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Hydroacoustic Evaluation of Overwintering Summer Steelhead Fallback and Kelt Passage at The Dalles Dam 2008–2009

FINAL REPORT

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GE Johnson
MA Weiland

September 2009

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Pacific Northwest National Laboratory
Richland, Washington 99352

Preface

This study was funded as part of the Anadromous Fish Evaluation Program (AFEP), which is managed by the U.S. Army Corps of Engineers, Portland District (USACE) to support management decisions on operations of The Dalles Dam sluiceway. The AFEP study codes are ADS-00-1 (Evaluation of adult salmon and steelhead delay and fallback at dams on Snake and Columbia rivers) and ADS-P-00-6 (Evaluation of steelhead kelt passage through Columbia and Snake river dams). The study was conducted by the Pacific Northwest National Laboratory (PNNL) for the USACE, whose technical lead was David Clugston (503 808 4751). The PNNL project manager was Fenton Khan (509 371 7230). The data are archived at PNNL offices in Richland, Washington. The final version of this report is the project deliverable (PNNL Project No. 55449).

Summary

This report presents the results of an evaluation of overwintering summer steelhead (*Oncorhynchus mykiss*) fallback and early out-migrating steelhead kelts downstream passage at The Dalles Dam (TDA) sluiceway and turbines during fall/winter 2008 and early spring 2009, respectively. The study was conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers, Portland District (USACE). Operating the sluiceway reduces the potential for hydropower production. However, this surface flow outlet may be the optimal non-turbine route for fallbacks in late fall after the sluiceway is typically closed for juvenile fish passage and for overwintering summer steelhead and kelt passage in the early spring before the start of the voluntary spill season. The goal of this study was to characterize adult steelhead spatial and temporal distributions and passage rates at the sluiceway and turbines, and their movements in front of the sluiceway at TDA to inform fisheries managers' and engineers' decision-making relative to sluiceway operations.

The study periods were from November 1 to December 15, 2008 (45 days) and from March 1 to April 9, 2009 (40 days). The study objectives were to 1) estimate the number and distribution of overwintering summer steelhead fallbacks and kelt-sized acoustic targets passing into the sluiceway and turbines at TDA during the two study periods, respectively, and 2) assess the behavior of these fish in front of sluice entrances. We obtained fish passage data using fixed-location hydroacoustics and fish behavior data using acoustic imaging.

For the overwintering summer steelhead, fallback occurred throughout the 45-day study period. We estimated that a total of 1,790 ± 250 (95% confidence interval) summer steelhead targets passed through the powerhouse intakes and operating sluices during November 1 to December 15, 2008. Ninety-five percent of these fish passed through the sluiceway. Therefore, without the sluiceway as a route through the dam, a number of steelhead may have fallen back through turbines. Run timing peaked in late November, but fish continued to pass the dam until the end of the study. Horizontal distribution data indicated that Sluice 1, especially sluice entrance 1-3, is the preferred route for these fish during fallback through the dam. Diel distribution for overwintering steelhead fallbacks was variable with no apparent distinct patterns. Therefore, sluiceway operations should not be based on diel distribution.

For the early spring study, overwintering summer steelhead and early out-migrating steelhead kelt downstream passage occurred throughout the 40-day study period. A total of 1,766 ± 277 (95% confidence interval) kelt-size targets were estimated to have passed through the powerhouse intakes and operating sluices. Ninety-five percent of these fish passed through the sluiceway. Therefore, as with steelhead fallback, not having the sluiceway as a route through the dam, a number of overwintering steelhead and kelts may use the turbines for downstream passage before the start of the spill season. Run timing peaked in late March; however, relatively large numbers of kelt-sized targets passed the dam on March 2 and March 6 (162 and 188 fish, respectively). Horizontal distribution indicated that Sluice 1, especially sluice entrance 1-3, is the preferred route for these adult salmonids as they migrate downstream through the dam. Again, no clear pattern was seen for diel distribution of overwintering steelhead and early out-migrating kelt passage.

Fish behavior of both steelhead fallbacks and kelts was that of a typical salmonid in front of a sluice entrance. Fish in front of the sluice entrance were oriented into the flow in the sluice nearfield, milling just upstream of the sill, entering into the sluiceway, or swimming upstream out into the forebay. These

fish also moved along the face of the dam. Juvenile shad were present from the beginning of the sampling period on November 1, 2008, until mid-November. Steelhead behavior did not change in the presence of thousands of juvenile shad.

The results of this study strongly suggest that operating the TDA sluiceway for fish passage (fallbacks and kelts) during the late fall, winter, and early spring months will provide an optimal, non-turbine route for these fishes to pass the dam. Fallback of overwintering summer steelhead during late fall and winter and passage of steelhead kelt and overwintering summer steelhead during early spring are instances of the benefits of using surface flow outlets instead of turbines to pass salmonids. All 13 dams on the mainstem Columbia and Snake rivers have installed or are developing surface flow outlets to pass juvenile salmonids. Fisheries and hydrosystem managers are responsibly considering the use of these structures to protect adult salmonids from hydropower turbines.

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- Schlosser Machine Shop: Vincent Schlosser.
- U.S. Army Corps of Engineers, Portland District personnel: Dave Clugston, Mike Langeslay, Robert Wertheimer.

Acronyms and Abbreviations

AFEP	Anadromous Fish Evaluation Program
cfs	cubic feet per second
CI	confidence interval
d	day(s)
DART	Data Access in Real Time
dB	decibel(s)
DIDSON	Dual Frequency Identification Sonar
ft	foot/feet
h	hour(s)
in.	inch(es)
kcfs	thousand cubic feet per second
kHz	kiloHertz
m	meter(s)
min	minute(s)
msl	mean sea level
MU	Main Unit – turbine intake
MW	megawatt(s)
NMFS	National Marine Fisheries Service
PAS	Precision Acoustic Systems
PNNL	Pacific Northwest National Laboratory
pps	pings per second
s	second(s)
TDA	The Dalles Dam
μPa	micro-Pascal
USACE	U.S. Army Corps of Engineers, Portland District

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1.0 Introduction

This report presents the results of an evaluation of overwintering summer steelhead (*Oncorhynchus mykiss*) fallback and steelhead kelt downstream passage at The Dalles Dam (TDA) sluiceway and turbines during fall/winter 2008 and early spring 2009 periods, respectively. The study was conducted by the Pacific Northwest National Laboratory (PNNL)[1] for the U.S. Army Corps of Engineers, Portland District (USACE). The goal of this study was to characterize adult steelhead spatial and temporal distributions and passage rates at the sluiceway and turbines, and movements in front of the sluiceway at TDA for fisheries managers and engineers to use in decision-making for sluiceway operations.

1.1 Background

The upstream migration of summer steelhead, an anadromous Pacific salmonid (rainbow trout), begins in spring and goes through late fall, and these salmonids overwinter in freshwater before spawning (Keefer et al. 2008). Very little information exists about steelhead behavior during winter at or near hydroelectric dams on the Columbia River (Keefer et al. 2008). These authors observed some summer steelhead overwintering within the hydrosystem before reaching spawning grounds. Some of these fish may fall back at hydroelectric dams on the Columbia River (Boggs et al. 2004). Fallback behavior is described by Reischel and Bjornn (2003) and Boggs et al. (2004) as adult salmonids straying from their normal upstream migration to spawning grounds and moving back downstream through the dams by way of turbine intakes, bypass systems, spillways, navigation locks, or other available routes. Also, during migration, some adult salmonids may travel upriver beyond their natal streams ("overshooting") and may fall back through dams to return to said streams (Boggs et al. 2004). In a letter report to the USACE, Keefer and Peery (2007) addressed the issue of steelhead falling back at TDA during late fall and winter months. In addition, Keefer et al. (2008) recorded wintertime fallbacks at TDA. Keefer and Peery (2007) suggested that overwintering adult summer steelhead are using the TDA turbines, sluiceways, and the navigation lock as fallback routes.

After overwintering and spawning in freshwater, steelhead can migrate back downstream to the ocean in the spring. These downstream migrants, commonly referred to as kelts, may eventually return to freshwater spawning grounds to spawn again. This life history pattern is termed iteroparity. Kelts have to navigate through hydroelectric dams on their outward migration. The dams may delay migration timing and negatively impact survival of said fish (Wertheimer and Evans 2005; Wertheimer et al. 2003). As with the fallback of overwintering summer steelhead, kelts pass the dam through available routes, including turbines and sluiceways.

The National Marine Fisheries Service (NMFS) stipulated in RPA 54 of the 2008 Biological Opinion on operation of the Federal Columbia River Power System (NMFS 2008) that: "…*In addition to the current sluiceway operation (generally April 1–November 30), evaluate operation of The Dalles Dam sluiceway from March 1–March 31 and from December 1–December 15 as a potential means to provide a safer fallback passage route for overwintering steelhead and kelts, implement if warranted…Investigate*

[1] Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy under Contract DE-AC05-76RL01830.

surface-flow outlets during wintertime to provide safer fallback opportunity for over wintering steelhead (need will be determined by results of further research…Planning dates and voluntary operation of The Dalles Dam sluiceway may be adjusted (increased or decreased) through the adaptive management process or for research purposes."

Because steelhead are listed by the Endangered Species Act as endangered in the upper Columbia River and threatened in the Snake and mid Columbia rivers (NMFS 2004), the USACE is dedicated to providing safe and timely passage for overwintering summer steelhead fallbacks and kelts at TDA. Providing optimal, non-fatal downstream routes at dams should improve return rates of kelts (Wertheimer and Evans 2005). The USACE 2006 Fish Passage Plan included operating the TDA sluiceway until November 30 as a route for fallbacks because of concerns about these fish using the turbines as a route through the dam. Operating the sluiceway reduces the potential for hydropower production, but this surface flow outlet may be the optimal non-turbine route for overwintering fallbacks in late fall and winter (November 1 to December 15) and kelt passage in early spring (March 1 to April 15) before the start of the voluntary spill season.

1.2 Study Periods and Objectives

The study periods were from November 1 to December 15, 2008, and from March 1 to April 9, 2009. The study objectives were as follows:

- Estimate the number and distribution of summer steelhead fallbacks and kelt-sized acoustic targets passing into the sluiceway and turbines at TDA during the two study periods, respectively.
- Assess the behavior of these fish in front of sluice entrances.

1.3 Study Area

The Dalles Dam (Figure 1.1), located at river mile 192, is the second closest dam in the Federal Columbia River Power System to the Pacific Ocean. It has a 2,090-ft-long powerhouse with 22 turbine units (main units), a total generating capacity of 1,800 MW, and a total hydraulic capacity of 375 kcfs. Full pool elevation is rated at 160 ft above mean sea level (msl) and minimum operating pool elevation is 155 ft. The normal operating pool is at elevation 158 ft. The face of the dam is 11.3° off vertical. The turbine intake ceiling intersects the trash racks at elevation 141 ft. The 1380-ft-long spillway consists of 23 bays with 50-ft wide radial gates.

The ice-and-trash sluiceway is a rectangular channel that extends the entire length of the powerhouse. Sluice entrances are 20 ft wide. The sill at each sluice entrance is at elevation 151 ft. Water enters the sluiceway from the forebay when gates are moved off a sill. When any of the sluiceway gates are opened, water and migrating fish near the water surface may be skimmed from the forebay into the sluiceway, passing the fish to the tailrace. Overall, sluiceway discharge is a relatively small proportion of total project discharge (~2%). Flow into the sluiceway is dependent on forebay elevation and the number and location of open gates. For example, given a forebay elevation equal to 158 ft (above msl) and six sluice gate operating conditions (MU 1-1, 1-2, 1-3, MU 5-2, and MU 18-1, 18-2), flows over the individual weir gates range from 564 (MU 18-2) to 944 (MU 1-1) cfs, with highest flows at the west end nearest the sluiceway channel outlet, and total flow being 4,309 cfs (data provided by Stephen Schlenker, USACE).

Figure 1.1. Aerial Photograph of The Dalles Dam. Flow is from right to left.

1.4 Report Contents

The ensuing sections of this report describe the study methods (Section 2.0), results (Section 3.0), associated discussion and conclusions (Section 4.0), and literature cited (Section 5.0). There are no appendices.

2.0 Methods

The methods section includes descriptions of the general approach, fixed-location hydroacoustics for fish passage, and acoustic imaging for fish behavior.

2.1 General Approach

The hydroacoustic and acoustic imaging evaluation of overwintering summer steelhead fallback and steelhead kelt downstream passage at TDA in 2008/2009 was divided into two study periods; late fall/early winter for steelhead fallback (November 1 to December 15; 45 days) and early spring for steelhead kelt passage (March 1 to April 9; 40 days). We obtained fish passage data using fixed-location hydroacoustics and fish behavior data using acoustic imaging.

2.2 Fixed-Location Hydroacoustics

The fixed-location hydroacoustic technique was used to accomplish the objective of this study. This technique, conceived by Carlson et al. (1981) for single-beam acoustic systems, is described by Thorne and Johnson (1993). In addition to single-beam technology, split-beam technology is now an important element of fixed-location hydroacoustics. The split-beam technique is explained by MacLennan and Simmonds (1992). The methods used in this study were similar to those used in the 2004 and 2005 hydroacoustic studies at TDA (Johnson et al. 2005 and 2006).

The general approach was to deploy a combination of single-beam and split-beam transducers to sample fish, and apply the acoustic screen model (Johnson 2000) to estimate fish passage rates and distributions. Split-beam transducers provided data to determine weighting factors, assess assumptions of the model, and determine the magnitude of any biases. Split-beam transducer deployments at each type of passage route were used to estimate the average backscattering cross section of fish for detectability modeling and the direction of fish travel through sampling volumes to assess the assumptions of the acoustic screen model. Single- and split-beam transducers were deployed to sample fish passage at the sluiceway and turbines. Transducer sampling volumes were positioned to minimize ambiguity in ultimate fish passage routes and the potential for multiple detections of the same fish.

2.2.1 Hydroacoustic Systems

Data collection involved three Precision Acoustic Systems (PAS) single-beam hydroacoustic systems and six PAS split-beam systems. All systems operated at 420 kHz. The data-collection systems consisted of either Harp-1B (Single-Beam) or Harp-SB (Split-Beam) Data Acquisition/Signal Processing Software installed on a personal computer controlling a PAS-103 Multi-Mode Scientific Sounder. The PAS-103 sounders controlled transducers deployed in main turbine units and sluice entrances. A total of 34 transducers (18 single-beam and 16 split-beam) were deployed at the powerhouse and sluiceway (Table 2.1). During data collection, all systems used a voltage output threshold range of -26 to -56 dB re: 1 μPa at 1 m.

Table 2.1. Sample Locations and Spatial Sampling Intensity at The Dalles Dam in 2008/2009

Unit	Intensity by Unit	Intensity by Intake	Number of Transducers	Sample Locations
Main Units 1-22	22 of 22	1 of 3	22	MU 1-1, 2-3, 3-1, 4-3, 5-1, 6-1, 7-2, 8-2, 9-2, 10-1, 11-3, 12-2, 13-3, 14-2, 15-3, 16-3, 17-2, 18-2, 19-1, 20-2, 21-2, 22-1
Sluice 1	1 of 1	3 of 3	6	Sluice entrances 1-1, 1-2, 1-3
Sluice 5	1 of 1	1 of 3	2	Sluice entrance 5-2
Sluice 18	1 of 1	2 of 3	4	Sluice entrances 18-1, 18-2

2.2.2 Transducer Locations and Orientations

Single-beam transducers (6°) were installed at all turbine unit sampling locations, except for MU 2, MU 5, MU 16, and MU 18, each of which had a 6° split-beam transducer (Figure 2.1). The intakes sampled at a given turbine unit were randomly chosen. At all turbine intake sampling locations, divers installed transducers on the bottom of the second to the bottom trash rack at elevation 75 ft and aimed the transducers downstream and upward toward the intake ceiling at a 23° angle to the plane of the trash rack (Figure 2.2). The transducer mounts were designed to fit between the vertical bars of the trash rack. This design allowed divers to secure the mount to the trash rack of each intake from the forebay. A diver took a transducer/mount/cable assembly to the bottom of the trash rack located just above the deepest installed rack (Figure 2.2). The diver then installed the mount between two vertical bars of the trash rack at elevation 75 ft and secured the mount to the trash rack with “J” bolts.

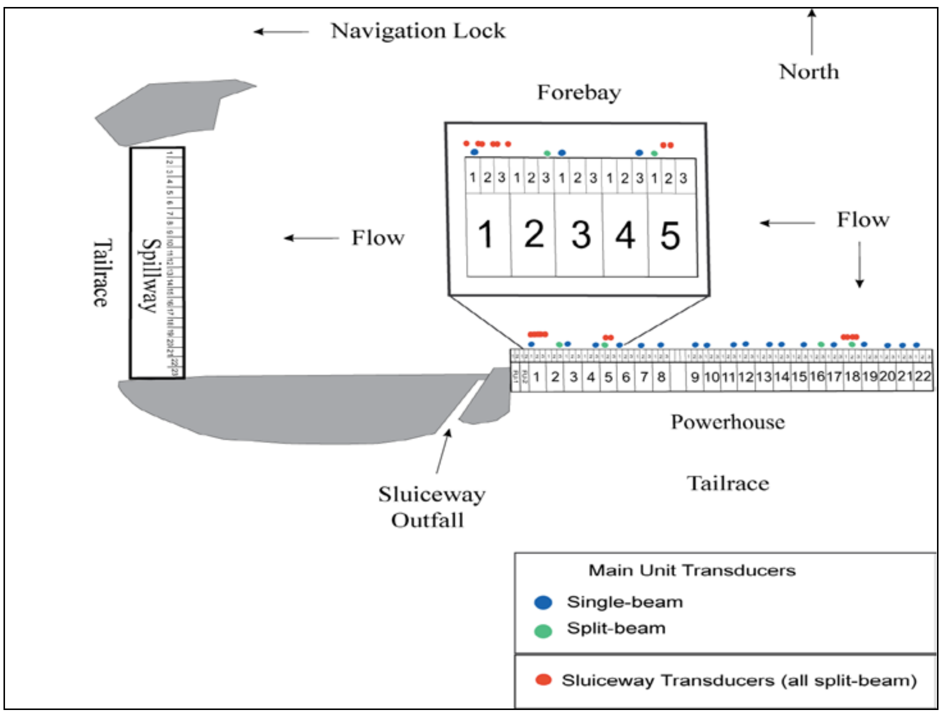


Figure 2.1. Plan View of The Dalles Dam Showing Transducer Locations

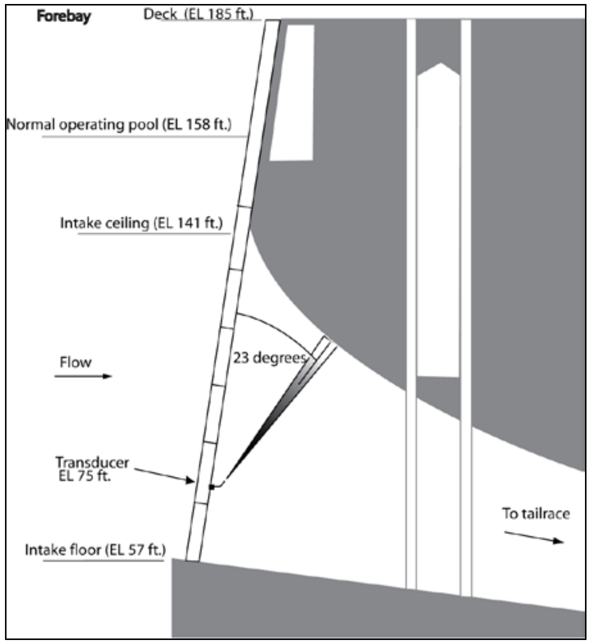


Figure 2.2. Cross-Sectional View of a Main Unit Intake Transducer Deployment

Sluiceway transducers (6° split-beam) were installed at each of the three sluice entrances of MU 1, one sluice entrance at MU 5 (5-2), and two sluice entrances at MU 18 (18-1, 18-2) at elevation 153 ft. Transducers were attached to trolley mounts, which were then affixed to steel I-beams attached to the front of pier noses and lowered into the water (Figure 2.3). Each sluice entrance was monitored by a pair of transducers aimed horizontally and back at a 60° angle to the plane of the sill across the sluice entrance with a 6° up-looking angle (Figures 2.4, 2.5, and 2.6).

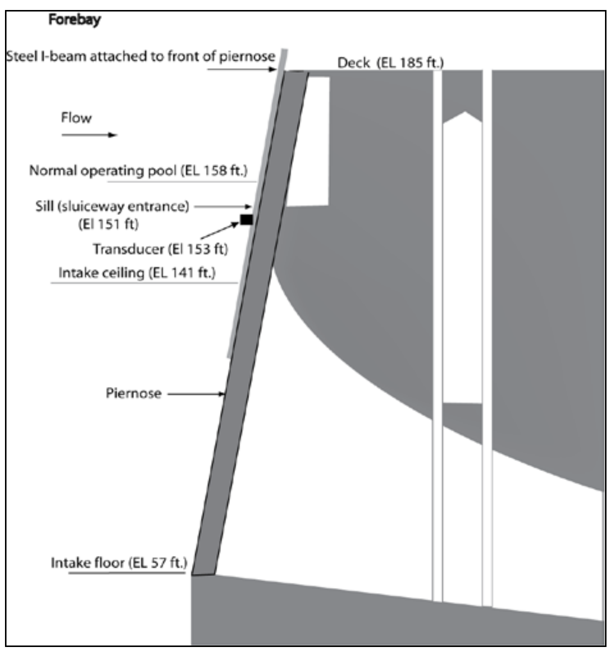


Figure 2.3. Deployment for a Side-Looking Sluiceway Transducer Mounted on a Steel I-Beam Attached to the Front of a Pier Nose

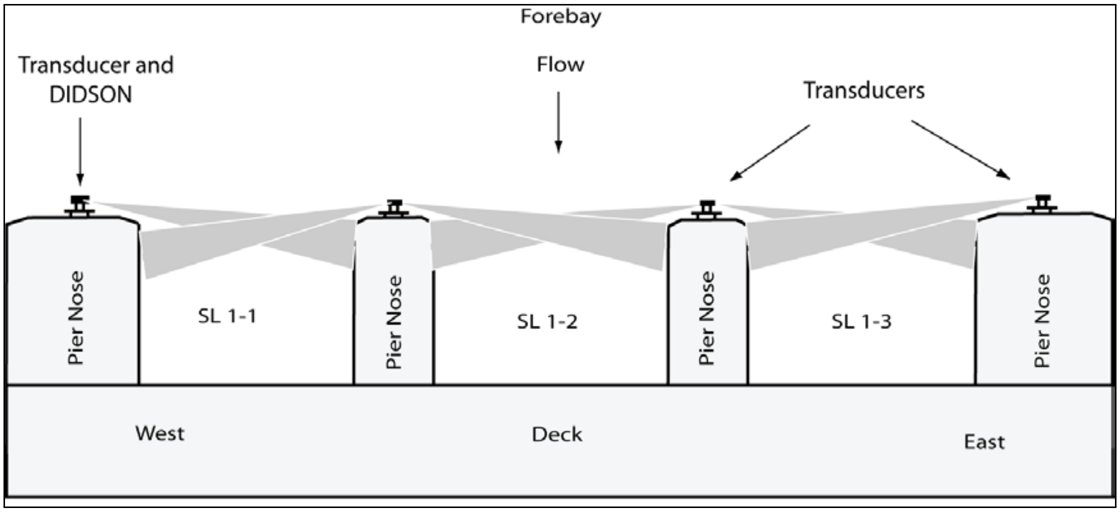


Figure 2.4. Top View of Transducer Deployment for Sluice 1

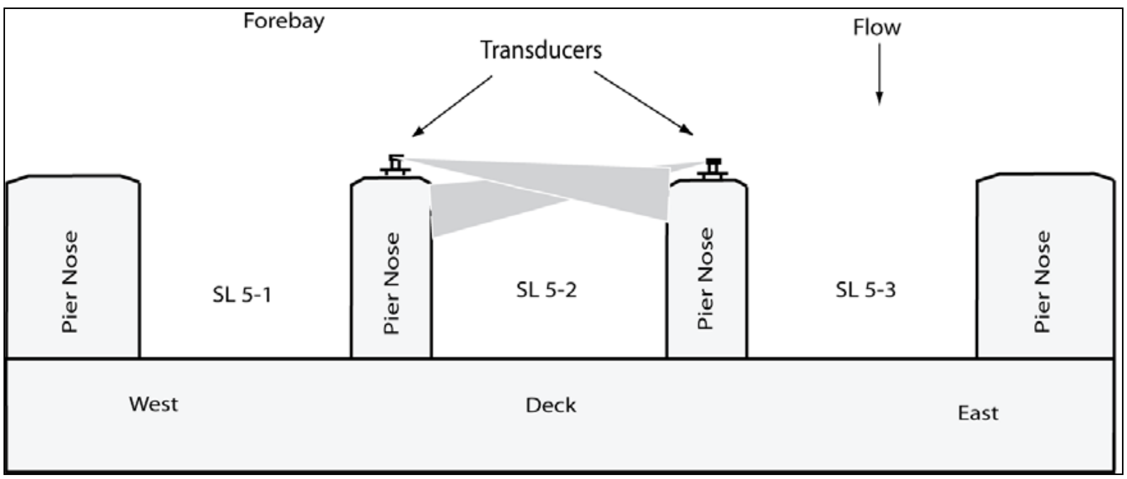


Figure 2.5. Top View of Transducer Deployment for Sluice 5

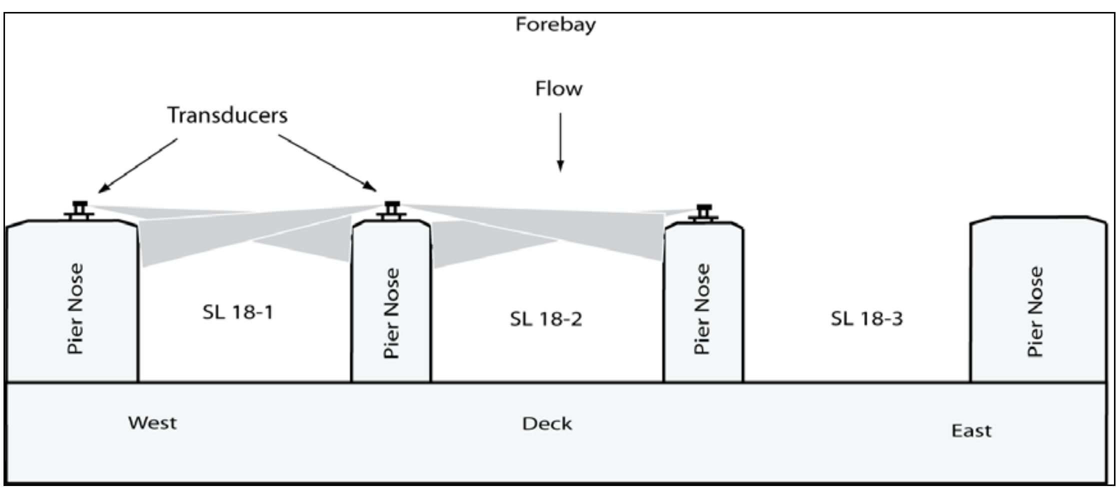


Figure 2.6. Top View of Transducer Deployment for Sluice 18

2.2.3 Sampling Design

Echo sounder transmission rates were 15 pps (pings per second) at the turbine intakes and 33 pps at the sluiceway. Systematic samples, i.e., same order among sampling locations each hour, were collected at 1-min intervals 24 h/d. Each location was sampled 10, 15, 20, or 30 times per hour depending on the number of transducers connected to the echo sounder.

2.2.4 Data Processing and Analysis

After the acoustic echo data were collected and archived, they were processed to extract fish tracks. At this stage in the analysis, we were careful to set the tracking parameters to include all fish at the expense of including spurious tracks. Next, to separate acceptable from unacceptable tracks, we filtered using fish tracks characteristics such as mean target strength, slope, speed, and pulse width. Subsamples of the data were manually checked to assure that valid fish tracks remained after filtering. Data processing and reduction methods were similar to those used by Johnson et al. (2005). Mean target strength as an indicator of fish size was used to distinguish relatively large adult steelhead fallback and kelt passage from smaller targets such as juvenile shad. The maximum target strength was set at -26 dB re: 1 µPa at 1 m during data collection. In retrospect, this threshold may have excluded some of the larger steelhead (Nealson and Gregory 2000). During data processing, we filtered for large fish using mean target strengths (Table 2.2) based on the expected sizes of the smallest fish of interest of about 30 cm (personal communication from R. Wertheimer, USACE) and the relationship between fish length and target strength for adult salmon in side aspect described by Burwen and Fleischman (1998). The 3-dB difference between sluice and turbine target strengths accounted for the side and ventral aspects, respectively, of the transducers relative to the fish.

Table 2.2. Mean Target Strength Filters

	Late Fall 2008 Steelhead Fallback	Early Spring 2009 Steelhead Passage
Sluice	-29 dB	-31 dB
Turbine	-32 dB	-34 dB

The process used to estimate passage rates from filtered tracked fish involved spatial and temporal extrapolations. Briefly, each fish track that survived the filtering process was weighted spatially to account for the sample width of the acoustic beam at the target's mid-range relative to the width of the depth bin it sampled; i.e., fish passage at unsampled portions of a passage route was estimated by extrapolating from the sampled areas. Turbine estimates were multiplied by three because one of three intakes at a given unit was sampled. The sum of these weighted fish was then extrapolated temporally by the hourly sampling fraction (60/total hourly sample time per location).

The hourly passage rate data for each transducer were used to estimate various performance metrics. Equations for each estimator follow. Let x_{ijky} be the expanded fish passage count in the i^{th} transducer ($i = 1,...,x$) during the j^{th} hour ($j = 1,...,24$) of the k^{th} day ($k = 1,...,d_y$) during y^{th} study period, where d_y is the number of study-days in the y^{th} study period (late fall 2008 or early spring 2009).

Total adult steelhead fallback (or kelt passage) for the y^{th} study period was estimated by the formula

$$\widehat{TP}_y = \sum_{i=1}^{6}\sum_{j=1}^{24}\sum_{k=}^{d_y} x_{ijky} \tag{2.1}$$

Daily adult steelhead fallback (or kelt passage) for the k^{th} day in the y^{th} study period for analysis of run timing was estimated by the formula

$$\widehat{DP}_{ky} = \sum_{i=1}^{6}\sum_{j=1}^{24} x_{ijky} \tag{2.2}$$

Hourly adult steelhead fallback (or kelt passage) for the j^{th} hour in the y^{th} study period for analysis of diel distribution was estimated by the formula

$$\widehat{HP}_{jy} = \sum_{i=1}^{6}\sum_{k=1}^{d_y} x_{ijky} \tag{2.3}$$

Johnson et al. (2005) describe methods to estimate variances for the passage rate estimates. The variances associated with each passage rate estimate were likely underestimated because between-intake variability in passage within a given turbine unit could not be accounted for because of sampling limitations. Ninety-five percent confidence intervals (CIs) for total and daily passage rates were calculated as follows:

$$CI = \pm 1.96 * \sqrt{Variance} \tag{2.4}$$

2.3 Acoustic Imaging

To determine fish movements at the sluiceway, a Dual Frequency Identification Sonar (DIDSON) was deployed at the sluice entrance of MU 1-1. The DIDSON bridges the gap between conventional scientific fisheries sonar, which can detect acoustic targets at long ranges but cannot record the shapes of targets, and optical systems, which can record images of fish but have limited range at low light levels or when turbidity is high. The DIDSON has high resolution and a fast frame rate enabling it to substitute for optical systems in turbid or dark water. This device was successfully applied at the TDA sluiceway in previous research on juvenile salmonids passage (Johnson et al. 2005, 2006). Figure 2.7 shows an example of an image of adult salmonid and juvenile shad observed using the DIDSON in 2008.

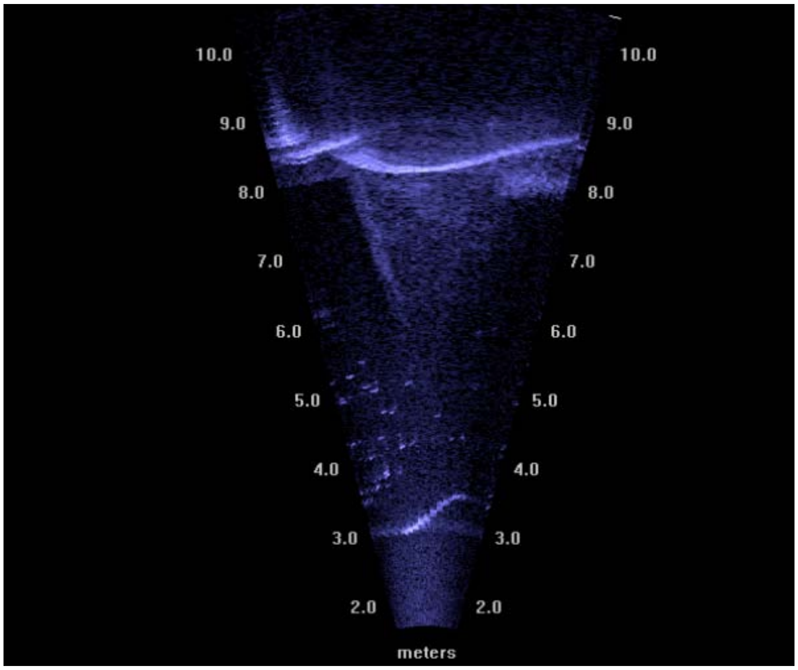


Figure 2.7. Screen from the DIDSON Display. The image shows one adult fish (foreground, ~3-m range) and juvenile fish (~3.5- to 5-m range) entering TDA sluice entrance 1-1 in November 2008. The sluice entrance is to the right in the image. The adult fish is oriented tail-first into the sluice.

2.3.1 Sampling Locations

The DIDSON was used to sample fish movement and behavior at sluice entrances 1-1 and 1-2. DIDSON data were collected 24 h/d during both study periods. The DIDSON was mounted to a trolley and deployed on a 4-in.-wide steel I-beam attached to the front of the westernmost pier of main unit 1, at elevation 154 ft (Figure 2.8). The instrument was aimed across the front of the sluice entrances 1-1 and 1-2 (Figure 2.9). The DIDSON was used in the low-frequency mode and the frame rate was 6–7 frames/s.

Figure 2.8. DIDSON Mounted to Trolley and Deployed on an I-Beam on the Front of the Pier

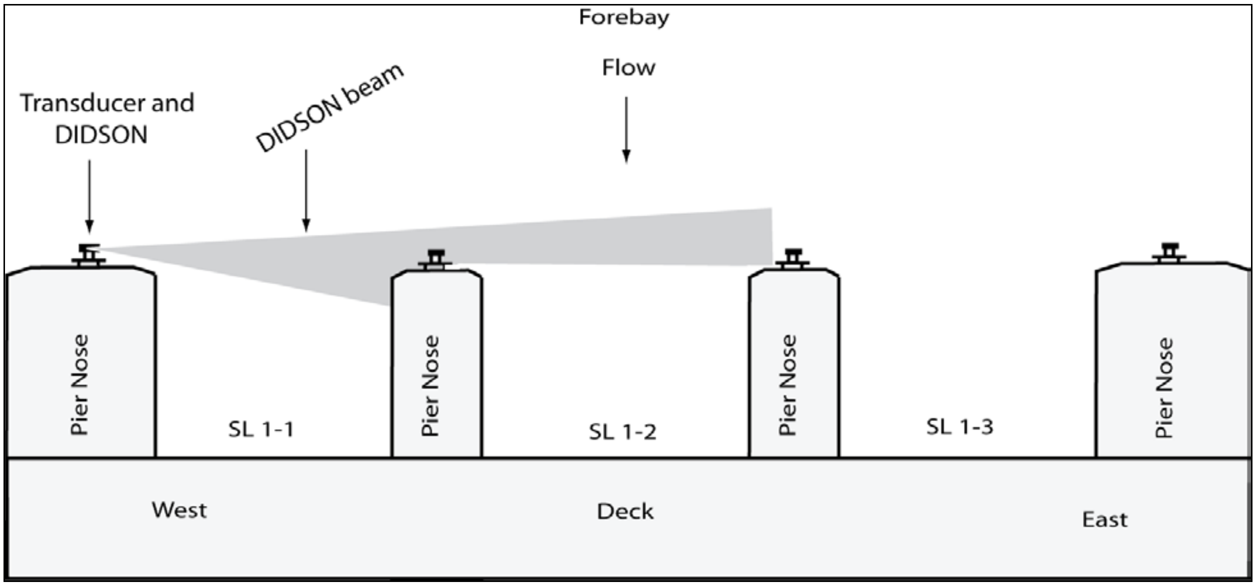


Figure 2.9. Top View Showing the DIDSON Sampling Location at Sluice (SL) 1. The DIDSON beam was aimed to sample across SL 1-1 and 1-2.

2.3.2 Data Processing

Observational data for fish behavior at the sluiceway were obtained from a subset of the DIDSON data. Because of the large amount of data collected (video files), we randomly selected 4 hours (1 hour from each 6-hour block of a 24-hour day) for each day of the study and reviewed each hour in the subset for fish behavior. We recorded behavior categories such as fish entering the sluiceway, swimming away from the sluiceway into the forebay, and orientation and milling patterns in front of the sluiceway.

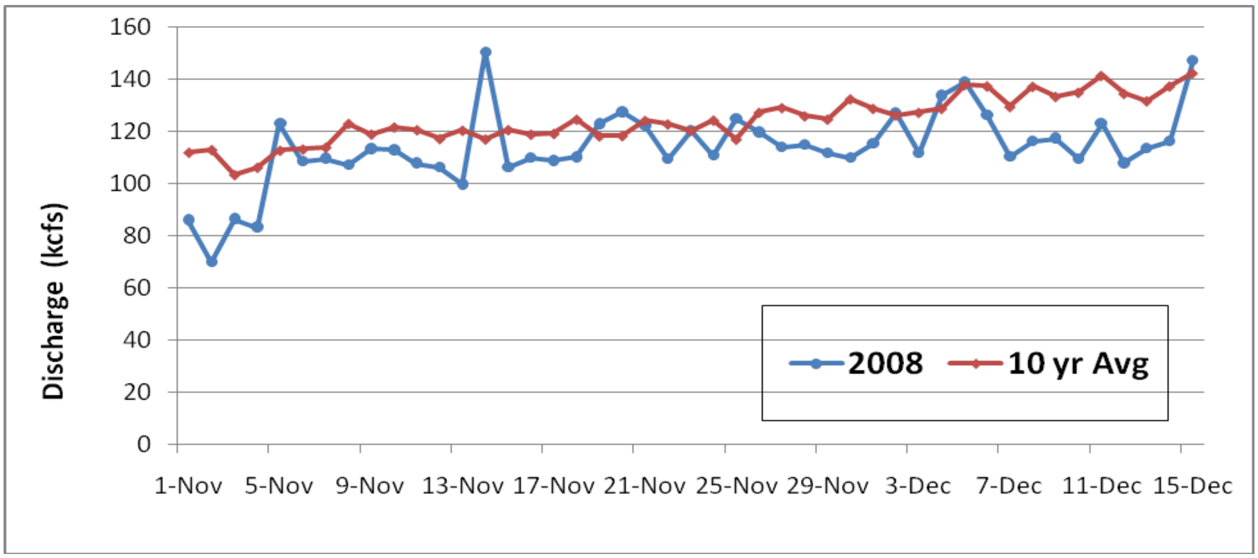
As a result of observations made during processing of the acoustic images, we performed a cursory passage analysis on the fixed-location hydroacoustics dataset by filtering for mean target strengths between -36 and -56 dB. We used these data to examine run timing curves for juvenile fish during both study periods.

3.0 Results

The results from the study are organized into three main sections: environmental conditions, fish passage evaluation, and fish behavior observations.

3.1 Environmental Conditions

Daily outflow at TDA ranged from 70 to 155 kcfs during the fall/winter study period (November 1–December 15), with a mean daily outflow of 117 kcfs (Figure 3.1). For the spring study period (March 1–April 9), daily outflow ranged from 100 to 212 kcfs, with a mean daily outflow of 133 kcfs (Figure 3.1). Spill commenced on April 10 for juvenile salmonid migration.



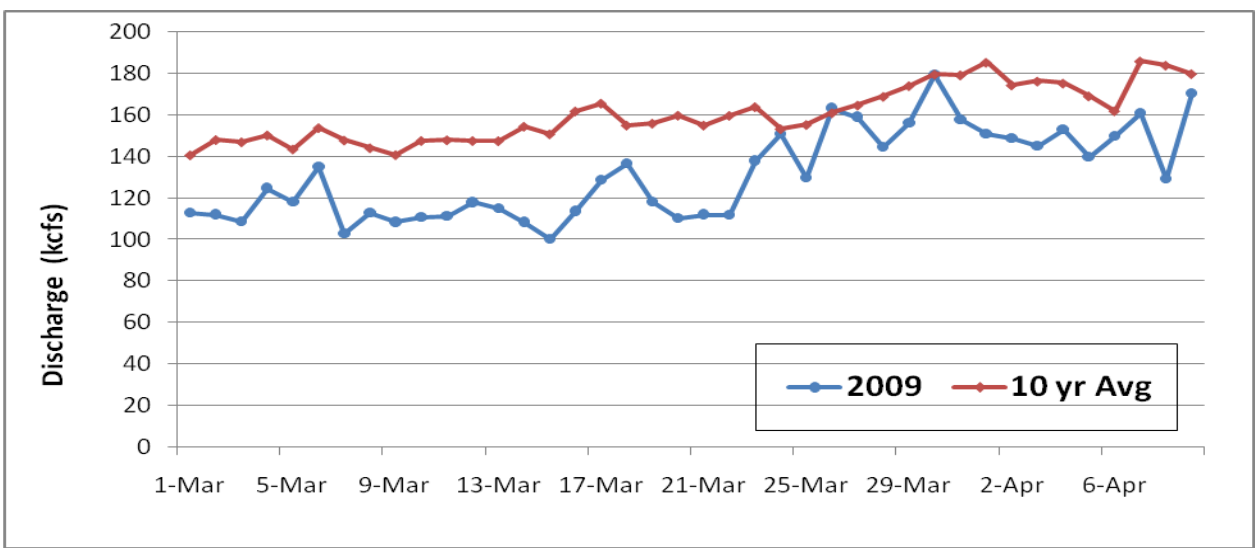


Figure 3.1. Total Outflow and 10-Year Average Outflow (kcfs) at TDA During Fall/Winter 2008 (top) and Early Spring 2009 (bottom). Data were obtained from DART (http://www.cbr.washington.edu/dart/dart.html), accessed on July 1, 2009.

During the fall/winter study period (November 1–December 15), forebay elevation at TDA ranged from 158 to 159.4 ft above msl, with an average elevation of 158.8 ft above msl (Figure 3.2). Sluiceway discharge ranged from 4.31 to 4.86 kcfs, with an average discharge of 4.63 kcfs (Figure 3.2).

For the early spring study period (March 1–April 9), forebay elevation at TDA ranged from 158.2 to 159.6 ft above msl, with an average elevation of 159 ft above msl (Figure 3.2). Sluiceway discharge ranged from 4.39 to 4.94 kcfs, with an average discharge of 4.72 kcfs (Figure 3.2).

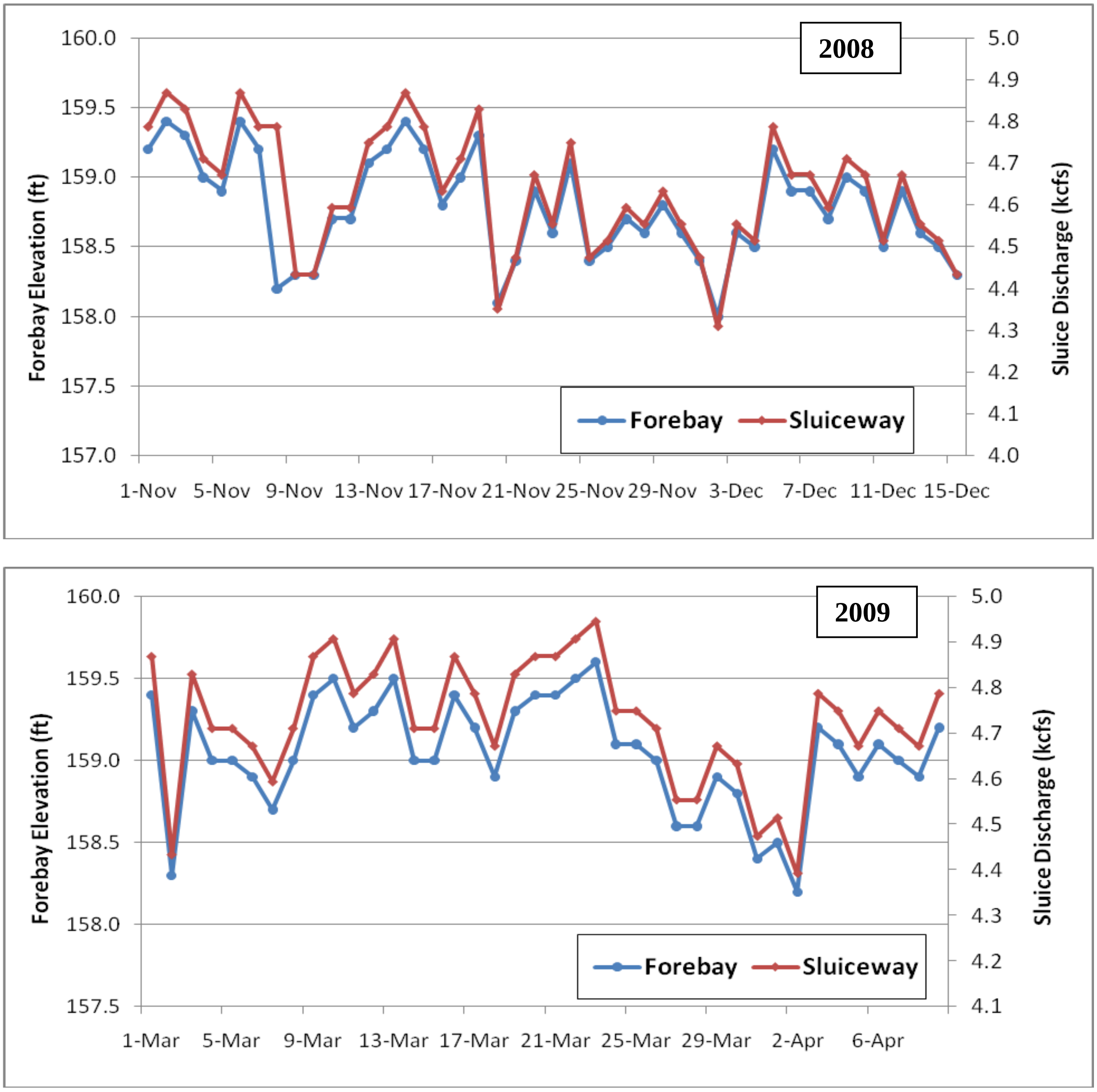


Figure 3.2. Forebay Elevation (ft above msl) and Total Sluiceway Discharge (kcfs) at TDA During Fall/Winter 2008 (top) and Early Spring 2009 (bottom). Forebay data were obtained from DART (http://www.cbr.washington.edu/dart/dart.html), accessed on July 1, 2009. Sluiceway discharge data were obtained from Stephen Schlenker, USACE.

3.2 Fish Passage Evaluation

Fish passage results are organized into two main sections: overwintering summer steelhead fallback in late fall/early winter and overwintering summer steelhead and early out-migrating steelhead kelt downstream passage in early spring. Under each of these topics, we present data on passage rates, run timing, horizontal distribution, and diel distribution.

3.2.1 Overwintering Summer Steelhead Fallback

3.2.1.1 Passage Rates and Run Timing

During the 45-day study period November 1 to December 15, 2008, a total of 1,790 ± 250 (95% CI) summer steelhead passed through the powerhouse intakes and operating sluice entrances. The mean number of fish passing (falling back) the dam on a daily basis was 40. At the sluiceway, 1,704 targets passed (95% of the total dam passage) and 86 passed through the powerhouse intake units. Run timing peaked in late November (Figure 3.3). Fallback occurred (10–25 fish/d) during the first and last days of the study period.

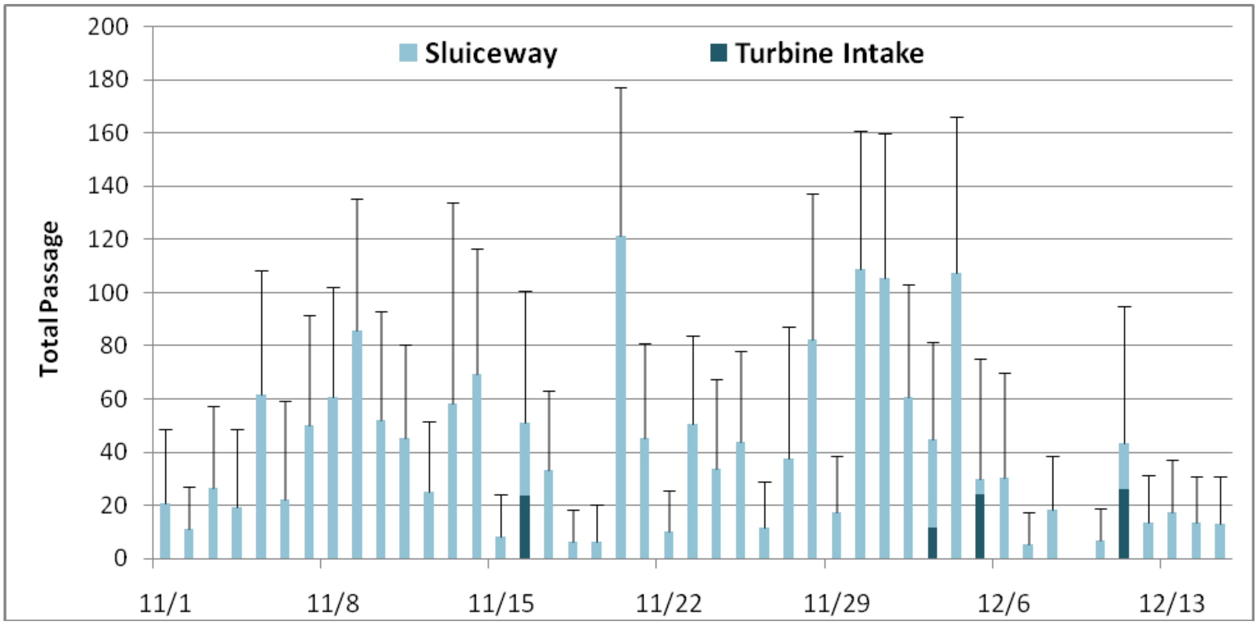


Figure 3.3. Total Number of Overwintering Summer Steelhead Targets Passing Daily at Each Route of the Powerhouse and Sluiceway from November 1–December 15, 2008 (95% CI)

3.2.1.2 Horizontal Distribution

Fallback of overwintering steelhead was highest at Sluice 1 (1,453 targets). Sluice 18 had the second highest number of fish passing (211) and a small number passed through Sluice 5 (40 fish) and powerhouse intake units 7, 8, and 18 (23, 51, and 12 fish, respectively) (Figure 3.4). For individual sluice entrances, sluice entrance 1-3 passed the highest number of fish (1,192 targets), followed by sluice entrance 1-2 (195) and sluice entrance 18-2 (122). Fewer than one hundred targets passed through sluice entrances 1-1, 5-2, and 18-1 (Figure 3.5).

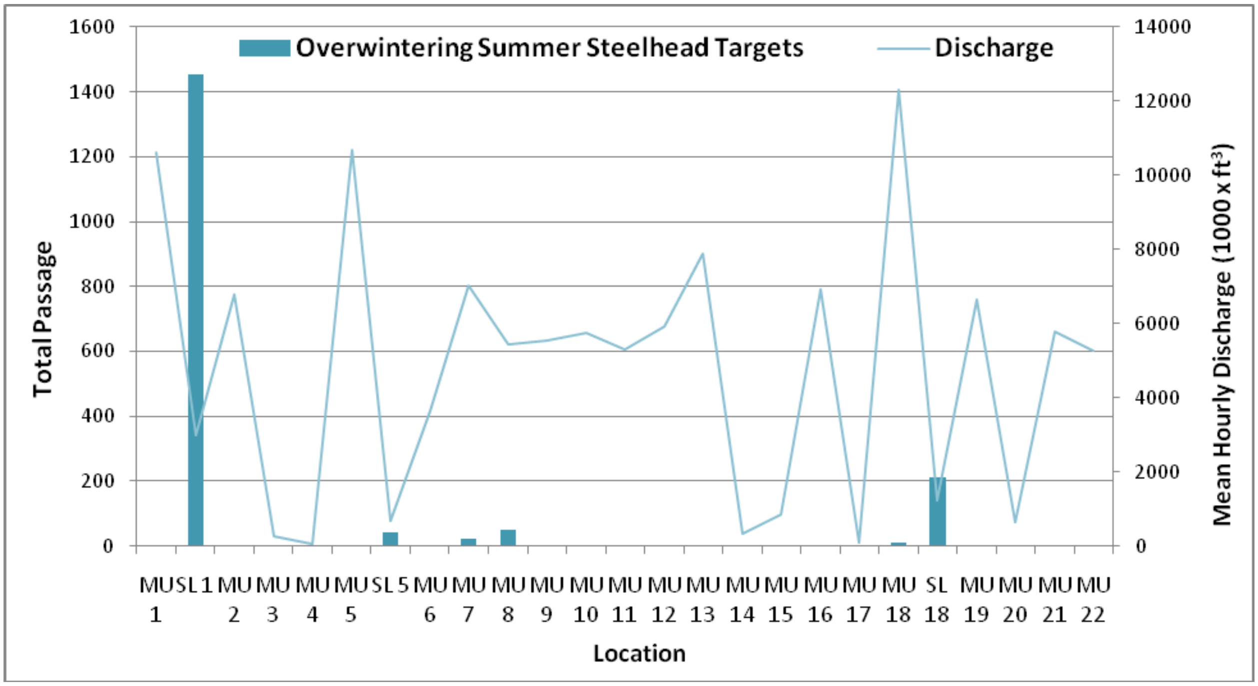


Figure 3.4. Horizontal Distribution of Total Passage Overwintering Summer Steelhead Targets at Each Route of the Powerhouse and Sluiceway, with Corresponding Powerhouse Intake Unit and Sluiceway Discharge, from November 1–December 15, 2008 (MU = main unit, SL = sluice)

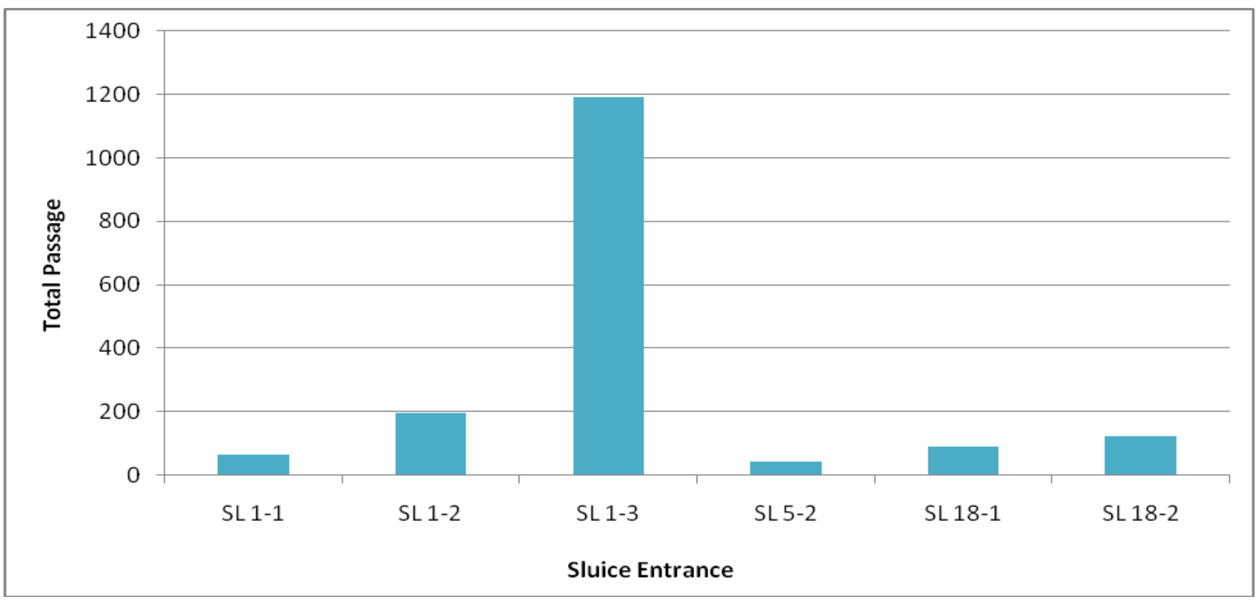


Figure 3.5. Horizontal Distribution of Total Passage of Overwintering Summer Steelhead Targets at Each Route of the Sluiceway from November 1–December 15, 2008 (SL = sluice entrance)

3.2.1.3 Diel Distribution

Diel distribution of overwintering steelhead fallback was highly variable and had no consistent pattern (Figure 3.6). Higher hourly estimates were often within 1 to 2 hours of below average estimates.

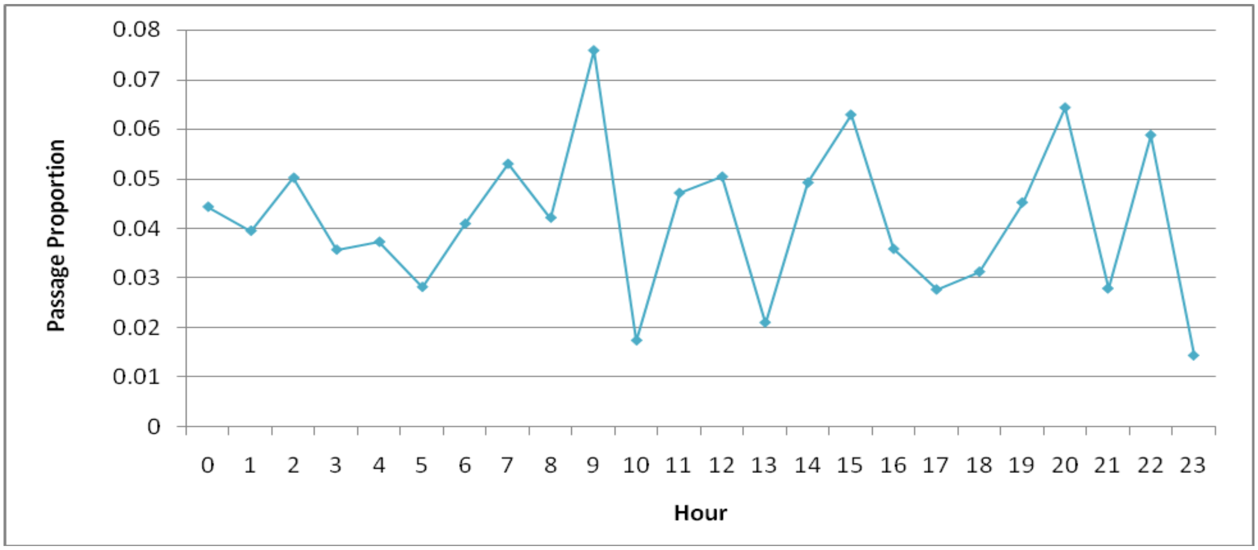


Figure 3.6. Diel Distribution of Overwintering Summer Steelhead Targets from November 1–December 15, 2008. Data are the hourly proportions of total passage.

3.2.2 Overwintering Summer Steelhead and Early Out-Migrating Kelt Downstream Passage

3.2.2.1 Passage Rates and Run Timing

During the 40-day study period March 1–April 9, 2009, a total of 1,766 ± 277 (95% CI) steelhead adult-sized targets passed through the powerhouse intakes and operating sluices. An average number of 44 targets passed the dam on a daily basis. A total of 1,673 targets passed through the sluiceway (95% of the total) and 93 passed through the powerhouse intake units. Run timing peaked in late March (Figure 3.7). However, relatively large numbers of targets passed the dam on March 2 and March 6, 2009.

3.2.2.2 Horizontal Distribution

Total overwintering steelhead and out-migrating kelt passage was highest at Sluice 1 (1,091 targets). Sluice 18 had the second highest number of fish passing (454). One hundred twenty-eight targets passed at Sluice 5 and a small number passed through the powerhouse intake units 8, 21, and 22 (24, 23, and 46 fish, respectively) (Figure 3.8). For individual sluice entrances, sluice entrance 1-3 passed the highest number of fish (785 targets), followed by sluice entrance 18-1 (337) and sluice entrance 1-2 (205). Sluice entrances 5-2 and 18-2 passed 127 and 117 targets, respectively. Sluice entrance 1-1 passed the least amount of fish (101) (Figure 3.9).

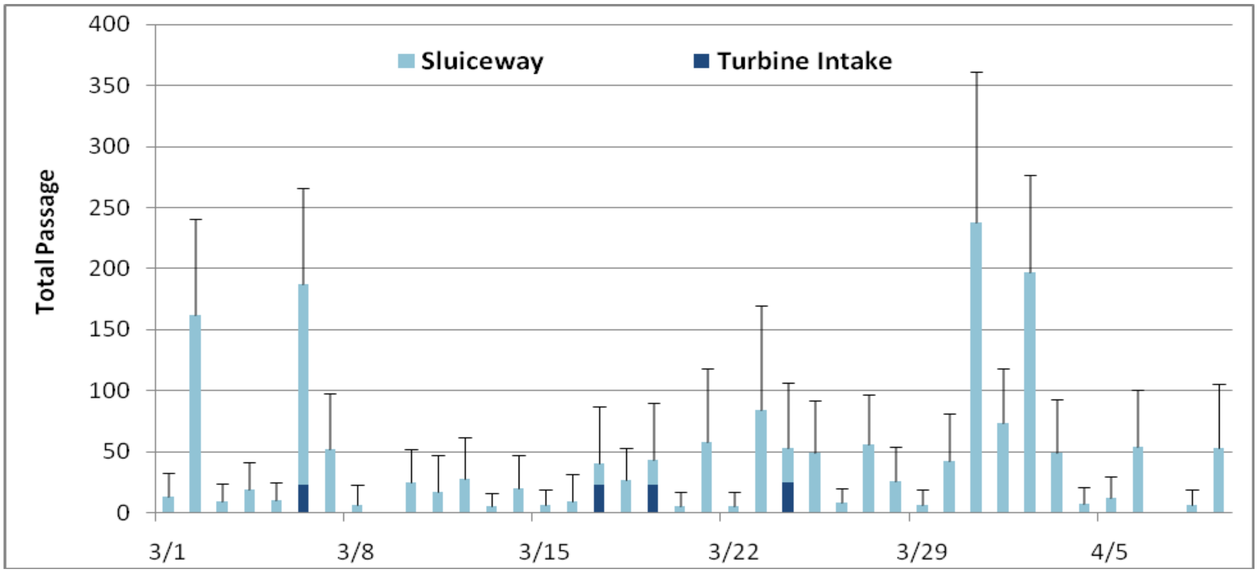


Figure 3.7. Total Number of Overwintering Summer Steelhead and Kelt-Sized Targets Passing Daily at Each Route of the Powerhouse and Sluiceway from March 1–April 9, 2009 (95% CI)

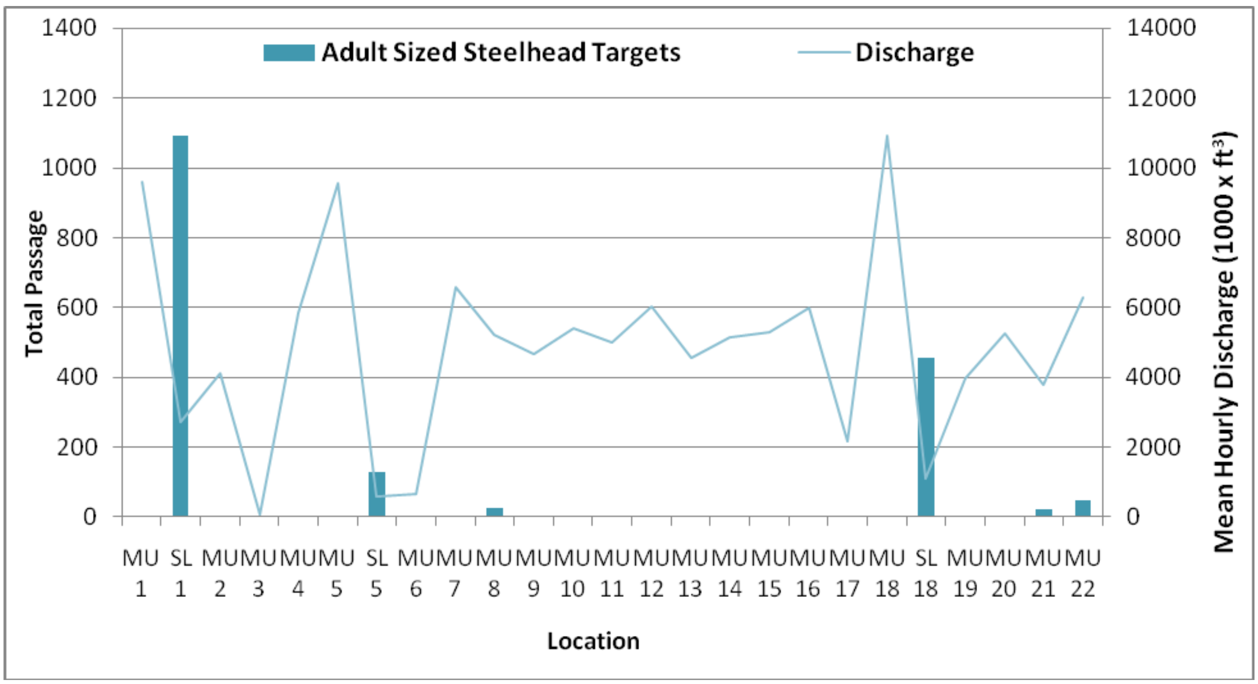


Figure 3.8. Horizontal Distribution of Total Passage of Overwintering Steelhead and Kelt-Sized Targets at Each Route of the Powerhouse and Sluiceway, with Corresponding Powerhouse Intake Unit Discharge, from March 1–April 9, 2009 (MU = main unit, SL = sluice)

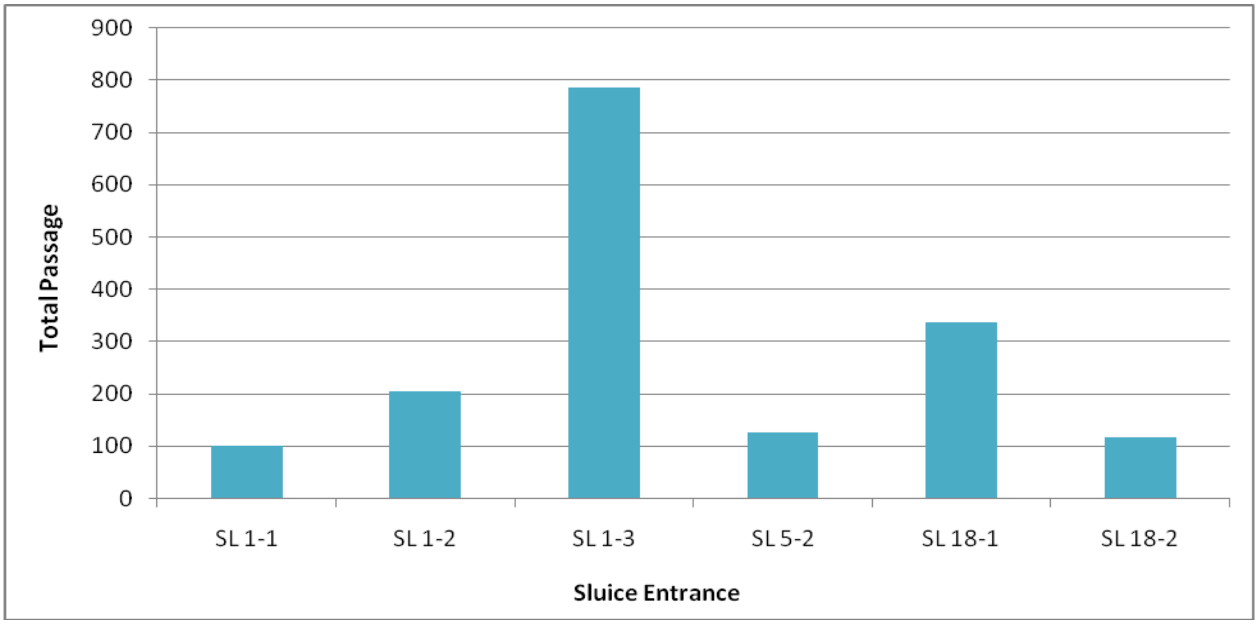


Figure 3.9. Horizontal Distribution of Total Passage of Overwintering Steelhead and Kelt-Sized Targets at Each Route of the Sluiceway from March 1–April 9, 2009 (SL = sluice entrance)

3.2.2.3 Diel Distribution

Passage was high during mid-morning hours and late afternoon/nighttime, except for a dip at 2200 h (Figure 3.10). Fish passage peaked at 2100 h and was lowest at 0500 h, 0700 h, and 1100 h.

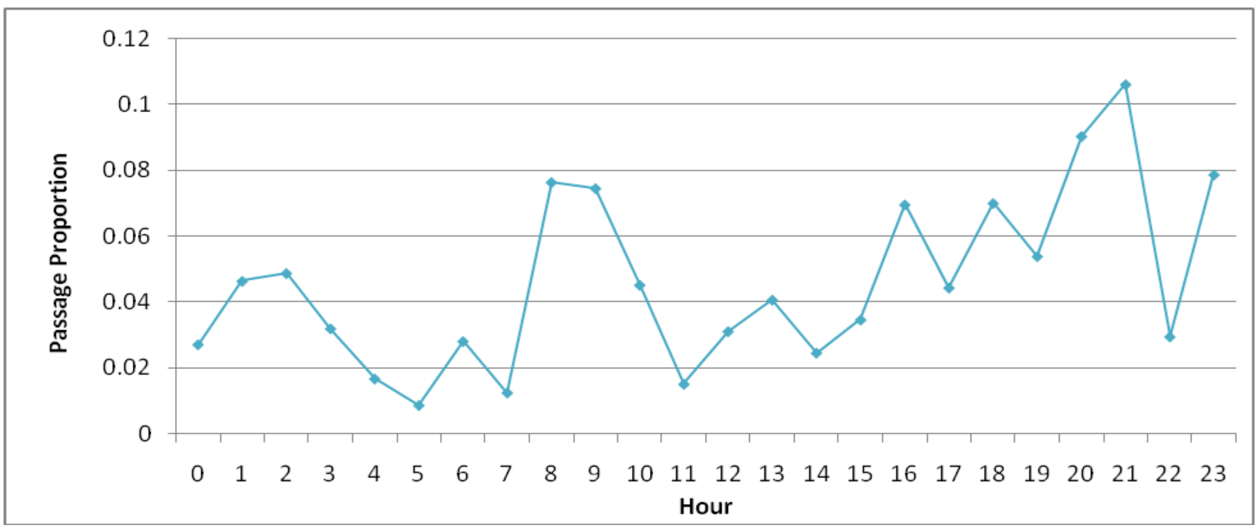


Figure 3.10. Diel Distribution of Overwintering Summer Steelhead and Kelt-Sized Targets from March 1–April 9, 2009. Data are the hourly proportions of total passage.

3.3 Fish Behavior Observations

For both the overwintering steelhead and kelts, fish in front of the sluice entrance exhibited several behaviors. Generally, most fish were oriented into the flow in the sluice nearfield (Figure 3.9). Some were milling just upstream of the sill, while others passed downstream into the sluiceway. Other fish swam upstream out into the forebay. Steelhead were also observed moving along the face of the dam from sluice entrance 1-2 to sluice entrance 1-1 and vice versa.

Juvenile shad (Figure 3.11) were present from the beginning of the sampling period on November 1, 2008 until mid-November. Steelhead behavior did not seem to change despite the presence of thousands of juvenile shad migrating downstream into the sluiceway.

From late November to the end of the sampling period on December 15, schools of yearling-sized salmonids were observed in the DIDSON images (Figure 3.12). These fish were present in large schools at times and they used the sluiceway to pass downstream.

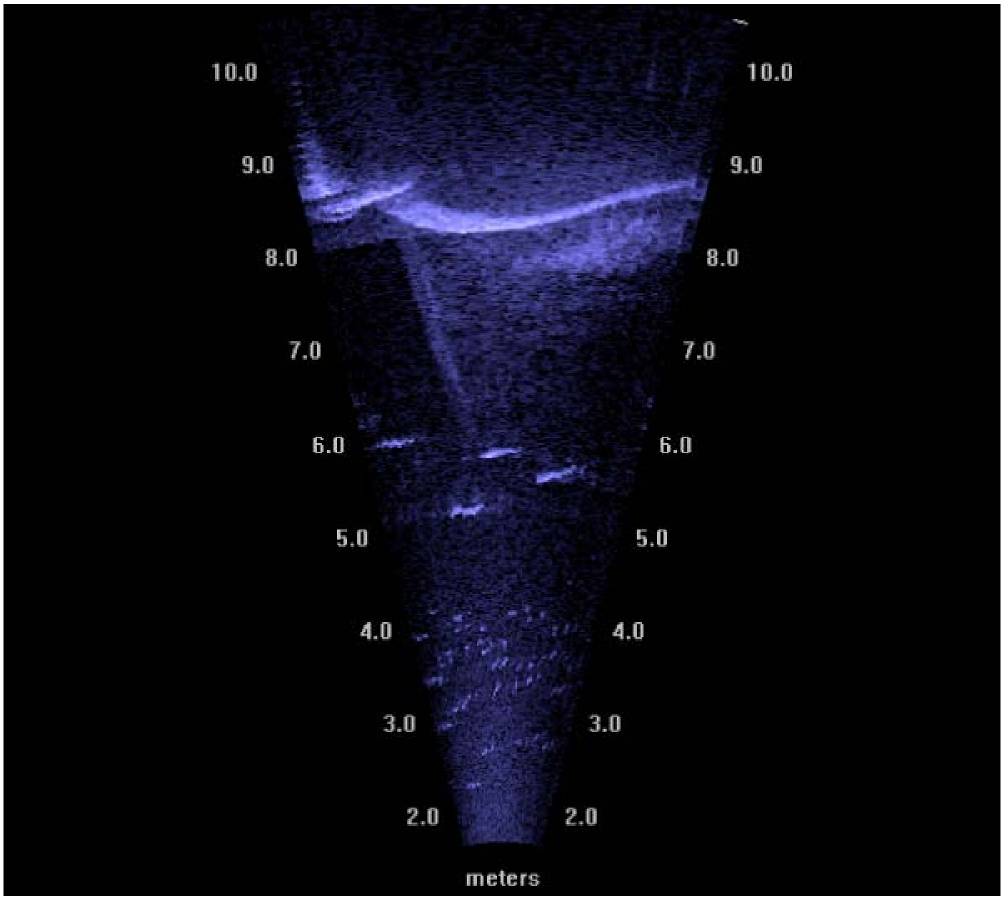


Figure 3.11. Adult Steelhead with Juvenile Shad During November 2008 at Sluice Entrance 1-1

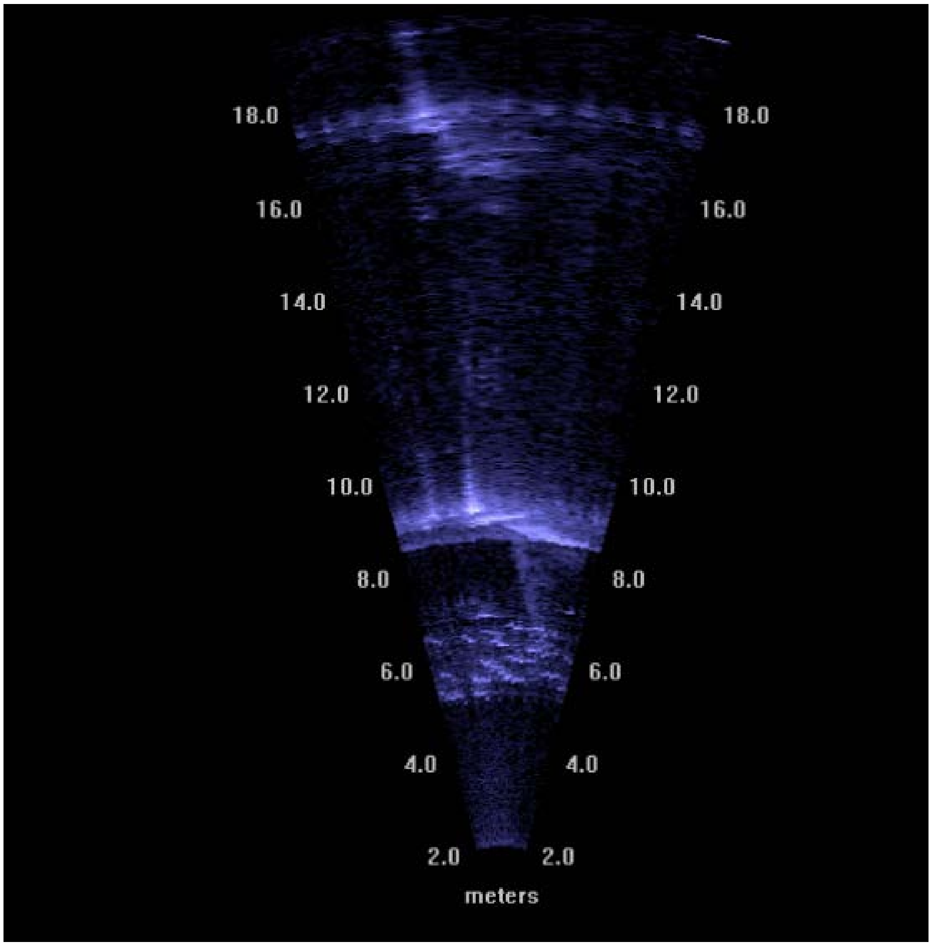


Figure 3.12. Yearling-Sized Salmonids During December 2008 at Sluice Entrance 1-1

After observing juvenile shad and yearling-sized fish targets during the fallback study in late fall, and knowing that some juvenile salmon emigrate in early spring, we analyzed the fixed-location hydro-acoustic data to learn more about the run timing of juvenile fish during both study periods. For targets with mean target strengths between -36 and -56 dB, passage peaked in late fall during the first two weeks of November 2008 (Figure 3.13). Based on our DIDSON observations and beach seine samples 70 miles downstream (Sather et al. 2009), it is likely that these targets were almost entirely comprised of juvenile shad. The juvenile shad emigration was completed by the third week in November. Passage rates for juvenile fish were lowest during the last week of the fallback study (Figure 3.13). During early spring 2009, we observed high passage on four different dates that occurred early and late in the sampled period (Figure 3.14). Passage of juvenile fish was sporadic in early spring 2009.

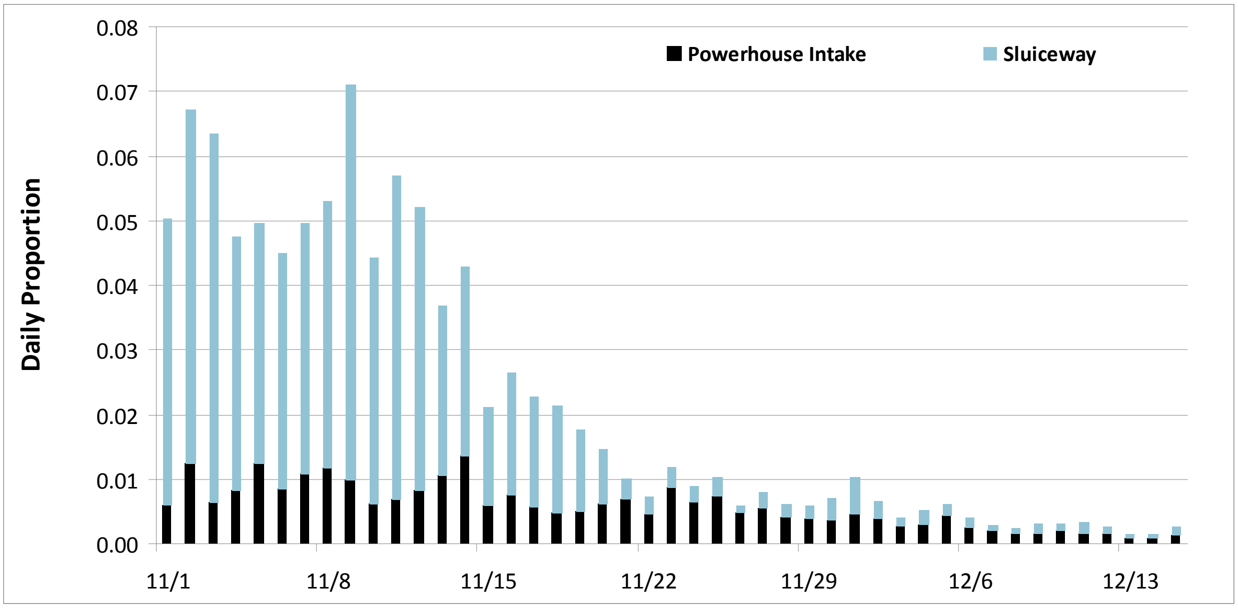


Figure 3.13. Run Timing for Juvenile Sized Fish During Late Fall 2008

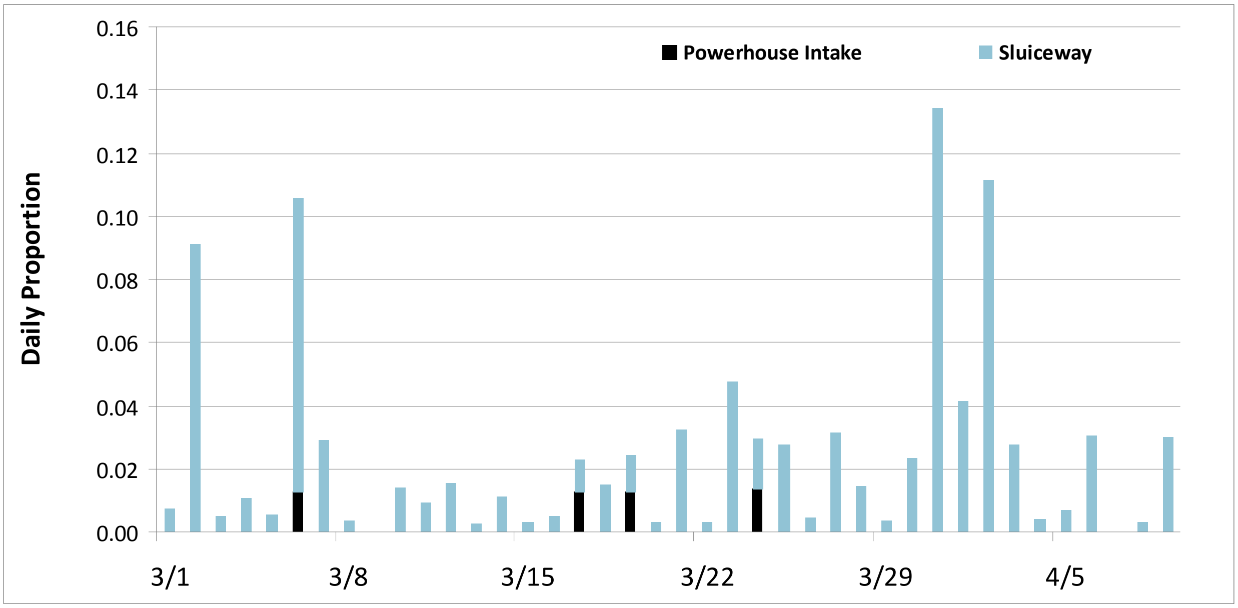


Figure 3.14. Run Timing for Juvenile Sized Fish During Early Spring 2009

4.0 Discussion and Conclusions

We conducted a hydroacoustic study at TDA from November 1 to December 15, 2008, and from March 1 to April 9, 2009, to evaluate overwintering summer steelhead falling back through the dam in the fall and winter months and overwintering summer steelhead and early out-migrating steelhead kelt passage in the spring. The overall goal of this study was to provide information about steelhead fallback and kelt passage at TDA to support decisions on the operations of the sluiceway in winter and early spring months to allow fish passage through that route, thereby reducing turbine passage to improve steelhead survival as they pass the dam. The USACE included in its 2006 Fish Passage Plan operating the TDA sluiceway until November 30 as a route for steelhead falling back during migration because of concerns about these fish using the turbines as a route through the dam. Operating the sluiceway reduces the potential for hydropower production, but this surface flow outlet may be the optimal non-turbine route for fallbacks in the fall and winter months and kelt passage in early spring before the start of the spill season. Johnson and Dauble (2006) concluded that surface flow outlets are prime routes for passing downstream migrating juvenile salmonids at dams. The results of this study indicate that overwintering summer steelhead falling back during migration in the fall and winter months and kelts migrating downstream in the early spring used the sluiceway and some turbines as routes through the dam. Passage through the sluiceway far exceeded passage through turbines even though only a fraction of powerhouse flow went through the sluiceway.

For the overwintering summer steelhead, fallback occurred throughout the 45-day study period, except for December 9, when no steelhead targets apparently passed the dam. During this study, a total of 1,790 ± 250 (95% CI) summer steelhead targets passed through the powerhouse intakes and operating sluices. Ninety-five percent (1,704 targets) of the total fish passed though the sluiceway. Therefore, without the sluiceway as a route through the dam, a number of steelhead may have fallen back through turbines. Run timing peaked in late November, but fish continued to pass the dam until the end of the study. Fallback occurred (~13 fish/d) through the sluiceway during the last 2 days of the study period, indicating that these fish are still passing the dam in the middle of December. Horizontal distribution data indicated that Sluice 1 is the preferred route for these fish during fallback through the dam. For individual sluice entrances, sluice entrance 1-3 passed the highest number of fish (1,192 targets), followed by sluice entrance 1-2 (195) and sluice entrance 18-2 (122). Fewer than one hundred targets passed through sluice entrances 1-1, 5-2, and 18-1. Diel distribution for overwintering steelhead fallbacks was variable with no apparent distinct patterns. The lack of a clear trend in diel passage suggests that fish are passing at all times of a day. Therefore, sluiceway operations should not be based on diel distribution in fall and winter.

Overwintering summer steelhead and early out-migrating kelt passage occurred throughout the 40-day spring study period, except for March 9 and April 7, when it appeared that no targets passed the dam. During this study, a total of 1,766 ± 277 (95% CI) steelhead adult-sized targets passed through the powerhouse intakes and operating sluices. Ninety-five percent (1,673 targets) of the total fish passed through the sluiceway. Therefore, not having the sluiceway as a route through the dam, a number of overwintering steelhead and out-migrating kelts may use the turbines for downstream passage before the start of the spill season. Run timing peaked in late March; however, relatively large numbers of adult-sized targets passed the dam on March 2 and March 6 (162 and 188 fish, respectively). Horizontal distribution shows the highest passage occurred at Sluice 1 (62% of total fish), followed by Sluice 18 (26%), indicating that Sluice 1 is the preferred route for fish passage as they migrate downstream through the dam. For individual sluice entrances, sluice entrance 1-3 passed the highest number of fish (785 targets), followed by sluice entrance 18-1 (337) and sluice entrance 1-2 (205). Sluice entrances 5-2 and 18-2 passed 127 and 117 targets, respectively. Sluice entrance 1-1 passed the least amount of fish (101). A weak diel trend in passage was observed in early spring, and it suggested that passage was generally higher at 0700 h and 0800 h and from afternoon until midnight than it was at other hours. Nevertheless, the observed trend was not strong enough to proposing diel changes in sluiceway operation.

Fish behavior of both overwintering summer steelhead fallbacks and out-migrating kelts was that of a typical salmonid in front of a sluice entrance. Fish in front of the sluice entrance were oriented into the flow in the sluice nearfield, milling just upstream of the sill, entering into the sluiceway, or swimming upstream out into the forebay. These fish also moved along the face of the dam. Juvenile shad were present from the beginning of the sampling period on November 1, 2008, until mid-November. Steelhead behavior did not change in the presence of thousands of juvenile shad.

The results of this study strongly suggest that operating the TDA sluiceway for fish passage (fallbacks and kelts) during the late fall, winter, and early spring months will provide an optimal, non-turbine route for these fishes to pass the dam. Johnson et al. (2005, 2006) found the sluiceway to be an efficient and effective route for juvenile salmonids as they migrate downstream. The same may be said for overwintering summer steelhead falling back or kelts migrating downstream. Results from a study conducted by Boggs et al. (2004) indicated that steelhead fallbacks “overshot” their natal streams or hatcheries during upstream migration and after falling back, these fishes were found in streams and hatcheries below the fallback site. Kelts migrating to the ocean are capable of returning to their freshwater spawning grounds to spawn again, which is an important factor for maintaining stable steelhead populations in their native rivers (Wertheimer and Evans 2005; Wertheimer 2007). Fallback of overwintering summer steelhead during late fall and winter and passage of out-migrating kelt and overwintering steelhead during early spring are instances of the benefits of using surface flow outlets instead of turbines to pass salmonids. All 13 dams on the mainstem Columbia and Snake rivers have installed or are developing surface flow outlets to pass juvenile salmonids. Fisheries and hydrosystem managers are responsibly considering the use of these structures to protect adult salmonids from hydropower turbines (NMFS 2008).

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