PNWD-4154

Hydroacoustic Evaluation of Adult Steelhead Fallback and Kelt Passage at McNary Dam, Winter 2010-2011

KD Ham
PS Titzler
RP Mueller
DM Trott

Final Report

Battelle
Pacific Northwest Division
Richland, Washington 99352

Prepared for
U.S. Army Corps of Engineers, Walla Walla District,
Walla Walla, Washington
Under Biological Services Contract W912EF-08-D-0004
Delivery Order 0002

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Summary

In the winter of 2010-2011, Battelle-Pacific Northwest Division conducted a hydroacoustic study at McNary Dam for the Walla Walla District of the U.S. Army Corps of Engineers (USACE) to evaluate the distributions of adult steelhead passing downstream through the powerhouse. The primary purpose of the study was to enumerate and determine the vertical and horizontal distribution of adult steelhead as they passed through the powerhouse. Downstream passage of adults through turbines is of greatest concern during winter months when other passage routes are typically unavailable and fish guidance screens are not in place to limit turbine passage. Study results have implications for winter operations as well as the operation or location of surface bypass improvements at the McNary project.

Adult passage was monitored at 8 of 14 turbine units from December 17, 2010 through April 13, 2011. Two of the units that were not monitored were out of service for the duration of the study. Fixed-aspect hydroacoustics were used to estimate the number of fish entering each turbine intake unit. A Dual frequency IDentification SONar (DIDSON) acoustic imaging device was used to monitor the region just upstream of the trash rack at units 5C and 6A in order to verify the presence of adult steelhead and other similar-sized individuals of other species.

Typical McNary winter operations do not include spill, turbine intake guidance screens are removed for maintenance, and adult ladders are taken out of service. As a result, turbines are the only downstream passage route for fish such as pre-spawning adult steelhead and kelts during this period. During much of the latter portion of the study period, atypically-high river flows resulted in forced spill, which created an unexpected and unmonitored passage route through the dam. As a result, turbine passage estimates in the present study are likely less than would occur in a typical year without spill.

Downstream passage of adult steelhead through the monitored turbine intakes at the powerhouse of McNary Dam across the entire study period was estimated to be 946 individuals, with 95% confidence bounds extending from 750 to 1142 individuals. If a similar rate of passage through unmonitored turbine intakes is assumed, the estimate of total powerhouse passage would be 50% higher at 1419. The rate of passage into turbines in the present study during the winter was higher than during the early spring. We speculate that even more adult steelhead would have passed through turbines if not for the unexpected spill during this 2010/2011 study at McNary Dam.

Horizontal distributions (among turbine units) appeared to be clumped due to the small number of individuals detected. Although flows were distributed relatively evenly among units available for operation during the study, passage was greater at turbine units nearer the north or south ends of the powerhouse, and lower near the center of the powerhouse. The lack of sampling at a third of the operating turbine units and the clumped distributions limited our ability to interpret horizontal distributions.

Vertical distributions (depth) were also somewhat clumped due to the small number of individuals detected, but a trend of passage nearer the ceiling of the intake was evident. This suggests that a high proportion of adult steelhead would encounter screens, if they were in place.

The unexpected occurrence of spill enabled a comparison between no spill and spill conditions, albeit without a planned treatment study design. During periods with forced spill, rates of turbine passage appeared lower, but it is not possible to determine whether those differences are related to spill or to the

occurrence of those periods later in the study. During periods of forced spill, passage was greater near the north end of the powerhouse, adjacent to the spillway. During periods of spill passage was distributed at greater depth than during periods without spill. While these findings suggest that spill is influencing turbine passage, the only conclusion we can draw with confidence is that spill does not eliminate turbine passage by adult steelhead. A planned treatment test would be required to differentiate whether changes in passage were related to spill by controlling for trends in other factors through the passage season.

Acknowledgments

This work was supported by the U.S. Army Corps of Engineers, Walla Walla District. We sincerely acknowledge the cooperation, assistance, and hard work of the following U.S. Army Corps of Engineers staff:

- Ann Setter, Fred Higginbotham, and Chris Pinney for overall project oversight and direction
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- Mike Remington for dive support
- The McNary Dam operators for research coordination activities at the dam including safety clearances and outages

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Finally, we acknowledge Associated Underwater Services Inc., which provided the dive team that installed and removed the underwater sampling equipment.

Abbreviations and Acronyms

ESBS	Extended-length Submersible Barrier Screen
JBS	juvenile bypass system
kHz	kilohertz
msl	mean sea level
PAS	Precision Acoustic Systems, Inc.
PIT	passive integrated transponder
STS	submerged traveling screen
USACE	U.S. Army Corps of Engineers

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1.0 Introduction

This report presents the results of a hydroacoustic evaluation of adult steelhead passing downstream through the powerhouse at McNary Dam funded by the Walla Walla District of the U.S. Army Corps of Engineers (USACE) and conducted by Battelle–Pacific Northwest Division (Battelle). This study, conducted during the winter of 2010-2011, estimated the number of steelhead kelts and adults passing downstream through the powerhouse at McNary Dam and evaluated how passage was distributed vertically in the water column and horizontally across the powerhouse.

1.1 Background

The USACE is committed to improving fish passage conditions and increasing survival rates for fish passing its hydroelectric projects on the Snake and Columbia rivers. During the winter of 2009-2010, adult steelhead were noticed in the forebay of McNary dam upstream of the powerhouse, spurring a renewed interest in downstream passage. Several Columbia River steelhead populations were listed as threatened under the U.S. Endangered Species Act (ESA) in 1997–1999, including all interior-basin summer-run fish (NMFS 1997; Good et al. 2005). These include Yakima River, Walla Walla River, mid- and upper-Columbia River and Snake River steelhead populations that must traverse McNary Dam to complete their life cycle.Summer steelhead return to tributaries of the Snake and Columbia River and spawn in January to June, up to a year after they return to freshwater (Busby et al. 1996; Quinn 2005). Summer steelhead passage upstream of McNary Dam consists of two separate runs, designated as the A and B groups. The A-group spends one year at sea and the adults migrating upstream normally pass McNary Dam from late June through August. The B-group, spend two years at sea and the adults pass the dam from early September through October (FPC 2011). Most of the larger B-group fish return to the Clearwater or Salmon River, and large proportions of these fish overwinter in the Federal Columbia River Power System (FCRPS) prior to spawning the following spring. Steelhead returning to tributaries upstream of McNary Dam in the Columbia River enter the river in May through September and pass Rock Island Dam in July through the following May. Fish that pass Rock Island Dam in the spring will overwinter in the mainstem Columbia River and will spawn the following spring (Chapman et al. 1994). Spawning takes place in the tributaries between March and June.

Unlike many anadromous Pacific salmon species, Steelhead are iteroparous, and do not necessarily die after spawning and are able to spawn multiple times. The post-spawn adults are referred to as kelts, and they migrate downstream to the ocean prior to beginning another spawning effort. During overwintering prior to spawning and during post-spawning migration, there is a concern that adult steelhead falling back downstream through the powerhouse at McNary Dam during the time of the year when Extended-length Submersible Barrier Screen (ESBS) screens are not in place may be susceptible to significant injury. This is of particular concern with reference to B run steelhead that, due to their larger size, may be more vulnerable to adverse effects when passing through a turbine. The turbine is typically the only route of passage available to adult fish travelling downstream during a portion of the winter when adult ladders are closed for maintenance, ESBS screens are removed, and spill is not planned.

Fallback occurs when adult upstream migrants pass a dam through a fishway but then pass back downstream of the dam. The fish can be either a permanent fallback (stays downstream of the dam) or a reascension (passes back upstream of the dam). 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. At McNary Dam, wild and hatchery steelhead fallback is highest in October through November, but may occur through the year (Wagner and Hillson 1993). Steelhead kelt downstream migrants are not considered fallbacks because downstream passage is their objective at that point. Kelts tend to appear during the late winter through April. In a 1990-1991 fallback study at McNary Dam kelt passage into the juvenile bypass system (intake screens operating) during April was ~1,000/month (Wagner and Hillson 1993). This is approximately 1% of the total steelhead count at the dam for the previous year.

Ensuring the survival of adult steelhead as they pass downstream at McNary Dam should result in more spawners arriving at the spawning grounds. Reasonable and Prudent Alternative #33 of the 2008 Federal Columbia River Power System Biological Opinion calls for the USACE and Bonneville Power Administration to create and update a "Snake River Steelhead Kelt Management Plan" in coordination with NOAA Fisheries and the Regional Forum. The goal is to improve the productivity of interior basin B-run steelhead populations through increasing the in-river survival of migrating kelts, collection and transport (either with or without short-term reconditioning) of kelts to areas below Bonneville Dam, long-term reconditioning to increase the number of viable females on the spawning grounds, and research as necessary to accomplish the elements of this plan. The results of this study have the potential to inform decisions on operational strategies to improve survival and returns through enhanced in-river migration or collection and transportation.

In this study, the number of fish passing through turbines during the season when screens were not in place was estimated in order to better understand the risk to populations. The vertical distribution of fish within the turbine intake was monitored to assess how deep fish were when they entered the intake. The horizontal distribution among turbine units at the powerhouse was also monitored to identify the region where passage is most prevalent. This vertical and horizontal distribution information will help evaluate potential surface bypass improvements to reduce turbine passage of adult steelhead, especially during period when other routes are not available.

1.2 Objectives

The winter study was planned to run from January 1 to April 16. Objectives of the winter hydroacoustic monitoring of adult steelhead passage at McNary Dam were as follows:

- Estimate the number of adult steelhead passing downstream through the powerhouse.
- Determine both horizontal and vertical distribution of adult steelhead as they pass downstream through the powerhouse.

1.3 Study Site Description

McNary Dam is located at Columbia River mile 292, includes a navigation lock, a spillway, and a powerhouse. The dam structure is 7365 feet long. The structure consists of 14 turbine units, 22 spillbays, a navigation lock, two fish ladders for adult fish traveling upstream, and an earth-filled section (Figure 1.1 and Figure 1.2). The McNary Dam powerhouse is 1422 feet long and contains six 70,000-kilowatt turbine units. All turbines are Kaplan, six-blade units that operate at 85.7 revolutions per minute. Turbine units are numbered 1 through 14 starting from the Oregon shore. Each turbine has three intakes designated A, B, and C. Two station service units are located south of Main Unit 1 and have a capacity of 3 MW each.

Extended length submerged bar screens (ESBS) are used at all of the turbine unit intakes during the juvenile fish passage season. Those screens are removed during the winter, when this study was conducted, so fish entering a turbine intake would pass through the turbine. The ice and trash sluiceway has been permanently walled off for use as the collection channel of the juvenile bypass system (JBS). Transportation facilities consist of a separator (to sort juvenile fish by size and to separate them from adult fish), sampling facilities, raceways, office and sampling building, truck- and barge-loading facilities, and passive integrated transponder (PIT)-tag detection and deflector systems. The JBS at McNary Dam became operational in 1987, and PIT-tag detection capabilities became operational in 1994.

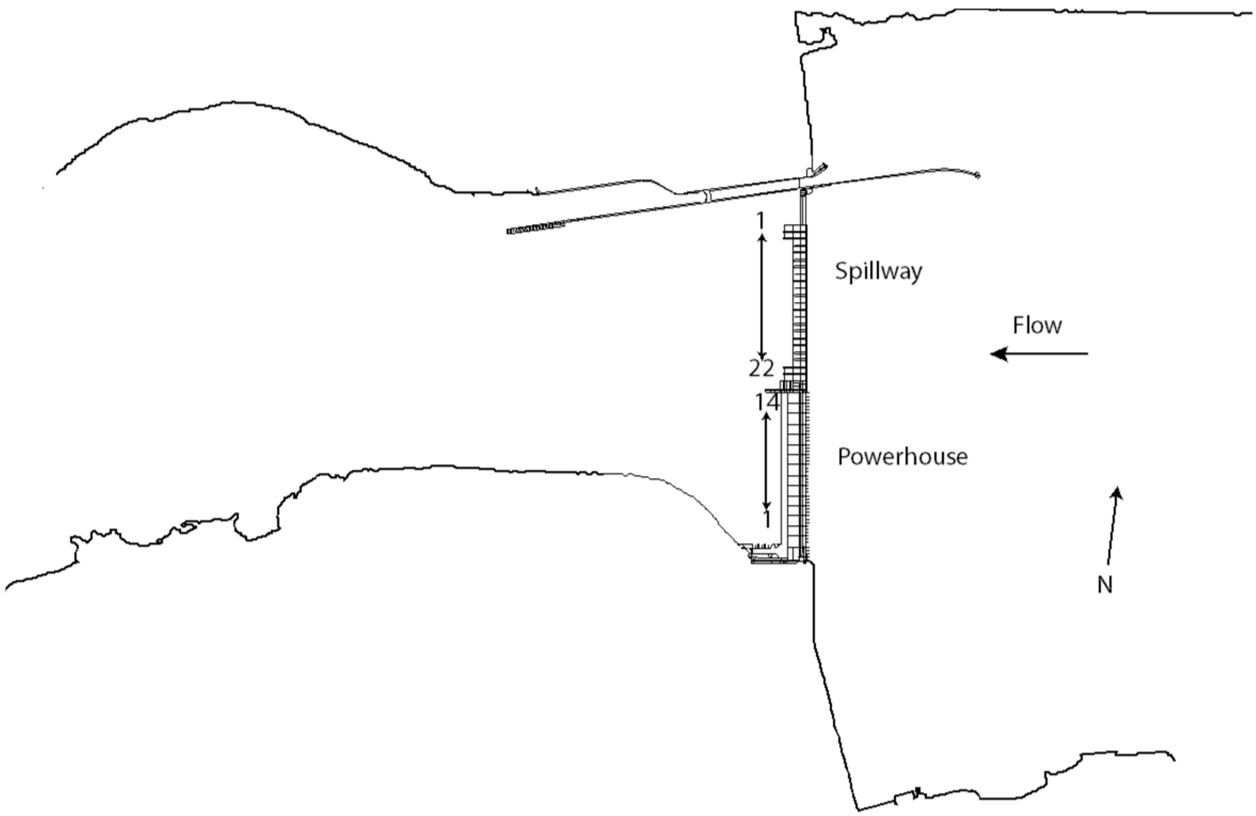

Figure 1.1. Plan View of McNary Dam Illustrating the Location of the Spillway and Powerhouse

The 1130-ft spillway is composed of 22 vertical lift gates, which are numbered sequentially starting from the Washington shore—the spillbay closest to the powerhouse is 22 (Figure 1.1). Spill gates are of split-leaf, vertical lift design. In the forebay, the thalweg is upstream of the powerhouse, but curves north in the tailrace, downstream of the spillway (Figure 1.2). There is also a 10-MW hydropower unit located on the Washington shore incorporated into the adult fishway. The gravity-flow auxiliary water supply system has a turbine unit installed on it, and this unit is operated by the Northern Wasco County Public Utility District. The south fish ladder includes the powerhouse collection system and both gravity and pumped auxiliary water supply systems.

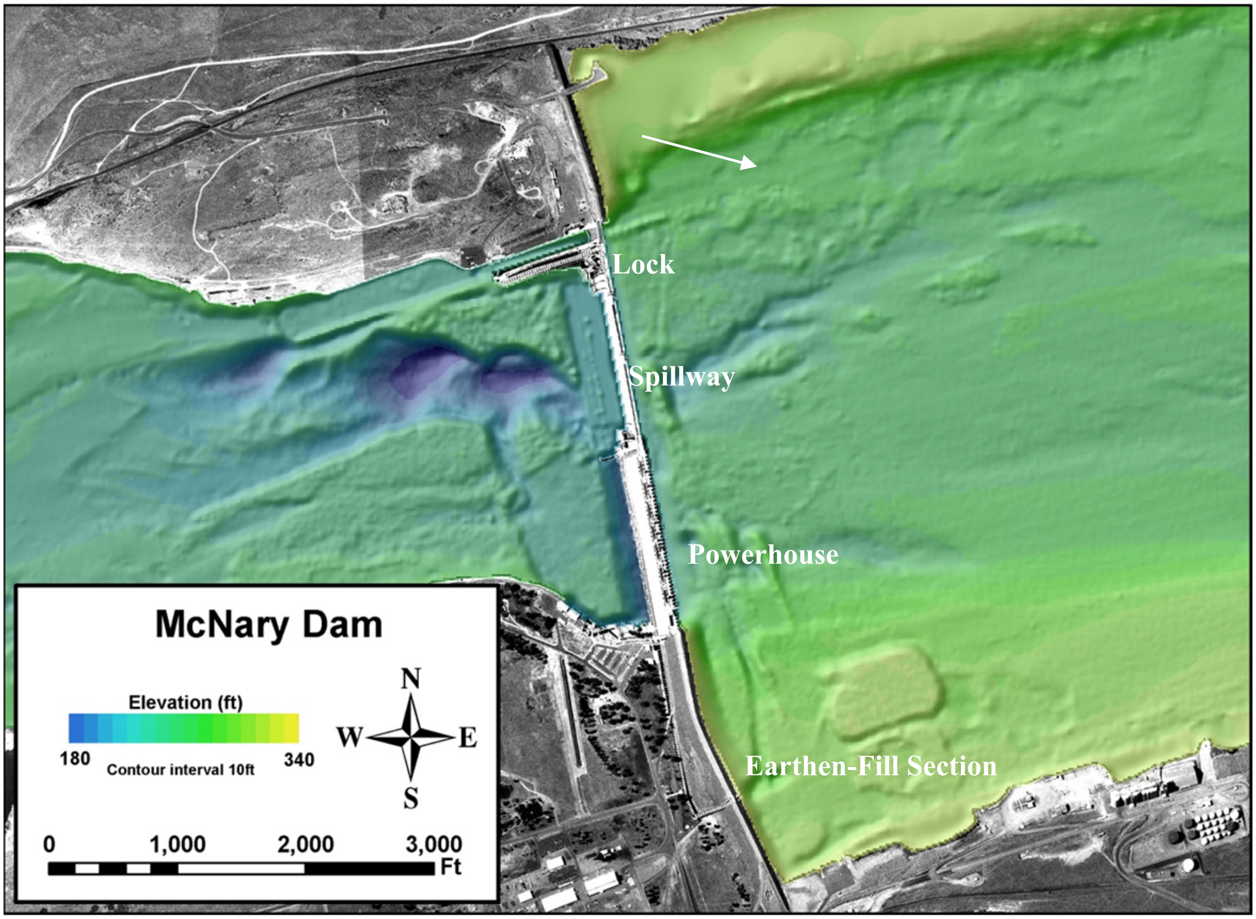

Figure 1.2. Plan View of McNary Dam Major Structural Features with River Bathymetry

1.4 Report Contents and Organization

The ensuing sections of this report present the results of the study of adult steelhead fallbacks and kelt downstream passage at McNary Dam in 2011. Chapter 2.0 contains a description of methods used, including the study design, sampling equipment, data analysis, and data processing. Chapter 3.0 provides results and discussion, including site conditions during the study, seasonal and diel fish passage distributions, and comparisons of operational conditions on passage distributions and fish trajectories as they pass the RSW. Chapter 4.0 provides our conclusions. Appendixes contain supplemental information, as follows: Appendix A, Equipment Configuration and Settings; Appendix B, Raw Hourly Passage and Dam Operations Data; Appendix C, Effective Beam Widths; and Appendix D, Statistical Methods.

2.0 Method

The fixed-aspect hydroacoustic approach was used to quantify the number of adult steelhead-sized acoustic targets passing through the powerhouse at McNary Dam during the winter of 2011. Split-beam transducers were deployed to detect passing adult fish and to quantify horizontal and vertical passage distributions using the acoustic screen model. A DIDSON sonar imaging device ("acoustic camera") was deployed on the upstream face of the dam to identify species present in the forebay and their relative abundance near the turbine intakes. The study plan called for monitoring passage through the winter and early spring seasons, with no specific treatments planned or imposed.

2.1 Study Design

No experimental treatments were planned. The study was intended to quantify adult steelhead passage during typical conditions over the winter period when guidance screens were not in place in the turbine intakes. If operations varied notably through time during the study, we planned to compare passage trends among those periods.

2.2 Hydroacoustic Sampling System

Hydroacoustic transducers were used to detect adult steelhead passing into the turbines. The details of hydroacoustic equipment installations are described in this section. Data collection relied on three split-beam hydroacoustic systems to monitor adult fish entering the powerhouse. All systems operated at a frequency of 420 kHz. Split-beam data collection was accomplished using Harp–SB Split-Beam Data Acquisition/Signal Processing Software; a DOS-based application that controlled a PAS-103 Split-Beam Multi-Mode Scientific Sounder. The PAS-103 Split-beam Sounder controlled a PAS-203 Split-Beam 4-Channel Transducer Multiplexer that multiplexed a maximum of four PAS 420-kHz Split-Beam Transducers. The sounder controlled the pulses (pings) emitted by the transducers and processed the signals received. When a fish passed through the sample volume of the beam, pings were reflected and received as an echo at the transducer. Ping rates of around 25 pings per second are typically used during juvenile studies, where conditions permit. Due to high levels of reverberation within the turbine intakes, ping rates were reduced to 21 or 19 pings per second to enable individual echoes to be differentiated. This rate is more than sufficient for detecting adult steelhead passing through the beam, and yielded effective beam widths (=detectability model output) well beyond the nominal widths. Each transducer was sampled in sequence 10 times per hour for 89 or 117 second intervals, depending upon the number of transducers attached to each sounder. Echo data were captured using the Harp–SB data acquisition and signal processing software that controls the sounder and stores the data. Hydroacoustic sampling was conducted at the dam 24 hours per day, seven days a week. The sounder and the data-acquisition equipment were housed in two equipment shacks on the forebay deck for the duration of the experiment. The equipment layout and the settings for each system are described in Appendix A.

Eight Precision Acoustic Systems, Inc. (PAS) 420-kHz split-beam transducers with a nominal beam angle of 6 degrees were used to sample adult fish passing downstream through the A slot of units 3, 4, 5, 6, 8, 9, 11, and 13 (Figure 2.1). One split-beam system (System C) sampled intakes 3A and 4A, a second system (System L) sampled intakes 5A, 6A, 8A, and 9A, and the third system (System K) sampled intakes 11A and 13A. Transducers were attached to the center of the trash rack horizontal member at an elevation of 239 feet above Mean Sea level (ft MSL), oriented to look up towards the intake ceiling and aimed 31 degrees downstream of the trash rack plane (Figure 2.2). In order to protect the transducer cables from debris and trash rack raking, cables were secured to the downstream side of the trash rack as they were routed up to the intake road deck.

Figure 2.1. Transducer Installed in an Adjustable Mount and Prepared for Installation

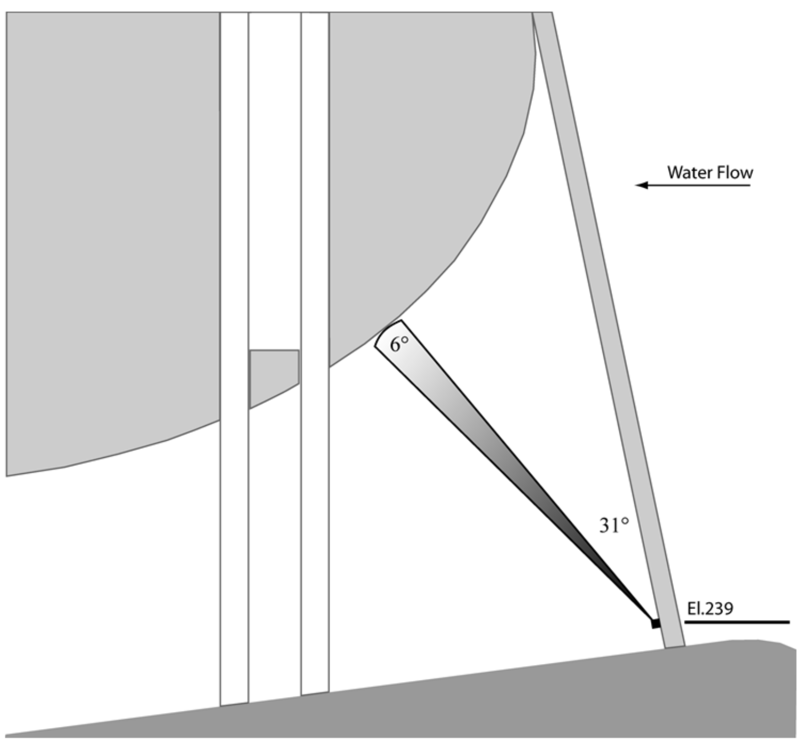

Figure 2.2. Side View of the Unit Intake Split-Beam Transducer Deployment. Each Transducer was Mounted on the Trash Rack at an Elevation of 239 ft, Aimed Downstream 31 Degrees from the Trash Rack Plane.

2.3 DIDSON Sonar Imaging System

The DIDSON provides a way to visualize fish shapes and movement under conditions where optical cameras would be severely limited by turbidity or the absence of light. This device was successfully applied at the sluiceway at The Dalles Dam in previous research on juvenile salmonids passage (Johnson et al. 2005, 2006), and adult passage studies at The Dalles in 2008-2009 (Khan et al 2009). In the present study, the DIDSON provided a way to differentiate among species groups and monitor the apparent relative abundance of those groups just upstream of the turbine intakes. In addition, it was possible to monitor their behavior within the sampled region to determine whether fish near the intakes were milling around for extended periods or quickly passing into a turbine intake.

2.3.1 Sampling Locations

The DIDSON sampled fish presence and behavior at entrances to Units 5 (slot B and C) and Unit 6 (slot A). Data was recorded for 15 min at the start of every hour beginning December 17 and continuing through January 20. From January 20 through April 15 data was collected for 20 min at the start of each hour. The system was deployed at an elevation of 332 ft above MSL until January 6 and at elevation 328 ft MSL thereafter. The DIDSON was mounted to a pan and tilt rotator (ROS PT-25) affixed to an aluminum trolley which was deployed down a 4-in.-wide steel flange beam attached to the upstream (east) side of the concrete pier between units 5 and 6 (Figure 2.3). For the initial part of the study (December 17 to January 6) the instrument was aimed across the forebay just upstream of the intakes 5B and 5C. From January 6 until the April 15, the aiming angle was changed to get a better view of the trashracks at intakes 5C or 6A. The new orientation was intended to provide a better indication of whether fish were entering the intakes, or were just milling around. By modifying the orientation to bring the trashracks into view, it was possible to visualize the orientation of the fish to the trashrack and to witness fish passing into the turbine intake beyond the trashrack. The new angle resulted in the sampling range being limited by the next pier nose (Figure 2.4), but that reduced range allowed the use of a higher frequency mode with greater resolution to differentiate among species.

Table 2.1. Sampling Schedule at McNary Dam for DIDSON Deployment

Dates	Turbine Unit	Intake #	Elevation	Frequency Mode
Dec 17-Jan 6	5	B and C	332	Low
Jan 6 – Jan 13	6	A	328	High
Jan 13 – Jan 20	5	C	328	High
Jan 20 – Jan 26	6	A	328	High
Jan 26 – Feb 8	5	C	328	High
Feb 8 – Feb 16	6	A	328	High
Feb 16 – Feb 25	5	C	328	High
Feb 25 – March 8	6	A	328	High
March 8 – April 5	5	C	328	High

Figure 2.3. DIDSON Mounted to Rotator and Trolley Prior to Being Deployed at Unit 5/6 Main Pier Nose

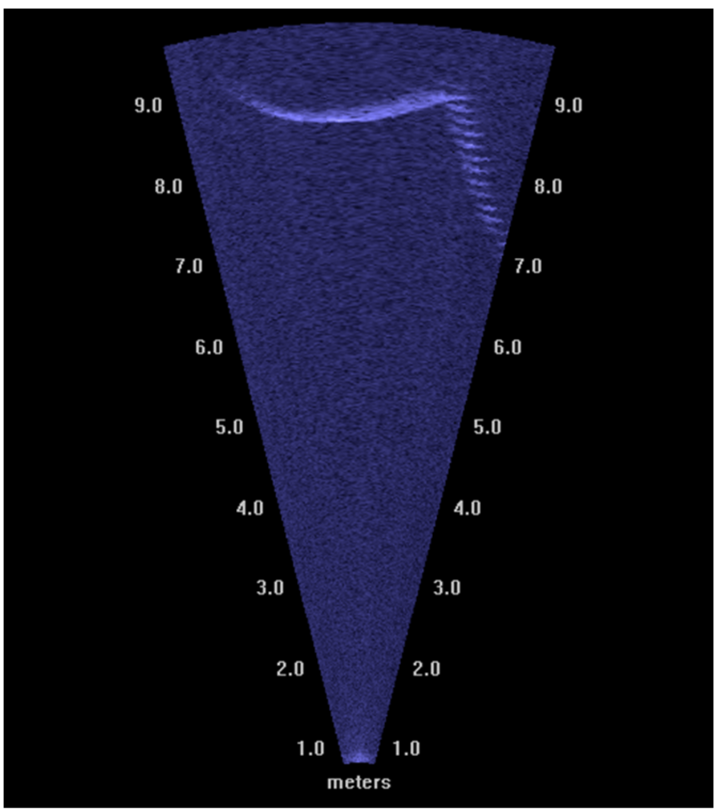

Figure 2.4. DIDSON View at Elevation 328 Showing Main Pier Nose and Trash Rack Structure

2.4 Data Processing

To estimate fish passage and evaluate it in the context of dam operations, data collected from sounders were processed to identify tracks of echoes created by individual fish. Counts of fish tracks were subsequently expanded to estimate fish passage at the turbine intakes. Passage estimates were integrated with dam operations to allow for the comparison of passage among time periods with varied operations. DIDSON data were processed to estimate the presence of fish of various species groups near the entrance of the turbine intakes and the behavior of those fish. This section describes the process that derives the estimates of fish passage from the raw data and the process of developing estimates of fish presence upstream of turbine intakes.

2.4.1 Dam Operations

Dam operations data, which were provided by the USACE, Walla Walla District, included the flows through each passage route on a 5-minute basis as collected by the Corps' GDACS data-acquisition system. These data were combined with the fish passage data for analysis of relationships between fish passage and flow. The dam operations data are included with the raw hourly passage data in Appendix B.

2.4.2 Autotracking to Identify Fish Tracks

The data produced by split-beam transducers were processed by autotracking software, which was initially developed by the USACE Portland District and underwent a major revision by Battelle in 2001. The autotracker identifies linear features in echograms, which exhibit characteristics consistent with a fish committed to passage by the monitored route, subsequently saved as tracks. Each track represents a potential fish target passing through the transducer beam. Further processing removed tracks with characteristics inconsistent with a fish passing through a turbine or with target strengths lower than expected for adult steelhead.

The autotracker software identifies any series of echoes that might be a fish track, but many of those can be the result of noise. To focus on adult steelhead, rather than noise, the post-processing filters eliminate any tracks that:

- Have fewer than 8 (noise) or more than 120 echoes (static objects or wandering fish), or with fewer than 4 echoes with no gaps between (noise)
- Have highly variable pulse widths (noise)
- Are in or very near an acoustically noisy location and time (noise)
- Are too consistent (static objects) or too variable (trash and noise) in their movement
- Have target strengths less than -25dB (large objects)
- Have target strengths greater than -31dB (small fish)
- Appear to be moving upstream (not passing into turbines).

The primary difference between these criteria and those used for a juvenile salmon passage study (with the same deployment) is the target strength criteria. Juvenile passage studies require target strength greater than or equal to -56db, which would accept fish from smolt-size and up. Increasing the minimum to -31dB ensures that only adult-steelhead-sized fish are detected.

2.4.3 Detectability and Effective Beam Widths

The movement characteristics (e.g., speed and direction) of targets passing through the transducer beam were used as inputs to a detectability model. The detectability model simulated individual echoes for fish passing through a transducer beam. The fish movement and echo characteristics were simulated to match those measured by split-beam transducers. A simulated fish was tabulated as detected, if enough echoes in a series exceeded a minimum number of consecutive echoes and minimum echo strength. The proportion of fish detected in the beam was used to compute an effective beam width. The nominal beam widths of 6 degrees assigned to a transducer do not accurately reflect the shape of the detection area for a transducer. The effective beam width is a measure that more accurately represents the cross-sectional area across which a transducer is able to detect adult-sized fish moving at the speed and direction that are characteristic of each deployment type. Effective beam widths were computed for each meter of range from the transducer, because track characteristics such as angle and speed are not constant throughout the passage route. Appendix C contains plots that illustrate effective beam widths across season, diel period, deployment type, and range.

2.4.4 Spatial and Temporal Expansion of Track Counts

Under the acoustic screen model, the number of tracks detected within the beam is expanded spatially and temporally to estimate total passage through a single passage route. The number of detected fish is adjusted for detectability and expanded for space and time between samples. Hourly passage was estimated by expanding the number of fish that passed through the beam for the cross-sectional area sampled (Equation 2.1) and the sampled fraction per hour (Equation 2.2):

$$W_{ij} = \frac{I_j}{2R_i \tan\left(\frac{\theta_j}{2}\right)} \tag{2.1}$$

where W_{ij} = the ith weighted fish at the jth location

I_j = the width (m) at the jth location

R_i = the mid-range (m) of the ith fish

θ_j = the effective beam width of the transducer at the jth location; and

$$\mathrm{X}_{jh} = \left(\frac{K}{k}\right)\sum_{i=1}^{n_{jh}} W_{ijh} \tag{2.2}$$

where X_{jh} = the fish passage at the jth location in the hth hour

W_{ijh} = the ith weighted fish at the jth location in the hth hour

n_{jh} = the number of fish at the jth location in the hth hour

K = the total number of sampling intervals in the hour

k = the number of intervals sampled in the hour.

All remaining analyses and response variables are based on these fundamental data. Raw hourly passage data may be found in Appendix B included with this report (a comma-delimited matrix of the raw hourly passage data and hourly operations.).

2.4.5 DIDSON Data Processing

To provide a margin of safety and to provide flexibility to analyze the timing of events, more time was sampled with the DIDSON than was needed for analysis. The DIDSON files were sub-sampled by reviewing 120 min of footage every other day. Blocks containing six hours for review were randomly assigned so that each block was reviewed once for every four days reviewed (Table 2.2). This provided a stratified random sample of collected data. Data was collected for the first 20 minutes of each hour, for a total of 120 minutes per block. Only 90 minutes of footage was available for days prior to January 20 because only 15 minutes of data were recorded at the beginning of each hour.

Table 2.2. Time Blocks Used for DIDSON Subsampling

Block	Hours	Total Sampling Time (min)
1	1700-1859, 0300-0459, 2300-0059	120
2	1100-1259, 0500-0659, 0100-0259	120
3	0700-0859, 1300-1459, 1500-1659	120
4	2100-2259, 1900-2059, 0900-1059	120

2.5 Data Analysis

Data analysis for fixed-aspect hydroacoustics consisted of estimating fish passage numbers and integrating them with flow and other conditions within specific time periods and passage routes. Because spill was not planned and passage at the spillway was not monitored, it was not possible to estimate or compare passage through spill. These general analysis results were then summarized to address specific questions of interest, such as how fish passage differed among operational conditions. Both spatial and temporal variations in the sampling were taken into account. The variances were calculated and carried through to the final estimates. The detailed statistical methods are described in Appendix D.

Counts of fish in each species group in DIDSON sample data were expanded to represent a 24-hour day. Didson counts are not intended to represent numbers of fish passing through turbines, because the great majority of fish within the view of the DIDSON did not appear to be entering the turbine intakes.

2.5.1 Organization

Fish passage results are presented for the entire study period and broken out by an ad hoc classification of operational conditions. The two most common operational conditions were no spill and forced spill. Confidence intervals in this section are based on within-day sampling variance due to not sampling every minute (temporal) and across the entire width of each route (spatial). Comparisons among No_Spill and Forced_Spill operational periods are dealt with in the subsequent sections, where inference is limited because of the ad hoc nature of the comparison. Graphical presentations were used to illustrate treatment effects for smaller time scales, such as trends among days or blocks of days.

3.0 Results and Discussion

The number of adult fish passing turbines at McNary Dam was not uniform across the study period. The following sections evaluate the trends in passage and attempt to interpret the impact of operational conditions as they changed through time. The unexpected occurrence of spill allowed a comparison of No_Spill and Forced_Spill conditions, but inference is limited because this was not a structured treatment comparison and because no detection equipment was installed at the spillway.

3.1 Study Conditions

The environmental conditions and the dam operations during the 2010/2011 study provide context for understanding and evaluating the number and distribution of adult fish entering the turbine intakes. In general, river flows were well above average beginning in mid-January, often exceeding the hydraulic capacity of the powerhouse. Flows in excess of powerhouse capacity resulted in forced spill, which was common for much of the remainder of the study period. The occurrence of spill likely had an important influence on downstream passage of adults. Extended length submersible bar screens (ESBS) were not intended to be in place during the study, but we sampled for a few days before they were removed in 2010 and after they were installed for the 2011 juvenile fish passage season. When passage results are presented, days having screens present will be identified or excluded from analysis.

3.1.1 River Discharge, Spill, and Temperature

This study monitored passage of adult fish through turbine units at the powerhouse of McNary Dam from December 18, 2010 to April 13, 2011. River discharge during that period was near the 10-year average until mid-January, after which it was well above average through the remainder of the study period (Figure 3.1). Starting in mid-January, the river discharge often exceeded powerhouse capacity, resulting in unplanned spill. The 10-year average spill for this period of the year was essentially 0% until the start of the juvenile fish passage season in April, so the amount of spill during the study period was very atypical. Temperature records were unavailable until mid-March, and temperatures after that date were below the 10-year average. To address the influence of unplanned spill on passage of adult steelhead at the powerhouse, we formed ad hoc analysis groups according to whether there was spill or not on a given day.

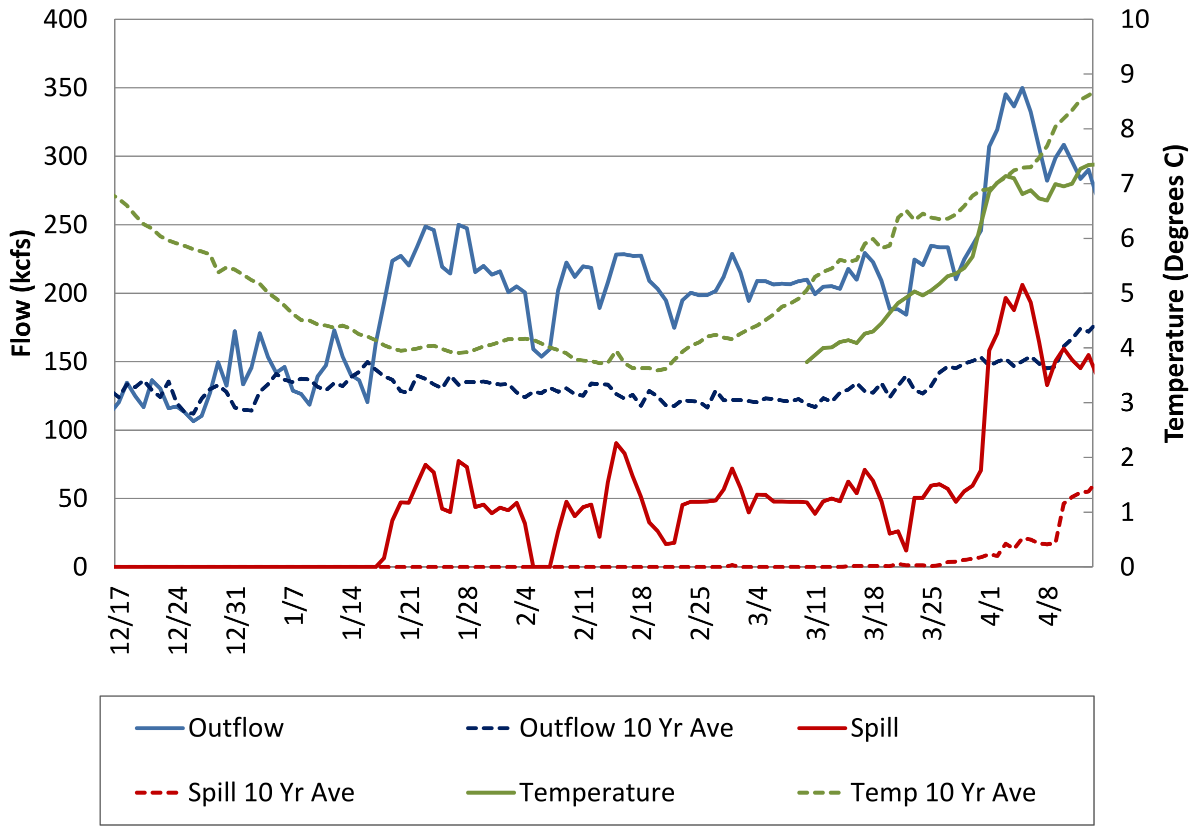

Figure 3.1. Daily Total Discharge, Spill Discharge, and Temperature for The Study Period (solid lines) and 10-Year Averages (dashed lines). Source: www.cbr.washington.edu/dart/dart.html).

3.1.2 Species Composition and Run Timing

DIDSON results provided an indication of the relative abundance of fish in the forebay upstream of the turbine intakes. Those results showed that adult shad were the most abundant large fish through the middle of January (Figure 3.2). Steelhead were the second most abundant large fish during that time period and became the most abundant after shad left the area. Other species of fish were typically much less abundant than steelhead. The tendency of shad to swim back and forth across the upstream face of the dam resulted in multiple detections of individuals, and an inflated estimate of shad abundance relative to species such as steelhead that did not move through the DIDSON sampling location as frequently.

To support our assertion that the fish observed by the DIDSON are adult steelhead, we looked for other sources of information on the relative abundance of adult salmonids during the time of year the study was conducted. Adult ladder counts at McNary Dam do not cover the full study period, but adult steelhead made up over 95% of total counts in December and March on average for the years from 2002-2012 (www.fpc.org). The Smolt Monitoring Program at McNary Dam reports the number of adults seen at the Juvenile Fish Facility separator, but only for those months when the Facility is operated. In April of 2009, steelhead made up 98% of those counts (Mensik and Layng 2009). While other species are present during the study period, they make up only a small proportion of total migrants.

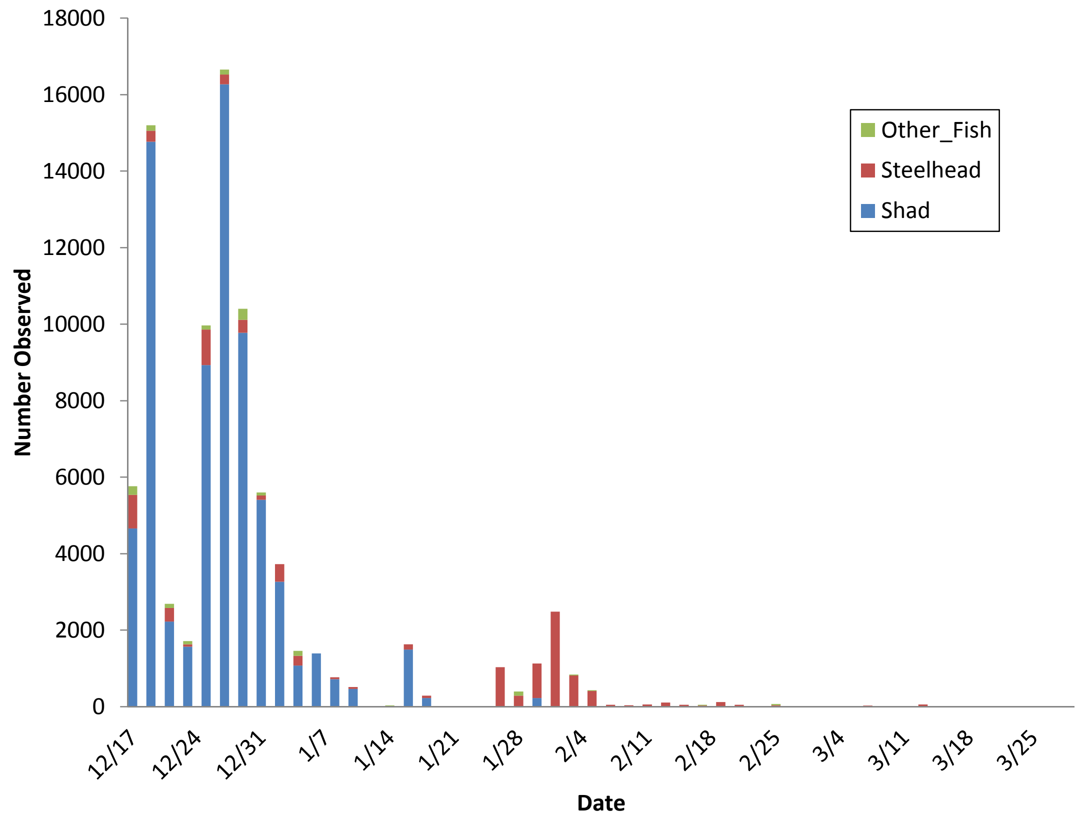

Figure 3.2. Expanded DIDSON Counts of Fish Observed in the Forebay Near Intake 5C and 6A

3.1.3 Dam Operations

The mean hourly discharge of each turbine unit, spillbay, or RSW was calculated from 5-minute interval dam operations data supplied by the USACE. The mean flow for the study period is shown for each route in Figure 3.3. With the exception of units 2 and 7 that were out of service, turbine units were in nearly continuous operation throughout the study period. Turbines operated near the high end of their range during forced spill, but ran closer to peak efficiency during the no spill period. During forced spill, flows were high enough to require that many spillbays be opened.

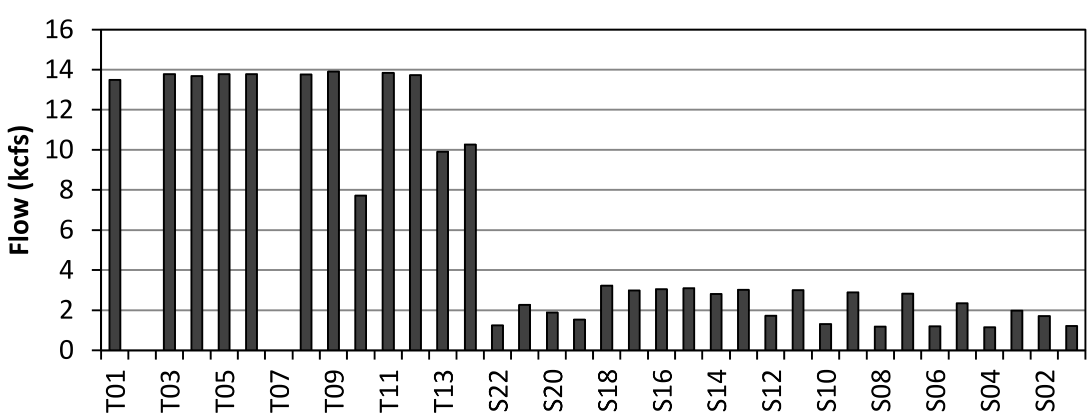

Figure 3.3. Mean Discharge by Location During the Entire Study Period

3.1.4 Operational Groups

Spill has only rarely occurred during the winter at McNary Dam in the ten years prior to this study. The occurrence of forced spill within the study period made it possible to compare periods of no spill at the beginning of the study with periods of spill later in the study. These conditions were not planned treatments, but it was possible to categorize each day into an operational group on the basis of spill occurrence. Because these operational groups were not planned, controlled, or distributed evenly across the study period, an ad hoc analysis is required where the inference is limited to the period of study. Although we hope this analysis provides insight into the influence of spill on passage, the lack of a structured design means that other factors may confound the comparisons we would like to make.

Operational groups were assigned according to the average daily spill proportion (Table 3.1). The operational groups of primary interest were the No_Spill and Forced_Spill periods. In addition, a few days near the end of the study were identified as fish passage plan spill or FPP_Spill. During FPP_Spill, the percent spill increased in part due to the reduced upper limit on turbine operation that is implemented during the juvenile fish passage season. The days early and late within the study period when some or all screens were in place were identified as Screens_In. We were able to collect data when screens were in place, but the fish we counted during that time would be likely to encounter the ESBS and be guided into the bypass, while fish counted during the other operational groups would pass unobstructed into the turbine. Because other groups included few days and few fish passing, our comparisons of operational groups will focus only on No_Spill and Forced_Spill periods.

Table 3.1. Operational Periods By Date

Date	Day	Spill	Screens	Operation	Date	Day	Spill	Screens	Operation
12/17/2010	1	0%	In	Screens_In	2/15/2011	61	41%	Out	Forced_Spill
12/18/2010	2	0%	In	Screens_In	2/16/2011	62	35%	Out	Forced_Spill
12/19/2010	3	0%	In	Screens_In	2/17/2011	63	28%	Out	Forced_Spill
12/20/2010	4	0%	In	Screens_In	2/18/2011	64	22%	Out	Forced_Spill
12/21/2010	5	0%	In	Screens_In	2/19/2011	65	16%	Out	Forced_Spill
12/22/2010	6	0%	In	Screens_In	2/20/2011	66	9%	Out	Forced_Spill
12/23/2010	7	0%	Out	No_Spill	2/21/2011	67	10%	Out	Forced_Spill
12/24/2010	8	0%	Out	No_Spill	2/22/2011	68	13%	Out	Forced_Spill
12/25/2010	9	0%	Out	No_Spill	2/23/2011	69	24%	Out	Forced_Spill
12/26/2010	10	0%	Out	No_Spill	2/24/2011	70	24%	Out	Forced_Spill
12/27/2010	11	0%	Out	No_Spill	2/25/2011	71	24%	Out	Forced_Spill
12/28/2010	12	0%	Out	No_Spill	2/26/2011	72	24%	Out	Forced_Spill
12/29/2010	13	0%	Out	No_Spill	2/27/2011	73	24%	Out	Forced_Spill
12/30/2010	14	0%	Out	No_Spill	2/28/2011	74	28%	Out	Forced_Spill
12/31/2010	15	0%	Out	No_Spill	3/1/2011	75	33%	Out	Forced_Spill
1/1/2011	16	0%	Out	No_Spill	3/2/2011	76	25%	Out	Forced_Spill
1/2/2011	17	0%	Out	No_Spill	3/3/2011	77	21%	Out	Forced_Spill
1/3/2011	18	0%	Out	No_Spill	3/4/2011	78	26%	Out	Forced_Spill
1/4/2011	19	0%	Out	No_Spill	3/5/2011	79	25%	Out	Forced_Spill
1/5/2011	20	0%	Out	No_Spill	3/6/2011	80	23%	Out	Forced_Spill
1/6/2011	21	0%	Out	No_Spill	3/7/2011	81	24%	Out	Forced_Spill
1/7/2011	22	0%	Out	No_Spill	3/8/2011	82	24%	Out	Forced_Spill
1/8/2011	23	0%	Out	No_Spill	3/9/2011	83	23%	Out	Forced_Spill
1/9/2011	24	0%	Out	No_Spill	3/10/2011	84	19%	Out	Forced_Spill
1/10/2011	25	0%	Out	No_Spill	3/11/2011	85	23%	Out	Forced_Spill
1/11/2011	26	0%	Out	No_Spill	3/12/2011	86	24%	Out	Forced_Spill
1/12/2011	27	0%	Out	No_Spill	3/13/2011	87	25%	Out	Forced_Spill
1/13/2011	28	0%	Out	No_Spill	3/14/2011	88	25%	Out	Forced_Spill
1/14/2011	29	0%	Out	No_Spill	3/15/2011	89	28%	Out	Forced_Spill
1/15/2011	30	0%	Out	No_Spill	3/16/2011	90	27%	Out	Forced_Spill
1/16/2011	31	0%	Out	No_Spill	3/17/2011	91	32%	Out	Forced_Spill
1/17/2011	32	0%	Out	No_Spill	3/18/2011	92	28%	Out	Forced_Spill
1/18/2011	33	4%	Out	Forced_Spill	3/19/2011	93	23%	Out	Forced_Spill
1/19/2011	34	19%	Out	Forced_Spill	3/20/2011	94	8%	Out	Forced_Spill
1/20/2011	35	22%	Out	Forced_Spill	3/21/2011	95	16%	Out	Forced_Spill
1/21/2011	36	22%	Out	Forced_Spill	3/22/2011	96	10%	Out	Forced_Spill
1/22/2011	37	28%	Out	Forced_Spill	3/23/2011	97	23%	Out	Forced_Spill
1/23/2011	38	30%	Out	Forced_Spill	3/24/2011	98	24%	Out	Forced_Spill
1/24/2011	39	27%	Out	Forced_Spill	3/25/2011	99	26%	Out	Forced_Spill
1/25/2011	40	18%	Out	Forced_Spill	3/26/2011	100	26%	Out	Forced_Spill
1/26/2011	41	21%	Out	Forced_Spill	3/27/2011	101	24%	Out	Forced_Spill
1/27/2011	42	32%	Out	Forced_Spill	3/28/2011	102	23%	Out	Forced_Spill
1/28/2011	43	28%	Out	Forced_Spill	3/29/2011	103	26%	Out	Forced_Spill
1/29/2011	44	21%	Out	Forced_Spill	3/30/2011	104	26%	Out	Forced_Spill
1/30/2011	45	20%	Out	Forced_Spill	3/31/2011	105	35%	Out	Forced_Spill
1/31/2011	46	21%	Out	Forced_Spill	4/1/2011	106	53%	Out	FPP_Spill
2/1/2011	47	19%	Out	Forced_Spill	4/2/2011	107	55%	Out	FPP_Spill
2/2/2011	48	23%	Out	Forced_Spill	4/3/2011	108	57%	Out	FPP_Spill
2/3/2011	49	21%	Out	Forced_Spill	4/4/2011	109	58%	Out	FPP_Spill
2/4/2011	50	13%	Out	Forced_Spill	4/5/2011	110	59%	In	Screens_In
2/5/2011	51	0%	Out	No_Spill	4/6/2011	111	58%	In	Screens_In
2/6/2011	52	0%	Out	No_Spill	4/7/2011	112	53%	In	Screens_In
2/7/2011	53	0%	Out	No_Spill	4/8/2011	113	48%	In	Screens_In
2/8/2011	54	17%	Out	Forced_Spill	4/9/2011	114	52%	In	Screens_In
2/9/2011	55	20%	Out	Forced_Spill	4/10/2011	115	53%	In	Screens_In
2/10/2011	56	18%	Out	Forced_Spill	4/11/2011	116	52%	In	Screens_In
2/11/2011	57	21%	Out	Forced_Spill	4/12/2011	117	52%	In	Screens_In
2/12/2011	58	20%	Out	Forced_Spill	4/13/2011	118	55%	In	Screens_In
2/13/2011	59	14%	Out	Forced_Spill	4/14/2011	119	54%	In	Screens_In
2/14/2011	60	33%	Out	Forced_Spill					

3.2 Overall Passage

This section describes adult steelhead passage at the powerhouse of McNary Dam for the entire study period, without differentiating ad hoc operational groups. The intent is to illustrate the rate of adult passage overall. All study days are included, unless noted otherwise.

3.2.1 Total Passage

Only 68 acoustic targets with track characteristics consistent with adult steelhead were detected. We refer to these as steelhead because we have not observed other large salmonids in either the DIDSON samples or in visual observations of fish from the surface. Those targets were expanded to account for spatial and temporal sample coverage to an estimate of passage. Downstream passage of adult steelhead through the monitored intakes at the powerhouse of McNary Dam across the entire study period was estimated to be 946 individuals, with 95% confidence bounds extending from 750 to 1142 individuals. If a similar rate of passage through unmonitored routes is assumed, the estimate of total powerhouse passage would be 50% higher at 1419 individuals. Spillway passage was outside the scope of this study, so it was not possible to produce a whole-dam estimate of passage.

3.2.2 Horizontal Distributions

The horizontal distribution of fish entering turbine intakes appeared to be skewed toward the outer turbine units (Figure 3.4). Because four operating units (1, 10, 12, and 14) were not sampled, it is possible that the full distribution could look somewhat different. What would not change is the relatively low passage numbers near the center of the powerhouse, for which sampling coverage was complete.

3.2.3 Vertical Distributions

While we have included all operational periods in the overall passage estimates and plots above, passage during times when screens were in place was excluded from the plot of vertical distributions. The influence of screens on the hydraulics within the intake and especially at the sampling point for this study has the potential to alter the vertical distribution of fish, so excluding those days produces a vertical distribution without that potential for bias. We would exclude the FPP_Spill operational period for similar influences on hydraulics, but an absence of passage during days assigned to that period mean that it would make no difference on the distribution. Most adult steelhead passing into turbine intakes were near the intake ceiling at 282 feet above Mean Sea Level (MSL) (Figure 3.5). For reference, the mean forebay water elevation at McNary Dam during this study was approximately 338.5 feet above MSL. Sampling extended to depths as great as 240 feet above MSL, but no fish were detected passing below 250 feet above MSL (32 feet deeper than the intake ceiling). The relatively small number of targets detected passing into the turbines resulted in these distributions being somewhat clumped around the detections of those individual targets. Greater resolution in these distributions would require more sampling effort, such as sampling all routes and using additional sounders so that each transducer could be sample for a greater proportion of time.

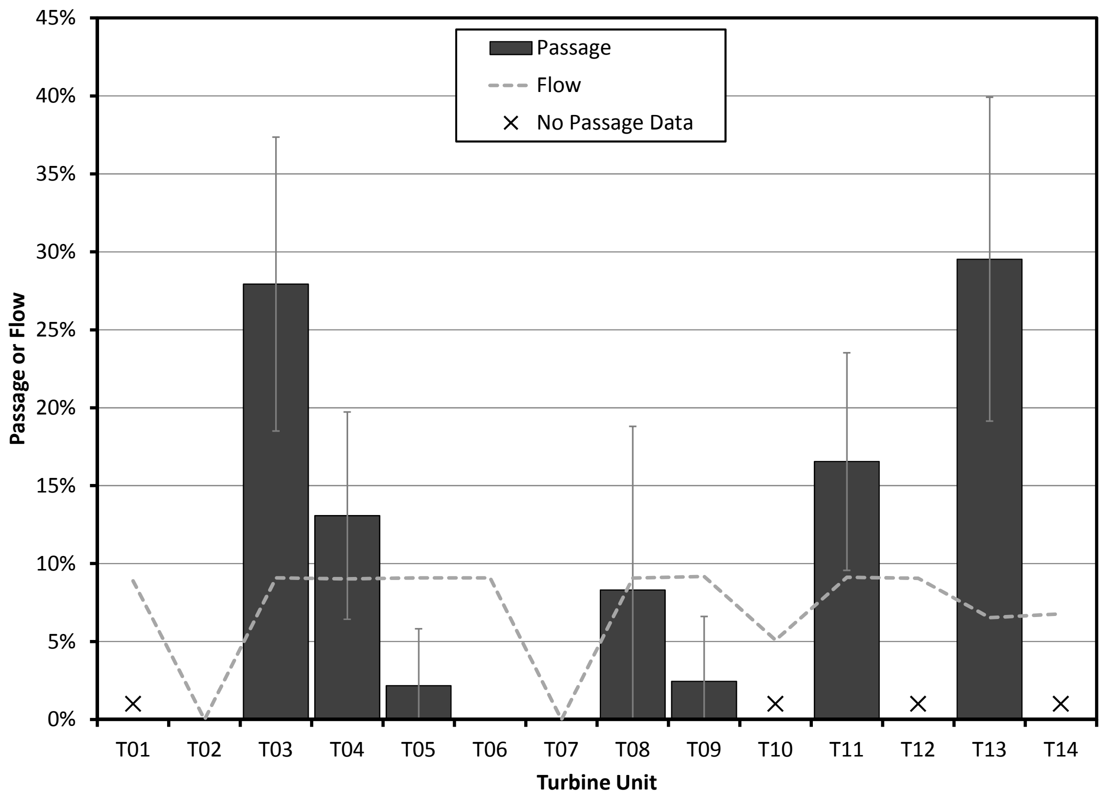

Figure 3.4. Horizontal Distribution of Fish Passing the Powerhouse. Error bars indicate 95% confidence intervals.

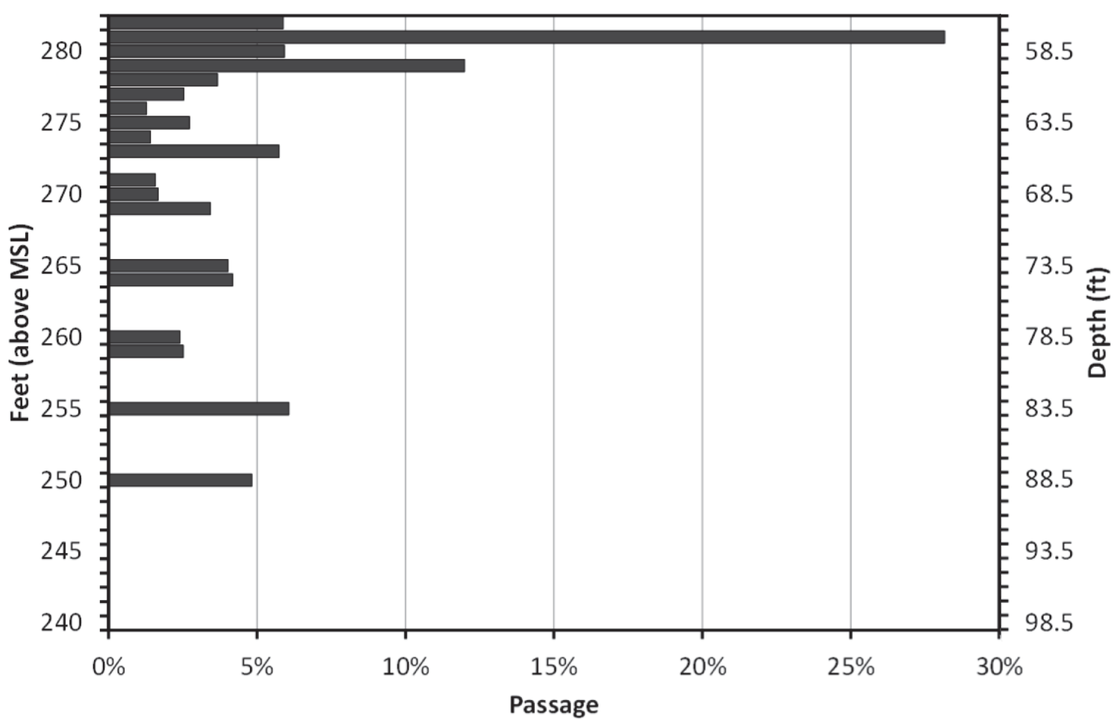

Figure 3.5. Histogram of Vertical Distribution for Sample Period With Screens Removed

3.2.4 Diel Trends

Fish passage often varies through diel cycles of daylight or dam operations. We used civil twilight as the boundary between daylight hours and dark hours for evaluating fish distributions (Table 3.2). The distribution of passage across the diel cycle appears to increase somewhat near noon and is relatively low during hours of darkness (Figure 3.6). The variation among consecutive hours suggests that the small number of targets detected do not provide enough information to reliably estimate a trend in passage through the course of a day. As was the case for spatial distributions, additional sampling effort to increase the chance of detecting more individual fish passing would increase the resolution of temporal distributions.

Table 3.2. Local (Umatilla, Oregon) Sunrise and Sunset Times for the Study Period. Twilight times below are civil twilight Pacific Standard Time. (Data from the U.S. Naval Observatory)

Date	Begin Twilight	Sunrise	Sunset	End Twilight
December 17, 2010 (first study day)	0650h	0734h	1612h	1648h
April 13, 2011 (last study day)	0544h	0615h	1941h	2013h

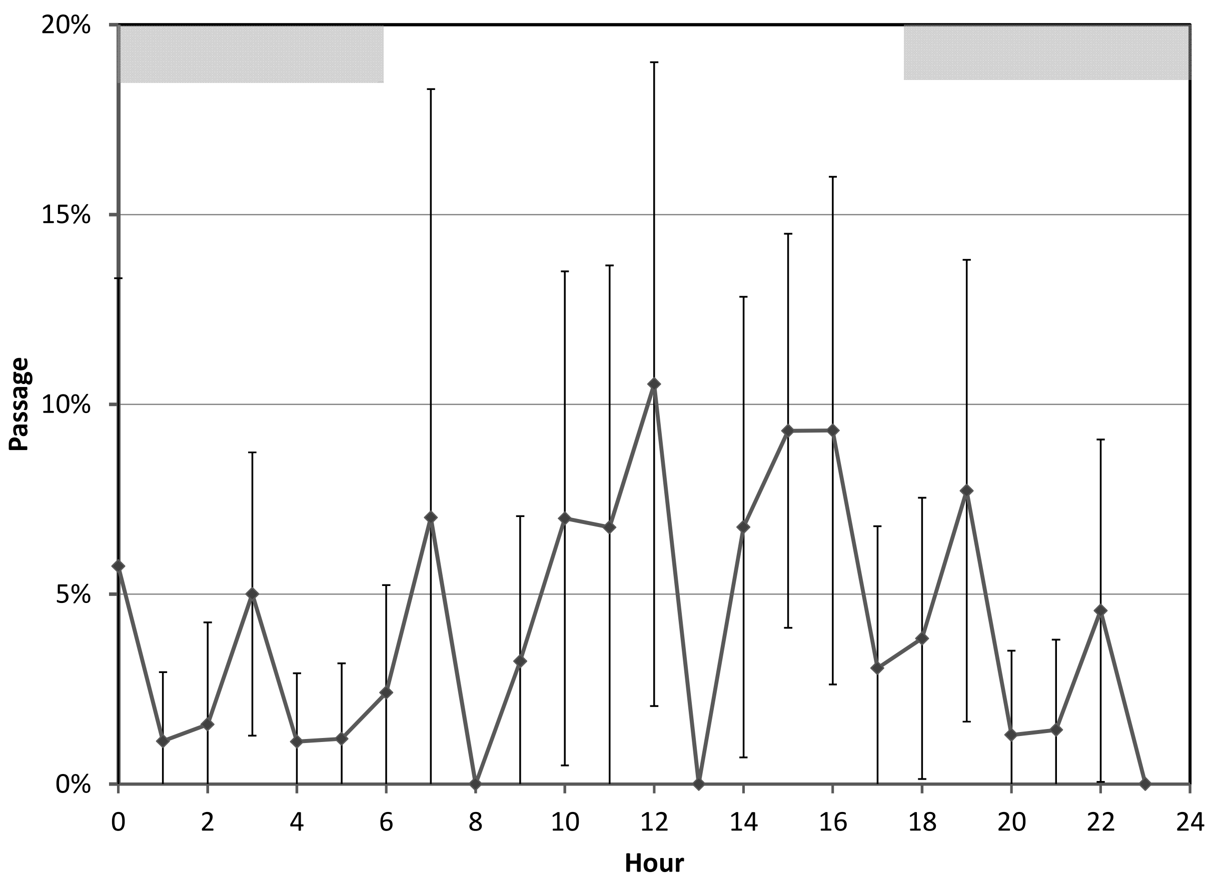

Figure 3.6. Diel Trend of Passage. Shaded blocks indicate hours of darkness. Error bars indicate 95% confidence intervals.

3.3 DIDSON Observations of Fish Behavior in the Forebay

This section addresses observations of fish behavior. The objective is to determine whether the observations suggest that fish detected passing into turbines are likely to be steelhead, or other large fish. Relative abundance of fish in the forebay, the primary objective of the DIDSON, has already been addressed in Section 3.1.2. Shad appeared numerous during the early part of the study, which is a potential concern when estimating steelhead passage. the same individuals multiple times most likely resulted in overestimates of shad abundance. Figure 3.7 illustrates a school of shad moving past intake A at turbine unit 6. In DIDSON videos, shad typically swam back and forth through the sample zone, which is not consistent with entering the turbine intakes. On the basis of those observations, we assume that the tracks detected in fixed aspect hydroacoustic samples were not likely to be shad. This is consistent with other lines of evidence on shad abundance and passage. Shad numbers dwindled rapidly with the onset of spill in mid-January, suggesting that they moved downstream through the spillway in preference to passing turbines. The behavior observed and the lack of correlation among shad numbers and passage counts suggest that shad were not commonly detected passing into turbines.

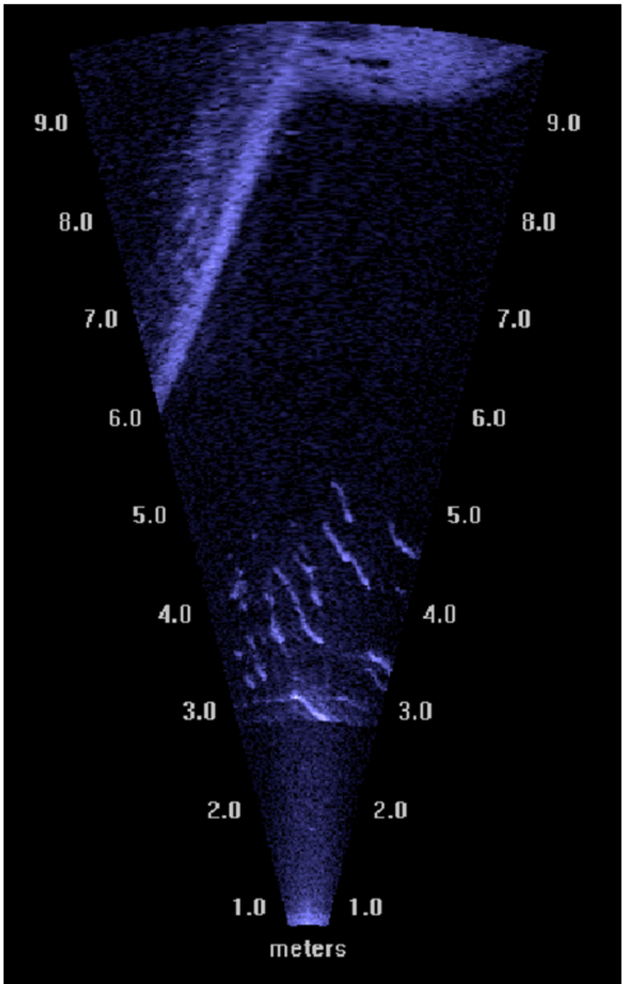

Figure 3.7. DIDSON Image of a School of Adult Shad Swimming Past Turbine Intake 6A. Large structure at top is the concrete above trashrack and the piernose between intakes 6A and 6B.

Adult steelhead were observed milling and slowly swimming just upstream of the intake and trash racks, with much less movement across the powerhouse than shad. Darting behavior was also observed on occasion. During brief periods, up to 20 steelhead adults could be observed milling within the region of a particular intake bay (Figure 3.8). It was not possible to determine with certainty that a steelhead or other fish passed downstream of the trash racks because a fish could exit the volume sampled by the DIDSON in more than one direction. The bulk of adult steelhead observed in the DIDSON samples were moving and behaving in ways that were not suggestive of turbine passage. In contrast to shad, they moved less across the upstream face of the powerhouse and were often closer to trash racks. Behavioral observations suggest that fish are holding upstream of the powerhouse, and the presence of fish in the forebay is not a reliable indicator of the number of fish passing downstream.

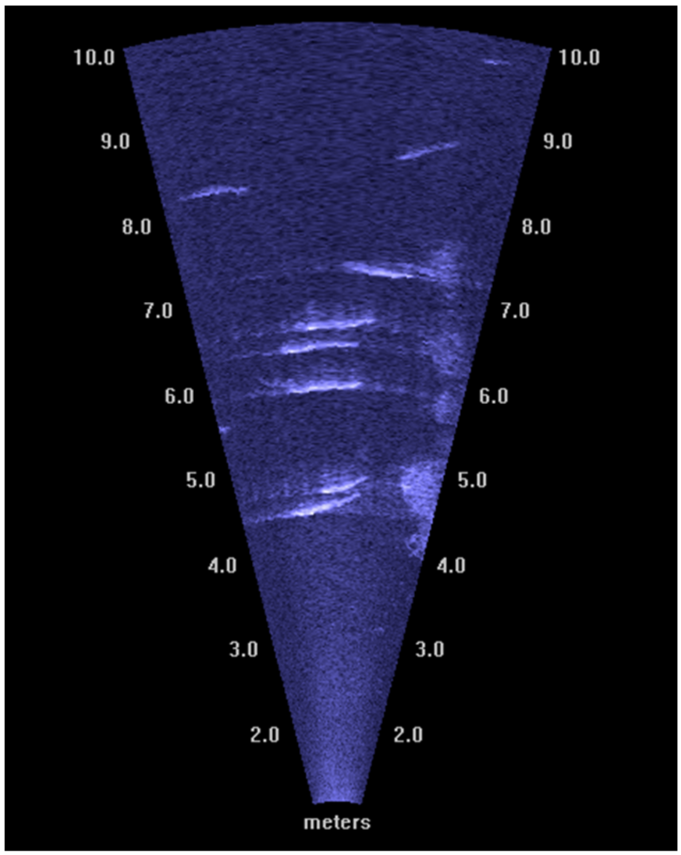

Figure 3.8. DIDSON Image of Several Adult Steelhead Milling Upstream of Intake 5C. Objects to right are tumbleweeds on trash rack.

3.4 Passage by Operational Period

This section reports the results of the analysis of differences in how fish passage at the McNary Dam powerhouse differed during operational conditions identified as No_Spill and Forced_Spill. Spill was not planned during the study period, and was not a typical feature of the period in previous years. For that reason, it is informative to differentiate between these operational conditions to ensure the management implications of the results can be interpreted correctly. If spill is a desired management action, additional study may be required to gauge its effectiveness at passing adult steelhead because spillway passage was not monitored and because the spill conditions were likely not typical of future conditions.

3.4.1 Operational Periods

In the absence of planned treatments, we have chosen to compare passage trends among selected operational periods. The breakdown of operational periods is summarized in Table 3.1 above. The primary operations of interest were No_Spill and Forced_Spill. Too few days were included in the other operational period types so they were excluded from this in-depth analysis. The operational differences between No_Spill and Forced_Spill are illustrated in Figure 3.9. No_Spill was the planned operation, and Forced_Spill occurred when inflows greater than the available turbine capacity were spilled. In addition, turbine flows were usually greater during Forced_Spill than during No_Spill, which would be unlikely to occur in a planned treatment test.

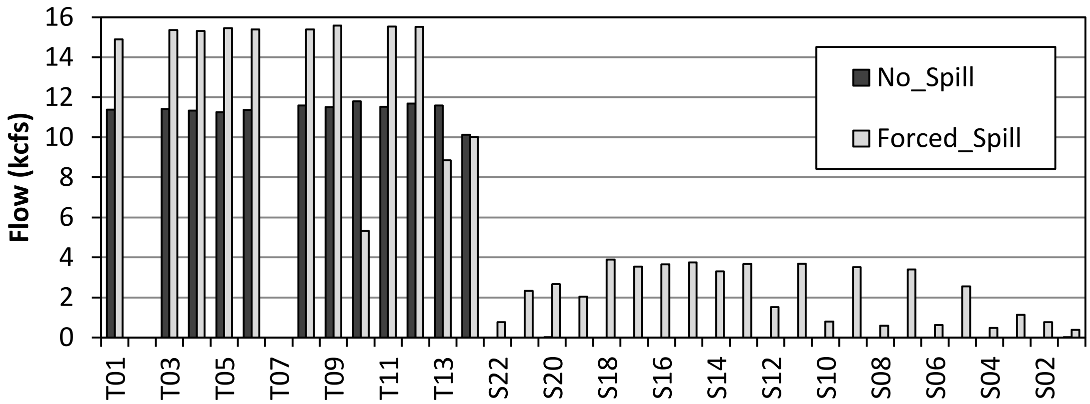

Figure 3.9. Mean Discharge by Location for No Spill and Forced Spill Periods

3.4.2 Daily Passage by Operational Period

Because operational periods were not planned, it is important to consider how they were distributed throughout the study period. Figure 3.10 illustrates daily passage estimates by operational period group. Passage during the No_Spill period, which occurred early in the study period, was highest around 24 December 2010, and declined through early January of 2011. Passage increased as the Forced_Spill period began in mid-January, but was low for all days after about 5 February 2011 (Figure 3.10). Passage during the Screens_In period was low in 2010 (first 6 days of the study) and negligible in 2011 (last 10 days of the study). No fish were detected passing during the brief FPP_Spill period late in the study. Table 3.1 illustrates when operational periods were in effect. Comparing the trends in Figure 3.10 with the DIDSON counts in Figure 3.2 does not reveal a close correlation of fish presence and apparent abundance in the near forebay with passage counts, even during periods when no water was spilled. Confidence intervals are relatively large due to the small number of individuals detected passing into turbines and the expansion of those counts in space and time to account for sample coverage.

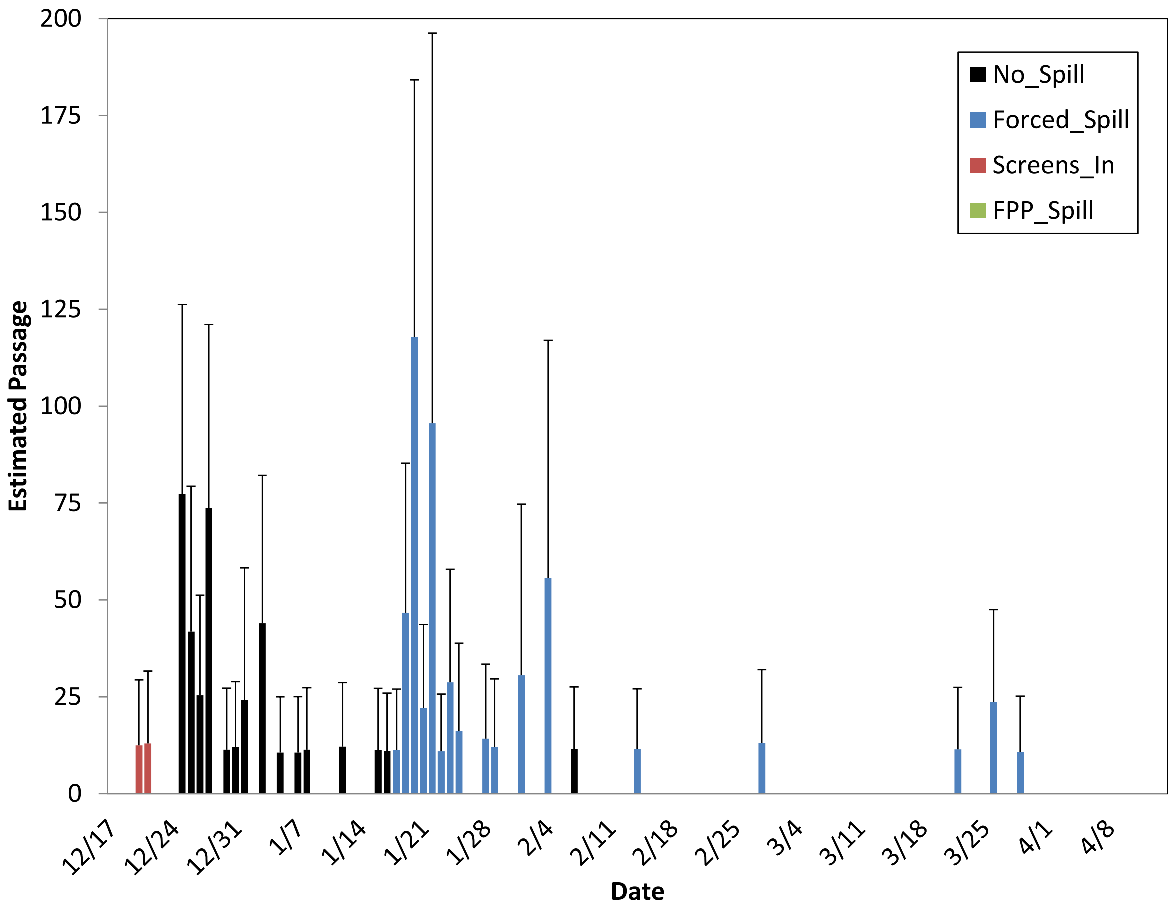

Figure 3.10. Hydroacoustic Estimates of Daily Passage by Operational Period. Error Bars indicate upper 95% confidence bounds.

3.4.3 Horizontal Distributions by Operational Period

The horizontal distributions of adult fish passing the McNary Dam powerhouse appeared skewed toward the north and south extremes of the powerhouse. Passage at units near the center of the dam was typically lower (Figure 3.11). The large confidence bounds around passage at individual routes suggest that caution is warranted when interpreting the apparent differences between No_Spill and Forced_Spill periods. It is notable that passage at turbine unit 13, the nearest sampled unit to the spillway, was higher during Forced_Spill, even though the difference would not be statistically significant. A similar trend was evident at turbine unit 3 on the other end of the powerhouse. The relatively low flow at turbine unit 10 during Forced_Spill appeared to result in a lower proportion of passage in the adjacent monitored units (9 and 11), rather than a higher proportion. Confidence bounds around estimates are broad, but the apparent differences suggest that passage is increasing near where flows in the vicinity of the route are higher and decreasing where flows in the vicinity of the route are lower. That is, passage does not appear to be related only to the flow within the individual route of passage, but also to the distribution of flows through adjacent routes and across the dam.

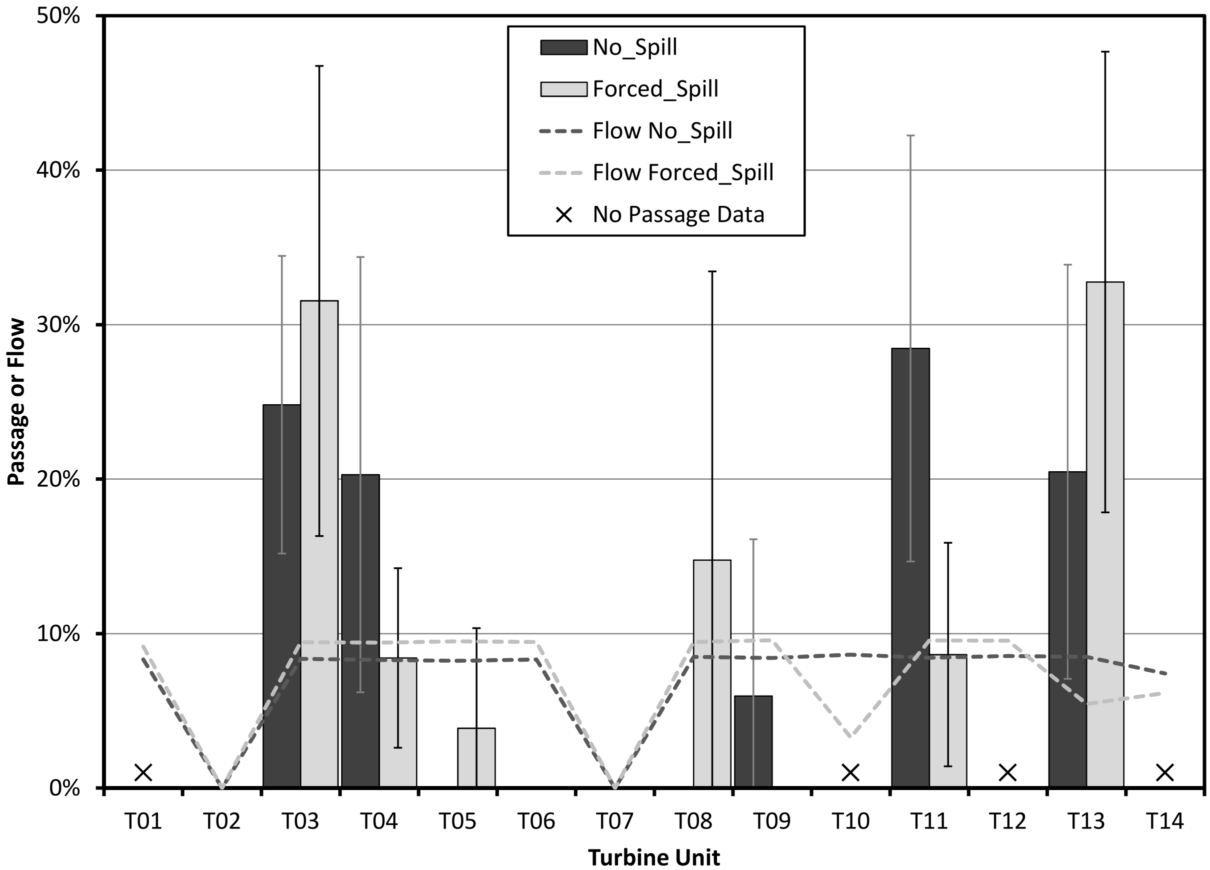

Figure 3.11. Horizontal Distribution of Fish Entering Turbine Intakes by Operational Period. Error bars indicate 95% confidence intervals.

3.4.4 Vertical Distributions by Treatment

During the No_Spill operational period, fish passage appeared to be skewed toward the intake ceiling. More fish passed at greater depths during the Forced_Spill operational period, but the bulk of passage was still near the intake ceiling. The differences in vertical distribution could be interpreted to suggest that fish that would pass near the intake ceiling during No_Spill operations may be passing the spillway during Forced_Spill operations. Unfortunately, the confounding of time and the operational periods means there are other possible explanations that cannot be evaluated. The relatively small number of targets detected passing into the turbines results in these distributions being somewhat clumped around the depths where individuals were detected, especially at greater depths where the cross section of the acoustic beam is smaller, resulting in greater expansion of targets detected at those depths. A greater sampling intensity (a higher proportion of time) would reduce how clumped these distributions appear.

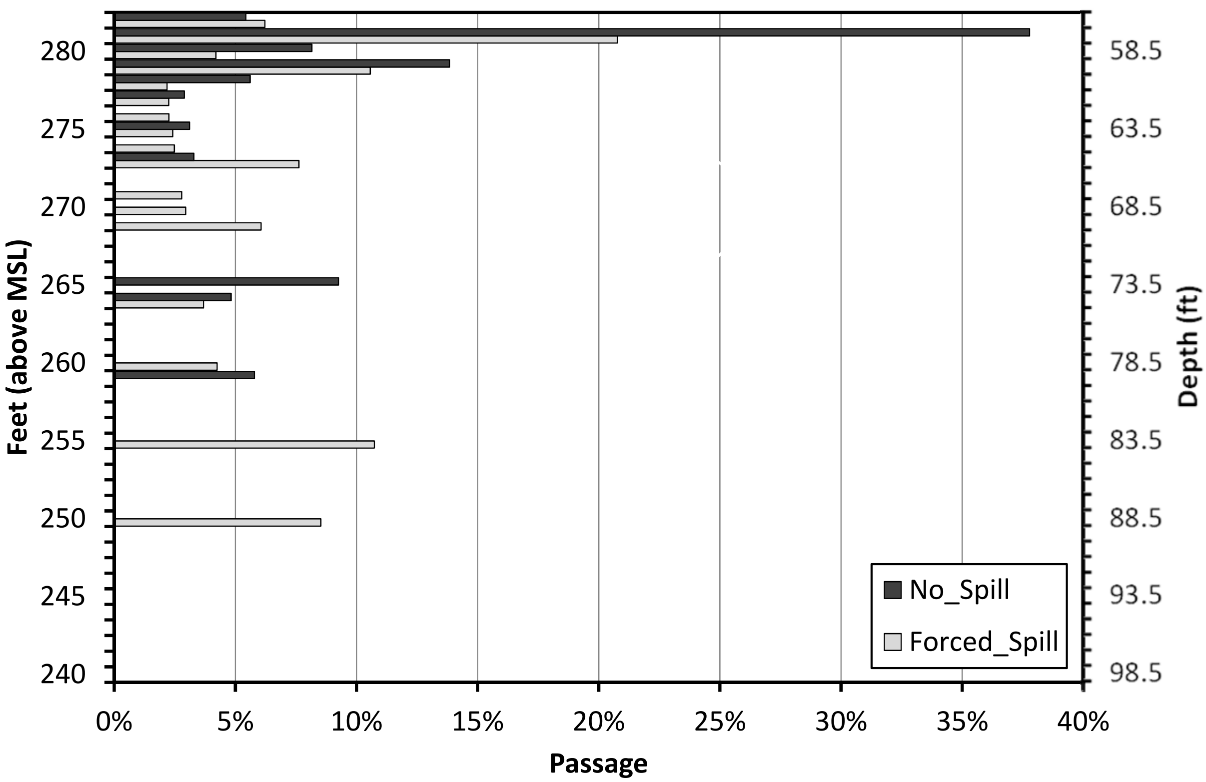

Figure 3.12. Histogram of Vertical Distribution for No_Spill and Forced_Spill Periods

4.0 Conclusions

This study focused on the number and distribution of adult steelhead passing downstream through the powerhouse at McNary Dam. Unplanned spill for part of the study period created an opportunity to compare and contrast passage among periods with and without spill.

4.1 Overall Fish Passage

About 950 adult steelhead were estimated to be passing the turbine units sampled in this study at McNary Dam in 2010 and 2011, and if we speculate that a similar number were passing the unmonitored operating turbine units, the estimate for the entire powerhouse would be around 1400.

We speculate that numerous adult steelhead passed downstream through the spillway at McNary Dam when it was open during the present study. This speculation cannot be confirmed because spill was not planned to occur during the study period, and sampling was not implemented at the spillway.

4.2 Fish Passage During No_Spill and Forced_Spill Operational Periods

Unplanned spill created an opportunity to compare passage and distribution of passage between No_Spill and Forced_Spill operational periods. The inference of those comparisons is limited to the current study period because time and operational period were confounded. During the earlier part of the season when No_Spill conditions occurred, passage was variable among days and tended to decline later during the period. At the onset of Forced_Spill conditions, daily rates of passage were higher still, were variable among days, and declined through time.

The horizontal distributions of adult fish passing the McNary Dam were not well defined due to the low numbers of individuals (68) detected passing the turbines. Apparent differences suggest that passage at a given route may be higher if it is adjacent to routes where flows are not low, relative to routes dam-wide, but may be lower if it is adjacent to routes where flows are low, relative to routes dam-wide.

During No_Spill conditions, steelhead tended to pass into the turbines near the intake ceiling. During Forced_Spill conditions fish passage was distributed at greater depth. The differences in vertical distribution suggest that fish that would pass near the intake ceiling during No_Spill operations may be passing the spillway during Forced_Spill operations.

4.3 Recommendations for Future Work

The variability of estimates and the clumped nature of spatial distributions that were evident in the estimates of passage is partially a consequence of the small number of individuals that are passing, which we have no control over. It is also partially a consequence of our approach to sampling, which was to subsample in both space and time. This is an approach that is cost effective for the more numerous migrating juvenile salmon and steelhead, but adult passage estimates may benefit from a higher proportion of sampling coverage. There are two ways to provide increased coverage. One is to increase the number of transducers deployed to sample all of the routes rather than two thirds of the routes. Another is to increase the number of sounders so that each transducer is sampled a greater proportion of the time. Both approaches are likely to be of value in improving our ability to resolve spatial and temporal distributions of passage.

5.0 References

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Appendix A

Equipment Configuration and Settings

Appendix A

Equipment Configuration and Settings

Tables A.1 and A.2, respectively, list configurations and settings for the sampling equipment.

Table A.1. Configurations of Sounder Systems Including Multiplexers, Transducers, and Cables, Including Locations and Sampling Rates

Description	S/N	Beam Width	Multiplexer Port	Location	Cable Lengths 4-ch	6-ch	S/N	Xducer Aiming Angle	Elevation (ft)	Pings/ Second
System McN_C										**21.4**
SPB Sounder						**470**				
Remote Multiplexer										
SPB Xducer 1	**452**	**6°**	**00**	**Unit 3A**	**313**		**205**	**31° downstream of vertical**	**239**	
SPB Xducer 2	**494**	**6°**	**02**	**Unit 4A**	**313**		**153**	**31° downstream of vertical**	**239**	
System McN_K										**21.4**
SPB Sounder						**470**				
Remote Multiplexer										
SPB Xducer 1	**489**	**6°**	**00**	**Unit 11A**	**313**		**182**	**31° downstream of vertical**	**239**	
SPB Xducer 2	**490**	**6°**	**01**	**Unit 13A**	**313**		**196**	**31° downstream of vertical**	**239**	
System McN_L										**18.8**
SPB Sounder						**235**				
Remote Multiplexer										
SPB Xducer 1	**492**	**6°**	**00**	**Unit 5A**	**313**		**197**	**31° downstream of vertical**	**239**	
SPB Xducer 2	**493**	**6°**	**10**	**Unit 6A**	**313**		**189**	**31° downstream of vertical**	**239**	
Local Multiplexer						**470**				
SPB Xducer 3	**470**	**6°**	**31**	**Unit 8A**	**313**		**154**	**31° downstream of vertical**	**239**	
SPB Xducer 4	**471**	**6°**	**32**	**Unit 9A**	**313**		**155**	**31° downstream of vertical**	**239**	

Table A.2. Operating Settings for Sounder Systems by Transducer

Static Transmit Power	Installed System	Channel	Location (Unit)	Sounder Number	Trans-ducer Serial Number	Receiver Gain (L) (db)	Source Level (SL) (db)	Receiver Sensitivity (db)	Target Strength of Smallest On-Axis Target (db)	Voltage of Smallest On-Axis Target at 20 dB per Volt (V)	Target Strength of Largest On-AxisTarget of Interest (db)	Voltage of Largest On-Axis Target at 20 dB per Volt (V)
-4	C	00	3A	50	452	6.50	215.61	-106.11	-56	3.0	-26	4.5
-4	C	02	4A	50	494	5.50	216.67	-106.17	-56	3.0	-26	4.5
-4	K	00	11A	51	489	6.25	214.37	-104.62	-56	3.0	-26	4.5
-4	K	01	13A	51	490	6.75	214.19	-104.94	-56	3.0	-26	4.5
-3	L	00	5A	52	492	0.75	217.80	-102.55	-56	3.0	-26	4.5
-3	L	10	6A	52	493	0.75	217.80	-102.55	-56	3.0	-26	4.5
-3	L	31	8A	52	470	5.75	215.64	-105.39	-56	3.0	-26	4.5
-3	L	32	9A	52	471	5.75	216.10	-105.35	-56	3.0	-26	4.5

Appendix B

Raw Data

Appendix B

Raw Data

Raw data are included in the attached file, “MCN_2011_Appendix_B_Raw_Data.csv.” The attached file, “MCN_2011_Appendix_B_Raw_Data_Metadata.csv,” contains metadata describing the data fields in the raw data file.

Appendix C

Effective Beam Widths

Appendix C

Effective Beam Widths

The effective beam width is calculated from a detectability model. Inputs to this model include fish speeds and trajectories as well as the sensitivity and beam pattern of each transducer. These inputs come from split-beam data of actual fish paths and from the equipment calibration process, respectively. The output forms the basis for expanding the fish counts. As shown below, the effective beam width varies by range and among systems. The large targets of interest to this study are often detectable outside the nominal beam width of 6 degrees. System K detectability was slightly lower because a slower ping rate (18.75 versus 21.43) was used for that system to reduce problems from reverberation (unwanted echoes bouncing off intake walls). Figure C.1 shows the effective beam widths used in this study.

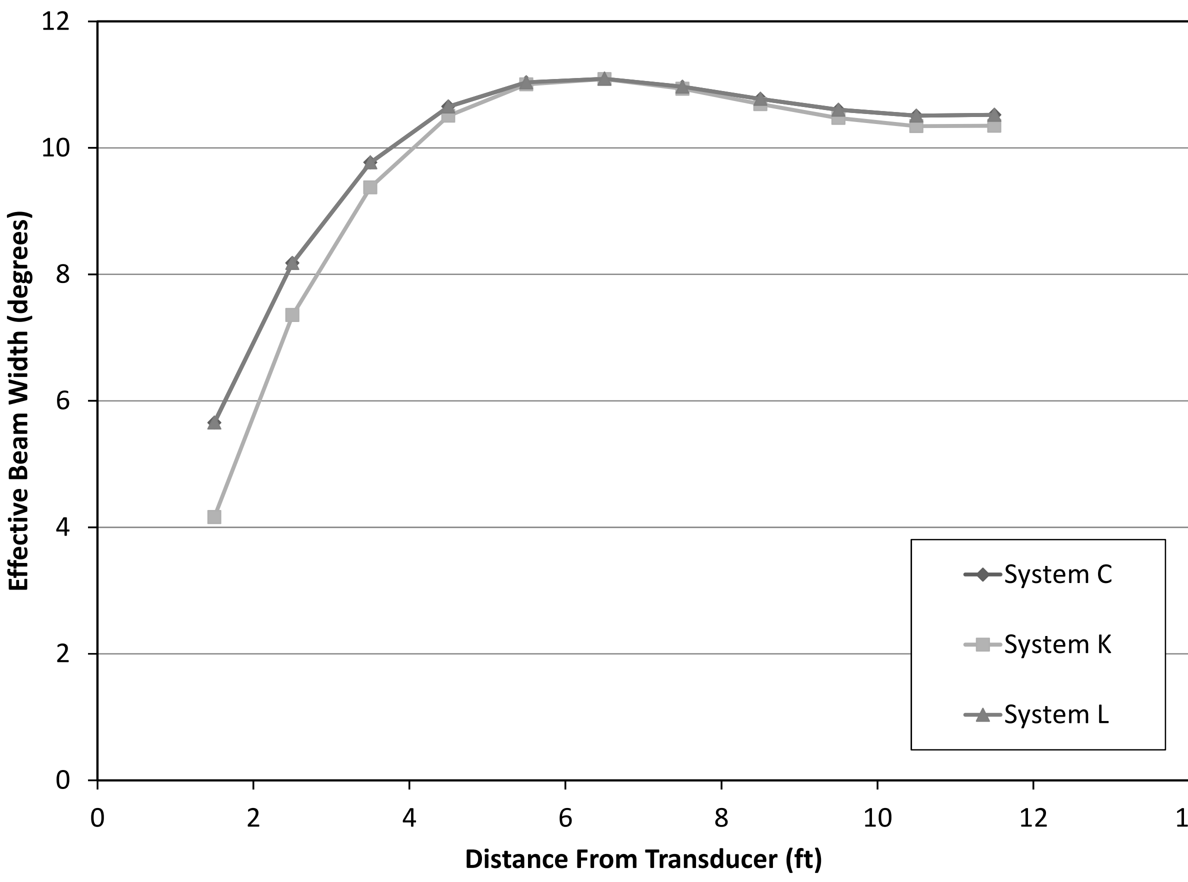

Figure C.1. Effective Beam Widths by System

Appendix D

Statistical Methods

Appendix D

Statistical Methods

The purpose of this synopsis is to describe the statistical methods used in the analysis of the 2010/2011 hydroacoustic study of adult steelhead passage at McNary Dam. The study estimated fish passage through the powerhouse during the winter and early spring, prior to the juvenile salmonid migration periods. The estimates of fish passage were also combined to illustrate the vertical and horizontal distributions of fish passing the turbines.

D.1 Estimating Fish Passage

When a fish passes through the beam of a hydroacoustic sensor, echoes are recorded to indicate when and where the fish passed through the beam. Those echoes are processed into tracks that are processed to quantify the number of fish passing through a given route. The following sections describe the processing steps required to convert track counts into estimates of smolt passage.

D.1.1 Fish Passing Through the a Turbine

The breadth of a turbine can be envisioned as being subdivided into three strata. Within each stratum, fish passage is independently monitored over time. Total turbine fish passage can then be estimated as

$$\hat{\mathrm{T}} = \sum_{i=1}^{D} \sum_{j=1}^{24} \frac{C_{ij}}{c_{ij}} \sum_{k=1}^{c_{ij}} t_{ijk} , \tag{D.1}$$

where t_{ijkl} = expanded fish count in the *k*th sampling unit $\left(l = 1, \ldots, c_{ijk}\right)$ in the *j*th hour $\left(j = 1, \ldots, 24\right)$ of the *i*th day $\left(i = 1, \ldots, D\right)$;

c_{ij} = number of sampling units actually observed in the *j*th hour $\left(j = 1, \ldots, 24\right)$ of the *i*th day $\left(i = 1, \ldots, D\right)$;

C_{ij} = total number of sampling units within the *j*th hour $\left(j = 1, \ldots, 24\right)$ of the *i*th day $\left(i = 1, \ldots, D\right)$.

Nominally, C_{ijk} = 30 and $c_{ij} = 15 \quad \forall ij$. Based on the assumptions of simple random sampling within the hour, then

$$\widehat{\mathrm{Var}}\left(\hat{\mathrm{T}}\right) = \sum_{i=1}^{D} \sum_{j=1}^{24} \left[\frac{C_{ij}^2 \left(1 - \frac{c_{ij}}{C_{ij}}\right) s_{t_{ij}}^2}{c_{ij}} \right], \tag{D.2}$$

where: $s_{t_{ij}}^2 = \frac{\sum_{l=1}^{c_{ij}} \left(t_{ijk} - \overline{t_{ij}}\right)^2}{\left(c_{ij} - 1\right)}$

and where: $\overline{t_{ij}} = \frac{\sum_{l=1}^{c_{ij}} t_{ijk}}{c_{ij}}$

D.2 Comparing Passage Conditions

Because passage was monitored at the powerhouse only, measures of passage efficiency and effectiveness are not a part of this study.

D.3 Confidence Interval Estimation

For all estimated passage and performance parameters (e.g., θ), confidence interval estimates were based on the assumption of asymptotic normality. Interval estimates were calculated according to the formula

$$\text{CI}\left(\hat{\theta} - Z_{1-\frac{\alpha}{2}} \sqrt{\widehat{\text{Var}}\left(\hat{\theta}\right)} < \theta < \hat{\theta} + Z_{1-\frac{\alpha}{2}} \sqrt{\widehat{\text{Var}}\left(\hat{\theta}\right)}\right) = 1 - \alpha \quad \text{(D.3)}$$

where $Z_{1-\frac{\alpha}{2}}$ = standard normal deviate corresponding to the probability $P\left(\left|Z\right| < Z_{1-\frac{\alpha}{2}}\right) = 1 - \alpha$.

For example, a Z-value of 1.96 is used to construct a 95%-confidence interval. The interval estimate, using Equation D.3, characterizes the statistical uncertainty associated with the measurement of a fish passage or performance parameter.