PNWD-4362

Hydroacoustic Evaluation of Adult Steelhead Fallback and Kelt Passage at McNary Dam, Winter 2011-2012

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 0008

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Summary

In the winter of 2011–2012, Battelle−Pacific Northwest Division conducted a second year of 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 Dam project.

Adult steelhead passage was monitored at 12 of 14 turbine units from December 1, 2011 through April 16, 2012. The two units that were not monitored (1 and 10) were expected to be out of service for the duration of the study, but they returned to service in the latter portion of the study. Fixed-aspect hydroacoustics were used to estimate the number of fish entering each monitored turbine intake unit. Sampling coverage was increased to 12 units, which is a 50% increase over the previous study year. This appears to have achieved the intended goal of better defining distributions and reducing confidence intervals around estimates.

A BlueView high-resolution multibeam acoustic imaging device was used to monitor the region just upstream of the trash rack at unit 6A in order to verify presence and estimate relative abundance of adult steelhead and similar-sized individuals of other species in the forebay of McNary Dam.

Typical McNary Dam winter operations do not include spill; turbine intake guidance screens are removed for maintenance and adult ladders are taken out of service for maintenance (one at a time between January 1 and February 28). As a result, turbines are the primary downstream passage route for fish such as pre-spawning adult steelhead and kelts during this period. During the last 5 weeks 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 1786 (±116) individuals. If a similar rate of passage through the two unmonitored turbine intakes is assumed, the estimate of total powerhouse passage would be 6% higher at 1893 individuals. 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 2011–2012 study at McNary Dam, but trends in turbine passage changed only slightly with the onset of spill.

The distribution of passage among turbine units was similar to the 2010–2011 study, in that passage was greatest at turbine units nearer the north or south ends of the powerhouse, and least near the center of the powerhouse. Passage was concentrated near the ceiling of the turbine intake. Very few fish passed at depths well below the intake ceiling.

Acknowledgments

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Abbreviations and Acronyms

Battelle	Battelle–Pacific Northwest Division
cm	centimeter(s)
dB	decibel(s)
ESA	Endangered Species Act of 1973
ESBS	extended-length submersible barrier screen
FCRPS	Federal Columbia River Power System
ft	foot(feet)
JBS	juvenile bypass system
kHz	kilohertz
m	meter(s)
MSL	mean sea level
MW	megawatt(s)
μPa	micropascal(s)
PAS	Precision Acoustic Systems, Inc.
PIT	passive integrated transponder
pps	pings per second
USACE	U.S. Army Corps of Engineers

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1.0 Introduction

This report presents the results from a hydroacoustic evaluation of adult steelhead passing downstream through the powerhouse at McNary Dam that was 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 2011–2012, estimated the number of steelhead adults, including kelts, 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 through 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. A 2010–2011 hydroacoustic evaluation of adult steelhead passage (Ham et al. 2012) found limited numbers of adult steelhead passing through turbines, but unplanned spill during the latter half of that study may have resulted in lower than average turbine passage. The 2011–2012 study was intended to supplement those results and spill was considered unlikely on the basis of flow forecasts available at the initiation of the study.

Several Columbia River steelhead populations were listed as threatened under the Endangered Species Act of 1973 (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 rivers 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 1 year at sea and the adults migrating upstream normally pass McNary Dam from late June through August. The B-group spends 2 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 rivers, 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 enter the Columbia River in May through September and pass Rock Island Dam from July through the following May. Fish that pass Rock Island Dam in the spring will overwinter in the main-stem 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; they 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 screens (ESBSs) are not in place may be susceptible to significant injury. This is of particular concern with reference to B-group steelhead that, because of their larger size, may be more vulnerable to adverse effects when passing through a turbine. The turbine is typically the primary route of passage available to adult steelhead travelling downstream during a portion of the winter when adult ladders are closed for maintenance (one at a time between January 1 and February 28), 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). Reischel and Bjornn (2003) and Boggs et al. (2004) describe fallback behavior 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 FCRPS Biological Opinion calls for the USACE and Bonneville Power Administration to create and update a “Snake River Steelhead Kelt Management Plan” in coordination with National Oceanic and Atmospheric Administration Fisheries and the Regional Forum. The goal is to improve the productivity of interior basin B-group steelhead populations by 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 adult steelhead 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 adult steelhead within the turbine intake was monitored to assess how deep they were when they entered the intake. The horizontal distribution among turbine units at the powerhouse was also monitored to identify the region where passage was most prevalent. This vertical and horizontal distribution information will help evaluate potential surface bypass improvements or other alternatives to reduce turbine passage of adult steelhead, especially during periods when other routes are not available.

1.2 Objectives

The winter study was planned to run from December 1, 2011 to April 16, 2012. 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 and it includes a navigation lock, a spillway, and a powerhouse. The dam structure is 7365 ft 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 ft long and contains fourteen 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.

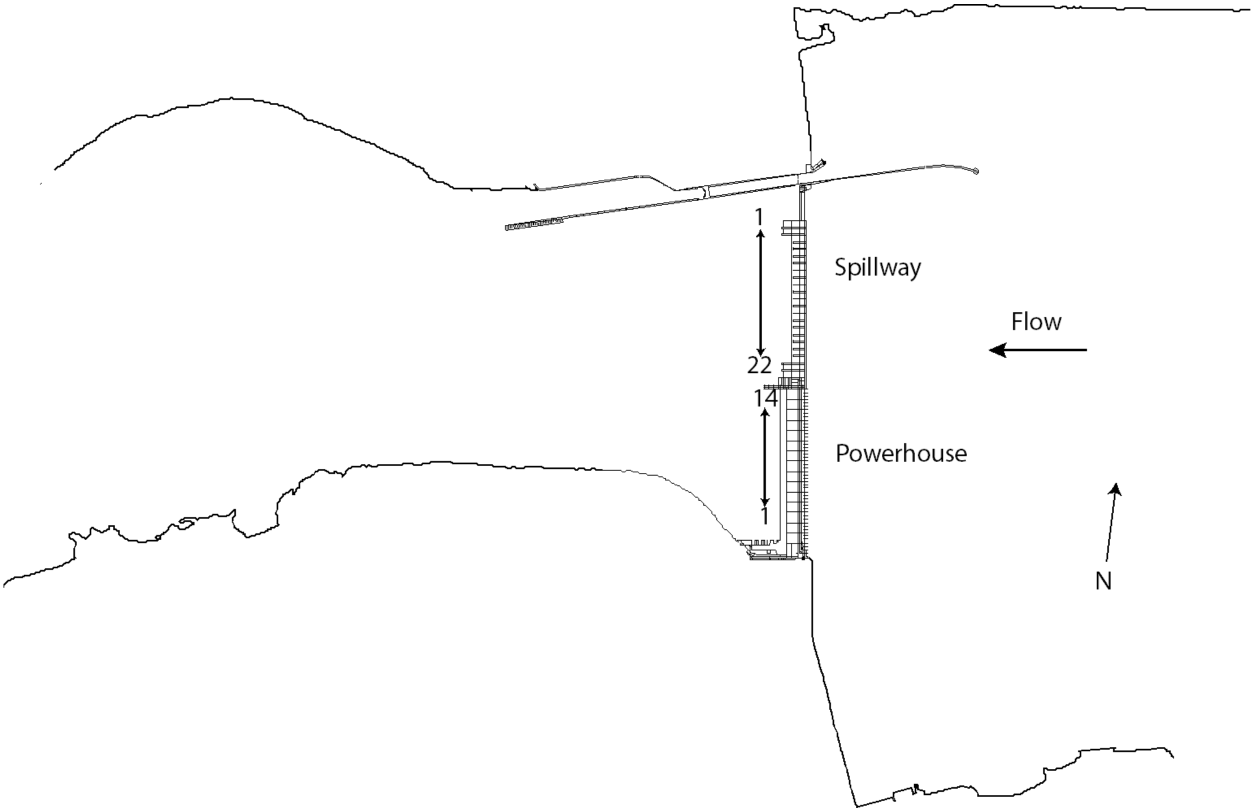

Figure 1.1. Plan View of McNary Dam Illustrating the Location of the Spillway and Powerhouse

Turbine unit intakes are fitted with ESBSs during the juvenile fish passage season. The 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 current JBS at McNary Dam became operational in 1994.

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). A 10-MW hydropower unit located on the Washington shore is 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.

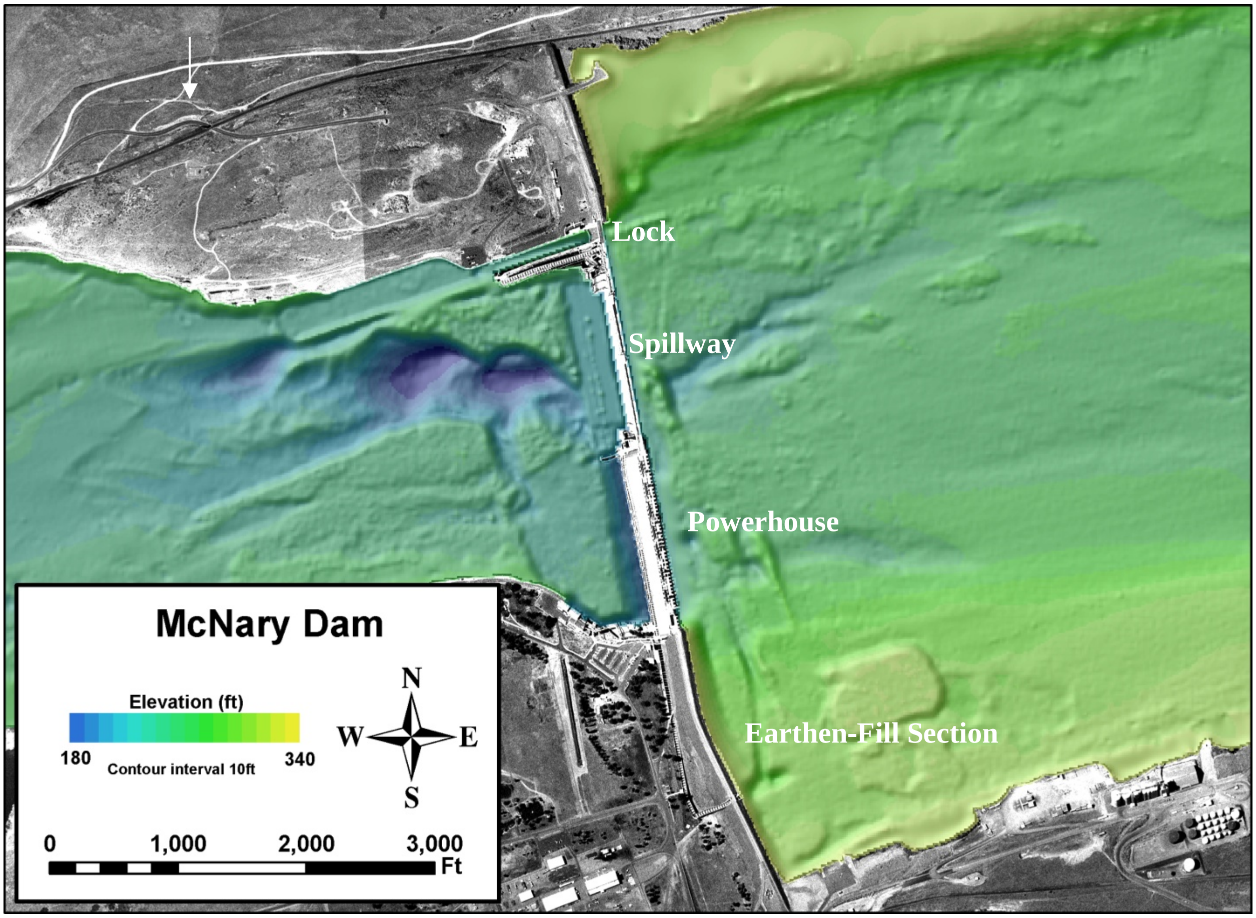

Figure 1.2. Plan View of McNary Dam Major Structural Features Showing River Bathymetry

1.4 Report Contents and Organization

The ensuing sections of this report present the results of a study of adult steelhead fallbacks and kelt downstream passage at McNary Dam in the winter of 2011–2012. 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. Chapter 4.0 provides our conclusions. Appendices 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 Methods

The fixed-aspect hydroacoustic approach was used to quantify the number of adult sized acoustic targets passing through the powerhouse at McNary Dam during the winter of 2012. Split-beam transducers were used to detect passing adult fish and to quantify horizontal and vertical passage distributions using the acoustic screen model. A BlueView sonar imaging device (sometimes referred to as an acoustic camera) was used on the upstream face of the dam to identify species present in the forebay and their relative abundance, behavior, and size 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 by classifying the study into periods based on operational characteristics.

2.2 Hydroacoustic Sampling System

Hydroacoustic transducers were used to detect adult fish passing into the turbines. The details of hydroacoustic equipment installations are described in this section. Data collection relied on six 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 Precision Acoustic Systems, Inc. (PAS) Harp–SB Split-Beam Data Acquisition/Signal Processing Software; a DOS-based application that controlled a PAS-103 Split-Beam Multi-Mode Scientific Sounder. Each PAS-103 Split-beam Sounder controlled a PAS-203 Split-Beam 4-Channel Transducer Multiplexer that multiplexed two 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 (pps) are typically used during juvenile studies, where conditions permit. Due to high levels of reverberation within the turbine intakes, ping rates were reduced to 20 pps 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 (these are created as the output of the detectability model) well beyond the nominal widths. Each transducer was sampled in sequence 15 times per hour for 117-second intervals. 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, 7 days a week. The sounder and the data-acquisition equipment were housed in three equipment shacks on the forebay deck for the duration of the experiment.

Twelve PAS 420-kHz split-beam transducers with a nominal beam angle of 6 degrees were used to sample adult fish passing downstream through a randomly selected slot in units 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, and 14 (Figure 2.1), with each split-beam sounder sampling two intake slots. Transducers were attached to the center of the trash rack horizontal member at an elevation of 239 ft above mean sea level (MSL), oriented to look up towards the intake ceiling and aimed 31 degrees downstream of the trash rack plane (Figure 2.2). 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

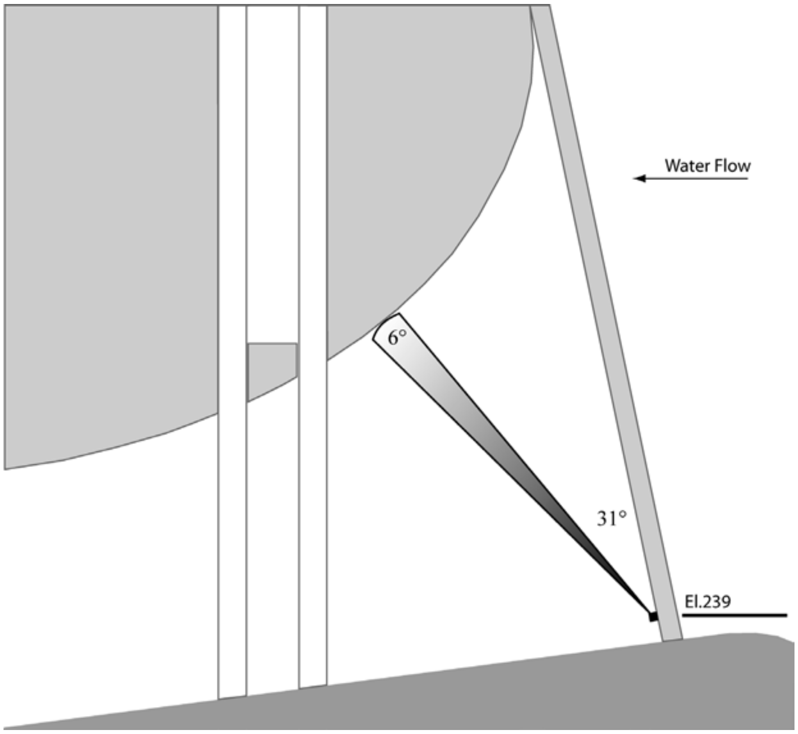

Figure 2.2. Side View of the Unit Intake Split-Beam Transducer Deployment. Each transducer was mounted on the trash rack at an elevation of 239 ft, aimed downstream 31 degrees from the trash rack plane.

2.3 BlueView Sonar Imaging System

A BlueView P-900-45 high-resolution multibeam sonar system was used at unit 6 (looking across slots A and B) to estimate the relative abundance of adult steelhead and similar-sized individuals of other species just upstream of the trash racks. The BlueView, using an ultrasonic signal at a frequency of 900 kHz, provided a way to visualize fish shapes and movement under conditions where optical cameras would be severely limited by turbidity or the absence of light (Figure 2.3). A similar multibeam sonar system (DIDSON) was successfully applied at The Dalles Dam on the Columbia River to image adult steelhead entering the powerhouse sluiceway structure (Khan et al. 2009), and at McNary Dam in 2010–2011 study to estimate the relative abundance and behavior of adult steelhead upstream of the trash racks (Ham et al. 2012). In the present study, using a previously installed slotted pipe located on the main pier nose between units 5 and 6, the BlueView was deployed to an elevation of 327 ft above MSL and sampled a volume 45 degrees wide and 20 degrees in deep (Figure 2.4). The BlueView 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.

Figure 2.3. BlueView Sonar Attached to Trolley and Ready for Deployment

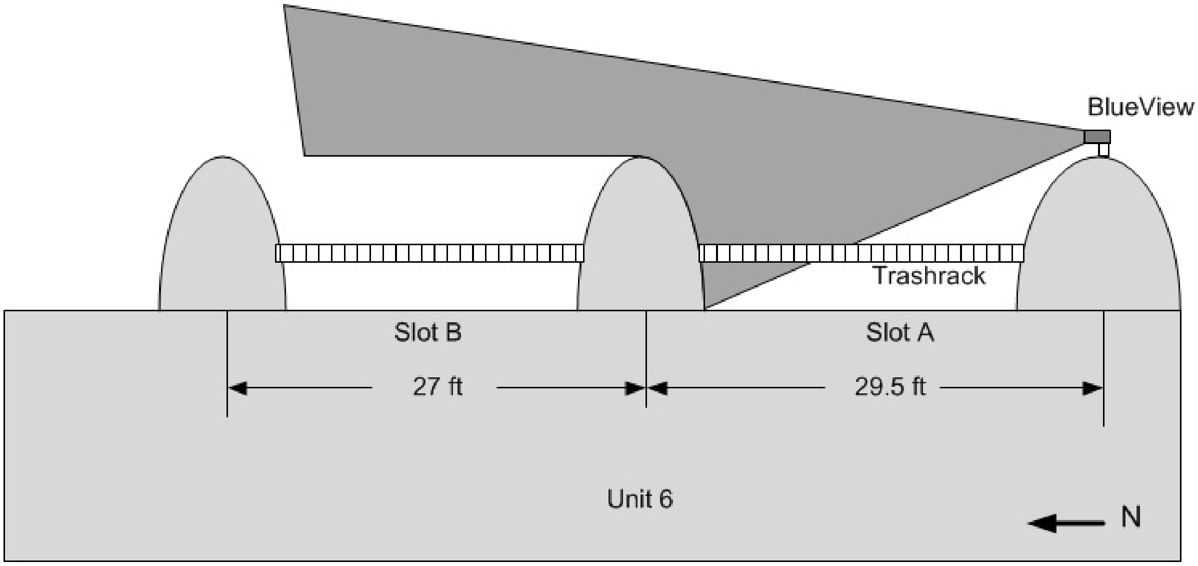

Figure 2.4. Plan View of BlueView Sonar Coverage Region at Powerhouse Unit 6

2.4 Data Processing

To estimate adult fish passage and evaluate it in the context of dam operations, data collected from hydroacoustic systems were processed to identify tracks of echoes created by individual fish. Counts of fish tracks in the sample volumes were subsequently expanded to estimate fish passage for the entire volume of the turbine intakes. Passage estimates were integrated with dam operations to allow for the comparison of passage among time periods with varied operations. BlueView data were processed to verify the presence and estimate the abundance of fish of various species groups in the forebay near the entrance of the turbine intakes and the behavior of those fish. This section describes the process of deriving the estimates of fish passage from the raw data and the process of developing estimates of fish abundance 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' Generic Data Acquisition and Control 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 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 -56 dB, which would accept fish from smolt size and up. Increasing the minimum to -31 dB ensures that only adult-steelhead-sized fish are detected. A target strength of -31 dB || 1 µPa at 1 m corresponds to a fish length of about 56 cm (Love 1971). This ensures that American shad are excluded from turbine passage counts and all but the smallest adult steelhead are included in those counts.

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 by 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 *i*th weighted fish at the *j*th location

I_j = the width (m) at the *j*th location

R_i = the mid-range (m) of the *i*th fish

θ_j = the effective beam width of the transducer at the *j*th 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 *j*th location in the *h*th hour

W_{ijh} = the *i*th weighted fish at the *j*th location in the *h*th hour

n_{jh} = the number of fish at the *j*th location in the *h*th 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. Because the sampling area of a transducer beam covers only a fraction of the intake and because sounders must cycle through two transducers each, each fish detected within the sample area is expanded several fold to estimate how many fish passed the entire intake. 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 BlueView Data Processing

The BlueView operated from December 17, 2011 to April 16, 2012. Files were subsampled by reviewing 120 minutes of footage every other day. Each sampling day was segregated into two 12-hour blocks with the day period starting at 0500 hours and ended at 1600 hours and the nighttime period 1700 to 0400 hours. A stratified random subsampling table was generated in which four day periods were selected followed by four nighttime periods. These periods were then reviewed in the laboratory using the BlueView ProViewer™ software. A count was made of targets of each type (e.g., shad, adult steelhead) for each sample. Individual fish cannot be differentiated reliably, so fish that exit the field of view were counted again if they re-entered it during the same sample.

2.4.6 Sampling Outages

While operating fixed-aspect hydroacoustic systems is mostly routine, sampling at remote field locations adds to the uncertainty of vital needs such as electrical power and makes monitoring system operation more of a challenge. For that reason, a system is in place to send status emails each hour that indicate the hydroacoustic equipment is still operational. That system provided rapid notification of issues and allowed technicians to quickly address them either through a remote connection or by driving to the dam to correct a problem or reinitiate sampling. In the 2011–2012 study, unexpected power outages were the most common source of problems in sampling. Software lock-ups also occurred, as did a small number of temporary and permanent equipment failures (some of which were associated with power outages). Sampling was restored in less than 4 hours for most outages, although in one instance a system was unable to be restored to operation for 12 hours. Although outages occurred, they were relatively infrequent. All outages combined resulted in a failure to collect data 1% of the total sample time, which can be stated as 99% uptime for the fixed-aspect hydroacoustic system. The small number of system-hours that went unsampled may have resulted in slightly higher or lower passage estimates for some days, but they are unlikely to alter the interpretation of the results of this study.

There was one significant BlueView outage following a power outage on February 16. The sonar imaging device restarted, but failed to store data files following that outage. The device appeared to be operational to those checking the system, but data were not being stored to disk until this malfunction was recognized and corrected on March 3. As a result, BlueView data were not available for analysis on eight sampling days (sampling occurred every other day). This represents a loss of 13% of sample days for an 87% uptime. Because the BlueView is used to support the use of the fixed-aspect hydroacoustics, rather than to estimate the primary metrics of interest, this loss will have little influence on the results of this study or their interpretation.

2.5 Data Analysis

Data analysis for fixed-aspect hydroacoustics consisted of estimating adult 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. The 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.

Adult steelhead 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 because sampling was not done 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 the effects of operational conditions for smaller time scales, such as trends among days or blocks of days.

3.0 Results and Discussion

The number of adult steelhead 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 2011–2012 study provide context for understanding and evaluating the number and distribution of adult steelhead entering the turbine intakes. In general, river flows were well above average beginning in mid-March, often exceeding the hydraulic capacity of the powerhouse. Flows in excess of powerhouse capacity resulted in forced spill, which was common until the initiation of spill for juvenile passage on April 1. The occurrence of spill likely had an influence on downstream passage of adults. Extended-length submersible barrier screens were not intended to be in place during the study, but we sampled for several days before they were removed in 2011 and after they were installed for the 2012 juvenile fish passage season. When passage results are presented, days having screens present will be identified or excluded from estimates of turbine passage because screens likely diverted those fish into the JBS.

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 1, 2011 to April 16, 2012. River discharge during that period was near the 10-year average until mid-March, after which it was well above average through the remainder of the study period (Figure 3.1). Starting in mid-March, the river discharge often exceeded powerhouse capacity, resulting in unplanned spill. The 10-year average spill for this period of the year was close to 0% until the start of the juvenile fish passage season in April, so the amount of spill during the study period was atypical. Spill began much later during this study compared to the 2010–2011 study, when spill began in mid-January. 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 on a given day.

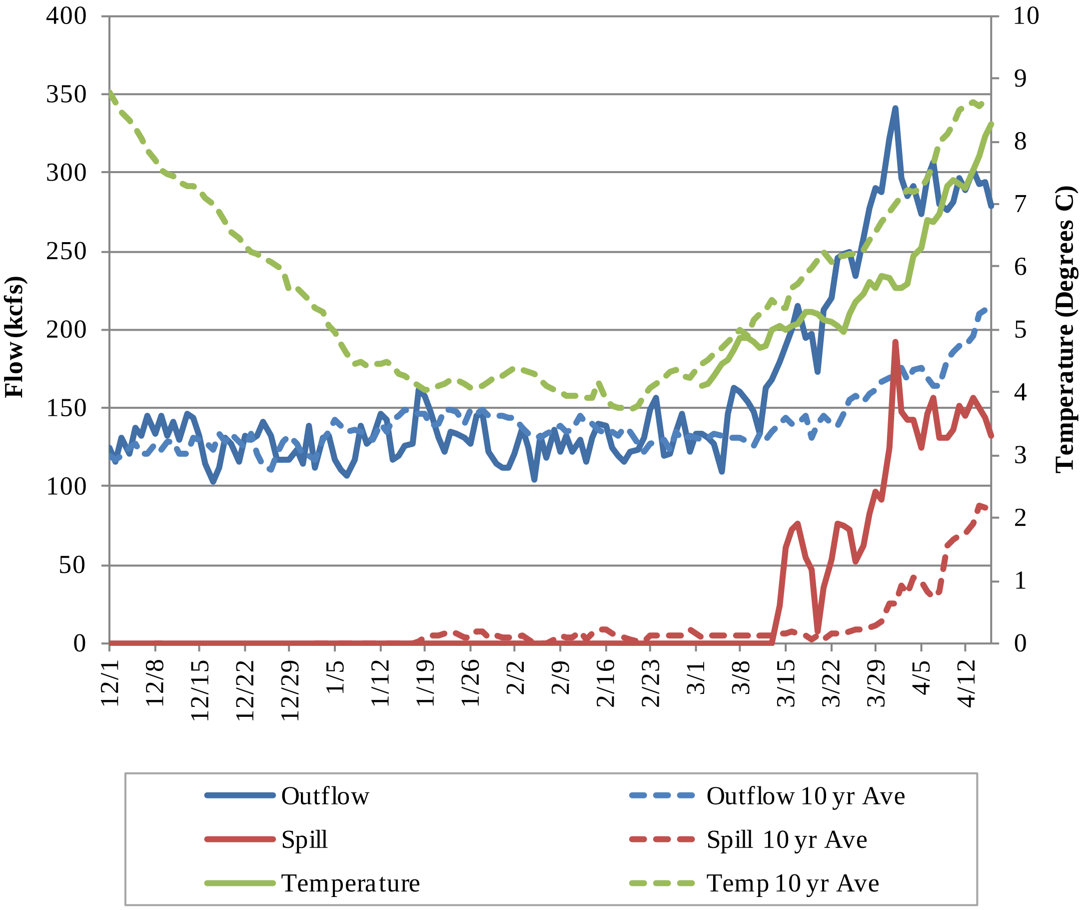

Figure 3.1. Daily Total Discharge, Spill Discharge, and Temperature for the Study Period (solid lines) and 10-Year Averages (dashed lines). (Source: www.cbr.washington.edu/dart/river.html)

3.1.2 Species Composition and Run Timing

The counts of fish in BlueView samples were used to estimate the apparent abundance of fish in the forebay upstream of turbine unit 6. Because downstream passage is not ensured for fish observed within the sampling area of the BlueView, fish can be counted more than once, especially within multiple samples throughout the day. Individuals of schooling species such as American shad, which have a tendency to move through the sample area often, are typically observed many times. As a result, apparent counts of shad were much higher than steelhead counts until January 20 (Figure 3.2). Adult steelhead were more often observed holding in place, based upon our observations, so apparent counts are not as inflated by multiple counts. Trends in steelhead counts suggest that they were more abundant during mid-December into early January with another small peak occurring in early March. A gap in sampling from late February to early March occurred due to the outage described previously in Section 2.4.6, but sampling was restored over a week prior to the onset of spill on March 14. Apparent counts of steelhead in the forebay upstream of turbine unit 6 appeared to decrease somewhat after spill began.

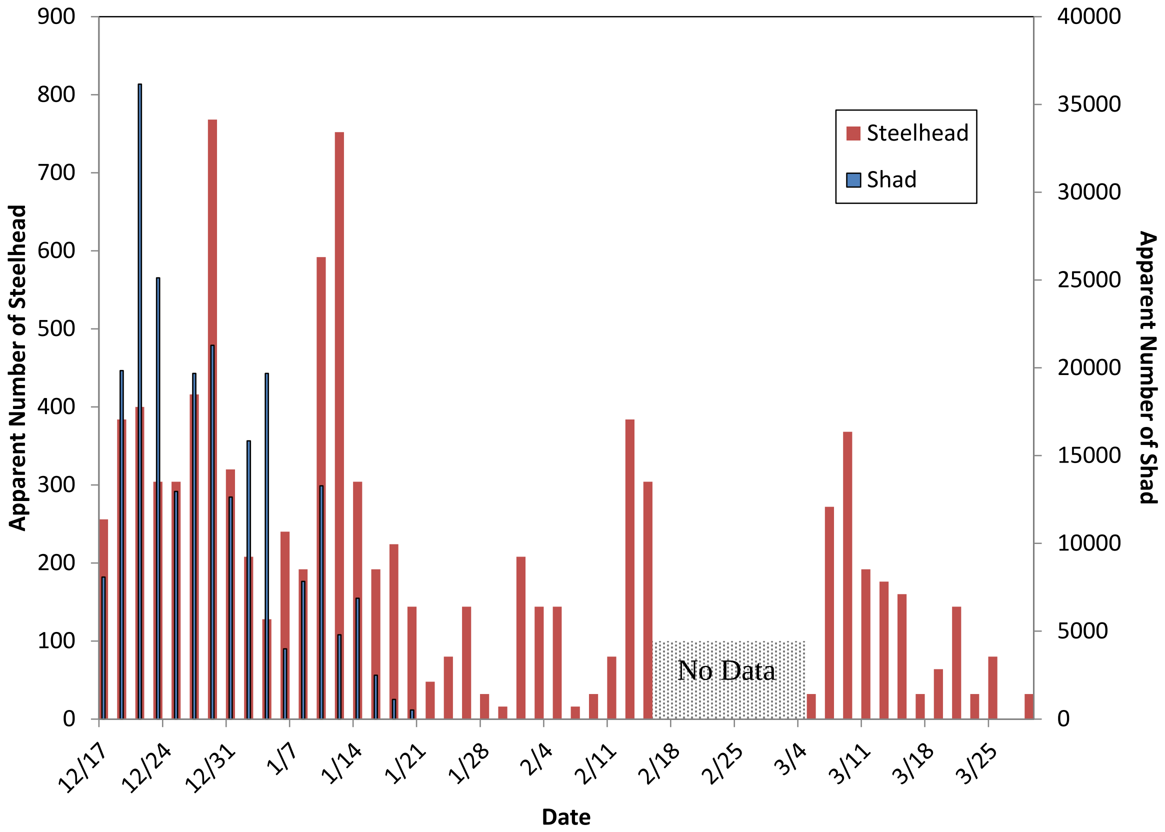

Figure 3.2. Apparent BlueView Counts of Fish Observed in the Forebay near Intake 6A

3.1.3 Dam Operations

The mean hourly discharge of each turbine unit or spillbay 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 1 and 10 that were out of service for the early part of the study period, turbine units were in nearly continuous operation throughout the study period. There was no spill prior to March 14, but after that date river flows became high enough to require that many spillbays be opened.

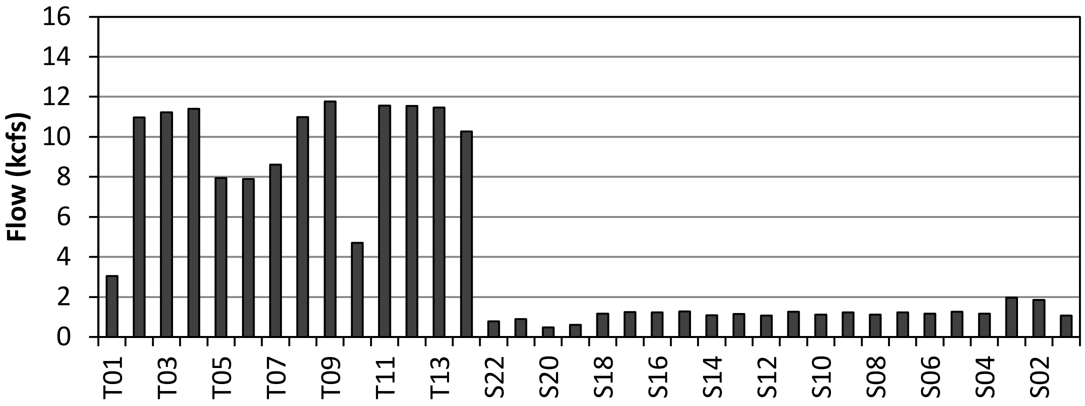

Figure 3.3. Mean Discharge by Location During the Entire Study Period

3.1.4 Operational Groups

Spill has only rarely occurred during the winter at McNary Dam in the 10 years prior to this study, with the winters of 2010–2011 and 2011–2012 being notable exceptions to that trend. 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 late 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. The days early and late within the study period when some or all screens were in place were identified as Screens_In, which was associated with No_Spill conditions at the start of the study and with FPP_Spill conditions near the end of the study. 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 JBS, 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	Operation	Date	Day	Operation	Date	Day	Operation
11/30/2011	1	Screens_In/No_Spill	1/16/2012	48	No_Spill	3/3/2012	95	No_Spill
12/1/2011	2	Screens_In/No_Spill	1/17/2012	49	No_Spill	3/4/2012	96	No_Spill
12/2/2011	3	Screens_In/No_Spill	1/18/2012	50	No_Spill	3/5/2012	97	No_Spill
12/3/2011	4	Screens_In/No_Spill	1/19/2012	51	No_Spill	3/6/2012	98	No_Spill
12/4/2011	5	Screens_In/No_Spill	1/20/2012	52	No_Spill	3/7/2012	99	No_Spill
12/5/2011	6	Screens_In/No_Spill	1/21/2012	53	No_Spill	3/8/2012	100	No_Spill
12/6/2011	7	Screens_In/No_Spill	1/22/2012	54	No_Spill	3/9/2012	101	No_Spill
12/7/2011	8	Screens_In/No_Spill	1/23/2012	55	No_Spill	3/10/2012	102	No_Spill
12/8/2011	9	Screens_In/No_Spill	1/24/2012	56	No_Spill	3/11/2012	103	No_Spill
12/9/2011	10	Screens_In/No_Spill	1/25/2012	57	No_Spill	3/12/2012	104	No_Spill
12/10/2011	11	Screens_In/No_Spill	1/26/2012	58	No_Spill	3/13/2012	105	No_Spill
12/11/2011	12	Screens_In/No_Spill	1/27/2012	59	No_Spill	3/14/2012	106	Forced_Spill
12/12/2011	13	Screens_In/No_Spill	1/28/2012	60	No_Spill	3/15/2012	107	Forced_Spill
12/13/2011	14	Screens_In/No_Spill	1/29/2012	61	No_Spill	3/16/2012	108	Forced_Spill
12/14/2011	15	Screens_In/No_Spill	1/30/2012	62	No_Spill	3/17/2012	109	Forced_Spill
12/15/2011	16	No_Spill	1/31/2012	63	No_Spill	3/18/2012	110	Forced_Spill
12/16/2011	17	No_Spill	2/1/2012	64	No_Spill	3/19/2012	111	Forced_Spill
12/17/2011	18	No_Spill	2/2/2012	65	No_Spill	3/20/2012	112	Forced_Spill
12/18/2011	19	No_Spill	2/3/2012	66	No_Spill	3/21/2012	113	Forced_Spill
12/19/2011	20	No_Spill	2/4/2012	67	No_Spill	3/22/2012	114	Forced_Spill
12/20/2011	21	No_Spill	2/5/2012	68	No_Spill	3/23/2012	115	Forced_Spill
12/21/2011	22	No_Spill	2/6/2012	69	No_Spill	3/24/2012	116	Forced_Spill
12/22/2011	23	No_Spill	2/7/2012	70	No_Spill	3/25/2012	117	Forced_Spill
12/23/2011	24	No_Spill	2/8/2012	71	No_Spill	3/26/2012	118	Forced_Spill
12/24/2011	25	No_Spill	2/9/2012	72	No_Spill	3/27/2012	119	Forced_Spill
12/25/2011	26	No_Spill	2/10/2012	73	No_Spill	3/28/2012	120	Forced_Spill
12/26/2011	27	No_Spill	2/11/2012	74	No_Spill	3/29/2012	121	Forced_Spill
12/27/2011	28	No_Spill	2/12/2012	75	No_Spill	3/30/2012	122	Forced_Spill
12/28/2011	29	No_Spill	2/13/2012	76	No_Spill	3/31/2012	123	Forced_Spill
12/29/2011	30	No_Spill	2/14/2012	77	No_Spill	4/1/2012	124	FPP_Spill
12/30/2011	31	No_Spill	2/15/2012	78	No_Spill	4/2/2012	125	FPP_Spill
12/31/2011	32	No_Spill	2/16/2012	79	No_Spill	4/3/2012	126	FPP_Spill
1/1/2012	33	No_Spill	2/17/2012	80	No_Spill	4/4/2012	127	FPP_Spill
1/2/2012	34	No_Spill	2/18/2012	81	No_Spill	4/5/2012	128	FPP_Spill
1/3/2012	35	No_Spill	2/19/2012	82	No_Spill	4/6/2012	129	FPP_Spill
1/4/2012	36	No_Spill	2/20/2012	83	No_Spill	4/7/2012	130	FPP_Spill
1/5/2012	37	No_Spill	2/21/2012	84	No_Spill	4/8/2012	131	FPP_Spill
1/6/2012	38	No_Spill	2/22/2012	85	No_Spill	4/9/2012	132	Screens_In/FPP_Spill
1/7/2012	39	No_Spill	2/23/2012	86	No_Spill	4/10/2012	133	Screens_In/FPP_Spill
1/8/2012	40	No_Spill	2/24/2012	87	No_Spill	4/11/2012	134	Screens_In/FPP_Spill
1/9/2012	41	No_Spill	2/25/2012	88	No_Spill	4/12/2012	135	Screens_In/FPP_Spill
1/10/2012	42	No_Spill	2/26/2012	89	No_Spill	4/13/2012	136	Screens_In/FPP_Spill
1/11/2012	43	No_Spill	2/27/2012	90	No_Spill	4/14/2012	137	Screens_In/FPP_Spill
1/12/2012	44	No_Spill	2/28/2012	91	No_Spill	4/15/2012	138	Screens_In/FPP_Spill
1/13/2012	45	No_Spill	2/29/2012	92	No_Spill	4/16/2012	139	Screens_In/FPP_Spill
1/14/2012	46	No_Spill	3/1/2012	93	No_Spill			
1/15/2012	47	No_Spill	3/2/2012	94	No_Spill			

3.2 Overall Passage

This section describes fish observations, behavior, and 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 BlueView Observations of Fish Behavior and Abundance in the Forebay

This section addresses fish observations and behavior in the forebay. The objective was to determine whether the observations suggest that fish detected passing into turbines are likely to be steelhead or other large fish. Relative abundance and behavior, the primary objectives of the BlueView, have already been addressed in Section 3.1.2. Shad were numerous during the early part of the study (schools of shad observed visually from the intake deck), which is a potential concern when estimating steelhead passage. Shad appeared to be numerous, in part, because they traveled in schools back and forth upstream of the dam and were counted each time they passed the BlueView within a sampling period (Figure 3.4). As reported in a previous Battelle study in 2011(Ham et al. 2012), the potential for counting the same individuals multiple times most likely resulted in inflated estimates of shad abundance. No shad were observed passing downstream through the trash racks, which suggests that the counts of shad in the forebay are likely to be much higher than the number of shad passing through turbines.

In contrast to shad, adult steelhead were much larger targets and were observed moving much less across the upstream face of the powerhouse, usually milling or slowly swimming just upstream of the intake and trash racks (Figure 3.5). 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 BlueView in more than one direction (i.e., above or below the sample volume). Steelhead were most numerous from mid-December through mid-January (Figure 3.2). Behavioral observations suggest that steelhead were holding upstream of the powerhouse for some time, and their apparent abundance in the forebay was not highly correlated with the number of fish passing downstream through the hydroacoustic sampling areas within the intake (adult steelhead were also observed visually from the intake deck).

3.2.2 Excluding Shad from Turbine Passage Counts

Fixed-aspect hydroacoustics detect targets passing into the turbines, but we are only interested in counting targets that are adult steelhead. Because American shad are smaller than adult steelhead, they reflect less of the acoustic energy emitted by the transducer back to the transducer, resulting in lower target strength. This target strength difference allows smaller fish, such as shad, to be excluded from passage counts. By setting a high threshold (-31 dB), we excluded fish that are less than about 56 cm (Love 1971). Most adult steelhead are larger than that, but it would be rare for an American shad to reach that length. By eliminating smaller fish, turbine passage counts will reflect the passage of larger adult steelhead.

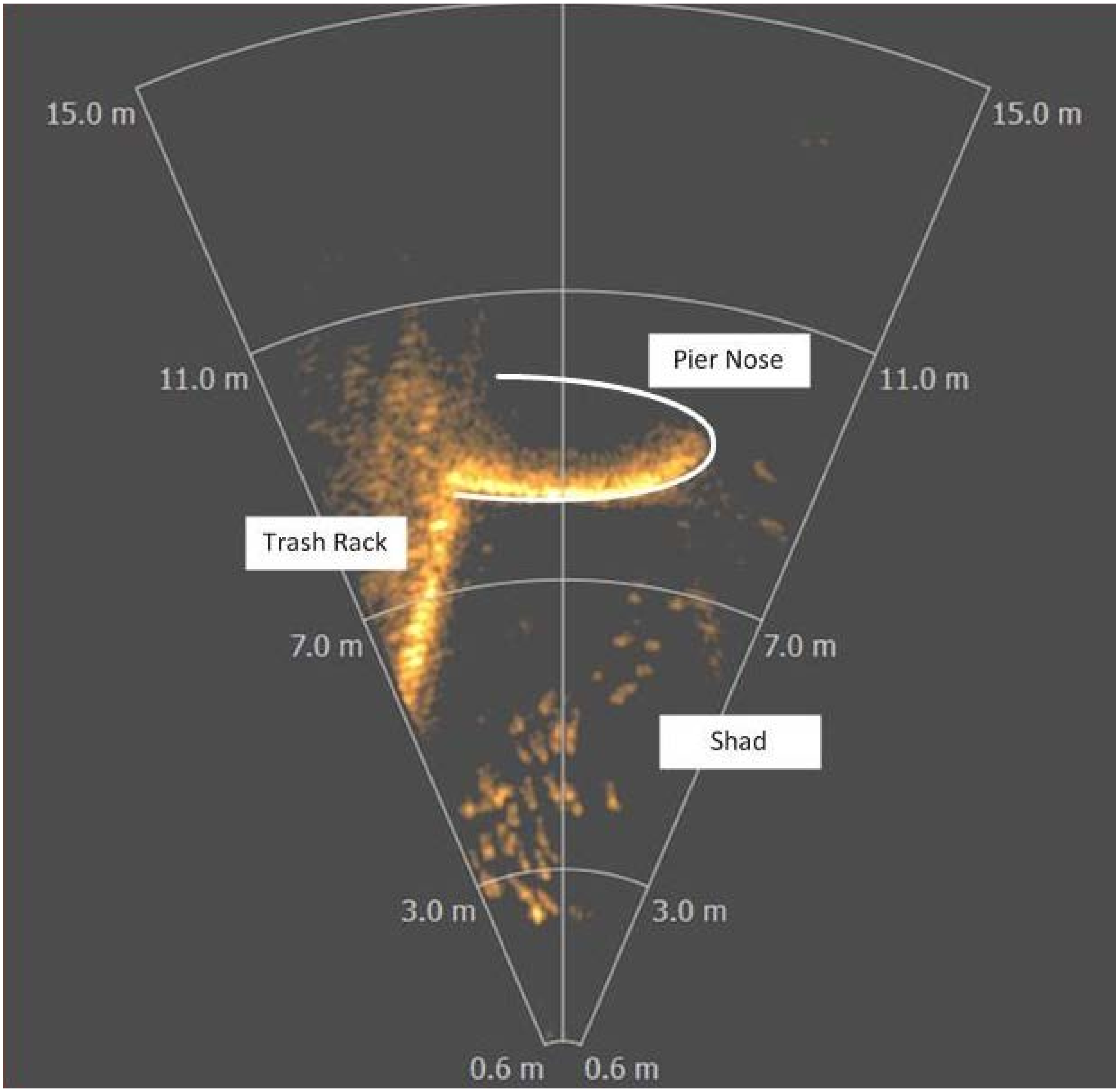

Figure 3.4. BlueView Field of View Showing Schooling Shad Moving Along the Dam

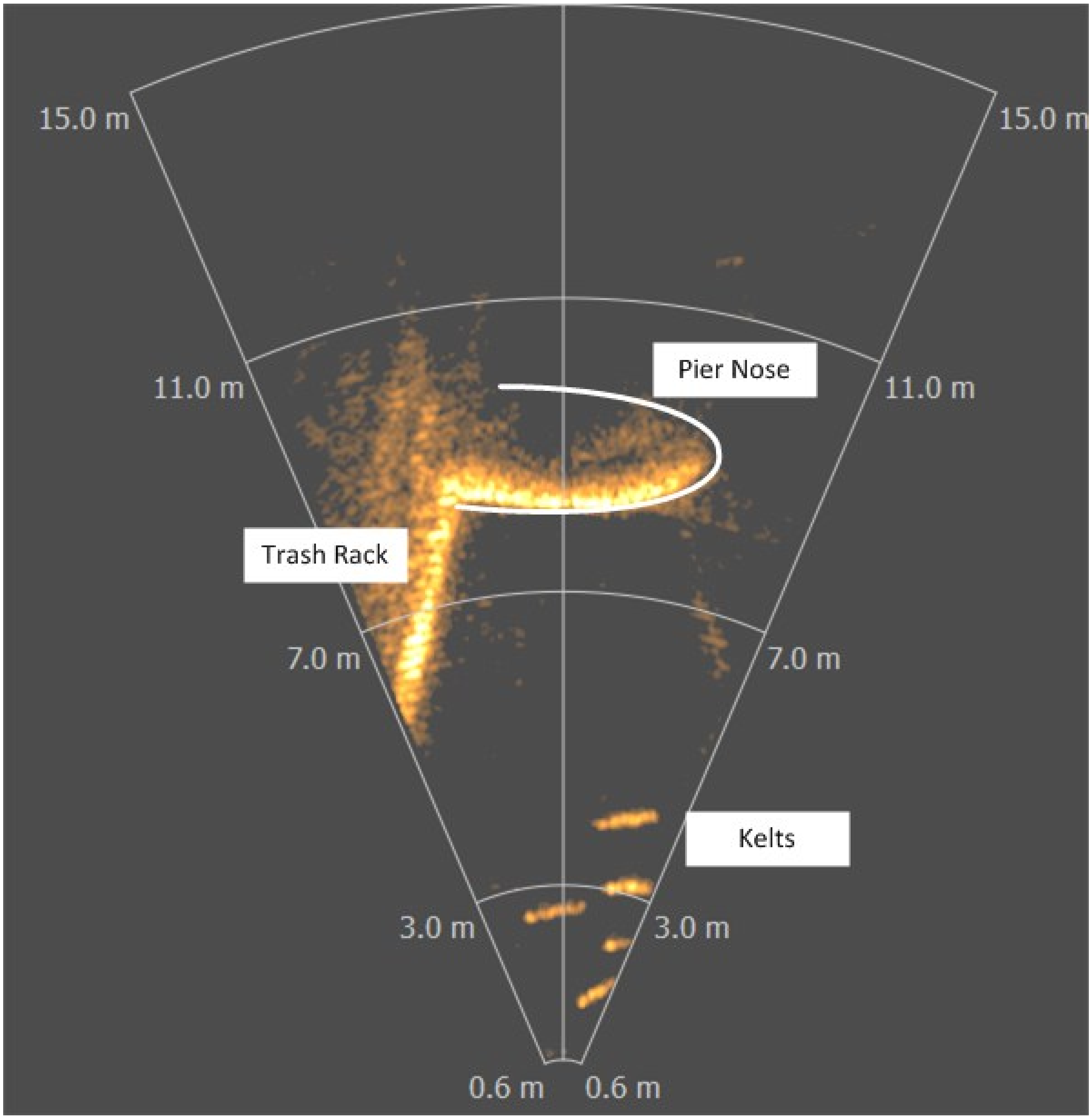

Figure 3.5. BlueView Field of View Showing Adult Steelhead Holding Upstream of the Trash Rack

3.2.3 Total Passage

A total of 193 acoustic targets with track characteristics consistent with adult steelhead were detected. Although the number of targets detected increased dramatically from 68 in the previous study year, sampling locations and sampling effort per location also increased, which means that targets detected would increase even if passage were the same. In addition, sampling began several days earlier. Targets detected within the sample volume targets were expanded to account for spatial and temporal sample coverage to an overall estimate of passage (see Appendix D for methods). Downstream passage of adult steelhead through the monitored intakes at the powerhouse of McNary Dam during the study period when screens were not in place was estimated to be 1786 individuals, with 95% confidence bounds extending from 1669 to 1902 individuals. If a similar rate of passage per unit flow is assumed when unmonitored routes were operated, the estimate of total powerhouse passage would be 6% higher at 1893 individuals. The relatively narrow confidence bounds around the estimate are evidence that increased sampling intensity in the 2011–2012 study was effective in decreasing uncertainty in the passage estimate. Spillway passage was outside the scope of this study, so it was not possible to produce a whole-dam estimate of passage.

3.2.4 Horizontal Distributions

The horizontal distribution of adult steelhead entering turbine intakes appeared to be skewed toward the outer turbine units (Figure 3.6). Although the two unmonitored units (1 and 10) did operate at times, they were operated for a limited period, and probably did not alter the distribution very much. The relatively low passage numbers near the center of the powerhouse, for which sampling coverage was complete, is consistent with the distribution for the 2010–2011 study.

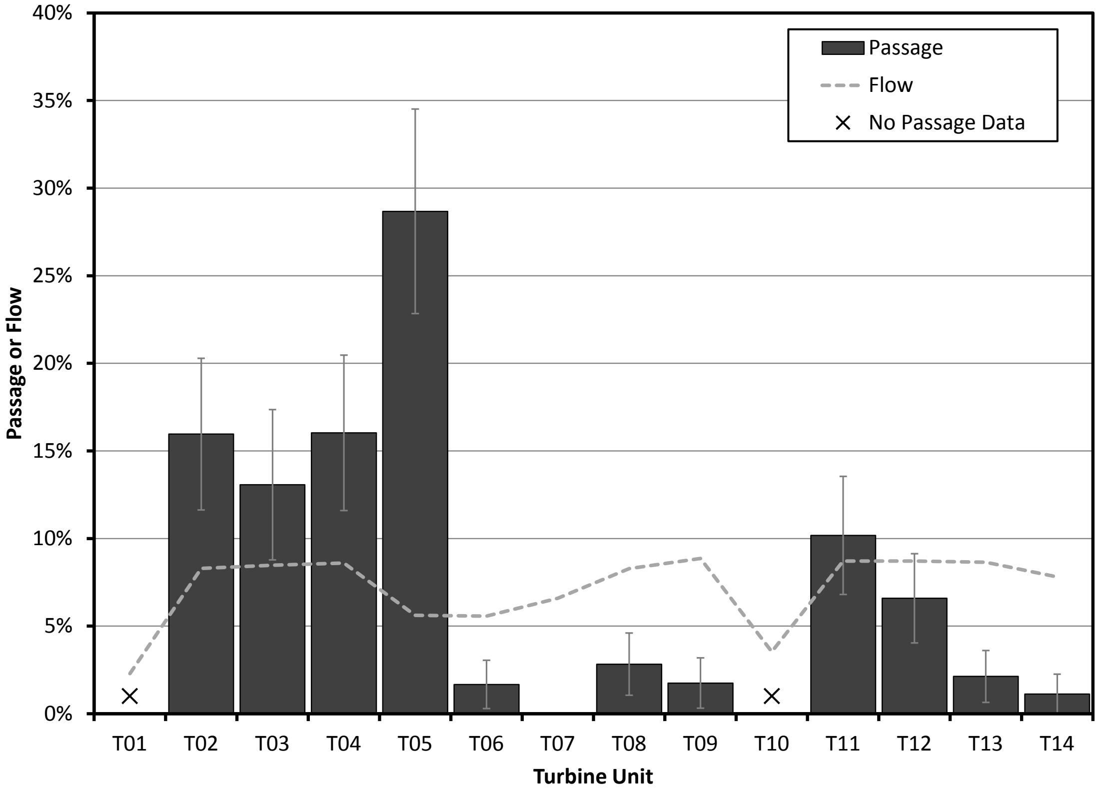

Figure 3.6. Horizontal Distribution of Adult Steelhead Passing the Powerhouse. Error bars indicate 95% confidence intervals.

3.2.5 Vertical Distributions

Passage during times when screens were in place was also 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. Excluding those days avoided a possible bias in the vertical distribution for adult steelhead passing in the presence of screens.

Most adult steelhead passing into turbine intakes were near the intake ceiling at 282 ft above MSL (Figure 3.7). For reference, the mean forebay water elevation at McNary Dam during this study was approximately 338.5 ft above MSL. Sampling extended to depths as great as 240 ft above MSL, but no steelhead were detected passing below 257 ft above MSL (25 ft deeper than the intake ceiling).

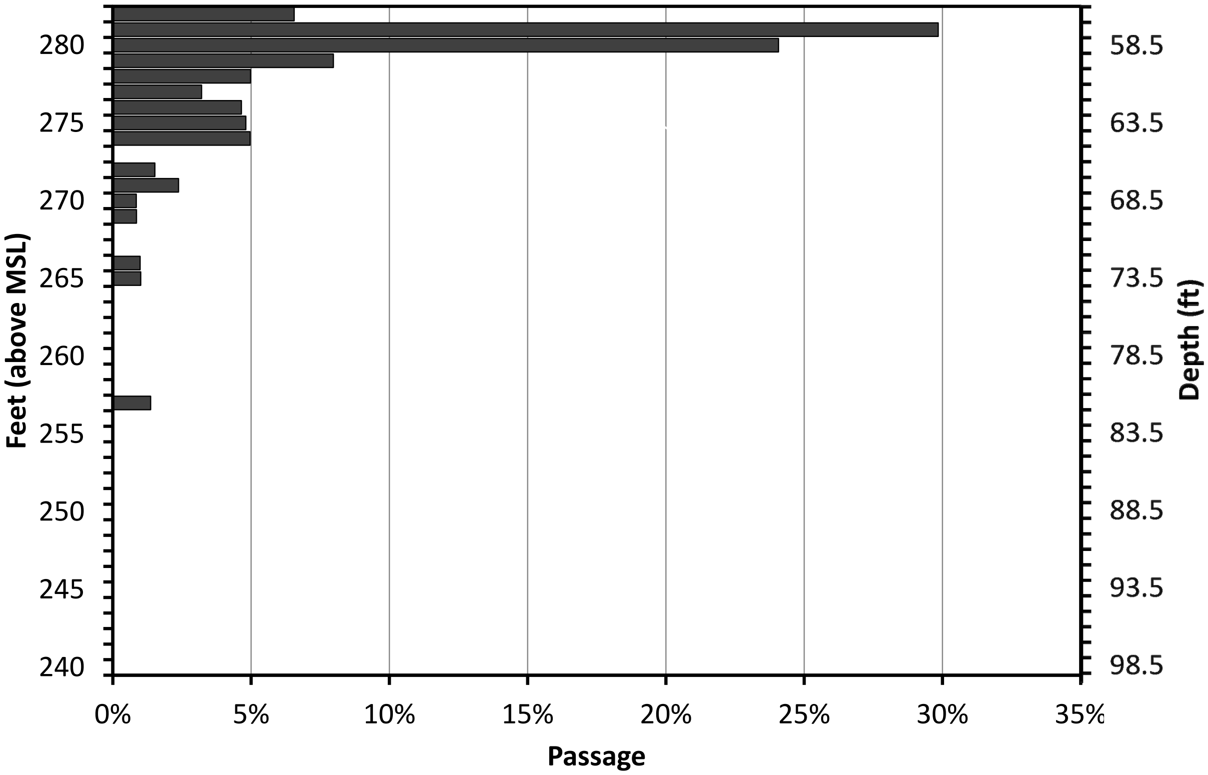

Figure 3.7. Histogram of Adult Steelhead Vertical Distribution for Sample Period with Screens Removed

3.2.6 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 adult steelhead distributions (Table 3.2). There was no obvious trend of passage across the diel cycle (Figure 3.8).

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 1, 2011 (first study day)	0645h	0718h	1614h	1648h
April 16, 2011 (last study day)	0537h	0609h	1946h	2018h

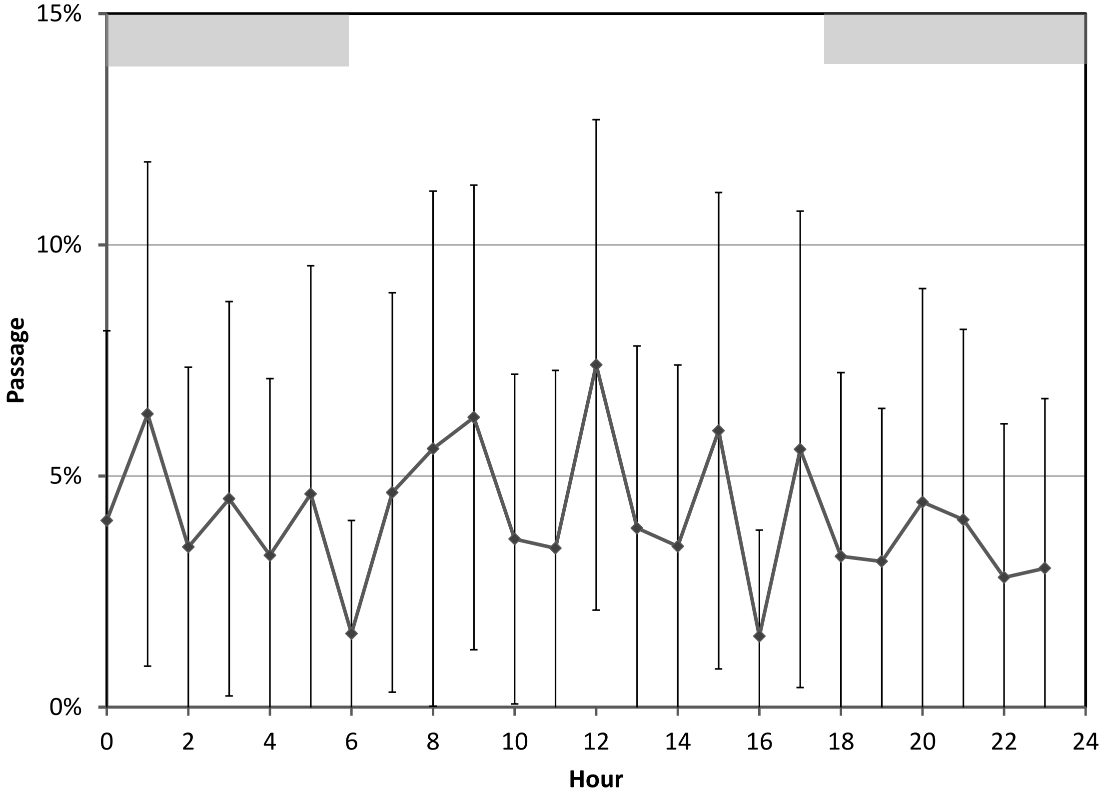

Figure 3.8. Diel Trend of Passage. Shaded blocks indicate hours of darkness. Error bars indicate 95% confidence intervals.

3.3 Passage by Operational Period

This section reports the results of the analysis of differences in how adult steelhead 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 steelhead because spillway passage was not monitored and because the spill conditions were likely not typical of future conditions.

3.3.1 Operational Periods

In the absence of planned treatments, we have chosen to provide an ad hoc comparison of 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 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 exceeded available turbine capacity and 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 or in an implementation of spill during a period where forced spill was not required.

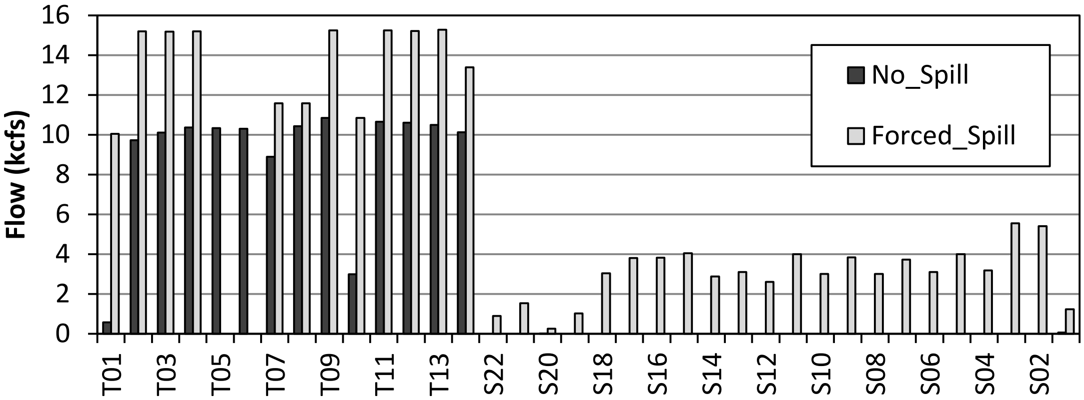

Figure 3.9. Mean Discharge by Location for No_Spill and Forced_Spill Periods

3.3.2 Daily Passage by Operational Period

Because operational periods were not planned, it is important to consider how adult steelhead 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 December 24, 2010, and declined through mid-March of 2012. Turbine passage increased slightly

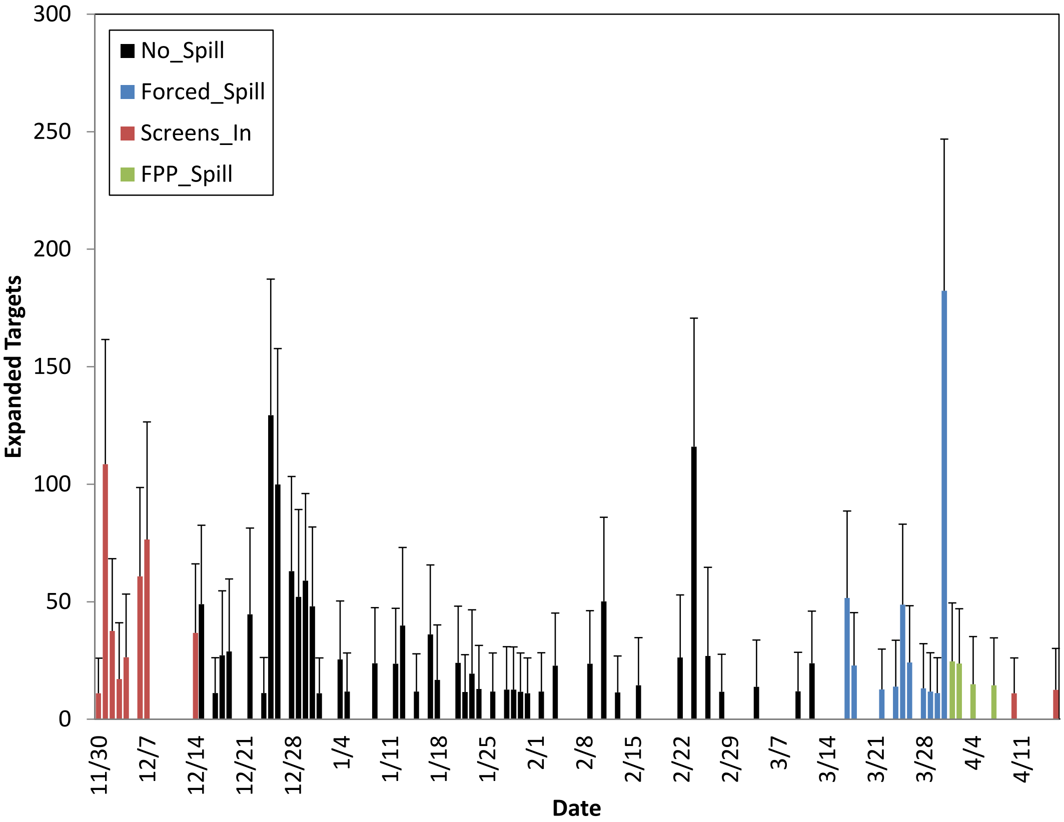

Figure 3.10. Hydroacoustic Estimates of Adult Steelhead Daily Passage by Operational Period. Error Bars indicate upper 95% confidence bounds. The Screens_In period did not include spill during December, but included FPP_Spill during April.

when the Forced_Spill period began in mid-March; another spike in passage occurred just prior to the transition to FPP_Spill (Figure 3.10). Passage during the Screens_In period ranged from high to low in 2011 (first 15 days of the study) when there was no spill and was low in 2012 (last 7 days of the study) when FPP spill was occurring. Steelhead passage was not high during the brief FPP_Spill period late in the study. Table 3.1 illustrates when operational periods were in effect.

3.3.3 Horizontal Distributions by Operational Period

The horizontal distributions of adult steelhead passing through 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 the northern portion of the powerhouse (turbine units 11−14) was higher during Forced_Spill. The northern end of the powerhouse is nearest the spillway. For the remainder of the powerhouse, trends among operational periods are not obvious.

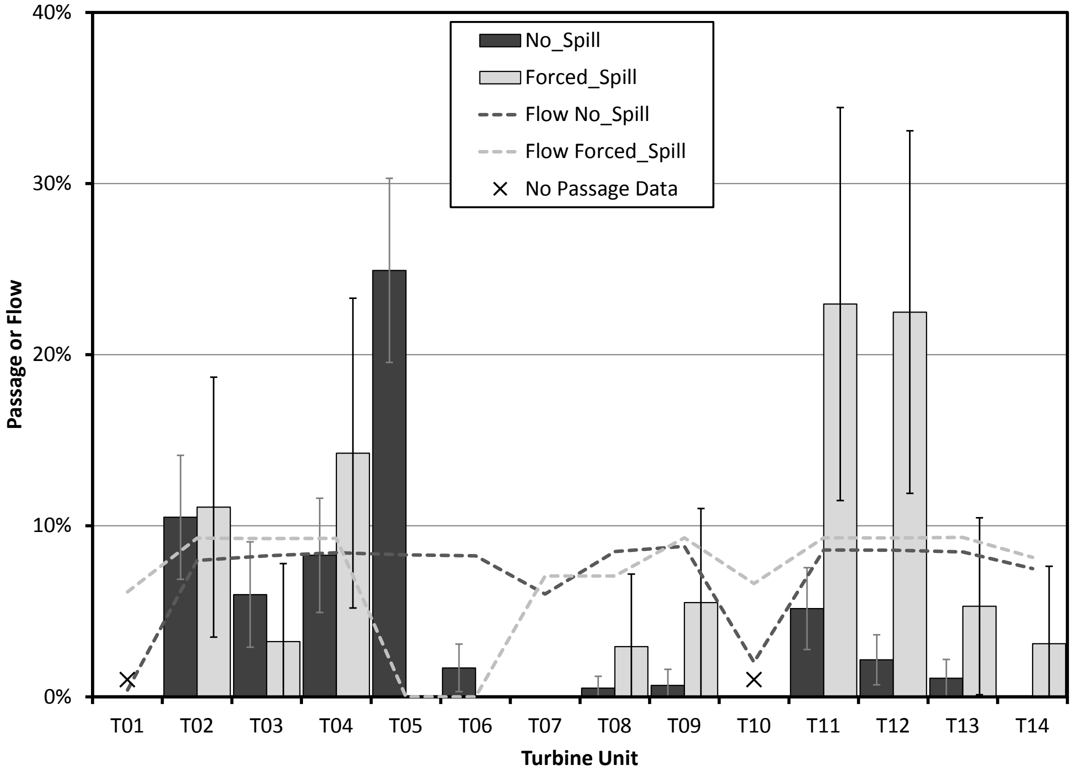

Figure 3.11. Horizontal Distribution of Adult Steelhead Entering Turbine Intakes by Operational Period. Error bars indicate 95% confidence intervals.

3.3.4 Vertical Distributions by Treatment

During the Forced_Spill operational period, adult steelhead passage appeared to be highly skewed toward the intake ceiling. More steelhead passed at greater depths during the No_Spill operational period, but the bulk of passage was still near the intake ceiling. The differences in vertical distribution could be interpreted as indicating that steelhead that would have passed at greater depths 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.

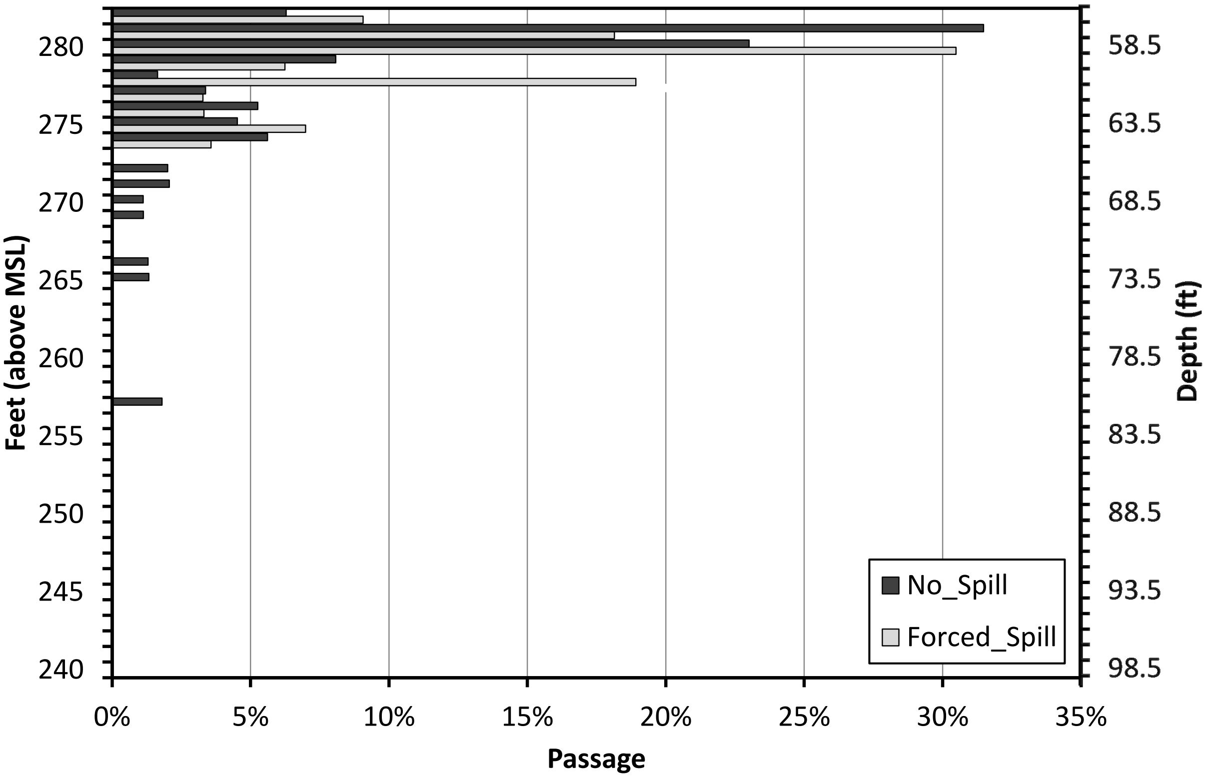

Figure 3.12. Histogram of Adult Steelhead Vertical Distribution for No_Spill and Forced_Spill Periods

4.0 Conclusions

This study estimated 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

Forebay observations of fish upstream of the trash racks revealed an abundance of shad early in the study period, but none later in the study. Although those shad must have passed through the turbines (we assume they did not move upstream away from the dam), their smaller size resulted in smaller target strengths in the fixed-aspect hydroacoustic data collected downstream of the trash racks. That difference made it possible to filter them out as described previously in Section 3.2.2 so they would not be included in passage estimates for adult steelhead.

Adult steelhead were found to be passing McNary Dam throughout the study period. The number of adult steelhead estimated to be passing through the turbine units sampled in this study in 2011 and 2012 was 1786 (±116). If we speculate that a similar number were passing through the unmonitored turbine units when they operated, the estimate for the entire powerhouse would be 6% higher at 1893 individuals. This level of passage was higher than for the 2010–2011 study, when 950 adult steelhead were estimated to pass through the monitored units, and around 1400 were estimated to pass through the entire powerhouse. If we exclude fish from this year's study that were detected prior to December 17 (the starting date for the 2010–2011 study), the estimate for the entire powerhouse would be 1829 individuals. That estimate of turbine passage is roughly 30% higher than for the same time period in the 2010–2011 study. Later initiation of spill and less spill overall during the 2011–2012 study meant that turbine passage was the primary passage route available for a much greater proportion of the study period, and that may explain some of the increase in passage relative to the 2010–2011 results. Confidence intervals around the passage estimates were smaller during this second study year because of the greater sampling intensity implemented after it was identified as a need during the first study year.

4.2 Adult Steelhead Passage During No_Spill and Forced_Spill Operational Periods

Unplanned spill created an opportunity to compare passage and the distribution of passage into turbines between No_Spill and Forced_Spill operational periods. The inference of those comparisons is limited to the current study period because time of year and operational condition were confounded, but they may provide useful information. 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, passage rates at the powerhouse appeared to increase slightly, relative to the previous weeks. We might have expected the availability of an alternate route, such as spill, to reduce powerhouse passage, but spill was only one of the factors that differed between the No_Spill and Forced_Spill periods. In addition to the occurrence of spill, turbine operations were also nearer to the upper operational range for turbines (refer to Figure 3.9) during Forced_Spill, and that also may have influenced the rates of turbine passage. The transition to FPP_Spill (and juvenile turbine operations within 1% of peak efficiency) had little apparent impact on passage. Passage during the Screens_In operational period is assumed to result in fish passing into the JBS, rather than into turbines.

Horizontal distributions were notably different between operational periods. Forced_Spill resulted in a notable change in the horizontal distribution of passage across the powerhouse. Powerhouse passage was skewed north toward the spillway during Forced_Spill, which is obviously different from the skew toward the south of the powerhouse during the No_Spill period.

Vertical distributions were somewhat different between operational periods. During Forced_Spill conditions, steelhead tended to pass into the turbines near the intake ceiling. During No_Spill conditions fish passage was distributed at slightly greater depth. The differences in vertical distribution may result from changes in spill or turbine operations, but the timing of the occurrence of Forced_Spill later in the study period might also have played a part in the differences.

4.3 Implications for Management

Adult steelhead were found to be passing through the McNary Dam powerhouse throughout the study period, with highest rates in December. Changes in operations late in the study (March) appeared to alter powerhouse passage rates slightly, and had a notable impact on the vertical and horizontal distributions of adult steelhead passage at the powerhouse. Although the ad hoc nature of this comparison makes it difficult to infer whether spill or increased turbine flow is responsible for the differences observed, the results indicate that it would be possible to alter adult steelhead passage rates or distributions through management action.

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		S/N	Xducer Aiming Angle	Elevation (ft)	Pings/ Second
					4-ch	6-ch				
System McN_F										**20**
SPB Sounder										
Remote Multiplexer						**470**				
SPB Xducer 1	**452**	**6^{o}**	**00**	**Unit 2B**	**313**		**179**	**31^{o} downstream of vertical**	**239**	
SPB Xducer 2	**494**	**6^{o}**	**01**	**Unit 3A**	**235**		**163**	**31^{o} downstream of vertical**	**239**	
System McN_D										**20**
SPB Sounder										
Remote Multiplexer						**235**				
SPB Xducer 1	**492**	**6^{o}**	**00**	**Unit 4C**	**313**		**197**	**31^{o} downstream of vertical**	**239**	
SPB Xducer 2	**461**	**6^{o}**	**02**	**Unit 5A**	**235**		**169**	**31^{o} downstream of vertical**	**239**	
System McN_C										**20**
SPB Sounder						**470**				
Remote Multiplexer										
SPB Xducer 1	**470**	**6^{o}**	**00**	**Unit 6C**	**235**		**177**	**31^{o} downstream of vertical**	**239**	
SPB Xducer 2	**471**	**6^{o}**	**01**	**Unit 7B**	**313**		**155**	**31^{o} downstream of vertical**	**239**	
System McN_B										**20**
SPB Sounder						**235**				
Remote Multiplexer										
SPB Xducer 1	**466**	**6^{o}**	**00**	**Unit 8C**	**235**		**190**	**31^{o} downstream of vertical**	**239**	
SPB Xducer 2	**463**	**6^{o}**	**01**	**Unit 9B**	**313**		**136**	**31^{o} downstream of vertical**	**239**	
System McN_E										**20**
SPB Sounder										
Remote Multiplexer						**470**				
SPB Xducer 1	**489**	**6^{o}**	**00**	**Unit 11A**	**313**		**205**	**31^{o} downstream of vertical**	**239**	
SPB Xducer 2	**491**	**6^{o}**	**02**	**Unit 12C**	**313**		**199**	**31^{o} downstream of vertical**	**239**	
System McN_A										**20**
SPB Sounder						**235**				
Remote Multiplexer										
SPB Xducer 1	**486**	**6^{o}**	**01**	**Unit 13A**	**235**		**132**	**31^{o} downstream of vertical**	**239**	
SPB Xducer 2	**453**	**6^{o}**	**02**	**Unit 14B**	**313**		**137**	**31^{o} 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	A	1	13A	26	486	4.00	211.83	-99.83	-56	3.0	-26	4.5
-4	A	2	14B	26	453	5.25	211.91	-101.16	-56	3.0	-26	4.5
-4	B	0	8C	10	466	6.50	213.48	-103.98	-56	3.0	-26	4.5
-4	B	1	9B	10	463	7.25	213.28	-104.53	-56	3.0	-26	4.5
-4	C	0	6C	55	470	4.25	213.53	-101.78	-56	3.0	-26	4.5
-4	C	1	7B	55	471	4.75	213.21	-101.96	-56	3.0	-26	4.5
-4	D	0	4C	52	492	3.25	212.74	-99.99	-56	3.0	-26	4.5
-4	D	2	5A	52	461	2.75	212.94	-99.69	-56	3.0	-26	4.5
-4	E	0	11A	50	489	4.25	213.33	-101.58	-56	3.0	-26	4.5
-4	E	2	12C	50	491	3.50	213.36	-100.86	-56	3.0	-26	4.5
-4	F	0	2B	53	452	6.75	212.17	-102.92	-56	3.0	-26	4.5
-4	F	1	3A	53	494	4.75	213.29	-102.04	-56	3.0	-26	4.5

Appendix B

Raw Data

Appendix B

Raw Data

Raw data are included in the attached file, "MCN_2012_Appendix_B_Raw_Data.csv." The attached file, "MCN_2012_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.

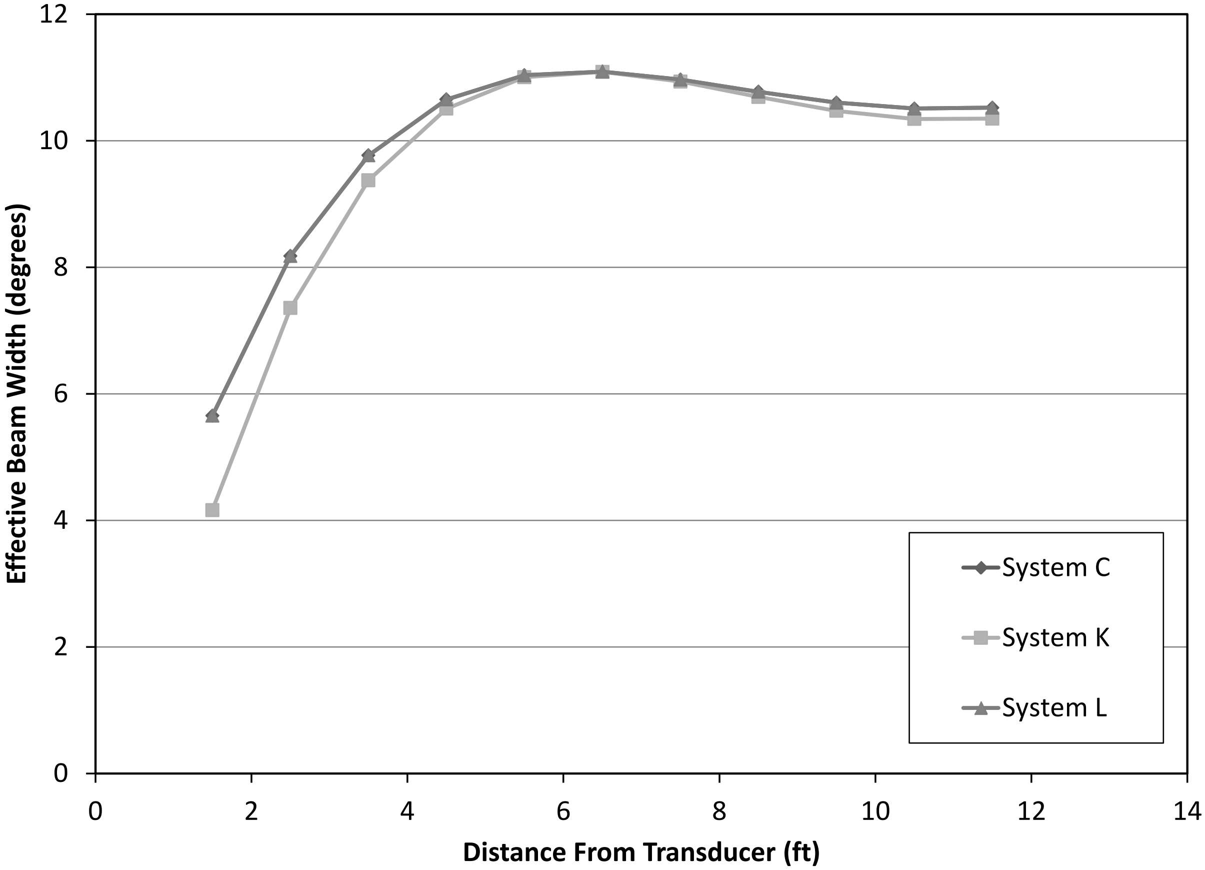

Figure C.1. Effective Beam Widths by System

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 adult steelhead passage through the powerhouse during the winter and early spring, prior to the juvenile salmonid migration periods. The estimates of steelhead 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 $c_{ij} = 15 \;\; \forall ij$. 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

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

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.