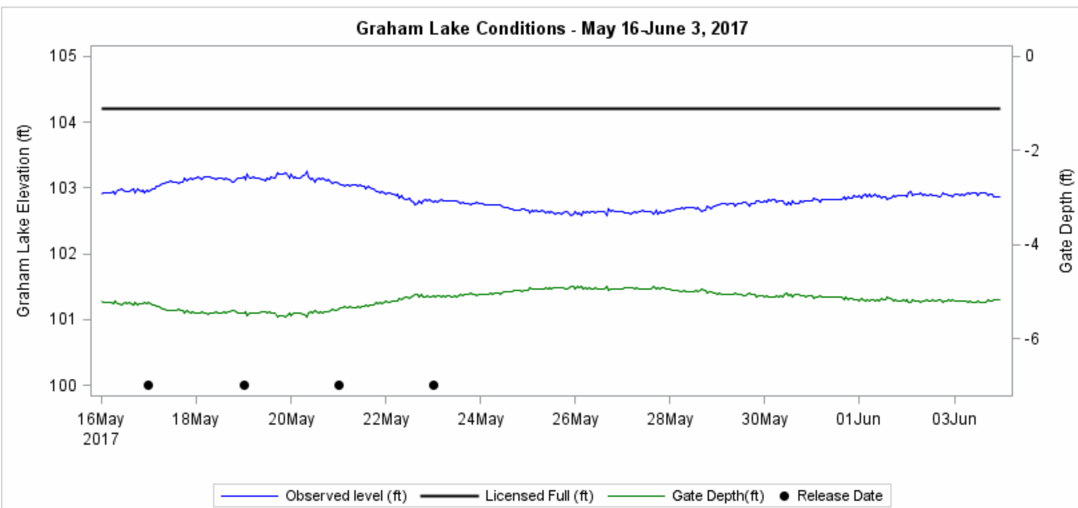

Figure 4–5. Graham Lake elevation levels and calculated spill depth through the Graham Lake Dam downstream bypass gate for the time period May 16-June 3, 2017. Full lake elevation and tagged fish release dates included for reference

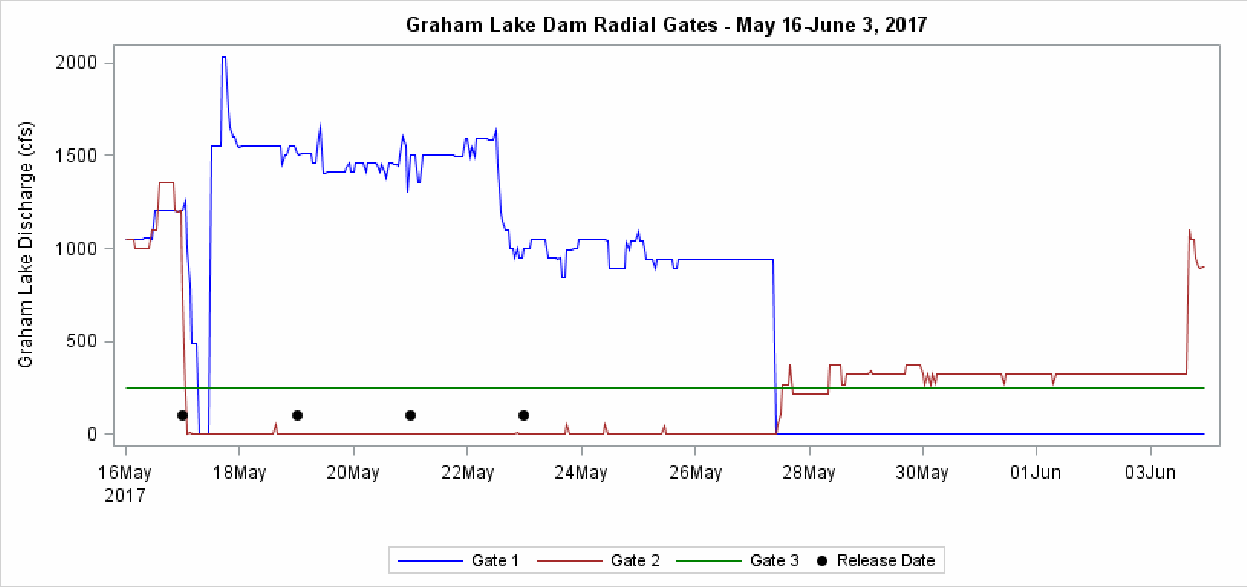

Figure 4-6. Discharge passing Graham Lake Dam via the three radial gates (1, 2 and 3) for the time period May 16-June 3, 2017. Tagged fish release dates included for reference

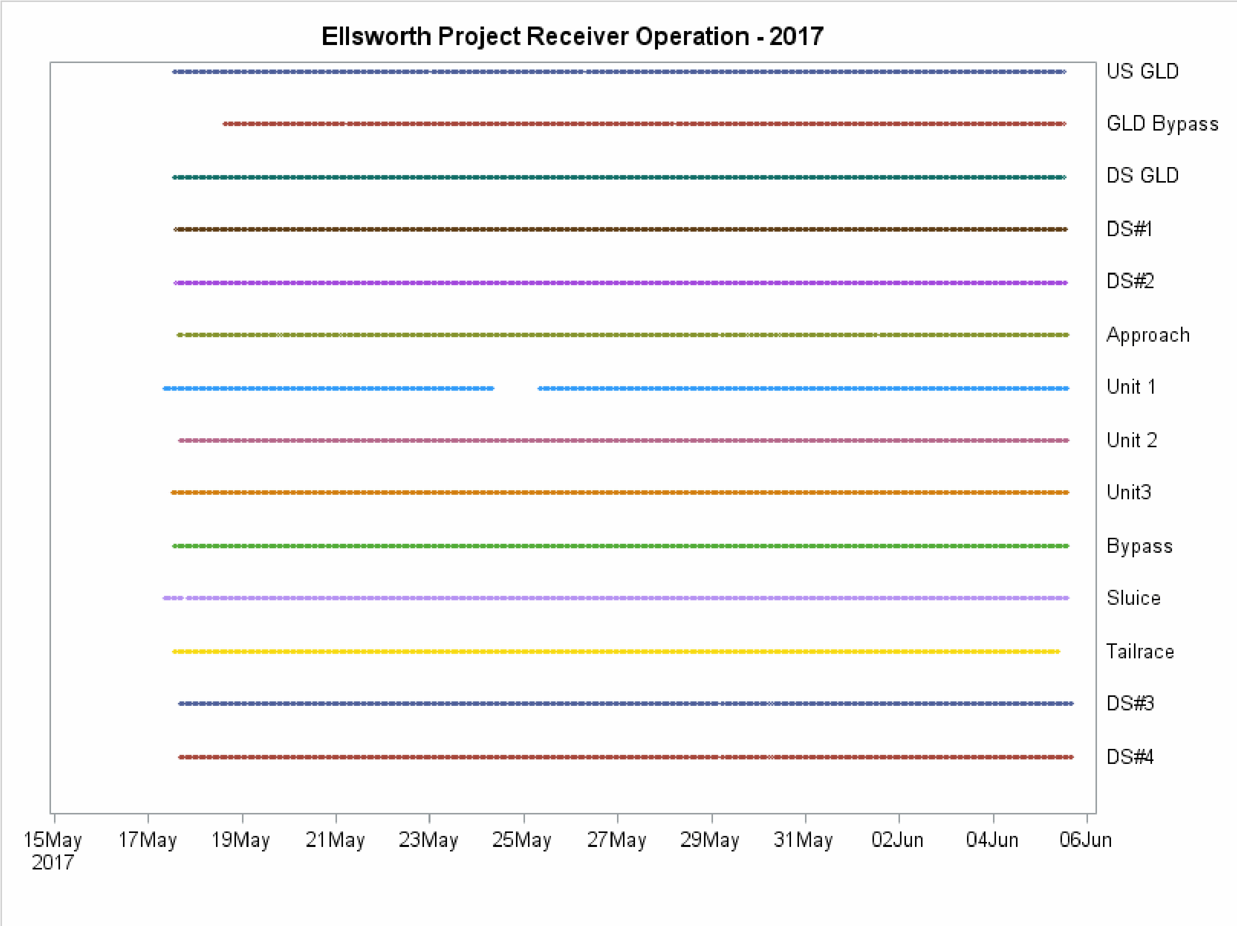

Figure 4–7. Receiver coverage for radio-telemetry monitoring stations located from the upstream side of Graham Lake Dam downstream to a point 0.4 miles below Ellsworth Dam, May 15 to June 5, 2017

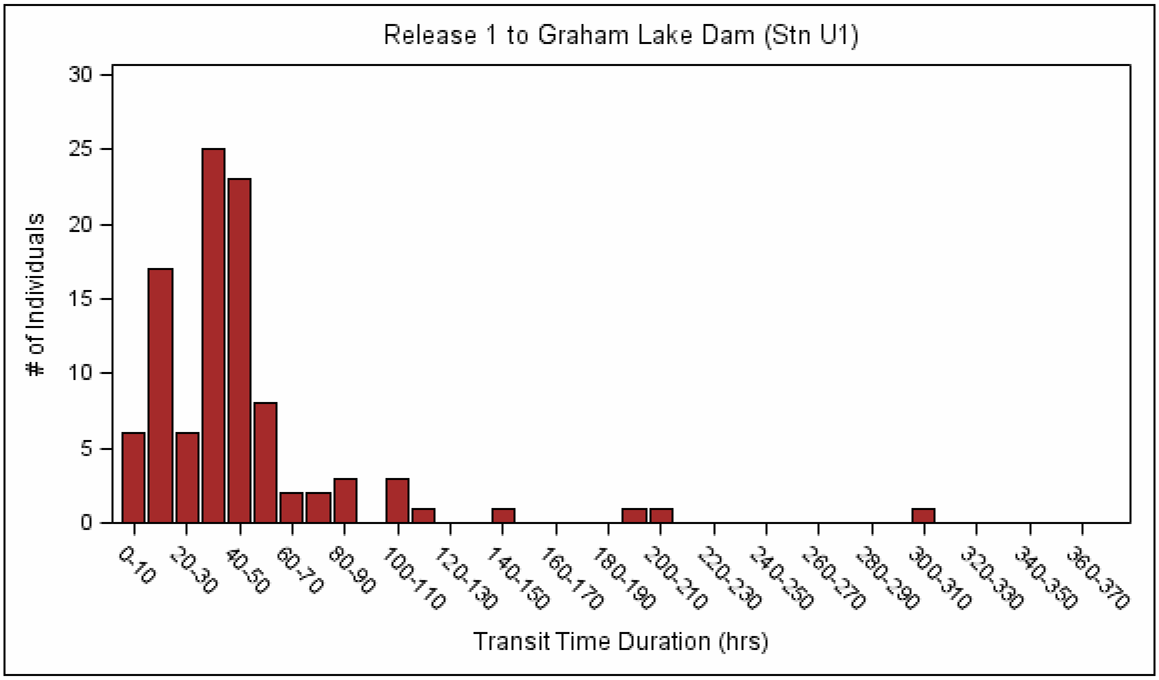

Figure 4-8. Frequency distribution of travel times (hrs) for 2017 radio-tagged smolts to move from release location 1 to the upstream side of Graham Lake Dam, a distance of approximately 0.75 miles

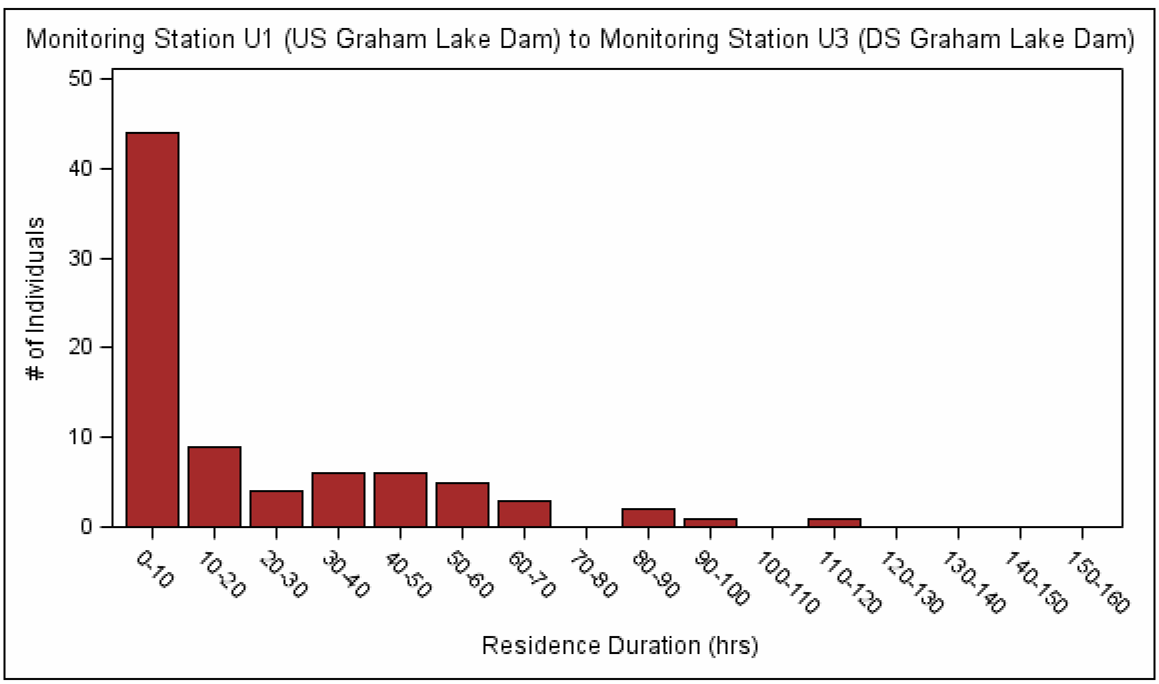

Figure 4-9. Frequency distribution of 2017 residence time (hrs) for radio-tagged smolts prior to downstream passage at Graham Lake Dam

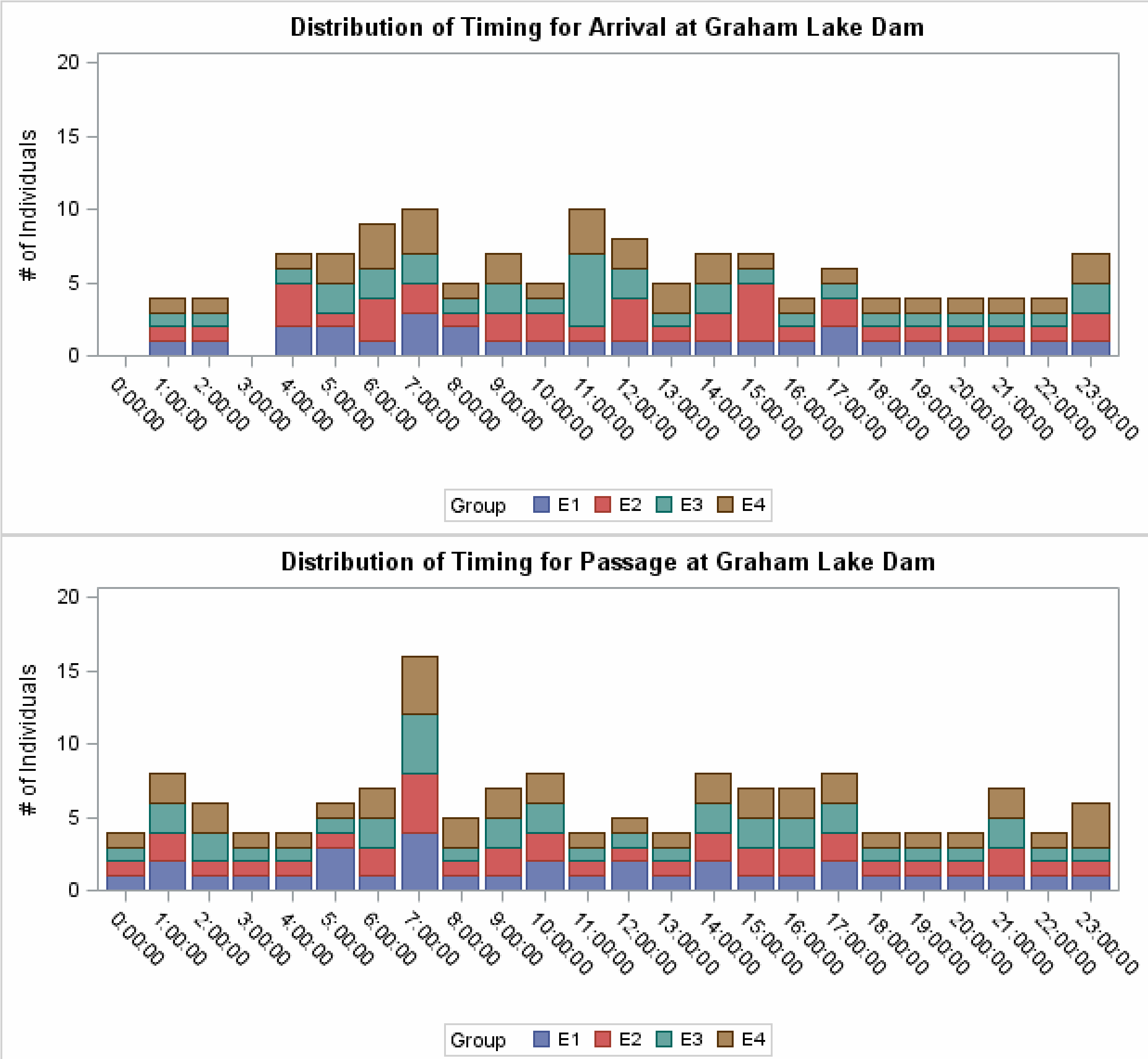

Figure 4–10. Temporal distribution of arrival (upper panel) and downstream passage times (lower panel) by release group for radio-tagged smolts at Graham Lake Dam during 2017

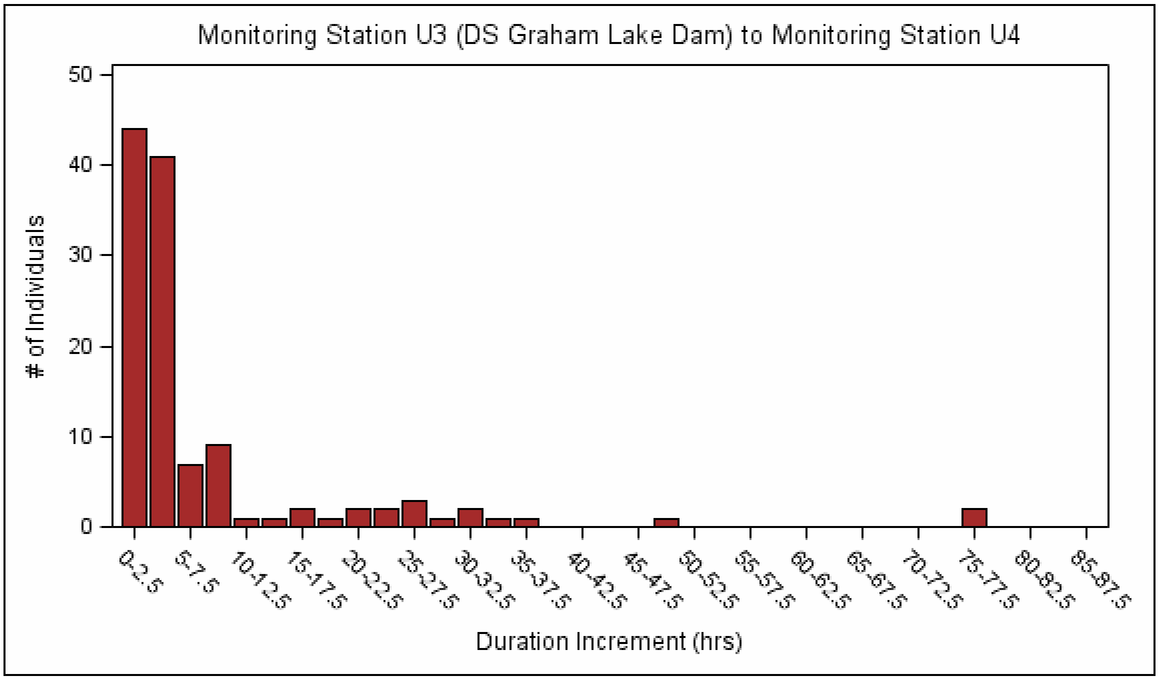

Figure 4–11. Frequency distribution of travel time (hrs) for 2017 radio-tagged smolts to move from the Graham Lake Dam tailrace to Monitoring Station U4, a distance of approximately 2.1 miles

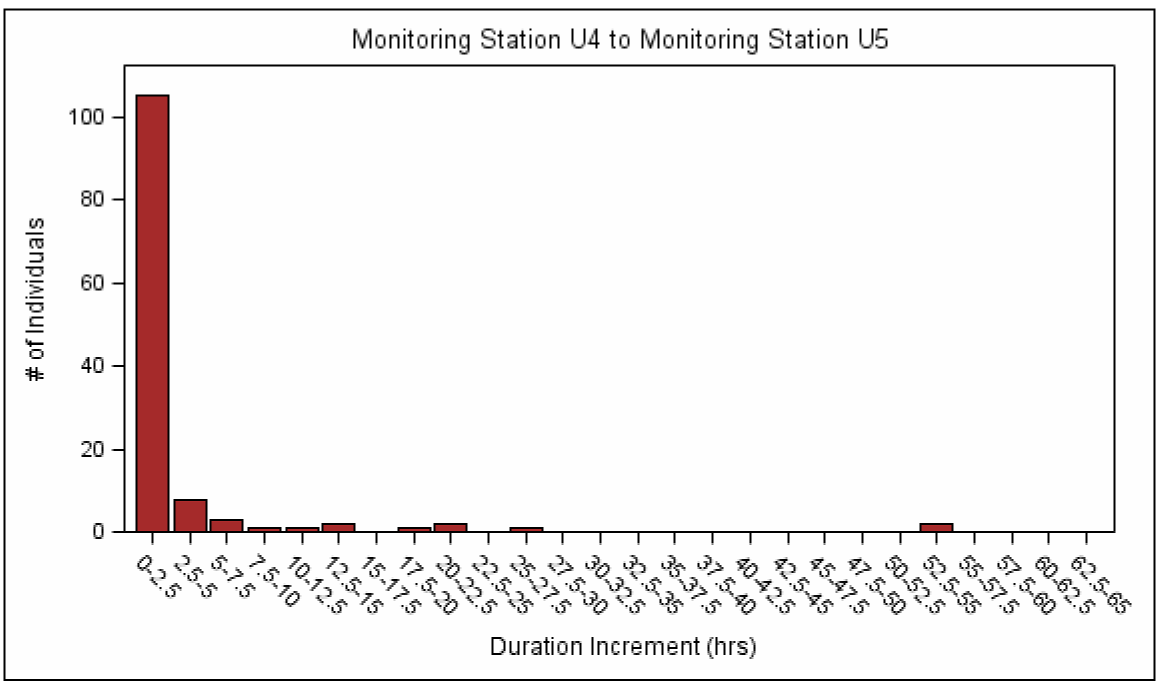

Figure 4–12. Frequency distribution of travel time (hrs) for 2017 radio-tagged smolts to move from Monitoring Station U4 to Monitoring Station U5, a distance of approximately 0.5 miles

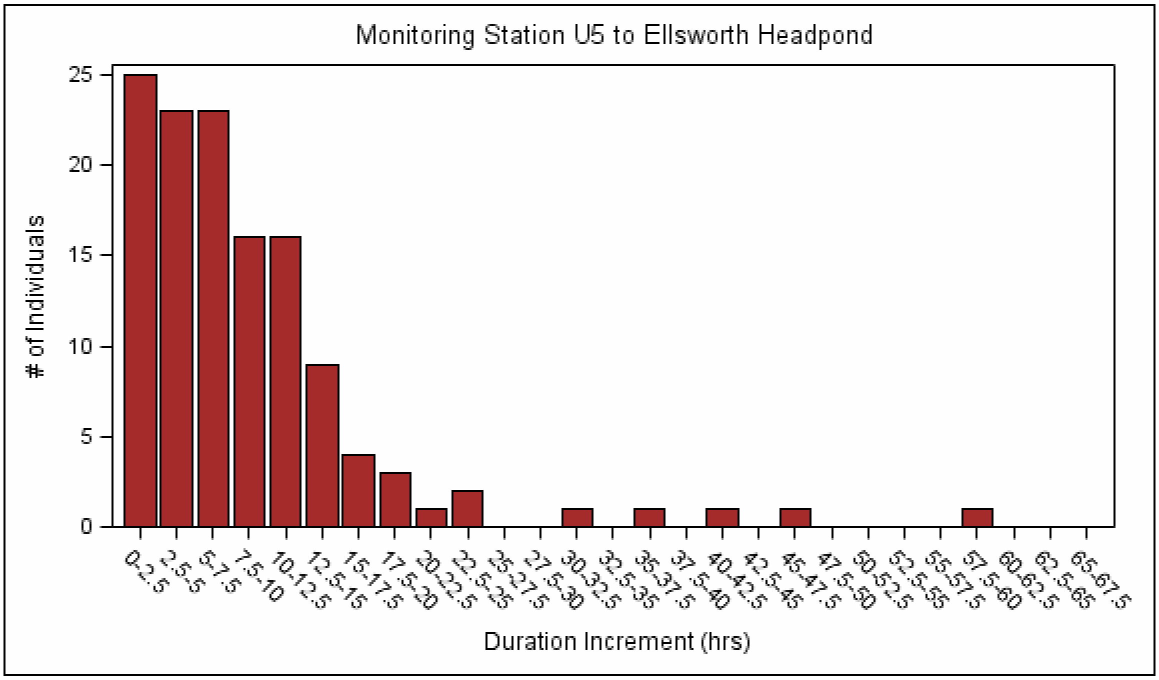

Figure 4–13. Frequency distribution of travel time (hrs) for 2017 radio-tagged smolts to move from Monitoring Station U5 to the Ellsworth Dam, a distance of approximately 1.5 miles

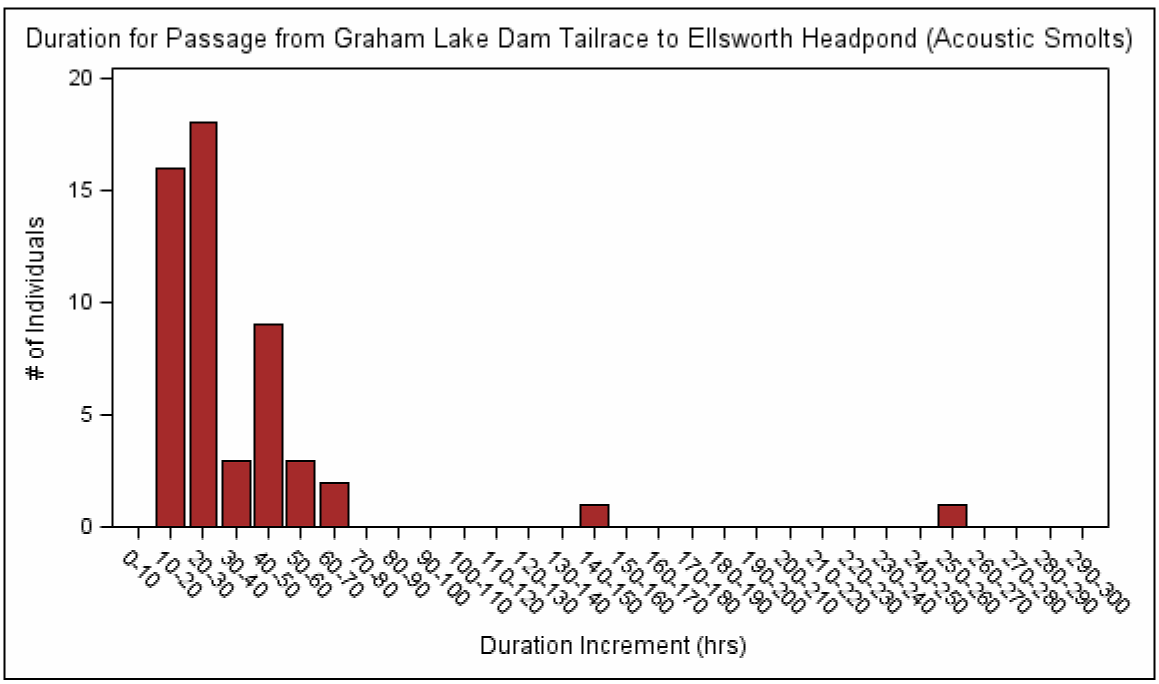

Figure 4–14. Frequency distribution of travel time (hrs) for 2017 acoustic-tagged smolts to move from release location 2 (Graham Lake Dam tailrace) to the Ellsworth Dam, a distance of approximately 4.1 miles

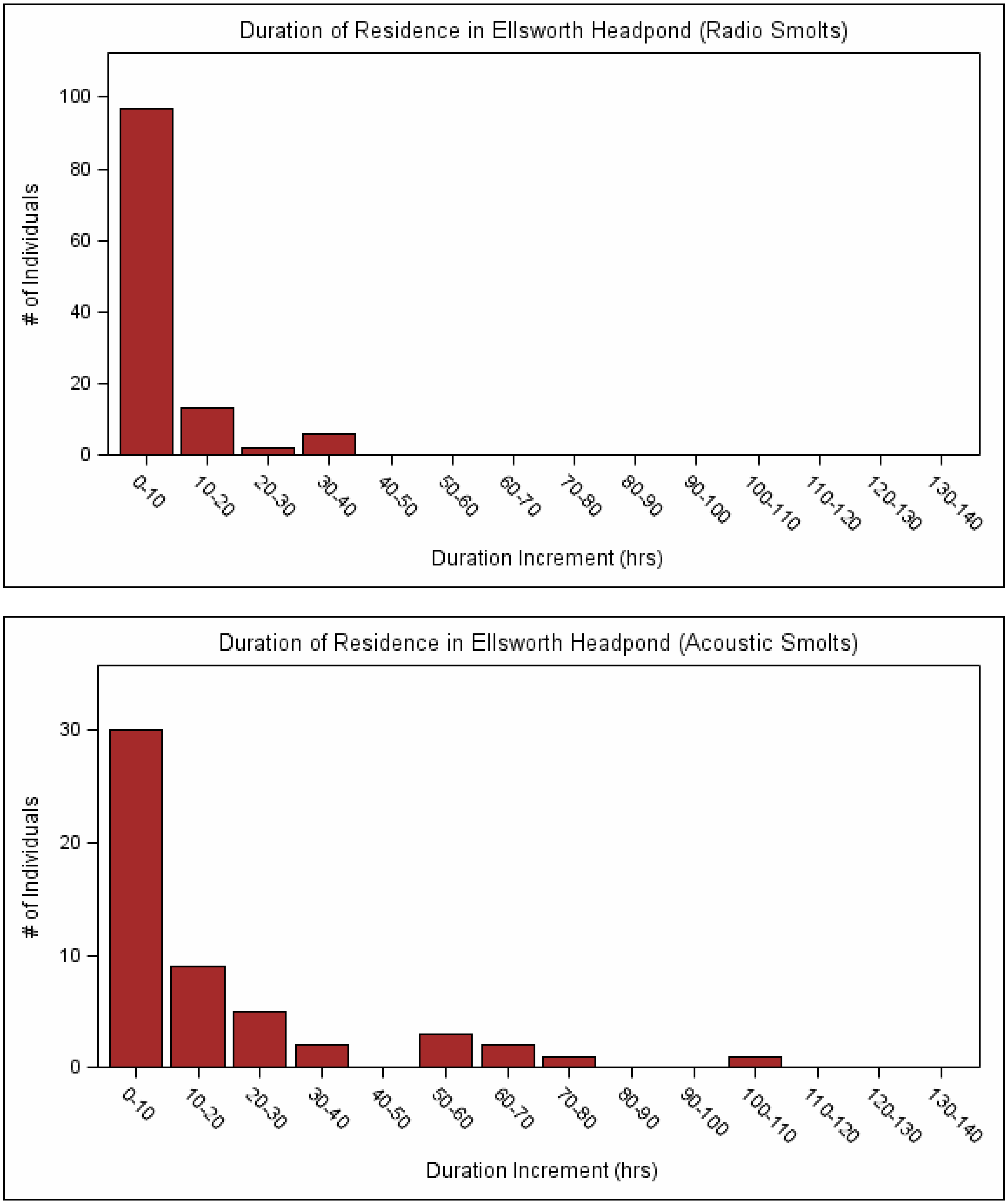

Figure 4–15. Frequency distribution of 2017 residence time (hrs) for radio-tagged (upper panel) and acoustic-tagged smolts (lower panel) prior to downstream passage at Ellsworth Dam

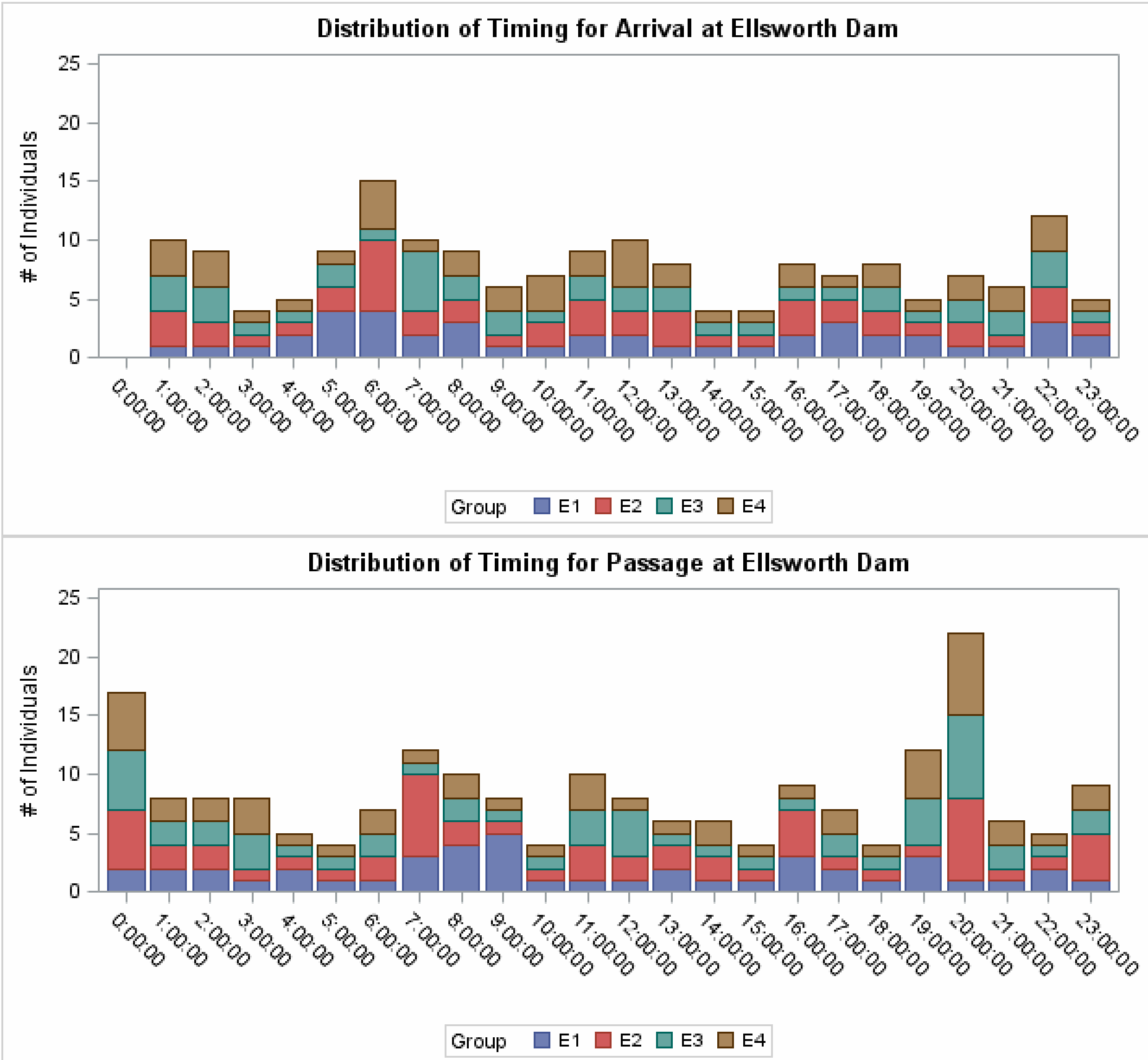

Figure 4–16. Frequency distribution of arrival (upper panel) and downstream passage times (lower panel) by release group for radio-tagged smolts at Ellsworth Dam during 2017

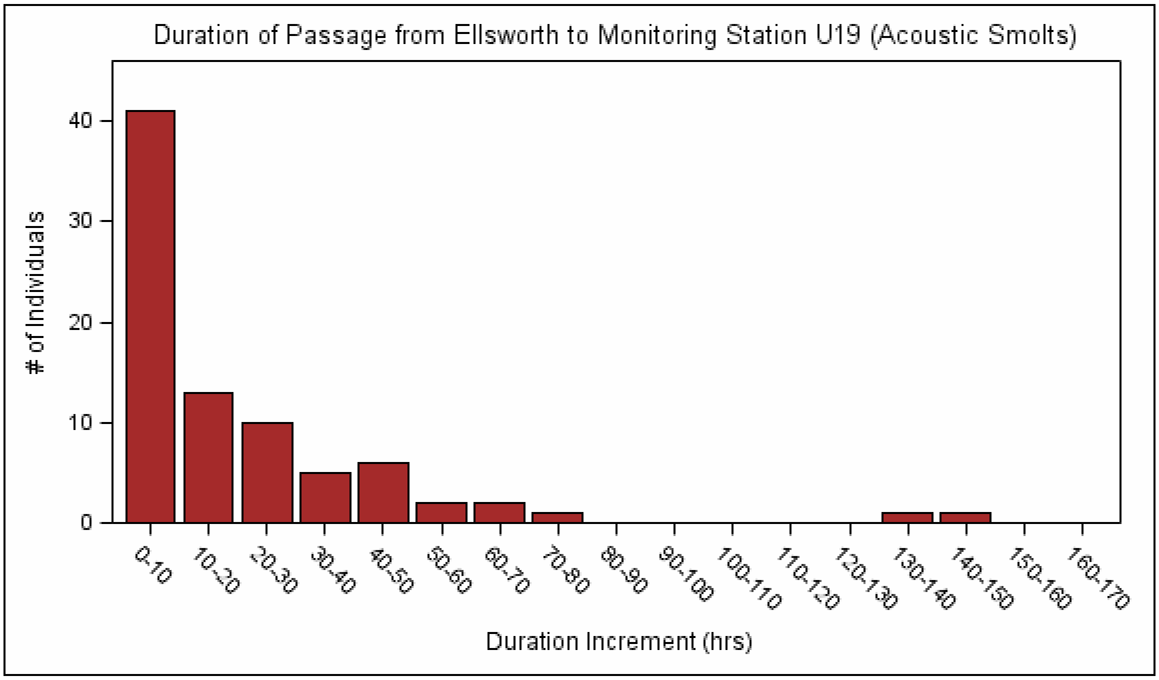

Figure 4–17. Frequency distribution of travel time (hrs) for radio-tagged smolts to move from the Ellsworth Dam to Monitoring Station U19, a distance of approximately 3.3 miles

Table 4-1. Summary of releases and biological information (fork length, weight) for Atlantic salmon smolts surgically tagged and released in the vicinity of the Ellsworth Project during May, 2017

Group	Location	Type	No. Smolts	Date	Fork Length (mm)			Weight (g)		
					Min	Max	Mean	Min	Max	Mean
E1	1	radio	30	17-May	173	214	193	48	103	68
	2	radio	15		170	212	189	46	100	66
	2	acoustic	15		176	209	194	51	95	73
	3	acoustic	15		180	202	190	50	85	70
E2	1	radio	30	19-May	180	207	191	52	91	67
	2	radio	15		176	200	188	20	84	66
	2	acoustic	15		177	216	189	55	100	65
	3	acoustic	15		179	202	191	54	81	69
E3	1	radio	30	21-May	176	225	193	51	118	71
	2	radio	15		168	206	194	45	95	74
	2	acoustic	15		171	210	189	46	92	66
	3	acoustic	15		175	211	193	47	90	69
E4	1	radio	30	23-May	170	229	186	46	114	65
	2	radio	13		177	214	190	53	92	67
	2	acoustic	15		175	204	191	51	82	65
	3	acoustic	15		175	211	189	46	91	95
All Releases			241		168	229	191	45	118	68

Table 4-2. Minimum, maximum, mean, and median transit times for radio-tagged Atlantic salmon smolts in release groups E1-E4 from release location 1 until arrival at Graham Lake Dam during 2017

River Reach	Release Group	Release Location	Minimum	Maximum	Mean	Median
Release Location 2 to Monitoring Station U2 (~ 0.75 miles)	E1	1	8.3	193.4	52.4	40.8
	E2	1	5.5	305.6	62.4	43.2
	E3	1	14.9	104.7	46.4	41.6
	E4	1	9.1	62.9	23.5	16.5
			5.5	**305.6**	**46.0**	**39.2**

Table 4-3. Minimum, maximum, mean, and median residence times for radio-tagged Atlantic salmon smolts in release groups E1-E4 at Graham Lake Dam during 2017

Release Group	Release Location	Minimum	Maximum	Mean	Median
E1	1	0.1	118.1	16.8	5.3
E2	1	0.1	99.1	16.2	1.5
E3	1	0.1	81.6	31.1	25.8
E4	1	0.1	63.3	19.7	15.2
		0.1	**118.1**	**20.7**	**5.6**

Table 4-4. Arrival and downstream passage information for radio-tagged Atlantic salmon smolts in release groups E1-E4 at Graham Lake Dam during 2017

Release Group	No. Released	No. Arrive GLD	No. Pass GLD	No. Confirmed Using Bypass	No. Arrive/Not Pass*	
					Approach Only	Approach and Bypass
E1	30	26.0	25	15	0	1
E2	30	28.0	19	12	6	3
E3	30	23.0	18	16	2	3
E4	30	27.0	24	20	3	0
	120	**104**	**86**	**63**	**11**	**7**

* Individuals classified as "Approach only" are radio-tagged smolts with valid detections at monitoring station U1 and no detection information at U2 or U3. Individuals classified as "Approach and bypass" are radio-tagged smolts with valid detections at monitoring stations U1 and U2 but no detection information at U3 to indicate downstream passage.

Table 4-5. Minimum, maximum, mean, and median transit times for radio-tagged Atlantic salmon Smolts in release groups E1-E4 from the Graham Lake Dam tailrace to Monitoring Station U4, between Monitoring Stations U4 and U5 and from Monitoring Station U5 to Ellsworth Dam during 2017

River Reach	Release Group	Release Location	Transit Time (hr)			
			Minimum	Maximum	Mean	Median
Graham Lake Dam Tailrace to Monitoring Station U4 (~2.1 miles)	E1	1	1.3	10.3	3.2	2.3
		2	2.7	291.3	38.5	14.6
	E2	1	1.2	8.6	2.8	2.1
		2	2.2	31.6	8.4	3.2
	E3	1	1.5	4.9	2.9	2.5
		2	2.2	76.8	20.0	9.1
	E4	1	1.6	34.7	6.4	2.8
		2	2.6	16.4	5.2	4.1
	All		**1.2**	**291.3**	**10.2**	**3.0**
Monitoring Station U4 to Monitoring Station U5 (~0.5 miles)	E1	1	0.1	6.1	0.9	0.4
		2	0.1	2.4	0.5	0.2
	E2	1	0.2	8.2	0.9	0.3
		2	0.2	12.9	1.9	0.4
	E3	1	0.2	10.6	1.3	0.3
		2	0.2	26.1	4.4	0.3
	E4	1	0.2	5.5	0.8	0.4
		2	0.2	54.1	14.1	2.4
	All		**0.1**	**54.1**	**2.6**	**0.3**
Monitoring Station U5 to Monitoring Station U6 (i.e., Ellsworth arrival; ~ 1.5 miles)	E1	1	1.0	13.9	4.6	2.5
		2	2.2	14.8	8.7	8.7
	E2	1	1.3	13.1	4.6	3.6
		2	2.6	36.5	9.0	7.3
	E3	1	1.4	19.8	9.2	7.3
		2	2.0	22.6	9.3	5.8
	E4	1	1.8	45.2	13.7	10.6
		2	7.0	58.8	14.7	11.3
	All		**1.0**	**58.8**	**8.8**	**6.9**

Table 4-6. Minimum, maximum, mean, and median transit times for acoustic-tagged Atlantic salmon smolts in release groups E1-E4 from the Graham Lake Dam tailrace to Ellsworth Dam during 2017

River Reach	Release Group	Release Location	Transit Time (hr)			
			Minimum	Maximum	Mean	Median
Release Location 2 to Ellsworth Dam (~ 4.1 miles)	E1	2	14.8	142.5	36.0	26.9
	E2	2	12.9	60.7	32.6	32.0
	E3	2	19.2	65.0	32.6	24.7
	E4	2	12.8	253.1	40.5	21.8
	All		**12.8**	**253.1**	**35.7**	**25.4**

Table 4-7. Total number of radio and acoustic-tagged smolts from release locations 1 and 2 determined to have approached Ellsworth Dam during 2017

Release Group	Release Location		
	Graham Lake	GLD Tailrace	All
Radio - E1	24	12	36
Radio - E2	18	15	33
Radio - E3	14	15	29
Radio - E4	20	12	32
Radio	**76**	**54**	**130**
Acoustic - E1	-	15	15
Acoustic - E2	-	12	12
Acoustic - E3	-	12	12
Acoustic - E4	-	14	14
Acoustic	**-**	**53**	**53**

Table 4-8. Minimum, maximum, mean, and median residence times for radio and acoustic-tagged Atlantic salmon smolts in release groups E1-E4 at Ellsworth Dam during 2017

Release Group	Tag Type	Residence Time (hr)			
		Minimum	Maximum	Mean	Median
E1	Radio	0.2	37.0	3.7	1.4
	Acoustic	0.4	29.4	6.4	2.2
E2	Radio	0.2	19.4	3.1	1.0
	Acoustic	0.3	104.2	21.3	9.3
E3	Radio	0.2	39.5	9.0	3.3
	Acoustic	0.1	29.4	10.9	7.4
E4	Radio	0.2	39.1	8.0	1.8
	Acoustic	1.7	67.0	28.5	26.3
All	**Radio**	**0.2**	**39.5**	**5.6**	**1.5**
	Acoustic	**0.1**	**104.2**	**16.6**	**5.7**

Table 4-9. Passage routes determined for radio-tagged Atlantic salmon smolts passing Ellsworth Dam, May 2017

	Release Group	E1	E2	E3	E4	Total
	Release Date	17-May	19-May	21-May	23-May	
	No. Detected	36	33	29	32	**130**
Passage Route	Downstream Bypass	1	0	4	2	**7**
	Surface Sluice	1	0	0	0	**1**
	Spill	7	7	11	12	**37**
	Unit 1	12	9	2	9	**32**
	Unit 2	9	7	8	0	**24**
	Unit 3	3	9	1	3	**16**
	Unknown	1	0	1	2	**4**
	No Pass	2	1	2	4	**9**

*Downstream bypass has overflow stop-log entrances adjacent to Units 2 and 4; Surface sluice entrance located on western end of spillway and adjacent to Unit 1

Table 4-10. Minimum, maximum, mean, and median transit times for acoustic-tagged Atlantic salmon smolts in release groups E1-E4 from the Ellsworth Dam Monitoring Station U17, from Monitoring Station U17 to U18 and from Monitoring Station U18 to U19 during 2017

River Reach	Release Group	Release Location	Transit Time (hr)			
			Minimum	Maximum	Mean	Median
Ellsworth Headpond to Monitoring Station U17 (~1.9 miles)	E1	2	0.8	36.4	6.8	4.0
		3	5.2	13.4	7.0	5.7
	E2	2	1.6	78.8	19.3	5.7
		3	5.3	52.1	16.1	6.9
	E3	2	0.8	12.2	4.2	1.5
		3	5.5	57.5	15.1	6.9
	E4	2	1.1	6.2	3.2	3.1
		3	7.1	129.4	21.7	8.5
	All		**0.8**	**129.4**	**12.2**	**6.1**
Monitoring Station U17 to Monitoring Station U18 (~0.9 miles)	E1	2	0.4	5.2	2.6	2.7
		3	1.5	18.7	8.1	5.5
	E2	2	0.6	60.4	13.9	2.0
		3	0.6	71.7	8.5	1.9
	E3	2	0.5	4.0	1.6	0.7
		3	0.8	61.6	8.6	1.4
	E4	2	0.5	1.5	0.8	0.7
		3	0.6	25.1	4.6	1.0
	All		**0.4**	**71.7**	**6.0**	**1.5**
Monitoring Station U18 to Monitoring Station U19 (~0.5 miles)	E1	2	0.2	2.9	0.7	0.4
		3	0.3	12.7	2.6	0.6
	E2	2	0.1	4.5	1.2	0.4
		3	0.2	20.9	2.9	1.1
	E3	2	0.2	0.9	0.4	0.3
		3	0.2	56.9	6.2	0.3
	E4	2	0.1	1.4	0.6	0.3
		3	0.2	17.9	1.9	0.4
	All		**0.1**	**56.9**	**2.5**	**0.4**

Table 4-11. CJS model selection criteria for the subset of radio-tagged smolt released into lower Graham Lake and approaching at Graham Lake Dam, 2017

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
S(t)*p*(.)	137.5769	0.0000	0.7948	1.0000	5	12.4830
S(.)*p*(.)	141.9554	4.3785	0.0890	0.1120	2	22.9542
S(t)*p*(t)	142.5023	4.9254	0.0677	0.0582	9	9.1740
S(.)*p*(t)	143.1706	5.5937	0.0485	0.0610	5	18.0766

Table 4-12. Reach-specific survival probability estimates, standard errors and likelihood 75 and 95% confidence intervals for radio-tagged Atlantic salmon smolts released into lower Graham Lake, 2017

Reach*	Reach Length (km)	Survival Estimate	SE	Confidence Interval			
				75% Lower	75% Upper	95% Lower	95% Upper
A	1.2	0.874	0.058	0.791	0.927	0.712	0.951
B	0.2	0.824	0.071	0.727	0.891	0.642	0.924
C	3.4	0.903	0.060	0.809	0.953	0.709	0.973
D	0.8	1.000	1.000	-	-	-	-
E	2.4	0.976	0.033	0.888	0.995	0.713	0.999

A = Release location 1 to upstream of Graham Lake Dam (U1)

B = Upstream of Graham Lake Dam (U1) to Graham Lake Dam tailrace (U3)

C = Graham Lake Dam tailrace (U3) to Station U4

D = Station U4 to Station U5

E = Station U5 to Ellsworth approach (U6)

Table 4-13. Calculated instantaneous rates of background mortality for radio-tagged Atlantic salmon smolts passing through the “representative” natural reach of the upper Union River, 2017

Release Location	Reach Length (km)	CJS-derived values			Instantaneous Mortality Rate		
		S	75% Lower CI	75% Upper CI	*r*	75% Lower CI	75% Upper CI
2	0.8	0.982	0.944	0.994	-0.023	-0.072	-0.007
1 & 2	0.8	0.992	0.966	0.998	-0.010	-0.044	-0.002

Table 4-14. Graham Lake Dam reach survival estimates and associated confidence intervals corrected for background mortality based on radio-tagged smolt passage during 2017

CJS Reach Survival Estimate	Correction Factor Source (Release Location)	Reach Length Scaled M Correction Factor	Estimated Project Survival (%)	Confidence Interval			
				75% Lower	75% Upper	95% Lower	95% Upper
0.744	2	0.078	82.2%	76.5%	95.1%	68.4%	98.2%
0.744	1 & 2	0.035	77.9%	73.5%	90.7%	74.3%	93.8%

Table 4-14a. Atlantic salmon smolt Graham Lake Dam reach survival estimates for individuals passing via the modified downstream bypass or the bottom opening gates

Passage Route	CJS Reach Survival Estimate	Correction Factor Source (Release Location)	Reach Length Scaled M Correction Factor	Estimated Project Survival (%)	Confidence Interval			
					75% Lower	75% Upper	95% Lower	95% Upper
Bypass	0.889	2	0.078	96.7%	82.1%	100.0%	80.8%	100.0%
	0.889	1 & 2	0.035	92.4%	86.5%	97.3%	83.8%	98.7%
Bottom Gate	0.978	2	0.078	100.0%	91.6%	100.0%	91.0%	100.0%
	0.978	1 & 2	0.035	100.0%	97.0%	100.0%	95.3%	100.0%

Table 4-15. CJS model selection criteria for the full set of radio-tagged smolt released into the Union River study reach during 2017

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
$S(t)p(t)$	412.8901	0.0000	0.9769	1.0000	13	31.6758
$S(t)p(.)$	420.5753	7.6852	0.0209	0.0214	8	49.5909
$S(.)p(t)$	425.1572	12.2671	0.0021	0.0022	6	58.2352
$S(.)p(.)$	438.6154	25.7253	0.0000	0.0000	2	79.7679

Table 4-16. Detection probability estimates, standard errors and likelihood 75 and 95% confidence intervals for radio-telemetry monitoring stations in the Union River study reach, 2017

Station	Detection Probability	SE	Confidence Interval			
			75% Lower	75% Upper	95% Lower	95% Upper
U1	0.953	0.030	0.905	0.978	0.847	0.987
U3	0.913	0.041	0.853	0.950	0.792	0.966
U4	0.947	0.025	0.910	0.970	0.870	0.980
U5	1.000	0.000	-	-	-	-
U6	0.975	0.018	0.943	0.990	0.898	0.994
Ellsworth	1.000	0.000	-	-	-	-

Table 4-17. Reach-specific survival probability estimates, standard errors and likelihood 75 and 95% confidence intervals for radio-tagged Atlantic salmon smolts released into the Union River study reach, 2017

Reach*	Survival Estimate	SE	Confidence Interval			
			75% Lower	75% Upper	95% Lower	95% Upper
A	0.874	0.041	0.819	0.914	0.770	0.935
B	0.825	0.050	0.760	0.876	0.704	0.904
C	0.927	0.029	0.886	0.954	0.846	0.967
D	0.992	0.010	0.966	0.998	0.907	0.999
E	0.979	0.017	0.948	0.992	0.903	0.996
F	0.929	0.030	0.887	0.957	0.844	0.969

A = Release location 1 to upstream of Graham Lake Dam (U1)

B = Upstream of Graham Lake Dam (U1) to Graham Lake Dam tailrace (U3)

C = Graham Lake Dam tailrace (U3) to Station U4

D = Station U4 to Station U5

E = Station U5 to Ellsworth approach (U6)

F = Ellsworth approach (U6) to passage

Table 4-18. CJS model selection criteria for the subset of acoustic-tagged smolt released downstream of Graham Lake Dam and approaching at Ellsworth Dam, 2017

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
S(t)*p*(t)	128.5794	0.0000	0.5000	1.0000	3	0.0000
S(t)*p*(.)	128.5794	0.0000	0.5000	1.0000	3	0.0000
S(.)*p*(t)	157.2848	28.7054	0.0000	0.0000	1	32.8199
S(.)*p*(.)	157.2848	28.7054	0.0000	0.0000	1	32.8199

Table 4-19. Reach-specific survival probability estimates, standard errors and likelihood 75 and 95% confidence intervals for acoustic-tagged Atlantic salmon smolts released downstream of Graham Lake Dam, 2017

Reach*	Reach Length (km)	Survival Estimate	SE	Confidence Interval			
				75% Lower	75% Upper	95% Lower	95% Upper
A	6.3	0.883	0.041	0.827	0.923	0.775	0.943
B	3.0	0.623	0.067	0.544	0.696	0.486	0.742
C	1.4	1.000	0.000	1.000	1.000	0.981	1.000

A = Release location 2 to upstream of Ellsworth Dam (U16)

B = Upstream of Ellsworth Dam (U16) to U17

C = U17 to U18

Table 4-20. Calculated instantaneous rates of background mortality for acoustic-tagged Atlantic salmon smolts passing through the "representative" natural reach of the lower Union River, 2017

Release Location	Reach Length (km)	CJS-derived values			Instantaneous Mortality Rate		
		S	75% Lower CI	75% Upper CI	*r*	75% Lower CI	75% Upper CI
3	1.4	0.909	0.854	0.945	-0.068	-0.113	-0.040
2 & 3	1.4	0.943	0.907	0.966	-0.042	-0.070	-0.025

Table 4-21. Ellsworth Dam reach survival estimates and associated confidence intervals corrected for background mortality based on acoustic-tagged smolt passage during 2017

CJS Reach Survival Estimate	Correction Factor Source (Release Location)	Reach Length Scaled M Correction Factor	Estimated Project Survival (%)	Confidence Intervals			
				75% Lower	75% Upper	95% Lower	95% Upper
0.623	3	0.185	80.8%	71.7%	88.7%	64.4%	93.6%
0.623	2 & 3	0.117	74.0%	65.7%	81.7%	60.3%	86.4%

Table 4-22. CJS model selection criteria for the full set of acoustic-tagged smolt released into the Union River study reach during 2017

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
S(t)*p*(.)	170.8381	0.0000	0.7381	1.0000	4	6.7426
S(t)*p*(t)	172.9106	2.0725	0.2619	0.3548	5	6.7426
S(.)*p*(.)	206.0847	35.2466	0.0000	0.0000	1	48.1183
S(.)*p*(t)	206.0847	35.2466	0.0000	0.0000	1	48.1183

Table 4-23. Reach-specific survival probability estimates, standard errors and likelihood 75 and 95% confidence intervals for acoustic-tagged Atlantic salmon smolts released into the Union River study reach, 2017

Reach*	Survival Estimate	SE	Confidence Interval			
			75% Lower	75% Upper	95% Lower	95% Upper
A	0.883	0.041	0.827	0.923	0.775	0.943
B	0.623	0.067	0.544	0.696	0.486	0.742
C	0.943	0.025	0.907	0.966	0.871	0.976

A = Release location 2 to upstream of Ellsworth Dam (U16)

B = Upstream of Ellsworth Dam (U16) to U17

C = U17 to U18

Table 4-24. Survivorship estimates calculated in Program MARK for tagged Atlantic salmon smolts released at Ellsworth during 2017 (by release date) within defined reaches from the lower portion of Graham Lake to Union River downstream of Ellsworth Dam.

Release Group	Survivorship Probability (SE)						
	A	B	C	D	E	F	G
17-May	0.87 (0.06)	0.96 (0.05)	0.97 (0.03)	0.97 (0.03)	0.94 (0.04)	0.67 (0.12)	0.78 (0.09)
19-May	0.93 (0.05)	0.68 (0.09)	0.97 (0.03)	1.00 (0.00)	1.00 (0.00)	0.500 (0.144)	1.00 (0.00)
21-May	0.77 (0.08)	0.79 (0.09)	0.88 (0.06)	1.00 (0.00)	1.00 (0.00)	0.500 (0.144)	1.00 (0.00)
23-May	0.90 (0.06)	0.89 (0.06)	0.89 (0.05)	1.00 (0.00)	0.97 (0.03)	0.786 (0.109)	1.00 (0.00)
All	**0.87 (0.04)**	**0.83 (0.05)**	**0.93 (0.03)**	**0.99 (0.01)**	**0.98 (0.02)**	**0.62 (0.67)**	**0.94 (0.03)**

A = release location 1 to upstream face of Graham Lake Dam (U1)

B = upstream face of Graham Lake Dam (U1) to Graham Lake Dam tailrace (U3)

C = Graham Lake Dam tailrace (U3) to Station U4

D = Station U4 to Station U5

E = Station U5 to Ellsworth Approach (U6)

F = Ellsworth Approach (U16) to Station U17

G = Station U17 to Station U18

A, B, C, D, & E based on radio-tagged

F & G based on acoustic-tagged

5.0 Summary

The downstream passage of Atlantic salmon smolts at the Ellsworth Project was initially evaluated during May, 2016 (Normandeau 2016). Based on observations made during the first study year, Black Bear temporarily modified the existing passage measures at Graham Lake and Ellsworth Dams. The approach to the existing downstream passage weir at Graham Lake Dam was modified by adding a sloped floor and two side panels to create an Alden weir and a bell shaped approach in an effort to modify approach velocities and improve attraction; additionally, three approximately seven-foot-wide sections of flashboards adjacent to the existing downstream passage weir were removed at the Ellsworth dam to provide a potential additional route for downstream passage. Modifications at both project facilities were implemented by Black Bear to help facilitate improved downstream Atlantic salmon smolt passage at the Project.

In addition to structural and operational modifications at the two dam facilities, 2017 smolt release locations and monitoring stations were placed in a manner to permit the estimation of background mortality rates for the sections of the Union River downstream of Graham Lake and Ellsworth Dams. These values were used to adjust dam reach survival estimates so they were reflective of solely passage at the project and not losses due to natural effects. The 2016 study did not differentiate mortality types at the two dam locations. Prior to the 2017 study it was decided that a single "representative reach" located at a point away from the two project facilities and within the upper Union River watershed would not provide an accurate representation of background losses expected for the reach downstream of Ellsworth. This decision was based on predator observations during 2016 and was further supported by observations from 2017 (note sizeable difference in number of avian observations at Graham Lake versus Ellsworth Dams - Appendix G). Placement of a representative reach for assessing background mortality in the lower Union River was made difficult by the limited total reach length downstream of the Project. Normandeau evaluated the full reach of the Union River downstream of Ellsworth Dam prior to the onset of the 2017 study. Subsequent to that reach evaluation, Normandeau elected to place the three downstream monitoring stations within the 5.2 km reach downstream of Ellsworth Dam and upstream of the point where the Union River channel width expands from approximately 75-125 m to 800+ m at the upper end of Union River Bay. Receivers were placed to (1) allow fish adequate time post-release in the Ellsworth tailrace to express any delayed handling/tagging effects prior to entry into the representative reach and (2) avoid any overlap in the detection fields of adjacent receivers.

A total of 298 hatchery-reared Atlantic salmon smolts were surgically tagged and released at three locations in the vicinity of the Ellsworth Project during May, 2017. Of that total, 120 smolts were equipped with Vemco acoustic transmitters and 178 with Lotek radio transmitters. Downstream movements of tagged smolts were monitored via a series of radio and acoustic receivers installed at fixed locations ranging from Graham Lake Dam to a point approximately 3.3 miles downstream of Ellsworth Dam. Releases were initiated on May 17 and completed on May 23, 2017. River flows during the study period were relatively high (1,190 cfs study period average vs a normal median monthly flow of approximately 900 cfs based on the Ellsworth Dam long-term flow duration curve for May). Continuous spill was provided at Ellsworth Dam via three open sections of flashboards adjacent to the Unit 1 intake. Unit 4 (one of the two vertical shaft propeller turbines) was not operated for the duration of the study.

During the 2016 telemetry evaluation 23% of radio-tagged smolts determined to have approached the upstream side of Graham Lake Dam subsequently passed downstream. Residence time for those individuals (calculated as the duration from initial detection at the upstream face of the dam until detection in the tailrace) had a median value of 79.8 hours (range = 2.1-287.4 hours; average = 106.5 hours). Of individuals passing downstream at Graham Lake Dam during 2016, 9% did so in less than 24 hours. The effectiveness and timeliness of downstream passage at Graham Lake Dam improved during the 2017 telemetry evaluation. Of the 104 radio-tagged smolts approaching the upstream side of Graham Lake Dam during 2017, 86 (83%) subsequently passed downstream. The majority of those (73%; 63 of 86) were confirmed passing via the modified downstream bypass. The mean (Mann-Whitney test; z =5.70 p = <.0001) and median (determined by non-overlapping bounds, Figure 5-1) residence times upstream of Graham Lake Dam were shorter during 2017 than was observed during the 2016 study. Of individuals passing downstream at Graham Lake Dam during 2017, 67% did so in less than 24 hours. Improved passage conditions at Graham Lake Dam in 2017 versus those observed for 2016 were likely a function of the weir modifications installed by Black Bear to improve the downstream bypass as well as increased flows through the facility.

Median residence times upstream of Ellsworth Dam (calculated as the duration from initial detection at the point 200 m upstream of the project until the determined time of passage) were 17.9 hours (range = 0.6-213 hours; mean = 29.9 hours) for radio-tagged smolts and 21.9 hours (range = 0.1-355.7 hours; mean = 55.1 hours) for acoustic-tagged smolts during 2016. Similar to observations at Graham Lake Dam, both the mean and median values of residence time were shorter for tagged smolts during 2017 than was observed during 2016[3]. Figure 5-4 presents the distribution of downstream passage route selection by radio-tagged smolts during 2016 and 2017. The percentage of use by downstream routes varied between 2016 and 2017 as would be expected given the differences in operations. During 2016 downstream passage was limited to the downstream bypass system and Units 2 and 3. During 2017, smolts had additional passage routes available via the spill provided adjacent

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[3] Radio-tagged smolts: The mean (Mann-Whitney test; z =7.02 p = <.0001) and median (determined by non-overlapping bounds, Figure 5-2) residence times upstream of Ellsworth Dam were shorter during 2017 than was observed during the 2016 study.

Acoustic-tagged smolts: The mean (Mann-Whitney test; z =-3.98 p = <.0001) and median (determined by non-overlapping bounds, Figure 5-3) residence times upstream of Ellsworth Dam were shorter during 2017 than was observed during the 2016 study.

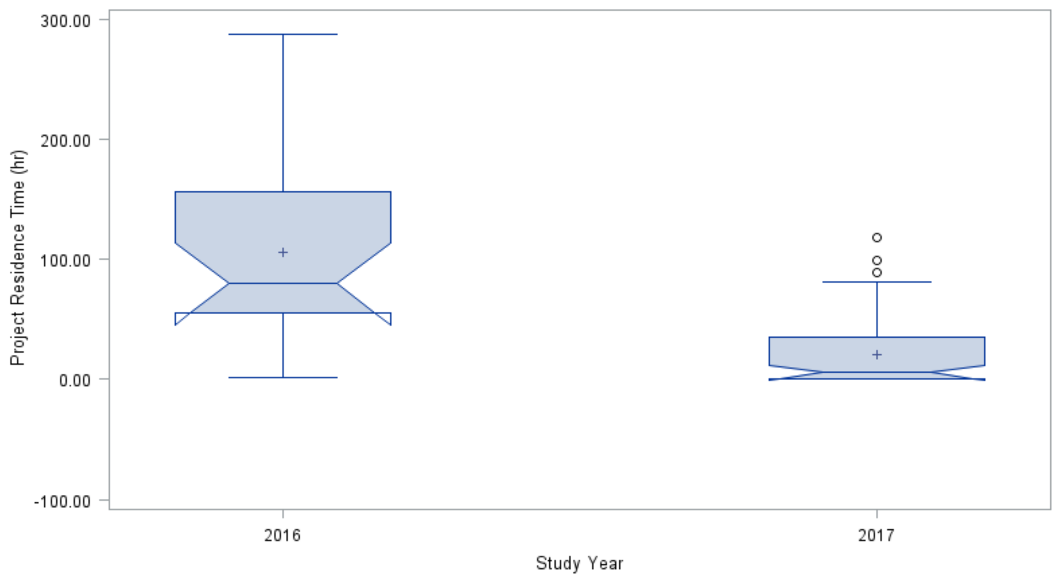
to the Unit 1 intake as well as Unit 1 itself. Unit 4 was offline during both study years. Similar to Graham Lake Dam it is likely that the decreases in residence time at Ellsworth Dam were a function of spill flows provided by Black Bear as well as increased Union River flows through the facility.

Downstream passage survival at Graham Lake Dam was estimated at 14.0% (95% CI = 8.0-21.0%) during the 2016 study. It should be noted that the 2016 study estimate for Graham Lake Dam did not differentiate between mortality attributable to background effects or direct project related effects. As a result, the 2016 survival estimate at Graham Lake Dam includes the impacts of both mortality sources. During 2017, downstream passage survival at Graham Lake Dam (including background and project related effects) was estimated at 74.4% (95% CI = 65.5-82.5%). When adjusted to correct for background mortality based on the set of radio-tagged smolts released downstream of Graham Lake Dam passing through the designated representative reach in the upper portion of the Union River, survival through the Graham Lake Dam reach during 2017 was estimated at 82.2% (95% CI = 68.4-98.2%). When the full set of radio-tagged smolts released upstream of the designated representative reach in the upper portion of the Union River was used to evaluate background mortality, survival through the Graham Lake Dam reach during 2017 was estimated at 77.9% (95% CI = 74.3-93.8%).

During 2016, project survival estimates were calculated for both the radio and acoustic-tagged smolts and estimates for both groups were comparable (73.7% (95% CI = 61.4-84.2%) for acoustic-tagged smolts; 74.6% (95% CI = 64.8-84.5%) for radio-tagged smolts). Similar to the 2016 estimate of survival at Graham Lake Dam, the 2016 estimates for survival at Ellsworth were a function of both background and project related effects. During 2017, downstream passage survival at Ellsworth Dam (including background and project related effects) was estimated at 62.3% (95% CI = 48.6-74.2%). When adjusted to correct for background mortality based on the set of acoustic-tagged smolts released downstream of Ellsworth Dam passing through the designated representative reach in the lower portion of the Union River, survival through the Ellsworth Dam reach during 2017 was estimated at 80.8% (95% CI = 64.4-93.6%). When the full set of acoustic-tagged smolts released upstream of the designated representative reach in the lower portion of the Union River was used to evaluate background mortality, survival through the Ellsworth Dam reach during 2017 was estimated at 74.0% (95% CI = 60.3-86.4%).

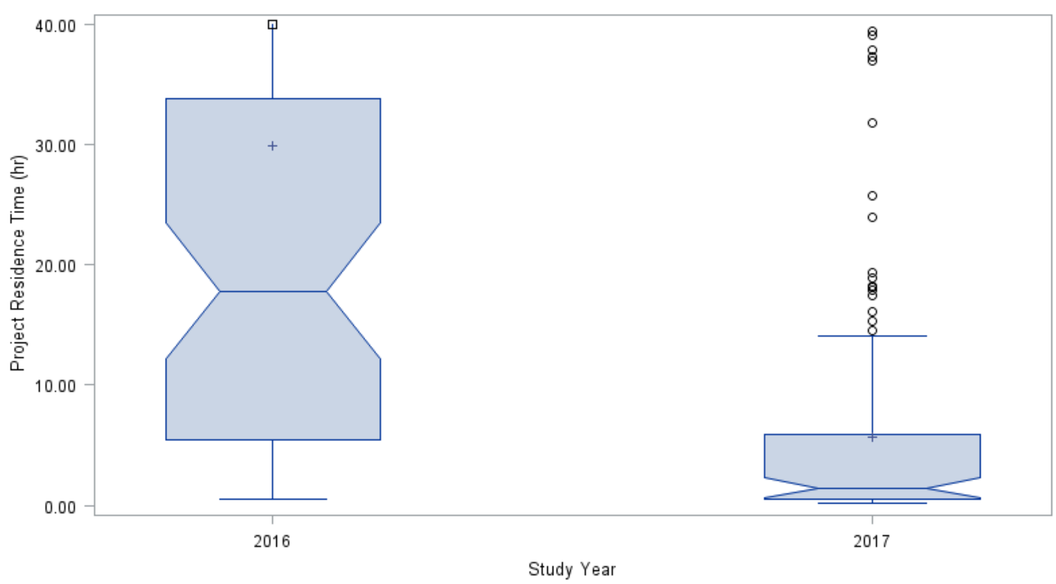
As part of a separate study, Normandeau evaluated the downstream survival of juvenile salmonids at the Ellsworth Dam during June, 2017 (Normandeau 2017). Juvenile brown trout were used as a surrogate in lieu of Atlantic salmon smolts for the evaluation. Individuals were passed downstream through Unit 1, Unit 2 and the downstream bypass and their survival was evaluated 48 hours post-passage. When the route specific rates observed during that study are combined with the proportional use of available downstream passage routes at Ellsworth (as observed during this study; Table 4-9), the estimate of downstream survival as impacted by only Ellsworth dam-related effects is 80.5%

(Table 5-1). This exercise provides support for the model-derived estimate corrected for background mortality and presented for Ellsworth Dam during 2017.



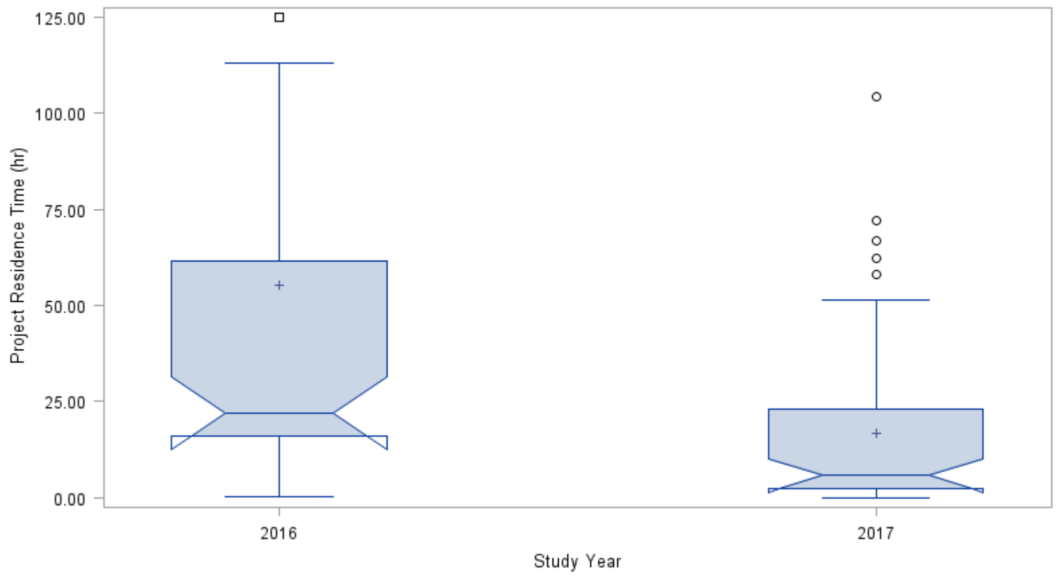
Median Residence Times by Year		
Q1	55.5525	0.823889
Q2	79.82597	5.643056
Q3	156.1894	35.50583
N	22	81

Figure 5-1. Notched box plot showing the median, 25th and 75th percentiles, and upper and lower bounds for project residence time (by study year) for radio-tagged smolts passing downstream at Graham Lake Dam



Median Residence Time by Year (Radio)		
Q1	5.415833	0.4725
Q2	17.85236	1.465278
Q3	33.87694	5.936944
N	62	118

Figure 5-2. Notched box plot showing the median, 25th and 75th percentiles, and upper and lower bounds for project residence time (by study year) for radio-tagged smolts passing downstream at Ellsworth Dam



Median Residence Time by Year (Acoustic)		
Q1	15.92611	2.143611
Q2	21.91667	5.698611
Q3	61.51944	22.85694
N	57	53

Figure 5-3. Notched box plot showing the median, 25th and 75th percentiles, and upper and lower bounds for project residence time (by study year) for acoustic-tagged smolts passing downstream at Ellsworth Dam

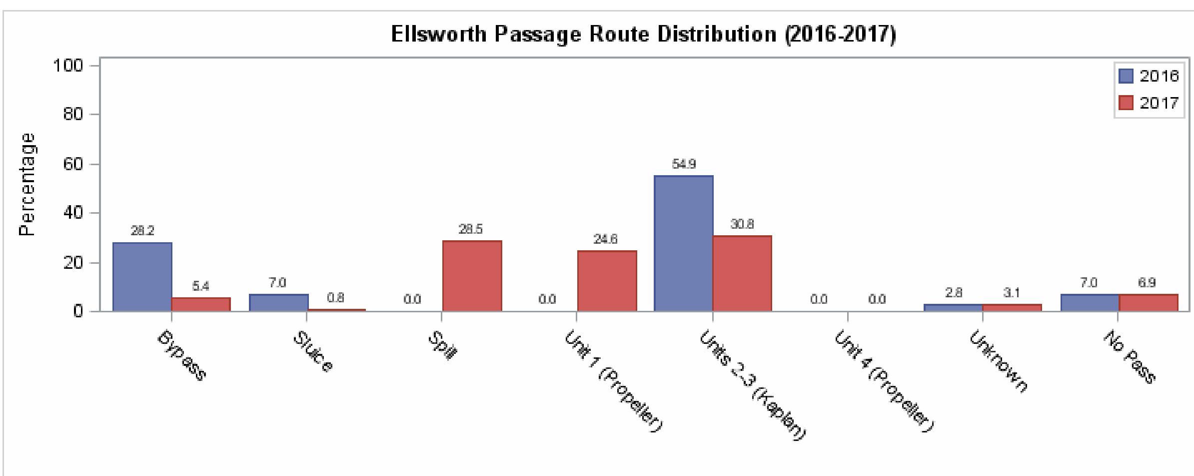


Figure 5-4. Distribution among downstream passage routes for radio-tagged Atlantic salmon smolts at Ellsworth Dam, 2016 and 2017

Table 5-1. Estimate of Ellsworth Dam reach survival based on route selection distribution obtained from radio-tagged smolts in this study and route-specific survival rates obtained from a HI-Z balloon tag evaluation conducted for passage of juvenile salmonids at the project

Downstream Passage Route	No. of Smolts	Percentage to Route	Route-specific Survival Rate*	Proportional Survival
Downstream Bypass	7	6.0%	0.962	0.058
Surface Sluice	1	0.9%	0.962	0.008
Spill	37	31.6%	0.962	0.304
Unit 1	32	27.4%	0.810	0.222
Unit 2	24	20.5%	0.624	0.128
Unit 3	16	13.7%	0.624	0.085
Total dam survival estimate				**0.805**

Route-specific rates obtained from Normandeau (2017). Spill rate based on observed results through downstream bypass. Unit 3 rate based on observed results for Unit 2.

6.0 Literature Cited

Normandeau Associates, Inc. (Normandeau). 2016. Evaluation of Atlantic Salmon Smolt Passage, Spring 2016 Ellsworth Project, FERC No. 2727. Report prepared for Black Bear Hydro Partners, LLC.

Normandeau Associates, Inc. (Normandeau). 2017. Evaluation of Survival and Injury Occurrence Associated with Downstream Passage for Juvenile Salmonids – Ellsworth Project FERC No. 2727. Draft in preparation for Black Bear Hydro Partners, LLC.

Appendix A

Summary of water quality conditions for all GLNFH Atlantic salmon smolts transported by truck in association with the Ellsworth Project.

Appendix Table A-1.

Date	Departing	Arriving	#Smolts	Time	Temp (°C)	DO (mg/L)	DO (%Sat)
5/15/2017	GLNFH	Ellsworth	185	1507	9.9	9.77	88.0
				1537	10.0	9.67	85.2
5/17/2017	Ellsworth	Release	75	1957	14.4	9.89	96.2
				2019	14.4	9.92	97.9
				2041	14.4	10.52	102.6
				2115	14.3	9.76	95.9
5/19/2019	GLNFH	Ellsworth	155	0925	13.8	9.60	92.0
				0945	13.8	8.83	85.2
5/19/2017	Ellsworth	Release	75	1947	15.3	9.54	96.2
				2000	15.3	9.35	92.7
				2024	15.3	9.10	91.2
				2102	15.1	9.77	96.2
5/21/2017	Ellsworth	Release	75	2004	16.8	9.23	95.0
				2028	16.7	9.55	98.0
				2107	16.5	9.44	96.7
5/23/2017	Ellsworth	Release	73	1956	16.2	9.38	95.8
				2021	16.1	9.50	96.2
				2040	16.1	9.67	97.9
				2103	16.0	9.54	96.1
5/24/2017	Ellsworth	Marina	85	0848	16.1	9.05	92.4
				0856	16.1	8.96	91.1

Appendix B

Rates of movements for radio and acoustic-tagged Atlantic salmon smolts through the Ellsworth Project area as defined by stationary telemetry equipment locations.

Appendix Table B-1. **Minimum, maximum, mean and median rate of movement for radio-tagged Atlantic salmon smolts by release group and release location for the reach between release location 1 and monitoring station U1, 2017**

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	<0.1	0.09	0.02	0.02
E2	<0.1	0.14	0.02	0.02
E3	0.01	0.05	0.02	0.02
E4	0.01	0.08	0.04	0.05
Release Location	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
1	<0.1	0.14	0.03	0.02
2	.	.	.	.
All	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
	<0.1	0.14	0.03	0.02

Appendix Table B-2. **Minimum, maximum, mean and median rate of movement for radio-tagged Atlantic salmon smolts by release group and release location for the reach between monitoring stations U1 and U4, 2017**

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.01	1.57	0.65	0.69
E2	0.07	1.81	0.8	0.88
E3	0.03	1.42	0.55	0.48
E4	0.06	1.3	0.61	0.66
Release Location	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
1	0.06	1.81	0.86	0.88
2	0.01	0.95	0.41	0.41
All	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
	0.01	1.81	0.66	0.7

Appendix Table B-3. Minimum, maximum, mean and median rate of movement for radio-tagged Atlantic salmon smolts by release group and release location for the reach between monitoring stations U4 and U5, 2017

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.08	3.73	1.63	1.65
E2	0.04	2.62	1.38	1.57
E3	0.02	2.83	1.41	1.68
E4	0.01	2.56	1.15	1.26
Release Location	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
1	0.05	3.73	1.46	1.54
2	0.01	3.47	1.33	1.57
All	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
	0.01	3.73	1.41	1.55

Appendix Table B-4. Minimum, maximum, mean and median rate of movement for radio-tagged Atlantic salmon smolts by release group and release location for the reach between monitoring station U5 and Ellsworth Dam, 2017

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.1	1.52	0.46	0.26
E2	0.04	1.17	0.38	0.31
E3	0.07	1.1	0.28	0.22
E4	0.03	0.84	0.22	0.14
Release Location	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
1	0.03	1.52	0.44	0.31
2	0.03	0.74	0.22	0.17
All	**Rate of Movement (mph)**			
	Min	**Max**	**Mean**	**Median**
	0.03	1.52	0.34	0.22

Appendix Table B-5. Minimum, maximum, mean and median rate of movement for acoustic-tagged Atlantic salmon smolts by release group and release location for the reach between release location 2 and Ellsworth Dam, 2017

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.03	0.38	0.19	0.18
E2	0.07	0.46	0.2	0.15
E3	0.07	0.27	0.17	0.17
E4	0.02	0.46	0.23	0.23
Release Location	Rate of Movement (mph)			
	Min	Max	Mean	Median
2	0.02	0.46	0.2	0.18
3	.	.	.	.
All	Rate of Movement (mph)			
	Min	Max	Mean	Median
	0.02	0.46	0.2	0.18

Appendix Table B-6. Minimum, maximum, mean and median rate of movement for acoustic -tagged Atlantic salmon smolts by release group and release location for the reach between Ellsworth Dam and monitoring station U17, 2017

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.05	2.38	0.58	0.34
E2	0.02	1.21	0.28	0.3
E3	0.03	2.32	0.55	0.28
E4	0.01	1.79	0.46	0.26
Release Location	Rate of Movement (mph)			
	Min	Max	Mean	Median
2	0.02	2.38	0.87	0.54
3	0.01	0.36	0.23	0.27
All	Rate of Movement (mph)			
	Min	Max	Mean	Median
	0.01	2.38	0.47	0.31

Appendix Table B-7. **Minimum, maximum, mean and median rate of movement for acoustic -tagged Atlantic salmon smolts by release group and release location for the reach monitoring stations U17 and U18, 2017**

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.05	2.25	0.47	0.23
E2	0.01	1.64	0.61	0.46
E3	0.01	1.75	0.73	0.77
E4	0.04	2.01	0.96	0.95
Release Location	Rate of Movement (mph)			
	Min	Max	Mean	Median
2	0.01	2.25	0.94	0.94
3	0.01	1.64	0.56	0.49
All	Rate of Movement (mph)			
	Min	Max	Mean	Median
	0.01	2.25	0.71	0.61

Appendix Table B-8. **Minimum, maximum, mean and median rate of movement for acoustic -tagged Atlantic salmon smolts by release group and release location for the reach between monitoring stations U18 and U19, 2017**

Release Group	Rate of Movement (mph)			
	Min	Max	Mean	Median
E1	0.04	3.11	1.11	1.04
E2	0.02	4.27	1.01	0.77
E3	0.01	2.47	1.47	1.53
E4	0.03	3.79	1.47	1.32
Release Location	Rate of Movement (mph)			
	Min	Max	Mean	Median
2	0.11	4.27	1.58	1.39
3	0.01	2.43	1.09	1.21
All	Rate of Movement (mph)			
	Min	Max	Mean	Median
	0.01	4.27	1.28	1.28

Appendix C

Encounter histories of radio and acoustic-tagged Atlantic salmon smolts as input into Program MARK for reach specific survivorship estimates and monitoring station detection efficiency values.

Input file for radio-tagged Atlantic salmon smolts (release location 1)

```
1000000    16;
1001111    4;
1100000    18;
1101110    1;
1101111    2;
1110000    8;
1110100    1;
1110111    4;
1111100    1;
1111101    2;
1111110    2;
1111111    61;
```

Input file for radio-tagged Atlantic salmon smolts (release location 2)

```
10000 2;
10110 1;
10111 1;
11000 1;
11100 1;
11101 1;
11110 5;
11111 46;
```

Input file for acoustic-tagged Atlantic salmon smolts (release location 2)

```
10000 7;
11000 20;
11110 1;
11111 32;
```

Input file for acoustic-tagged Atlantic salmon smolts (release location 3)

```
1000  5;
1100  5;
1111  50;
```

Appendix D

Summary of manual radio-tracking data from 2017 Ellsworth smolt evaluation

Appendix Table D-1. Manual radio-tracking detections, Graham Lake downstream to Ellsworth public marina, 2017

Frequency	Code	Date	Reach	Approximate Mileage	Latitude	Longitude
100	10	5/19/2017	GLD to Ellsworth	2	-68.444206	44.565048
100	11	5/19/2017	Graham Lake	1.25	-68.418284	44.602820
100	11	5/23/2017	Graham Lake	1	-68.427710	44.600779
100	14	5/23/2017	Graham Lake	1.75	-68.414860	44.608558
100	14	5/24/2017	GLD to Ellsworth	0.75	-68.441607	44.550851
100	15	5/30/2017	GLD to Ellsworth	1.25	-68.445556	44.559397
100	17	5/21/2017	Downstream Ellsworth	-0.5	-68.425655	44.539731
100	18	5/19/2017	GLD to Ellsworth	1.5	-68.445699	44.560238
100	19	5/19/2017	Graham Lake	1.25	-68.420021	44.602445
100	20	5/19/2017	Downstream Ellsworth	-0.75	-68.423263	44.538481
100	22	5/21/2017	GLD to Ellsworth	0.75	-68.437056	44.549762
100	23	5/19/2017	Downstream Ellsworth	-0.75	-68.422376	44.535937
100	24	5/19/2017	Downstream Ellsworth	-1	-68.422097	44.535685
100	26	5/21/2017	Graham Lake	2	-68.403743	44.605805
100	27	5/21/2017	Graham Lake	2.75	-68.390641	44.611691
100	28	5/24/2017	Downstream Ellsworth	-0.25	-68.429431	44.544292
100	28	5/24/2017	Downstream Ellsworth	-0.5	-68.426050	44.541307
100	28	5/30/2017	Downstream Ellsworth	-0.25	-68.429251	44.544127
100	31	5/21/2017	Graham Lake	0.25	-68.437530	44.593761
100	33	5/21/2017	Graham Lake	1	-68.428809	44.597804
100	35	5/21/2017	GLD to Ellsworth	0.75	-68.437749	44.549302
100	37	5/21/2017	Graham Lake	0.75	-68.442548	44.606108
100	37	5/23/2017	Graham Lake	1.75	-68.411566	44.605001
100	37	5/31/2017	Graham Lake	0.75	-68.442512	44.608541
100	40	5/24/2017	GLD to Ellsworth	0.25	-68.430249	44.544786
100	40	5/30/2017	GLD to Ellsworth	0.25	-68.430402	44.544880
100	47	5/23/2017	Graham Lake	0.5	-68.441498	44.598231
100	49	5/23/2017	Graham Lake	3.75	-68.395459	44.625569
100	49	5/23/2017	Graham Lake	4.5	-68.388328	44.637791
100	49	5/31/2017	Graham Lake	2.25	-68.419205	44.629995
100	50	5/23/2017	Graham Lake	0.5	-68.445641	44.598538
100	52	5/31/2017	Graham Lake	1	-68.428189	44.602027
100	53	5/23/2017	Graham Lake	1.75	-68.423413	44.614044
100	53	5/24/2017	GLD to Ellsworth	1.5	-68.446149	44.556797
100	55	5/24/2017	GLD to Ellsworth	1.75	-68.445657	44.560734
100	56	5/23/2017	Graham Lake	1.5	-68.423452	44.613996
100	57	5/31/2017	Graham Lake	2.25	-68.420871	44.631132
100	61	5/31/2017	Graham Lake	0.75	-68.443797	44.607662
300	76	5/24/2017	GLD to Ellsworth	1.75	-68.445810	44.560082
300	77	5/24/2017	GLD to Ellsworth	1.75	-68.445603	44.559731
300	78	5/24/2017	GLD to Ellsworth	0.5	-68.435670	44.548854
300	78	5/31/2017	GLD to Ellsworth	0.5	-68.436111	44.548961

Frequency	Code	Date	Reach	Approximate Mileage	Latitude	Longitude
300	79	5/24/2017	GLD to Ellsworth	0.25	-68.429967	44.544940
300	80	5/24/2017	GLD to Ellsworth	2	-68.444775	44.564679
300	81	5/19/2017	Graham Lake	0.5	-68.443585	44.596883
300	81	5/21/2017	Graham Lake	2.25	-68.405667	44.605947
300	81	5/23/2017	Graham Lake	4.5	-68.400705	44.633186
300	81	5/31/2017	Graham Lake	4	-68.385763	44.626136
300	82	5/19/2017	Graham Lake	0.5	-68.447776	44.599964
300	84	5/19/2017	GLD to Ellsworth	2.25	-68.443995	44.565026
300	84	5/21/2017	GLD to Ellsworth	2.25	-68.444074	44.565067
300	84	5/24/2017	GLD to Ellsworth	2.25	-68.444010	44.564983
300	84	5/31/2017	GLD to Ellsworth	2	-68.445250	44.564566
300	88	5/24/2017	Downstream Ellsworth	-0.25	-68.429404	44.544409
300	88	5/30/2017	Downstream Ellsworth	-0.25	-68.429327	44.544139
300	89	5/21/2017	Downstream Ellsworth	-0.75	-68.423179	44.538375
300	94	5/21/2017	GLD to Ellsworth	2.25	-68.444070	44.565135
300	95	5/21/2017	Graham Lake	2.75	-68.398536	44.611478
300	95	5/23/2017	Graham Lake	5.25	-68.417257	44.644879
300	95	5/31/2017	Graham Lake	1.5	-68.424469	44.612925
300	97	5/21/2017	Graham Lake	8	-68.367995	44.681501
300	97	5/30/2017	Graham Lake	0.25	-68.439833	44.591834
300	97	5/31/2017	Graham Lake	2.25	-68.406584	44.606259
300	101	5/21/2017	Downstream Ellsworth	-0.5	-68.425567	44.539620
300	102	5/21/2017	Graham Lake	1.25	-68.423371	44.598721
300	102	5/23/2017	Graham Lake	0.5	-68.441497	44.595770
300	103	5/21/2017	Graham Lake	0.25	-68.441724	44.594353
300	105	5/21/2017	Graham Lake	1.25	-68.426534	44.605826
300	105	5/31/2017	Graham Lake	1.75	-68.412241	44.603276
300	111	5/31/2017	Graham Lake	2.25	-68.419227	44.628331
300	112	5/31/2017	Graham Lake	2.75	-68.416970	44.632023
300	113	5/23/2017	Graham Lake	0.25	-68.441006	44.592053
300	113	5/23/2017	Graham Lake	2.75	-68.417465	44.631184
300	114	5/23/2017	Graham Lake	1	-68.429460	44.599886
300	114	5/30/2017	GLD to Ellsworth	4	-68.439833	44.590414
300	115	5/23/2017	Graham Lake	2	-68.422825	44.621699
300	116	5/23/2017	Graham Lake	0.5	-68.440895	44.596239
300	117	5/23/2017	Graham Lake	2.25	-68.419934	44.626767
300	118	5/23/2017	Graham Lake	0.5	-68.441823	44.598049
300	118	5/24/2017	GLD to Ellsworth	1	-68.442175	44.550546
300	119	5/23/2017	Graham Lake	0.25	-68.438744	44.593404
300	119	5/30/2017	Downstream Ellsworth	-0.25	-68.429303	44.544358
300	120	5/23/2017	Graham Lake	0.5	-68.441025	44.598188
300	121	5/21/2017	Graham Lake	1.25	-68.423547	44.598738
300	128	5/30/2017	GLD to Ellsworth	1.75	-68.446021	44.560327
300	130	5/19/2017	Graham Lake	0.5	-68.441933	44.595998
300	131	5/19/2017	Graham Lake	1.25	-68.425491	44.602350
300	131	5/23/2017	Graham Lake	1	-68.429172	44.600054

Frequency	Code	Date	Reach	Approximate Mileage	Latitude	Longitude
300	131	5/31/2017	Graham Lake	1	-68.427951	44.601413
300	132	5/19/2017	Graham Lake	0.5	-68.441695	44.595952
300	132	5/21/2017	Downstream Ellsworth	-0.5	-68.425661	44.539882
300	133	5/19/2017	Graham Lake	0.75	-68.446501	44.604231
300	135	5/21/2017	Graham Lake	0.25	-68.439450	44.591507
300	137	5/23/2017	Graham Lake	8.25	-68.363338	44.685211
340	144	5/21/2017	GLD to Ellsworth	0.75	-68.437450	44.549429
340	146	5/21/2017	GLD to Ellsworth	2	-68.444923	44.564595
340	147	5/21/2017	Graham Lake	1.25	-68.417865	44.595913
340	147	5/23/2017	Graham Lake	2.75	-68.399976	44.614076
340	147	5/31/2017	Graham Lake	3.75	-68.388932	44.624014
340	148	5/21/2017	Graham Lake	0.75	-68.443391	44.605000
340	148	5/24/2017	GLD to Ellsworth	2.25	-68.444188	44.564948
340	148	5/30/2017	GLD to Ellsworth	1.5	-68.445644	44.559250
340	149	5/21/2017	Graham Lake	0.75	-68.443805	44.607307
340	150	5/21/2017	Graham Lake	0.5	-68.444271	44.599530
340	151	5/23/2017	Graham Lake	0.25	-68.434645	44.591824
340	152	5/21/2017	Graham Lake	0.75	-68.442577	44.605696
340	152	5/23/2017	Graham Lake	6.5	-68.371503	44.662636
340	152	5/31/2017	Graham Lake	6.25	-68.375586	44.658239
340	153	5/21/2017	Graham Lake	0.75	-68.442983	44.604765
340	153	5/23/2017	Graham Lake	1.75	-68.425252	44.620701
340	159	5/24/2017	GLD to Ellsworth	0.75	-68.442408	44.550884
340	159	5/30/2017	GLD to Ellsworth	0.75	-68.442053	44.550040
340	161	5/23/2017	Graham Lake	0.25	-68.441736	44.593032
340	162	5/23/2017	Graham Lake	2	-68.411892	44.604448
340	162	5/31/2017	Graham Lake	0.5	-68.446804	44.602220
340	163	5/23/2017	Graham Lake	1	-68.436523	44.607060
340	163	5/31/2017	Graham Lake	1	-68.438733	44.609025
340	164	5/23/2017	Graham Lake	0.25	-68.442150	44.594156
340	165	5/23/2017	Graham Lake	0.75	-68.432721	44.597167
340	166	5/23/2017	Graham Lake	1	-68.428318	44.600435
340	167	5/23/2017	Graham Lake	1.75	-68.423401	44.617904
340	168	5/23/2017	Graham Lake	0.25	-68.439786	44.592887
340	169	5/31/2017	Graham Lake	1.25	-68.431917	44.612060
340	172	5/30/2017	GLD to Ellsworth	0.75	-68.439236	44.549917
340	179	5/31/2017	Graham Lake	0.5	-68.447014	44.601409
340	183	5/24/2017	Downstream Ellsworth	-0.25	-68.429291	44.544441
340	183	5/24/2017	Downstream Ellsworth	-1	-68.422228	44.534316
340	184	5/24/2017	GLD to Ellsworth	0.5	-68.436211	44.548502
340	185	5/24/2017	GLD to Ellsworth	2.25	-68.444133	44.565017
340	186	5/24/2017	Downstream Ellsworth	-0.25	-68.429419	44.544274
340	186	5/24/2017	Downstream Ellsworth	-0.25	-68.425973	44.541240
340	186	5/30/2017	Downstream Ellsworth	-0.25	-68.429129	44.543990
340	188	5/19/2017	GLD to Ellsworth	1.75	-68.445402	44.562041
340	191	5/21/2017	Downstream Ellsworth	-0.5	-68.425508	44.539697

Frequency	Code	Date	Reach	Approximate Mileage	Latitude	Longitude
340	191	5/24/2017	Downstream Ellsworth	-0.5	-68.424022	44.539164
340	191	5/31/2017	Downstream Ellsworth	-0.5	-68.424022	44.539164
340	192	5/19/2017	GLD to Ellsworth	0.75	-68.440951	44.549819
340	193	5/19/2017	Graham Lake	1	-68.437937	44.609767
340	193	5/21/2017	Graham Lake	0.25	-68.442238	44.592983
340	195	5/19/2017	Graham Lake	2.5	-68.404896	44.611834
340	196	5/19/2017	Graham Lake	1.75	-68.416952	44.603706
340	198	5/19/2017	Graham Lake	1.25	-68.425991	44.602196
340	198	5/21/2017	Graham Lake	2.25	-68.407119	44.606074
340	199	5/19/2017	Graham Lake	1	-68.430446	44.600511
340	201	5/24/2017	GLD to Ellsworth	0.25	-68.431502	44.546045
340	201	5/30/2017	GLD to Ellsworth	0.25	-68.430859	44.545555
340	202	5/19/2017	Graham Lake	0.25	-68.435853	44.592296
340	204	5/19/2017	Graham Lake	1.75	-68.416711	44.603881

Note: Approximate mileage based on 0.25 mile increments. Values for the Graham Lake and GLD to Ellsworth reaches are presented in an upstream direction (e.g., 0.25 miles = tag was detected within the reach from 0 to 0.25 miles upstream of the dam). Values for the Downstream Ellsworth reach are presented in a downstream direction (e.g., -0.25 miles = tag detected within the reach from 0 to 0.25 miles downstream of the dam).

Appendix E

Correspondence related to agency review of the draft 2017 Ellsworth smolt telemetry report

From: Dill, Richard
Sent: Wednesday, October 11, 2017 1:50 PM
To: Anna Harris (anna_harris@fws.gov); Asha Ajmani (aajmani@wabnaki.com); Atkinson, Ernie (ernie.atkinson@maine.gov); Bernier, Kevin (Kevin.Bernier@brookfieldrenewable.com); Bley, Wendy (wbley@trcsolutions.com); Browne, Peter (Peter.Browne@hdrinc.com); Bryan Sojkowski (Bryan_Sojkowski@fws.gov); Cole, James (James.Cole@brookfieldrenewable.com); Colin Shankland (colin.shankland@maine.gov); Dan Tierney (dan.tierney@noaa.gov); Dill, Richard (Richard.Dill@brookfieldrenewable.com); donald.dow@noaa.gov; Dunlap,Frank (Frank.Dunlap@brookfieldrenewable.com); Gail Wippelhauser (gail.wippelhauser@maine.gov); Greg Burr (gregory.burr@maine.gov); John Sewell (johnsewell44@hotmail.com); Maloney, Kelly (Kelly.Maloney@brookfieldrenewable.com); Marvin Cling, Sr. (marvin@wabanaki.com); Overlock, Joe (Joe.Overlock@maine.gov); Sean McDermott (sean.mcdermott@noaa.gov); Simpson, Mitch (mitch.simpson@maine.gov); Steve Shepard (Steven_Shepard@fws.gov)
Subject: Draft 2017 Ellsworth Project Atlantic salmon smolt passage study report

All,
For your review, attached please find the draft *2017 Ellsworth Project Atlantic Salmon Smolt Passage Study Report*. A summary of key findings from this year's passage study was previously distributed and discussed at the Ellsworth SPP held September 14th. We anticipate further discuss the report at the next SPP meeting to be held October 19th. Formal comments on the report should be submitted to Brookfield by November 10, 2017.

Thanks, and feel free to contact Frank or I with any questions.

Richard Dill
Compliance Specialist

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Brookfield

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930-2276

OCT 31 2017

Richard Dill
Compliance Specialist
Brookfield Renewable
44 Davenport Street
Milford, ME 04461

Re: 2017 Atlantic Salmon Smolt Survival Study at the Ellsworth Project (P-2727)

Dear Mr. Dill:

In your October 11, 2017 e-mail, you requested that we review and comment on Black Bear's draft Atlantic salmon smolt survival study report from the May 2017 study conducted at the Ellsworth Project (FERC No. 2727) on the Union River in Ellsworth, Maine. This was a well designed and implemented study, and we appreciate the speed with which the results were analyzed and presented. We acknowledge the Licensee's efforts working with us and other stakeholders on the Union River to conduct the best possible assessments of Atlantic salmon. Although the installation of the entrance weir led to significant improvements in passage at the Graham Lake Dam, it is apparent from these results that additional operational or structural changes are needed at the project to adequately protect endangered Atlantic salmon.

Comments on the 2017 draft study report

In your study plan filed with FERC in January 2017, you proposed to adjust your passage survival estimates using the survival of naïve Atlantic salmon smolts (i.e. those that have not passed any dams) through a "representative reach". In our comments on the study plan, we recommended that you use a reach upriver of all dam influence in the West Branch of the Union River. Instead, you selected two short reaches: 1) a 0.8 kilometer reach (U4 to U5) between the Graham Lake Dam and Ellsworth Dam impoundments, and 2) a 1.4 kilometer reach (U17 and U18) approximately one kilometer downriver of Ellsworth Dam in the tidally influenced portion of the river. We have a few comments regarding the use of these reaches:

a. The lengths of these reaches are too short to adequately represent the survival of smolts through the Union River. A short reach is more susceptible to random events, and is therefore less likely to represent the *average* survival through the lower Union River. This could bias the results in either direction. At your projects on the Penobscot River, you consulted with the agencies to identify a representative reach that was both sufficiently long and free of project effects. As a result, you selected a reach that was over 31 kilometers long, which was significantly longer than the study reach where you were assessing dam impacts. On the Union, you have selected reaches that are *shorter* than the reaches you are attempting to assess.

b. These "representative" reaches do not represent a "natural" (i.e. free of dam effects) level of mortality in the Union River. The upper reach (U4 to U5) is located immediately upriver of the Leonard Lake impoundment and is only three kilometers downriver of Graham Lake Dam and its impoundment. The predator assemblage is likely heavily influenced by the presence of these features. That said, this reach might be useful in isolating the effects of dam passage if it were an adequate length (see above comment).

The lower reach (U17 to U18) is located within the Union River estuary. The salinity, temperature, and species assemblage are all expected to be different in this reach as compared to the freshwater reach containing the dam. It has been noted in other rivers in the GOM DPS and elsewhere that Atlantic salmon mortality rates increase significantly in the estuary. As indicated in Stich et al (2015)[1]:

> *The transition of Atlantic Salmon smolts to saltwater is recognized as a period of high mortality in estuaries (Lacroix 2008; Kocik et al. 2009; Dempson et al. 2011) and fjords (Gudjonsson et al. 2005; Svenning et al. 2005; Thorstad et al. 2012b). This period is marked by high predation risk (Hvidsten and Lund 1988; Kocik et al.), physiological stresses (Handeland et al. 1997), and novel environmental conditions (McCormick et al. 1998).*

Therefore, it is not appropriate to use a reach in the estuary to represent background conditions in freshwater reaches of the Union River. The study reach for the Ellsworth Dam is 3.2 km long (U16 to U17), with 0.9 km of the reach classified as riverine according to National Wetland Inventory. In contrast, the entire representative reach (U17 to U18) is classified as estuarine. Given the difference in survival between the freshwater and estuarine representative reaches, adjusting the Ellsworth Dam survival based on survival in the estuary underestimates the effect of the dam.

c. The intent of monitoring smolts that had not passed a dam previously was to ensure that the survival through the "representative reach" was not influenced by injury or stress sustained in dam passage. This is a valid concern, and studies should make an effort to discern if such an effect is confounding results. However, when such an effect is not detected, it is more appropriate to use all the fish released upriver of the representative reach as it improves the precision of the estimate (i.e. larger sample sizes equate to lower standard error). This is the approach we have taken at other projects operated by Brookfield on the Penobscot and Kennebec Rivers.

[1] Stich, D.S., G.B. Zydlewski, J.F. Kocik, J.D. Zydlewski. 2015. Linking Behavior, Physiology, and Survival of Atlantic Salmon Smolts During Estuary Migration, Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 7:1, 68-86.

Table 4-12 shows that 100% of the smolts that passed the Graham Lake Dam (release 1) survived in the upper representative reach (U4 to U5). Table 4-13 indicates that only 98.2% of the smolts that had *not* passed Graham Dam (Release 2) survived through the same reach. Table 4-14 indicates that you adjusted the dam survival using the survival of the fish that had *not* passed the dam, even though Table 4-17 indicates that the *overall* (Release 1 and 2) smolt survival through that reach was higher (99.2%). Using the lower survival rate (98.2%) rather than the overall survival rate (99.2%) to adjust your dam survival estimate suggests that you believe there is a bias associated with the upper release (release 1). However, as the survival of release 1 was higher than release 2, that bias would have to be positive. As it is illogical to assume that fish that pass Graham Lake Dam would somehow be more likely to survive in the representative reach downstream than fish that did not, it is appropriate to conclude that there were no latent effects from Graham Lake Dam passage within that reach (U4 to U5).

Although the difference between the release 2 survival and the overall survival is seemingly small (1%), it does have an effect on the survival rates you are reporting. The estimate of background mortality you have presented for the upper reference reach (based only on release 2) would suggest that 2.3% of smolts are dying per kilometer in the free flowing reach of the river. However, if you look at *all* the fish released, the background mortality is approximately only 1% per kilometer. This effect is apparent in your Ellsworth background adjustment as well (see Tables 4-19, 4-20, 4-21, and 4-23). There is a significant difference (~10%) in estimated whole station survival (Graham Lake Dam and Ellsworth Dam) depending on the method of calculating background mortality. Therefore, please include both methods of calculating survival in your final study report.

Additionally, we recommend the following changes be made for the final report:

- There were no receivers at the 200 meter mark at Graham Lake Dam. It should be noted on page 8 of the report that you are making the assumption that the upstream receiver at the dam (U1) is providing coverage of the area between the dam and 200 meters upriver.

- The report should justify why the drift study results do not apply to either the acoustic tag results at the Ellsworth Dam, or the radio tag results at Graham Lake Dam. In future studies, consider injecting some dead fish mid-water column to simulate fish that are killed via turbine entrainment.

- Explain the survival rate of fish released in the Graham Lake Dam tailrace between the U3 and U4 receivers. Additionally, the report should note how many fish from each of the release groups reached station U4.

- Differentiate the survival of smolts passing the Graham Lake Dam via the downstream bypass and the two Tainter gates.

- Provide the Program MARK output (similar to Table 4-22 in the 2016 study report) that shows reach specific survivals for each release.
- Indicate whether observations of avian predators made during the study period. If so, report the results of your observations.
- There is a notable difference in the proportion of acoustically tagged versus radio tagged smolts reaching Ellsworth Dam (88% versus 93%), and in their median residence time (5.7 hours versus 1.5 hours). Provide information to clarify if there is any evidence that these fish suffered from more handling stress while they were being held that may have affected their health.
- At the bottom of page 15, you indicate that detection probabilities would be calculated for U1, U3, U4, U5, U6, Ellsworth facilities, and U14. The report should address why these probabilities aren't all 100%.

We look forward to working with you to find solutions to the issues that were revealed through this study. Based upon the results of two years of smolt studies at the project (2016 and 2017), it is apparent that significant modifications are needed at the Ellsworth Project to fully protect endangered Atlantic salmon in the Union River. If you have any questions concerning these comments, please contact Dan Tierney (207-866-3755 or Dan.Tierney@noaa.gov).

Sincerely,

Julia Crocker

Julia Crocker
Endangered Species Coordinator

CC: McDermott, Boelke - F/GAR4

Appendix F

Responses to resource agency comments

The following comments were provided by NMFS:

NMFS Comment 1: *In your study plan provided to FERC in January 2017, you proposed to adjust your passage survival estimates using the survival of naïve Atlantic salmon smolts (i.e., those that have not passed any dams) through a 'representative' reach. . . . The intent of monitoring smolts that had not passed a dam previously was to ensure that the survival through the 'representative reach' was not influenced by injury or stress sustained in dam passage. This is a valid concern, and studies should make an effort to discern if such an effect is confounding results. However, when such an effort is not detected, it is more appropriate to use all the fish released upriver of the representative reach as it improves the precision of the estimate (i.e., larger sample size equates to lower standard error). . . . Therefore please include both methods of calculating survival in your final study report.*

Response to NMFS Comment 1: As requested, the final report has been updated to include a pair of reach survival estimates for both Graham Lake and Ellsworth Dams utilizing background mortality adjustments calculated based on detection information for (1) the subset of tagged smolts released upstream of the references reach and unexposed to prior dam passage and (2) the full set of tagged smolts released upstream of the reference reach. Sections 4.5.1.2 and 4.5.1.3 and corresponding Tables 4-13 and 4-14 have been modified to reflect the pair of survival estimates for Graham Lake Dam and Sections 4.5.2.2 and 4.5.2.3 and corresponding Tables 4-20 and 4-21 have been modified to reflect the pair of survival estimates for Ellsworth Dam.

NMFS Comment 2: *There were no receivers at the 200 meter mark at Graham Lake Dam. It should be noted on page 8 of the report that you are making the assumption that the upstream receiver at the dam (U1) is providing coverage of the area between the dam and 200 meters upriver.*

Response to NMFS Comment 2: The report has been edited as requested. The decision to monitor the approach to Graham Lake Dam from the upstream side of the facility rather than in a cross-river manner at a point approximately 200 meters upstream was a logistical one. Unlike the vast majority of sites where Normandeau has monitored smolt approach to a project, Graham Lake Dam at the point 200 m upstream is nearly 1,000 m wide. Even with receivers on opposite sides of the lake this would exceed the anticipated range of detection for NTC-3-2 transmitters.

NMFS Comment 3: *The report should justify why the drift study results do not apply to either the acoustic tag results at Ellsworth Dam or the radio tag results at Graham Lake Dam. Inn future studies, consider injecting some dead fish mid-water column to simulate fish that are killed via turbine environment.*

Response to NMFS Comment 3: Based on the physical constraints for radio-telemetry within the section of the Union River downstream of Ellsworth Dam (i.e., the presence of seawater influence), stationary radio-receivers intended to aid in survival determination needed to be placed a relatively short distance downstream (0.4 km). In the event that radio-tagged smolts killed during passage did not settle prior to reaching that receiver they would be falsely assigned as alive and result in a positively biased survival estimate for the dam. As a result, the drift component was designed to specifically evaluate radio-tagged smolts downstream of Ellsworth. Receivers placed downstream of Ellsworth dam for acoustic-tagged smolts (3.0 km) and downstream of Graham Lake Dam for radio-tagged smolts (3.4 km) were at a distance felt to be adequate for post passage mortality to have been expressed (i.e. dead smolts would have settled) prior to detection. Support for this assumption is provided by Havn et al. (2017)[4] which estimated the median settlement distance for six separate release groups of freshly-dead turbine or tailrace released Atlantic salmon smolts within three rivers to range from 0 to 1.5 km. No individual smolts drifted further than 2.4 km downstream during that evaluation.

NMFS Comment 4: *Explain the survival rate of fish released in the Graham Lake Dam tailrace between the U3 and U4 receivers. Additionally, the report should note how many fish from each of the release groups reached station U4.*

Response to NMFS Comment 4: A total of 58 radio-tagged smolts were released into the Graham Lake Dam tailrace and monitored for arrival at the first receiver downstream of the dam (Monitoring Station U4). Of that total, 97% (56 of 58 individuals) reached Station U4. The two radio-tagged smolts not reaching the first downstream receiver were released with group 1 on May 17 and group 4 on May 23. Losses in that stretch can likely be attributed to predation within the tailrace and riverine reach leading up to the first monitoring station or possibly latent handling/tagging effects not expressed during the 24+ hour holding period. The requested information has been added to the study report.

NMFS Comment 5: *Differentiate the survival of smolts passing the Graham Lake Dam via the downstream bypass and the two taintor gates.*

Response to NMFS Comment 5: The requested information has been added to the study report. Please see Section 4.5.1.3 and Table 14a.

NMFS Comment 6: *Provide the Program MARK output (similar to Table 4-22 in the 2016 study report) that shows reach specific survival for each release.*

Response to NMFS Comment 6: The requested information has been added to the study report. Please see Section 4.5.3 and Table 24.

[4] Havn, T.B., F. Okland, M.A.K. Teichert, L. Heermann, J. Borcherding, S.A. Saether, M. Tambets, O.H. Diserud and E.B. Thorstad. 2017. Movements of dead fish in rivers. Animal Biotelemetry. (2017) 5:7.

NMFS Comment 7: *Indicate whether observations of avian predators were made during the study period. If so, report the results of your observations.*

Response to NMFS Comment 7: Avian observations were made by Brookfield personnel in the area immediately upstream and downstream of Graham Lake Dam between the dates of May 11 and June 4, 2017. Counts were conducted three times daily and the full table of counts is included in Appendix G of this report. In addition, Normandeau recorded avian observations immediately upstream and downstream of Graham Lake and Ellsworth Dams as well as at the lowermost stationary radio-telemetry receiver location. Normandeau counts were conducted between May 19 and May 26 and occurred at the time study personnel were at those locations for receiver downloading. Counts from the Normandeau observations are also included in Appendix G.

Observations of predatory avian species were limited at Graham Lake Dam as noted by both Brookfield and Normandeau personnel. In contrast, numerous cormorants and gulls were present upstream and downstream of Ellsworth Dam as well as at the lowermost radio-receiver location on all dates/times of observation.

NMFS Comment 8: *There is a notable difference in the proportion of acoustically tagged versus radio tagged smolts reaching Ellsworth Dam (88 vs 93%), and in their median residence time (5.7 hours versus 1.5 hours). Provide information to clarify if there is any evidence that these fish suffered from more handling stress while they were being held that may have affected their health.*

Response to NMFS Comment 8: Atlantic salmon smolts marked with radio and acoustic tags were subjected to the same housing and handling. Fish were transported from GLNFH and maintained in a common tank on site. Individuals were randomly selected for tagging with no preferential selection for tag types. There were no significant differences in the mean fork length ($t = 0.29$; $p = 0.7716$) or mean weight ($z = -00862$; $p = 0.9313$) for individuals selected for radio- or acoustic-tags. Tagged smolts were transported to the same release site and released within minutes of one another following an identical field approach. When the median residence times are compared (see Figure A-1 below) there was no significant difference as evidenced by the overlap between the upper and lower bounds of the box plot notches for the two groups. Given the sample sizes of the two treatment groups and the contribution of a single individual (near to 2%) to the total, it is likely that the perceived difference in arrival proportion is likely a function of sample size and not related to differential handling.

Median Forebay Residence by Transmitter		
Q1	2.143611	0.4725
Q2	5.698611	1.465278
Q3	22.85694	5.936944
N	53	118

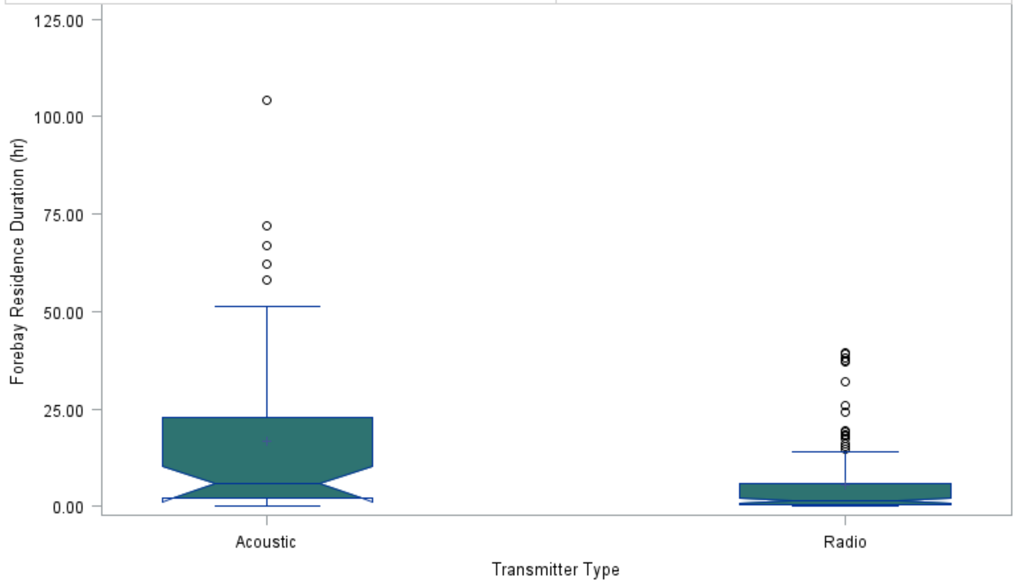

Figure A-1. Notched box plot showing the median, 25th and 75th percentiles, and upper and lower bounds for the forebay residence duration (by transmitter type) of tagged Atlantic salmon smolts at Ellsworth Dam.

NMFS Comment 9: *At the bottom of page 15, you indicate that detection probabilities would be calculated for U1, U3, U4, U5, U6, Ellsworth facilities and U14. The report should address why these probabilities aren't all 100%.*

Response to NMFS Comment 9: Outmigrating tagged Atlantic salmon smolts were monitored via a series of stationary receivers. As presented in the draft report, detection efficiencies were not 100% at all stations. The detection efficiencies are a function of a number of factors including (but not limited to) travel rate of the individual, transmitter depth, transmitter range (i.e., proximity to antenna), transmitter size, pulse rate, and background interference at the specific monitoring location. All of these considerations must be weighed when selecting equipment (receiver/antenna type) and physical placement. As each parameter has associated trade-offs, detection efficiencies for migrating fish will rarely be 100% (Adams et al. 2012[5]). The range of detection probabilities observed during 2017 was well within the bounds Normandeau has observed for successful smolt telemetry studies conducted on the Kennebec, Androscoggin and Penobscot Rivers over the past seven years.

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[5] Adams, N.S., J.W. Beeman, and J.H. Eiler, editors. 2012. Telemetry techniques: a user guide for fisheries research. American Fisheries Society, Bethesda, Maryland.

Appendix G

2017 Avian Observations

Table G-1. Brookfield avian observations – Graham Lake Dam (May 11-June 4, 2017).

Date	Time	Weather	Upstream							Downstream						
			CL	DCCO	BE	O	GS	HS	Unk	CL	DCCO	AE	O	GS	HS	Unk
	10:03	CLOUDY	0							0						
	12:07	RAIN														
5/11/2017	14:09	CLOUDY								1						
	8:07	CLOUDY														
	12:58	PARTLY SUNNY														
5/12/2017	15:15	SUNNY														
	11:05	SUNNY														
	13:00	SUNNY														
5/13/2017	18:30	PARTLY SUNNY														
	11:02	RAIN														
	15:06	RAIN														
5/14/2017	18:42	RAIN														
	8:45	CLOUDY														
	10:00	RAIN														
5/15/2017	12:45	RAIN														
	11:07	SUNNY														
	13:03	SUNNY														
5/16/2017	15:10	SUNNY														
	9:03	SUNNY														
	10:12	SUNNY														
5/17/2017	15:17	SUNNY														
	16:51	SUNNY	2													
5/18/2017	17:35	SUNNY	2													
	11:00	MOSTLY SUNNY														
	17:40	MOSTLY SUNNY														
5/19/2017	18:50	MOSTLY SUNNY														

Date	Time	Weather	Upstream							Downstream						
			CL	DCCO	BE	O	GS	HS	Unk	CL	DCCO	AE	O	GS	HS	Unk
	11:05	SUNNY														
	12:40	SUNNY														
5/20/2017	16:10	SUNNY							2							1
	13:06	SUNNY														
	15:01	SUNNY														
5/21/2017	16:17	SUNNY												1		
	11:13	CLOUDY														
	12:30	CLOUDY														
5/22/2017	13:53	CLOUDY														
	9:17	CLOUDY														
	12:03	CLOUDY														
5/23/2017	16:21	CLOUDY														
	10:10	PARTLY SUNNY														
	14:30	PARTLY SUNNY														
5/24/2017	17:05	CLOUDY														
	8:45	CLOUDY														
	11:20	CLOUDY														
5/25/2017	18:00	RAIN														
	8:02	RAIN														
	11:18	CLOUDY														
5/26/2017	13:51	CLOUDY		1							2					
	9:00	CLOUDY														
5/27/2017	16:35	CLOUDY														
	8:07	SUNNY			1											
	12:11	SUNNY														
5/28/2017	16:02	SUNNY														
	11:17	CLOUDY														
5/29/2017	11:50	CLOUDY														

Date	Time	Weather	Upstream							Downstream						
			CL	DCCO	BE	O	GS	HS	Unk	CL	DCCO	AE	O	GS	HS	Unk
	13:26	CLOUDY														
	8:06	SUNNY														
5/30/2017	9:55	SUNNY														
	10:00	CLOUDY														
	13:05	CLOUDY														
5/31/2017	14:30	CLOUDY														
	11:10	SUNNY						2								
	14:52	SUNNY														
6/1/2017	15:36	CLOUDY														
	8:00	SUNNY											1			
	13:15	SUNNY														
6/2/2017	18:25	RAIN														
	13:05	CLOUDY														
	15:45	CLOUDY														
6/3/2017	18:30	CLOUDY										1				
	8:00	CLOUDY														
	13:10	CLOUDY														
6/4/2017	14:30	CLOUDY														

CL = Common Loon
DCCO = Double-crested Cormorant
BE = Bald Eagle
O = Osprey
GS = Gull species
HS = Heron species
Unk = Unknown species

Table G-2. Normandeau avian observations – Graham Lake Dam, Ellsworth Dam, Station U15 (May 19-May 26, 2017).

Location	Date	Time	Upstream		Downstream	
			Cormorant	Gulls	Cormorant	Gulls
Graham Lake Dam	5/19/2017	8:40	0	0	0	0
	5/20/2017	13:45	0	0	0	0
	5/21/2017	13:00	0	0	0	0
	5/22/2017	12:05	0	0	0	0
	5/23/2017	11:15	0	0	0	0
	5/24/2017	12:15	0	0	0	0
	5/25/2017	12:10	0	0	0	0
	5/26/2017	11:00	0	0	0	0
Ellsworth Dam	5/19/2017	12:25	20	10	40	10
	5/20/2017	10:15	25	3	10	6
	5/20/2017	16:15	45	8	6	8
	5/21/2017	8:30	35	16	30	9
	5/21/2017	14:00	35	10	5	2
	5/22/2017	7:15	55	12	25	5
	5/22/2017	13:00	31	6	11	2
	5/23/2017	9:00	80	15	15	7
	5/23/2017	13:15	55	10	20	6
	5/24/2017	7:25	80	5	10	2
	5/24/2017	13:25	40	5	9	2
	5/25/2017	7:10	50	4	4	3
	5/25/2017	12:30	115	15	4	3
	5/26/2017	8:30	55	3	15	2
	5/26/2017	13:35	65	7	4	2
Station U15	5/19/2017	15:18	-	-	15	20
	5/20/2017	12:15	-	-	6	3
	5/21/2017	7:15	-	-	5	2
	5/22/2017	11:26	-	-	5	2
	5/23/2017	10:45	-	-	5	2
	5/24/2017	11:00	-	-	7	2
	5/25/2017	9:50	-	-	2	0
	5/26/2017	7:30	-	-	35	2

Ellsworth Project, FERC No. 2727

Evaluation of Survival and Injury Occurrence Associated with Downstream Passage for Juvenile Salmonids

Prepared For:

Black Bear Hydro Partners, LLC

Lewiston, Maine

Submitted:

December 2017

Prepared By:

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Executive Summary

This study was designed to assess direct injury and relative survival (at 1 hour and 48 hours) of juvenile salmonids passed through a propeller turbine (Unit 1), a Kaplan turbine (Unit 2) and the fish downstream bypass system at the Ellsworth Dam on the Union River in Ellsworth, Maine by utilizing the HI-Z Turb'n Tag methodology. This tag allows for immediate recapture of fish after passage through specific routes (turbines, spillways, etc.) in order to assess fish condition and determine the extent and type of any injuries that may occur. This study occurred between June 12 and June 17, 2017.

Test fish (juvenile brown trout) for this study were obtained from the Shy Beaver Fish Hatchery in Hollis, Maine. This species was selected as a surrogate for federally endangered Atlantic salmon. The fish were transported and held onsite at Ellsworth Dam prior to tagging and release.

Direct post-passage survival at 1 and 48 hours was determined. The post passage condition of recaptured fish was evaluated by a malady-free metric, which accounted for fish free of visible injuries and/or loss of equilibrium, as well as an injury-free metric (fish free of visible injuries).

A sufficient sample size of fish to be released through each passage route (turbine Unit 1, turbine Unit 2, and the downstream bypass) was determined prior to the start of the study in order to obtain survival, malady-free, and injury-free estimates within a precision level of ±10%, 90% of the time. Due to low survival and high injury rates for fish passed through turbine Unit 2, the sample size was increased to obtain the desired precision of the estimates. The sample sizes were as follows: 59 fish for Unit 1, 85 fish for Unit 2, and 53 fish for the downstream bypass. Fifty-four fish were released directly into the tailrace of the facility as a control sample.

The total length of study fish ranged in size from 158-228 millimeters (average 189 millimeters). Approximately 90% of the fish were recaptured within 10 minutes of release. The 1 hour survival estimates were 84.4, 65.9, and 98.1% for Unit 1, Unit 2, and the downstream bypass, respectively. The corresponding 48 hour survival estimates were 81.0, 62.4, and 96.2%, respectively. The malady-free rates were 79.3% for Unit 1, 71.6% for Unit 2, and 98.0% for the downstream bypass. The injury-free rates were 87.0% for Unit 1, 75.7% for Unit 2, and 96.2% for the downstream bypass. The dominant injuries observed for fish passed through Unit 1 were bruising (5.6%), severance/decapitation (3.7%), and broken bones (3.7%). The dominant injuries for Unit 2 were severance/decapitation (8.1%) and gill/operculum damage (8.1%). Only two fish were injured during passage through the downstream bypass; one had a partial decapitation and a ruptured eye and the other had bruising.

Comparison of results from this study to those from previous studies conducted by Normandeau Associates show that the survival estimates are lower and injury rates are higher for the Kaplan turbine at Ellsworth Dam than most other hydroelectric facilities where similar studies have been conducted. The results for the Ellsworth propeller turbine were within the

range of the results for previously evaluated propeller turbines. The low survival and high injury rate especially at Ellsworth's Kaplan unit is likely a result of the combination of two turbine characteristics that negatively impact survival/injury rates: small runner diameter and high runner speed. The survival and injury free results obtained for the downstream fish bypass system at Ellsworth Dam were substantially better compared to the turbines, and the results were within the range of those previously obtained at other spillways and bypass structures studied by Normandeau using the HI-Z tag methodology.

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Acronyms and Abbreviations

°C	degrees Celsius or Centigrade
cfs	cubic feet per second
CI	confidence interval
FERC	Federal Energy Regulatory Commission
ft	foot (feet)
gal	gallon
h	hours
kW	kilowatt
m	meters
mm	millimeters
min	minute
MW	megawatt
no.	number
rpm	revolutions per minute
SE	standard error

1.0 Introduction

1.1 Background

Black Bear Hydro Partners, LLC (Black Bear) owns and operates the Ellsworth Hydroelectric Project (Ellsworth Dam or Ellsworth) on the lower Union River (Federal Energy Regulatory Commission [FERC] No. 2727). Black Bear is currently in the process of relicensing the existing Ellsworth Project. In a National Marine Fisheries Service (NMFS) letter sent to the FERC on November 30, 2016, concerns were expressed that injuries observed among juvenile alewives following downstream passage during the 2016 outmigration period may also be occurring to downstream migrating endangered Atlantic salmon at Ellsworth Dam. In response to those concerns, Black Bear contracted Normandeau Associates, Inc. (Normandeau) to evaluate the direct injury and relative survival of juvenile salmonids passing downstream via the turbines and downstream bypass system at Ellsworth Dam. Prior to evaluation, a draft study plan for this effort was prepared and was submitted to representatives from NMFS, the United States Fish and Wildlife Service (USFWS), Maine Department of Marine Resources (MDMR), Maine Department of Inland Fisheries and Wildlife (MDIFW) and FERC on January 24, 2017. Written comments provided by USFWS on March 14, 2017 and NMFS on March 19, 2017 were incorporated into the final study plan which was filed with FERC on March 31, 2017.

The HI-Z Turb'n Tag (HI-Z tag) methodology (Heisey et al. 1992) was used to assess direct survival and relative injury rates of juvenile brown trout (*Salmo trutta*) following passage through turbine Units 1 and 2 and the downstream bypass system at Ellsworth Dam. Juvenile brown trout were selected as a surrogate species/life stage for the smolt life stage of the federally endangered Atlantic salmon. The HI-Z tag methodology allows for the estimation of direct passage survival and injury of fish after passage through turbines, spillways, and other hydraulic control structures via release and recapture of a known (calculated) number of HI-Z-tagged live fish. These fish are released upstream (treatment group(s)) and downstream (control group) of specific passage routes. This study assessed only the direct effects (immediate injury/mortality or loss of equilibrium) of downstream fish passage through the aforementioned passage routes.

1.2 Site Description

The Ellsworth Dam is located on the lower Union River in Ellsworth, Maine and is situated approximately 3.5 miles upstream of the Union River Bay. The dam is approximately 377 feet long, consisting of a 275-foot-long spillway that is 65 feet high with 27 inch flashboards on the eastern side; the powerhouse is situated on the western shore (Figure 1.1). The powerhouse and intake structure has three short horizontal penstocks that provide flow to turbine units 2, 3, and 4, and one vertical penstock that provides flow to turbine unit 1. These four turbines have a total rated capacity of 8,900 kW. Units 1 and 4 are vertical shaft propeller turbines, and Units 2 and 3 are vertical shaft Kaplan turbines. The turbine characteristics are identical for the two propeller turbines (Units 1 and 4) and the two Kaplan turbines (Units 2 and 3) (Table 1.1). The propeller turbines have four blades, rotate at 200 rpm, and have a runner diameter of 4.65 feet. The Kaplan units have 4 blades, rotate at 360 rpm, and have a runner diameter of 5 feet.

Ellsworth Dam has a downstream fish passage system (downstream bypass) that consists of three surface weirs, all of which flow into a common sluice located on the western side of the spillway. With all three surface weirs operating at a depth of 18 inches during the study period, approximately 17 cfs of water was discharged through each weir for a total attraction flow of 51 cfs into the downstream passage system. [1] When operating the two bypass weirs by Units 2 and 4, approximately 85% of the attraction flow is recycled back into the impoundment leaving approximately 15%, or 5 cfs as transport flow through this part of the system. When combined with the attraction/transport flow at weir 3, this resulted in a net transport flow of approximately 22 cfs through the bypass system during the study. During normal operating conditions the net transport flow is approximately 25 cfs.

A draft report, providing a summary of the methods and results of the 2017 HI-Z tag evaluation at Ellsworth Dam was submitted to NMFS, USFWS, MDMR, and MDIFW on November 17, 2017. The transmittal correspondence, along with written comments provided by NMFS on December 8, 2017, is included in Appendix D. No other agency provided comments on the draft report. Responses to the NMFS comments are provided in Appendix E and where appropriate, this final study report has been updated to reflect the content of those responses.

2.0 Study Objectives

This study had the following goals:

1. Estimate 1 and 48 hour survival and injury probabilities (within ±10%, 90% of the time) of juvenile salmonids passing through the Ellsworth Kaplan units (Units 2 and 3), propeller units (Units 1 and 4) and the downstream bypass system; and
2. Determine injury rates and types attributed to downstream passage at Ellsworth.

3.0 Study Methodology

3.1 Fish Procurement and Holding

The brown trout used in this study were obtained from the Shy Beaver Trout Hatchery in Hollis, Maine. Fish were transported in a truck equipped with a 250-gallon tank supplied with oxygen. The fish were then placed into a pair of 300 gallon holding pools supplied with ambient river water located on the headworks of the facility (near the tagging site). Due to air

[1] The operation of the bypass system during the study period was typical of normal operations except that Lake Leonard was maintained approximately 6 inches lower than normal to prevent spillage over the flashboards during this study. Operating with a lower headpond reduced the flow over the weirs which resulted in somewhat lower attraction flow than would normally occur.

temperatures approaching 32 degrees Celsius, these fish were transported in two trips (one on June 12 and a second on June 13, 2017). Water temperature at the hatchery was approximately 11.0 °C, while holding pools at Ellsworth Dam were >20.0 °C. After approximately three hours travel time to the study site, the water temperatures in the transport tank ranged from 14.1 to 16.3 °C. To minimize transport and handling stress on the fish, the water temperature in the transport tank was slowly raised to within 2.0 °C of the holding pool temperature(s) prior to the transfer of the fish to the holding pools. Fish were held for a minimum of 24 hours prior to tagging and release. A single mortality occurred during the transport, handling, and initial holding period.

3.2 Sample Size Requirements

One of the primary considerations associated with HI-Z tag evaluations of direct injury and relative survival is to release an adequate number of individuals through each passage route to be evaluated such that the resulting survival estimates will be within a pre-specified precision (ε) level. The required sample size is a function of the recapture rate (PA), expected passage survival ($\hat{\tau}$) or mortality ($1-\hat{\tau}$), survival of control fish (S), and the desired precision (ε) at a given probability of significance (α). In general, sample size requirements decrease with an increase in control survival and recapture rates (Normandeau Associates, Inc. *et al.* 1996). Only precision (ε) and α level can be strictly controlled by the investigator. For the purposes of this study a target release of 54 treatment fish (per each of the three downstream routes to be evaluated) accompanied by a release of 54 control fish downstream of the powerhouse was considered to be sufficient to obtain a precision (ε) of ± 0.10, 90% of the time. This sample size assumed ≥95% control survival, a recapture rate of 99%, and expected passage survival rates ~90% for the study. The projected number of fish needed for this evaluation was 216 (162 treatment and 54 controls). As results are available daily, sample sizes can be adjusted as a study progresses (Mathur *et al*. 1996; Normandeau Associates *et al*. 1996; Normandeau Associates, Inc. and Skalski 2006a). If recapture and control survival rates are higher than initially assumed, sample size can be reduced or precision increased (Table 3.1). Conversely, if the values of these parameters are lower than initially assumed, sample size may be increased to achieve the pre-specified statistical precision. This flexibility enables fish to be allocated to other treatments to gain insight into specific concerns that may arise during the course of the investigation. Because of a lower than expected initial survival estimate after the release of 60 treatment fish into Unit 2, an additional 30 fish were released to attain the desired precision level.

3.3 Fish Tagging and Release

Tagging, release, and recapture methods were similar to those of numerous other HI-Z tag studies conducted on juvenile salmonids and were similar for treatment and control groups (Heisey *et al*.1992; Mathur *et al*.1996 and 2000, Normandeau Associates, Inc. 2015). Juvenile brown trout in good physical condition were removed from holding pools and anesthetized prior to tagging. The total length of each fish was recorded and a fin clip or punch specific to each passage route was applied (e.g., fish released into turbine Unit 1 were marked with a right pelvic fin clip). The mark allowed for the passage route of each fish to be determined at the end of the 48 hour holding period. Two HI-Z tags were attached along the dorsal musculature of each fish via a stainless steel pin. A radio tag was attached in combination with one of the HI-Z tags. The fish were then placed into 20 gallon recovery tubs supplied with ambient river water.

Once fully recovered, the batch of fish was transported to the induction system in the 20 gallon tub (Figures 3.1 and 3.2). Each fish was then placed into the induction system and the two balloon tags activated by injecting a measured amount of water. Fish were released tail-first into the induction system to simulate the orientation of fish that are naturally entrained into a turbine. After activation and release, the tags inflated in approximately 1-2 minutes giving the fish ample time to pass through the study route and downstream into the tailrace. Control fish were released via the same type of induction system directly into the tailrace to evaluate the effects of handling, tagging, releasing, and recapturing, as well as to provide additional data on recapture probabilities (Figure 3.3).

The induction system consisted of a holding basin supplied with ambient river water with a 3-inch trash pump. The holding basin was attached to a 4-inch smooth-walled flexible release hose into which all treatment and control fish were released that directed the fish to a release point. Treatment fish were released into turbine Unit 1, Unit 2, and the downstream bypass. The release point for fish released into the turbines was in the penstock of each unit downstream of the trash racks (Figure 3.4). The release point for the downstream bypass was in a conduit pipe shared by surface weirs 1 and 2 of the downstream bypass system which discharged to the sluice of bypass weir 3 on the western end of the spillway. All release points were in a location that would ensure the fish were committed to passing through each route.

A daily schedule of the fish releases is shown in Table 3.2.

3.4 Fish Recapture

Post-passage dispersal of the fish in the tailrace was determined from radio signals received on a loop antenna coupled to an Advanced Telemetry Systems (ATS) receiver as well as visual identification of surfaced balloons. Most fish were tracked and recaptured by two boat crews when the HI-Z tags buoyed them to the surface (Figure 3.5). Some fish were buoyed to the surface and became trapped in an eddy area near the powerhouse. Those fish were recaptured by station personnel via a drop net through access panels in powerhouse floor. In an effort to reduce the number of fish that would become trapped in this area, the turbine units that were not being tested were placed into an idle mode which allowed a small amount of water to flow through these units; this increased the flow from the tested unit that helped move the buoyed fish away from the powerhouse. Recaptured fish were placed into an on-board holding facility or 5-gallon buckets and the tags were removed. Each fish was immediately examined for injuries and loss-of-equilibrium (LOE). Recaptured fish were transferred in 5-gallon buckets to on-shore holding pools. A flow-through system was maintained in each holding pool and covered to prevent predation or escapement.

3.5 Classification of Recaptured Fish

The immediate post-passage status of recaptured fish or retrieval of dislodged inflated HI-Z tags was designated as described in Normandeau Associates, Inc. *et al*. (1996). Each fish was designated as alive, dead, predation, recapture of dislodged balloons, or unknown. The following criteria have been established to define these designations:

1. Alive – recaptured alive and remained so for 1 hour or when the fish does not surface but radio signals indicate movement patterns typical of emigrating fish.
2. Dead – recaptured dead or dead within 1 hour of release or when only dislodged inflated tag(s) without fish are recovered, telemetry tracking indicates a stationary signal, or the manner in which inflated tag(s) surfaced is not indicative of predation.
3. Predation – when fish are either visually observed being preyed upon, the predator is buoyed to the surface, distinctive bite marks are present on a recaptured fish, or subsequent telemetry tracking and/or tag dislodgement indicates predation (i.e. rapid movements of tagged fish in and out of turbulent water or sudden appearance of fully inflated tags; unrecovered preyed upon fish are assumed dead in survival calculations).
4. Unknown – when neither tags nor fish are recovered or telemetry signals are received only briefly and the subsequent status cannot be ascertained. Only a small proportion of fish are typically categorized as unknown.

Maladies (visible injuries, scale loss, loss of equilibrium, or fish that died within 1 hour without visible injuries) were evaluated immediately upon recapture and later during a detailed examination after expiration of the 48 hour holding period. This procedure allowed for the determination of some visible injuries, such as bleeding, which may no longer be evident at 48 hours, and detection of other injuries which may not have been apparent or were overlooked during the initial examination. Injury was categorized by type, extent, and area of body (Table 3.3). Fish without any visible injuries that were not actively swimming were classified as "loss of equilibrium" (LOE). This condition has been noted in previous studies and often disappears within 10 to 15 minutes after recapture if the fish is uninjured.

Fish without visible injuries and/or LOE that survived beyond 1 hour, or fish with injuries that were solely tag-induced (tear at tag site) were classified at "malady-free". This metric is based solely upon fish that were physically recaptured and examined.

An injury- free metric was also calculated which included fish free of visible injuries and/or having less than 20% scale loss; fish with only LOE were excluded. The primary intent of this metric was to focus on hydraulic and mechanical forces that contributed to visible injuries.

Digital images of expired injured fish and injuries were recorded. Mortalities of recaptured fish occurring after 1 hour post-passage were considered 48 hour mortalities. Dead fish were identified by the fin clip along with the length of the fish, examined for descaling and injury, and necropsied to determine the probable cause of mortality.

3.6 Data Analysis

Passage survival probabilities for each evaluated passage route were estimated relative to controls using the likelihood model given in Mathur *et al.* (1996). Appendix A describes the likelihood model and provides statistical derivation of precision, sample size calculations, and likelihood parameters.

The following are the estimators associated with the likelihood model:

For estimating survival ($\hat{\tau}$)

$$\hat{\tau} = \frac{a_T R_c}{R_T a_c}$$

Where,

R_T = number of fish released for the treatment condition;

a_T = number of fish alive for the treatment condition;

R_c = number of control fish released;

a_c = number of control fish alive.

For malady-free (MF)

$$MF = \frac{m_T E_c}{E_T m_c}$$

Where,

E_T = number of treatment fish examined for maladies

m_T = number of treatment fish without maladies

E_c = number of control fish examined for maladies

m_c = number of control fish without maladies

A likelihood ratio test was used to determine whether recapture probabilities are similar for live (P_a) and dead (P_d) fish. The statistic tests the null hypothesis of the simplified model (H_o: $P_a=P_d$) versus the alternative of the generalized model (Ha: $P_a \neq P_d$). The outcome of this test indicated that a simplified model (H_o:$P_a=P_d$) could be used for estimating survival and MF rates.

Mathematical equations for estimating survival are presented in Appendix A. Appendix B provides the individual fish disposition and Appendix C provides the statistical outputs. Only summarized information is discussed in the main body of the report.

The malady-free metric provides a standard methodology to depict a specific passage route's effects on the condition of entrained fish and was based solely on fish physically recaptured and examined. Malady-free estimates were based on the proportion of recaptured fish without passage related visible injuries, LOE, and/or scale loss or fish with injuries that were not attributable to passage (i.e., injuries attributed to tagging/release procedures). The malady-free estimate for the treatment group was made relative to the control fish without maladies. Based on HI-Z tag study guidelines for major and minor injury classifications (Table 3.4), a fish with no visible internal or external injuries that dies beyond one hour is classified as a non-passage related minor injury (Normandeau Associates, Inc. 2004; Normandeau Associates, Inc. and Skalski 2005, 2006a and b; and PNNL *et al*. 2001).

4.0 Study Results

4.1 Fish Size and Recapture Rates

Fish released through Unit 1 ranged from 162 to 220 mm in total length with an average of 189.1 mm. Fifty-nine treatment fish were released through Unit 1 and 54 (91.5%) were recaptured. Five fish were not recaptured; three of those fish were assigned a dead status based on recovery of inflated HI-Z tags without fish, one was assigned dead based on a stationary radio signal, and one was assigned an unknown status (Table 4.1, Figure 4.1).

Fish released through Unit 2 ranged from 160 to 228 mm in total length with an average of 187.6 mm. Eighty-five treatment fish were released through Unit 2 and 74 (87.1%) were recaptured (18 of which were dead upon recapture). Of the 11 fish that were not recaptured, nine were assigned dead based on recovery of inflated HI-Z tags without fish and two were assigned dead based on stationary radio signals (Table 4.1, Figure 4.1).

Fish released through the downstream bypass ranged from 158 to 215 mm in total length with an average of 189.0 mm. Fifty-three treatment fish were released through the downstream bypass and all were recaptured. Only one fish released through the downstream bypass was dead upon recapture (Table 4.1, Figure 4.1).

An additional fish from Unit 1, five from Unit 2 and three from the downstream bypass were removed from the analytical sample size presented above because they could not be tracked with radio telemetry equipment (they either did not enter the tailrace or had a tag malfunction) and were never seen visually. Also, there was a location in the Union River approximately 200 meters downstream of the dam that was not navigable by boat at lower tides, and therefore fish that passed downstream of that location could not be retrieved.

4.2 Recapture Times

The average recapture time for fish released through Unit 1 was 17.1 minutes, and ranged from two to 418 minutes. All but three of those fish were recaptured within 30 minutes. The average recapture time for fish released through Unit 2 was 9.4 minutes, and ranged from two to 165 minutes. All but two of those fish were recaptured within 30 minutes. For fish released through the downstream bypass, the average recapture time was 6.2 minutes and ranged from one to 80 minutes. All but two of those fish were recaptured within 8 minutes. The recapture times for the control fish ranged from one to 26 minutes and averaged 6.1 minutes (Figure 4.2).

The recapture times of released fish were partially dependent upon whether the buoyed fish got caught up in an eddy area near the turbine discharge which increased recapture times. Treatment fish released through the downstream bypass did not get caught in that eddy area and therefore had the lowest average recapture time of the three treatment groups.

4.3 Passage Survival

Five of the 54 fish passed through Unit 1 were dead upon recapture, and 4 others were assigned a dead status, resulting in a direct survival estimate at 1 hour of 84.4% (SE = 3.2%). The 48 hour direct survival estimate for Unit 1 was 81.0 (SE = 5.2%); two fish died during the 48 h holding period. Eighteen of the 85 fish that passed through Unit 2 were dead at recapture and 11 others were assigned a dead status. This resulted in a 1 hour direct survival estimate of 65.9% (SE = 5.1%). The 48 hour direct survival estimate for Unit 2 was 62.4% (SE = 5.3%); three fish died in holding. The 1 and 48 hour direct survival estimates for the downstream bypass were 98.1 (SE = 1.9%) and 96.2% (SE = 2.6%), respectively; one fish was dead upon recapture and another died in holding. The target precision level of ±10%, 90% of the time was attained for all survival estimates. The survival estimates were significantly different ($p<0.05$) among all three passage routes (Appendix C).

The 1 hour survival estimates for the turbines can be considered conservative because some fish were assigned a dead status based on the recovery of only HI-Z tags, and it is possible that some of those fish survived. However, there were several fish released through the turbines of which only single HI-Z tags were recovered that were initially assigned a dead status and these fish were later recovered dead (severed) with a single HI-Z tag attached, which reinforces that these fish can conservatively be considered dead at 1 hour. There were no fish that were assigned a dead status and later recovered alive. There were also no fish released through the fish bypass system that were assigned a dead status based on the recovery of only HI-Z tags, and these fish underwent the same tagging procedures and were of similar size.

4.4 Injury and Malady-Free Rates

The injury rate and malady-free rate for a particular passage route compared the number of fish that had passage-related visible injuries or passage-related maladies against the number of fish that were recaptured and physically examined. Fish that had injuries not attributable to passage and fish that were not recaptured were not included in these assessments. Maladies include both visible injuries and LOE.

The malady-free rate for Unit 1 was 79.3% (SE = 6.0%), and the injury-free rate, which excluded fish with only LOE, was 87.0% (SE = 4.6%). Twelve of the fish that were examined after passage through Unit 1 had passage-related maladies. Seven (13.0%) had visible injuries and the other five exhibited LOE only. None of the seven fish with visible injuries were alive at the end of the 48-hour holding period. All five fish that exhibited only LOE were alive at the end of the 48-hour holding period. The dominant injuries were bruising on the head or body (5.6%), severance or decapitation (3.7%), and broken bones (3.7%). Some fish had multiple injury types. Of the 12 fish with passage-related maladies, seven were classified as major maladies and 5 were minor. Six were attributed to mechanical forces, one was due to shear forces, and five could not be assigned a probable causal mechanism (Tables 4.2-4.5, Figure 4.3).

The malady-free rate for Unit 2 was 71.6% (SE = 5.6%), and the injury-free rate was 75.7% (SE = 5.0%). Twenty-two of the fish that were examined after passage through Unit 2 had passage-related maladies. Eighteen (24.3%) had visible injuries, two had LOE only, and two died within 1 hour and had no obvious visible injuries. Only one fish with a visible injury was alive at the end of the 48-hour holding period. The dominant injuries were severance or decapitation (8.1%), gill/operculum damage (8.1%), and hemorrhaged eyes (6.8%). Most fish had multiple injuries. Twenty of the fish were assigned a major malady status, and only two were minor. Ten of the maladies were due to mechanical forces, seven were attributed to shear forces, one was caused by both shear/mechanical forces, and 4 were undetermined. (Tables 4.2-4.5, Figure 4.4).

The malady-free rate for the downstream bypass was 98.0% (SE = 3.2%) and the injury-free rate was 96.2% (SE = 2.6%). Only two of the examined fish had passage-related maladies. Both of those fish (3.8%) had visible injuries. One fish was decapitated and had a hemorrhaged eye (major malady), and the other had bruising (minor malady). The bruised fish was alive at the end of the 48-hour holding period. These respective injuries were attributed to shear and mechanical forces (Figure 4.5).

A precision of ±10%, 90% of the time was attained for all malady-free and injury-free estimates. The malady-free and injury-free rates for the downstream bypass were significantly higher than either of the turbine units ($p<0.01$). The injury-free estimate for Unit 1 was significantly higher than Unit 2 ($p<0.10$), but the malady-free estimates between the two turbine types were not significantly different (Appendix C).

5.0 Discussion

5.1 Turbines

The results for the Ellsworth propeller turbine (i.e., Unit 1) were within the range of passage survival and injury estimates for turbines previously evaluated by Normandeau at other hydroelectric facilities. Comparison of results from this study to those from previous HI-Z tag studies indicates that passage survival is lower and passage-related injury rates are higher for the Kaplan turbine evaluated at Ellsworth Dam (i.e., Unit 2) than previously estimated rates for other hydroelectric facilities (Figures 5.1 and 5.2). The low survival and high injury rate at Ellsworth's Kaplan Unit 2 is likely a result of the combination of two turbine characteristics that negatively impact survival/injury rates: small runner diameter and high runner speed. Ellsworth Unit 2 combines the smallest runner diameter and highest runner speed for any turbine evaluated using the HI-Z tag methodology. Two general trends that have been observed from previous studies show that survival decreases with an increase in runner speed and survival increases as runner diameter increases. The relatively small diameters (4.65 and 5.0 feet) and high runner speeds (200 and 360 rpm) of Units 1 and 2, respectively, increase the chances of fish being struck during passage (Figures 5.1 and 5.2).

5.2 Downstream Bypass

The survival (48-hr) and injury free estimates for the downstream bypass system are relatively high (both 96.2%) when compared to downstream bypass structures or spillways at other facilities that have been evaluated using the HI-Z tag methodology (Figures 5.3 to 5.5). The relationships between juvenile salmonid 48-hour survival and injury to project head, spillway/bypass discharge, and to the location of a fish within the spillway/bypass jet (distance to structure) are shown in Figures 5.3 to 5.5. The data in these figures has been compiled from studies conducted at 22 other facilities with over 200 test conditions. The spillway/bypass characteristic with the strongest relation to survival and injury is project head (Figure 5.3), and the results from the current study agree with the general trend observed at other sites. Figure 5.4 shows that survival generally increases as discharge increases, and there is much more variability of survival/injury estimates at low discharge rates. The total discharge of the downstream bypass at Ellsworth Dam is low, yet the 48-hour survival estimate was relatively high. Figure 5.5 shows that as fish pass nearer to spillway/bypass structures (within the water column) survival rates decrease and injury rates increase. This is intuitive, as fish closer to "boundary" areas of a spillway or bypass jet are more likely to come into contact with a structure. With a weir gate opening of 18 inches at the Ellsworth downstream bypass (as was tested), the average distance to structure for fish released during this treatment was assumed to be near 9 inches. Again, there is more variability in survival estimates and injury rates as the distance to structure decreases, yet the downstream bypass at Ellsworth obtained a relatively high survival rate and low incidence of injuries.

The injuries that resulted in mortality at the downstream bypass were due to shear forces (partial decapitation, ruptured left eye). It's plausible that these injuries occurred where the water from the first two weirs meets the flow from the third weir along the spillway (Figure 5.6). The intersection of these two flows is approximately perpendicular. If the angle of the pipe from the first two weirs were adjusted downward to match the direction of flow from the third weir, higher survival and lower injury rates may be observed (Pacific Northwest National Laboratory 2000). Another explanation is that some of the water is not entirely contained within the downstream sluiceway walls due to the short height of the walls and gaps. This could result in fish hitting sharp edges/surfaces such as the stake-posts supporting the stub walls of the sluiceway.

5.3 Potential Project Effects on Other Species

In addition to the limited number of stocked juvenile Atlantic salmon present in the Union River, there are a large number of river herring present in the Union River watershed and both the adult and juvenile life stages of those species must migrate downstream of the Ellsworth Project. Mortality and/or injury of alosines migrating downstream of the Ellsworth Project cannot be reliably estimated with the salmonid data set collected during this study. However, it is likely that the rates for incidence of injury and mortality for alosines passing through the propeller turbines (Units 1 and 4) would be lower than that observed for alosines passing through the Kaplan turbines (Units 2 and 3) based on the physical characteristics of the two turbine types as well as observations from the present study. Based on observations made during the evaluation of juvenile salmonids at Ellsworth Dam, the incidence of shear-related trauma may be higher for alosines that pass through Kaplan turbine Units 2 and 3.

HI-Z tag studies have been conducted to evaluate the injury and mortality rates of alosines at a number of other hydroelectric projects that have propeller-type turbines and 1-hour survival estimates at those locations ranged from 89.7 to 100%. These project locations include Crescent Hydro in NY, Hadley Falls in MA, Vernon Dam in NH/VT, and York Haven and Safe Harbor Dams in PA. Propeller-type turbines tested to date are larger in size (runner diameters ranged from 7.8 to 18.3 feet) and rotate at slower speeds (109 to 200 rpm) than the turbines at the Ellsworth project. The previously tested propeller-type turbine with characteristics most similar to the Ellsworth Unit 1 had a runner speed of 200 rpm but the runner diameter was nearly double (7.8 feet), and the 1 hour survival estimate was 92.7% (Normandeau Associates, Inc. 1998, 2001, and 2016; RMC 1992a-b). It is possible that alosines passing downstream through the fish bypass system at Ellsworth may have survival and injury rates similar to those described in this study for juvenile salmonids, however precise estimates cannot be obtained from this data set.

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Report Tables

Table 1.1. Characteristics of Ellsworth Project turbine units.

	Unit 1*	Unit 2*	Unit 3	Unit 4
Turbine type	Propeller	Kaplan	Kaplan	Propeller
Turbine orientation	Vertical	Vertical	Vertical	Vertical
Number of blades	4	4	4	4
Maximum discharge (cfs)	685	545	545	685
Runner diameter (ft)	4.65	5	5	4.65
Runner speed (rpm)	200	360	360	200
Rated head (ft)	60	60	60	60

*Asterisk indicates unit evaluated during HI-Z evaluation

Table 3.1. Required sample sizes for treatment and control fish releases for various combinations of control survival, recapture probability, and turbine related mortality to obtain a precision of ≤±0.10 at 1-α =0.90.

Control Survival	Recapture Rate	Turbine Mortality	Number of Fish
1.00	0.99	0.05	18
		0.1	29
		0.15	39
		0.25	55
	0.95	0.05	39
		0.1	49
		0.15	57
		0.25	70
	0.9	0.05	69
		0.1	76
		0.15	82
		0.25	90
0.95	0.99	0.05	45
		0.1	54
		0.15	107
		0.25	111

Note that this table also applies to malady-free estimates

Table 3.2. Daily schedule of released juvenile brown trout at Ellsworth Dam, June 2017.

Date	Water temperature (°C)	Unit 1	Unit 2	Downstream Bypass	Controls	Daily Total Released
14-Jun	20	60	60			120
15-Jun	20		30	56	54	140
Total		**60**	**90**	**56**	**54**	**260**

Table 3.3. Condition codes assigned to fish and dislodged HI-Z tags for fish passage survival studies.

Code	Description		
	Turbine/passage-related Malady Codes		
4	Damaged gill(s): hemorrhaged, torn or inverted		
5	Major scale loss, >20%		
6	Severed body or nearly severed		
7	Decapitated or nearly decapitated		
8	Damaged eye: hemorrhaged, bulged, ruptured or missing, blown pupil		
9	Damaged operculum: torn, bent, inverted, bruised, abraded		
A	No visible marks on fish		
B	Flesh tear at tag site(s)		
C	Minor scale loss, <20%		
E	Laceration(s): tear(s) on body or head (not severed)		
F	Torn isthmus		
G	Hemorrhaged, bruised head or body		
H	Loss of Equilibrium (LOE)		
J	Major		
K	Failed to enter system		
L	Fish likely preyed on (telemetry, circumstances relative to recapture)		
M	Minor		
P	Predator marks		
Q	Other information		
S	Special describe as needed		
R	Removed from sample		
T	Trapped in the rocks/recovered from shore		
V	Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin		
W	Abrasion / Scrape		
	Survival Codes		
1	Recovered alive		
2	Recovered dead		
3	Unrecovered – tag & pin only		
4	Unrecovered – no information or brief radio telemetry signal		
5	Unrecovered – trackable radio telemetry signal or other information		
	Dissection Codes		
1	Shear	M	Minor
2	Mechanical	N	Heart damage, rupture, hemorrhaged
3	Pressure	O	Liver damage, rupture, hemorrhaged
4	Undetermined	R	Necropsied, no obvious injuries
5	Mechanical/Shear	S	Necropsied, internal injuries
6	Mechanical/Pressure	T	Tagging/Release
7	Shear/Pressure	U	Undetermined
B	Swim bladder rupture	W	Head removed; i.e., otolith
D	Kidney hemorrhage		
E	Broken bones obvious		
F	Hemorrhaged internally		
J	Major		
L	Organ displacement		

Table 3.4. Guidelines for major and minor injury classifications for fish passage survival studies using the HI-Z Tag methodology.

Guidelines for major and minor injury classifications for fish passage survival studies using the HI-Z Tag methodology.
A fish with only Loss of Equilibrium (LOE) is classified as major if the fish dies within 1 hour. If it survives or dies beyond 1 hour it is classified as minor.
A fish with no visible external or internal maladies is classified as a passage related major injury if the fish dies within 1 hour. If it dies beyond 1 hour it is classified as a non-passage related minor injury.
Any minor injury that leads to death within 1 hour is classified as a major injury. If it lives or dies after 1 hour it remains a minor injury.
Hemorrhaged eye: minor if less than 50%. Major if 50% or more
Deformed pupil(s) are a: major injury.
Bulged eye: major unless one eye is only slightly bulged. Minor if slight.
Bruises are size-dependent. Major if 10% or more of fish body per side. Otherwise minor.
Inverted or bleeding gills or gill arches is major
Operculum tear at dorsal insertion is: major if it is 5 % of the fish or greater. Otherwise minor.
Operculum folded under or torn off is a major injury
Scale loss: major if 20% or more of fish per side. Otherwise minor
Scraping (damage to epidermis): major if 10% or more per side of fish. Otherwise minor.
Cuts and lacerations are generally classified as major injuries. Small flaps of skin or skinned up snouts are: minor.
Internal hemorrhage or rupture of kidney, heart or other internal organs that results in death at 1 to 48 hours is a major injury.
Multiple injuries: use the worst injury

Table 4.1. Tag-recapture data and estimated 1 hour and 48 hour survival data for juvenile brown trout passed through Unit 1, Unit 2, and the downstream bypass at Ellsworth Dam, June 2017.

	Unit 1	Unit 2	Downstream Bypass	Controls
No. Released*	59	85	53	54
No. Recaptured	54	74	53	54
No. Recaptured Alive	49	56	52	54
No. Recaptured Dead	5	18	1	0
No. Assigned Dead	4	11	0	0
Tags recovered	3	9	N/A	N/A
Stationary signal	1	2	N/A	N/A
No. Unknown	1	0	0	0
No. Predated	0	0	0	0
1 Hour Survival (%)	84.4	65.9	98.1	100
SE (%)	3.2	5.1	1.9	N/A
No. Held	49	56	52	54
Died in Holding	2	3	1	0
Alive 48 h	47	53	51	54
48 Hour Survival (%)	81	62.4	96.2	100
SE (%)	5.2	5.3	2.6	N/A
90% Margin of error (%)	8.4	8.7	4.3	N/A

*An additional 1, 5, and 3 fish were released at Units 1, 2 and the downstream bypass, respectively. These fish were removed from analytical sample; they were never detected or visually observed in the tailrace.

Table 4.2. Summary of injury rates and visible injury types for juvenile brown trout after passage through the three tested routes at Ellsworth Dam, June 2017. Proportions are given in parentheses.

Passage route	No. Released	No. Examined	Passage-related visibly injured	LOE** Only	Injury Type*						
					Severance or decapitation	Hemorrhaged eye(s)	Bruised head/body	Gill/operculum damage	Laceration	Torn isthmus	Broken bones
Unit 1	59	54	7 (13.0%)	5 (9.3%)	2 (3.7%)	0	3 (5.6%)	1 (1.9%)	1 (1.9%)	1 (1.9%)	2 (3.7%)
Unit 2	85	74	18 (24.3%)	2 (2.7%)	6 (8.1%)	5 (6.8%)	3 (4.1%)	6 (8.1%)	2 (2.7%)	2 (2.7%)	1 (1.4%)
Downstream Bypass	53	53	2 (3.8%)	0	1 (1.9%)	1 (1.9%)	1 (1.9%)	0	0	0	0
Controls	54	54	0	1 (1.9%)	0	0	0	0	0	0	0

*** Some fish had multiple injuries**
**** Loss of equilibrium (LOE)**

Table 4.3. Probable sources and severity of maladies observed on recaptured juvenile brown trout after passage through the three tested routes at Ellsworth Dam, June 2017.

Passage Route	No. of Fish Examined	No. with Passage-related Maladies*	Probable Cause				Severity	
			Mechanical	Shear	Undetermined	Mechanical/Shear	Minor	Major
Unit 1	54	12	6	1	5	0	5	7
Unit 2	74	22	10	7	4	1	2	20
Downstream Bypass	53	2	1	1	0	0	1	1
Controls	54	1	0	0	1	0	1	0

* Maladies include both visible injuries and LOE attributed to turbine passage.

Table 4.4. Incidence of maladies for individual fish released through the three tested passage routes and controls at Ellsworth Dam, June 2017.

Date	Fish ID	Status		Maladies	Passage Malady*	Photo	Malady Severity	Probable Cause
Unit 1								
6/14/2017	3	Alive		LOE	Yes	No	Minor	Undetermined
6/14/2017	7	Dead	1 h	Severed body	Yes	Yes	Major	Mechanical
6/14/2017	8	Alive		LOE; tear at tag site	No	No		
6/14/2017	12	Dead	24 h	Bruising on dorsum and left side; scrape on right side	Yes	Yes	Major	Mechanical
6/14/2017	14	Alive		LOE	Yes	No	Minor	Undetermined
6/14/2017	17	Dead	1 h	Torn isthmus; crushed head (broken skull)	Yes	Yes	Major	Mechanical
6/14/2017	20	Dead	24 h	LOE; broken skull	Yes	No	Major	Mechanical
6/14/2017	22	Alive		LOE	Yes	No	Minor	Undetermined
6/14/2017	26	Alive		LOE	Yes	No	Minor	Undetermined
6/14/2017	27	Dead	1 h	Bruised dorsum	Yes	Yes	Major	Mechanical
6/14/2017	29	Dead	1 h	Decapitated; bruising on right side	Yes	No	Major	Mechanical
6/14/2017	40	Dead	1 h	Operculum damage	Yes	Yes	Major	Shear
6/14/2017	56	Alive		LOE	Yes	No	Minor	Undetermined
Unit 2								
6/14/2017	63	Dead	1 h	Bruising on head and dorsum	Yes	Yes	Major	Mechanical
6/14/2017	64	Dead	1 h	Necropsied - no obvious injuries	Yes	No	Major	Undetermined
6/14/2017	65	Dead	1 h	Decapitated	Yes	Yes	Major	Shear
6/14/2017	71	Dead	1 h	Crushed head; ruptured eye	Yes	Yes	Major	Mechanical
6/14/2017	85	Dead	1 h	Laceration at caudal peduncle; torn isthmus	Yes	Yes	Major	Mechanical/shear
6/14/2017	88	Dead	24 h	LOE	Yes	No	Minor	Undetermined
6/14/2017	93	Dead	1 h	Bulging right eye; torn right operculum	Yes	Yes	Major	Shear
6/14/2017	94	Dead	24 h	LOE	Yes	No	Minor	Undetermined
6/14/2017	98	Dead	1 h	Necropsied - no obvious injuries	Yes	No	Major	Undetermined
6/14/2017	102	Dead	1 h	Decapitated	Yes	No	Major	Mechanical
6/14/2017	106	Dead	1 h	Torn left operc.; hemorrhaged left eye; tear at tag site	Yes	No	Major	Shear

Date	Fish ID	Status		Maladies	Passage Malady*	Photo	Malady Severity	Probable Cause
6/14/2017	114	Dead	1 h	Decapitated; mangled body	Yes	Yes	Major	Mechanical
6/14/2017	116	Dead	1 h	Right eye removed; bent operculum	Yes	No	Major	Shear
6/14/2017	117	Dead	1 h	Laceration on right side of head	Yes	No	Major	Mechanical
6/15/2017	61	Dead	1 h	Decapitated	Yes	No	Major	Mechanical
6/15/2017	62	Alive		LOE; bruising on right side	Yes	No	Major	Mechanical
6/15/2017	65	Dead	24 h	LOE; bruising on left side and dorsum	Yes	No	Major	Mechanical
6/15/2017	67	Dead	1 h	Torn right operculum; bulging left eye	Yes	No	Major	Shear
6/15/2017	73	Dead	1 h	Bent left operculum; gill damage	Yes	No	Major	Shear
6/15/2017	75	Dead	1 h	Decapitated	Yes	No	Major	Mechanical
6/15/2017	80	Alive		Tear at tag site	No	No		
6/15/2017	81	Alive		Tear at tag site	No	No		
6/15/2017	83	Dead	1 h	Bleeding gills; torn isthmus	Yes	Yes	Major	Shear
6/15/2017	84	Dead	1 h	Severed body	Yes	No	Major	Mechanical
Downstream Bypass								
6/15/2017	1	Dead	1 h	Partial decapitation; left eye ruptured	Yes	Yes	Major	Shear
6/15/2017	24	Alive		LOE; tear at tag site	No	No		
6/15/2017	27	Alive		Bruised head	Yes	No	Minor	Mechanical
Controls								
6/15/2017	98	Alive		LOE	No	No	Minor	Undetermined

Table 4.5. Summary malady data, malady-free estimates, and injury-free estimates for brown trout after passage through the three routes at Ellsworth Dam, June 2017.

	Unit 1	Unit 2	Downstream Bypass	Controls
Number released	59	85	53	54
Number examined for maladies	54	74	53	54
Number with passage related maladies	12	22	2	1
Visible injuries	6	18	2	0
Loss of equilibrium only	5	2	0	1
No obvious injuries - 1 h mortality	1	2		
Number without passage related maladies	42	52	51	53
Without passage related maladies that died	0	0	0	0
Malady-free rate (%)	79.3	71.6	98	
SE (%)	6	5.6	3.2	
90% Margin of error (%)	9.4	8.7	5.3	
Visible injury-free rate (%)	87	75.7	96.2	
SE (%)	4.3	5	2.6	
90% Margin of error (%)	7.1	8.2	4.3	

Report Figures

Figure 1.1. Ellsworth Dam with the powerhouse shown at left. Turbine Unit 1 discharges perpendicular to the face of the dam and turbine Units 2-4 discharge parallel to the dam face. The downstream bypass sluice can be seen directly to the right of the powerhouse.

Figure 3.1. Juvenile brown trout with two HI-Z tags attached. A radio tag is attached in combination with the yellow HI-Z tag.

Figure 3.2. Five to 10 fish were tagged and allowed to recover prior to being released.

Figure 3.3. Fish tagging site with induction system at left. The release basin sat atop a wooden frame with the release pipe below. This was the control release system, and an identical system was used to release treatment fish into each passage route.

Figure 3.4. A 4-inch release hose was installed into a vent pipe into the penstock of turbine Unit 1. A similar release hose was lowered into a vent slot into the penstock of turbine Unit 2 and the downstream bypass.

Figure 3.5. Two boat crews tracking released fish in the tailrace to be recaptured when buoyed to the surface.

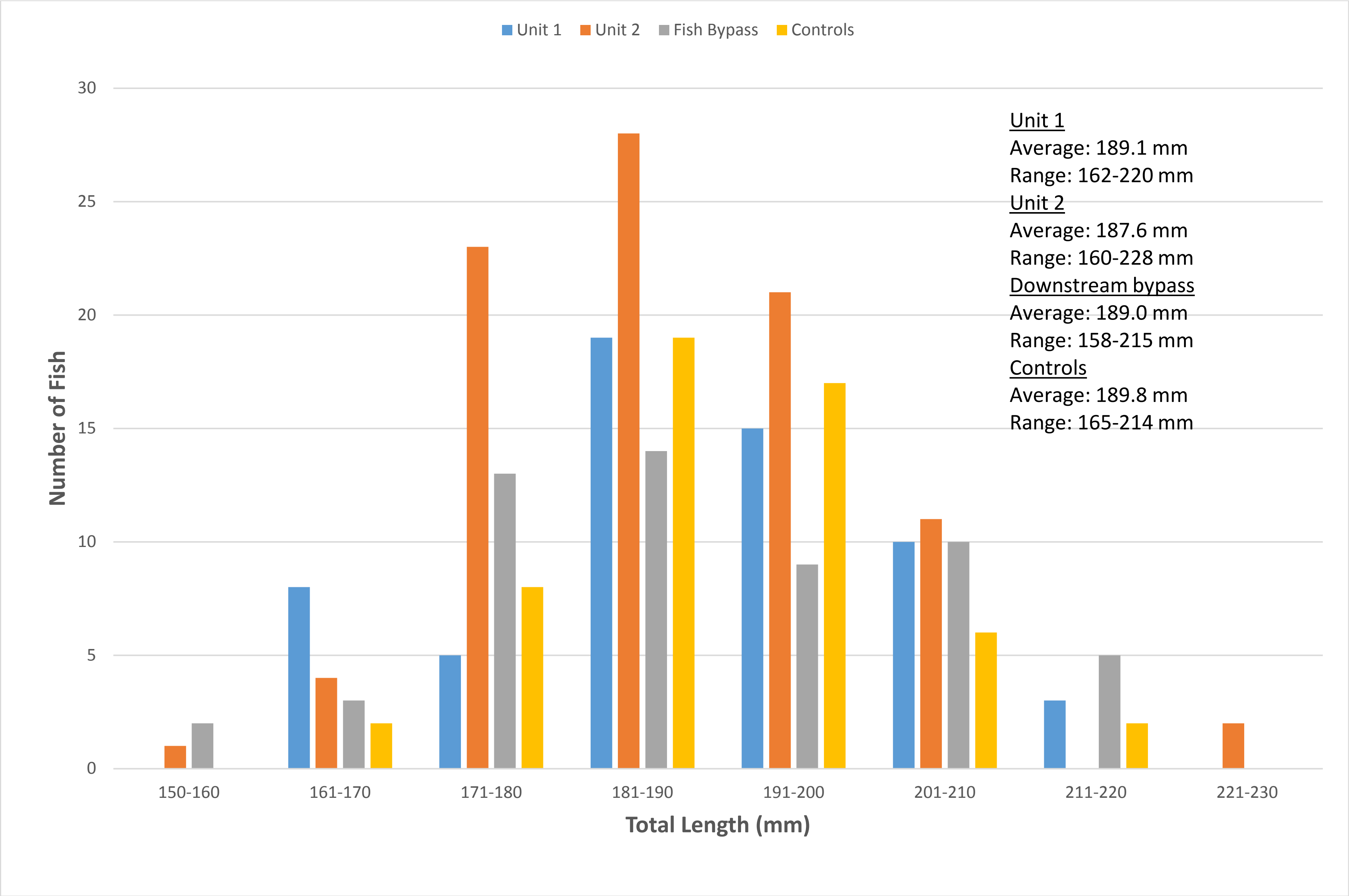


Figure 4.1. Length distributions (total length; mm) of brown trout released through the three passage routes and controls.

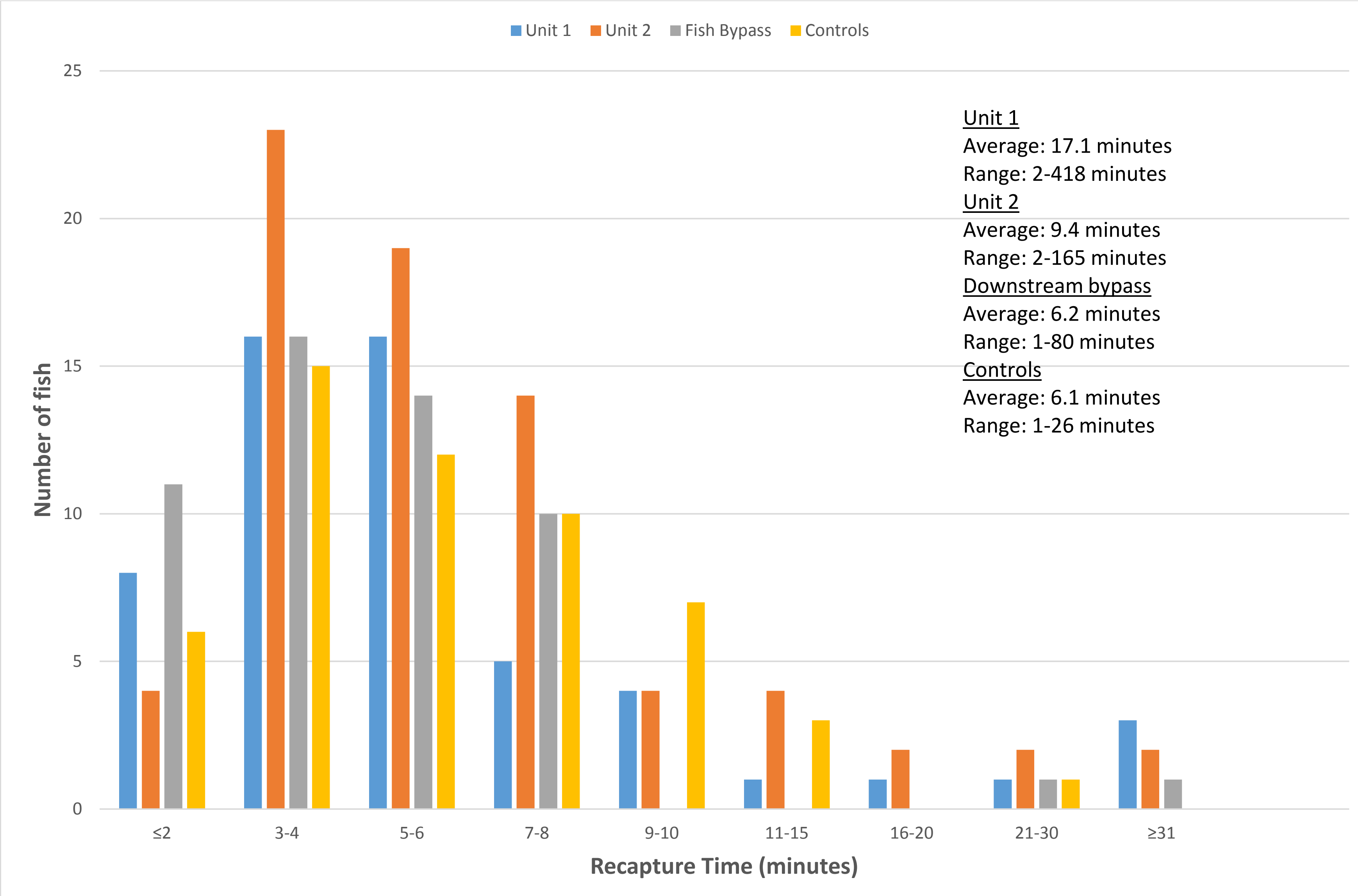


Figure 4.2. Distribution of recapture times for fish released through the three passage route and controls.

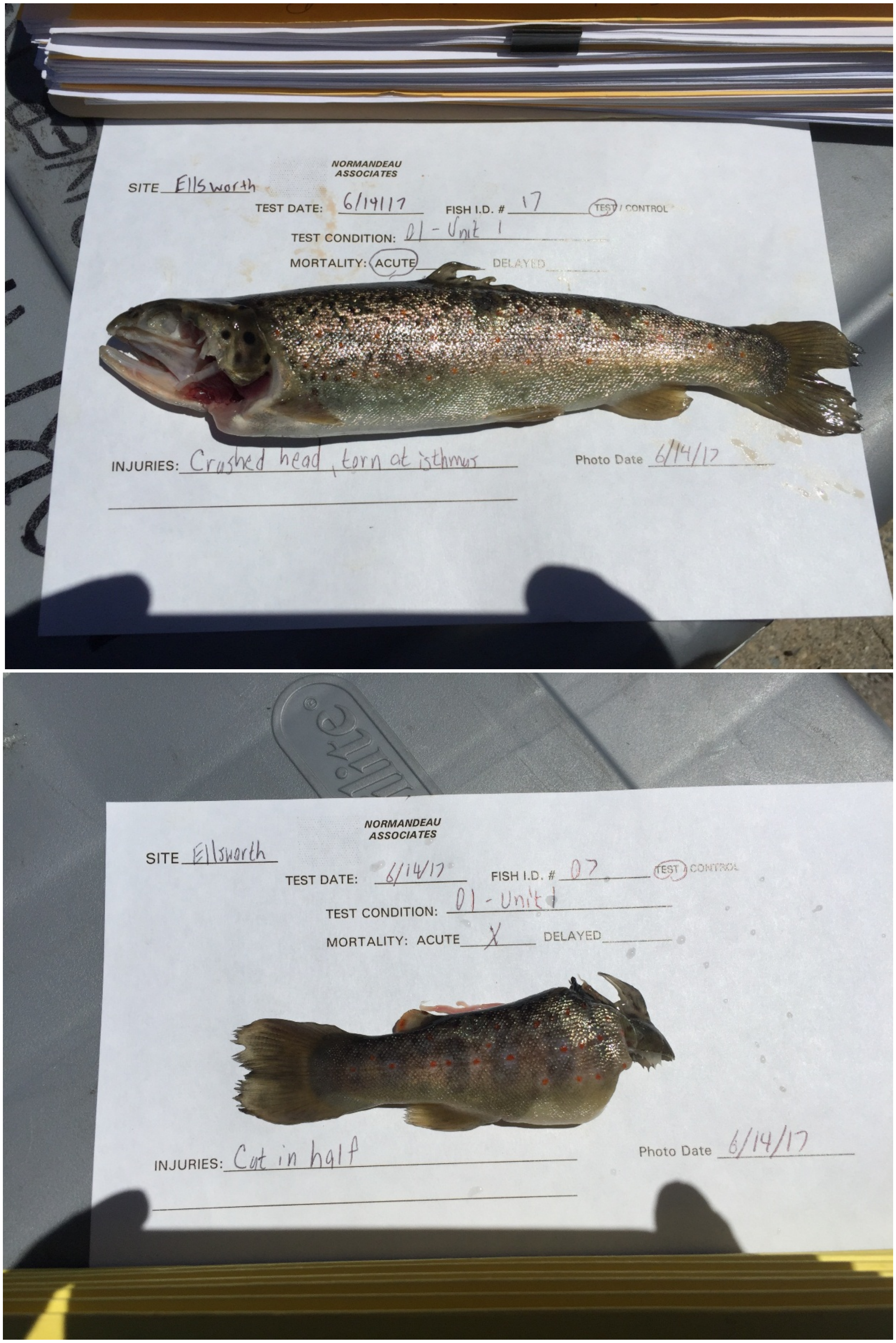


Figure 4.3. Example of injuries sustained to fish released through turbine Unit 1.

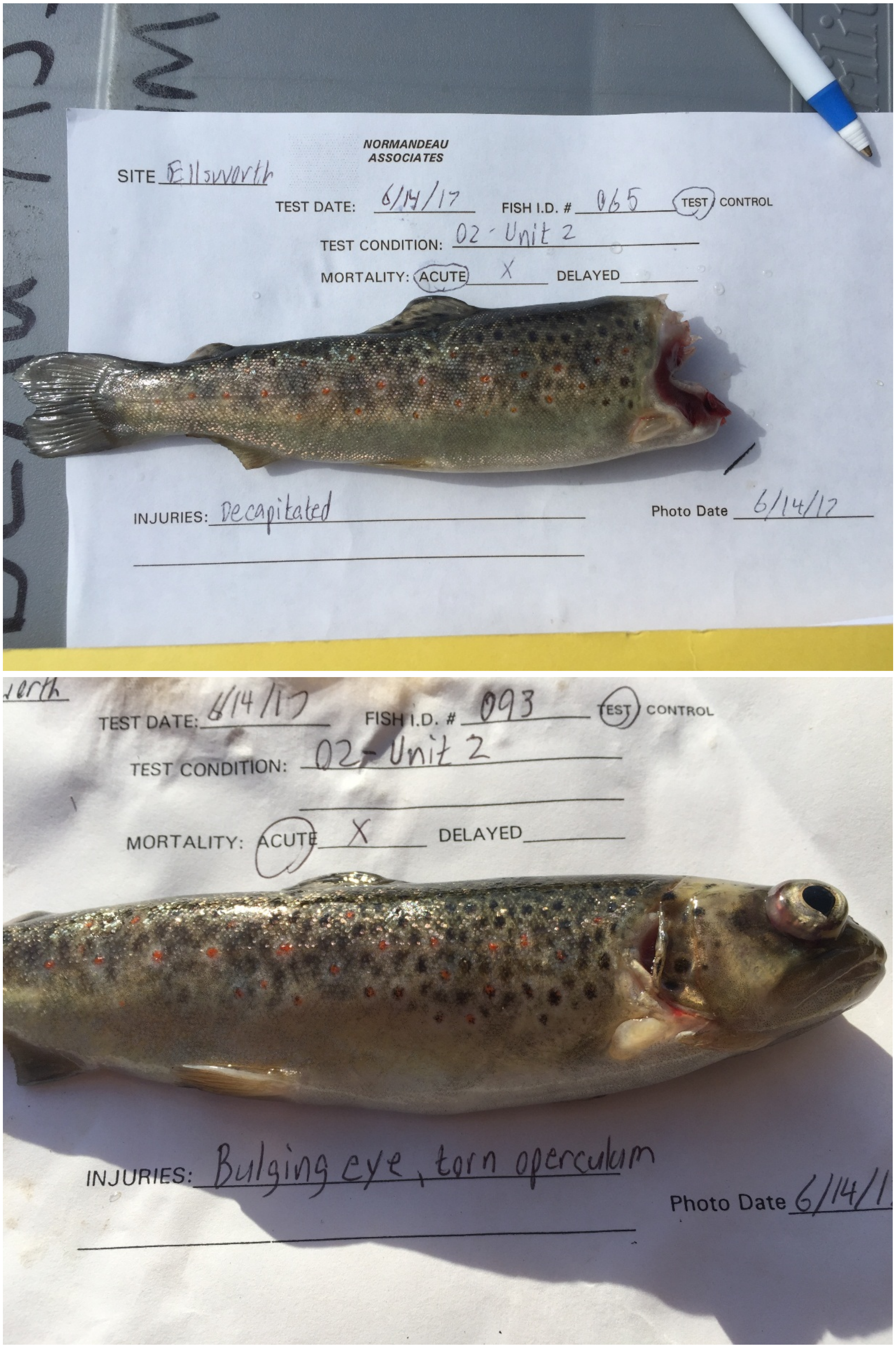
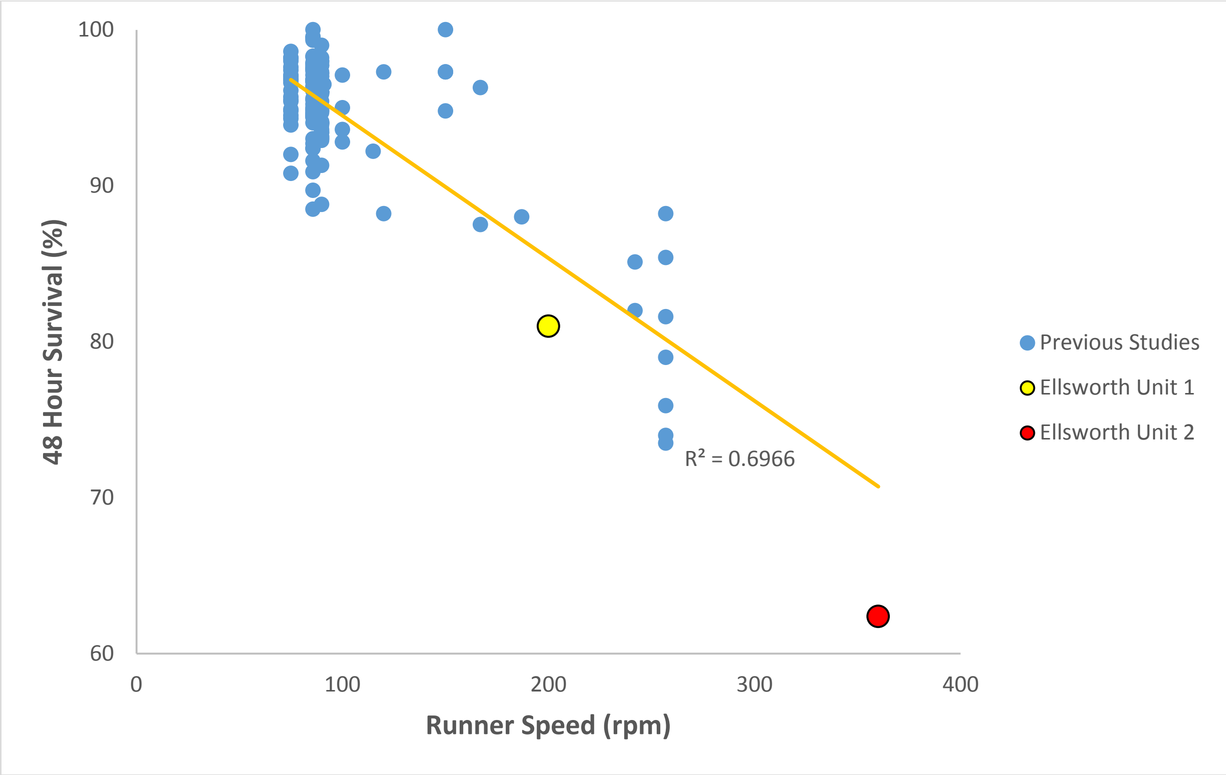


Figure 4.4. Example of injuries sustained to fish released through turbine Unit 2.

Figure 4.5. Single recorded major injury sustained by an individual fish released through the downstream bypass.



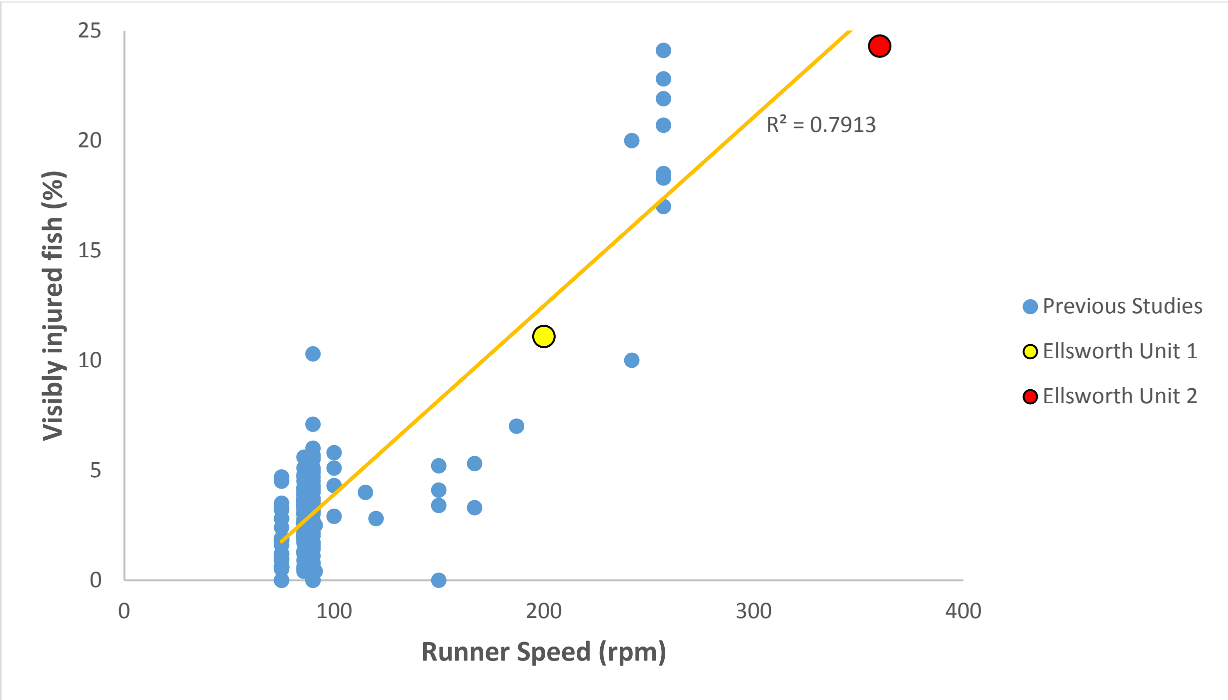
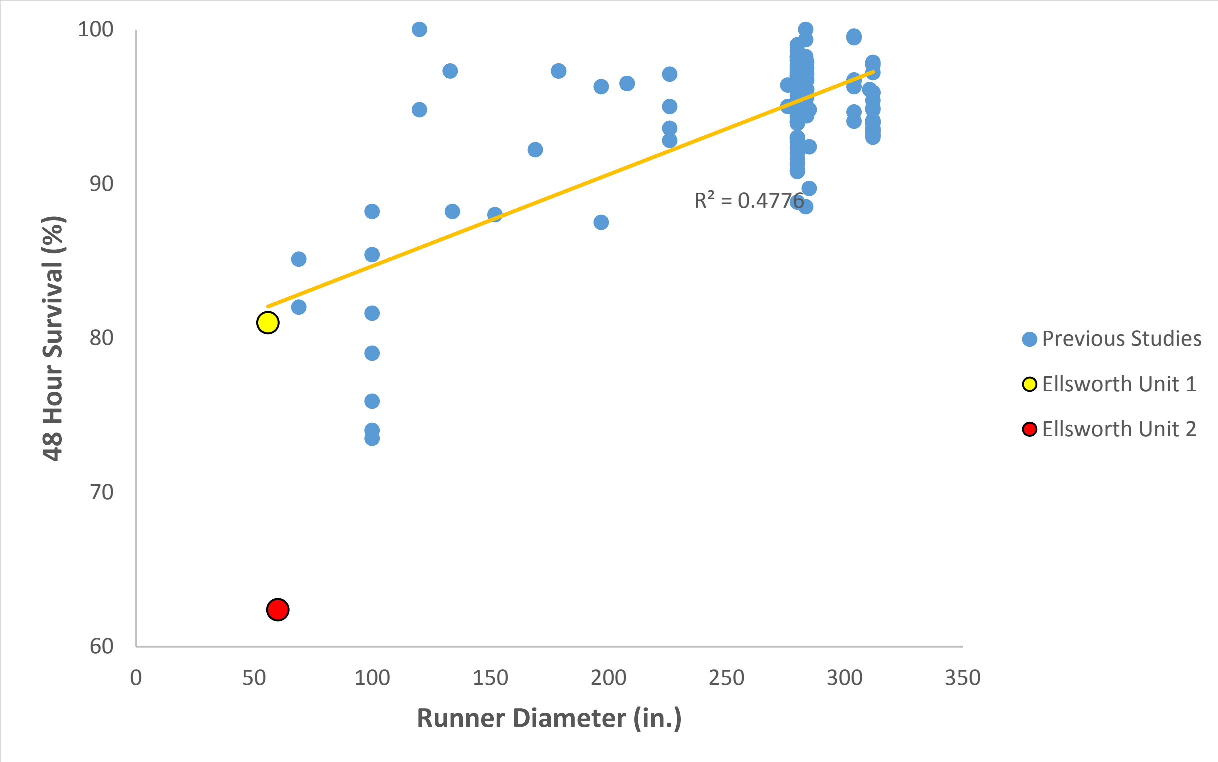


Figure 5.1. The relationships between the runner speed of a turbine to 48 hour survival (upper) and visible injury rate (lower) from previous studies compared to the results observed at Ellsworth Dam.



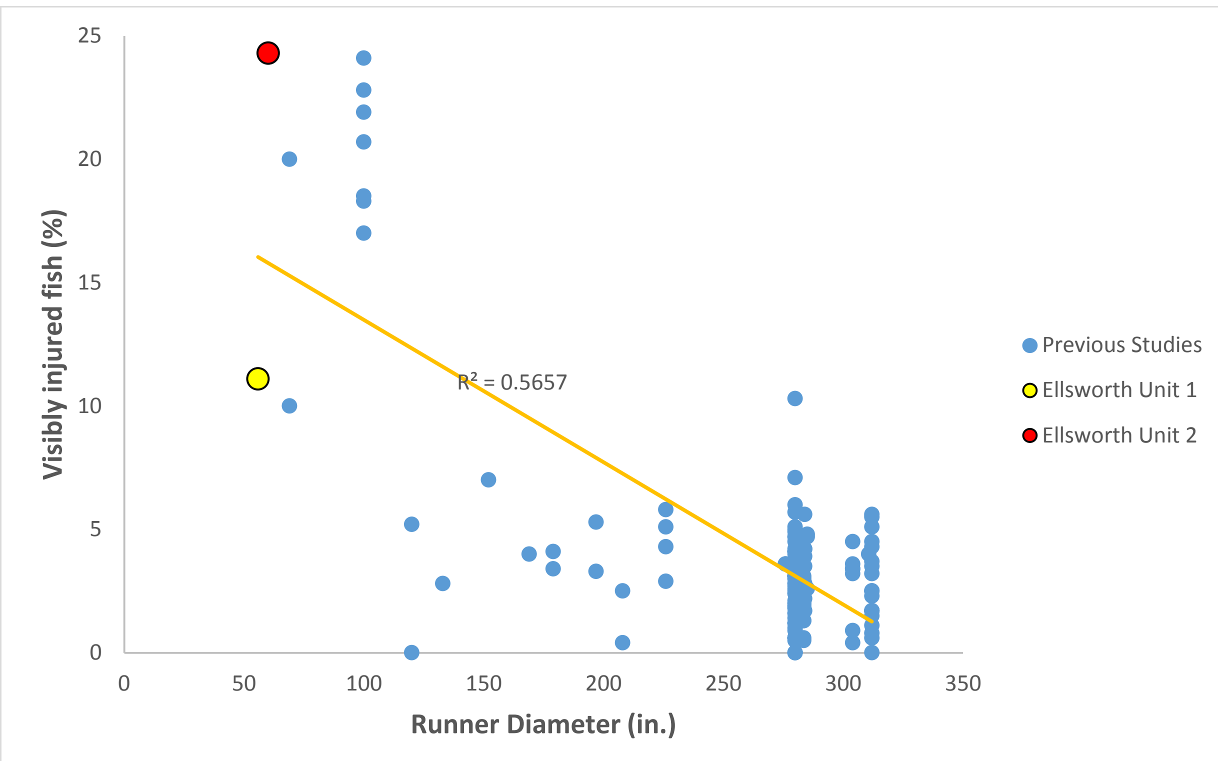
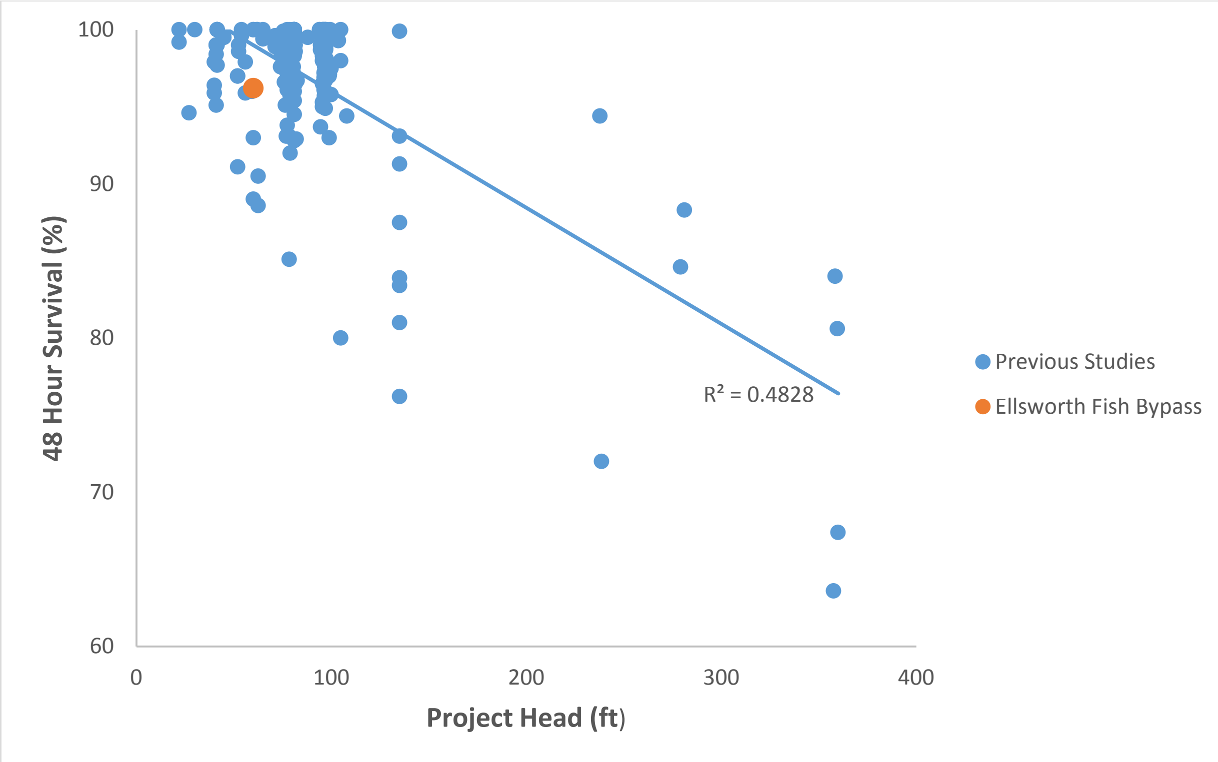


Figure 5.2. The relationships between the runner diameter of a turbine to 48 hour survival (upper) and visible injury rate (lower) from previous studies compared to the results observed at Ellsworth Dam.



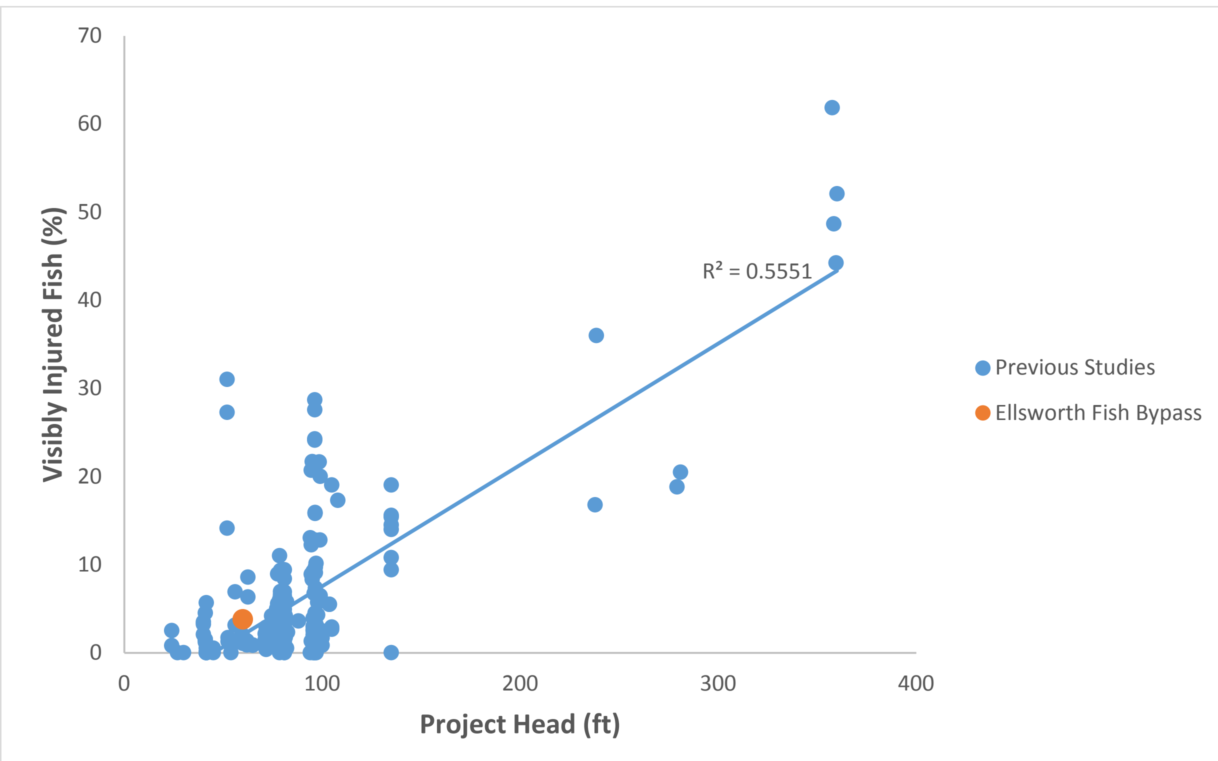


Figure 5.3. The relationships between project head and 48 hour survival (upper) and visible injury rate (lower) from previous studies of spillways and bypass structures compared to the results observed at the downstream bypass at Ellsworth Dam.

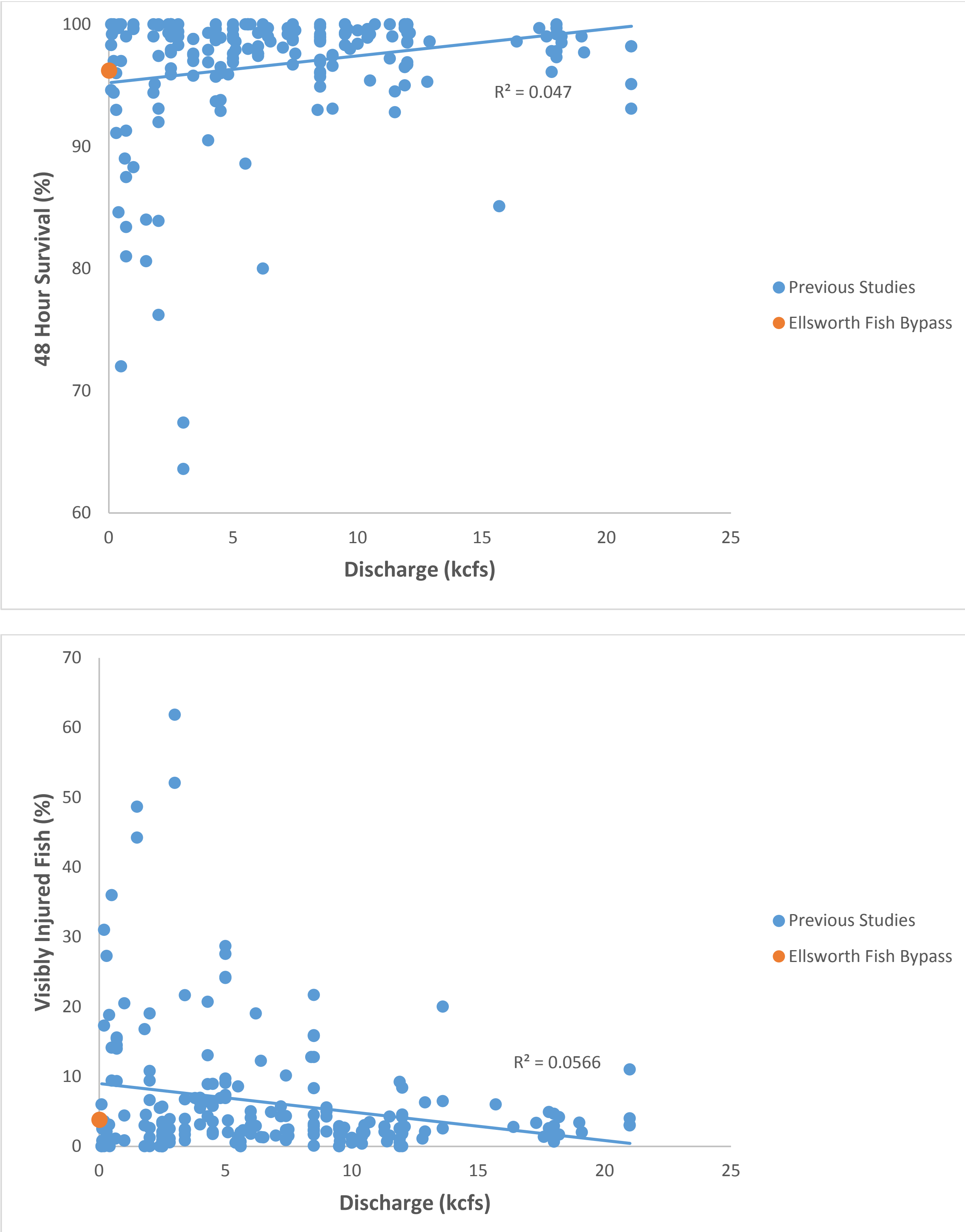
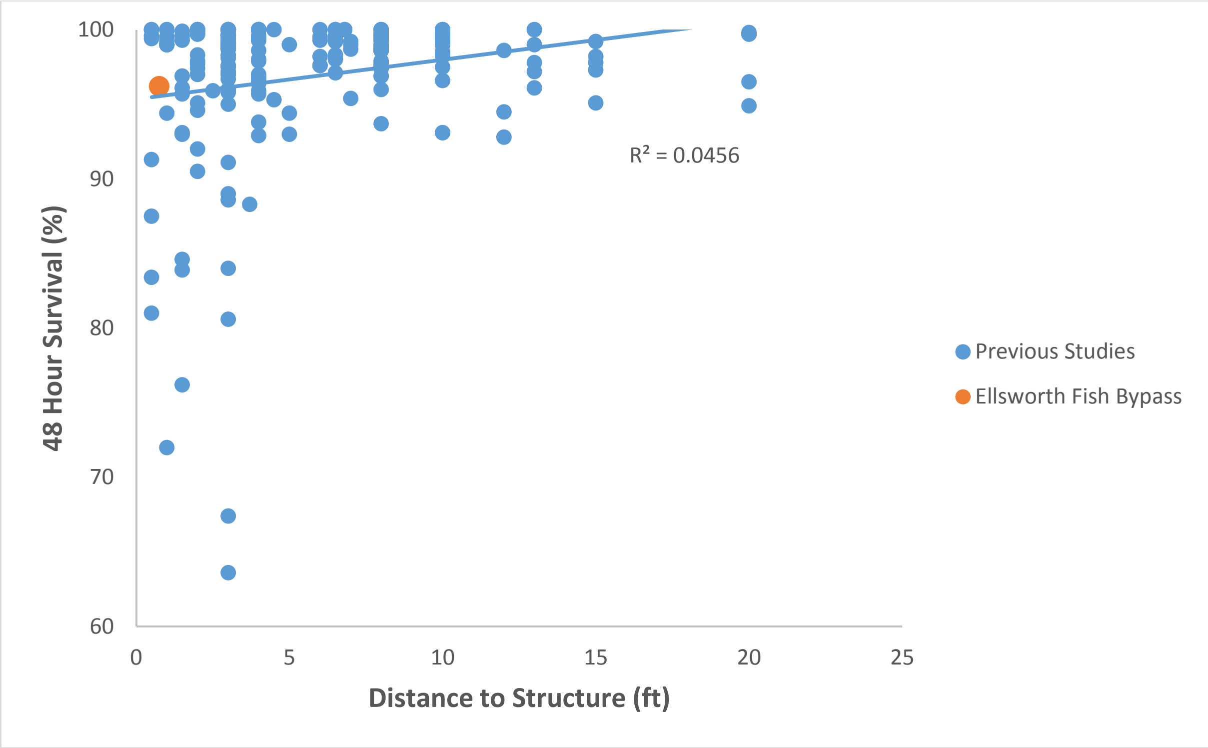


Figure 5.4. The relationships between the discharge of spillways and bypass systems and 48 hour survival (upper) and visible injury rate (lower) from previous studies compared to the results observed at the downstream bypass at Ellsworth Dam.



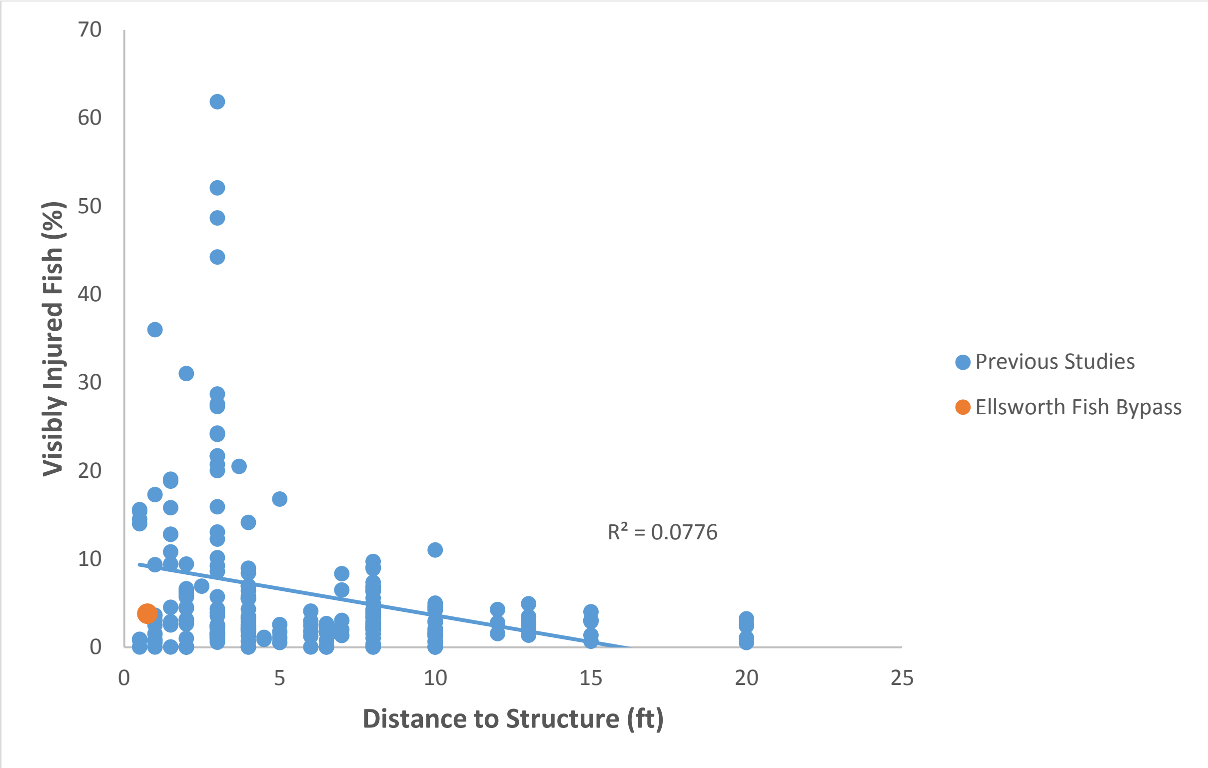


Figure 5.5. The relationship of the distance from a fish release point to a spillway or bypass structure to 48 hour survival (upper) and to visible injury rate (lower) from previous studies compared to the results observed at the downstream bypass at Ellsworth Dam.

Figure 5.6. Zone of shear along the downstream bypass system at Ellsworth Dam. The flow from the third weir flows is nearly perpendicular to the direction of the flow from the first two weirs.

Appendix A: Derivation of Precision, Sample Size, and Maximum Likelihood Parameters

The statistical description below is excerpted from Normandeau Associates and Skalski (2000). For the sake of brevity, references within the text have been removed. However, interested readers can look up these citations in the report prepared by Normandeau Associates and Skalski (2000).

The estimation for the likelihood model parameters and sample size requirements discussed in the text are given herein. Additionally, the results of statistical analyses for evaluating homogeneity in recapture and survival probabilities, and in testing hypotheses of equality in parameter estimates under the simplified (H_O:P_A=P_D) versus the most generalized model (H_A:P_A≠P_D) are given.

The following terms are defined for the equations and likelihood functions which follow:

R_C	=	Number of control fish released
R_T	=	Number of treatment fish released
R	=	R_C=R_T
n	=	Number of replicate estimates $\hat{\tau}_i$ (i=1,…,n)
a_C	=	Number of control fish recaptured alive
d_C	=	Number of control fish recaptured dead
a_T	=	Number of treatment fish recaptured alive
d_T	=	Number of treatment fish recaptured dead
S	=	Probability fish survive from the release point of the controls to recapture
P_A	=	Probability an alive fish is recaptured
P_D	=	Probability a dead fish is recaptured
τ	=	Probability a treatment fish survives to the point of the control releases (*i.e.*, passage survival)
1-τ	=	Passage-related mortality.

The precision of the estimate was defined as:

$$P(-\varepsilon < \hat{\tau} - \tau < \varepsilon) = 1 - \alpha$$

or equivalently

$$P(-\varepsilon <| \hat{\tau} - \tau |< \varepsilon) = 1 - \alpha$$

where the absolute errors in estimation, *i.e.*, $|\hat{\tau} - \tau|$, is <ε (1-α) 100% of the time, $\hat{\tau}$ is the estimated passage survival, and ε is the half-width of a (1-α) 100% confidence interval for $\hat{\tau}$ or 1-$\hat{\tau}$. A precision of ±5%, 90% of the time is expressed as P($|\hat{\tau} - \tau|$<0.05)=0.90.

Using the above precision definition and assuming normality of $\hat{\tau}-\tau$, the required total sample size (R) is as follows:

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}} < Z < \frac{\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = 1-\alpha$$

$$P\left(Z < \frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = \alpha/2$$

$$\Phi\left(\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = \alpha/2$$

$$\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}} = Z_{\alpha/2}$$

$$Var(\hat{\tau}) = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}}$$

$$\frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right] = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}} \quad .$$

where Z is a standard normal deviate satisfying the relationship $P(Z>Z_{1-\alpha/2})=\alpha/2$, and Φ is the cumulative distribution function for a standard normal deviate.

If data can be pooled across trials and letting $R_C=R_T=R$, the sample size for each release is

$$R = \frac{\tau}{SP_A}\left[1+\tau-2S\tau P_A\right]\frac{Z^2_{1-\alpha/2}}{\varepsilon^2} \quad .$$

By rearranging, this equation can be solved to predetermine the anticipated precision given the available number of fish for a study. In most previous investigations (Normandeau Associates and Skalski 2000) this equation has been used to calculate sample sizes because of homogeneity between trials; in the present investigation sample size was predetermined using this equation.

If data cannot be pooled across trials the precision is based on

$$\sum_{i=1}^{n}(1-\hat{\tau}_i)/n = 1-\sum_{i=1}^{n}\hat{\tau}_i/n = 1-\bar{\hat{\tau}} \quad .$$

Precision is defined as

$$P(|\bar{\hat{\tau}} - \bar{\tau}| < \varepsilon) = 1 - \alpha$$

$$P(-\varepsilon < \bar{\hat{\tau}} - \bar{\tau} | < \varepsilon) = 1 - \alpha$$

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} < t_{n-1} < \frac{\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = 1 - \alpha$$

$$P\left(t_{n-1} < \frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = \alpha / 2$$

$$\Phi\left(\frac{-\varepsilon}{Var(\bar{\hat{\tau}})}\right) = \alpha / 2$$

$$\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} = t_{\alpha/2,n-1}$$

$$Var(\bar{\hat{\tau}}) = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

$$\frac{\sigma_\tau^2 + \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right]}{n} = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

where σ_τ^2=natural variation in passage-related mortality.

Now letting R_T=R_C

$$\frac{\sigma_\tau^2 + \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R} + \frac{(1-SP_A)\tau}{R}\right]}{n} = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

which must be iteratively solved for n given R. Or R given n where

$$R = \frac{\frac{\tau}{SP_A}\left[(1-S\tau P_A) + (1-SP_A)\tau\right]}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma_\tau^2\right]}$$

$$R = \frac{\frac{\tau(1+\tau)}{SP_A}}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma^2_\tau\right]}$$

$$R = \frac{\tau(1+\tau)}{SP_A}\left[\frac{t^2_{1-\alpha/2,n-1}}{n\varepsilon^2 - \sigma^2_\tau t^2_{1-\alpha/2,n-1}}\right].$$

The joint likelihood for the passage-related mortality is:

$$L(S, \tau, P_A, P_D \mid R_C, R_T, a_C, a_T, d_C, d_T) =$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_T}{a_T d_T}(S\tau P_A)^{a_T}((1-S\tau)P_D)^{d_T}(1-S\tau P_A-(1-S\tau)P_D)^{R_T-a_T-d_T}.$$

The likelihood model is based on the following assumptions: (1) fate of each fish is independent, (2) the control and treatment fish come from the same population of inference and share that same survival probability, (3) all alive fish have the same probability, P_A, of recapture, (4) all dead fish have the same probability, P_D, of recapture, and (5) passage survival (τ) and survival (S) to the recapture point are conditionally independent. The likelihood model has four parameters (P_A, P_D, S, τ) and four minimum sufficient statistics (a_C, d_C, a_T, d_T).

Because any two treatment releases were made concurrently with a single shared control group we used the likelihood model which took into account dependencies within the study design (Normandeau Associates *et al.* 1995). For any two treatment groups (denoted T_1 and T_2), the likelihood model is as follows:

$$L(S,\tau_1,\tau_2,P_A,P_D \mid R_C,R_{T_1},R_{T_2},a_C,d_c,a_{T_1},d_{T_1},a_{T_2},d_{T_2}) =$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_{T_1}}{a_{T_1} d_{T_1}}(S\tau_1 P_A)^{a_{T_1}}((1-S\tau_1)P_D)^{d_{T_1}}(1-S\tau_1 P_A-(1-S\tau_1)P_D)^{R_{T_1}-a_{T_1}-d_{T_1}}$$

$$\times\binom{R_{T_2}}{a_{T_2} d_{T_2}}(S\tau_2 P_A)^{a_{T_2}}((1-S\tau_2)P_D)^{d_{T_2}}(1-S\tau_2 P_A-(1-S\tau_2)P_D)^{R_{T_2}-a_{T_2}-d_{T_2}}.$$

This likelihood model has the same assumptions as stated in Normandeau Associates and Skalski (2000) but has five estimable parameters (S, τ_1, τ_2, P_A, and P_D). The survival rate for treatment T_1 is estimated by τ_1 and for treatment T_2, by τ_2. A likelihood ratio test with 1 degree of freedom was used to test for equality in survival rates between treatments τ_1 and τ_2 based on the hypothesis H_O: $\tau_1 = \tau_2$ versus H_a: $\tau_1 \neq \tau_2$.

Likelihood models are based on the following assumptions: (a) the fate of each fish is independent; (b) the control and treatment fish come from the same population of inference and share the same natural survival probability, S; (c) all alive fish have the same probability, P_A, of recapture; (d) all dead fish have the same probability, P_D, of recapture; and (e) passage survival (τ) and natural survival (S) to the recapture point are conditionally independent.

The estimators associated with the likelihood model are:

$$\hat{\tau} = \frac{a_T R_C}{R_T a_C}$$

$$\hat{S} = \frac{R_T d_C a_C - R_C d_T a_C}{R_C d_C a_T - R_C d_T a_C}$$

$$\hat{P}_A = \frac{d_C a_T - d_T a_C}{R_T d_C - R_C d_T}$$

$$\hat{P}_D = \frac{d_C a_T - d_T a_C}{R_C a_T - R_T a_C} .$$

The variance (Var) and standard error (SE) of the estimated passage mortality ($1-\hat{\tau}$) or survival ($\hat{\tau}$) are:

$$Var(1-\hat{\tau}) = Var(\hat{\tau}) = \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_{A)}}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right]$$

$$SE(1-\hat{\tau}) = SE(\hat{\tau}) = \sqrt{Var(1-\hat{\tau})}$$

Appendix B: Individual fish disposition data

Appendix B

Individual fish disposition data

Fish ID	Total Length (mm)	Release Date	Passage route	Time			No. HI-Z tags recovered	Survival Code	Status Codes			
				Released	Recaptured	Recapture time (minutes)			1	2	3	4
1	182	6/14	Unit 1	11:04	12:00	56	2	1	A			
2	191	6/14	Unit 1	11:06	11:08	2	2	1	A			
3	200	6/14	Unit 1	11:00	11:04	4	2	1	H			
4	185	6/14	Unit 1	11:01	11:08	7	2	1	A			
5	187	6/14	Unit 1	11:02	11:09	7	2	1	A			
6	210	6/14	Unit 1	11:29	11:38	9	2	1	A			
7	187	6/14	Unit 1	11:31	11:34	3	1	2	6	*		
8	195	6/14	Unit 1	11:30	11:35	5	2	1	H	B		
9	205	6/14	Unit 1	11:29	11:31	2	2	1	A			
10	194	6/14	Unit 1	11:30	11:34	4	2	1	A			
11	195	6/14	Unit 1	11:45	11:47	2	2	1	A			
12	220	6/14	Unit 1	11:47	11:49	2	2	1	G	*		
13	181	6/14	Unit 1	11:46	11:49	3	2	1	A			
14	190	6/14	Unit 1	11:46	11:50	4	2	1	H			
15	185	6/14	Unit 1	11:46	11:51	5	2	1	A			
16	201	6/14	Unit 1	12:03	12:08	5	2	1	A			
17	204	6/14	Unit 1	12:03	12:05	2	2	2	8	F	G	*
18	211	6/14	Unit 1	12:04	12:11	7	2	1	A			
19	162	6/14	Unit 1	12:04	12:10	6	1	1	A			
20	195	6/14	Unit 1	12:02	12:29	27	2	1	G	H	*	

21	182	6/14	Unit 1	12:32	12:38	6	2	1	A		
22	167	6/14	Unit 1	12:34	12:44	10	2	1	H		
23	202	6/14	Unit 1	12:33			1	3	Q		
24	188	6/14	Unit 1	12:35	12:40	5	2	1	A		
25	176	6/14	Unit 1	12:32	12:35	3	2	1	A		
26	203	6/14	Unit 1	12:35	12:41	6	2	1	H		
27	193	6/14	Unit 1	12:34	12:50	16	2	2	G	*	
28	220	6/14	Unit 1	12:33	12:36	3	2	1	A		
29	170	6/14	Unit 1	12:33	19:31	418	2	2	7	G	*
30	190	6/14	Unit 1	12:32			0	5	Q		
31	186	6/14	Unit 1	13:04	13:14	10	2	1	A		
32	192	6/14	Unit 1	13:04	13:06	2	2	1	A		
33	205	6/14	Unit 1	13:06	13:14	8	2	1	A		
34	176	6/14	Unit 1	13:06	16:00	174	2	2	S	R	
35	193	6/14	Unit 1	13:07	13:13	6	1	1	A		
36	196	6/14	Unit 1	13:06	13:11	5	2	1	A		
37	183	6/14	Unit 1	13:05			1	3	Q		
38	201	6/14	Unit 1	13:04	13:14	10	2	1	A		
39	199	6/14	Unit 1	13:05	13:13	8	2	1	A		
40	187	6/14	Unit 1	13:03	13:07	4	2	2	9	*	
41	167	6/14	Unit 1	13:40	13:44	4	2	1	A		
42	165	6/14	Unit 1	13:43	13:49	6	2	1	A		
43	205	6/14	Unit 1	13:45	13:47	2	2	1	A		
44	176	6/14	Unit 1	13:46	13:51	5	2	1	A		
45	170	6/14	Unit 1	13:45	13:49	4	2	1	A		
46	165	6/14	Unit 1	13:43	13:49	6	2	1	A		
47	195	6/14	Unit 1	13:44	13:47	3	2	1	A		
48	186	6/14	Unit 1	13:42	13:56	14	2	1	A		
49	184	6/14	Unit 1	13:45	13:50	5	2	1	A		
50	188	6/14	Unit 1	13:43			2	3	Q		
51	176	6/14	Unit 1	14:01			0	4	S		

52	180	6/14	Unit 1	14:01	14:06	5	2	1	A		
53	205	6/14	Unit 1	14:00	14:05	5	2	1	A		
54	192	6/14	Unit 1	14:01	14:03	2	2	1	A		
55	181	6/14	Unit 1	14:00	14:03	3	2	1	A		
56	191	6/14	Unit 1	14:31	14:36	5	1	1	H		
57	193	6/14	Unit 1	14:29	14:33	4	2	1	A		
58	166	6/14	Unit 1	14:31	14:34	3	2	1	A		
59	186	6/14	Unit 1	14:29	14:32	3	2	1	A		
60	185	6/14	Unit 1	14:30	14:33	3	2	1	A		
61	185	6/14	Unit 2	15:42	15:45	3	2	1	A		
62	186	6/14	Unit 2	15:42	15:47	5	2	1	A		
63	190	6/14	Unit 2	15:41	15:56	15	2	2	G	*	
64	175	6/14	Unit 2	15:41	15:44	3	2	2	Q	*	
65	185	6/14	Unit 2	15:41	15:43	2	2	2	7	*	
66	195	6/14	Unit 2	16:17			1	3	Q		
67	175	6/14	Unit 2	16:15	16:20	5	2	1	A		
68	196	6/14	Unit 2	16:14	16:17	3	2	1	A		
69	182	6/14	Unit 2	16:17	16:39	22	2	1	A		
70	191	6/14	Unit 2	16:15	19:00	165	2	1	A		
71	178	6/14	Unit 2	16:14	16:17	3	2	2	8	E	*
72	180	6/14	Unit 2	16:13	16:18	5	2	1	A		
73	180	6/14	Unit 2	16:16	16:19	3	2	1	A		
74	222	6/14	Unit 2	16:13			0	4	S	R	
75	180	6/14	Unit 2	16:06	16:14	8	2	1	A		
76	180	6/14	Unit 2	16:40	16:45	5	2	1	A		
77	185	6/14	Unit 2	16:40	16:44	4	2	1	A		
78	176	6/14	Unit 2	16:38			0	4	X	R	
79	210	6/14	Unit 2	16:36			1	3	2		
80	170	6/14	Unit 2	16:37	17:45	68	2	1	A		
81	178	6/14	Unit 2	16:39	16:44	5	2	1	A		
82	180	6/14	Unit 2	16:42			1	3	Q		

83	188	6/14	Unit 2	16:40	16:45	5	2	1	A			
84	202	6/14	Unit 2	16:43			0	3	Q			
85	201	6/14	Unit 2	16:42	16:46	4	2	2	E	F	*	
86	195	6/14	Unit 2	17:09			2	3	Q			
87	191	6/14	Unit 2	17:12	17:15	3	2	1	A			
88	208	6/14	Unit 2	17:11	17:20	9	2	1	H			
89	187	6/14	Unit 2	17:11	17:13	2	2	1	A			
90	185	6/14	Unit 2	17:12			0	4	X	R		
91	190	6/14	Unit 2	17:10	17:12	2	2	1	A			
92	195	6/14	Unit 2	17:09	17:15	6	2	1	A			
93	192	6/14	Unit 2	17:08	17:15	7	2	2	8	9	*	
94	177	6/14	Unit 2	17:08	17:11	3	2	1	H			
95	192	6/14	Unit 2	17:09	17:14	5	2	1	A			
96	177	6/14	Unit 2	18:27	18:31	4	2	1	A			
97	196	6/14	Unit 2	18:23	18:26	3	2	1	A			
98	207	6/14	Unit 2	18:26	18:33	7	2	2	Q	*		
99	174	6/14	Unit 2	18:22	18:25	3	2	1	A			
100	187	6/14	Unit 2	18:26			0	4	X	R		
101	186	6/14	Unit 2	18:22	18:34	12	2	1	A			
102	201	6/14	Unit 2	18:23	18:28	5	2	2	7	*		
103	180	6/14	Unit 2	18:26	18:29	3	2	1	A			
104	183	6/14	Unit 2	18:24	18:27	3	2	1	A			
105	187	6/14	Unit 2	18:25			1	3	Q			
106	196	6/14	Unit 2	19:01	19:08	7	2	2	9	8	B	*
107	195	6/14	Unit 2	18:58			1	3	Z	Q		
108	187	6/14	Unit 2	18:57			0	4	X	Q		
109	191	6/14	Unit 2	18:59	19:04	5	2	1	A			
110	160	6/14	Unit 2	19:00	19:07	7	2	1	A			
111	197	6/14	Unit 2	18:59	19:06	7	2	1	A			
112	181	6/14	Unit 2	18:58	19:06	8	2	1	A			
113	199	6/14	Unit 2	18:58	19:03	5	2	1	A			

114	178	6/14	Unit 2	19:04	19:08	4	2	2	7	E	*
115	203	6/14	Unit 2	19:00	19:08	8	2	1	A		
116	170	6/14	Unit 2	19:00	19:04	4	2	2	9	8	*
117	185	6/14	Unit 2	19:04	19:22	18	2	2	E	*	
118	185	6/14	Unit 2	19:04	19:08	4	2	1	A		
119	200	6/14	Unit 2	18:57	19:01	4	2	1	A		
120	186	6/14	Unit 2	18:56	19:00	4	2	1	A		
1	200	6/15	Bypass	8:59	9:05	6	2	2	7	8	*
2	194	6/15	Bypass	8:58	9:02	4	2	1	A		
3	203	6/15	Bypass	8:59	9:00	1	2	1	A		
4	174	6/15	Bypass	9:02	9:05	3	2	1	A		
5	164	6/15	Bypass	9:00	9:03	3	2	1	A		
6	174	6/15	Bypass	8:57	8:59	2	2	1	A		
7	204	6/15	Bypass	9:00	9:07	7	2	1	A		
8	182	6/15	Bypass	9:01	9:05	4	2	1	A		
9	213	6/15	Bypass	8:58	9:04	6	2	1	A		
10	199	6/15	Bypass	8:57	8:59	2	2	1	A		
11	185	6/15	Bypass	9:34			0	4	Q	R	
12	212	6/15	Bypass	9:33	9:39	6	2	1	A		
13	180	6/15	Bypass	9:30	9:33	3	2	1	A		
14	210	6/15	Bypass	9:33	9:39	6	2	1	A		
15	177	6/15	Bypass	9:35	9:37	2	2	1	A		
16	207	6/15	Bypass	9:34	9:36	2	2	1	A		
17	214	6/15	Bypass	9:31	9:52	21	2	1	A		
18	174	6/15	Bypass	9:30	9:32	2	2	1	A		
19	205	6/15	Bypass	9:31	9:38	7	2	1	A		
20	158	6/15	Bypass	9:29	9:32	3	2	1	A		
21	184	6/15	Bypass	10:24	10:28	4	2	1	A		
22	185	6/15	Bypass	10:24	10:27	3	2	1	A		
23	172	6/15	Bypass	10:23	10:29	6	2	1	A		
24	168	6/15	Bypass	10:21	10:26	5	2	1	H	B	

25	196	6/15	Bypass	10:19	11:39	80	2	1	A		
26	183	6/15	Bypass	10:21	10:29	8	2	1	A		
27	193	6/15	Bypass	10:20	10:25	5	2	1	H	G	*
28	160	6/15	Bypass	10:22	10:30	8	2	1	A		
29	203	6/15	Bypass	10:24	10:26	2	2	1	A		
30	215	6/15	Bypass	10:19	10:21	2	2	1	A		
31	168	6/15	Bypass	11:06	11:12	6	2	1	A		
32	190	6/15	Bypass	11:08			0	5	Q	R	
33	190	6/15	Bypass	11:06	11:09	3	2	1	A		
34	187	6/15	Bypass	11:06	11:08	2	2	1	A		
35	188	6/15	Bypass	11:05	11:12	7	2	1	A		
36	175	6/15	Bypass	11:07	11:11	4	2	1	A		
37	201	6/15	Bypass	11:08	11:13	5	2	1	A		
38	201	6/15	Bypass	11:04	11:11	7	2	1	A		
39	171	6/15	Bypass	11:06	11:09	3	2	1	A		
40	176	6/15	Bypass	11:04	11:06	2	2	1	A		
41	174	6/15	Bypass	11:43	11:45	2	2	1	A		
42	195	6/15	Bypass	11:44	11:49	5	2	1	A		
43	200	6/15	Bypass	11:44	11:48	4	2	1	A		
44	180	6/15	Bypass	11:43	11:46	3	2	1	A		
45	178	6/15	Bypass	11:45	11:52	7	2	1	A		
46	188	6/15	Bypass	11:44	11:47	3	2	1	A		
47	187	6/15	Bypass	11:46	11:53	7	2	1	A		
48	175	6/15	Bypass	11:46	11:50	4	2	1	A		
49	212	6/15	Bypass	11:44	11:51	7	2	1	A		
50	202	6/15	Bypass	11:47	11:51	4	2	1	A		
51	189	6/15	Bypass	12:20	12:28	8	2	1	A		
52	186	6/15	Bypass	12:20	12:26	6	2	1	A		
53	206	6/15	Bypass	12:21	12:27	6	2	1	A		
54	184	6/15	Bypass	12:20	12:26	6	2	1	A		
55	193	6/15	Bypass	12:21	12:26	5	2	1	A		

56	198	6/15	Bypass	12:20			0	4	Q	R	
57	202	6/15	Unit 2	13:05			1	3	Q		
58	171	6/15	Unit 2	13:07	13:12	5	1	1	A		
59	191	6/15	Unit 2	13:07	13:11	4	2	1	A		
60	175	6/15	Unit 2	13:06	13:11	5	2	1	A		
61	173	6/15	Unit 2	13:07	13:27	20	2	2	7	*	
62	175	6/15	Unit 2	13:06	13:13	7	2	1	G	H	*
63	202	6/15	Unit 2	13:05	13:09	4	2	1	A		
64	187	6/15	Unit 2	13:08	13:13	5	2	1	A		
65	207	6/15	Unit 2	13:04	13:13	9	2	1	G	H	*
66	193	6/15	Unit 2	13:45	13:52	7	2	1	A		
67	186	6/15	Unit 2	13:46	13:54	8	2	2	9	8	*
68	191	6/15	Unit 2	13:43	13:53	10	2	1	A		
69	181	6/15	Unit 2	13:43	13:49	6	2	1	A		
70	181	6/15	Unit 2	13:45			0	5	Q		
71	188	6/15	Unit 2	13:47	13:54	7	2	1	A		
72	168	6/15	Unit 2	13:46	13:55	9	2	1	A		
73	197	6/15	Unit 2	13:45	13:49	4	2	2	9	*	
74	187	6/15	Unit 2	13:45	13:47	2	2	1	A		
75	184	6/15	Unit 2	13:46	13:50	4	2	2	7	*	
76	199	6/15	Unit 2	14:03	14:16	13	2	1	A		
77	176	6/15	Unit 2	14:02	14:07	5	2	1	A		
78	172	6/15	Unit 2	14:03	14:08	5	2	1	A		
79	228	6/15	Unit 2	14:02			0	5	Q		
80	180	6/15	Unit 2	14:06	14:28	22	2	1	B		
81	165	6/15	Unit 2	14:22	14:29	7	2	1	B		
82	185	6/15	Unit 2	14:23			2	3	Q		
83	198	6/15	Unit 2	14:21	14:26	5	2	2	4	F	*
84	210	6/15	Unit 2	14:20	14:31	11	2	2	6	*	
85	174	6/15	Unit 2	14:21	14:27	6	2	1	A		
86	189	6/15	Unit 2	14:21	14:28	7	2	1	A		

87	191	6/15	Controls	16:03	16:07	4	2	1	A
88	186	6/15	Controls	16:03	16:05	2	2	1	A
89	196	6/15	Controls	16:04	16:30	26	2	1	A
90	173	6/15	Controls	16:02	16:05	3	2	1	A
91	176	6/15	Controls	16:01	16:04	3	2	1	A
92	198	6/15	Controls	16:01	16:03	2	2	1	A
93	182	6/15	Controls	16:04	16:09	5	2	1	A
94	188	6/15	Controls	16:02	16:07	5	2	1	A
95	212	6/15	Controls	16:04	16:08	4	2	1	A
96	186	6/15	Controls	16:39	16:48	9	2	1	A
97	184	6/15	Controls	16:36	16:44	8	2	1	A
98	208	6/15	Controls	16:35	16:48	13	1	1	A
99	186	6/15	Controls	16:37	16:40	3	2	1	H
100	195	6/15	Controls	16:40	16:45	5	2	1	A
101	193	6/15	Controls	16:39	16:44	5	2	1	A
102	210	6/15	Controls	16:41	16:44	3	2	1	A
103	186	6/15	Controls	16:37	16:44	7	2	1	A
104	205	6/15	Controls	16:36	16:44	8	2	1	A
105	200	6/15	Controls	16:36	16:46	10	2	1	A
106	192	6/15	Controls	17:13	17:20	7	2	1	A
107	202	6/15	Controls	17:12	17:15	3	2	1	A
108	202	6/15	Controls	17:14	17:17	3	2	1	A
109	167	6/15	Controls	17:12	17:23	11	2	1	A
110	201	6/15	Controls	17:13	17:21	8	2	1	A
111	191	6/15	Controls	17:16	17:28	12	2	1	A
112	194	6/15	Controls	17:11	17:12	1	2	1	A
113	180	6/15	Controls	17:12	17:15	3	2	1	A
114	200	6/15	Controls	17:13	17:19	6	2	1	A
115	214	6/15	Controls	17:11	17:19	8	2	1	A
116	177	6/15	Controls	17:10	17:16	6	2	1	A
117	190	6/15	Controls	17:41	17:43	2	2	1	A

118	186	6/15	Controls	17:41	17:45	4	2	1	A
119	165	6/15	Controls	17:36	17:39	3	2	1	A
120	186	6/15	Controls	17:34	17:44	10	2	1	A
121	190	6/15	Controls	17:37	17:47	10	2	1	A
122	195	6/15	Controls	17:36	17:46	10	2	1	A
123	173	6/15	Controls	17:37	17:46	9	2	1	A
124	178	6/15	Controls	17:40	17:47	7	2	1	A
125	185	6/15	Controls	17:40	17:45	5	2	1	A
126	180	6/15	Controls	17:37	17:43	6	2	1	A
127	190	6/15	Controls	18:05	18:14	9	2	1	A
128	190	6/15	Controls	18:03	18:08	5	2	1	A
129	194	6/15	Controls	18:05	18:11	6	2	1	A
130	186	6/15	Controls	18:06	18:13	7	2	1	A
131	179	6/15	Controls	18:07	18:10	3	2	1	A
132	193	6/15	Controls	18:03	18:06	3	2	1	A
133	191	6/15	Controls	18:04	18:12	8	2	1	A
134	196	6/15	Controls	18:04	18:06	2	2	1	A
135	185	6/15	Controls	18:03	18:11	8	2	1	A
136	185	6/15	Controls	18:06	18:08	2	2	1	A
137	182	6/15	Controls	18:23	18:29	6	2	1	A
138	198	6/15	Controls	18:24	18:27	3	2	1	A
139	195	6/15	Controls	18:24	18:27	3	2	1	A
140	182	6/15	Controls	18:23	18:28	5	2	1	A

Appendix C: Survival, malady-free, and injury-free outputs

1 hour survival estimates for brown trout after passing through the Ellsworth downstream bypass, June 2017. Controls released into the tailrace. Control fish: 54 released and 54 alive. Downstream bypass treatment fish: 53 released, 52 alive, and 1 dead.

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RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S = 1.0 N/A Control group survival*
Pa = Pd 1.0 N/A Recovery probability*
Tau = 0.9811 (0.0187) Downstream bypass survival
1-Tau = 0.0189 (0.0187) Downstream bypass mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -4.960798

Variance-Covariance matrix for estimated probabilities:
0.00035

Profile likelihood intervals:

	Downstream bypass survival	**Downstream bypass mortality**
90 percent:	(0.9722, 1.0000)	(0.0000, 0.0278)
95 percent:	(0.0000, 1.0000)	(0.0000, 1.0000)
99 percent:	(0.0000, 1.0000)	(0.0000, 1.0000)

==

Likelihood ratio statistic for equality of recovery probabilities:
0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

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1 hour survival estimates for brown trout after passing through Ellsworth Unit 1 and Unit 2. Controls released into the tailrace.
Control fish: 54 released and 54 alive.
Unit 1 treatment fish: 59 released, 49 alive, and 9 dead.
Unit 2 treatment fish: 85 released, 56 alive, and 29 dead.

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RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S1 = 1.0 N/A Control group*
Pa = Pd 0.9949 (0.0038) Recovery probability
S2 = 0.8448 (0.0315) Unit 1
S3 = 0.6588 (0.0514) Unit 2

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -85.8713

Tau = 0.8448 (0.0358) Unit 1
Tau = 0.6588 (0.0513) Unit 2

Z statistic for the equality of equal turbine survivals:
2.9736

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

-0.00002533	-0.00001682	-0.00017902	0.00000000
-0.00001682	0.00001421	-0.00011889	0.00000000
-0.00017902	-0.00011889	0.00099487	0.00000000
0.00000000	0.00000000	0.00000000	0.00264441

Confidence intervals:

	Unit 1 Tau	**Unit 2 Tau**
90 percent:	(0.7860, 0.9037)	(0.5744, 0.7432)
95 percent:	(0.7747, 0.9149)	(0.5582, 0.7594)
99 percent:	(0.7527, 0.9369)	(0.5267, 0.7910)

==

Likelihood ratio statistic for equality of recovery probabilities:
0.0933

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

==

48 hour survival estimate for brown trout after passing through the Ellsworth downstream bypass. Controls released into the tailrace.
Control fish: 54 released and 54 alive.
Downstream bypass treatment fish: 53 released, 51 alive, and 2 dead.

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S = 1.0 N/A Control group survival*
Pa = Pd 1.0 N/A Recovery probability*
Tau = 0.9623 (0.0262) Downstream bypass survival
1-Tau = 0.0377 (0.0262) Downstream bypass mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -8.516070

Variance-Covariance matrix for estimated probabilities:
0.00069

Profile likelihood intervals:

	Downstream bypass survival	**Downstream bypass mortality**
90 percent:	(0.9486, 1.0000)	(0.0000, 0.0514)
95 percent:	(0.0000, 1.0000)	(0.0000, 1.0000)
99 percent:	(0.0000, 1.0000)	(0.0000, 1.0000)

===

Likelihood ratio statistic for equality of recovery probabilities:
0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

===

48 hour survival estimates for brown trout after passing through Ellsworth Unit 1 and Unit 2.
Controls released into the tailrace.
Control fish: 54 released and 54 alive.
Unit 1 treatment fish: 59 released, 47 alive, and 11 dead.
Unit 2 treatment fish: 85 released, 53 alive, and 32 dead.

===
RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S1 = 1.0 N/A Control group survival*
Pa = Pd 0.9949 (0.0050) Recovery probability
S2 = 0.8103 (0.0515) Unit 1
S3 = 0.6235 (0.0526) Unit 2

* -- Because of constraints in the data set, this probability is assumed
equal to 1.0; not estimated.

log-likelihood : -90.7540

Tau = 0.8103 (0.0515) Unit 1
Tau = 0.6235 (0.0526) Unit 2

Z statistic for the equality of equal turbine survivals:
2.5396

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00002538	0.00000000	0.00000000
0.00000000	0.00000000	0.00264976	0.00000000
0.00000000	0.00000000	0.00000000	0.00276165

Confidence intervals:

	Unit 1 Tau	Unit 2 Tau
90 percent:	(0.7257, 0.8950)	(0.5371, 0.7100)
95 percent:	(0.7095, 0.9112)	(0.5205, 0.7265)
99 percent:	(0.6778, 0.9429)	(0.4882, 0.7588)

===

Likelihood ratio statistic for equality of recovery probabilities:
0.0745

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

===

Malady-free rate for brown trout after passing through the Ellsworth downstream bypass. Controls released into the tailrace.
Control fish: 54 examined, 53 without maladies, 1 with a malady.
Downstream bypass treatment fish: 53 examined, 51 without maladies, and 2 with maladies.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S = 0.9815 (0.0183) Control group
Pa = Pd 1.0 N/A Recovery probability*
Tau = 0.9804 (0.0324) Downstream bypass
1-Tau = 0.0196 (0.0324) Downstream bypass

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -13.495737

Variance-Covariance matrix for estimated probabilities:
0.00034 -0.00034
-0.00034 0.00105

Profile likelihood intervals:

	Downstream bypass	**Downstream bypass**
90 percent:	(0.9163, 1.0000)	(0.0000, 0.0837)
95 percent:	(0.9009, 1.0000)	(0.0000, 0.0991)
99 percent:	(0.8675, 1.0000)	(0.0000, 0.1325)

==

Likelihood ratio statistic for equality of recovery probabilities:
0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

==

Malady-free estimates for brown trout passed through Units 1 and 2 at Ellsworth Dam. Controls released into the tailrace.
Control fish: 54 examined, 53 without maladies, and 1 with a malady.
Unit 1 treatment fish: 54 examined, 42 without maladies, and 12 with maladies.
Unit 2 treatment fish: 74 examined, 52 without maladies, and 22 with maladies.
==
RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9815	(0.0183)	Control group
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	**0.7778**	**(0.0566)**	**Unit 1**
S3 =	**0.7027**	**(0.0531)**	**Unit 2**

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -78.6170

Tau = 0.7925 (0.0595) Unit 1
Tau = 0.7160 (0.0558) Unit 2

Z statistic for the equality of equal turbine survivals:
0.9379

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00033658	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00320073	0.00000000
0.00000000	0.00000000	0.00000000	0.00282313

Confidence intervals:

	Unit 1 Tau	**Unit 2 Tau**
90 percent:	(0.6946, 0.8904)	(0.6242, 0.8077)

95 percent: (0.6758, 0.9091) (0.6067, 0.8253)
99 percent: (0.6392, 0.9457) (0.5724, 0.8596)

===

Likelihood ratio statistic for equality of recovery probabilities:
0.0000

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

===

Injury-free estimate for brown trout after passing through the Ellsworth downstream bypass. Controls released into the tailrace.
Control fish: 54 examined, 54 without injuries
Downstream bypass treatment fish: 53 examined, 51 without injuries

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S = 1.0 N/A Control group*
Pa = Pd 1.0 N/A Recovery probability*
Tau = 0.9623 (0.0262) Downstream bypass
1-Tau = 0.0377 (0.0262) Downstream bypass

* -- Because of contraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -8.516070

Variance-Covariance matrix for estimated probabilities:
0.00069

Profile likelihood intervals:

	Downstream bypass	**Downstream bypass**
90 percent:	(0.9486, 1.0000)	(0.0000, 0.0514)
95 percent:	(0.0000, 1.0000)	(0.0000, 1.0000)
99 percent:	(0.0000, 1.0000)	(0.0000, 1.0000)

===

Likelihood ratio statistic for equality of recovery probabilities:
0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

===

Injury-free estimates for Ellsworth Units 1 and 2. Controls released into the tailrace.
Control fish: 54 examined, 54 without injuries
Unit 1 treatment fish: 54 examined, 47 without injuries
Unit 2 treatment fish: 74 examined, 56 without injuries
==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group*
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	0.8704	(0.0457)	**Unit 1**
S3 =	0.7568	(0.0499)	**Unit 2**

* -- Because of contraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -61.8813

Tau = 0.8704 (0.0457) Unit 1
Tau = 0.7568 (0.0499) Unit 2

Z statistic for the equality of equal turbine survivals:
1.6794

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00182896	0.00000000
0.00000000	0.00000000	0.00000000	0.00248753

Confidence intervals:

	Unit 1 Tau	**Unit 2 Tau**
90 percent:	(0.7952, 0.9456)	(0.6747, 0.8388)
95 percent:	(0.7808, 0.9600)	(0.6590, 0.8545)

99 percent: (0.7527, 0.9881) (0.6283, 0.8852)

===

Likelihood ratio statistic for equality of recovery probabilities:
0.0000

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix D: Correspondence related to agency review of the Ellsworth HI-Z tag evaluation draft report

From: Dunlap, Frank
Sent: Friday, November 17, 2017 2:39 PM
To: Anna Harris; Steve Shepard (Steven_Shepard@fws.gov); Bryan Sojkowski; Dan Tierney - NOAA Federal; donald.dow@noaa.gov; Sean McDermott - NOAA Federal; Atkinson, Ernie; Overlock, Joe; Colin Shankland; Gail Wippelhauser (gail.wippelhauser@maine.gov); Simpson, Mitch; Greg Burr (gregory.burr@maine.gov); John Sewell (johnsewell44@hotmail.com); Asha Ajmani; Marvin Cling, Sr. (marvin@wabanaki.com)
Cc: Dill, Richard; Bernier, Kevin; Cole, James; Maloney, Kelly; Browne, Peter; Bley, Wendy
Subject: Ellsworth Project - draft 2017 HI-Z Study Report - For Review

All,

For your review, attached please find the draft HI-Z study report, the *Ellsworth Project Evaluation of Survival and Injury Occurrence Associated with Downstream Passage for Juvenile Salmonids*. A summary of key findings from the study was previously distributed and discussed at the Ellsworth SPP meeting held September 14th. Please review and provide any formal comments on the report to Brookfield by Friday, December 15, 2017.

Thanks, and feel free to contact either Richard or I with any questions.

Frank

Frank H. Dunlap
Licensing Specialist
Brookfield Renewable
150 Main Street, Lewiston, Maine 04240
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Brookfield

From: Dan Tierney - NOAA Federal [mailto:dan.tierney@noaa.gov]
Sent: Friday, December 08, 2017 4:00 PM
To: Dunlap, Frank
Cc: Dill, Richard; Maloney, Kelly
Subject: Re: Ellsworth Project - draft 2017 HI-Z Study Report - For Review

Hi Frank, Here are NMFS's comments on the Hi-Z balloon tag study. Thanks, Dan

On Fri, Nov 17, 2017 at 2:39 PM, Dunlap, Frank <Frank.Dunlap@brookfieldrenewable.com> wrote:

All,

For your review, attached please find the draft HI-Z study report, the *Ellsworth Project Evaluation of Survival and Injury Occurrence Associated with Downstream Passage for Juvenile Salmonids*. A summary of key findings from the study was previously distributed and discussed at the Ellsworth SPP meeting held September 14th. Please review and provide any formal comments on the report to Brookfield by Friday, December 15, 2017.

Thanks, and feel free to contact either Richard or I with any questions.

Frank

Frank H. Dunlap
Licensing Specialist

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National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930-2276

DEC 07 2017

Frank Dunlap
Licensing Specialist
Brookfield Renewable
150 Main Street, Lewiston, Maine
04240

Re: 2017 Downstream Survival Study at the Ellsworth Project (P-2727)

Dear Mr. Dunlap:

In your November 17, 2017 e-mail, you requested that we review and comment on Black Bear's draft study report, entitled *Ellsworth Project Evaluation of Survival and Injury Occurrence Associated with Downstream Passage for Juvenile Salmonids.* This report is a result of the study conducted in June 2017 at the Ellsworth Project (FERC No. 2727) on the Union River in Ellsworth, Maine. This study assessed injury and mortality of hatchery reared brown trout using Hi-Z balloon tags. The intent of the study was to ascertain the effects (i.e. survival, injury, loss of equilibrium (LOE)) associated with downstream turbine and bypass passage. We acknowledge the Licensee's efforts working with us and other stakeholders on the Union River to conduct the best possible assessments of the effects of the Ellsworth Project on diadromous fish.

Comments on the 2017 Draft Study Report

- We have expressed concern about the recurring mortality events of river herring at the project in letters to the FERC (July 5, 2017 and November 30, 2016), as well as in numerous conversations with you. It was the observed injury and mortality of juvenile and adult alewives that led us to request this study. Using the results of this salmonid study, can you provide an analysis regarding injury and mortality of juvenile and adult alosines?

- There has been significant discussion about the effect of pressure related injuries associated with turbine passage (i.e. shear trauma) on juvenile and adult alewives. According to the observations made by the Downeast Salmon Federation and Black Bear staff, it appears that a large proportion of the fish (>50%) observed dead and injured downstream of the project show signs of shear trauma (missing eyes). However, we do not have any information regarding the proportion of alewives that pass the Ellsworth project that experience this type of injury. On page 16, you have reported the level of shear related injuries on the study fish. Specifically, you conclude that one fish (~2%) exhibited signs of shear forces after passing through Unit 1, eight (~11%) exhibited it after passing through Unit 2, and one (~2%) was observed with this type of injury after passing through the bypass. From this study, can you show the scale of this effect on other species and life stages?

- On page 12, the draft report indicates that study fish were classified as alive, dead, predated, or unknown. It appears that no fish were classified as predated; however, that is not explicitly stated anywhere. Please incorporate this information into Table 4-1 (or other appropriate table), which indicates the number of fish recaptured that were dead, alive, or unknown. The lack of predation in the tailrace is notable given the high level of smolt mortality attributed to predation in the smolt survival study in 2017. It is probable that the disturbance caused by the two motorboats in the project tailrace, as well as the short period of time that the fish were in the water (average of 6-17 minutes depending on passage route), would confound any effort to estimate predation.

- On page 16, you indicate that 24.3% of the brown trout that went through Unit 2 were injured. You also indicate that the 1-hour mortality rate of that turbine was 34.1%. The fact that the mortality rate is higher than the injury rate implies that some proportion of the dead fish did not show signs of injury. Can you report the proportion of fish that died yet had no sign of injury? Additionally, can you provide the proportion of the fish that survived passage, but were classified as injured? These sub-lethal injuries are likely one of the causative factors of hydrosystem delayed mortality (i.e. mortality associated with dam passage that occurs later in time in the estuary) (Stich et al 2015). Therefore, an understanding of the extent of sub-lethal injuries will be valuable in assessing the full effects of the Ellsworth Project.

- On page 18, you indicate potential modifications to the downstream bypass that would further reduce the relatively low mortality rate. We agree that the proposals may be effective at reducing mortality. Although 96.2% survival is relatively high, it is still not as high as we would expect in a properly designed fishway. Ideally, no smolts that use this passage route would be killed. You have shown this to be possible at other projects within the GOM DPS.

  Although you suggest potential remedies to fix the downstream bypass, the report does not contain any suggestions on how to fix the much more significant issue of mortality through the turbines. We look forward to hearing how you intend to resolve this critical issue.

- Although it has been cited as the safer of the two turbine types at the Ellsworth project, it is clear from the study results that the large propeller turbine (Unit 1) is not a suitable passage route for any species of fish. You state on page 17 that the survival of fish through Unit 1 was "…within the range of passage survival and injury estimates for turbines previously evaluated at other hydroelectric facilities". While this may be true, it should not imply that this is an acceptable rate given the requirements of diadromous fish in the Union River. The 48-hour survival for Unit 1 is 81%, which although better than the 62% survival rate found at Unit 2, is still not adequate for any of our trust species. At the top of page 17, you indicate that although there is a significant difference in injury between Unit 1 (propeller) and Unit 2 (Kaplan), there is not a significant difference in malady occurrence. This suggests that fish that pass through the safer of the two units (Unit 1) are still subjected to injury and extensive loss of equilibrium, which could lead to higher predation rates downstream of the dam. These LOE effects, in addition to high mortality and injury rates, make it clear that turbine passage is not an option through any of the four turbines at this Project.

- You indicate that flow through the downstream bypass was 22 cfs during the study, which is only a third of what it should be passing. Please explain why the bypass was only being operated at 22 cfs, and whether or not this is typical for the fish passage season.

We look forward to working with you to find solutions to the issues that were revealed through this study. Based upon the results of this study, in addition to two years of Atlantic salmon smolt studies at the project (2016 and 2017), it is apparent that significant modifications are needed at the Ellsworth Project to fully protect endangered Atlantic salmon and other diadromous species in the Union River. If you have any questions concerning these comments, please contact Dan Tierney (207-866-3755 or Dan.Tierney@noaa.gov).

Sincerely,

Dan Kircheis
Acting ESA Fish Recovery Coordinator

CC:
Dan Tierney
Julie Crocker

Appendix E: Responses to resource agency comments

NMFS Comment 1: *We have expressed concern about the recurring mortality events of river herring at the project in letters to the FERC (July 5, 2017 and November 30, 2016), as well as in numerous conversations with you. It was the observed injury and mortality of juvenile and adult alewives that led us to request this study. Using the results of this salmonid study, can you provide an analysis regarding injury and mortality of juvenile and adult alosines?*

Response to NMFS Comment 1: In the November 30, 2016 letter from NMFS to the FERC, NMFS referenced documentation previously filed by the Downeast Salmon Federation (DSF) related to observed alewife and American eel passage injury and mortality at Ellsworth. This study was developed in response to the NMFS concern that the effects observed by DSF may not be limited to alewife and may also be affecting downstream migrating endangered Atlantic salmon.

Turbine survival and injury estimates should be examined on a species-specific and length-specific basis. The use of a surrogate fish species for assessing potential passage injuries and mortality rates should be considered carefully (such as the use of the closely related brown trout in lieu of Atlantic salmon for this evaluation). It would be difficult to reliably estimate the survival and injury of adult river herring passing downstream of the Ellsworth project through the turbines or the fish bypass system with the present data set obtained on juvenile salmonids. Although direct survival/injury studies have been conducted on alosines, primarily juvenile and adult American shad, the propeller-type turbines tested in those studies did not have characteristics similar to the turbines at the Ellsworth project. However, with this data set it can be noted that turbine unit 1 would likely be safer for passing adult river herring than turbine unit 2.

Although direct application of the injury and mortality rates observed for juvenile salmonids in this evaluation is not appropriate for application to juvenile and adult alosines, an additional section has been added in the discussion (see Section 5.3) which provides a brief summary of previously HI-Z tag estimated passage survival rates for alosines at other hydroelectric projects with propeller-type turbines.

NMFS Comment 2: *There have been significant discussions about the effect of pressure related injuries associated with turbine passage (i.e., shear trauma) on juvenile and adult alewives. According to the observations made by the Downeast Salmon Federation and Black Bear staff, it appears that a large proportion of the dead and injured downstream of the project show signs of shear trauma (missing eyes). However, we do not have any information regarding the proportion of alewives that pass the Ellsworth project that experience this type of injury. On page 16, you have reported the level of shear related injuries on the study fish. Specifically, you conclude that one fish (~2%) exhibited signs of shear forces after passing through Unit 1, eight (~11%) exhibited it after passing through Unit 2, and one (~2%) was observed with this type of injury after passing through the bypass. From this study, can you show the scale of this effect on other species and life stages?*

Response to NMFS Comment 2: At present, there is no data regarding the proportional distribution of outmigrating alosines among available downstream passage routes at the Ellsworth Dam. The data from the present study cannot be used to estimate the effects of shear trauma on species of fish other than salmonids. There have been some field observations that suggest that alosines may be more susceptible to shear-induced eye injury than other species of fish. However, a direct injury/survival study has not been performed to confirm these findings where juvenile alosines and salmonids were passed through the same turbine. See the first paragraph in Section 5.3.

NMFS Comment 3: *On page 12, the draft report indicates that study fish were classified as alive, dead, predated or unknown. It appears that no fish were classified as predated; however this is not explicitly stated anywhere. Please incorporate this information into Table 4-1 (or other appropriate table), which indicates the number of fish recaptured that were dead, alive or unknown. The lack of predation in the tailrace is notable given the high level of smolt mortality attributed to predation in the smolt survival study in 2017. It is probable that disturbance caused by the two motorboats in the project tailrace, as well as the shorter period of time that the fish were in the water (average of 6-17 minutes depending on passage route), would confound any effort to estimate predation.*

Response to NMFS Comment 3: A row has been added to Table 4.1 regarding predated fish. However, the occurrence of predation is only quantified during HI-Z tag studies for use during the statistical analyses of survival and injury. If a fish is released and not recaptured due to predation, it can affect the precision of the study estimates. These studies are not designed to quantify predation or long term effects of passage beyond the 48 hour post-passage holding period. Based on numerous observations, the majority of individuals which succumb during the 48 hour delayed assessment holding period do so within the first 24 hours.

Tailrace conditions during the HI-Z tag study were not comparable to those observed during the 2016 and 2017 smolt biotelemetry evaluations. The presence of the study-related boats operating in the tailrace during the HI-Z study greatly reduced the number of avian predators (i.e., gulls and cormorants) from those observed during bird counts conducted during the telemetry studies. As noted by NMFS, these observations coupled with the short duration of tailrace exposure for HI-Z tagged fish prevents any estimation of a normal background mortality rate.

NMFS Comment 4: *On page 16, you indicate that 24.3% of the brown trout that went through Unit 2 were injured. You also indicate that thee 1-hour mortality rate of that turbine was 34.1%. The fact that the mortality rate is higher than the injury rate implies that some proportion of the dead fish did not show signs of injury. Can you report the proportion of fish that died yet had no sign of injury? Additionally, can you provide the proportion of the fish that survived passage but were classified as injured? These sub-lethal injuries are likely one of the causative factors of hydrosystem delayed mortality (i.e., mortality associated with dam passage that occurs later in time in the estuary) (Stitch et al. 2015). Therefore, an* *understanding of the extent of sub-lethal injuries will be valuable to assessing he full effects of the Ellsworth Project.*

Response to NMFS Comment 4: The 1-hour mortality rate that was higher than the injury rate for Unit 2 (and also Unit 1 to a lesser degree) was due to a large number (n = 11) of fish which passed through Unit 2 and were not recaptured but were assigned a dead status based on radio telemetry signals and/or recapture of only HI-Z tags for those fish. These 11 fish were not included in calculations of injury or malady-free rates. The conservative approach of assigning these fish a "dead" status has been maintained during all previous HI-Z tag studies. Fish that are not physically recaptured and examined are not included in calculations of injury rates because the condition of these fish is not known.

There were no fish that died without signs of visible injury for any of the passage routes that were tested. All fish that were recaptured dead or died during the 48 hour holding period showed signs of visible injury. There were only two fish (one for Unit 2 and one for the fish bypass) that had visible injuries (bruising) and survived the 48-hour holding period. There were also five fish that passed through Unit 1 which had passage-related maladies (only loss of equilibrium) which survived the 48-hour holding period. This data is reported in Table 4.4. As mentioned above, this report does not attempt to quantify the delayed effects of downstream passage beyond 48 hours through the Ellsworth Project. Section 4.4 has been modified to specify those fish which survived the 48-hour holding period and had injuries and/or LOE.

NMFS Comment 5: *On page 18, you indicated potential modifications to the downstream bypass that would further reduce the relatively low mortality rate. We agree that the proposals may be effective at reducing mortality. Although 96.2% survival is relatively high, it is still not as high as we would expect in a properly designed fishway. Ideally, no smolts that use this passage route would be killed. You have shown this to be possible at other projects within the GOM DPS.*

Although you suggest potential remedies to fix the downstream bypass, the report does not contain any suggestions on how to fix the much more significant issue of mortality through the turbines. We look forward to hearing how you intend to resolve this critical issue.

Response to NMFS Comment 5: Brookfield will continue to collaborate with the resource agencies regarding potential improvements to reduce downstream passage mortality at Ellsworth Dam.

NMFS Comment 6: *Although it has been cited as the safer of the two turbine types at the Ellsworth Project, it is clear from the study results that the large propeller turbine (Unit 1) is not a suitable passage route for any species of fish. You state on page 17 that the survival of fish through Unit 1 was "…within the range of passage survival and injury estimates for turbines previously evaluated at other hydroelectric facilities". While this may be true, it should not imply that this is an acceptable rate given the requirements of diadromous fish in the Union River. The 48-hour survival for Unit 1 is 81%, which although better than the 62% survival rate found at Unit 2, is still not adequate for any of our trust* *species. At the top of page 17, you indicated that although there is a significant difference in injury between Unit 1 (propeller) and Unit 2 (Kaplan), there is not a significant difference in malady occurrence. This suggests that fish that pass through the safer of the two units (Unit 1) are still subjected to injury and extensive loss of equilibrium, which could lead to higher predation rates downstream of the dam. These LOE effects, in addition to high mortality and injury rates, make it clear that turbine passage is not an option through any of the four turbines at this project.*

Response to NMFS Comment 6: The statement on page 17 was simply intended to indicate to the reader that the survival rate observed for Unit 1 was within the range of estimates previously observed at other hydroelectric sites. This report did not attempt to quantify any delayed effects beyond the 48-hour holding period, including susceptibility to predation.

There was no significant difference in malady occurrence between the turbine units because of a higher incidence of LOE (which is classified as a malady, but not an injury) for fish passed through Unit 1 compared to Unit 2.

NMFS Comment 7: *You indicate that flow through the downstream bypass was 22 cfs during the study, which is only a third of what it should be passing. Please explain why the bypass was only being operated at 22 cfs, and whether this is typical for the fish passage season.*

Response to NMFS Comment 7: The downstream bypass system was operated as it typically would be during the anadromous downstream passage season. However, it should be noted that the forebay elevation was ~6 inches lower than the normal operational level during the HI-Z tag testing to prevent potential spill events which would have presented hazardous conditions for boating in the tailrace. The flow that was reported as 22 cfs is an estimate of only the volume of water exiting the bypass system and passing downstream along the face of the spillway (i.e., the transport flow), and does not include all of the flow that enters the entire fish bypass system (i.e., the attraction flow) as most of the flow that enters two of the surface weirs is recycled back into the reservoir.

Document Content(s)

P-2727 Ellsworth 2017 Downstream Passage Reports.PDF..................1-200