Boundary Hydroelectric Project (FERC No. 2144)

Study No. 12
Fish Entrainment and Habitat Connectivity Study
Second Interim Report

Prepared for
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March 2009

TABLE OF CONTENTS

1 Introduction..........1

2 Study Objectives..........1

3 Study Area..........2

3.1. Boundary Project Description and Operations..........3

4 Methods..........4

4.1. Hydroacoustic Sampling Methods..........5

4.1.1. Hydroacoustic Powerhouse Entrainment..........7

4.1.2. Hydroacoustic Spillway Entrainment..........10

4.2. Fyke Net Sampling Methods..........11

4.2.1. Powerhouse Fish Entrainment Estimation..........13

4.2.2. Spillway Fish Entrainment Estimation..........14

5 Results..........15

5.1. Hydroacoustic Powerhouse Distributions..........15

5.1.1. Total Estimated Entrainment..........15

5.1.2. Entrainment Timing..........21

5.1.3. Temporal Entrainment Distributions..........24

5.1.4. Entrainment by Turbine Unit (Horizontal Distribution)..........31

5.1.5. Hydroacoustic Target Entrainment at Unit Start Up..........38

5.1.6. Hydroacoustic Velocity Distributions..........40

5.1.7. Target Strength Distributions..........41

5.2. Hydroacoustic Spillway Distributions..........47

5.2.1. Spillway Entrainment Distributions..........48

5.2.2. Target Strength Distributions by Spill Bay..........52

5.3. Fyke Net Sampling at Turbine Unit 54..........54

5.3.1. Fyke Net Catch Species Composition..........55

5.3.2. Target Strength Distributions during Fyke Net Tests..........57

5.3.3. Fyke Net and Hydroacoustic Entrainment Comparisons..........58

5.3.4. Spatial Distribution of Entrainment at Unit 54..........63

5.4. Powerhouse Fish Entrainment Estimates..........65

5.4.1. Fyke Net NBT Recapture Efficiency..........67

6 Summary..........68

6.1. Powerhouse Fish Entrainment Estimates..........68

6.2. Fyke Net Sampling at Turbine Unit 54..........69

6.3. Hydroacoustic Spillway Distributions..........69

6.4. Hydroacoustic Powerhouse Distributions 70
6.5. Hydroacoustic and Fyke Net Relationship 71

7 Variances and Modifications from the FERC-approved Study Plan 73

7.1. Hydroacoustic Sampling 73
7.2. Proposed Sampling Modifications 73

8 References 73

Appendices

Appendix 1: Study No. 12 Fish Entrainment and Habitat Connectivity Study Interim Report (Methods and Results Sections Only)
Appendix 2: Fish Entrainment Study Methods Outline Report
Appendix 3: Fyke Net Fish Passage Estimator with Variance
Appendix 4: Fyke Net Fish Capture Summary

List of Tables

Table 5.1-1. Total estimated target entrainment with 90 percent CI, raw detections (N), megawatt hours (MWh) produced, mean targets per MWh, and mean targets per hour of turbine operation for the May 2, 2007-October 15, 2008 study period. 16
Table 5.1-2. Monthly total estimated target entrainment with 90 percent CI, raw detections (N), total megawatt hours (MWh) produced, mean targets per MWh, and mean targets per hour of turbine operation for the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate.......................... 19
Table 5.1-3. Monthly total estimated target entrainment, total megawatt hours (MWh) produced, and mean targets per MWh for the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate. 20
Table 5.1-4. Weekly estimated entrainment, with 90 percent CI, total megawatt hours produced, targets per MWh and targets per hour of unit operation for the October 16, 2007-October 15, 2008 study period. Weeks are numbered sequentially with Week 1 beginning at January 1, 2007. Week 1 for 2008 includes December 30 and 31, 2007. Note: Only a 5 day monitoring period is reflected in the Week 42 (07) estimate and a 4 day period in the Week 42 (08) estimate.. 22
Table 5.1-5. Diel (24 h) distribution of hydroacoustic targets entrained at the powerhouse (all units combined) over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at all turbine units and entrainment rates (targets per MWh and targets per hour of unit operations) are shown for each hour. 26
Table 5.1-6. Diel (24 h) distribution of total hours of unit operations (all units combined) over the October 16, 2007-October 15, 2008 study period... 28
Table 5.1-7. Horizontal distribution of total estimated hydroacoustic entrainment at each turbine unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at each unit and entrainment rates (targets per MWh and targets per hour of unit operation) are also presented. 32
Table 5.1-8. Total estimated monthly hydroacoustic entrainment by unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at each unit and entrainment rates (targets per MWh and targets per hour of unit operation) are also presented on a monthly basis. 35
Table 5.1-9. Mean estimated target entrainment by 15 minute sequence after unit start up, with 90 percent CI, April 16-July 15, 2008. 39
Table 5.1-10. Mean target velocity at the powerhouse and by unit, with 90 percent CI, October 16, 2007-July 15, 2008.. 41
Table 5.1-11. Weekly mean target strength (TS) and corresponding estimated mean fish length (based on Love 1971) for all turbine units combined over the October 16, 2007-October 15, 2008 study period. The 90 percent CI bounds surrounding each weekly TS and length estimate are shown. 43
Table 5.1-12. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI bounds. 45
Table 5.2-1. Mean gate opening, mean gate spill discharge, hours of spill at each gate and the difference between Gate 1 and Gate 2, for each day of spill between March and July, 2008. 48

Table 5.2-2. Total estimated target entrainment by spill gate, with 90 percent CI, entrainment per million cubic feet (mcf) of spill, total entrainment per hour of spill, and mean discharge (cfs) for all spill events in 2008. 50
Table 5.2-3. Total estimated number of hydroacoustic targets entrained with 90 percent CI, entrainment per million cubic feet (mcf), entrainment per hour of spill, and mean discharge (cfs) by month for each spill gate, March-July 2008. 52
Table 5.2-4. Mean target strength and mean length, with corresponding 90 percent confidence intervals at the two spill gates during spill conducted in 2008. 53
Table 5.2-5. Mean target strength (TS) and estimated mean length, with corresponding 90 percent CI, for each spill gate by month, 2008. 54
Table 5.3-1. Summary of the fyke net sampling capture data, including mean length and range, by species, for all fish captured between February 16 and October 26, 2008. 56
Table 5.3-2. Summary of the numbers of fish captured during fyke net sampling, by species, for each month of the fyke net sampling period, February 16-October 26, 2008. 57
Table 5.3-3. Fyke net fish counts and weighted (for beam spread) acoustic counts for fyke net tests conducted between April 12 and October 26, 2008. All fyke net tests were conducted at a unit load of 90 MW. 59
Table 5.3-4. Fyke net sample date and time, and weighted target entrainment estimate for each transducer at Unit 54 at Boundary Dam, May-July, 2008. 64
Table 5.3-5. Summary table of the ANOVA (α=0.10) of target entrainment for each of the three transducers located at Unit 54, May 10-July 15, 2008. 65
Table 5.4-1. Estimated Boundary Dam fish entrainment through all operating turbine units on a monthly basis for the April-October 2008 sampling period, with surrounding 90 percent confidence intervals. 66

List of Figures

Figure 3.0-1. Plan view of the proposed Boundary Dam hydroacoustic system transducer deployment, showing the six 6°x10° nominal beam width transducers monitoring the powerhouse and the four 15° nominal beam width transducers installed at the spillway. 2
Figure 3.1-1. Photograph of the powerhouse during Project construction, showing the six turbine unit intakes. Elevations use NAVD 88 datum. 4
Figure 4.1-1. Schematic showing the location of the hydroacoustic transducers at the turbine unit intakes, relative to the fyke net sampling location in the draft tube gate slot at Boundary Dam. Elevations use NAVD 88 datum. 8
Figure 4.1-2. Two additional transducers (top) were added to the mount at Unit 54 on May 10, 2008 to test the spatial weighting assumptions of target detection. 9
Figure 5.1-1. Estimated hydroacoustic target entrainment per month, with 90 percent CI, and total megawatt hours (MWh) produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate. 17
Figure 5.1-2. Estimated monthly hydroacoustic target entrainment per megawatt hour (MWh) produced, and total MWh produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate. 18
Figure 5.1-3. Total estimated hydroacoustic target entrainment per hour of operation for each month, and total megawatt hours (MWh) produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate. 18
Figure 5.1-4. Total estimated hydroacoustic target entrainment per MWh of operation for each month, produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 16 day monitoring period is reflected in the October 2007 monthly estimate, and only a 15 day period in October 2008. Note: Fish per MWh for the October 1-15, 2007 period was 0.34. 21
Figure 5.1-5. Total estimated number of targets entrained, with 90 percent CI, and total MWh produced by week, for the October 16, 2007-October 15, 2008 study period. Note: Only a 5 day monitoring period is reflected in the Week 42 (07) estimate and a 4 day period in the Week 42 (08) estimate. 22
Figure 5.1-6. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at the Project by hour over the period is displayed on the secondary Y-axis. 25
Figure 5.1-7. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the January-March, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the January-March, 2008 period are displayed on the secondary Y-axis. 29
Figure 5.1-8. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the April-June, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the April-June, 2008 period are displayed on the secondary Y-axis. 29

Figure 5.1-9. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the July-September, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the July-September, 2008 period is displayed on the secondary Y-axis. 30
Figure 5.1-10. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the October-December, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the October-December period is displayed on the secondary Y-axis. 30
Figure 5.1-11. Horizontal distribution of total estimated hydroacoustic entrainment by turbine unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. The total MWh produced at each unit of the powerhouse is shown on the secondary Y-axis. ... 31
Figure 5.1-12. Horizontal distribution of estimated hydroacoustic target entrainment at each turbine unit on a monthly basis over the October 16, 2007-April, 2008 study period, with 90 percent CI. Total MWh for each unit is presented on the secondary Y-axis. 33
Figure 5.1-13. Horizontal distribution of estimated hydroacoustic target entrainment at each turbine unit on a monthly basis over the May-October 15, 2008 study period, with 90 percent CI. Total MWh for each unit is presented on the secondary Y-axis. 33
Figure 5.1-14. Monthly hydroacoustic target entrainment estimates by turbine unit over the October 16, 2007-April, 2008 study period, with 90 percent CI. Total MWh (all units combined) for each month is presented on the secondary Y-axis. 34
Figure 5.1-15. Monthly hydroacoustic target entrainment estimates by turbine unit over the May-October 15, 2008 study period, with 90 percent CI. Total MWh (all units combined) for each month is presented on the secondary Y-axis. 34
Figure 5.1-16. Total estimated hydroacoustic target entrainment per MWh of operation at each turbine unit and total MWh produced at each unit over the October 16, 2007-October 15, 2008 study period. 37
Figure 5.1-17. Total estimated hydroacoustic target entrainment per hour of unit operation at each turbine and total MWh produced at each unit over the October 16, 2007-October 15, 2008 study period. 38
Figure 5.1-18. Mean estimated entrainment, and 90 percent CI, for successive 15 minute intervals after unit start up, April 16-July 15, 2008. 39
Figure 5.1-19. Estimated mean target entrainment velocity, with 90 percent CI, at each powerhouse unit between October 16, 2007 and July 15, 2008. 40
Figure 5.1-20. Weekly estimated mean fish length (based on Love 1971) for all turbine units combined over the October 16, 2007-October 15, 2008 study period. The 90 percent CI bounds surrounding each weekly length estimate are shown. 42
Figure 5.1-21. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the October 16, 2007-April 30, 2008 study period. The 90 percent CI bounds surrounding each estimate are shown. 44
Figure 5.1-22. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the May 1-October 15, 2008 study period. The 90 percent CI bounds surrounding each estimate are shown. 45
Figure 5.2-1. Total estimated number of hydroacoustic targets at each spill gate, with 90 percent CI, and mean discharge (cfs) at each spill gate in 2008. 50
Figure 5.2-2. Total estimated entrainment at each spill gate, by month, during the 2008 spill period. Total gate spill (mcf) is shown on the secondary y-axis. 51

Figure 5.2-3. Mean target strength (dB) and mean length (cm), with corresponding 90 percent CI, at the two spill gates during spill events in 2008. 53
Figure 5.2-4. Mean target strength (dB) and mean length (cm), with corresponding 90 percent CI, at the two spill gates during spill events in 2008. March values were deleted from the graphic due to small sample size. 54
Figure 5.3-1. Summary of the fyke net sampling capture data, for all fish captured between February 16 and October 26, 2008. 55
Figure 5.3-2. Length frequency histogram of fish caught during fyke net tests compared to the estimated length of acoustic targets (using Love 1971) detected at Unit 54 during fyke net testing, February 16-October 26, 2008. 58
Figure 5.3-3. Estimated entrainment at Unit 54 on each of the three transducers during fyke net tests conducted at Boundary Dam, 2008........ 63
Figure 5.4-1. Estimated Boundary Dam fish entrainment through all operating turbine units on a monthly basis for the April to October 2008 sampling period, with surrounding 90 percent confidence intervals. 66
Figure 5.4-2. Neutrally buoyant target (NBT) recapture efficiencies from the 80 fyke net samples conducted between April 12 and October 26, 2008. 68

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Study No. 12: Fish Entrainment and Habitat Connectivity Study Second Interim Report Boundary Hydroelectric Project (FERC No. 2144)

1 INTRODUCTION

Study No. 12, the Fish Entrainment and Habitat Connectivity Study, is being conducted in support of the relicensing of the Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP; SCL 2007a) submitted by Seattle City Light (SCL) on February 14, 2007 and approved by the FERC in its Study Plan Determination letter dated March 15, 2007.

This 2008 Study 12 Second Interim Report summarizes the results of the hydroacoustic fish entrainment monitoring effort at Boundary Dam for the period from October 16, 2007 through October 15, 2008. These results are compared with those reported in the 2007 Interim Report (SCL 2008), which describes the May 2, 2007 to October 15, 2007 Study 12 results. All Study 12 hydroacoustic entrainment data collected since the beginning of the sampling effort on May 2, 2007 are included in the Second Interim Report. Monthly hydroacoustic target entrainment data for the May 2, 2007 to October 15, 2008 period are described in the body of this Second Interim Report. In addition, the results of the fish entrainment estimates collected at Unit 54 using paired fyke net capture and hydroacoustic techniques from April 12 to October 26, 2008 are also reported here. The earlier hydroacoustic entrainment distributions from the May 2, 2007 to October 15, 2007 period are provided in Appendix 1.

A complete summary of all Boundary Dam hydroacoustic and fyke net fish entrainment results over the entire May 2007 to February 2009 monitoring period will be presented in the Study 12 Final Report in June 2009. The Study 12 Final Report will also include Study 9 fish distribution information collected in the Boundary Dam reservoir and tailrace, as relevant for interpretation of the Study 12 results.

2 STUDY OBJECTIVES

The goal of the Fish Entrainment and Habitat Connectivity Study is to estimate the number, size, species, and passage timing of fish that may be entrained within the Project turbine intakes and spillways. The limited frequency, duration of use, and flow conditions associated with the use of the sluiceways, and the discontinued use of the skimmer gate, reduces the need to quantify the number of fish potentially entrained through these pathways. For this reason, the assessment of the potential impact of fish entrainment at the Project is focused on entrainment through the turbine and spillway routes (RSP; SCL 2007a). Fish entrainment through all operating turbine and spillway pathways has been monitored at the Project since spring 2007 to quantify potential impacts to the resource. This entrainment monitoring is scheduled to conclude during the first quarter of 2009. The final results of the Study will be used to estimate the effects of powerhouse and spillway operations on hourly, daily and seasonal patterns of fish entrainment at Boundary Dam.

Additional details describing the Fish Entrainment and Habitat Connectivity Study objectives are provided in the Study 12 Methods Outline document dated July 17, 2007, located in Appendix 2 of this report.

3 STUDY AREA

The Study 12 sampling area encompasses Boundary Dam and associated structures, the turbine intake forebay, and the reservoir immediately upstream of the spillway. The hydroacoustic monitoring study area is located immediately upstream of Units 51-56 in the Boundary forebay, and in front of the two spill gates (Figure 3.0-1). Fyke net sampling is conducted in the Unit 54 draft tube gatewell, downstream of the turbine unit and adjacent to the tailrace outlet.

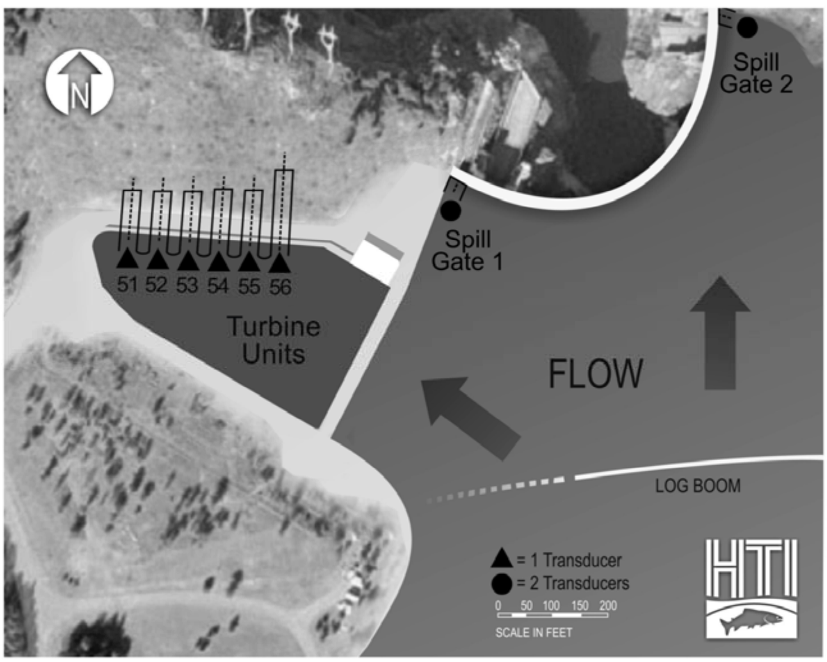

Figure 3.0-1. Plan view of the proposed Boundary Dam hydroacoustic system transducer deployment, showing the six 6°x10° nominal beam width transducers monitoring the powerhouse and the four 15° nominal beam width transducers installed at the spillway.

3.1. Boundary Project Description and Operations

Boundary Dam is constructed with six deep turbine intakes 30 feet wide by 34 feet high (horseshoe-shaped in cross section) located at an invert elevation of 1,907 feet NAVD 88[1] (1,903 feet NGVD 29) in the Boundary forebay (Figure 3.1-1). The six turbine intakes/units are referred to as Units 51-56, with Unit 51 located at the west end of the powerhouse (Figure 3.1-1). The Project has a maximum turbine flow capacity of 55,000 cfs, which is more than twice the average annual flow of the Pend Oreille River near Boundary Dam (SCL 2006).

The floor of the forebay intake channel beneath the turbine intakes is located at elevation 1,904 feet NAVD 88 (1,900 feet NGVD 29), and the top of the turbine intakes are located at elevation 1,941 feet NAVD 88 (1,937 feet NGVD 29).

Boundary Dam has two spillways, one on either side of the main arch dam section (Figure 3.0-1). Both spill gates are bottom-opening tainter gates, 50 feet high by 45 feet wide. When fully closed, the top of the gates are at an elevation of 1,994 feet NAVD 88 (1,990 feet NGVD 29), which corresponds to the normal maximum pool elevation of Boundary Reservoir in the forebay area.

Spillway 1 is on the left bank looking downstream, and Spillway 2 on the right bank.
When the powerhouse flows reach full capacity (i.e., 55,000 cfs) during higher flow or flood conditions, the spillway gates are opened to pass flows downstream. Spill events typically occur during April through July.

Boundary Dam also incorporates seven sluiceways located at about mid-height of the dam that discharge into the plunge pool below the dam. The sluiceways are generally used to supplement the spill flow during extreme high-flow events. They are rarely operated and were not monitored during this study.

The Project is operated using a load-following strategy, meaning the power plant adjusts its power output as demand for electricity fluctuates throughout the day (SCL 2006). Load-following power plants typically run during the day and early evening, and then either shut down or greatly curtail output during the night and early morning, when the demand for electricity is lowest. The exact hours of operation depend on daily power demand and other factors.

At the Project, the normal maximum reservoir water surface is at elevation 1,994 feet NAVD 88 (1,990 feet NGVD 29). The reservoir has relatively little active storage (about 41,000 acre-feet) within the maximum drawdown of 40 feet (active storage from elevation 1,994 to elevation 1,954 feet NAVD 88 [1,990-1,950 feet NGVD 29]) authorized under the current license. SCL voluntarily restricts and maintains the summer forebay pool to a water surface elevation above

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[1] SCL is in the process of converting all Project information from an older elevation datum (National Geodetic Vertical Datum of 1929 [NGVD 29]) to a more recent elevation datum (North American Vertical Datum of 1988 [NAVD 88]). As such, elevations are provided relative to both data throughout this document. The conversion factor between the old and new data is approximately 4 feet (e.g., the crest of the dam is 2,000 feet NGVD 29 and 2,004 feet NAVD 88).

1,984 feet, NAVD 88 [1,980 feet NGVD 29] from 0600 hours through 2000 hours from Memorial Day weekend through Labor Day weekend to facilitate reservoir access and related recreational activities during daytime hours. At night during the summer, from 2000 hours to 0600 hours, the forebay pool elevation is maintained above elevation 1,982 feet (NAVD 88) [1,978 feet NGVD 29]. Storage between elevation 1,974 feet and 1,954 feet NAVD 88 (1,970-1,950 feet NGVD 29) is reserved for extreme system load requirements. Flood storage is not provided at the Project, and other than the operating goals noted above, there are no seasonal or minimum flow requirements (SCL 2006).

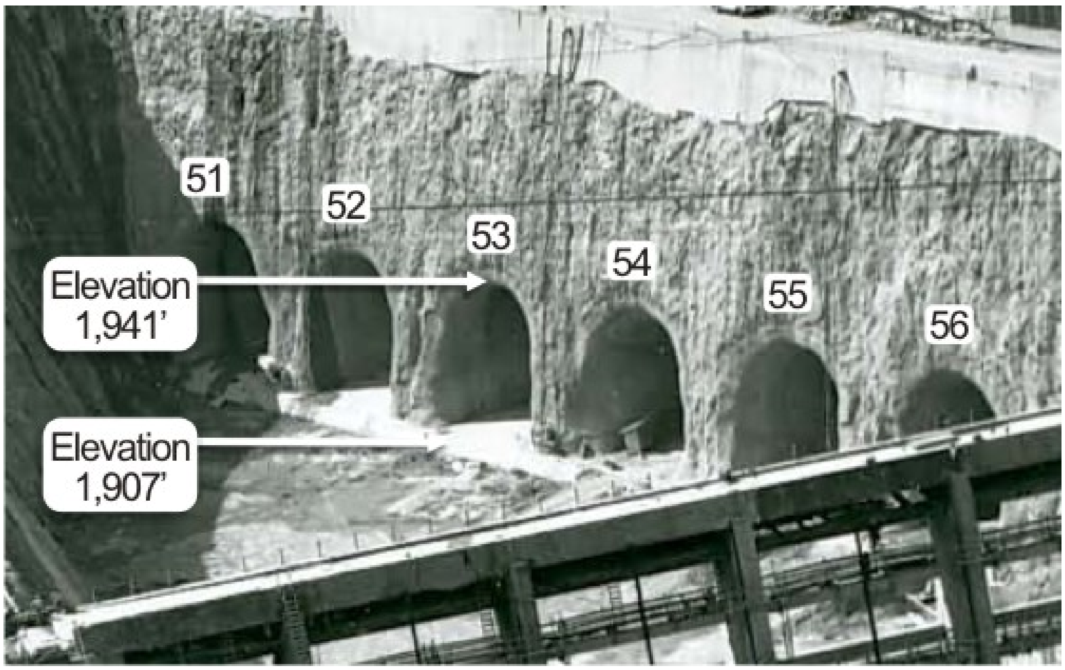

Figure 3.1-1. Photograph of the powerhouse during Project construction, showing the six turbine unit intakes. Elevations use NAVD 88 datum.

4 METHODS

The Fish Entrainment and Habitat Connectivity Study consists of separate turbine and spillway monitoring components. Entrainment information from both components is summarized to estimate total entrainment through the Project over time. Study 12 uses complementary hydroacoustic and net sampling methods to describe fish passage through the Project. Turbine entrainment is estimated using both hydroacoustic and fyke netting techniques, while spillway entrainment is estimated using hydroacoustic sampling only.

Hydroacoustics provides high temporal and spatial coverage at each turbine and spillway passage route. The hydroacoustic monitoring program was designed to provide measures of total fish entrainment that are comparable between passage locations and over time, with associated confidence intervals. Hydroacoustic data collection was initiated at Boundary Dam on May 2,

2007. The results of the monitoring efforts through October 15, 2008 are presented in this report.

Systematic netting at Unit 54 is used in the Fish Entrainment and Habitat Connectivity Study to validate the corresponding acoustic counts and for fish species identification. The fyke net fish capture data is compared with the concurrent hydroacoustic results at Unit 54 over time using orthogonal regressions and other methods. These comparisons evaluate the relationship between the two data sets and are periodically updated as additional information is collected. The fish capture rates from the netting are also extrapolated across all turbines at the Boundary Dam Powerhouse based on unit operations to provide a measure of total entrainment at the Project. This fyke net entrainment estimate assumes that the Unit 54 fish capture rates are representative of all turbines and that fish entrainment has a linear relationship with the magnitude of turbine operations.

Investigations of both the hydroacoustic and fyke net data sets are continuing, and final recommendations regarding the relationship of the two data sets will be presented in the Study 12 Final Report in June 2009.

The Study 12 data collection and analysis methods are summarized below. Additional details describing these methods are provided in the Study 12 Methods Outline document (Appendix 2) dated July 17, 2007, and approved by the relicensing participants on February 28, 2008.

4.1. Hydroacoustic Sampling Methods

Hydroacoustic target entrainment data are collected and analyzed using split-beam target tracking techniques as described by Ehrenberg and Torkelson (1996), and following the scientific acoustic sampling principles outlined in MacLennan and Simmonds (1992). The principle of fixed-location, split-beam hydroacoustic techniques is based on placing one or more transducers on fixed structures and sampling targets as they pass through the insonified acoustic beams. The targets produce characteristic echo returns that are processed to produce total passage estimates. Additional information describing target passage rates, direction of movement, size, velocity, vertical distributions and other parameters is also available from the hydroacoustic data set.

The hydroacoustic equipment required for a quantitative fixed-location study includes a scientific-quality echo sounder/transceiver, transducers, and a computer-based echo processor. The primary component of a hydroacoustic data collection system is the scientific echo sounder. When triggered, the echo sounder transmits a short electrical pulse of known frequency, duration, and power. The transducer then converts the electrical pulse into mechanical energy (i.e., a sound pulse with the same characteristics as the electrical pulse). In fixed-location applications, the transducers typically have relatively narrow beam widths so they can be aimed close to physical boundaries (e.g., the face of a dam) and maximize sampling coverage in specific areas of interest, such as a turbine intake.

When the sound waves encounter fish or other targets, echoes are reflected back to the transducer. The transducer then converts the sound energy back into electrical energy and sends it back to the receiver portion of the echo sounder. The echo signals are relayed to a computer-based echo processor, which records each echo detection to a computer file for subsequent analysis.

Individual targets were manually identified, tracked and summarized from these echo detection files by experienced data entry technicians using the HTI EchoScape data entry program. EchoScape allows the user to interactively investigate individual echoes within each observed target. Individual echoes can be added or excluded to completely describe each observation, and the echoes from each accepted fish trace are written to a summary output data file. Since the split-beam system collects data in three dimensions, all potential entrained targets were scrutinized as they passed through the acoustic beam in the X, Y, and Z-axes. The manual review and entry of the Boundary Dam hydroacoustic data set ensured consistency in all logged target detections and minimized the potential for "false positive" detections that could occur due to entrained air bubbles or other non-biological interference. The manual hydroacoustic data entry process incorporated rigorous quality control procedures, where randomly-selected data files from each technician were blindly re-entered by other technicians and compared by the senior data analyst. Significant discrepancies between data entry technicians have not been observed to date. Hydroacoustic target tracking methods are described in additional detail in Ehrenberg and Torkelson (1996).

Once individual entrained targets were identified using the EchoScape software, the tracked target data files were output to a SQL database for final analysis. The descriptive parameters for each target included its' position in the X, Y, and Z coordinates, distance traveled in each plane, acoustic size, location of the sample and other descriptive parameters.

Within the database, each marked target observation was weighted by the ratio of the turbine intake (or spill bay) width to the diameter of the acoustic beam at the range of a detected target. This spatial weighting factor was applied to each target detection to account for unsampled area across each turbine intake opening. Spatial weighting removes the effect of increasing sample volume with range (transducer beam spreading). Each detection was weighted by the following equation:

$$Wf = \frac{IW}{2*R*\tan(BW/2)}$$

where;

Wf = weighted fish (target) value,
R = range of the target from the transducer in meters,
IW = intake width at range R, and
BW = the nominal transducer beamwidth of the transducer, defined by the maximum off-axis echo acceptance angle criteria used during data collection.

Following identification, entry to the database, and weighting for unsampled area, all targets with characteristics consistent with entrainment were extracted and summarized. The entrained target selection and analysis criteria for the powerhouse and spillway are described below in Sections 4.1.1 and 4.1.2, respectively.

4.1.1. Hydroacoustic Powerhouse Entrainment

The Boundary powerhouse consists of six turbine units, numbered Units 51-56. Vertically-oriented 6˚x10˚ nominal beam width[2] transducers are mounted on the centerline of each turbine intake at elevation 1,972 feet NAVD 88 (1,968 feet NGVD 29) and aimed down to monitor the water column immediately upstream of each turbine intake opening (Figure 4.1-1). The transducers operate at a sampling frequency of 200 kHz and use split-beam technology to track the position and direction of individual targets in three-dimensional space. Only targets exhibiting net movement into the intake are considered to be entrained. The six transducer turbine intake monitoring array is sampled continuously, 24 h/d. Individual transducers at each turbine intake are sequentially-sampled in 2.5-min increments across the powerhouse within each 1-hour data replicate, such that each location is monitored 10 min/h. All entrained target detections are weighted for unsampled time and space, and the resulting estimates represent total hourly target passage at each location.

[2] The actual beam pattern plots and other parameters that describe each transducer are measured during laboratory calibrations and referenced in each transducer's calibration file. These values are used in the weighting of raw detections (among other things) to provide entrainment values. A more detailed discussion of transducer characteristics and their function can be found in MacLennan and Simmonds (1992).

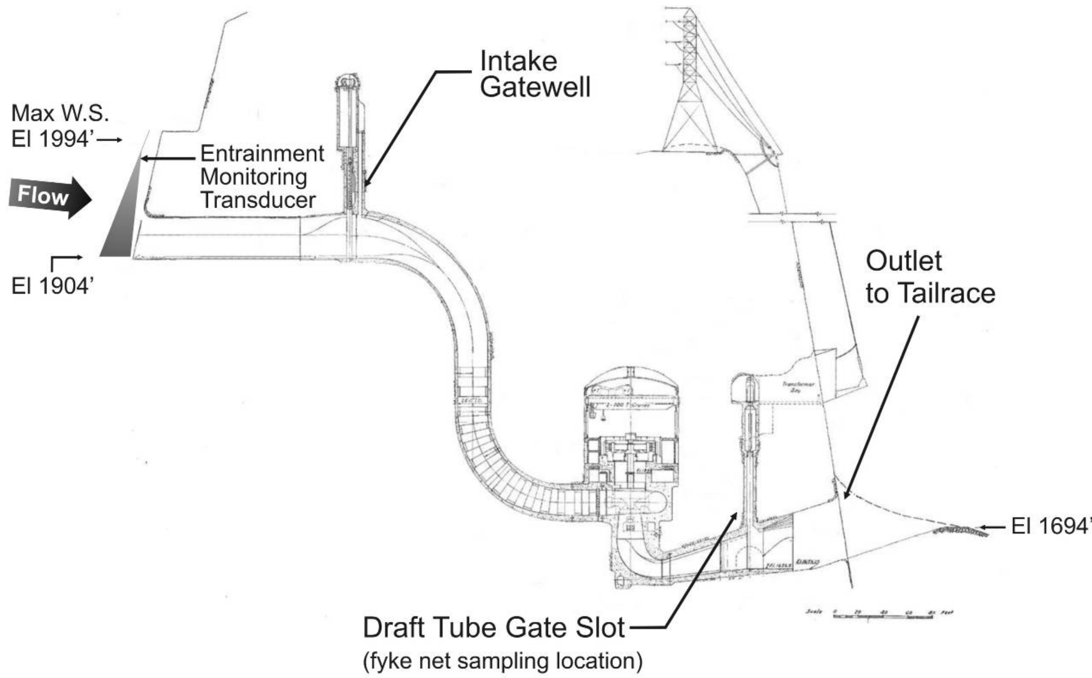

Figure 4.1-1. Schematic showing the location of the hydroacoustic transducers at the turbine unit intakes, relative to the fyke net sampling location in the draft tube gate slot at Boundary Dam. Elevations use NAVD 88 datum.

Each transducer monitors approximately 40 percent of the turbine intake cross-sectional area and the axis of the sampling volume is aligned with the intake centerline. Target detections are weighted for unsampled area (as described in Section 4.1 above) in the intake based on the total intake width at the depth at which the target was observed divided by the width of the transducer beam at that depth. This spatial weighting expands the observed counts to total turbine entrainment estimates, and considers the variable width of the arched turbine intakes with depth. At the top of the turbine intake opening (30.8 feet below each transducer) the acoustic sampling volume is 5.9 feet wide. At the bottom of each intake (69 feet below each transducer), the acoustic volume is 13.3 feet wide, relative to a total base intake width of 30 feet. Range-weighting of each detected target corrects for the increasing sample volume with range and provides an estimate of total turbine entrainment. Turbine unit operations are also referenced during the analyses, such that only targets moving into operating turbines are included in the hydroacoustic entrainment estimates.

Two additional transducers were installed on May 10, 2008 to evaluate the spatial distribution of entrained targets across the Unit 54 intake. The purpose of this investigation was to validate the assumptions of the hydroacoustic fish weighting factor, which extrapolates the hydroacoustic target observations to total estimates of turbine entrainment. The fish weighting factor assumes that entrained targets are randomly distributed across the turbine intake openings, and that the approximately 40 percent of each intake sampled by the hydroacoustics is representative of rates across the entire opening. The three transducers (one existing, and two additional) were mounted in a side-by-side orientation, with an aiming offset angle of eight degrees from the centerline for the two outside transducers, and a vertical (on unit centerline) orientation for the center transducer. This arrangement provided near complete coverage of the entire Unit 54 intake opening at maximum range (Figure 4.1-2). The results of this analysis were used to determine the validity of the hydroacoustic target spatial weighting assumptions, and to assess if changes to this weighting factor were warranted. This evaluation was temporary in nature, and was not planned during the initial study design. The spatial distribution of targets considered to be entrained at Unit 54 was evaluated over an approximately two month period from May 10 to July 15, 2008, with the objective of assessing the validity of the hydroacoustic weighting factor applied to estimate total target entrainment into the turbines at Boundary Dam.

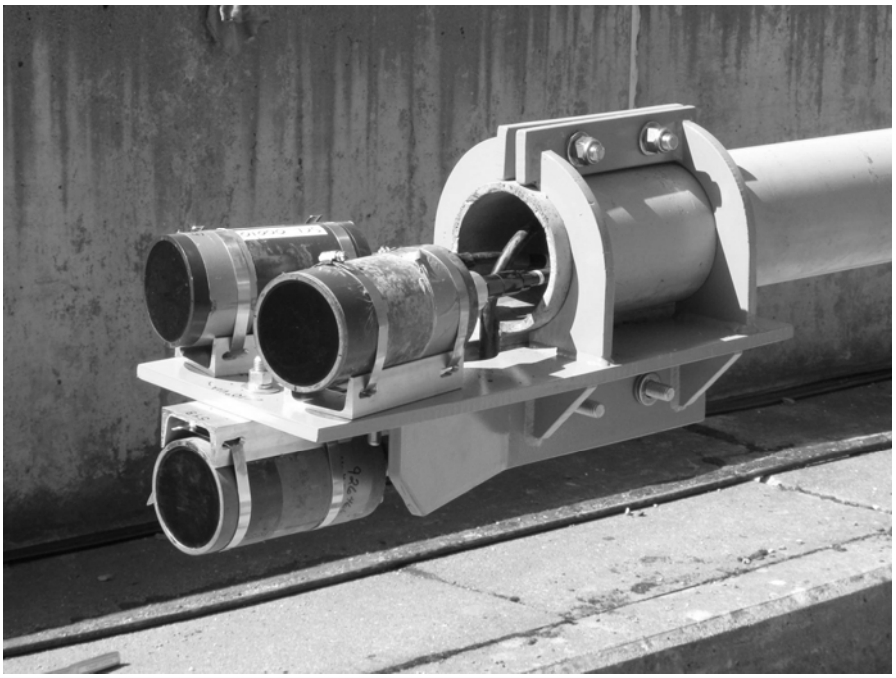

Figure 4.1-2. Two additional transducers (top) were added to the mount at Unit 54 on May 10, 2008 to test the spatial weighting assumptions of target detection.

An acoustic sampling (ping) rate of 12 pings per second (pps) is used at all turbine units. This relatively fast ping rate provides high acoustic detectability (i.e., multiple echo returns) of individual entrained targets. Target detectability at the Boundary turbine intakes was modeled before the data collection period, based on the transducer beam widths, sampling ranges, and maximum water velocities present at the site. A minimum echo detection threshold of -52 decibels (dB) was used for monitoring at the Boundary powerhouse, equivalent to a minimum fish detection length of 43 mm (1.7 inches) based on Love (1971), an empirical formula relating backscattered acoustic energy to fish length. Hydroacoustic data were subsequently filtered in post-processing to include only detections with a mean target strength (acoustic size) of $\geq$ -45 dB, equivalent to an estimated minimum fish detection length of 100 mm (4 inches) using Love (1971). A narrow broadcast pulse width (PW) of 0.2 ms is used by the acoustic system to optimize the detection of closely-spaced individual targets.

To minimize the potential for inclusion of detections from debris, entrained air, and non-fish targets in the hydroacoustic entrainment summaries, each hydroacoustic detection was filtered using multiple criteria. Targets reflecting less energy than expected from a 4-inch long fish (≤ -45 dB mean target strength, based on Love, 1971) were excluded from the data record. If suspended debris were present in the study area, the majority of this debris would be anticipated to return target strength values less than -45 dB and would be removed by this filtering. Only echo returns with pulse widths within +/- 50 percent of the 0.2 ms transmitted signal (values of 0.08 to 0.29 ms, as measured at the echo half-amplitude point) were considered during target tracking. Debris typically returns echo widths wider than the transmitted signal, due to the variable shape and aspect of the particles. Echoes reflected from individual fish typically have widths similar to the transmitted acoustic pulse. In addition, only targets located at depths below the top of the turbine intakes (>30.8 feet below each transducer) and exhibiting consistent net movement downstream into the intakes were considered in the acoustic target counts. To be detected by the acoustic system, targets must have a significant difference in density from the surrounding water. In fish, the air-filled swim bladder is responsible for over 90 percent of the energy reflected from the target (Foote et al. 1986). Debris incorporating sufficient air to return echoes with high enough amplitudes to be detected by the acoustic system would tend to be positively buoyant and not be present at depths below the intake openings. Lastly, each target was required to be detected a minimum of six times as it transited through the acoustic sampling volume, and these detections had to occur sequentially and be located in close spatial proximity. This echo detection redundancy minimized the potential of false detections due to noise or small particles, which are typically variable in position relative to returns from fish.

4.1.2. Hydroacoustic Spillway Entrainment

The Boundary Dam spillway consists of two spill bays, each 45 feet in height and 50 feet in width, located at each end of the arch dam (see Figure 3.0-1). Spill Gate 1 is located at the dam's left abutment, closest to the powerhouse forebay intake channel. Spill Gate 2 is located at the far end of the arch dam, at the right abutment and adjacent to the east shoreline of the reservoir.

In order to monitor targets passing through the spill bays during spill events, two vertically-oriented 15˚ nominal beam width transducers are deployed at each spill bay (four transducers in total) to maximize spatial sampling coverage across each spill gate opening. For the purposes of estimating entrainment, each spill bay is conceptually divided into two halves with one down-looking transducer located equidistantly in each half. The spillway transducers are deployed at an elevation of 1,988 feet NAVD (1,984 feet NGVD 29) and aimed down vertically to monitor the water column immediately upstream of each spill gate opening.

Each spill bay transducer is sampled for six 5-min time intervals per hour during all periods when spill is occurring at the Project. This sampling design provides 60 min of sampling time within each spill bay per hour (30 min per hour in each half of the spill bay opening). The transducers operate at a sampling frequency of 200 kHz and use split-beam technology to track the direction of individual targets in three-dimensional space. Only targets exhibiting movement into the spill bays are considered in the entrainment counts. All entrained target detections are weighted for unsampled time and space (as described in Section 4.1 above), and the resulting estimates represent total target passage at each location. Spillway operations were considered during the analyses, such that only targets moving into the operating spill bay(s) were included in the hydroacoustic entrainment estimates.

The spillway monitoring transducers are sampled using a ping rate of 15 pps, which provides high acoustic detectability of individual entrained targets. Target detectability at the Boundary Dam spillway was modeled prior to the data collection period, based on the transducer beam widths, sampling ranges, and maximum water velocities estimated in the region upstream of the spill gates. The higher potential water velocity in the spill bays relative to the turbine intakes indicated the use of a relatively higher ping rate at the former location. Target detectability is equivalent at the monitored Boundary Dam turbine intake and spill gate locations, based on the model results.

Estimated hydroacoustic target entrainment at the spillway is analyzed, summarized and presented in an identical manner as at the turbine intakes (Section 4.1.1). The same target detection filtering criteria applied at the powerhouse (i.e., a -45 dB minimum mean target strength, echo width bounds, six minimum echo returns) were used at the spillway to minimize the potential impact of echo returns from suspended debris or air bubbles in the entrainment estimates.

4.2. Fyke Net Sampling Methods

A fyke net sampling array was initially installed in the draft tube gatewell of Unit 54 in September 2007. The fyke nets were tested on several occasions between October 2007 and January 2008 and the information gained during these tests was used to refine the sampling design. Following the testing period, routine fyke net sampling was initiated on February 16, 2008. Sampling following standardized fishing protocols has generally occurred on a weekly basis since April 12, 2008. The Unit 54 draft tube is sampled using fyke nets over a 24 h period each week. Weekly fyke net sampling is scheduled to continue through the month of February 2009.

The purpose of the fyke net sampling at Unit 54 is to verify the concurrent hydroacoustic passage estimates at that location and to provide fish species composition information. The fish capture data from the netting is also extrapolated across the entire Boundary Dam Powerhouse to provide estimates of total fish entrainment into all operating turbines at Boundary Dam. The net capture results are compared with the concurrent hydroacoustic results at Unit 54 over time using orthogonal regressions and other methods, in order to evaluate the relationship between the two data sets.

Unit 54 was selected as a representative location for net sampling at the Boundary Dam Powerhouse based on relative target entrainment trends measured by the hydroacoustic monitoring system from May and June 2007. Physical site constraints, project operational considerations, and turbine frequency of use were also considered during the selection of the netting location.

Fyke net sampling is typically conducted for four 24 h periods each month. The typical duration of individual fyke net tests within each 24 h sampling period is approximately 3 h, although individual tests have varied from about 1-4 h in duration. The weekly fyke net sampling period normally begins at 0930 h each Saturday and concludes at 0930 h on Sunday.

Sampling is conducted using two fyke net frames, each incorporating arrays of eight net panels. These arrays consist of two rows of four vertically-stacked nets per net frame. The two frames are lowered in a side-by-side configuration in the Unit 54 draft tube and are designed to sample the entire cross-section of this opening. This deployment is intended to sample 100 percent of the flow in both slots of the Unit 54 turbine draft tube. Each frame measures 17 feet wide by 28 feet high. The frames are massive, weighing approximately 8,200 pounds apiece. The draft tube stop log gantry crane is used to deploy the net frames. The gantry crane is located approximately 135 feet above the sill of the draft tube gatewell. Crews fish the fyke nets from the deck of draft tube gate maintenance chamber, located approximately 92 feet above the draft tube gatewell sill.

The fyke net frames are located downstream of the turbine in the Unit 54 draft tube and the hydroacoustic transducer(s) sample entrainment at the upstream end of the draft tube, at the intake opening. Figure 4.1-1 shows the locations of the hydroacoustic monitoring transducer and the fyke net sampling frame at Unit 54. The hydroacoustic system is switched to sample continuously at Unit 54 during all fyke net tests, to maximize temporal sampling coverage. Only tests where both fyke net frames were fished concurrently are considered in the comparisons with the hydroacoustic results.

The fyke net deployment was designed to provide complete net sampling coverage across the entire Unit 54 draft tube. To establish measures of fish capture efficiency, neutrally-buoyant targets (NBT) are introduced into the Unit 54 draft tube during each netting test. Fifty NBT are typically released, and the net fish recapture efficiency for the test is estimated based on the proportion of these targets that are recaptured in the fyke net panels. The NBT consist of approximately 1-2 cubic inch chunks of vegetables (so they pass through the 4 inch diameter delivery pipe), such as radishes, carrots, or potatoes. It is assumed that these NBT distribute within the draft tube in a similar manner as fish, and have the same net retention characteristics as fish with lengths > 4 inches (equivalent to the minimum size fish included in the hydroacoustic target estimates). Only tests with NBT recapture ratios of 20 percent or greater were considered in the fish entrainment estimates derived from the Unit 54 net sampling described in this report. This NBT efficiency cut-off value was derived based on a review of target recovery efficiencies over all tests to date. The fish capture results of tests with NBT recoveries of less than 20 percent were heavily weighted to account for the presumed lower sampling efficiencies, resulting in inflated variance estimates.

To test the assumption of whether the NBT are suitable surrogates for estimating fish recapture efficiencies, release groups of 50 live triploid rainbow trout, marked in unique locations with India ink, have been released in addition to the NBT during some fyke net tests, beginning October 18, 2008. The complete data set from the marked fish releases will be included in the Study 12 Final Report in June 2009, once sufficient tests have been conducted to provide meaningful results.

Fyke net operation requires the sampled turbine to be shut down during deployment and recovery of the two fyke net frames, both of which are sampled simultaneously during each test. The two net frames are deployed in the draft tube using a crane. The turbine is restarted and sampled for a fixed period. The unit is stopped again and the net frames are retrieved to the deck of draft tube gate maintenance chamber. Unit 54 is operated consistently at a 90 megawatt (MW) loading during all sampling. Based on a hydroacoustic data set collected at Unit 54, loadings of 90 MW and above appeared to result in higher and more consistent entrainment rates and fish approach velocities than loadings below 90 MW. Higher unit loadings (i.e., above 90 MW) have also resulted in significant net damage and potentially reduced sampling efficiencies. A 90 MW loading is assumed to be representative of the typically higher unit loadings during routine generation.

The netting crew inspects each net panel on both frames following retrieval. Any net damage or missing panels are noted. Three types of information are recorded for each fyke net sampling period; total fish capture numbers, fish length data and fish species composition. Each metric is summarized by individual net location and for the entire fyke net array. All fish captured within each net panel are enumerated, identified to species (if possible), and their total length is measured to the nearest millimeter (mm). All captured salmonids are checked for tags, including scanning for passive integrated transponder (PIT) tags using a portable tag reader. The number of NBT target, and marked triploid rainbow trout recaptures, are also summarized for each net panel to estimate overall net efficiency for the test. Any net damage from the previous test is then repaired and the process is repeated.

The fyke net sampling plan was designed to be adaptive in nature, due to uncertainties related to fish passage distributions over time and equipment performance. For maximum statistical power, a minimum of 30 fish captures (for all nets combined per test) was recommended in the Boundary Dam Methods Outline document, with 50 or more fish preferred (> 100 mm total length for all species) per sampled temporal strata (Appendix 2). To date, these sample sizes have not been achieved, but the duration and number of sampling events may be varied under the fyke net sampling plan during future sampling, in an effort to increase sample sizes. To date, extending net sampling beyond approximately 3 h duration has proved difficult, due to increased net damage and causing excessive damage to the fish catch, during extended sampling. Sampling regimes may be modified based on ongoing review of the hydroacoustic counts, associated target strengths and temporal changes in fyke net catches. This evaluation process will continue for the duration of the study period, as differing patterns of river flow and fish movement over the year may indicate changes in sampling frequency over time. This adaptive fyke net sampling approach will allow in-season flexibility to quantify fish entrainment under variable environmental conditions.

Fyke netting results and comparisons with the concurrent hydroacoustic entrainment estimates at Unit 54 for the April 12 to October 26, 2008 period are presented in this report. Subsequent 2008 and 2009 fyke net sampling results will be reported in the Study 12 Final Report in June 2009.

4.2.1. Powerhouse Fish Entrainment Estimation

Both the hydroacoustic and fyke net sampling methods employed at Boundary Dam are imperfect estimators of fish entrainment, and incorporate different potential sampling biases. The two techniques do provide complementary information. The hydroacoustic sampling provides very high temporal and spatial sampling coverage across all operating turbine and spillway openings, but can not absolutely identify fish species. The netting efforts can identify the species composition and lengths of entrained fish and entrainment rates at Unit 54 can be independently estimated using these data. Fyke netting is very labor-intensive and requires a substantial investment in hardware to sample in the high flow environment present in a turbine draft tube. These requirements limit the number of locations and time periods that can be sampled using nets, resulting in a small sample size relative to the hydroacoustic monitoring. However, if the sampling biases of the hydroacoustic and fyke netting efforts are understood, concurrent entrainment rates derived by each method at Unit 54 would be expected to be correlated, given a sufficient sample size.

To date, a 1:1 correlation between the hydroacoustic and fyke net sampling at Unit 54 has not been consistently observed, and the estimates within individual tests are variable relative to one another. The relationship between the hydroacoustic target entrainment estimate and the fyke net catch from sampling at Unit 54 continues to be investigated. The results of ongoing weekly tests at Unit 54 for the November 2008 to February 2009 period will be described in the Study 12 Final Report in June 2009. If a 1:1 relationship of fyke net to hydroacoustic entrainment can be established at Unit 54, the hydroacoustic counts would be validated as absolute measures of Project fish entrainment. A strong positive correlation between the two methods that is different than 1:1 would allow implementation of a combined entrainment estimation approach that considers both the hydroacoustic and fyke netting results. If a significant positive correlation between the two entrainment estimators is not observed, a fyke net only entrainment estimate will be presented.

Two separate estimates of powerhouse entrainment have been produced for this report. The first estimate is based on the hydroacoustic data collected across the powerhouse and provides an estimate of total powerhouse target entrainment. The hydroacoustic target detections are considered as relative measures of fish entrainment, pending additional validation relative to the fyke net capture data. The second method is based solely on the fyke net sampling conducted at Unit 54 and is described in Appendix 3. This approach assumes that the fish capture rates observed at Unit 54 are representative of all operating turbine units and extrapolates these counts based on unit operation. It uses the ratio of fish per megawatt hour for each month of fyke net sampling to account for monthly differences in entrainment rates at Unit 54.

4.2.2. Spillway Fish Entrainment Estimation

Hydroacoustic monitoring at the Boundary Dam spillway is used to estimate the number, size and timing of targets entrained within Boundary Dam Spillways 1 and 2. Fyke net sampling within the Unit 54 draft tube gatewell is used to verify hydroacoustic targets and identify species composition of entrained fish at that location. For the purposes of estimating fish entrainment at the spillways, the following assumptions were made in the February 2007 Boundary Dam RSP (SCL 2007a):

- The species composition of fish captured in the turbine fyke nets is similar to the composition of fish entrained in the spillways (see Section 5.3.1, Fyke Net Catch Species Composition).

- Hydroacoustic target signatures can be adequately translated to size and numbers of fish.

- If the spillway hydroacoustic target signatures cannot be satisfactorily translated to fish entrainment and size estimates using the available Study 12 data, other potential data and sampling methods will be considered for this purpose. Data that may be considered in future fish entrainment translation efforts at the spillway includes the results of biological sampling in the forebay and immediately in front of the spillway gates during days/nights when spillways are not in use (collected under Study No. 9, Fish Distribution, Timing and Abundance Study) and the observed relationship between the paired hydroacoustic and fyke net capture entrainment estimates at Unit 54. Additional sampling methods that may be evaluated include, but are not limited to, an underwater video system installed to record the passage of fish during periods of spillway operation, or a trap (screw or scoop type) installed in the tailrace during spill events.

The ongoing paired hydroacoustic and fyke net entrainment comparisons at Unit 54 comprise the Study 12 data set currently available for translation of the hydroacoustic target passage indices at the spillway into fish entrainment estimates. The results of the Unit 54 comparisons are inconclusive to date, but will be summarized in the Study 12 Final Report document in June 2009. Therefore, the hydroacoustic spillway target entrainment estimates described below should be considered as relative measures, comparable with the hydroacoustic powerhouse results, but not established as absolute measures of fish entrainment at this time.

5 RESULTS

For purposes of comparison, selected 2007 results have been incorporated (where appropriate) and discussed in individual results sections. The complete results from the May 2 to October 15, 2007 sampling period, as summarized and reported in the 2007 Interim Report (SCL 2008), are also provided in Appendix 1.

5.1. Hydroacoustic Powerhouse Distributions

5.1.1. Total Estimated Entrainment

Estimated total hydroacoustic target entrainment at the powerhouse was summarized on a monthly and study period basis. To evaluate potential effects of variable turbine operations on target entrainment, two entrainment rate metrics were calculated and compared. Entrainment rates were expressed as both the number of targets per hour of unit operation and targets per megawatt hour (MWh) of power production. Both metrics were estimated on a monthly and study period basis.

Table 5.1-1 shows the estimated total entrainment of hydroacoustic targets through all turbine units for the May 2, 2007 through October 15, 2007 and the October 16, 2007 through October 15, 2008 sampling periods, with the associated 90 percent confidence intervals (CI). The table also includes the total megawatts produced by all units; the estimated number of targets passed per MWh, and the estimated targets per hour of unit operation over the period.

A total of 985,864 entrained targets were estimated to have passed downstream through Units 51-56 over the twelve month period between October 16, 2007 and October 15, 2008. This was equivalent to mean entrainment rates of 35.04 targets per hour of unit operation, or 0.26 targets per MWh of power production. These estimates include only targets equal to or greater than 10 cm in length (approximately 4 inches), assuming the targets are fish and applying the Love (1971) relationship.

By comparison, estimated target entrainment during the 5.5 month study period from May-October 15, 2007 was 169,752, or 0.10 targets per MWh of power production and 13.22 targets per hour of unit operation (Table 5.1-1). The total entrainment estimates for this earlier period do not encompass a full annual cycle, and therefore are not directly comparable to the current sampling period.

Table 5.1-1. Total estimated target entrainment with 90 percent CI, raw detections (N), megawatt hours (MWh) produced, mean targets per MWh, and mean targets per hour of turbine operation for the May 2, 2007-October 15, 2008 study period.

Date	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
05/02/07 – 10/15/07	169,752	10,941	4,782	1,735,946	0.10	13.22
10/16/07 – 10/15/08	985,864	57,754	9,946	3,754,066	0.26	35.04

Total estimated monthly target entrainment at the powerhouse, entrainment per MWh of power produced, and entrainment per hour of unit operation in 2007-2008 is presented in Figure 5.1-1 to Figure 5.1-3 and summarized in Table 5.1-2.

Monthly estimated hydroacoustic target entrainment was variable over the reported October 2007-October 2008 period, ranging from 23,806 to 148,568 targets per month (Figure 5.1-1 and Table 5.1-2). Project generation and total outflow also varied on a monthly basis, from 136,277 MWh in October 2007 to 667,347 MWh in June 2008, and declining to 179,612 MWh for the October 1-15, 2008 period. It should be noted that the entrainment and project generation values reported for October 2007 and October 2008 represent only 16 and 15 day periods, respectively. Total estimated entrainment for the entire month of October 2007 was estimated as 116,525 targets, of which 72,954 were estimated to have passed between October 16 and 31 (reported here) and 43,571 from October 1-15 (reported in the Study 12 2007 First Interim Report). Turbine operations were relatively high for the entire month of October, totaling 263,638 MWh (127,361 MWh from October 1-15 and 136,277 MWh from October 16-31). Total powerhouse entrainment decreased to 41,704 in November, as did total project generation (168,118 MWh). An increase in monthly estimated entrainment of 91,686 targets was observed in December, when total project generation also increased to 250,389 MWh. For the month of January, total entrainment was estimated as 53,715 targets during 198,155 MWh of generation. Entrainment during February declined to 23,806 targets during 178,903 MWh of generation, and then increased in March (59,178 targets during 205,599 MWh of generation). A second peak in monthly estimated entrainment was observed in May (140,853) and June (148,568), when total project generation increased to 628,403 and 667,347 MWh, respectively. The magnitude of hydroacoustic target entrainment was strongly correlated with turbine operations, as was observed during the May 2-October 15, 2007 monitoring period. A positive correlation (r^2 =0.88) between monthly estimated entrainment and the magnitude of total powerhouse generation was observed over the October 16, 2007 to October 15, 2008 sampling period. This positive correlation between the magnitude of estimated entrainment and turbine operations, was not reflected in the entrainment rate estimates (i.e., fish/MWh or fish per hour of operation). This was largely due to the relatively low entrainment rate estimates during the months of May, June, and July, 2008, when project generation was relatively high and the spillway was operating (Figures 5.1-2 and 5.1-3).

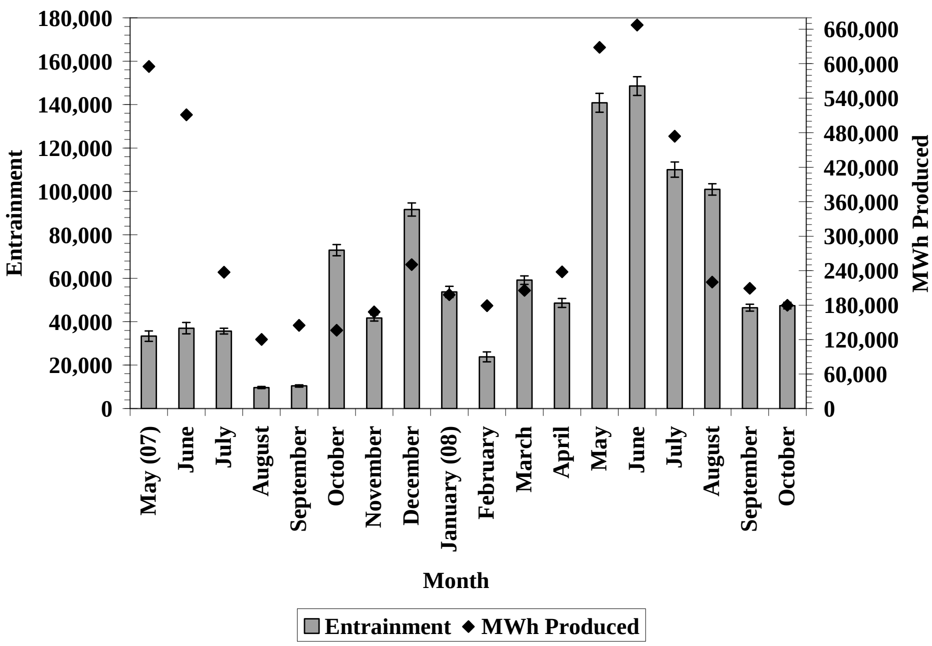

Figure 5.1-1. Estimated hydroacoustic target entrainment per month, with 90 percent CI, and total megawatt hours (MWh) produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate.

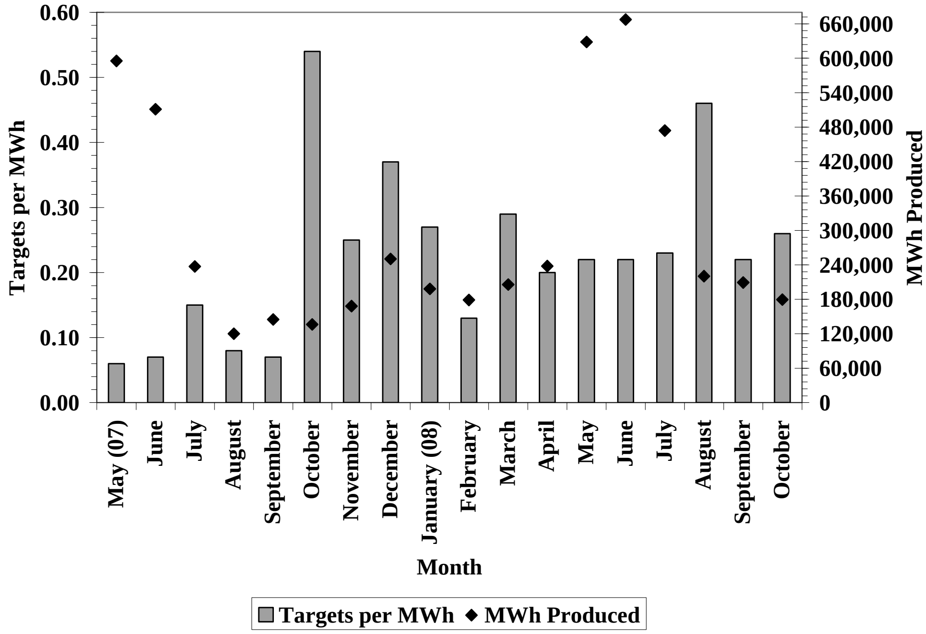

Figure 5.1-2. Estimated monthly hydroacoustic target entrainment per megawatt hour (MWh) produced, and total MWh produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate.

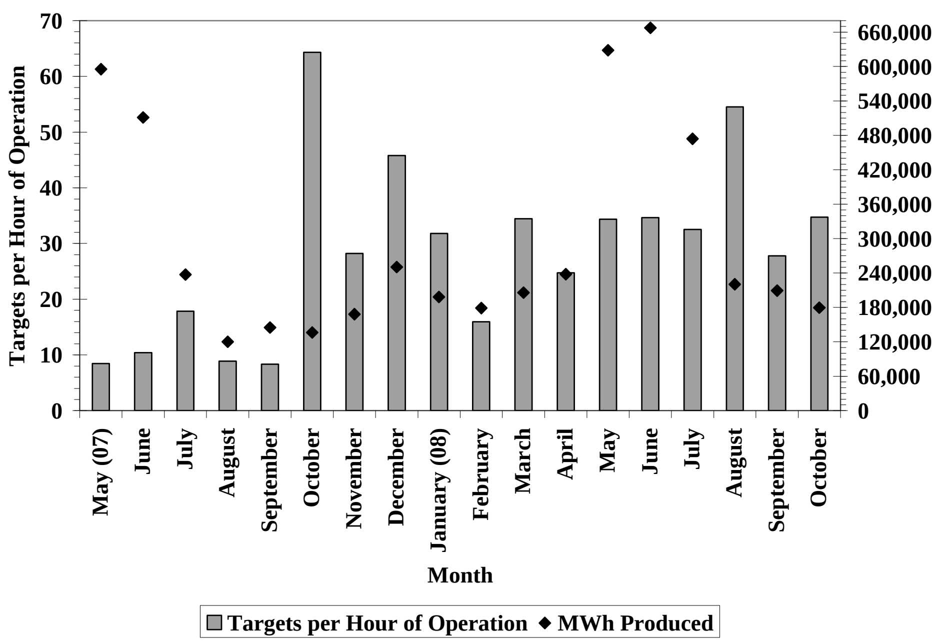

Figure 5.1-3. Total estimated hydroacoustic target entrainment per hour of operation for each month, and total megawatt hours (MWh) produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate.

Table 5.1-2. Monthly total estimated target entrainment with 90 percent CI, raw detections (N), total megawatt hours (MWh) produced, mean targets per MWh, and mean targets per hour of turbine operation for the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate.

Month	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
May (07)	33,379	2,424	2,396	595,228	0.06	8.46
June	37,051	3,015	2,629	511,152	0.07	10.40
July	35,651	1,954	1,379	237,259	0.15	17.86
August	9,682	527	485	120,139	0.08	8.91
September	10,418	591	547	144,808	0.07	8.34
October	72,954	4,023	2,622	136,277	0.54[1]	64.31
November	41,704	2,328	1,415	168,118	0.25	28.20
December	91,686	5,054	3,014	250,389	0.37	45.80
January (08)	53,715	3,025	2,579	198,155	0.27	31.79
February	23,806	1,382	2,246	178,903	0.13	15.97
March	59,178	3,342	1,958	205,599	0.29	34.44
April	48,630	3,340	2,031	237,870	0.20	24.74
May	140,853	8,095	4,336	628,403	0.22	34.37
June	148,568	8,533	4,318	667,347	0.22	34.64
July	110,043	6,580	3,481	473,931	0.23	32.52
August	100,922	6,559	2,607	220,167	0.46	54.52
September	46,422	2,631	1,617	209,294	0.22	27.76
October	47,383	2,862	1,545	179,612	0.26	34.74

Notes:

1 Fish per MWh for the October 1-15, 2007 period was 0.34.

For comparable months, monthly target entrainment estimates were generally higher during the 2008 study period (reported here) than during the May-October 15, 2007 study period (Table 5.1-3; Figure 5.1-4). For the 2007 study period, targets per MWh ranged from 0.06-0.34, with a median of 0.08 targets per MWh. This contrasts with an entrainment estimate range of 0.22-0.46 and a median of 0.23 targets per MWh for comparable months (i.e., May-October 15) during the 2008 study period. Expressed on a target per hour of operation basis, estimates ranged from 8.46-43.48, with a median of 9.66 targets per hour of operation in 2007 (Appendix 1, Table 5.1-4). For the 2008 study period, estimates ranged from 27.76-54.52, with a median of 34.51 targets per hour of operation.

Table 5.1-3. Monthly total estimated target entrainment, total megawatt hours (MWh) produced, and mean targets per MWh for the May 2, 2007-October 15, 2008 study period. Note: Only a 15 day monitoring period is reflected in the October 2008 monthly estimate.

Month	Hydroacoustic Entrainment	MWh Produced	Targets per MWh
May 07	33,379	595,228	0.06
June	37,051	511,152	0.07
July	35,651	237,259	0.15
Aug	9,682	120,139	0.08
Sept	10,418	144,808	0.07
Oct	72,954	136,277	0.54[1]
Nov	41,704	168,118	0.25
Dec	91,686	250,389	0.37
Jan 08	53,715	198,155	0.27
Feb	23,806	178,903	0.13
Mar	59,178	205,599	0.29
April	48,630	237,870	0.20
May	140,853	628,403	0.22
June	148,568	667,347	0.22
July	110,043	473,931	0.23
Aug	100,922	220,167	0.46
Sept	46,422	209,294	0.22
Oct	47,383	179,612	0.26
Total/Mean	1,112,029	5,362,651	0.21

Notes:
1 Fish per MWh for the October 1-15, 2007 period was 0.34.

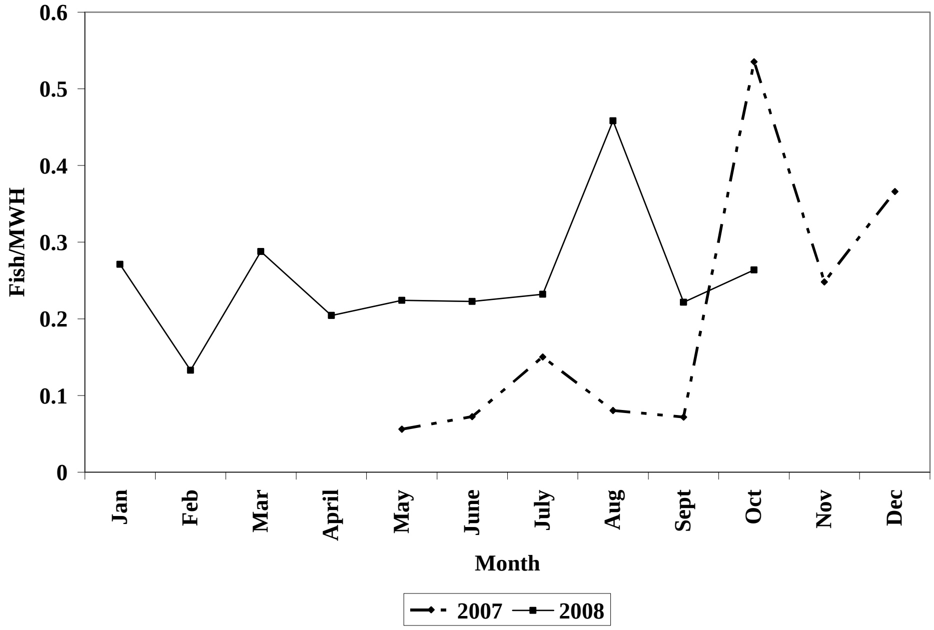

Figure 5.1-4. Total estimated hydroacoustic target entrainment per MWh of operation for each month, produced for all turbine units combined over the May 2, 2007-October 15, 2008 study period. Note: Only a 16 day monitoring period is reflected in the October 2007 monthly estimate, and only a 15 day period in October 2008. Note: Fish per MWh for the October 1-15, 2007 period was 0.34.

5.1.2. Entrainment Timing

Hydroacoustic target entrainment for the entire powerhouse (all turbine units combined) was estimated on a weekly basis and compared over the October 16, 2007 to October 15, 2008 study period to evaluate temporal passage trends (Figure 5.1-5 and Table 5.1-4). Total weekly powerhouse generation in MWh was also summarized and plotted to explore potential relationships between entrainment and total powerhouse flow. Weekly entrainment rates, expressed as targets per MWh of power produced and per hour of unit operation, are shown in Table 5.1-4.

Total weekly target entrainment for all turbines combined varied between 1,289 and 66,077 targets over the 2007-2008 study period. A relatively high entrainment rate of 42,383 targets was estimated for the first reported week of this summary (October 16-20, 2007). This elevated entrainment in mid-October represented a continuation of the relatively high estimates reported for the October 1-15, 2007 period (43,571 targets) in the First Interim Report (2008). Total estimated weekly turbine entrainment decreased to 3,686 and 2,369 targets during Weeks 47 and 48 (November 18-December 1, 2007), respectively, and then increased to 32,732 targets in Week 52 (December 23-29, 2007). A general decline in entrainment levels was observed between January 6 (Week 2) and March 1 (Week 9). The Week 9 estimate of 1,289 targets was the lowest for the October 16, 2007 to October 15, 2008 monitoring period. Estimated weekly entrainment peaked again between Weeks 19 and 25 (May 4-June 21), and then generally declined through July 12, 2008. An additional minor peak in estimated entrainment occurred between July 13 and August 9 (Weeks 29-32), and then generally declined toward the end of the study period.

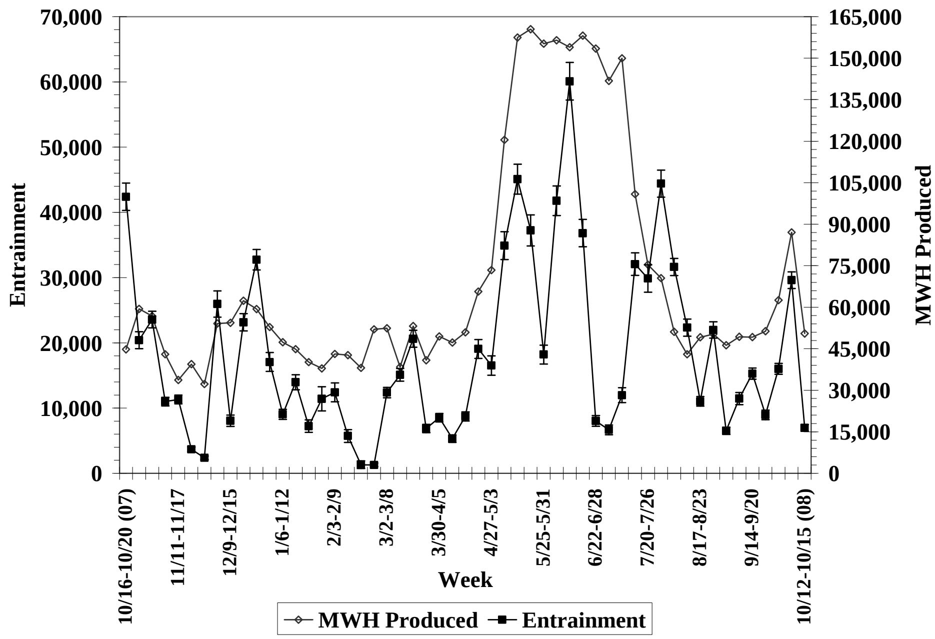

Figure 5.1-5. Total estimated number of targets entrained, with 90 percent CI, and total MWh produced by week, for the October 16, 2007-October 15, 2008 study period. Note: Only a 5 day monitoring period is reflected in the Week 42 (07) estimate and a 4 day period in the Week 42 (08) estimate.

Table 5.1-4. Weekly estimated entrainment, with 90 percent CI, total megawatt hours produced, targets per MWh and targets per hour of unit operation for the October 16, 2007-October 15, 2008 study period. Weeks are numbered sequentially with Week 1 beginning at January 1, 2007. Week 1 for 2008 includes December 30 and 31, 2007. Note: Only a 5 day monitoring period is reflected in the Week 42 (07) estimate and a 4 day period in the Week 42 (08) estimate.

Week	Date	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
42 (07)	10/16-10/20	42,383	2,329	2,104	44,798	0.95	121.70
43	10/21-10/27	20,405	1,124	1,314	59,396	0.34	41.01
44	10/28-11/3	23,561	1,312	1,288	56,810	0.41	47.65
45	11/4-11/10	10,996	613	663	42,979	0.26	29.00
46	11/11-11/17	11,309	633	671	33,712	0.34	36.84
47	11/18-11/24	3,686	206	338	39,457	0.09	10.72
48	11/25-12/1	2,369	137	290	32,223	0.07	8.22

Table 5.1-4, continued…

Week	Date	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
49	12/2-12/8	25,950	1,445	2,019	54,129	0.48	59.18
50	12/9-12/15	8,052	442	856	54,379	0.15	18.39
51	12/16-12/22	23,150	1,283	1,332	62,349	0.37	46.96
52	12/23-12/29	32,732	1,787	1,566	59,356	0.55	71.08
1	12/30-1/5	17,052	932	1,445	52,831	0.32	38.06
2	1/6-1/12	9,033	506	768	47,344	0.19	22.10
3	1/13-1/19	13,958	766	1,161	44,820	0.31	36.28
4	1/20-1/26	7,224	432	948	40,193	0.18	21.05
5	1/27-2/2	11,409	665	1,855	37,906	0.30	36.66
6	2/3-2/9	12,411	729	1,445	43,151	0.29	35.03
7	2/10-2/16	5,725	330	981	42,714	0.13	15.95
8	2/17-2/23	1,316	76	579	38,068	0.03	3.93
9	2/24-3/1	1,289	73	280	52,041	0.02	3.03
10	3/2-3/8	12,372	708	794	52,426	0.24	30.06
11	3/9-3/15	15,092	837	962	38,371	0.39	46.12
12	3/16-3/22	20,608	1,164	1,297	53,178	0.39	46.76
13	3/23-3/29	6,860	399	636	40,841	0.17	19.63
14	3/30-4/5	8,522	536	643	49,435	0.17	19.82
15	4/6-4/12	5,322	306	574	47,218	0.11	13.21
16	4/13-4/19	8,724	1,032	687	50,926	0.17	20.85
17	4/20-4/26	19,068	1,056	1,455	65,673	0.29	36.13
18	4/27-5/3	16,518	950	1,490	73,415	0.22	27.96
19	5/4-5/10	34,894	2,046	2,144	120,462	0.29	41.34
20	5/11-5/17	45,095	2,580	2,293	157,436	0.29	45.74
21	5/18-5/24	37,235	2,098	2,381	160,441	0.23	37.34
22	5/25-5/31	18,208	1,057	1,445	155,236	0.12	18.32
23	6/1-6/7	41,005	2,383	2,256	156,481	0.26	41.16
24	6/8-6/14	60,077	3,443	2,878	153,955	0.39	60.38
25	6/15-6/21	36,801	2,098	2,098	158,149	0.23	36.70
26	6/22-6/28	8,034	462	819	153,428	0.05	7.98
27	6/29-7/5	6,661	380	740	141,788	0.05	6.65
28	7/6-7/12	11,972	725	1,142	149,941	0.08	12.27
29	7/13-7/19	32,065	1,923	1,725	100,838	0.32	44.17
30	7/20-7/26	29,854	1,910	2,090	75,394	0.40	52.12
31	7/27-8/2	44,403	2,661	2,071	70,525	0.63	80.84
32	8/3-8/9	31,627	2,083	1,320	51,093	0.62	76.44

Table 5.1-4, continued…

Week	Date	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
33	8/10-8/16	22,322	1,556	1,310	43,017	0.52	60.41
34	8/17-8/23	11,031	720	747	49,154	0.22	26.00
35	8/24-8/30	21,973	1,235	1,257	50,317	0.44	51.52
36	8/31-9/6	6,514	364	542	46,278	0.14	16.08
37	9/7-9/13	11,454	636	923	49,300	0.23	28.87
38	9/14-9/20	15,276	907	861	49,215	0.31	40.25
39	9/21-9/27	8,953	491	747	51,381	0.17	23.34
40	9/28-10/4	5,146	284	461	20,440	0.25	30.05
41	10/5-10/11	29,604	1,810	1,280	87,075	0.34	46.18
42 (08)	10/12-10/15	6,950	395	524	50,467	0.14	18.91

Estimated entrainment rates per MWh produced and per hour of unit operation followed the same general trends outlined for total estimated entrainment. Peak entrainment rates for the reported period occurred during Week 42 (October 16-20, 2007), when 0.95 targets per MWh and 121.7 targets per hour of unit operation were estimated. Entrainment rates were relatively lower for the remaining weeks of the October 16, 2007 to October 15, 2008 monitoring period, varying between approximately 3 and 81 targets per hour of unit operation and 0.02-0.63 targets per MWh.

The lower hydroacoustic entrainment estimates and rates observed on a monthly and seasonal basis for the May-October 15, 2007 reporting period, are again reflected on a weekly basis when compared to the 2008 reporting period for comparable weeks, with the exception of Weeks 41 and 42 (Appendix 1; Table 5.1-3). Estimated entrainment rates for Week 41 in 2007 was 0.53 targets per MWh, and 68.22 targets per hour of operation. This compares with rates of 0.34 targets per MWh, and 46.18 targets per hour of operation for Week 41 in 2008 (Table 5.1-4). A similar relationship was observed when Week 42 from 2007 (0.36 targets per MWh and 42.38 targets per hour of operation) and 2008 were compared. The observed seasonal differences in weekly entrainment estimates between comparable periods (i.e., May through September) of 2007 and 2008, are generally related to the magnitude of Project outflow (Table 5.1-2). Project outflow was greater at both the powerhouse and spillway during May-September 2008 than during comparable months in 2007.

5.1.3. Temporal Entrainment Distributions

Temporal (mean hourly entrainment over a 24 h period) distributions of hydroacoustic target entrainment for all turbines combined were summarized over the entire October 16, 2007 through October 15, 2008 study period. These results are shown in Figure 5.1-6 and Table 5.1-5. The hours designate the start time of each sample, i.e., 0600 h passage occurred between 0600-0700 h.

Over a 24 h period, hydroacoustic target entrainment was highest in the afternoon through the early evening hours. Approximately 37 percent of all targets entrained at the powerhouse passed over the 6 h period between 1600 h and 2100 h. However, generally elevated entrainment was observed from early morning (0600 h) as units came on-line to meet morning power demands, and through late evening (2100 h). About 88 percent of total Project entrainment occurred during this period.

On a per MWh basis, the 0600 h had the highest number of targets per MWh (0.35, Table 5.1-5). Slightly reduced entrainment rates, between 0.30 and 0.29 targets per MWh, were observed during the 0700 and 0800 hours, respectively. The second highest period of target entrainment on a per MWh basis occurred between 1700 and 2000 h, when rates varied between 0.29 and 0.33 targets per MWh. Rates of entrainment per operating unit hour were 44.46 targets per hour during the 0600 h and 42.74-45.29 targets per hour between 1700 and 1900 h.

The magnitude of total hourly hydroacoustic target entrainment over the October 16, 2007 to October 15, 2008 study period was observed to generally follow patterns of generation at the Project. Relatively fewer turbine units are operated during nighttime hours at Boundary Dam (from approximately 2300-0500 h), than during the day. Fewer targets were observed passing via the Boundary Dam turbines during the night than the day, presumably due to decreased unit operations during the former period. Mean hourly MWh had a strong positive correlation ($r^2 = 0.94$) with target entrainment over the October 16, 2007 to October 15, 2008 study period.

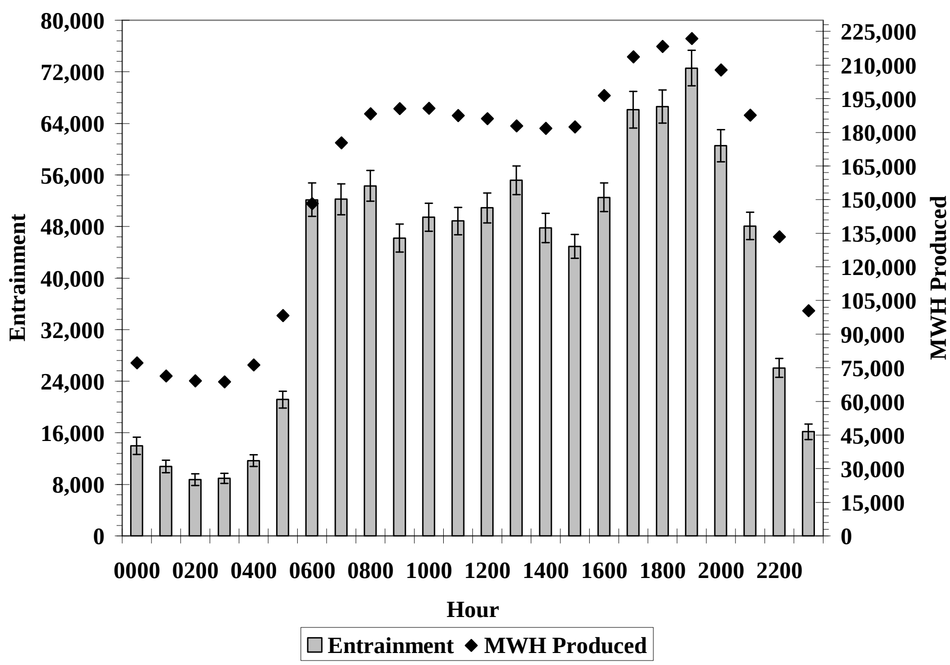

Figure 5.1-6. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at the Project by hour over the period is displayed on the secondary Y-axis.

Table 5.1-5. Diel (24 h) distribution of hydroacoustic targets entrained at the powerhouse (all units combined) over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at all turbine units and entrainment rates (targets per MWh and targets per hour of unit operations) are shown for each hour.

Hour	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
0000	13,988	837	1,343	77,143	0.18	22.75
0100	10,772	678	986	71,299	0.15	20.08
0200	8,735	549	914	69,164	0.13	16.77
0300	8,939	548	779	68,630	0.13	16.89
0400	11,683	723	916	76,220	0.15	19.40
0500	21,139	1,252	1,325	98,306	0.22	25.51
0600	52,157	3,009	2,610	148,260	0.35	44.46
0700	52,221	2,998	2,380	175,279	0.30	40.07
0800	54,305	3,059	2,374	188,235	0.29	39.61
0900	46,213	2,651	2,158	190,546	0.24	32.97
1000	49,442	2,785	2,161	190,789	0.26	35.45
1100	48,850	2,819	2,131	187,500	0.26	35.38
1200	50,883	3,151	2,320	186,022	0.27	36.89
1300	55,170	3,473	2,223	182,909	0.30	40.69
1400	47,773	2,855	2,259	181,808	0.26	35.58
1500	44,927	2,597	1,861	182,433	0.25	33.21
1600	52,529	3,028	2,228	196,399	0.27	36.39
1700	66,111	3,811	2,846	213,596	0.31	42.74
1800	66,606	3,888	2,549	218,345	0.31	41.90
1900	72,578	4,294	2,740	221,854	0.33	45.29
2000	60,538	3,501	2,480	207,809	0.29	39.56
2100	48,086	2,783	2,128	187,652	0.26	34.13
2200	26,051	1,510	1,478	133,427	0.20	23.69
2300	16,170	955	1,197	100,440	0.16	19.48

A generally similar diel distribution of hydroacoustic targets was observed during the May-October 2007 study period, although the magnitude of the morning (i.e., 0700-1100 h) entrainment was not as high as during the 2008 study period (Appendix 1; Figure 5.1-10 and Table 5.1-6). Differences in powerhouse operations (i.e., number of units operating, and unit output) and the magnitude of outflow through the spillway, may explain the observed differences in the diel distribution of estimated target entrainment, between the 2007 and 2008 study periods.

Target entrainment, on a per MWh basis, was highest during the 0600 h for both the 2007 (0.17 targets per MWh) and the 2008 (0.35 targets per MWh) reported study periods. Target entrainment on a per-hour-of-unit operation basis, was also highest for the 0600 h in 2007 (21.67 targets per hour) and in 2008 (44.46 targets per hour).

Diel distributions of entrainment were examined on a monthly basis, and are presented in Figures 5.1-7 to 5.1-10. For each hour (e.g., 0600 h), the estimate of target entrainment was summed for each month, and compared to the total number of hours of unit operation for the corresponding hour and month. The total number of hours of unit operation (all units combined) for each hour, were summed for each month, and plotted on the secondary y-axis of each graph. For example, the 1300 h for the month of June had 180 h of unit operations (i.e., 6 units operating x 30 days = 180 h), meaning that all units were operating every day of the month of June during the 1300 hour (Table 5.1-6).

Total estimated target entrainment generally mirrored the distribution of total hours of unit operations for the January-March 2008 period (Figure 5.1-7). This general trend was also apparent in April, but not in the May or June distributions, when unit operations were very high (Figure 5.1-8). Entrainment estimates were elevated between 0500 h and 1300 h, during the month of June. Total number of hours of unit operations remained relatively high during July, and target entrainment rates exhibited a morning peak between the hours of 0500 h and 0700 h, and another peak between 1200 h and2000 h (Figure 5.1-9). During the May 18-July 9, 2008 period, substantial water was also being passed through both spillgates, and may have influenced target entrainment at the powerhouse during this period.

Diel trends in target entrainment at the powerhouse were observed during the October-December 2008 period. Elevated periods of passage occurred between 0600 h and 1200 h and again between 1600 h and 2100 h, generally mirroring the total hours of unit operations (Figure 5.1-10).

Table 5.1-6. Diel (24 h) distribution of total hours of unit operations (all units combined) over the October 16, 2007-October 15, 2008 study period.

Hour	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
0000	1.75	2.50	16.25	18.50	147.75	178.00	115.75	25.50	16.75	61.50	13.00	17.25	51.21
0100	1.00	0.50	8.25	7.75	146.75	179.00	105.75	17.00	9.00	53.25	1.75	6.50	44.71
0200	0.00	0.00	6.25	7.50	147.00	180.00	104.75	11.50	8.50	50.25	0.00	5.00	43.40
0300	0.00	0.25	8.50	9.75	146.00	179.00	109.25	10.50	8.50	51.25	0.50	5.75	44.10
0400	1.75	4.25	17.50	25.25	150.25	178.75	111.75	15.75	13.00	60.50	7.75	15.75	50.19
0500	18.50	31.75	37.25	57.00	164.00	177.00	122.00	27.50	27.75	83.00	34.00	49.00	69.06
0600	68.00	74.50	84.25	107.75	174.25	177.00	140.50	58.00	46.50	106.00	59.75	76.75	97.77
0700	90.50	88.25	96.50	115.00	178.50	177.50	141.75	64.50	53.50	117.00	79.25	101.00	108.60
0800	102.00	91.25	102.50	118.50	181.00	177.75	142.50	67.50	60.00	123.00	89.25	115.75	114.25
0900	104.00	91.00	104.25	117.50	180.25	179.25	146.25	74.25	67.75	124.50	90.50	122.00	116.79
1000	101.75	82.75	100.25	107.25	178.00	178.00	147.75	83.00	89.50	126.50	84.75	115.00	116.21
1100	91.75	75.00	91.75	106.25	178.00	178.75	148.00	98.00	95.75	127.00	79.00	111.50	115.06
1200	86.50	63.00	84.00	103.00	180.50	179.75	150.50	119.50	105.25	125.50	73.75	108.00	114.94
1300	81.75	60.25	77.00	100.25	181.00	180.00	152.75	124.00	108.00	121.00	70.25	99.50	112.98
1400	80.50	61.75	75.25	98.25	180.00	179.50	155.25	123.75	110.00	116.50	66.25	95.75	111.90
1500	83.00	65.50	73.25	99.50	178.50	178.50	154.25	122.75	110.50	116.50	68.75	101.75	112.73
1600	101.00	85.50	79.25	101.25	177.75	178.00	155.00	125.25	110.50	121.25	86.50	122.25	120.29
1700	124.00	106.75	92.25	107.00	177.75	178.00	156.25	127.25	112.50	124.75	105.25	135.25	128.92
1800	130.75	122.50	102.50	108.00	179.00	178.25	160.50	123.50	113.25	128.50	107.00	135.75	132.46
1900	129.00	120.75	116.75	112.75	180.25	179.25	164.00	121.75	110.50	130.25	103.25	134.00	133.54
2000	120.75	111.00	121.25	115.75	181.00	180.00	163.00	99.50	104.50	126.75	90.00	116.75	127.52
2100	104.50	94.00	110.00	107.50	179.50	180.00	162.75	84.75	97.75	118.25	74.50	95.50	117.42
2200	54.00	44.75	74.50	73.00	170.25	179.25	143.75	73.50	59.00	101.25	56.75	69.50	91.63
2300	12.75	12.75	39.00	41.75	161.00	178.00	130.25	52.50	34.25	84.00	37.25	46.50	69.17

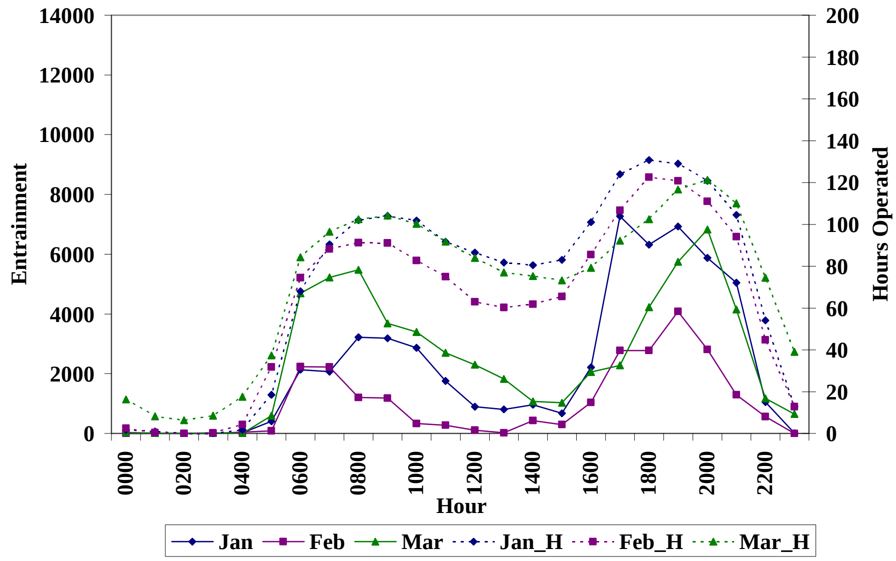

Figure 5.1-7. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the January-March, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the January-March, 2008 period are displayed on the secondary Y-axis.

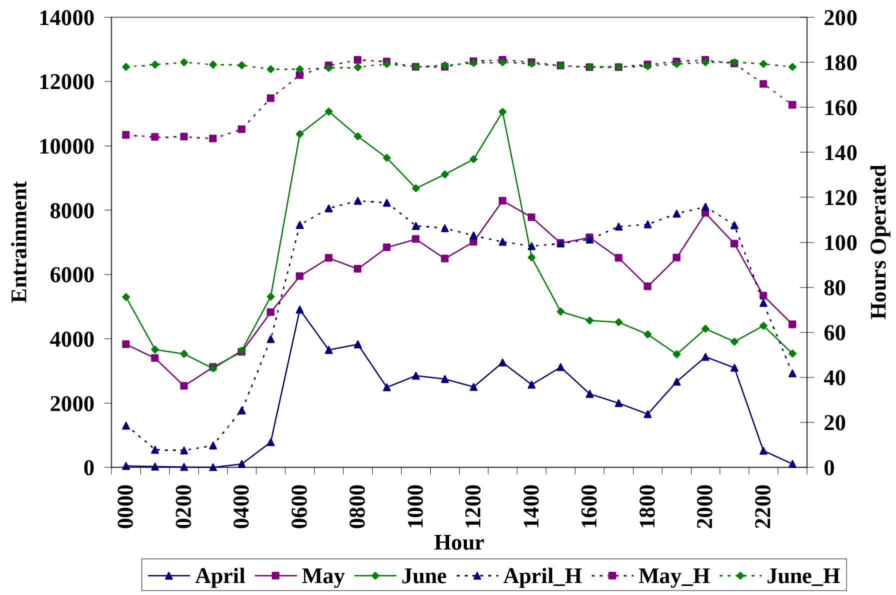

Figure 5.1-8. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the April-June, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the April-June, 2008 period are displayed on the secondary Y-axis.

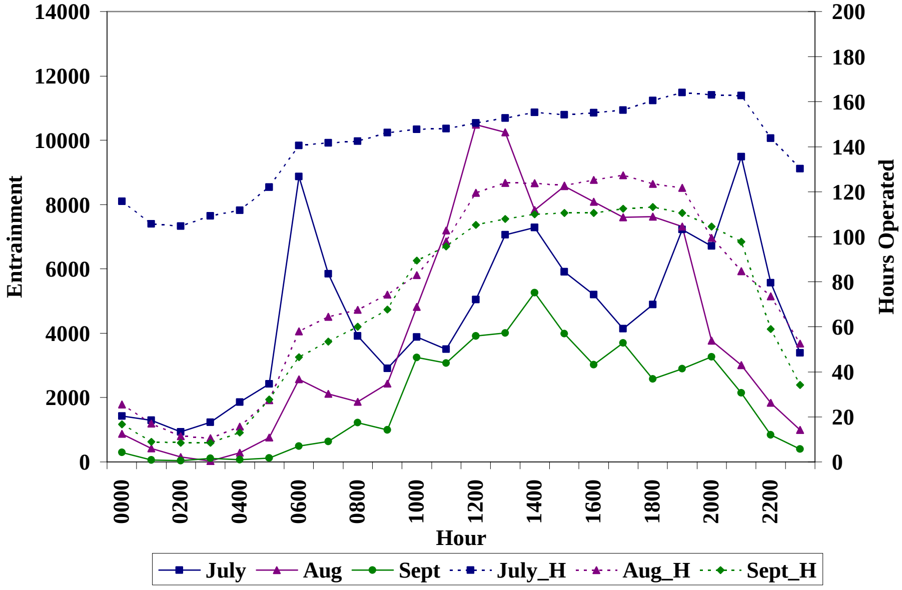

Figure 5.1-9. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the July-September, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the July-September, 2008 period is displayed on the secondary Y-axis.

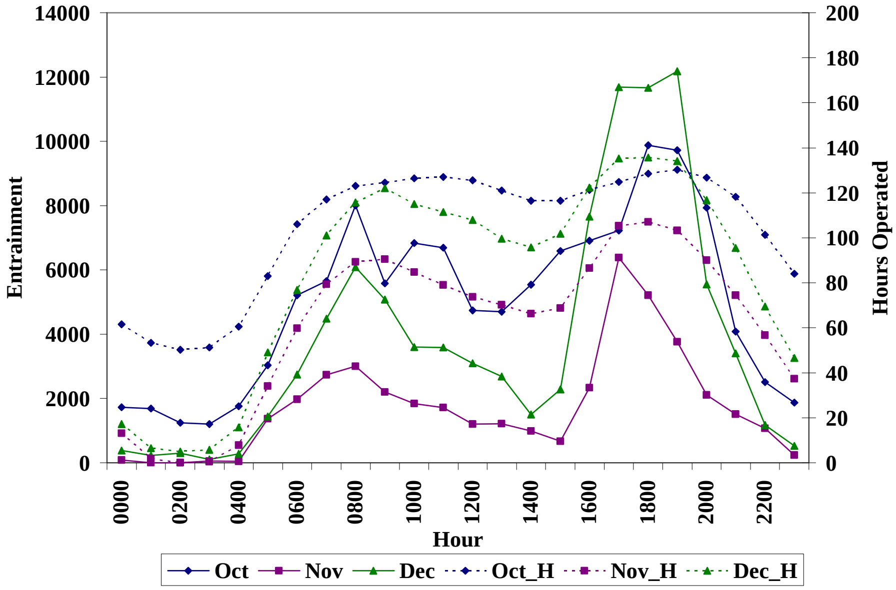

Figure 5.1-10. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) by month for the October-December, 2008 study period. Total hours of unit operations at the Project, by hour, for each month over the October-December period is displayed on the secondary Y-axis.

5.1.4. Entrainment by Turbine Unit (Horizontal Distribution)

Estimated hydroacoustic target entrainment was summarized for each turbine unit on a monthly and study period basis. Total target entrainment and entrainment rates were compared between units across time to evaluate relative passage trends across the powerhouse (Figure 5.1-11 and Table 5.1-7).

Over the entire October 16, 2007 through October 15, 2008 study period, Unit 52 demonstrated the highest estimated target entrainment (260,288 targets, or 26 percent), followed by Unit 53 (219,542 targets, or 22 percent) and Unit 54 (192,607 targets, or 19 percent). Power production was relatively evenly distributed (i.e., 17-18 percent of total Project MWh output per unit) across the powerhouse over the entire reported twelve month period, except at Unit 51 which produced approximately 11 percent of the total MWh. The three units farthest away from the forebay entrance (Units 51-53) entrained approximately 58 percent of all hydroacoustic targets in 46 percent of total powerhouse flow. Total entrainment by turbine did not appear to be absolutely correlated with unit loading. Unit 55 had approximately 10 per cent higher total MW loading as did Unit 52, but demonstrated a lower relative entrainment rate (0.17 versus 0.41 targets per MWh, respectively). The pattern and magnitude of observed target entrainment at the turbine units was variable, and likely related to unit operations and unit outages (e.g., for routine maintenance).

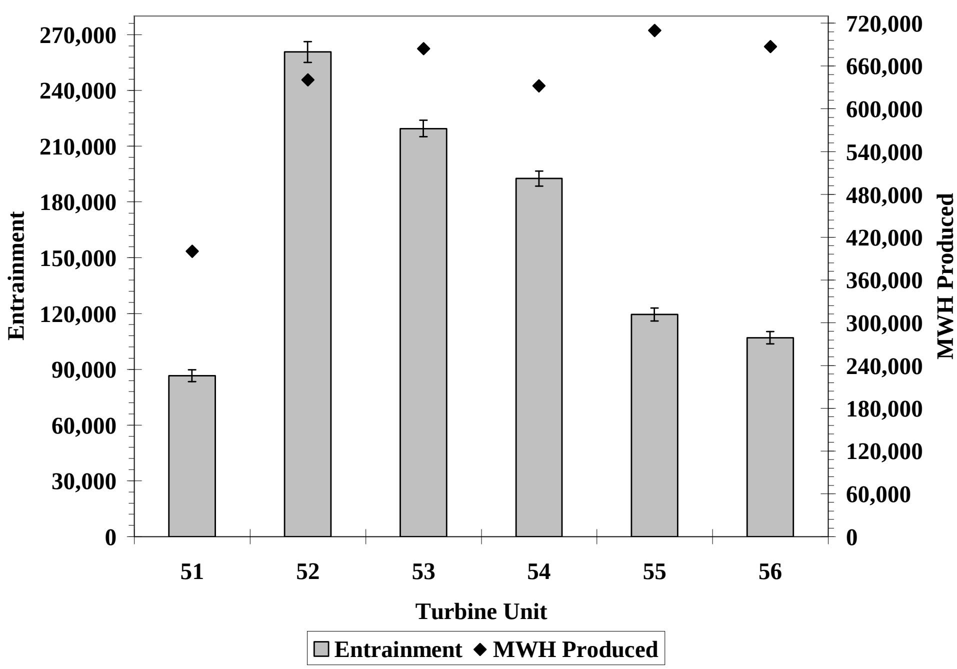

Figure 5.1-11. Horizontal distribution of total estimated hydroacoustic entrainment by turbine unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. The total MWh produced at each unit of the powerhouse is shown on the secondary Y-axis.

Table 5.1-7. Horizontal distribution of total estimated hydroacoustic entrainment at each turbine unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at each unit and entrainment rates (targets per MWh and targets per hour of unit operation) are also presented.

Turbine Unit	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour of Operation
51	86,569	4,715	3,183	399,933	0.22	27.92
52	260,688	14,587	5,535	640,601	0.41	49.32
53	219,542	12,067	4,388	684,051	0.32	37.53
54	192,607	13,846	4,033	632,256	0.30	35.41
55	119,455	6,579	3,464	709,847	0.17	27.74
56	107,003	5,960	3,265	687,379	0.16	25.74

Figures 5.1-12 through 5.1-15, and Table 5.1-8 show the monthly estimates of target entrainment by turbine unit. The relatively high total entrainment estimated at Unit 52 over the entire reported study period was due primarily to high passage at that location during the months of October and December, 2007. Approximately 28 percent of all targets estimated to have passed through Unit 52 during the 2007-2008 study period reported here did so in October and December. Through April 2008, estimated entrainment was higher at Unit 52 than at the other turbine units. During May through June 2008, target passage estimates were highest at Unit 54 (Figure 5.1-13).

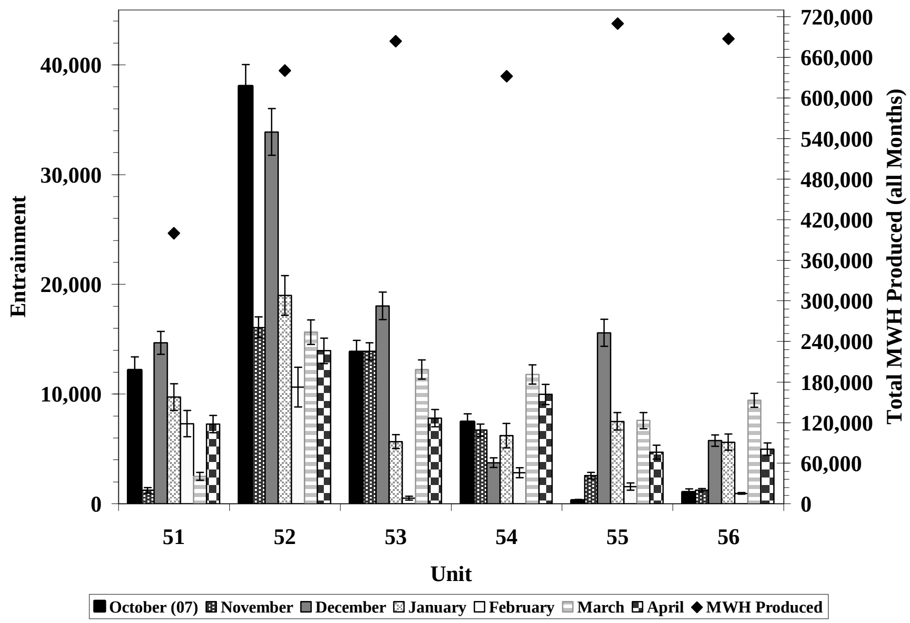

Figure 5.1-12. Horizontal distribution of estimated hydroacoustic target entrainment at each turbine unit on a monthly basis over the October 16, 2007-April, 2008 study period, with 90 percent CI. Total MWh for each unit is presented on the secondary Y-axis.

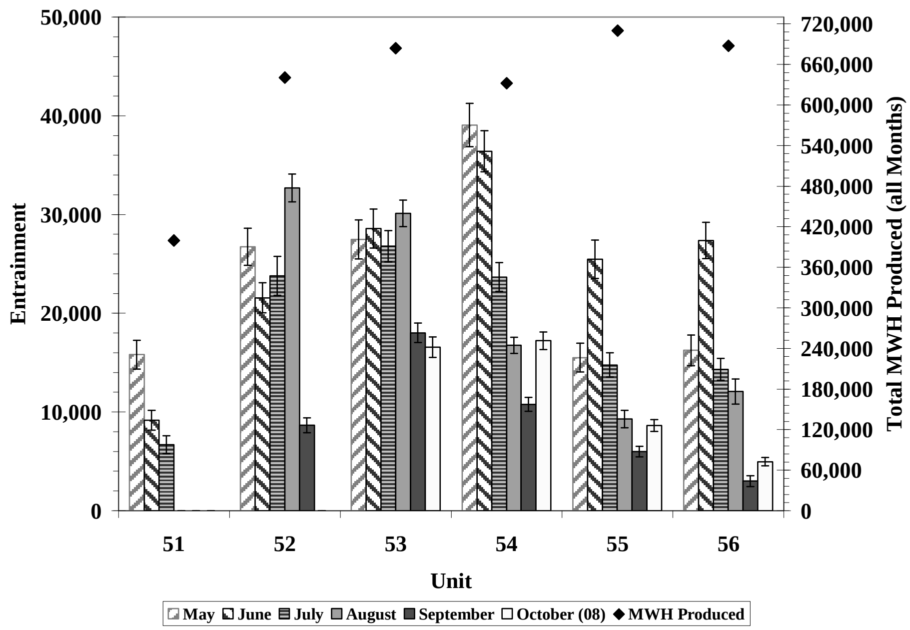

Figure 5.1-13. Horizontal distribution of estimated hydroacoustic target entrainment at each turbine unit on a monthly basis over the May-October 15, 2008 study period, with 90 percent CI. Total MWh for each unit is presented on the secondary Y-axis.

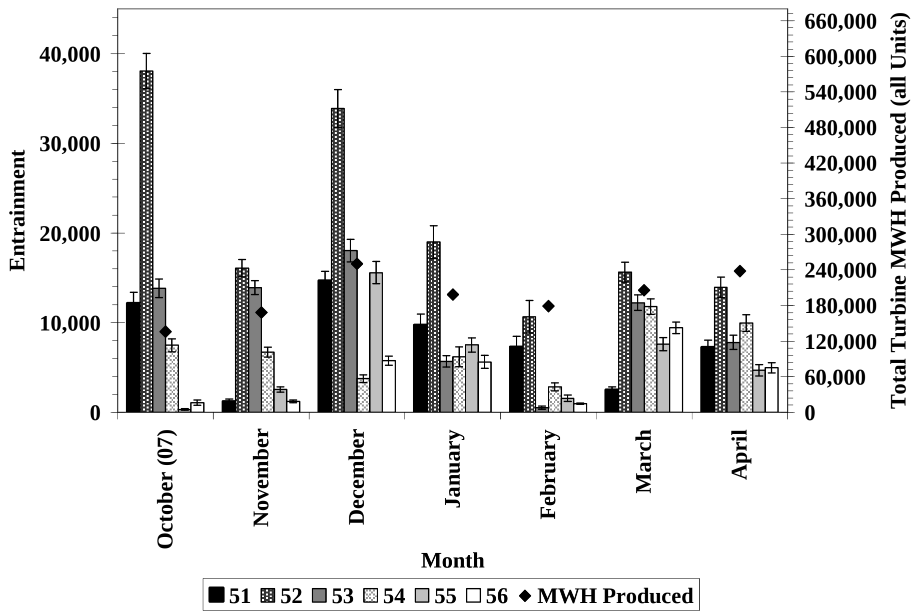

Figure 5.1-14. Monthly hydroacoustic target entrainment estimates by turbine unit over the October 16, 2007-April, 2008 study period, with 90 percent CI. Total MWh (all units combined) for each month is presented on the secondary Y-axis.

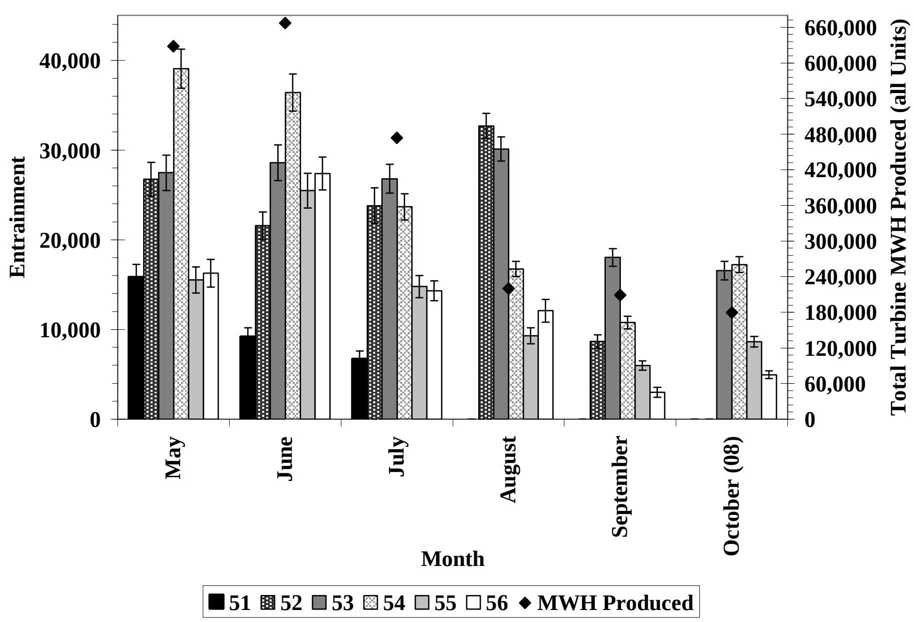

Figure 5.1-15. Monthly hydroacoustic target entrainment estimates by turbine unit over the May-October 15, 2008 study period, with 90 percent CI. Total MWh (all units combined) for each month is presented on the secondary Y-axis.

Table 5.1-8. Total estimated monthly hydroacoustic entrainment by unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI. Total MWh produced at each unit and entrainment rates (targets per MWh and targets per hour of unit operation) are also presented on a monthly basis.

Month	Unit	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour Operations
October (07)	51	12,190	656	1,189	11,401	1.07	111.84
October (07)	52	38,073	2,118	1,954	30,442	1.25	143.81
October (07)	53	13,848	760	1,034	32,657	0.42	47.92
October (07)	54	7,477	408	726	28,165	0.27	30.03
October (07)	55	301	19	97	17,843	0.02	2.46
October (07)	56	1,065	62	287	15,770	0.07	10.60
November	51	1,221	66	246	1,742	0.70	70.81
November	52	16,073	908	957	30,657	0.52	55.04
November	53	13,907	772	786	48,102	0.29	30.38
November	54	6,715	373	560	41,084	0.16	17.26
November	55	2,557	138	295	29,281	0.09	12.49
November	56	1,231	71	143	17,253	0.07	10.41
December	51	14,674	795	1,042	34,049	0.43	49.74
December	52	33,893	1,883	2,119	48,601	0.70	81.13
December	53	18,030	994	1,256	55,865	0.32	36.65
December	54	3,748	211	436	25,330	0.15	16.90
December	55	15,583	852	1,229	51,605	0.30	45.90
December	56	5,758	319	514	34,939	0.16	24.42
January	51	9,726	546	1,219	32,443	0.30	32.53
January	52	18,984	1,090	1,819	47,185	0.40	44.15
January	53	5,676	320	636	21,852	0.26	27.13
January	54	6,197	342	1,118	29,782	0.21	22.03
January	55	7,512	414	798	34,719	0.22	30.94
January	56	5,620	313	730	32,175	0.17	24.73
February	51	7,305	426	1,194	19,502	0.37	41.74
February	52	10,649	608	1,814	44,342	0.24	27.84
February	53	509	29	189	23,042	0.02	2.44
February	54	2,830	170	446	43,942	0.06	7.14
February	55	1,566	94	335	21,713	0.07	10.51
February	56	948	55	80	26,363	0.04	5.29
March	51	2,504	138	354	12,893	0.19	20.23
March	52	15,633	868	1,116	41,198	0.38	42.95
March	53	12,226	671	873	45,350	0.27	29.28
March	54	11,792	733	872	39,843	0.30	31.40
March	55	7,591	408	742	31,315	0.24	36.67
March	56	9,432	524	640	35,002	0.27	40.87
April	51	7,269	395	783	30,382	0.24	27.66
April	52	13,948	783	1,154	50,342	0.28	31.26

Table 5.1-8, continued…

Month	Unit	Entrainment	N	CI 90 percent (+/-)	MWh Produced	Targets per MWh	Targets per Hour Operations
April	53	7,800	426	790	48,567	0.16	18.00
April	54	9,963	1,198	924	44,315	0.22	24.97
April	55	4,689	257	632	28,879	0.16	25.01
April	56	4,962	281	570	35,386	0.14	20.91
May	51	15,815	848	1,459	96,003	0.16	23.06
May	52	26,740	1,498	1,880	97,693	0.27	37.67
May	53	27,467	1,508	1,980	96,033	0.29	39.17
May	54	39,068	2,519	2,184	87,472	0.45	59.58
May	55	15,511	834	1,442	126,365	0.12	22.91
May	56	16,254	888	1,554	124,835	0.13	24.30
June	51	9,148	488	1,018	102,968	0.09	12.73
June	52	21,523	1,205	1,520	101,384	0.21	29.89
June	53	28,402	1,569	1,979	98,521	0.29	39.45
June	54	36,230	2,323	2,068	92,953	0.39	52.51
June	55	25,385	1,406	1,931	135,595	0.19	35.26
June	56	27,111	1,501	1,825	135,926	0.20	37.65
July	51	6,696	356	906	58,551	0.11	16.16
July	52	23,799	1,315	1,987	82,076	0.29	36.86
July	53	26,795	1,475	1,594	72,350	0.37	43.39
July	54	23,668	1,826	1,455	72,475	0.33	39.48
July	55	14,776	815	1,229	98,827	0.15	25.51
July	56	14,310	793	1,103	89,653	0.16	27.10
August	51	0	0	0	0	0.00	0.00
August	52	32,683	1,837	1,406	49,144	0.67	72.19
August	53	30,115	1,637	1,335	55,244	0.55	59.08
August	54	16,751	1,888	836	37,321	0.45	46.11
August	55	9,288	520	879	34,355	0.27	39.73
August	56	12,087	677	1,263	44,103	0.27	41.46
September	51	0	0	0	0	0.00	0.00
September	52	8,652	472	764	17,537	0.49	53.99
September	53	18,019	980	981	49,088	0.37	40.86
September	54	10,772	667	710	53,821	0.20	21.93
September	55	5,964	336	528	46,014	0.13	19.78
September	56	2,997	175	547	42,792	0.07	10.78
October (08)	51	0	0	0	0	0.00	0.00
October (08)	52	0	0	0	0	0.00	0.00
October (08)	53	16,569	917	1,041	37,370	0.44	46.97
October (08)	54	17,227	1,179	879	35,754	0.48	52.56
October (08)	55	8,630	480	605	53,305	0.16	25.25
October (08)	56	4,958	286	418	53,183	0.09	14.51

Comparisons of estimated entrainment as a function of unit MWh loading (entrained targets per MWh) for the entire study period are presented in Figure 5.1-16. Between October 16, 2007 and October 15, 2008, the mean entrainment rate at the three lower numbered units was higher than the mean rate at the three higher numbered units. Unit 52 had the highest entrainment rate (0.41 targets per MWh) over the study period. Unit 53 had the next highest rate (0.32 targets per MWh), followed by Unit 54 (0.30 targets per MWh). Unit 51, and Units 55 and 56, had progressively lower rates of 0.22, 0.17, and 0.16 targets per MWh, respectively.

Figure 5.1-17 shows the target entrainment rates per hour of turbine unit operation for the entire study period. The general trend between turbines was similar to that observed in the comparisons of targets per MWh in Figure 5.1-16. Units 52 and 53 had the highest rates of target entrainment per operating hour (49.32 and 37.53, respectively) over the study period. The lowest rate of hourly entrainment (25.74 targets per hour) was observed at Unit 56.

As discussed above, the elevated entrainment rates at Unit 52 over the entire study period reported here were primarily due to the spike in estimated target entrainment that occurred in late October and during the month of December. Unit 52 also demonstrated higher estimated entrainment rates than the remaining units during November, and also during January through March, but the magnitude of these differences (relative to the other units) was less than observed in late October and December.

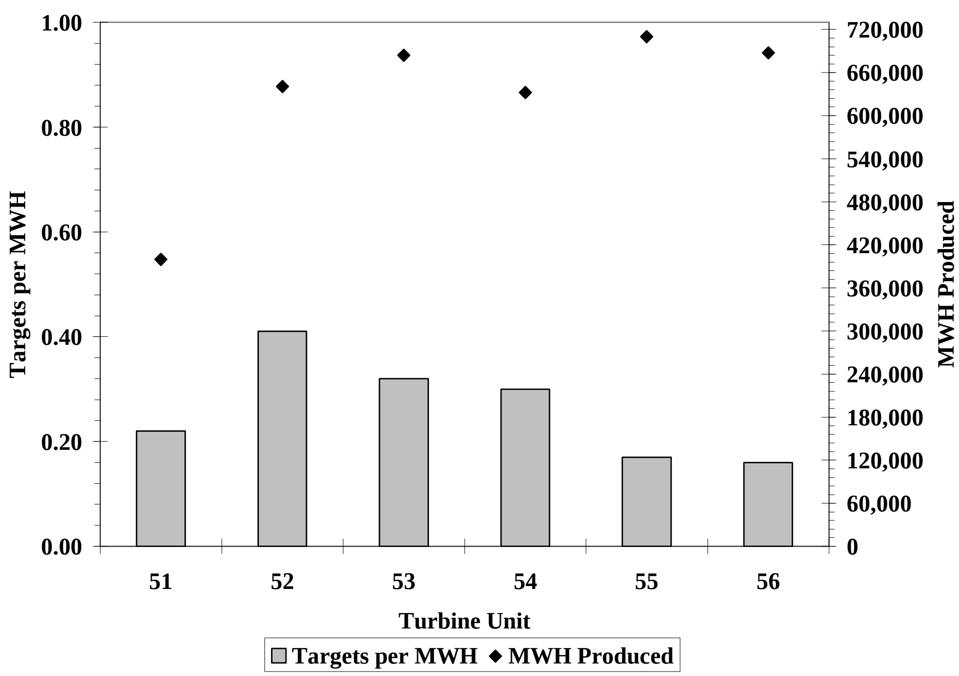

Figure 5.1-16. Total estimated hydroacoustic target entrainment per MWh of operation at each turbine unit and total MWh produced at each unit over the October 16, 2007-October 15, 2008 study period.

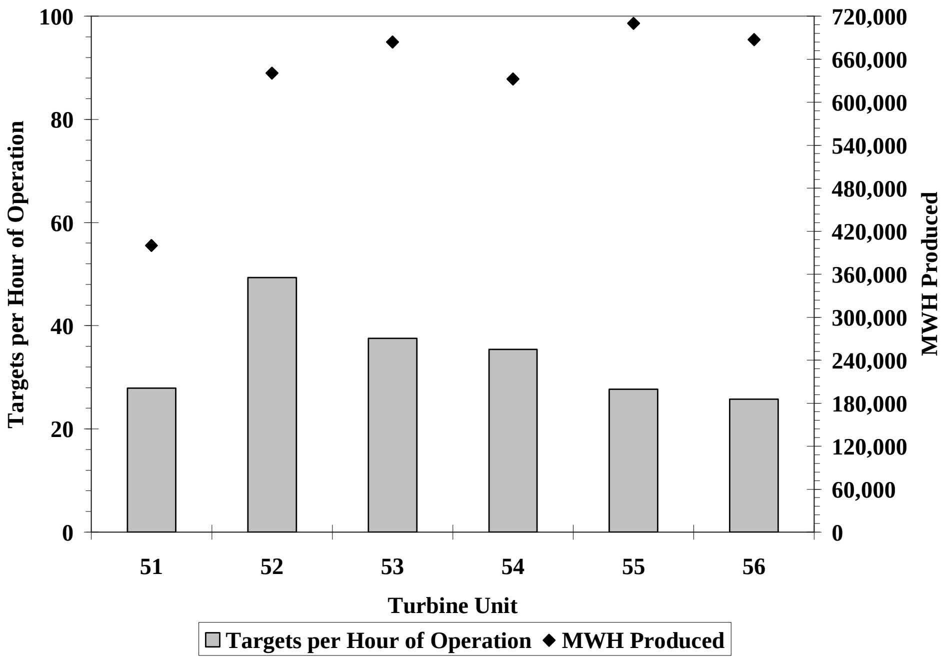

Figure 5.1-17. Total estimated hydroacoustic target entrainment per hour of unit operation at each turbine and total MWh produced at each unit over the October 16, 2007-October 15, 2008 study period.

Entrainment rates expressed as a function of unit loading (targets per MWh) were generally higher during the study period reported here, than during the May-October 2007 study period (Appendix 1; Table 5.1-4). During the May-October 2007 study period, Unit 51 had the highest target entrainment rate as a function of unit loading (0.15 targets per MWh). Unit 52 had the next highest rate (0.13 targets per MWh), followed by Unit 54 (0.12 targets per MWh). Units 55, 56 and 53 had progressively lower rates of 0.09, 0.07, and 0.04 targets per MWh, respectively.

Target entrainment rates, on a per hour of turbine unit operation basis, were also higher during the current study period relative to the May-October 2007 study period. The general trend was similar to that observed between turbines in the comparisons of targets per MWh. Units 51 and 52 had the highest rates of target entrainment per operating hour (18.84 and 16.98, respectively) over the 2007 study period. Hourly entrainment rates ranged from 5.09 (Unit 53) to 15.67 (Unit 55) targets per hour for the remaining units.

5.1.5. Hydroacoustic Target Entrainment at Unit Start Up

During routine powerhouse operations, several units are typically shutdown during the late night and early morning hours of each day, due to reduced Project power demands. To evaluate if there was a large increase in target entrainment associated with subsequent unit start up (i.e., is there a large influx in entrainment when units first come on-line), the hydroacoustic target entrainment data across all units for the April 16 to July 15, 2008 monitoring period was segregated into time periods relative to turbine unit start-up. The April 16 to July 15, 2008 study period was assumed to be a representative subset of the overall hydroacoustic monitoring period, and of sufficient duration to address this question. The results of these analyses are summarized below in Figure 5.1-18 and Table 5.1-9.

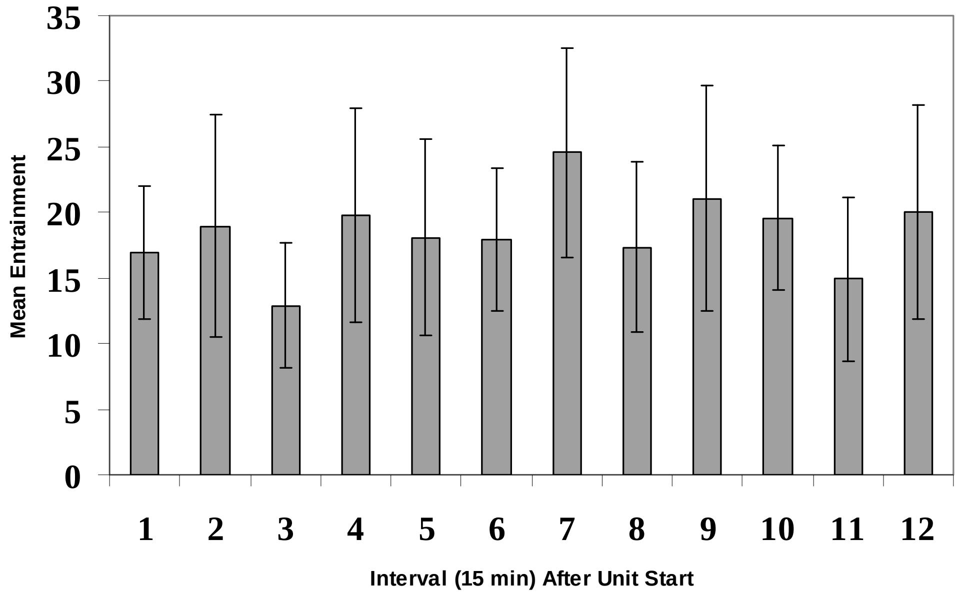

Figure 5.1-18. Mean estimated entrainment, and 90 percent CI, for successive 15 minute intervals after unit start up, April 16-July 15, 2008.

Table 5.1-9. Mean estimated target entrainment by 15 minute sequence after unit start up, with 90 percent CI, April 16-July 15, 2008.

Interval (15 min)	N	Mean Entrainment	CI 90 percent (+/-)	Lower CI	Upper CI
1	30	16.91	5.09	11.82	22.01
2	30	18.95	8.45	10.50	27.40
3	30	12.89	4.78	8.12	17.67
4	30	19.78	8.10	11.68	27.89
5	30	18.11	7.44	10.67	25.54
6	30	17.95	5.47	12.48	23.42
7	28	24.58	8.00	16.57	32.58
8	28	17.37	6.49	10.88	23.86
9	28	21.08	8.58	12.51	29.66
10	26	19.60	5.53	14.07	25.12
11	26	14.92	6.27	8.65	21.20
12	26	20.04	8.14	11.90	28.18

Mean entrainment estimates for twelve 15 minute intervals after unit start up, ranged from 12.89-24.58 targets, with peak entrainment occurring in interval seven (one and a half hours after unit start up). Entrainment estimates and time interval after unit start up were not significantly associated (α=0.10) for the April 16-July 15, 2008 study period examined in this report. This result indicated that elevated numbers of targets are not entrained immediately after unit start-up, and that entrainment rates did not differ significantly over time within the evaluated period.

5.1.6. Hydroacoustic Velocity Distributions

As hydroacoustic sampling at the powerhouse uses transducers located immediately in front of the unit intakes, the hydroacoustic estimates could conceivably include some number of targets that ultimately are not entrained, resulting in an overestimate of absolute entrainment. While the hydroacoustic target filtering criteria only includes targets demonstrating net movement toward the intake opening, fish might be able to resist ultimate entrainment, if water velocities at the opening were low. The split-beam transducers used for sampling at Boundary Dam provide velocity and directional measures for each observed target. Fish maximum swimming speed is related to body length (Beamish, 1978) and typical maximum burst speeds are approximately 10 times the fish body length. For the 10-20 cm fish lengths comprising the majority of the fyke net captures at Boundary Dam (Section 5.3.1), this equates to a maximum burst speed of 1-2 meters/sec. Fish can typically sustain burst speeds for only short periods (< 20 seconds).

The velocity distributions of entrained targets at the powerhouse were evaluated to assess if the mean velocities of targets toward the intakes were generally sufficient to ensure entrainment. The results are presented below in Figure 5.1-19 and Table 5.1-10.

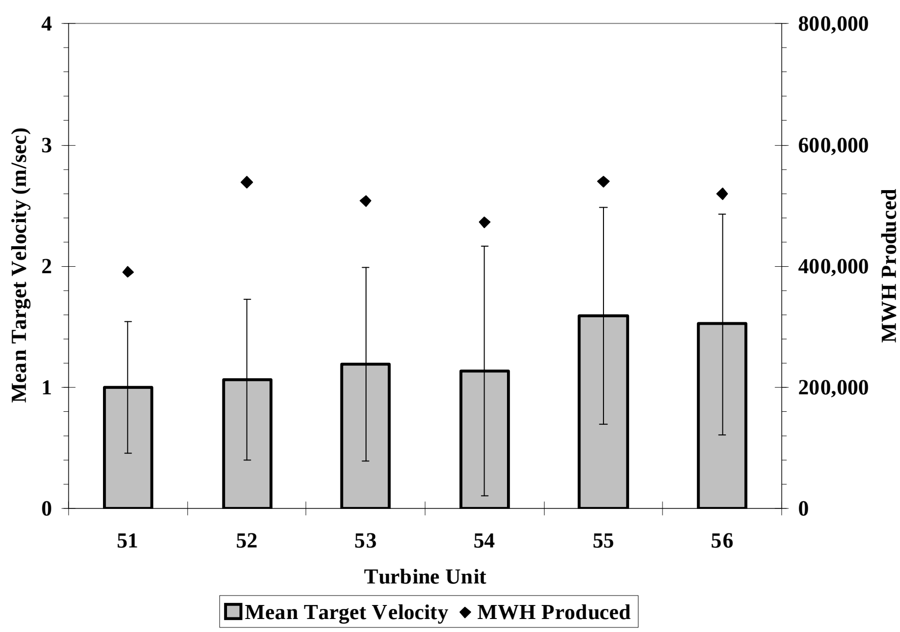

Figure 5.1-19. Estimated mean target entrainment velocity, with 90 percent CI, at each powerhouse unit between October 16, 2007 and July 15, 2008.

Table 5.1-10. Mean target velocity at the powerhouse and by unit, with 90 percent CI, October 16, 2007-July 15, 2008.

Turbine Unit	Mean Target Velocity (m/sec)	N	CI 90 percent (+/-)	MWh Produced
51	1.00	2,248	0.54	390,092
52	1.06	4,859	0.66	538,216
53	1.19	4,184	0.80	507,456
54	1.13	3,910	1.03	472,534
55	1.59	2,770	0.90	539,409
56	1.52	2,591	0.91	518,993
Season	1.22	20,562	0.89	2,966,698

Mean velocity of entrained targets for all units combined was 1.22 meters per second. On an individual unit basis, mean target velocity ranged from 1.06-1.59 meters per second, and was highest at Units 55 and 56, likely due to the larger operating capacity of these units.

These mean fish velocity values are near the maximum burst swimming speeds of 10-20 cm length fish. Fish of this size would not be able to hold position for significant periods, or mill in front of the intakes under water velocities exceeding 1 meter per second. In addition, target behavior indicating entrainment avoidance has not been observed in the hydroacoustic record. The vast majority of targets appear to follow flow directly toward the intake opening in a linear manner.

These results indicate that the hydroacoustic entrainment filtering criteria used during the monitoring effort to date are segregating targets with patterns-of-movement and velocities consistent with ultimate turbine entrainment.

5.1.7. Target Strength Distributions

Target strength (TS) is a measure of the ratio of reflected sound energy to the energy incident on the target, and is related to fish length. In general, physically-larger targets reflect greater proportions of the transmitted sound, resulting in higher (less negative) TS values. Mean TS values were transformed to estimated fish lengths in cm using an equation published by Love (1971), which considered multiple fish species monitored in dorsal-aspect. Length frequency distributions, and mean target strength values of all entrained detections were calculated for each turbine unit on a monthly and study period (October 16, 2007 through October 15, 2008) basis.

Length frequency distributions calculated from the hydroacoustic TS measurements for the powerhouse (all units combined) were summarized on a weekly basis (Figure 5.1-20; Table 5.1-11), and by turbine unit on a monthly basis to assess potential changes in target strength by location over time (Figures 5.1-21 and 5.1-22; Table 5.1-12). The 90 percent confidence intervals surrounding each TS and length estimate are shown (where appropriate) in each figure and table.

Mean TS was generally consistent on a weekly basis over the October 16, 2007 to October 15, 2008 period, ranging from -40.83 to -34.86 dB. These mean TS values were equivalent to estimated fish lengths of 16.53 to 33.95 cm based on Love (1971). An increase in the estimated mean TS (-36.02 to -34.86 dB, or 29.4 to 33.8 cm length) of entrained targets was observed between January 20 and February 23, 2008 (Weeks 4-8). Total entrainment was relatively low during this period and the increased target size was based on a modest number of detections. Of the four fish caught in the two Unit 54 fyke net tests conducted during this period (February 16-17, 2008), two were burbot with a mean length of 49.4 cm (TS=-31.8 dB), and two were yellow perch averaging 12.6 cm in length (TS=-43.1 dB).

Significant (α=0.10) differences in mean TS were not observed between units at the powerhouse on a monthly basis (Figures 5.1-21 and 5.1-22; Table 5.1-12), with the exception of January and February. During these two months, the mean TS of entrained targets, was significantly greater at Unit 51 and Unit 52 than at the remaining units. As mentioned above, total powerhouse entrainment was relatively low in January and February relative to the remainder of the reported study period, and the majority of targets passing through the powerhouse during January and February did so via Units 51 and 52. In general, the observed monthly differences in mean TS over the study period were deemed to be minor and unlikely to indicate large differences in the size composition of targets entrained at different intakes.

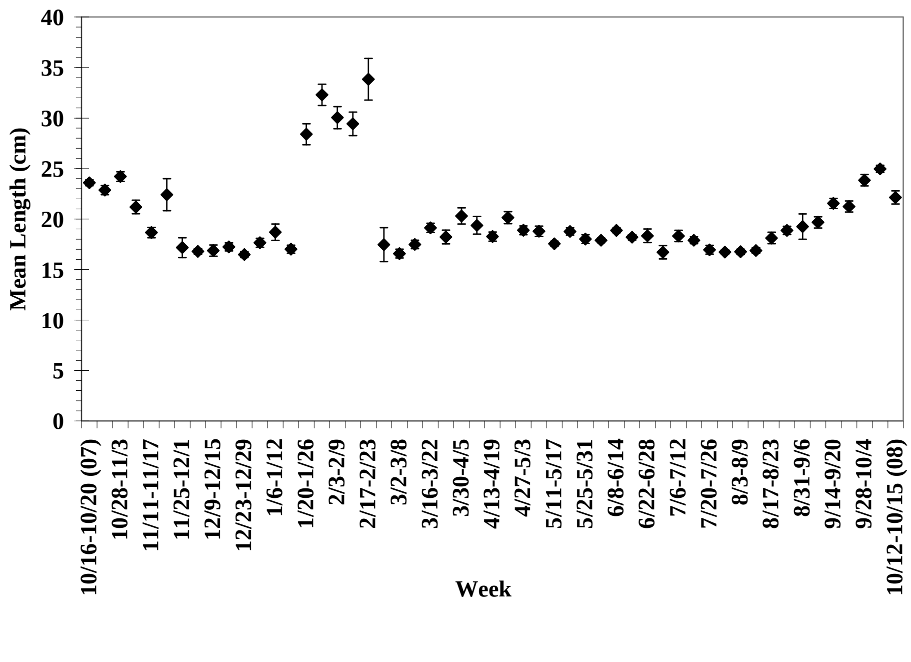

Figure 5.1-20. Weekly estimated mean fish length (based on Love 1971) for all turbine units combined over the October 16, 2007-October 15, 2008 study period. The 90 percent CI bounds surrounding each weekly length estimate are shown.

Table 5.1-11. Weekly mean target strength (TS) and corresponding estimated mean fish length (based on Love 1971) for all turbine units combined over the October 16, 2007-October 15, 2008 study period. The 90 percent CI bounds surrounding each weekly TS and length estimate are shown.

Week	Date	N	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
42 (07)	10/16-10/20	2,329	-37.85	0.29	23.59	0.84
43	10/21-10/27	1,124	-38.11	0.46	22.86	1.31
44	10/28-11/3	1,308	-37.64	0.48	24.20	1.43
45	11/4-11/10	611	-38.74	0.68	21.19	1.80
46	11/11-11/17	633	-39.80	0.51	18.66	1.18
47	11/18-11/24	206	-38.28	1.58	22.40	4.70
48	11/25-12/1	137	-40.49	0.99	17.16	2.17
49	12/2-12/8	1,445	-40.67	0.30	16.79	0.61
50	12/9-12/15	442	-40.63	0.55	16.87	1.17
51	12/16-12/22	1,282	-40.45	0.40	17.24	0.85
52	12/23-12/29	1,779	-40.83	0.30	16.48	0.61
1	12/30-1/5	931	-40.26	0.45	17.65	0.98
2	1/6-1/12	450	-39.78	0.80	18.70	1.90
3	1/13-1/19	765	-40.57	0.39	17.01	0.82
4	1/20-1/26	430	-36.31	1.04	28.39	3.79
5	1/27-2/2	665	-35.25	1.05	32.29	4.36
6	2/3-2/9	728	-35.85	1.09	30.04	4.22
7	2/10-2/16	330	-36.02	1.17	29.42	4.45
8	2/17-2/23	76	-34.86	2.06	33.83	9.53
9	2/24-3/1	73	-40.35	1.69	17.46	3.94
10	3/2-3/8	708	-40.78	0.44	16.57	0.90
11	3/9-3/15	836	-40.34	0.42	17.48	0.92
12	3/16-3/22	1,164	-39.59	0.46	19.13	1.08
13	3/23-3/29	399	-40.00	0.69	18.22	1.57
14	3/30-4/5	536	-39.10	0.80	20.30	2.07
15	4/6-4/12	306	-39.49	0.87	19.37	2.13
16	4/13-4/19	1,032	-39.97	0.46	18.26	1.04
17	4/20-4/26	1,056	-39.17	0.60	20.13	1.51
18	4/27-5/3	947	-39.70	0.44	18.88	1.03
19	5/4-5/10	1,919	-39.74	0.51	18.78	1.20
20	5/11-5/17	1,909	-40.30	0.25	17.55	0.53
21	5/18-5/24	1,655	-39.75	0.36	18.76	0.84
22	5/25-5/31	886	-40.09	0.43	18.01	0.95
23	6/1-6/7	2,286	-40.15	0.24	17.88	0.52
24	6/8-6/14	3,368	-39.70	0.25	18.87	0.57
25	6/15-6/21	2,049	-40.01	0.26	18.19	0.58

Table 5.1-11, continued…

Week	Date	N	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
26	6/22-6/28	449	-39.94	0.67	18.33	1.55
27	6/29-7/5	362	-40.72	0.65	16.70	1.37
28	7/6-7/12	680	-39.95	0.57	18.32	1.30
29	7/13-7/19	1923	-40.14	0.34	17.89	0.74
30	7/20-7/26	1909	-40.59	0.44	16.95	0.92
31	7/27-8/2	2661	-40.71	0.23	16.72	0.46
32	8/3-8/9	2083	-40.69	0.27	16.75	0.55
33	8/10-8/16	1556	-40.63	0.29	16.88	0.59
34	8/17-8/23	717	-40.04	0.57	18.12	1.30
35	8/24-8/30	1234	-39.70	0.42	18.87	0.97
36	8/31-9/6	364	-39.54	1.25	19.25	3.14
37	9/7-9/13	633	-39.36	0.56	19.67	1.38
38	9/14-9/20	907	-38.61	0.50	21.54	1.34
39	9/21-9/27	491	-38.72	0.55	21.23	1.45
40	9/28-10/4	942	-37.77	0.56	23.83	1.65
41	10/5-10/11	1810	-37.38	0.37	24.96	1.13
42 (08)	10/12-10/15	395	-38.38	0.66	22.13	1.82

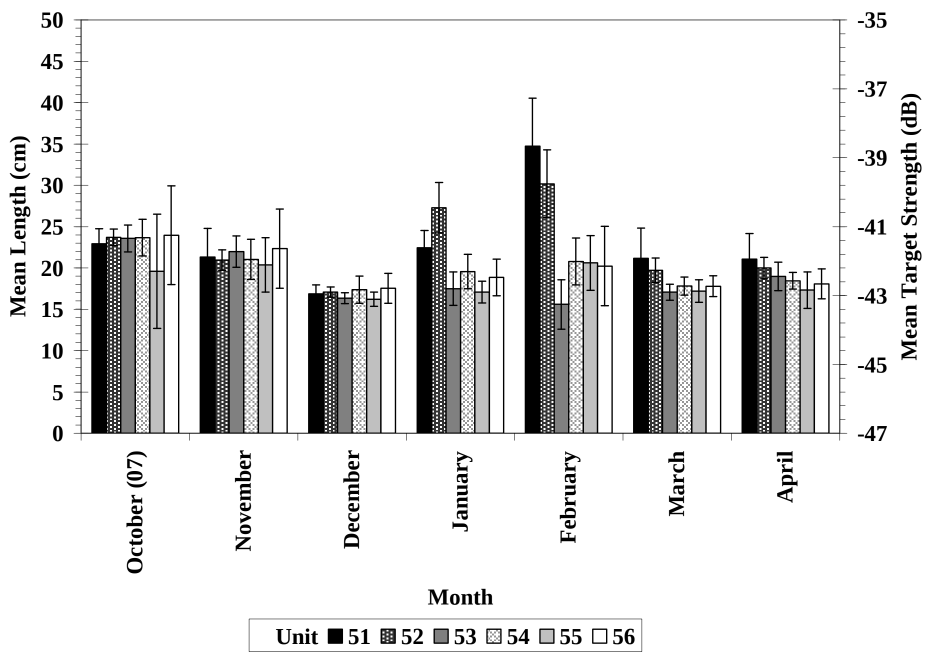

Figure 5.1-21. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the October 16, 2007-April 30, 2008 study period. The 90 percent CI bounds surrounding each estimate are shown.

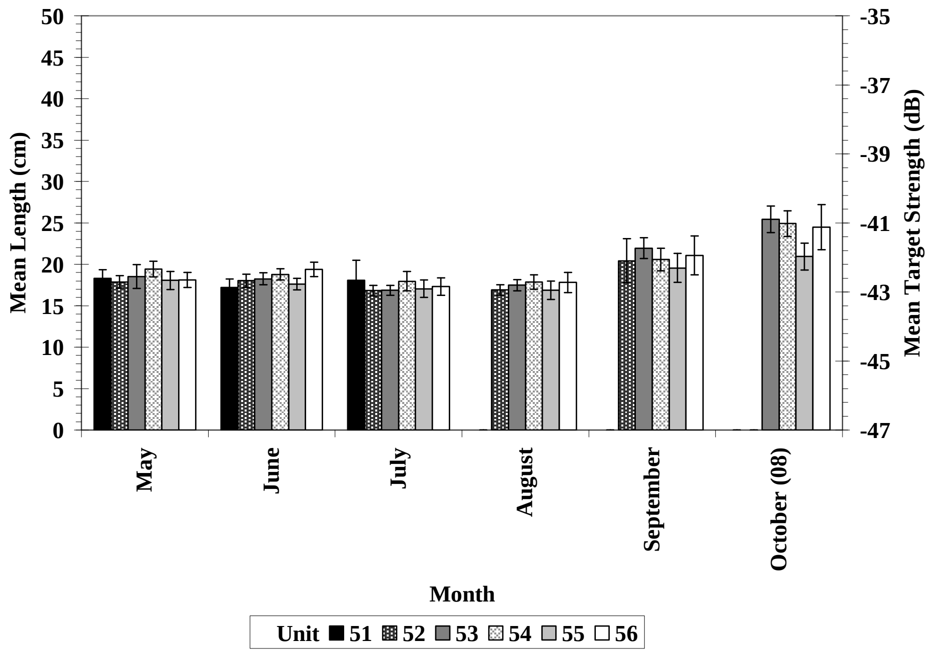

Figure 5.1-22. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the May 1-October 15, 2008 study period. The 90 percent CI bounds surrounding each estimate are shown.

Table 5.1-12. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the October 16, 2007-October 15, 2008 study period, with 90 percent CI bounds.

Month	Unit	N	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
October (07)	51	656	-38.09	0.63	22.93	1.80
October (07)	52	2,118	-37.81	0.34	23.72	0.99
October (07)	53	760	-37.86	0.55	23.57	1.63
October (07)	54	408	-37.83	0.75	23.65	2.23
October (07)	55	19	-39.39	2.51	19.59	6.92
October (07)	56	62	-37.72	1.84	23.96	5.97
November	51	66	-38.69	1.25	21.31	3.45
November	52	902	-38.84	0.48	20.95	1.24
November	53	772	-38.44	0.68	21.97	1.88
November	54	373	-38.80	0.91	21.04	2.43
November	55	138	-39.07	1.24	20.38	3.30
November	56	71	-38.31	1.62	22.33	4.80
December	51	794	-40.63	0.52	16.87	1.09
December	52	1,875	-40.53	0.29	17.09	0.61

Table 5.1-12, continued…

Month	Unit	N	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
December	53	994	-40.90	0.33	16.34	0.67
December	54	211	-40.39	0.74	17.37	1.63
December	55	852	-40.97	0.44	16.21	0.87
December	56	319	-40.31	0.82	17.54	1.82
January	51	546	-38.27	0.75	22.43	2.11
January	52	1,066	-36.65	0.88	27.28	3.06
January	53	289	-40.33	0.90	17.50	2.01
January	54	340	-39.41	0.84	19.56	2.08
January	55	411	-40.53	0.62	17.09	1.32
January	56	313	-39.71	0.92	18.86	2.22
February	51	426	-34.64	1.29	34.72	5.83
February	52	608	-35.81	1.06	30.18	4.11
February	53	29	-41.29	1.45	15.59	2.98
February	54	169	-38.90	1.06	20.78	2.83
February	55	94	-38.98	1.24	20.60	3.33
February	56	55	-39.13	1.77	20.22	4.80
March	51	138	-38.75	1.32	21.17	3.65
March	52	868	-39.34	0.61	19.71	1.49
March	53	671	-40.54	0.45	17.06	0.96
March	54	733	-40.19	0.50	17.80	1.10
March	55	407	-40.48	0.63	17.19	1.36
March	56	524	-40.19	0.56	17.79	1.25
April	51	395	-38.80	1.14	21.05	3.10
April	52	781	-39.22	0.52	19.99	1.30
April	53	426	-39.65	0.72	18.98	1.72
April	54	1,198	-39.89	0.45	18.45	1.02
April	55	257	-40.42	0.99	17.31	2.19
April	56	281	-40.07	0.79	18.05	1.81
May	51	847	-39.95	0.46	18.32	1.04
May	52	1,497	-40.15	0.34	17.88	0.75
May	53	1,506	-39.86	0.62	18.52	1.44
May	54	1,110	-39.46	0.40	19.42	0.96
May	55	834	-40.07	0.49	18.05	1.09
May	56	888	-40.05	0.40	18.10	0.91
June	51	488	-40.46	0.48	17.22	1.03
June	52	1,204	-40.09	0.36	18.01	0.81
June	53	1,568	-39.99	0.32	18.24	0.73
June	54	2,093	-39.74	0.30	18.78	0.68
June	55	1,405	-40.27	0.32	17.62	0.70
June	56	1,500	-39.47	0.36	19.41	0.87
July	51	356	-40.07	1.04	18.06	2.42

Table 5.1-12, continued…

Month	Unit	N	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
July	52	1311	-40.66	0.31	16.82	0.64
July	53	1473	-40.64	0.29	16.86	0.60
July	54	1423	-40.11	0.53	17.96	1.18
July	55	815	-40.55	0.50	17.04	1.05
July	56	793	-40.42	0.48	17.31	1.04
August	51	0	0	0	0	0
August	52	1835	-40.62	0.31	16.90	0.65
August	53	1637	-40.34	0.31	17.47	0.66
August	54	1272	-40.16	0.39	17.86	0.86
August	55	520	-40.64	0.53	16.86	1.11
August	56	677	-40.19	0.55	17.81	1.21
September	51	0	0	0	0	0
September	52	469	-39.05	1.02	20.42	2.66
September	53	980	-38.45	0.46	21.94	1.26
September	54	663	-38.99	0.53	20.57	1.37
September	55	337	-39.41	0.71	19.55	1.75
September	56	175	-38.79	0.87	21.07	2.33
October (08)	51	0	0	0	0	0
October (08)	52	0	0	0	0	0
October (08)	53	917	-37.23	0.51	25.44	1.60
October (08)	54	1179	-37.40	0.50	24.92	1.53
October (08)	55	480	-38.84	0.62	20.93	1.62
October (08)	56	286	-37.54	0.87	24.49	2.72

5.2. Hydroacoustic Spillway Distributions

Estimated total hydroacoustic target entrainment was summarized for each spill bay and examined for trends in relative entrainment. To evaluate potential effects of variable spill levels on target entrainment by spill gate, entrainment rates per unit of flow were also calculated and compared. The number of targets per hour of spill gate operation was evaluated as a relative measure of passage per unit of water volume. Spillway entrainment distributions based on the hydroacoustic monitoring are presented below in Sections 5.2.1 to 5.2.3.

Comparisons with spillway results from the May through October 15, 2007 study period are limited, since spill in 2007 was confined to a relatively small number of controlled test spill events, and the data are not directly comparable to the results from the 2008 spill period reported here.

5.2.1. Spillway Entrainment Distributions

During the study period reported here, spill principally occurred during the months of May through July, 2008. Limited spill (i.e., a total of 10 hours) occurred during the month of March, but did not contribute a significant number of entrained targets. Spill occurred on 54 days, and generally concurrently from both spill gates during the spill periods (Table 5.2-1). A total of 1190 hours of spill occurred at Spill Gate 1 (the west gate, closest to the powerhouse) and 1188 hours occurred at Spill Gate 2 (closest to the east shore of the reservoir). Although both spill gates were opened and closed simultaneously (except on May 21), Spill Gate 1 typically had a larger spill gate opening, and therefore a higher discharge than Spill Gate 2.

Table 5.2-1. Mean gate opening, mean gate spill discharge, hours of spill at each gate and the difference between Gate 1 and Gate 2, for each day of spill between March and July, 2008.

Month	Day	Mean Gate 1 Opening (ft)	Mean Gate 1 Spill (cfs)	Mean Gate 2 Opening (ft)	Mean Gate 2 Spill (cfs)	Gate Opening Difference (Gate 1-2)	Gate Spill Difference (Gate 1-2)	Hours of Spill per Gate
March	27	3.9	5,479	4.0	5,579	-0.07	-100.0	5
May	18	6.1	10,024	3.2	5,247	2.89	4,777.1	8
	19	5.1	8,132	3.9	6,156	1.19	1,975.9	18
	20	3.6	5,851	3.5	5,756	0.06	94.5	6
	21	5.0	8,271	4.8	7,936	0.21	335.2	16/14[1]
	22	3.8	7,465	3.8	7,248	0.09	217.3	16
	23	8.3	14,286	7.8	13,459	0.51	826.8	19
	24	10.9	17,427	10.7	17,168	0.16	259.3	24
	25	12.4	19,646	11.5	18,272	0.87	1,374.0	24
	26	12.5	19,623	11.9	18,696	0.58	927.3	24
	27	12.2	19,188	11.1	17,353	1.17	1,834.8	24
	28	13.0	20,353	11.0	17,179	2.06	3,173.9	24
	29	13.3	21,307	9.8	15,659	3.56	5,648.5	24
	30	15.0	23,538	11.0	17,177	4.04	6,360.8	24
	31	17.3	26,588	12.8	19,761	4.45	6,827.1	24

Table 5.2-1, continued…

Month	Day	Mean Gate 1 Opening (ft)	Mean Gate 1 Spill (cfs)	Mean Gate 2 Opening (ft)	Mean Gate 2 Spill (cfs)	Gate Opening Difference (Gate 1-2)	Gate Spill Difference (Gate 1-2)	Hours of Spill per Gate
June	1	16.0	24,672	12.9	19,879	3.13	4,792.8	24
	2	15.7	24,728	13.8	21,776	1.87	2,952.1	24
	3	15.4	24,556	11.8	18,864	3.57	5,691.8	24
	4	15.8	24,937	15.0	23,752	0.75	1,185.2	24
	5	16.6	26,025	11.2	17,591	5.37	8,434.0	24
	6	15.8	24,857	11.7	18,505	4.03	6,351.9	24
	7	16.9	26,835	13.1	20,798	3.79	6,036.9	24
	8	15.3	23,835	12.2	18,949	3.13	4,886.6	24
	9	14.0	22,379	9.8	15,629	4.22	6,750.1	24
	10	15.2	23,979	11.6	18,323	3.60	5,656.1	24
	11	15.4	24,189	11.4	17,963	3.96	6,225.9	23
	12	15.0	23,787	9.2	14,600	5.78	9,186.9	24
	13	12.2	19,445	9.4	14,987	2.81	4,457.3	24
	14	13.4	21,286	9.9	15,762	3.48	5,524.8	24
	15	12.2	19,409	9.5	15,116	2.70	4,293.6	24
	16	11.6	18,570	8.8	14,186	2.73	4,384.0	24
	17	10.9	17,291	8.1	12,813	2.80	4,477.6	24
	18	7.8	13,087	7.8	13,169	-0.03	-82.1	23
	19	5.4	10,166	5.4	10,068	-0.02	98.0	21
	20	5.2	8,286	5.3	8,391	-0.07	-105.7	23
	21	4.4	6,863	4.5	7,019	-0.10	-156.4	24
	22	6.4	10,057	6.4	10,115	-0.04	-58.1	24
	23	5.6	8,670	5.6	8,759	-0.06	-89.3	24
	24	6.6	10,057	6.7	10,207	-0.10	-150.0	22
	25	5.9	9,267	6.0	9,372	-0.07	-105.0	24
	26	7.5	11,820	7.6	11,937	-0.07	-117.3	24
	27	8.7	13,781	8.7	13,847	-0.04	-66.6	24
	28	7.1	11,219	7.1	11,222	0.00	-3.1	24
	29	5.4	8,510	5.5	8,651	-0.09	-141.2	24
	30	2.5	3,936	2.5	3,968	-0.02	-32.2	24
July	1	3.7	5,904	3.7	5,901	0.00	2.8	24
	2	4.6	7,274	4.6	7,325	-0.03	-51.3	24
	3	3.9	6,113	3.9	6,205	-0.06	-91.6	24
	4	5.1	7,979	5.1	7,995	-0.01	-15.9	24
	5	7.1	11,404	7.1	11,353	0.03	51.2	24
	6	5.7	8,948	5.7	9,017	-0.04	-69.6	24
	7	4.9	7,903	4.9	7,913	-0.01	-10.5	24
	8	1.8	2,813	1.9	2,872	-0.04	-58.5	24
	9	1.0	1,475	0.9	1,407	0.05	68.4	6

Note:
1 Spill Gate 1 operated for 16 hours, and Spill Gate 2 for 14 hours.

A total of 33,555 targets were estimated to have passed downstream through both spill gates in 2008 (Figure 5.2-1 and Table 5.2-2). On a per hour of spill basis, this was equivalent to 14.13

targets per operating gate hour. This mean rate was lower than the mean passage rates observed at the powerhouse during the October 16, 2007 to October 15, 2008 study period (35.04 targets per operating turbine hour). Mean spillway entrainment per unit flow for both gates combined was estimated as 0.28 targets per million cubic feet (mcf) of water passed (Table 5.2-2).

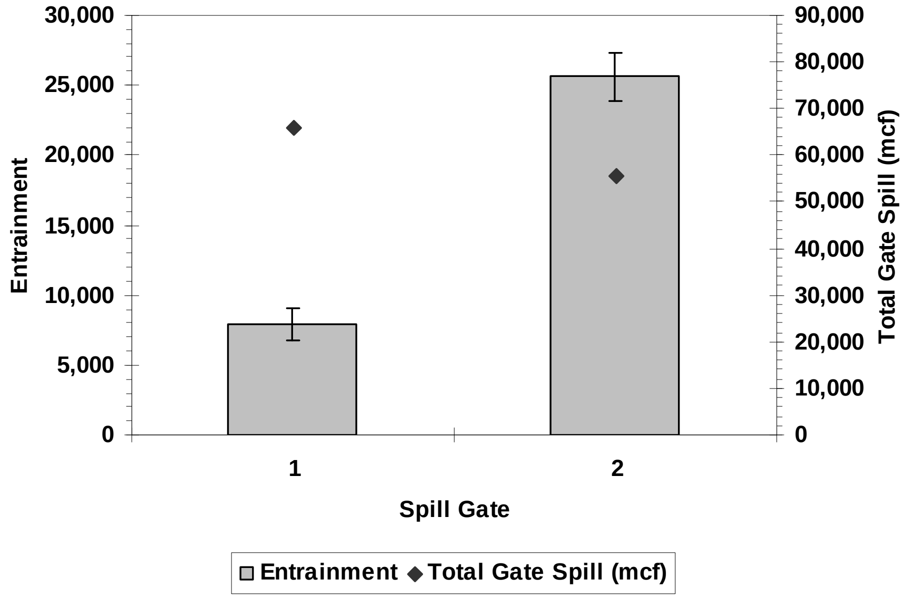

Figure 5.2-1. Total estimated number of hydroacoustic targets at each spill gate, with 90 percent CI, and mean discharge (cfs) at each spill gate in 2008.

Table 5.2-2. Total estimated target entrainment by spill gate, with 90 percent CI, entrainment per million cubic feet (mcf) of spill, total entrainment per hour of spill, and mean discharge (cfs) for all spill events in 2008.

Gate	N	Entrainment	CI 90 percent Entrainment (+/-)	Mean Gate Opening (feet)	Total Gate Spill Volume (mcf)	Mean Gate Spill (cfs)	Entrainment /mcf	Entrainment /Hour of Spill
1	689	7,939	1,174	9.71	66,011	15,435	0.12	6.68
2	3,107	25,615	1,761	8.16	55,458	12,989	0.46	21.60
Combined	3,796	33,555	2,116	8.94	121,461	14,212	0.28	14.13

Total hydroacoustic target entrainment was dissimilar between Spill Gates 1 and 2 over the entire spill period, with approximately 24 percent of entrained targets passing through Gate 1 and 76 percent passing through Gate 2 (Figure 5.2-2; Table 5.2-2). Estimated entrainment per unit volume of spill was also dissimilar between the two gates, with 0.12 targets per million cubic feet (mcf) passing through Gate 1 and 0.46 targets per mcf, passing through Gate 2.

The estimated mean target entrainment rate per hour of spill was higher at Spill Gate 2 (21.60 targets/h) than at Spill Gate 1 (6.68 targets/h) over the 2008 monitoring period.

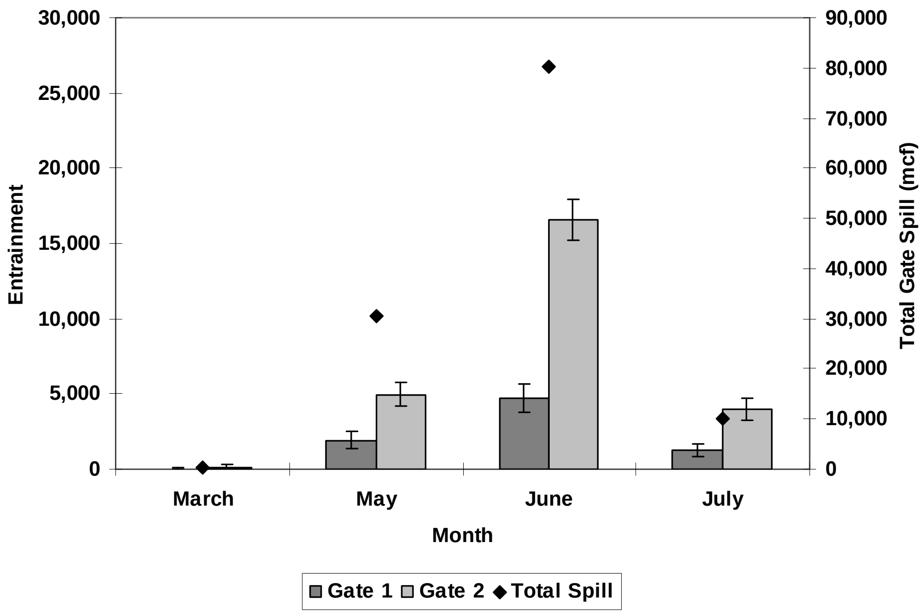

Figure 5.2-2. Total estimated entrainment at each spill gate, by month, during the 2008 spill period. Total gate spill (mcf) is shown on the secondary y-axis.

Hydroacoustic target entrainment through the spillway did not appear to be directly correlated with spill volume during the 2008 study period (Figure 5.2-2; Table 5.2-3). The highest hydroacoustic target entrainment through the spillway occurred at Spill Gate 2, with 16,547 targets passing at a mean gate spill level of 14,140 cfs, or an estimated entrainment rate of 23.27 targets per hour of spill. The highest passage estimate per unit volume of spill (0.78/mcf), was also observed at Gate 2 during July (excluding the limited March spill), when the mean gate spill level was 7,159 cfs.

Table 5.2-3. Total estimated number of hydroacoustic targets entrained with 90 percent CI, entrainment per million cubic feet (mcf), entrainment per hour of spill, and mean discharge (cfs) by month for each spill gate, March-July 2008.

Gate	Month	N	Entrainment	CI 90 percent Entrainment (+/-)	Mean Gate Opening (ft)	Total Gate Spill (mcf)	Mean Gate Spill (cfs)	Entrainment /mcf	Entrainment /Hour of Spill
1	March	2	50	100	3.99	102.11	5,672.87	0.49	9.99
1	May	169	1,922	558	10.55	16,682.96	16,912.98	0.12	7.02
1	June	421	4,735	930	10.83	43,929.67	17,162.71	0.11	6.66
1	July	97	1,232	441	4.50	5,083.32	7,131.48	0.24	6.22
2	March	5	97	169	4.05	103.58	5,754.24	0.94	19.44
2	May	570	4,980	825	8.82	13,880.10	14,174.94	0.36	18.31
2	June	2,127	16,547	1,352	8.92	36,192.95	14,140.08	0.46	23.27
2	July	405	3,991	757	4.51	5,103.06	7,159.17	0.78	20.15

5.2.2. Target Strength Distributions by Spill Bay

Mean target strength (TS) values were calculated for all entrained detections at each spill bay for all spill events in 2008. Mean TS and calculated mean length (cm), with associated 90 percent CI, for each spill gate is given in Figure 5.2-3 and Table 5.2-4.

Estimated mean TS at Spill Gate 1 was significantly higher (at α=0.10), than at Spill Gate 2 (Table 5.2-4). Monthly mean TS estimates at each spill gate for spill conducted in 2008, are given in Figure 5.2-4 and Table 5.2-5. Mean TS was observed to be relatively consistent on a monthly basis at each spill gate.

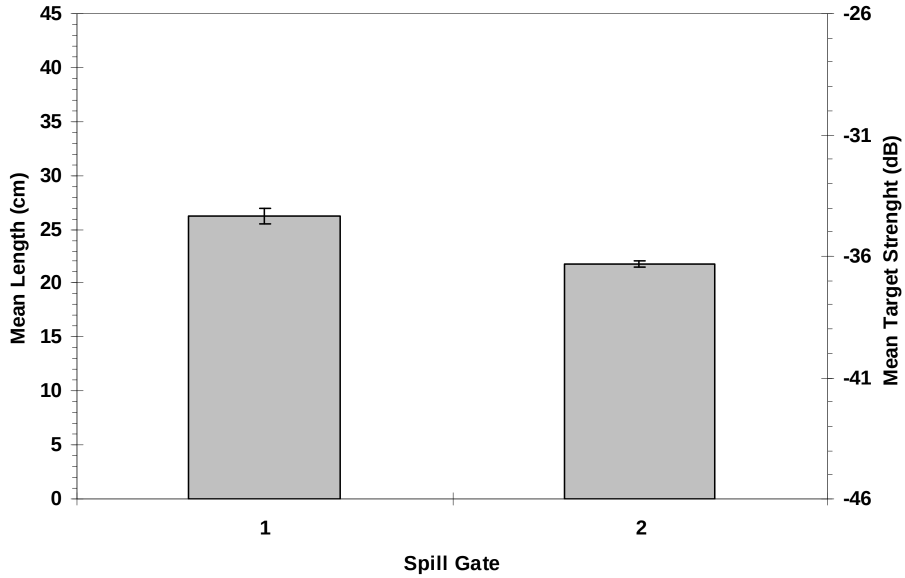

Figure 5.2-3. Mean target strength (dB) and mean length (cm), with corresponding 90 percent CI, at the two spill gates during spill events in 2008.

Table 5.2-4. Mean target strength and mean length, with corresponding 90 percent confidence intervals at the two spill gates during spill conducted in 2008.

Gate	N	Mean TS (dB)	CI 90 percent TS (+/-)	Mean Length (cm)	CI 90 percent Mean Length (+/-)
1	687	-36.98	0.78	26.22	2.57
2	3,103	-38.52	0.24	21.77	0.65
Combined	3,790	-38.20	0.27	22.63	0.75

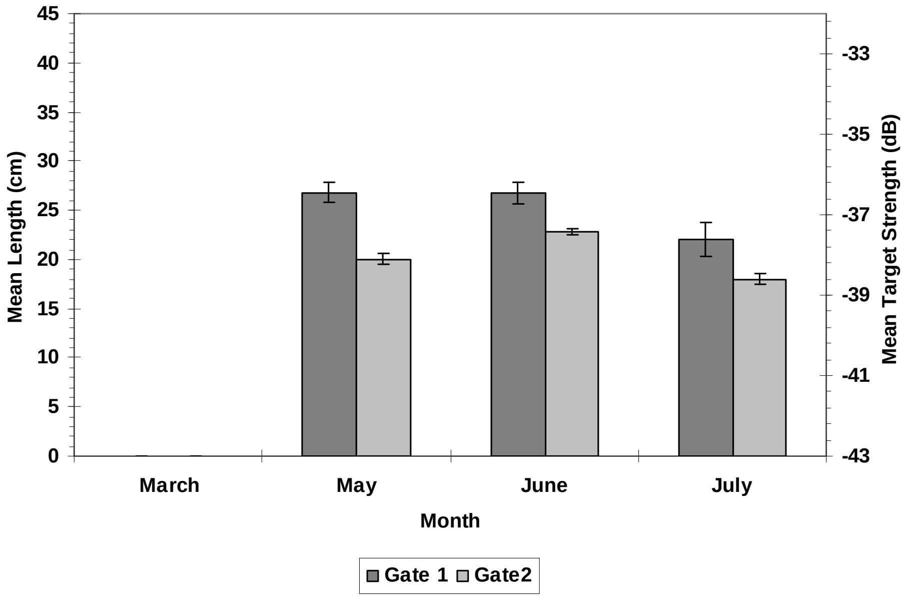

Figure 5.2-4. Mean target strength (dB) and mean length (cm), with corresponding 90 percent CI, at the two spill gates during spill events in 2008. March values were deleted from the graphic due to small sample size.

Table 5.2-5. Mean target strength (TS) and estimated mean length, with corresponding 90 percent CI, for each spill gate by month, 2008.

Gate	Month	N	Mean TS (dB)	CI 90 percent TS (+/-)	Mean Length (cm)	CI 90 percent Mean Length (+/-)
1	March	2	-32.26	15.48	46.30	252.91
1	May	167	-36.80	0.99	26.79	3.40
1	June	421	-36.81	1.08	26.74	3.72
1	July	97	-38.40	1.71	22.07	5.04
2	March	5	-40.62	5.04	16.90	14.14
2	May	570	-39.21	0.53	20.02	1.32
2	June	2,123	-38.11	0.30	22.87	0.83
2	July	405	-40.10	0.53	17.98	1.19

5.3. Fyke Net Sampling at Turbine Unit 54

Routine sampling of the two fyke net frames installed in the Unit 54 draft tube was initiated on February 16, 2008. Paired Unit 54 fyke net fish capture and hydroacoustic target entrainment samples following consistent protocols have generally been collected once per week since April 12, 2008. Multiple fyke net tests are conducted within each 24 h period. Total fyke net fish entrainment estimates (i.e., expanded catch) were derived by dividing the number of fish captured per test by the net sampling efficiency for that test.

5.3.1. Fyke Net Catch Species Composition

A total of 414 fish were captured in the fyke nets during all fyke net sampling (approximately 259 hours) conducted between February 16 and October 26, 2008 (Figure 5.3-1; Table 5.3-1). Segregated by species, the fyke net fish catch for the sampling period was dominated by sucker species (n=173, or 41.6 percent), pumpkinseed (n=89, or 21.4 percent), yellow perch (n=50, or 12.0 percent), burbot (n=21, or 5.1 percent), and kokanee (n=16, or 3.9 percent). Triploid rainbow trout (n=14, or 3.4 percent), black crappie (n=11, or 2.7 percent), and smallmouth bass (n=10, or 2.4 percent) made up the three next largest groups. Other species present in smaller numbers (n=30, or 7.2 percent of total catch) were northern pikeminnow, tench, brown bullhead, brown trout, walleye, redside shiner, slimy sculpin, and unidentified fish.

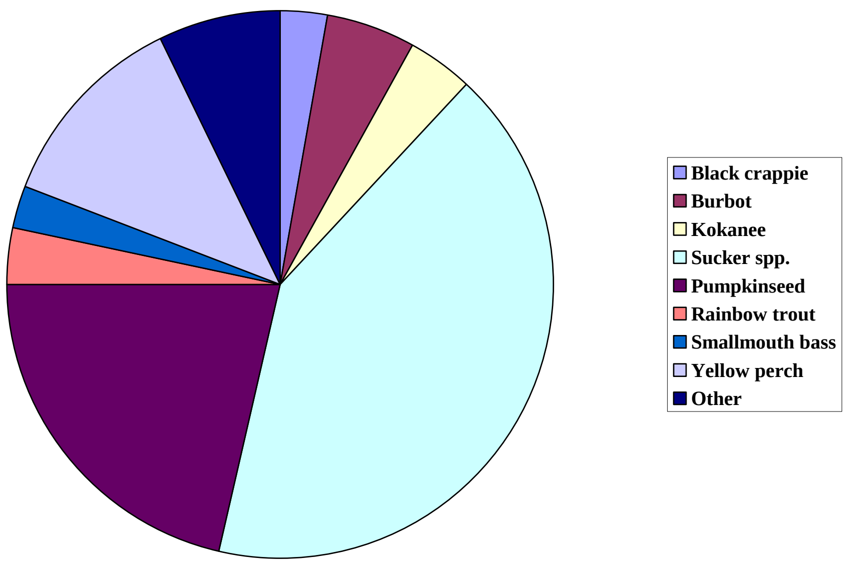

Figure 5.3-1. Summary of the fyke net sampling capture data, for all fish captured between February 16 and October 26, 2008.

Table 5.3-1. Summary of the fyke net sampling capture data, including mean length and range, by species, for all fish captured between February 16 and October 26, 2008.

Common Name	N	Length (cm)			
		Minimum	Mean	Median	Maximum
Sucker spp.	173	11.5	32.8	33.4	44.0
Pumpkinseed	89	4.5	8.4	8.5	16.2
Yellow Perch	50	6.0	12.9	12.8	23.8
Burbot	21	35.0	51.4	50.0	65.0
Kokanee	16	8.4	13.8	14.0	21.6
Rainbow Trout (triploid)	14	14.1	24.9	24.1	37.5
Black Crappie	11	6.0	9.2	9.0	14.0
Smallmouth Bass	10	8.5	17.1	17.0	26.1
Unidentified[1]	8	n/a	n/a	n/a	n/a
Brown Bullhead	8	6.8	16.3	17.0	21.5
Northern Pikeminnow	5	13.5	22.5	15.5	35.2
Tench	4	5.8	10.0	9.4	15.5
Brown Trout	1	17.0	17.0	17.0	17.0
Walleye	1	9.2	9.2	9.2	9.2
Redside Shiner	1	n/a	n/a	n/a	n/a
Slimy Sculpin	1	8.0	8.0	8.0	8.0
Black Bullhead	1	16.0	16.0	16.0	16.0
Total	414				

Note:
1 No identification - fish physically damaged beyond recognition.

Fyke net catch summarized on a monthly basis indicates that suckers were the predominant catch in tests conducted between April and October, whereas pumpkinseed were most common in the May through September catch (Table 5.3-2). Yellow perch were prevalent in the March-May fyke net catch. Burbot were represented in low numbers during most months of the fyke net testing conducted to date. Native salmonids have not been observed in the fyke net capture data to date.

Table 5.3-2. Summary of the numbers of fish captured during fyke net sampling, by species, for each month of the fyke net sampling period, February 16-October 26, 2008.

	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Totals
Black bullhead						1				1
Black crappie				1		4	5		1	11
Brown bullhead		1	1			1	5			8
Brown trout				1						1
Burbot	2	8	2	1		2	3	2	1	21
Kokanee				1	3	7	4		1	16
Northern pikeminnow				3		2				5
Pumpkinseed		1		18	4		40	26		89
Rainbow trout			6	3	1		3	1		14
Redside shiner		1								1
Slimy sculpin			1							1
Smallmouth bass						3	6	1		10
Sucker spp.		1	18	58	6	61	15	8	6	173
Tench				3	1					4
Unidentified		4			2	1	1			8
Walleye							1			1
Yellow perch	2	12	14	9	3	9			1	50
Totals	4	28	42	98	20	91	83	38	5	414

Size classes within individual fish species were not evident in the fyke net catch to date, but this may be due to the relatively few numbers of fish caught during fyke net sampling. A complete summary of the fish caught during the fyke netting effort to date is given in Appendix 4.

5.3.2. Target Strength Distributions during Fyke Net Tests

The target strength distribution of all acoustic targets detected at Unit 54 during fyke net testing were converted to fish lengths based on Love's relationship (1971). Length frequency distributions of all fish captured in the fyke net and of the estimated fish lengths of the acoustic targets detected at Unit 54 during the fyke tests are given in Figure 5.3-2. The acoustic target distribution was skewed toward fish of smaller lengths (approximately 10-18 cm). Although the fyke net catch also exhibited a distribution of smaller length fish (approximately 8-18 cm) a second mode of larger fish centered at approximately 34 cm was also observed. The acoustic distribution exhibited a rapidly diminishing number of fish of larger lengths represented in the tail of the distribution. Approximately 23 percent of all measureable fish caught in the fyke nets were less than or equal to 10 cm in length.

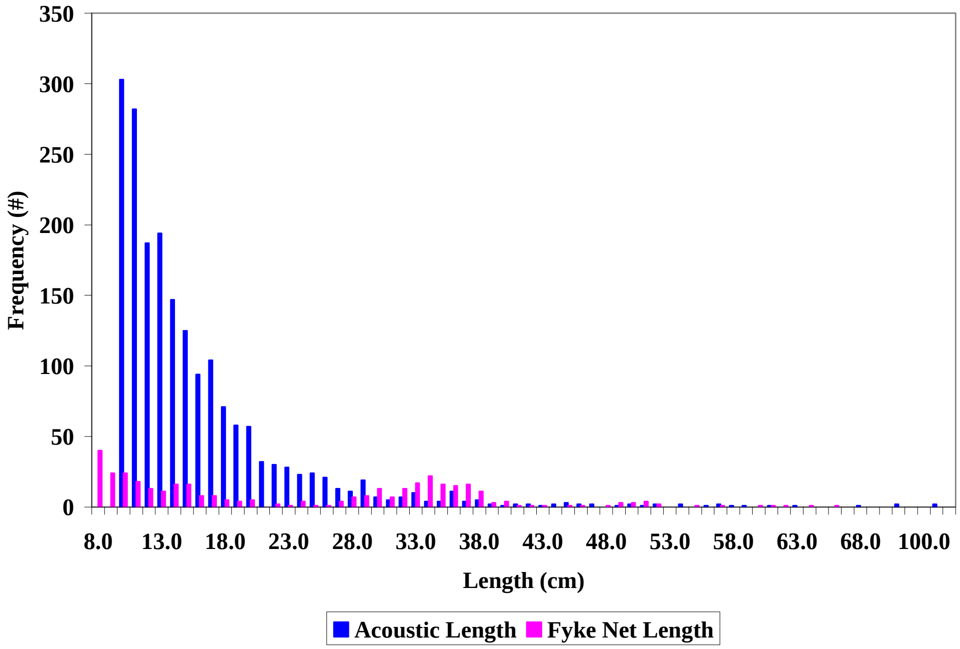

Figure 5.3-2. Length frequency histogram of fish caught during fyke net tests compared to the estimated length of acoustic targets (using Love 1971) detected at Unit 54 during fyke net testing, February 16-October 26, 2008.

5.3.3. Fyke Net and Hydroacoustic Entrainment Comparisons

Comparisons between the Unit 54 fyke net (paired Frame 1 and 2 samples only) and hydroacoustic entrainment estimates collected between April 12 and October 26, 2008 are presented in Table 5.3-3. Tests that had NBT recapture ratios less than 20 percent, resulting from procedural difficulties during testing, were dropped from analysis. Fyke net tests conducted prior to April 12, 2008 did not meet the paired sampling protocol required for statistical comparisons, and were also not considered in the analysis.

To date, the relationship between the fyke net and hydroacoustic entrainment estimates has been variable. During the 80 paired tests presented in Table 5.3-3, the hydroacoustic system estimated a total entrainment of 4,527 targets and the total expanded fyke net fish catch was 520 fish, based on 274 fish caught during 239 hours of fyke net sampling (80 individual fyke net tests). This was equivalent to a ratio of 0.12 fyke net fish per entrained acoustic target. The correlation between the two entrainment estimates continues to be refined during ongoing sampling. Additional comparisons will be described in the Study 12 Final Report in June 2009.

Table 5.3-3. Fyke net fish counts and weighted (for beam spread) acoustic counts for fyke net tests conducted between April 12 and October 26, 2008. All fyke net tests were conducted at a unit load of 90 MW.

Sample Date	Sample ID	Start Time	Length (h)	Estimated Net Efficiency	Fyke Capture	Expanded Fyke Capture	Fyke Entrainment /H	Fyke Entrainment /MWh	Weighted Acoustic Estimate[1]	Acoustic Entrainment /H	Acoustic Entrainment /MWh
Apr-12	35/36	13:19	2:08	0.88	4	4.55	2.13	0.02	15	7.03	0.08
Apr-12	37/38	19:01	3:09	0.74	1	1.35	0.43	0.00	19	6.16	0.07
Apr-13	39/40	0:40	3:05	0.70	6	8.57	2.78	0.03	7	2.27	0.03
Apr-19	43/44	11:40	1:06	0.56	4	7.14	6.49	0.07	0	0.00	0.00
Apr-19	45/46	15:28	3:11	0.64	4	6.25	1.96	0.02	12	3.77	0.04
Apr-19	47/48	22:01	3:04	0.78	2	2.56	0.84	0.01	15	4.89	0.05
Apr-20	49/50	4:08	3:12	0.80	2	2.50	0.78	0.01	3	0.94	0.01
Apr-27	54/55	0:02	3:03	0.70	1	1.43	0.47	0.01	42	13.77	0.15
May-3	58/59	11:51	2:05	0.64	4	6.25	3.00	0.03	3	1.44	0.02
May-3	60/61	16:50	3:06	0.52	3	5.77	1.86	0.02	11	3.55	0.04
May-3	62/63	23:51	3:07	0.70	6	8.57	2.75	0.03	13	4.17	0.05
May-10	67/68	18:36	3:04	0.46	5	10.87	3.54	0.04	19	6.20	0.07
May-10	69/70	23:40	3:01	0.60	5	8.33	2.76	0.03	23	7.62	0.08
May-17	71/72	8:12	1:14	0.68	4	5.88	4.77	0.05	9	7.30	0.08
May-17	73/74	12:33	3:26	0.46	6	13.00	3.79	0.04	47	13.69	0.15
May-17	75/76	20:21	3:05	0.70	3	4.29	1.39	0.02	26	8.43	0.09
May-24	77/78	13:18	3:04	0.64	4	6.25	2.04	0.02	8	2.61	0.03
May-24	79/80	18:51	3:08	0.20	9	45.00	14.36	0.16	35	11.17	0.12
May-25	81/82	1:18	2:46	0.66	4	6.06	2.19	0.02	19	6.87	0.08
May-25	83/84	7:33	2:04	0.78	2	2.56	1.24	0.01	7	3.39	0.04
May-31	85/86	12:00	3:04	0.42	2	4.76	1.55	0.02	21	6.85	0.08
May-31	87/88	17:31	3:05	0.54	0	0.00	0.00	0.00	15	4.86	0.05
May-31	89/90	11:55	3:00	0.28	6	21.43	7.14	0.08	30	10.00	0.11

Table 5.3-3, continued…

Sample Date	Sample ID	Start Time	Length (h)	Estimated Net Efficiency	Fyke Capture	Expanded Fyke Capture	Fyke Entrainment /H	Fyke Entrainment /MWh	Weighted Acoustic Estimate[1]	Acoustic Entrainment /H	Acoustic Entrainment /MWh
Jun-7	93/94	19:46	3:09	0.40	1	2.50	0.79	0.01	22	6.98	0.08
Jun-8	95/96	2:00	3:02	0.45	2	4.45	1.47	0.02	36	11.87	0.13
Jun-14	97/98	12:14	3:10	0.62	5	8.06	2.55	0.03	57	18.00	0.20
Jun-14	99/100	18:50	3:10	0.40	4	10.00	3.16	0.04	73	23.05	0.26
Jun-15	101/102	1:26	3:05	0.44	6	13.64	4.42	0.05	68	22.05	0.25
Jul-5	103/104	11:22	3:11	0.70	17	50.00	15.72	0.17	0	0.00	0.00
Jul-5	105/106	17:33	3:09	0.72	12	16.67	5.29	0.06	5	1.59	0.02
Jul-5	107/108	22:54	3:02	0.56	1	1.79	0.59	0.01	7	2.31	0.03
Jul-6	109/110	4:20	2:54	0.78	1	1.28	0.44	0.00	172	59.31	0.66
Jul-12	111/112	13:31	3:03	0.68	21	30.88	10.13	0.11	46	15.08	0.17
Jul-13	115/116	3:10	3:04	0.52	1	1.92	0.63	0.01	25	8.14	0.09
Jul-19	117/118	12:30	3:06	0.64	6	9.38	3.02	0.03	65	20.97	0.23
Jul-19	119/120	18:56	3:06	0.50	7	14.00	4.52	0.05	18	5.81	0.06
Jul-20	121/122	0:46	3:52	0.34	2	5.88	1.52	0.02	69	17.83	0.20
Jul-20	123/124	6:43	1:20	0.46	0	0.00	0.00	0.00	6	4.51	0.05
Jul-26	125/126	13:45	3:17	0.78	5	6.41	1.95	0.02	246	75.00	0.83
Jul-26	127/128	20:09	3:44	0.62	7	11.29	3.03	0.03	52	13.94	0.15
Jul-27	129/130	3:45	3:14	0.44	2	4.55	1.41	0.02	0	0	0

Table 5.3-3, continued…

Sample Date	Sample ID	Start Time	Length (h)	Estimated Net Efficiency	Fyke Capture	Expanded Fyke Capture	Fyke Entrainment /H	Fyke Entrainment /MWh	Weighted Acoustic Estimate[1]	Acoustic Entrainment /H	Acoustic Entrainment /MWh
Aug-2	131/132	11:10	3:06	0.70	4	5.71	1.84	0.02	119	38.39	0.43
Aug-2	133/134	17:31	3:01	0.62	0	0.00	0.00	0.00	99	32.78	0.36
Aug-2	135/136	23:01	3:23	0.60	5	8.33	2.47	0.03	14	4.14	0.05
Aug-3	137/138	4:29	3:18	0.60	0	0.00	0.00	0.00	54	16.36	0.18
Aug-9	139/140	10:37	3:30	0.71	2	2.80	0.80	0.01	111	31.71	0.35
Aug-9	141/142	16:38	3:08	0.70	3	4.29	1.37	0.02	243	77.64	0.86
Aug-9	143/144	22:34	3:25	0.74	2	2.70	0.79	0.01	44	12.87	0.14
Aug-10	145/146	4:47	2:37	0.60	5	8.33	3.18	0.04	32	12.21	0.14
Aug-16	147/148	10:32	3:09	0.52	1	1.92	0.61	0.01	250	79.37	0.88
Aug-16	149/150	17:06	3:02	0.60	1	1.67	0.55	0.01	154	50.83	0.56
Aug-16	151/152	23:02	3:05	0.44	0	0.00	0.00	0.00	72	23.38	0.26
Aug-17	153/154	5:45	2:17	0.52	4	7.69	3.37	0.04	0	0.00	0.00
Aug-23	155/156	10:34	3:02	0.30	1	3.33	1.10	0.01	11	3.63	0.04
Aug-30	163/164	10:31	3:07	0.68	2	2.94	0.94	0.01	38	12.18	0.14
Aug-30	165/166	18:17	3:05	0.68	5	7.35	2.39	0.03	0	0.00	0.00
Aug-31	167/168	0:16	3:04	0.78	4	5.13	1.67	0.02	0	0.00	0.00
Aug-31	169/170/	6:08	1:38	0.64	1	1.56	0.96	0.01	0	0.00	0.00
Sep-13	171/172	10:29	3:02	0.56	3	5.36	1.77	0.02	21	6.93	0.08
Sep-13	173/174	16:38	3:06	0.66	2	3.03	0.98	0.01	16	5.16	0.06
Sep-13	175/176	22:00	3:24	0.44	5	11.36	3.34	0.04	13	3.82	0.04
Sep-14	177/178	3:12	3:12	0.68	15	22.06	6.89	0.08	0	0.00	0.00
Sep-20	179/180	10:40	3:04	0.68	4	5.88	1.92	0.02	219	71.34	0.79
Sep-20	181/182	17:21	2:59	0.58	5	8.62	2.89	0.03	40	13.42	0.15
Sep-21	183/184	0:15	3:06	0.65	3	4.59	1.48	0.02	8	2.58	0.03

Table 5.3-3, continued…

Sample Date	Sample ID	Start Time	Length (h)	Estimated Net Efficiency	Fyke Capture	Expanded Fyke Capture	Fyke Entrainment /H	Fyke Entrainment /MWh	Weighted Acoustic Estimate[1]	Acoustic Entrainment /H	Acoustic Entrainment /MWh
Oct-4	185/186	10:40	3:13	0.62	1	1.61	0.50	0.01	54	16.77	0.19
Oct-4	187/188	16:08	3:16	0.72	0	0.00	0.00	0.00	75	22.94	0.25
Oct-5	189/190	22:04	3:11	0.44	0	0.00	0.00	0.00	176	55.35	0.61
Oct-5	191/192	3:50	2:58	0.50	4	8.00	2.69	0.03	373	125.59	1.40
Oct-11	193/194	10:44	2:59	0.94	2	2.13	0.71	0.01	49	16.44	0.18
Oct-11	195/196	17:00	3:01	0.76	0	0.00	0.00	0.00	37	12.25	0.14
Oct-11	197/198	22:16	3:02	0.34	2	5.88	1.94	0.02	54	17.82	0.20
Oct-18	201/202	10:53	3:02	0.92	0	0.00	0.00	0.00	89	29.37	0.33
Oct-18	203/204	16:39	3:05	0.74	0	0.00	0.00	0.00	95	30.84	0.34
Oct-18	205/206	22:37	3:14	0.60	0	0.00	0.00	0.00	92	28.48	0.32
Oct-19	207/208	4:14	3:02	0.72	1	1.39	0.46	0.01	143	47.19	0.52
Oct-25	209/210	10:27	3:07	0.68	0	0.00	0.00	0.00	75	24.04	0.27
Oct-25	211/212	16:16	2:58	0.68	0	0.00	0.00	0.00	183	61.62	0.68
Oct-25	213/214	21:26	3:01	0.68	0	0.00	0.00	0.00	61	20.20	0.22
Oct-26	215/216	2:31	3:00	0.68	0	0.00	0.00	0.00	47	15.67	0.17
Total	n=80		238.54		274	520			4,527		

Note:

1 Represents a total Unit 54 target entrainment estimate for the period, based on spatial and temporal weighting of all observations.

5.3.4. Spatial Distribution of Entrainment at Unit 54

The hydroacoustic transducers monitoring each turbine intake sample approximately 40 percent of the entire cross-section of each opening, and are located on the vertical centerline of each intake. During the comparisons of the hydroacoustic target and concurrent fyke net entrainment estimates at Unit 54, questions were raised regarding whether fish distributions entering the Boundary turbine intakes might tend to pass primarily on one-side of the intake, or possibly primarily through the monitored center area of each turbine opening. Skewed spatial distributions of entrainment could result in biases in the total hydroacoustic estimates, if the monitored area is not representative of passage across the entire intake.

To test the assumption of random distribution of entrained targets across a turbine intake, three transducers were deployed at the Unit 54 intake to provide essentially complete sampling coverage across the entire opening. All three transducers were simultaneously-sampled during the evaluations. Hydroacoustic target entrainment was compared between all three transducers at Unit 54 during each fyke net test to evaluate the assumption of random fish distribution across the intake. The number of targets per fyke net test detected by each transducer was compared using analysis of variance and correlation analysis techniques. Statistically-equivalent hydroacoustic target entrainment estimates between all three transducers would indicate that targets were randomly-distributed across the Unit 54 opening during the evaluated periods. A total of 27 fyke net tests were evaluated with the three transducer configuration at Unit 54 between May 10 and July 15, 2008 (Figure 5.3-3; Table 5.3-4).

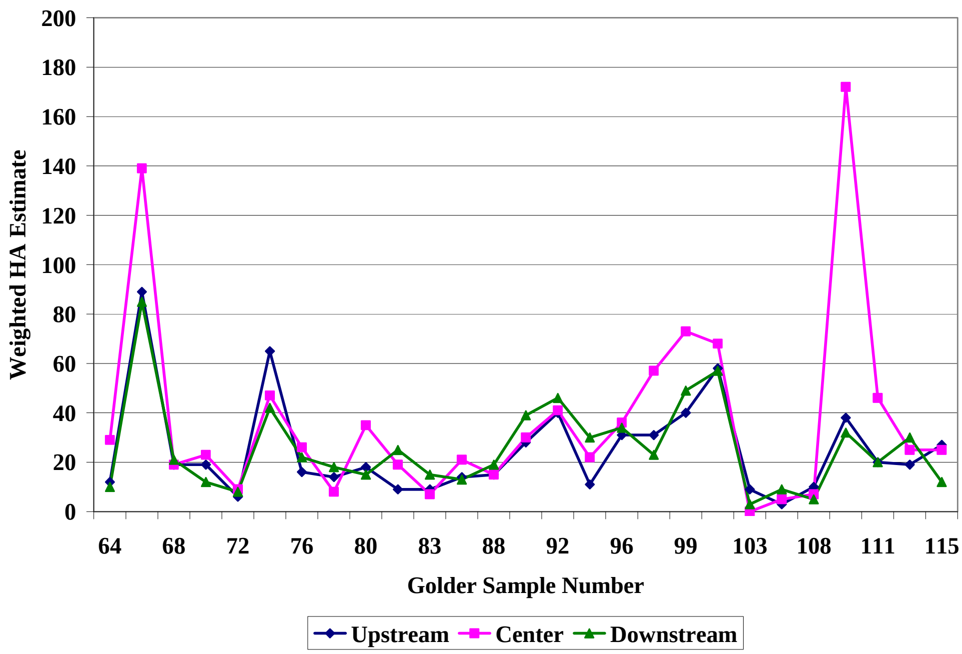

Figure 5.3-3. Estimated entrainment at Unit 54 on each of the three transducers during fyke net tests conducted at Boundary Dam, 2008.

Table 5.3-4. Fyke net sample date and time, and weighted target entrainment estimate for each transducer at Unit 54 at Boundary Dam, May-July, 2008.

Sample (Golder)	Start Date	Start Time	End Date	End Time	Left (Upstream)	Middle (Center)	Right (Downstream)
64	5/10/08	9:16	5/10/08	9:48	12	29	10
66	5/10/08	11:44	5/10/08	14:48	89	139	85
68	5/10/08	18:36	5/10/08	21:40	19	19	21
70	5/10/08	23:40	5/10/08	2:41	19	23	12
72	5/17/08	8:12	5/17/08	9:26	6	9	8
73	5/17/08	12:33	5/17/08	15:59	65	47	42
76	5/17/08	20:21	5/17/08	23:26	16	26	22
78	5/24/08	13:18	5/24/08	16:22	14	8	18
80	5/24/08	18:51	5/24/08	21:59	18	35	15
82	5/25/08	1:18	5/25/08	4:04	9	19	25
83	5/25/08	7:33	5/25/08	9:37	9	7	15
85	5/31/08	12:00	5/31/08	15:04	14	21	13
88	5/31/08	17:31	5/31/08	20:36	15	15	19
89	5/31/08	23:55	6/1/08	2:55	28	30	39
92	6/7/08	11:20	6/7/08	14:24	40	41	46
93	6/7/08	19:46	6/7/08	22:55	11	22	30
96	6/8/08	2:00	6/8/08	5:02	31	36	34
98	6/14/08	12:14	6/14/08	15:24	31	57	23
99	6/14/08	18:50	6/14/08	22:00	40	73	49
102	6/15/08	1:26	6/15/08	4:31	58	68	57
103	7/5/08	11:22	7/5/08	14:33	9	0	3
105	7/5/08	17:33	7/5/08	20:42	3	5	9
108	7/5/08	22:54	7/6/08	1:56	10	7	5
109	7/6/08	4:20	7/6/08	7:14	38	172	32
111	7/12/08	13:31	7/12/08	16:34	20	46	20
113	7/12/08	21:15	7/13/08	0:20	19	25	30
115	7/13/08	3:10	7/13/08	6:14	27	25	12
Totals					670	1,004	694

The results of the multiple transducer target entrainment analysis of variance (ANOVA) comparisons indicated that there was not a significant difference (α=0.10; Table 5.3-5) in the Unit 54 hydroacoustic passage estimates between transducers over the evaluated period. This result indicates that transducers sampling the left, center, or right thirds of the Unit 54 intake opening returned equivalent estimates of total hydroacoustic target entrainment over the monitoring period. Evidence of a spatial bias in the pattern of target entrainment across the intake opening was not observed, indicating that the assumptions of the hydroacoustic weighting factor used to estimate total turbine target entrainment appeared to be valid. However, final analysis of the multiple transducer target entrainment data is not yet complete. Additional statistical tests and data sets may be considered, and any additional information will be described in the Study 12 Final Report (June 2009).

Table 5.3-5. Summary table of the ANOVA (α=0.10) of target entrainment for each of the three transducers located at Unit 54, May 10-July 15, 2008.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	27	670	24.81481	396.0028		
Column 2	27	1004	37.18519	1524.464		
Column 3	27	694	25.7037	337.2165		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2570.765	2	1285.383	1.708011	0.187934	2.371916
Within Groups	58699.78	78	752.5613			
Total	61270.54	80				
P = 0.10						

Note:
F < Fcrit – Therefore: No significant difference in sample means at a 90 percent confidence level.

5.4. Powerhouse Fish Entrainment Estimates

The results of weekly fyke net sampling at Unit 54 were extrapolated to provide estimates of monthly fish entrainment through all turbines comprising the Boundary Dam Powerhouse. The methods used to extrapolate the fish capture rates at Unit 54 to the surrounding turbine units were derived by Dr. John Skalski at the University of Washington and are described in Appendix 3. The technique multiplied the mean fish capture rate per MWh of Unit 54 operation by the total MWh generated by all operating turbines, on a monthly basis. These monthly estimates were summed to estimate total turbine entrainment for the April to October, 2008 period over which consistent fyke net samples have been collected at Boundary Dam. Fyke net sampling across the full Unit 54 draft tube (both netting frames deployed concurrently) has occurred since April 12, 2008. Only tests with net capture efficiency estimates exceeding 20 percent were considered in the monthly fish/MWh estimates. Eighty individual fyke net tests capturing a total of 274 fish met these critieria during the fyke net sampling period. The monthly entrainment estimates for the April to October 2008 period are presented in Table 5.4-1 and Figure 5.4-1.

Table 5.4-1. Estimated Boundary Dam fish entrainment through all operating turbine units on a monthly basis for the April-October 2008 sampling period, with surrounding 90 percent confidence intervals.

Sample Month	Valid Fyke Net Samples (n)	Number of Fish Captured	Monthly Mean Fish/MWh	Total Powerhouse MWh for Month	Monthly Powerhouse Fish Passage Estimate	90 percent CI (+/-)
April	8	24	0.0221	237,870	5,247	1,621
May	15	63	0.0388	628,403	24,387	10,491
June	5	18	0.0275	667,347	18,373	6,687
July	13	82	0.0412	473,931	19,543	10,254
August	17	40	0.0125	220,167	3,228	1,086
September	7	37	0.0306	209,294	6,402	2,671
October	15	10	0.0047	179,612	839	593
Sum	80	274		2,616,625	78,020	33,403

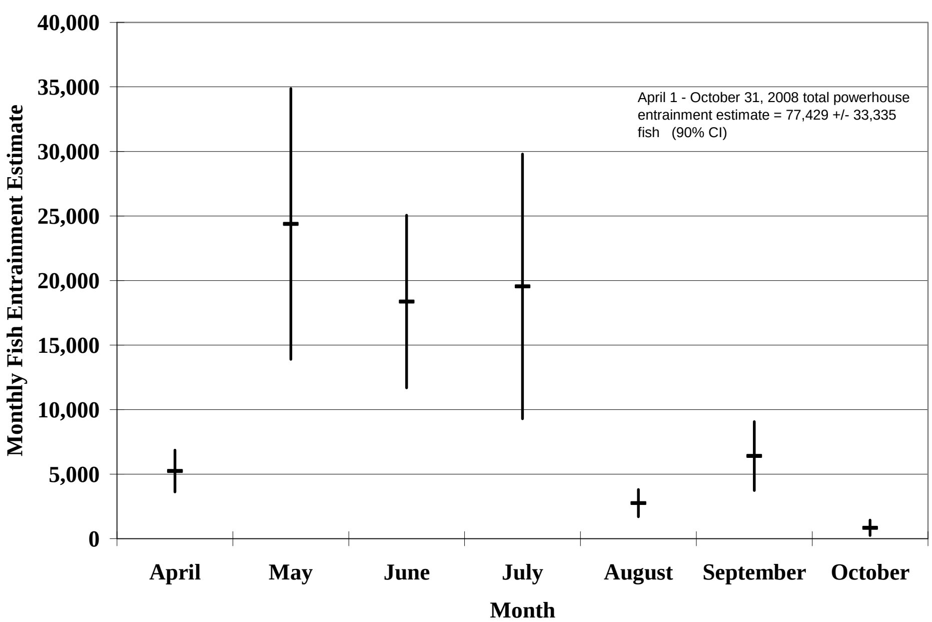

Figure 5.4-1. Estimated Boundary Dam fish entrainment through all operating turbine units on a monthly basis for the April to October 2008 sampling period, with surrounding 90 percent confidence intervals.

Based on the net sampling at Unit 54, a total of 78,020 +/- 33,403 fish (90 percent CI) were estimated as having been entrained through all turbine units between April 1 and October 31, 2008.

The Boundary Dam fyke net sampling at Unit 54 is ongoing, and additional samples are being collected on a weekly basis. Additional fyke net samples are intended to reduce the variability surrounding powerhouse entrainment estimates, and to provide additional information regarding the relationship between the hydroacoustic detections and associated fyke net fish capture data. The fish entrainment estimates presented here should be considered as preliminary, pending collection of additional fyke net data and the results of continuing investigations of the existing data sets. Final turbine fish entrainment estimates and the results of the ongoing Unit 54 comparisons will be presented in the Study 12 Final Report in June 2009.

5.4.1. Fyke Net NBT Recapture Efficiency

To establish measures of fish capture efficiency, neutrally-buoyant targets are introduced into the Unit 54 draft tube during each netting test. Fifty NBT are typically released, and the net fish recapture efficiency for the test is estimated based on the proportion of these targets that are recaptured in the fyke net panels. Only tests with NBT recapture ratios of 20 percent or greater were considered in the fish entrainment estimates derived from the Unit 54 net sampling described in this report. The NBT efficiency cut-off value was based on a review of target recovery efficiencies from all tests to date.

Fyke net recapture efficiencies were variable on a test by test basis. Mean fyke net recapture efficiency for the 80 tests included to date was 61 percent (Figure 5.4-2; Table 5.3-3). Mean net capture efficiency estimates may be utilized in the final fyke net based fish entrainment estimate, pending the outcome of future fyke net testing.

To test the assumption of whether the NBT are suitable surrogates for estimating fish recapture efficiencies, release groups of 50 live triploid rainbow trout, marked in unique locations with India ink, have been released in addition to the NBT during some fyke net tests, beginning on October 18, 2008. Only four tests using the marked triploid rainbow trout (MRB) have been conducted to date. Preliminary results indicate that the recapture efficiencies between NBT and live triploid rainbow trout releases are similar. Data from all of the paired marked fish and NBT releases will be included in the Study 12 Final Report in June 2009.

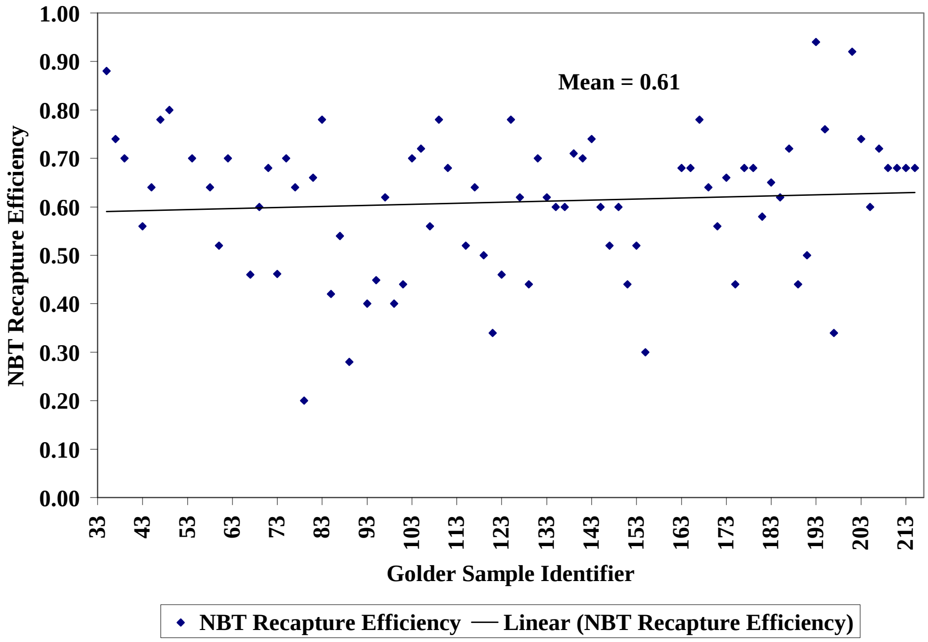

Figure 5.4-2. Neutrally buoyant target (NBT) recapture efficiencies from the 80 fyke net samples conducted between April 12 and October 26, 2008.

6 SUMMARY

The major results from Study 12 for the May 2, 2007 to October 15, 2008 period are summarized and discussed below.

6.1. Powerhouse Fish Entrainment Estimates

A total of 78,020 +/- 33,403 fish (90 percent CI) were estimated as having been entrained through all turbine units over the seven month period between April 1 and October 31, 2008, based on the Unit 54 fyke net capture results extrapolated across the entire Boundary Dam powerhouse. A total of 80 individual fyke net tests capturing a total of 274 fish were used to derive this estimate.

The fish entrainment estimates presented in this report are preliminary in nature. Final turbine entrainment estimates over the entire fyke net sampling period will be provided in the Study 12 Final Report in June 2009. Both the hydroacoustic and fyke net data collected to date indicate that fish entrainment is occurring at the Boundary Dam Powerhouse, but the magnitude of this entrainment remains to be defined. Evaluations have been conducted to quantify the correlation between the two fish entrainment techniques at Unit 54, including comparisons over differing time periods, using subsets of the netting tests with relatively higher estimated capture efficiencies, and also comparing hydroacoustic estimates filtered to more stringent entrainment acceptance criteria. In addition, the sampling assumptions of both methods have been investigated to assess potential sampling biases that may hinder correlation of the data sets. For the fyke net sampling these analyses have included comparisons of recaptured NBT and fish spatial distributions in the nets, correlations with the hydroacoustic data using weighted and unweighted fish capture estimates and comparisons using only tests with minimal net damage. The hydroacoustic sampling assumptions that have been tested to date include confirmation of the spatial weighting factor used to estimate total turbine entrainment, determination that the acoustic data filtering parameters used to establish target entrainment are appropriate, evaluation of fish velocities and approach behavior at the turbine intake, and a thorough review of the hydroacoustic targets identified for analysis. Additional tests proposed for 2009, and to be reported in the Study 12 Final Report, include a comparison of fyke net recapture efficiencies for known introduced fish and NBT, measurements to determine if fish passing the hydroacoustics might hold within areas of the Unit 54 draft tube and delay their availability for fyke net recapture, and correlations using only net capture data above some minimum fish length. The results of all of these tests will be evaluated and considered during the analysis of the final Boundary Dam fish entrainment estimates in 2009.

6.2. Fyke Net Sampling at Turbine Unit 54

A total of 414 fish were captured in the fyke nets during all fyke net sampling (approximately 259 hours) conducted between February 16 and October 26, 2008 (Table 5.3-1). Segregated by species, the fyke net fish catch for the sampling period was dominated by sucker species (n=173, or 41.6 percent), pumpkinseed (n=89, or 21.4 percent), yellow perch (n=50, or 12.0 percent), burbot (n=21, or 5.1 percent), and kokanee (n=16, or 3.9 percent). Triploid rainbow trout (n=14, or 3.4 percent), black crappie (n=11, or 2.7 percent), and smallmouth bass (n=10, or 2.4 percent) made up the three next largest groups. Other species present in smaller numbers (n=30, or 7.2 percent of total catch) were northern pikeminnow, tench, brown bullhead, brown trout, walleye, redside shiner, slimy sculpin, and unidentified fish. No apparent size classes within individual fish species were evident in the 2008 fyke net catch to date.

Fyke net catch summarized on a monthly basis indicated that suckers were the predominant catch in tests conducted between April and October, whereas pumpkinseed were most common in the May through September catches (Table 5.3-2). Burbot were represented in low numbers during most months of the 2008 fyke net sampling. Primary concerns at the Boundary Project center on native salmonids (i.e., bull trout, westslope cutthroat trout, and mountain whitefish). To date, no native salmonids have been identified in the fyke net catch data.

6.3. Hydroacoustic Spillway Distributions

During the 2008 study period, spill principally occurred during the months of May through July. Spill occurred on 54 days, and was generally passed concurrently from both spill gates during all spill periods. A total of 1190 hours of spill occurred at Spill Gate 1 (the west gate, closest to the powerhouse) and 1188 hours occurred at Spill Gate 2 (closest to the east shore of the reservoir). Although both spill gates were opened and closed simultaneously (except on May 21), Spill Gate 1 typically had a larger spill gate opening, and therefore had a higher total discharge than Gate 2.

A total of 33,555 targets were estimated to have passed downstream through both spill gates in 2008. On a per hour of spill basis, this was equivalent to 14.13 targets per operating gate hour.

This mean rate was lower than the passage rates observed at the powerhouse during the October 16, 2007 to July 15, 2008 study period (32.74 targets per operating turbine hour).

Total hydroacoustic target entrainment was dissimilar between Spill Gates 1 and 2 over the entire 2008 spill period, with approximately 24 percent of entrained targets passing through Gate 1 and 76 percent passing through Gate 2. Estimated mean entrainment rates per hour of spill were higher at Spill Gate 2 (21.60 targets/h) than at Spill Gate 1 (6.68 targets/h).

Based on the hydroacoustic TS estimates, the mean length of fish passing through Spill Gate 1 (26.2 cm) was significantly greater than at Spill Gate 2 (21.8 cm). Mean TS, and the corresponding estimates of mean fish length, was observed to be relatively consistent on a monthly basis at each spill gate.

The fish species, length and passage timing distributions measured at Unit 54 are presumed to be representative of those present at the spillway, based on the assumptions stated in the Boundary Dam RSP dated February 2007 (SCL 2007a).

6.4. Hydroacoustic Powerhouse Distributions

A total of 985,864 entrained targets were estimated to have passed downstream through Units 51-56 over the twelve month period between October 16, 2007 and October 15, 2008. This was equivalent to mean entrainment rates of 35.04 targets per unit operating hour, or 0.26 targets per MWh of power production. These estimates include only targets equal to or greater than 10 cm in length (approximately 4 inches), assuming the targets are fish and applying the Love (1971) relationship.

Estimated target entrainment during the 5.5 month study period from May-October 15, 2007 was 169,752, or 0.10 targets per MWh and 13.22 targets per hour of unit operation. Monthly target entrainment estimates were generally higher, for comparable months, during the 2008 study period than during the 2007 study period. Differences in powerhouse operations (i.e., number of units operating, and unit output) and the magnitude of outflow through the spillway, may explain the observed differences in the estimated total target entrainment, between the 2007 and 2008 study periods.

Monthly estimated hydroacoustic target entrainment was variable over the reported October 2007-October 2008 period, ranging from 23,806 to 148,568 targets per month (Figure 5.1-1 and Table 5.1-2). Project generation and total outflow also varied on a monthly basis, from 136,277 MWh in October 2007 to 667,347 MWh in June, and declining to 179,612 MWh for the October 1-15, 2008 period. Monthly target entrainment, on a targets per MWh basis, was higher during the reported October 2007-October 2008 period, than during the May 2-October 15, 2007 study period for all months except for the October 1-15 period, when 0.26 and 0.34 targets per MWh were estimated for comparable periods, respectively.

A strong positive correlation (r^2 =0.88) between monthly estimated entrainment and the magnitude of total powerhouse generation was observed over the October 16, 2007 to October 15, 2008 sampling period. This positive correlation between the magnitude of estimated entrainment and turbine operations, was not reflected in the entrainment rate estimates (i.e., fish/MWh or fish per hour of operation). This was largely due to the relatively low entrainment rate estimates during the months of May, June, and July 2008, when project generation was relatively high and the spillway was operating.

Over the entire October 16, 2007 through October 15, 2008 study period, Unit 52 demonstrated the highest estimated target entrainment (260,288 targets, or 26 percent), followed by Unit 53 (219,542 targets, or 22 percent) and Unit 54 (192,607 targets, or 19 percent). Power production was relatively evenly distributed (i.e., 17-18 percent of total Project MWh output per unit) across the powerhouse over the entire reported twelve month period, except at Unit 51 which produced approximately 11 percent of the total MWh. The three units farthest away from the forebay entrance (Units 51-53) entrained approximately 58 percent of all hydroacoustic targets in 46 percent of total powerhouse flow. Total entrainment by turbine did not appear to be absolutely correlated with unit loading. A number of factors may affect the distribution and magnitude of hydroacoustic target entrainment across individual turbine units. These include the physical configuration of the forebay itself, in combination with patterns of unit operation. Hydraulic conditions in the forebay may vary and impact the manner in which fish approach and enter individual units. Fish species composition is known to vary over the year and different species may distribute in ways that selectively affect their availability for entrainment. Integration of data from other Boundary Dam studies may aid in interpreting the observed differences in hydroacoustic target entrainment between turbine units over time. Information from Study 9 (Fish Distribution, Timing and Abundance Study) could provide additional data describing the distribution of fish assemblages available for entrainment over time. Information describing flow patterns in the forebay could also be compared to the observed patterns of hydroacoustic target entrainment across individual turbines at the powerhouse.

The mean acoustic TS of hydroacoustic detections across the entire powerhouse was generally consistent on a weekly basis over the October 16, 2007 to October 15, 2008 period, ranging from -40.83 to -34.86 dB. These mean TS values were equivalent to estimated mean fish lengths of 16.53 to 33.95 cm based on Love (1971). Significant (α=0.10) differences in mean TS were not observed between units at the powerhouse on a monthly basis (Figures 5.1-16 and 5.1-17; Table 5.1-8), with the exception of January and February. During these two months, the mean TS of entrained targets, was significantly greater at Units 51 and 52, relative to the remaining units. In general, the observed monthly differences in mean TS over the study period were deemed to be minor and unlikely to indicate large differences in the size composition of targets entrained at different intakes.

6.5. Hydroacoustic and Fyke Net Relationship

The combined hydroacoustic and fyke net sampling approach at Boundary Dam has provided useful information to estimate patterns of fish entrainment at the site to date. The paired data collection approach is scheduled to continue through the end of February 2009. Hydroacoustic monitoring provides high temporal and spatial sampling coverage of the entrainment routes through Boundary Dam. Hydroacoustic data have been collected continuously at all six Boundary Dam turbine units and both spillways (when operational) since May 2, 2007, and provides a long-time series of entrainment estimates. Over 12,000 hours of data have been collected by the hydroacoustic system through October 31, 2008. The fyke net fish capture data collected at Unit 54 provides finer-scale entrainment estimates at a single location and complementary fish species composition and distribution information which is not directly available from the hydroacoustic information. The fyke net data set consists of 80 valid tests (through October 31, 2008) of approximately 239 hours duration.

It was anticipated that a linear relationship would be observed between the paired hydroacoustic and fyke net results at Unit 54. Such a relationship would either validate the hydroacoustic target entrainment results as absolute estimators of total turbine fish entrainment at the Project (if a 1:1 relation between the estimators was observed), or establish a constant to translate the hydroacoustic target results into measures of absolute fish entrainment. A 1:1 relation has not been observed between the two entrainment estimation methods thus far. The hydroacoustic target entrainment estimates at Unit 54 have tended to be greater than the corresponding total fyke net fish capture estimates for individual tests. Regressions between the two data sets have indicated that the relationship between the two estimators is variable. This may be due to sampling biases in both methods, and does not necessarily indicate that one is flawed and the other is accurate. Investigations of both the hydroacoustic and fyke net data sets are continuing, and final recommendations regarding the relationship of the two data sets will be presented in the Study 12 Final Report in June 2009.

To increase the precision of the Boundary Dam powerhouse entrainment estimates, the variability surrounding the relationship between hydroacoustic target and fyke net entrainment at Unit 54 needs to be reduced. The additional paired Unit 54 sampling scheduled in 2008-2009 is intended to improve the correlation between the two entrainment estimators, but to what degree is uncertain. Ongoing efforts are focused on exploring the sampling assumptions of each estimation method, to evaluate potential biases that could be addressed to improve the relationship between them.

Based on the evidence to date, the variability in the fyke net capture efficiency estimates (as determined by the percentage of introduced targets recaptured in the nets) has a significant effect on the fyke net total fish passage estimates, and is a source of uncertainty in establishing the fyke net/hydroacoustic relationship. Additional effort will be invested in confirming that the methods currently applied to estimate net capture efficiency for fish are valid. One such investigation is planned for the last quarter of sampling in 2008, involving comparisons of the net recapture efficiency of live triploid trout releases at Unit 54, paired with concurrent introduced NBT releases. Statistical comparisons of the net recapture efficiency for both target types will provide information regarding whether introduced NBT are suitable surrogates for estimating net capture efficiency for fish. Investigations of fish densities present in the Unit 54 upstream draft tube gatewell are also scheduled. It is possible that some fish detected entering the turbine opening may follow the draft tube ceiling and enter the still water area within the gatewell (Figure 4.1-1), and potentially not transit the area downstream of the turbine unit (where the fyke nets are located) until some later time.

A number of evaluations have been conducted to evaluate the sampling assumptions and methods used by the hydroacoustic monitoring system to estimate entrainment. The hydroacoustic target estimates could conceivably include some number of fish that ultimately are not entrained into the draft tube (i.e., overestimating entrainment). Tests were conducted at Unit 54 in 2008 to evaluate if the spatial distribution of target detections across the intake was skewed, which could result in extrapolation errors. The Unit 54 intake was instrumented with additional transducers to provide near-complete sampling coverage. The comparisons of target distributions across the entire intake did not indicate spatial entrainment biases, validating the hydroacoustic weighting used to date. Both the hydroacoustic and fyke net techniques are estimators of absolute fish entrainment at Boundary Dam and have different biases. Efforts to understand the potential sampling biases in the Boundary Dam entrainment estimators are underway, and definitive powerhouse fish entrainment results will be presented in the Study 12 Final Report in June 2009.

7 VARIANCES AND MODIFICATIONS FROM THE FERC-APPROVED STUDY PLAN

7.1. Hydroacoustic Sampling

To date, the hydroacoustic portion of the Fish Entrainment and Habitat Connectivity Study has proceeded in accordance with the FERC-approved study plan, and variances have not occurred.

7.2. Proposed Sampling Modifications

The following proposed study modification is intended to refine hydroacoustic and fyke net sampling efforts for 2009. This recommendation is not considered a variance from the FERC-approved RSP (SCL 2007a).

- Completion of the hydroacoustic and fyke net sampling effort on March 1, 2009.

As detailed in the RSP, the hydroacoustic and fyke net sampling was to be completed at the end of the first quarter, 2009 consistent with the proposed modification. In the July 2007 Study No. 12 Fish Entrainment Study Methods Outline (SCL 2007b; Appendix 2) produced subsequent to the RSP (SCL 2007a), sampling was modified to extend to May 2, 2009. However, as specified within the methods outline document (Appendix 2, page 2), sampling efforts could be curtailed if sufficient data were gathered to allow an informed development of the Preliminary Licensing Proposal (PLP).

Currently, hydroacoustic and fyke net sampling are being conducted and data collection and analysis indicate that sampling to March 1, 2009 would be sufficient in providing the necessary information for the informed development of the PLP. In addition to PLP development, this information will be necessary to support the Integrated Resource Analysis (IRA) which is the basis for the identification of appropriate protection, mitigation, and enhancement measures to be included in the License Application. IRA activities are scheduled to begin in January 2009. The proposed modification will be made in cooperation with relicensing participants.

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Appendix 1: Study No. 12 Fish Entrainment and Habitat Connectivity Study Interim Report (Methods and Results Sections Only)

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 12

Fish Entrainment and Habitat Connectivity Study

Interim Report

(Methods and Results Sections Only)

Prepared for
Seattle City Light

Prepared by
Hydroacoustic Technology, Inc.
715 NE Northlake Way
Seattle, WA 98105

Final Report: March, 2008

4 METHODS

The data collection methods used in the Fish Entrainment Study, are described in detail in the Study 12 Methods Outline, which is included as Appendix 1 in this report. An overview of the hydroacoustic data collection methods is summarized below in Section 4.1.

The Fish Entrainment Study consists of separate turbine and spillway components. Entrainment information from both components is summarized to estimate total target entrainment through the Project over time. Turbine entrainment is estimated using both hydroacoustic and fyke netting techniques. Spillway entrainment is estimated using only hydroacoustic sampling, although periodic gill netting is conducted near the spillway to provide complementary species composition information (see Study No. 9 Fish Distribution, Timing, and Abundance Study interim report - Task 1, SCL 2008).

4.1. Hydroacoustic Sampling Methods

Hydroacoustic target entrainment data are collected and analyzed using split-beam target tracking techniques as described by Ehrenberg and Torkelson (1996), and following the scientific acoustic sampling principles outlined in MacLennan and Simmonds (1992). The principle of fixed-location, split-beam hydroacoustic techniques is based on placing one or more transducers on fixed structures and sampling targets as they pass through the insonified acoustic beams. The targets produce characteristic echo returns that are processed to produce total passage estimates. Additional information describing target passage rates, direction of movement, size, velocity, vertical distributions and other parameters is also available from the hydroacoustic data set.

The hydroacoustic equipment required for a quantitative fixed-location study includes a scientific-quality echo sounder/transceiver, transducers, and a computer-based echo processor. The primary component of a hydroacoustic data collection system is the scientific echo sounder. When triggered, the echo sounder emits a short electrical pulse of known frequency, duration, and transmit power. The transducer then converts the electrical pulse into mechanical energy (i.e., a sound pulse with the same characteristics as the electrical pulse). In fixed-location applications, the transducers typically have relatively narrow beam widths so they can be aimed close to physical boundaries (e.g., the face of a dam) and maximize sampling coverage in specific areas of interest, such as a turbine intake.

When the sound waves encounter fish or other targets, echoes are reflected back to the transducer. The transducer then converts the sound energy back into electrical energy and sends it back to the receiver portion of the echo sounder. The echo signals are relayed to a computer-based echo processor, which records each detection to a computer file for subsequent analysis.

4.1.1. Hydroacoustic Powerhouse Entrainment

The Boundary powerhouse consists of six turbine units, numbered Units 51-56. Vertically-oriented 6˚x10˚ nominal beam width[1] transducers are mounted on the centerline of each turbine intake at elevation 1,972 feet NAVD 88 (1,968 feet NGVD 29) and aimed down to monitor the water column immediately upstream of each turbine intake opening (Figure 4.1-1). The transducers operate at a sampling frequency of 200 kHz and use split-beam technology to track the direction of individual targets in three-dimensional space. Only targets exhibiting net movement into the intake are considered to be entrained. The six transducer turbine intake monitoring array is sampled continuously, 24 h/d. Individual transducers at each turbine intake are sequentially-sampled in 2.5-min increments across the powerhouse within each 1-hour data replicate, such that each location is monitored 10 min/h. All entrained target detections are weighted for unsampled time and space, and the resulting estimates represent total hourly target passage at each location.

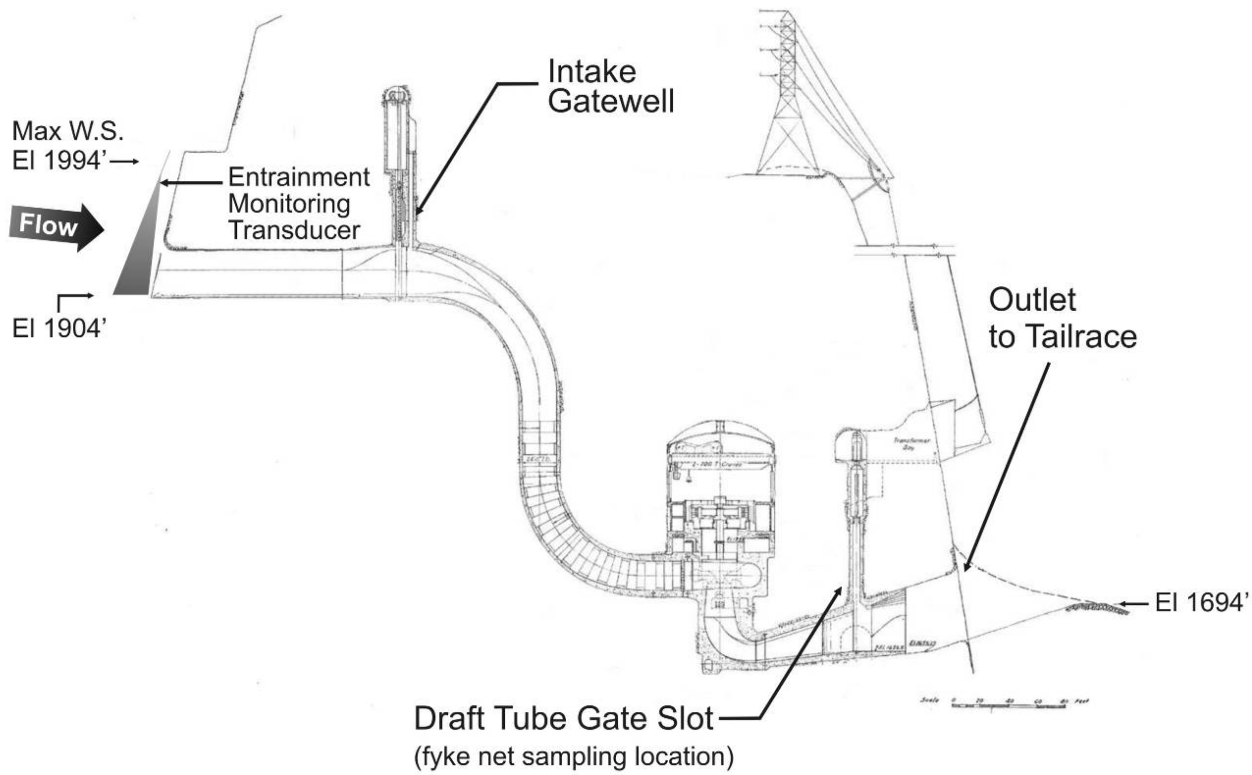

Figure 4.1-1. Schematic showing the location of the hydroacoustic transducers at the turbine unit intakes, relative to the fyke net sampling location in the draft tube gate slot at Boundary Dam. Elevations use NAVD 88 datum.

[1] The actual beam pattern plots and other parameters that describe each transducer are measured during laboratory calibrations and referenced in each transducer's calibration file. These values are used in the weighting of raw detections (among other things) to provide entrainment values. A more detailed discussion of transducer characteristics and their function can be found in MacLennan and Simmonds (1992).

Each transducer monitors approximately 40 percent of the intake cross-sectional area and the sampling volume axis is aligned with the intake centerline. Target detections are weighted for unsampled area in the intake based on the total intake width at the depth at which the target was observed divided by the width of the transducer beam at that depth. This spatial weighting expands the observed counts to total turbine entrainment estimates, and considers the variable width of the arched turbine intakes with depth. At the top of the turbine intake opening (30.8 feet below each transducer) the acoustic sampling volume is 5.9 feet wide. At the bottom of each intake (69 feet below each transducer), the acoustic volume is 13.3 feet wide, relative to a total base intake width of 30 feet. Range-weighting of each detected target corrects for the increasing sample volume with range and provides an estimate of total turbine entrainment. Turbine unit operations are also referenced during the analyses, such that only targets moving into operating turbines are included in the hydroacoustic entrainment estimates.

An acoustic sampling (ping) rate of 12 pings per second (pps) is used at all turbine units. This relatively fast ping rate provides high acoustic detectability (i.e., multiple echo returns) of individual entrained targets. Target detectability at the Boundary turbine intakes was modeled before the data collection period, based on the transducer beam widths, sampling ranges, and maximum water velocities present at the site. A minimum echo detection threshold of -52 decibels (dB) was used for monitoring at the Boundary powerhouse, equivalent to a minimum fish detection length of 43 mm (1.7 inches) based on Love (1971), an empirical formula relating backscattered acoustic energy to fish length. Hydroacoustic data were subsequently filtered in post-processing to include only detections with a mean target strength (acoustic size) of $\geq$ -45 dB, equivalent to an estimated minimum fish detection length of 100 mm (4 inches) using Love (1971). A relatively narrow broadcast pulse width (PW) of 0.2 ms is used by the acoustic system to optimize detection of closely-spaced individual targets.

The installation is configured to allow remote control of the hydroacoustic system for monitoring and data transfer purposes. The hourly hydroacoustic target passage data files are transferred on a daily basis to SCL for ongoing data review and analysis.

To minimize the potential for inclusion of detections from debris, entrained air, and non-fish targets in the hydroacoustic entrainment summaries, each hydroacoustic detection was filtered using multiple criteria. Targets reflecting less energy than expected from a 4-inch long fish ($\leq$ -45 dB mean target strength) were excluded from the data record. If suspended debris were present in the study area, the majority of this debris would be anticipated to return target strength values less than -45 dB and would be removed by this filtering. Only echo returns with pulse widths within +/- 50 percent of the 0.2 ms transmitted signal (values of 0.08 to 0.29 ms, as measured at the echo half-amplitude point) were considered during target tracking. Debris typically returns echo widths wider than the transmitted signal, due to the variable shape and aspect of debris targets. Echoes reflected from individual fish typically have widths similar to the transmitted pulse. In addition, only targets located at depths below the top of the turbine intakes (>30.8 feet below each transducer) and exhibiting consistent movement downstream into the intakes were considered in the acoustic counts. To be detected by the acoustic system, targets must have a significant difference in density from the surrounding water. In fish, the air-filled swim bladder is responsible for over 90 percent of the energy reflected from the target (Foote et al. 1986). Debris incorporating sufficient air to return echoes with high enough amplitudes to be detected by the acoustic system would tend to be positively buoyant and not be present at depths below the intake opening. Lastly, each target was required to be detected a minimum of 6 times as it transited through the acoustic sampling volume, and these detections had to occur sequentially and be located in close spatial proximity. This echo detection redundancy minimized the potential of false detections due to noise or small particles, which are typically variable in position relative to returns from fish.

4.1.2. Hydroacoustic Spillway Entrainment

The Boundary Dam spillway consists of two spill bays, each 45 feet in height and 50 feet in width, located at each end of the arch dam (see Figure 3.0-1). Spill Gate 1 is located at the dam's left abutment, closest to the powerhouse forebay intake channel. Spill Gate 2 is located at the far end of the arch dam, at the right abutment and adjacent to the east shoreline of the reservoir.

In order to monitor targets passing through the spill bays during spill events, two vertically-oriented 15˚ nominal beam width transducers are deployed at each spill bay (four transducers in total) to maximize spatial sampling coverage across each spill gate opening. For the purposes of estimating entrainment, each spill bay is conceptually divided into two halves with one down-looking transducer located equidistantly in each half. The spillway transducers are deployed at an elevation of 1,988 feet NAVD (1,984 feet NGVD 29) and aimed down vertically to monitor the water column immediately upstream of each spill gate opening.

Each spill bay transducer is sampled for six 5-min time intervals per hour during all periods when spill is occurring at the Project. This sampling design provides 60 min of sampling time within each spill bay per hour (30 min per hour in each half of the spill bay opening). The transducers operate at a sampling frequency of 200 kHz and use split-beam technology to track the direction of individual targets in three-dimensional space. Only targets exhibiting movement into the spill bays are considered in the entrainment counts. All entrained target detections are weighted for unsampled time and space, and the resulting estimates represent total target passage at each location. Spillway operations were considered during the analyses, such that only targets moving into the operating spill bay(s) were included in the hydroacoustic entrainment estimates.

The spillway monitoring transducers are sampled using a ping rate of 15 pps, which provides high acoustic detectability of individual entrained targets. Target detectability at the Boundary Dam spillway was modeled prior to the data collection period, based on the transducer beam widths, sampling ranges, and maximum water velocities estimated in the region upstream of the spill gates. The higher potential water velocity in the spill bays relative to the turbine intakes indicated the use of a relatively higher ping rate at the former location. Target detectability is equivalent at the monitored Boundary Dam turbine intake and spill gate locations, based on the model results.

Estimated hydroacoustic target entrainment at the spillway is summarized and presented in an identical manner as at the turbine intakes (Section 4.1.1). The same target detection filtering criteria applied at the powerhouse (i.e., a -45 dB minimum mean target strength, echo width bounds, six minimum echo returns) were used at the spillway to minimize the potential impact of echo returns from suspended debris or air bubbles in the entrainment estimates.

4.1.3. Spillway Gill Netting

Gill nets were deployed approximately once per month at a distance of 100-400 feet upstream of Spill Gate 2, located on the east side of the dam, between March and October 2007. Four separate gill nets, 100 feet long by 8 feet wide, were deployed vertically in the upper 100 feet of the water column. Each net had a different mesh size (0.5-, 1.0-, 1.5-, and 2.0-inch square mesh). In addition, a net was deployed horizontally along the channel bottom upstream of Spill Gate 2. This net was a 200-foot wide by 8-foot long, horizontal multi-panel gill net with the same mesh sizes as previously described. The location of each gill net set was standardized to the extent practicable. Variations in monthly deployment locations were tracked using handheld Global Positioning System (GPS) units and marked on high-resolution aerial photographs. All standard gill net sampling occurred between approximately one hour prior to sunset and approximately two hours after sunrise. Set duration ranged from 3 to 9 hours. The spillway nets were not deployed in April, as reservoir inflow conditions prevented the Boundary Powerhouse Operator from locking out the spillway gates during this period.

4.2. Fyke Net Sampling Methods

The purpose of the fyke net sampling is to verify the concurrent hydroacoustic passage estimates at Unit 54 and to provide fish species composition information. A fyke net sampling array was installed in the draft tube gatewell of Turbine Unit 54 at Boundary Dam in September 2007. Figure 4.1-1 shows the locations of the hydroacoustic monitoring transducer and the fyke net sampling frame at Unit 54. The fyke net array consists of two frames of 8 net panels each, and is designed to screen the entire draft tube downstream of Turbine Unit 54. Each frame measures 17 feet wide by 28 feet high. The frames are massive, weighing approximately 8,200 pounds apiece. The draft tube stop log gantry crane is used to deploy the net frames. The gantry crane is located approximately 135 feet above the sill of the draft tube gatewell. Crews fish the fyke nets from the deck of draft tube gate maintenance chamber, located approximately 92 feet above the draft tube gatewell sill.

A dive crew spent three weeks installing the fyke net frame guide rails during late September and early October 2007. Subsequently, there have been three efforts to deploy the nets. The first effort was made on October 6, 2007; the second on October 27, 2007; and the third on December 1, 2007.

While each effort to deploy nets in the draft tube has failed, our understanding of the complex fishing environment has increased. Following each effort, modifications to the nets and frames were made in response to the observed failure modes.

Ideally, the fyke net fishing would occur while the turbine produced 140 megawatts. This is the point where typically another unit is brought on line if more generation is to occur. This operating load is associated with a flow of approximately 7,000 cfs. Because all nets deployed were damaged or lost at this flow, the hydroacoustic data were queried to determine if there was a lower operating level that provided adequate numbers and a similar size distribution of hydroacoustic targets. A lower operating level would reduce the forces on the fishing gear and still provide data on species composition. The second fishing effort on October 27 began with a flow of 90 megawatts (approximately 5,000 cfs). This was the cut-off point indicated in the hydroacoustic data at which the full complement of sizes of entrained targets present at higher flows were evident. The forces at this flow still exceeded the capacity of the netting system and all nets failed. Interestingly, during both fishing efforts in October, the nets in the frame nearest the left bank were inverted, indicating that flow was reversed on one side of the draft tube, flowing towards the turbine. During the third effort on December 1, 2007 which began with a turbine load of 45 megawatts (approximately 3,000 cfs), a camera was mounted above an empty net bay. A light was attached to a line so that flow direction could be observed during net deployment. In this manner it was discovered that, counter intuitively, the water actually moved in the direction of the turbine during the entire fishing period. This leads to the conclusion that water is drawn from the tailrace through the back of one net frame, adding to the flow discharge from the turbine. All nets deployed on December 1 failed during the sampling event.

The reverse water flow in half of the draft tube has significant implications for the sampling effort. The frame and guide rails were designed to function at 1.5 times the average velocity of water passing through the entire flow area. With all of the flow passing through half of the flow area, plus an unknown amount of water drawn in from the tailrace, the actual velocity could be 3 to 5 times what was expected.

Ultimately, it may prove impossible to hold nets in place over the entire cross-section of the draft tube sampling area. Therefore, partial netting of the draft tube cross-sectional area, coupled with a statistical approach to verify net capture efficiency is under consideration for sampling efforts that will begin in January 2008. Fishing under a reduced flow regime may also be required. This may inhibit the program's ability to ascertain the full complement of sizes and species. Alternate methods for identifying species composition are under review. Alternate methods for correlating the hydroacoustic target information are also under review, should it be determined that fyke netting in the draft tube gatewell is not possible. Details of the fishing efforts envisioned for 2008 are included in Section 7.

A detailed description of the fyke net sampling methods for the Fish Entrainment and Habitat Connectivity Study is given in the Study 12 Methods Outline document previously provided to relicensing participants, dated July 17, 2007 (see Appendix 1).

5 RESULTS

5.1. Hydroacoustic Powerhouse Distributions

5.1.1. Total Estimated Entrainment

Estimated total hydroacoustic target entrainment at the powerhouse was summarized on a monthly and study period basis for evaluation and comparison. To evaluate potential effects of variable turbine operations on target entrainment, two entrainment rates were also calculated and compared. Entrainment rates expressed as the number of targets per hour of unit operation and targets per megawatt hour (MWH) were estimated on a monthly and study period basis. The former metric described entrainment as a mean hourly rate and the latter as the number of targets per MWH of power produced. At any given pool elevation, unit MWH is proportional to turbine flow and rates of entrainment per MWH provide a relative measure of passage per unit of water volume. This relationship may be biased by summarizing results collected at different pool elevations over time, and target per MWH estimates should be considered as relative measures of entrainment. Unit MWH measures can be converted to total intake flow and water velocities, and this information may be considered in future entrainment analyses.

Table 5.1-1 shows the estimated total entrainment of hydroacoustic targets through all turbine units for the May 2 through October 15, 2007 sampling period, with the associated 90 percent confidence intervals (CI). The table also includes the total megawatts produced by all units; estimated targets passed per megawatt hour (MWH), and estimated targets per hour of unit operation over the period.

A total of 169,752 targets were estimated to have passed downstream through Units 51-56 over the 2007 monitoring period considered in this report (approximately 5.5 months in duration). On average, this was equivalent to 13.22 targets per unit operating hour, or 0.1 targets per MWH of power production. These estimates include only targets equal to or greater than 10 cm in length (approximately 4 inches), assuming the targets to be fish and applying the Love (1971) relationship.

Table 5.1-1. Total estimated target entrainment, megawatt hours (MWH) produced, mean targets per MWH, and mean targets per hour of turbine operation for the May 2-October 15, 2007 study period.

Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour of Operation
169,752	10,941	4,782	1,735,946	0.10	13.22

Total estimated monthly entrainment at the powerhouse, entrainment per MWH produced, and entrainment per hour of turbine unit operation in 2007 is presented in Figure 5.1-1 to Figure 5.1-3 and summarized in Table 5.1-2.

Monthly estimated entrainment was relatively consistent for the first three months of the study period (May-July), varying from 33,379 to 37,051 targets (Figure 5.1-1 and Table 5.1-2). Project generation and total outflow decreased over this period, from 595,228 MWH in May to 237,259 MWH in July. Monthly entrainment did not appear to be correlated with total Project generation. Monthly estimated powerhouse entrainment declined in August and September to 9,682 and 10,418 targets, respectively. Project generation also decreased in August (120,139 MWH) and September (144,808 MWH), relative to May-July. A peak in monthly estimated entrainment of 43,571 targets was observed in October; despite the abbreviated sampling period (only data through October 15 were evaluated). Total power production for the abbreviated October monitoring period was 127,361 MWH, comparable to the total monthly MWH values for August and September. The majority of target entrainment in October (approximately 87 percent of the total for the 15 day monitoring period reported for the month) occurred during the first week.

Hydroacoustic target entrainment on a per MWH and per hour of unit operation basis, was similar for the May-June and August-September periods (Figures 5.1-2 and 5.1-3, respectively). Approximately 0.06-0.08 targets were estimated to have been entrained per MWH of power produced during these months, or 8.46-10.40 targets per hour of unit operation. A slight increase in entrainment rates was observed in July, when 0.15 targets per MWH and 17.86 targets per unit operating hour were estimated. The highest entrainment rates observed during the 2007 monitoring period occurred during the first half of October (0.34 targets per MWH and 43.48 targets per hour of unit operation).

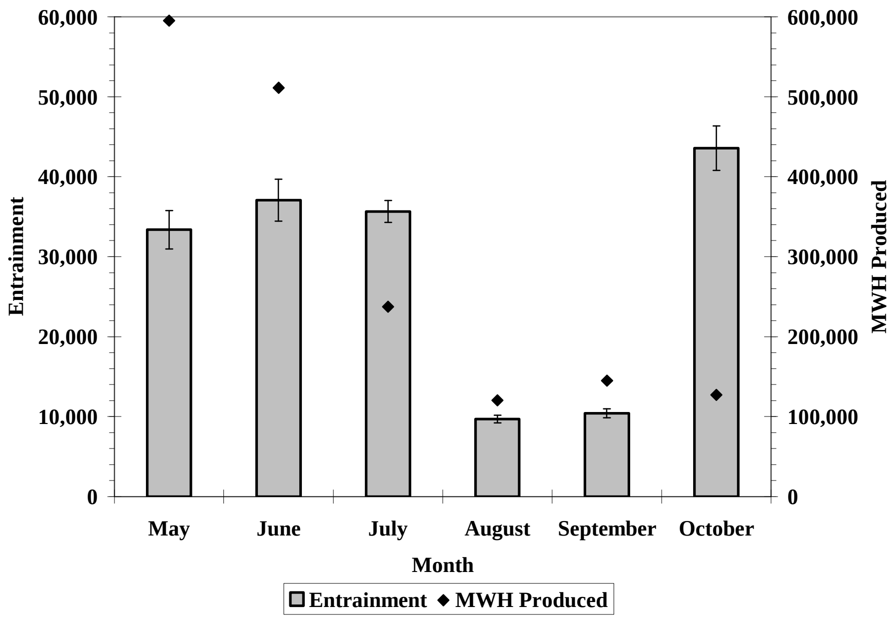

Figure 5.1-1. Estimated hydroacoustic target entrainment per month, with 90% CI, and total megawatt hours (MWH) produced for all turbine units combined over the May 2-October 15, 2007 study period. Note: Only a 15 day monitoring period is reflected in the October monthly estimate.

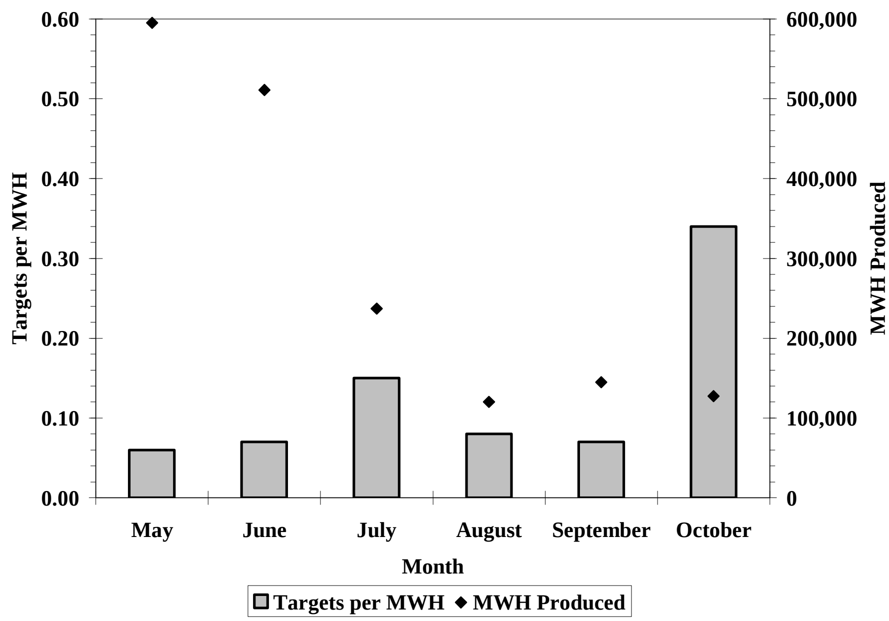

Figure 5.1-2. Estimated monthly hydroacoustic target entrainment per megawatt hour (MWH) produced, and total MWH produced for all turbine units combined over the May 2-October 15, 2007 study period. Note: Only a 15 day monitoring period is reflected in the October monthly estimate.

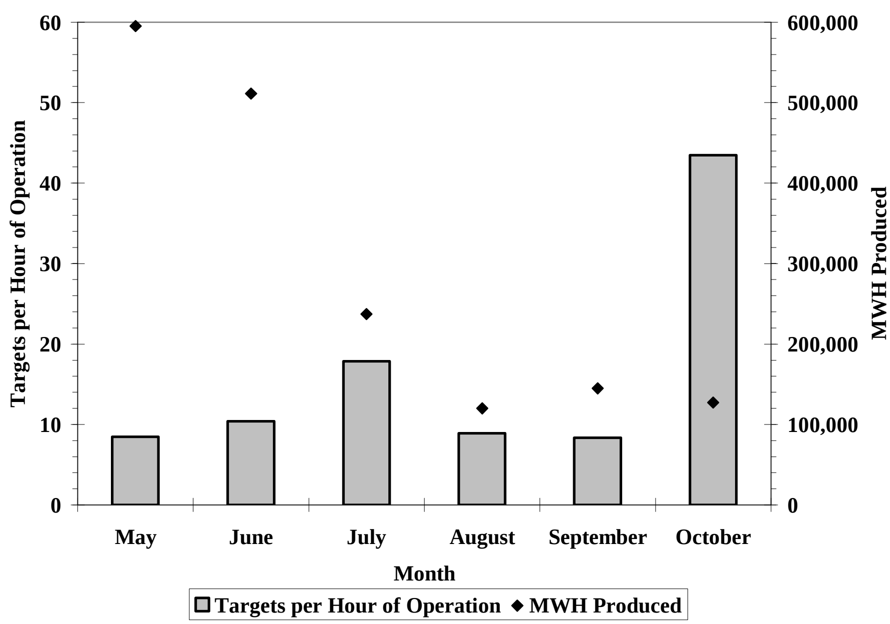

Figure 5.1-3. Total estimated hydroacoustic target entrainment per hour of operation for each month, and total megawatt hours (MWH) produced for all turbine units combined over the May 2-October 15, 2007 study period. Note: Only a 15 day monitoring period is reflected in the October monthly estimate.

Table 5.1-2. Monthly total estimated target entrainment with 90 percent CI, total megawatt hours (MWH) produced, mean targets per MWH, and mean targets per hour of turbine operation for the May 2-October 15, 2007 study period. Note: Only a 15 day monitoring period is reflected in the October monthly estimate.

Month	Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour of Operation
May	33,379	2,424	2,396	595,228	0.06	8.46
June	37,051	3,015	2,629	511,152	0.07	10.40
July	35,651	1,954	1,379	237,259	0.15	17.86
August	9,682	527	485	120,139	0.08	8.91
September	10,418	591	547	144,808	0.07	8.34
October	43,571	2,430	2,793	127,361	0.34	43.48

5.1.2. Entrainment Timing

Weekly estimates of hydroacoustic target entrainment for all turbine units combined were estimated on a weekly basis and compared over the 2007 study period to evaluate temporal passage trends (Figure 5.1-4 and Table 5.1-3). Total powerhouse generation in MWH was also summarized on a weekly basis and plotted to explore potential relationships between entrainment and total powerhouse flow. Entrainment rates, expressed as targets per MWH and hour of unit operation, were also calculated on a weekly basis and are shown in Table 5.1-3.

Hydroacoustic sampling commenced on Week 18, and total weekly target entrainment for all turbines combined varied between 3,843-10,287 targets for the first 14 weeks of the study (through August 4). Total estimated weekly turbine entrainment decreased to 322-5,159 targets during Weeks 15-23 (August 5-October 6). A substantial increase in estimated weekly entrainment (33,531 targets) was observed in Week 41 (October 7-13), near the end of the reported 2007 study period. The increase in entrainment during Week 41 was also reflected in the passage rates of number of targets per MWH (0.53), and in the number of targets per hour of unit operation (68.22).

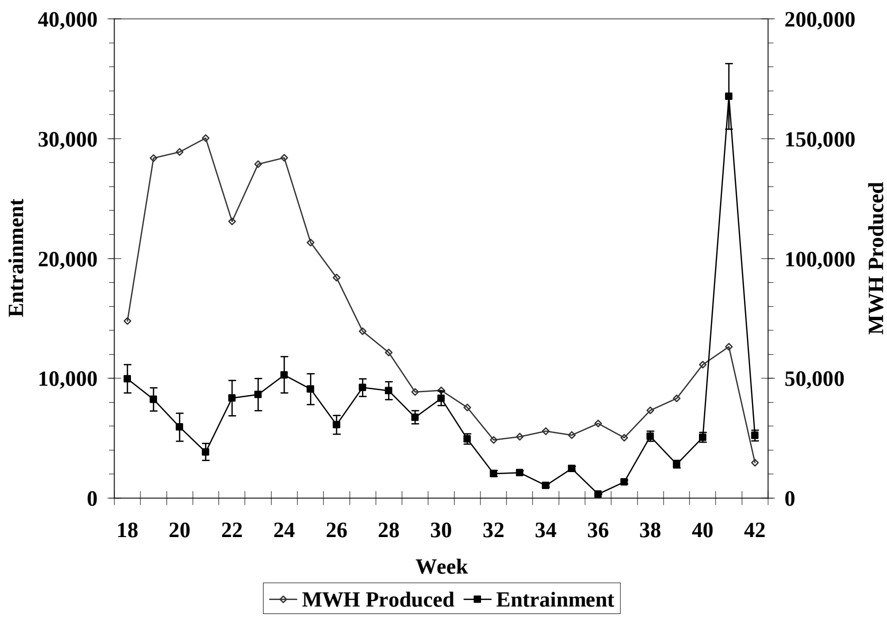

Figure 5.1-4. Total estimated number of targets entrained, with 90 percent CI, and total MWH produced by week, for the May 2-October 15, 2007 study period.

Table 5.1-3. Weekly estimated entrainment, with 90 percent CI, total megawatt hours produced, targets per MWH and targets per hour of unit operation for the May 2-October 15, 2007 study period. Weekly mean lake elevation is also presented (Elevations use NAVD 88 datum). Weeks are numbered sequentially with Week 1 beginning at January 1, 2007.

Week	Date	Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour of Operation	Mean Reservoir Elevation
18	5/2-5/5	9,952	594	1,181	73,963	0.13	19.52	1,981.96
19	5/6-5/12	8,235	588	967	141,981	0.06	9.11	1,982.90
20	5/13-5/19	5,918	512	1,157	144,438	0.04	6.24	1,978.88
21	5/20-5/26	3,843	296	710	150,271	0.03	3.91	1,983.33
22	5/27-6/2	8,346	672	1,472	115,550	0.07	10.17	1,984.08
23	6/3-6/9	8,630	685	1,346	139,412	0.06	9.31	1,985.84
24	6/10-6/16	10,287	892	1,505	142,024	0.07	11.17	1,985.22
25	6/17-6/23	9,098	766	1,287	106,683	0.09	11.89	1,985.51
26	6/24-6/30	6,121	434	778	92,060	0.07	8.41	1,985.09
27	7/1-7/7	9,219	504	746	69,618	0.13	15.69	1,985.60
28	7/8-7/14	8,961	495	760	60,724	0.15	17.23	1,982.65
29	7/15-7/21	6,743	365	559	44,327	0.15	18.67	1,984.57
30	7/22-7/28	8,325	452	606	44,916	0.19	22.55	1,985.24
31	7/29-8/4	4,930	281	429	37,814	0.13	14.73	1,985.28
32	8/5-8/11	2,048	110	251	24,246	0.08	8.78	1,985.50
33	8/12-8/18	2,113	114	173	25,665	0.08	9.60	1,986.05
34	8/19-8/25	1,052	57	129	27,894	0.04	4.27	1,981.37
35	8/26-9/1	2,457	131	204	26,241	0.09	10.03	1,986.24
36	9/2-9/8	322	19	29	31,088	0.01	1.13	1,976.23
37	9/9-9/15	1,352	79	162	25,211	0.05	6.23	1,977.77
38	9/16-9/22	5,159	292	413	36,608	0.14	16.49	1,984.71
39	9/23-9/29	2,827	161	302	41,609	0.07	7.94	1,985.07
40	9/30-10/6	5,061	282	404	55,726	0.09	11.74	1,982.16
41	10/7-10/13	33,531	1,877	2,732	63,190	0.53	68.22	1,983.64
42	10/14-10/15	5,223	283	444	14,690	0.36	42.38	1,985.57

5.1.3. Entrainment by Turbine Unit (Horizontal Distribution)

Estimated hydroacoustic target entrainment was summarized for each turbine unit on a monthly and study period basis and compared to evaluate relative passage trends across the powerhouse (Figure 5.1-5 and Table 5.1-4).

Over the entire May 2 through October 15, 2007 study period, Unit 51 demonstrated the highest estimated target entrainment (39,127, or 23 percent), followed by Unit 54 (34,614, or 20 percent) and Unit 52 (29,839, or 18 percent). The two units farthest away from the forebay entrance (Units 51-52) entrained approximately 41 percent of all hydroacoustic targets, even though Units 53-56 had higher MW loadings over the period. Total entrainment by turbine did not appear to be absolutely correlated with unit loading. Unit 53 had similar total MW loading as did Units 54-56, but demonstrated lower relative entrainment (15,073, or 9 percent). Minimum target detection sensitivity at Unit 53 was equivalent to the other turbine units based on a review of the hydroacoustic sampling parameters and system calibration data.

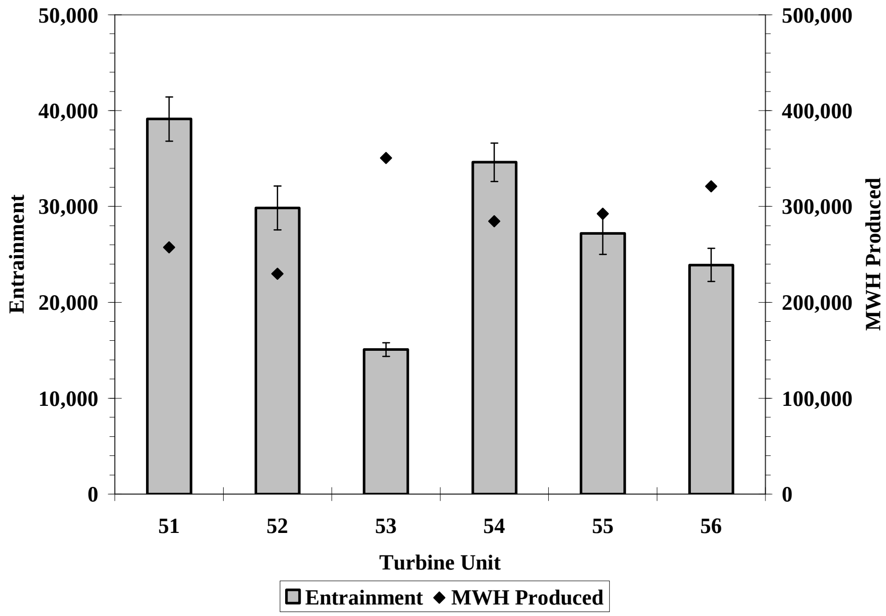

Figure 5.1-5. Horizontal distribution of total estimated hydroacoustic entrainment by turbine unit over the May 2 through October 15, 2007 study period, with 90 percent CI. The total MWH produced at each unit of the powerhouse is shown on the secondary Y-axis.

Table 5.1-4. Horizontal distribution of total estimated hydroacoustic entrainment at each turbine unit over the May 2 through October 15, 2007 study period, with 90 percent CI. Total MWH produced at each unit and entrainment rates (targets per MWH and targets per hour of unit operation) are also presented.

Turbine Unit	Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour of Operation
51	39,127	2,204	2,304	257,565	0.15	18.84
52	29,839	1,819	2,291	229,972	0.13	16.98
53	15,073	898	698	350,604	0.04	5.09
54	34,614	2,522	2,006	284,608	0.12	14.48
55	27,197	1,901	2,188	292,299	0.09	15.67
56	23,901	1,597	1,740	320,898	0.07	12.44

Figures 5.1-6 and 5.1-7 and Table 5.1-5 show estimates of target entrainment by turbine unit on a monthly basis. The study period estimate of relative turbine entrainment was affected by high passage at Units 51 and 52 during the first two weeks of October. Approximately 84 percent of all targets estimated to have passed through Unit 52 during the 2007 study period did so in October. At Unit 51, 68 percent of the 2007 study period entrainment at that location occurred in October. During the months of May-August, the largest percentage of targets were observed to pass via Units 54-56, and Unit 54 was recommended as the optimal unit for fyke net placement based on these results (see the Study 12 Fyke Net Placement Memorandum Report, submitted to SCL on November 2, 2007). The shift from relatively higher entrainment at Units 54-56 observed during the first 4 months of the 2007 study to increased relative entrainment at Units 51-52 during the months of September and October may have been due to changes in the pattern of turbine operations. Unit 55 was undergoing service in September and October and was essentially not operated during this period. This resulted in a relative increase in turbine operations at Units 51-53. The percentage of total powerhouse generation through Units 51-53 for the months of May-August varied between 43-47 percent, but increased to 64-66 percent in September and October. Increased flow through the lower-numbered units at the Boundary powerhouse in September and October may have affected target distributions in the forebay intake channel and subsequent patterns of entrainment by unit.

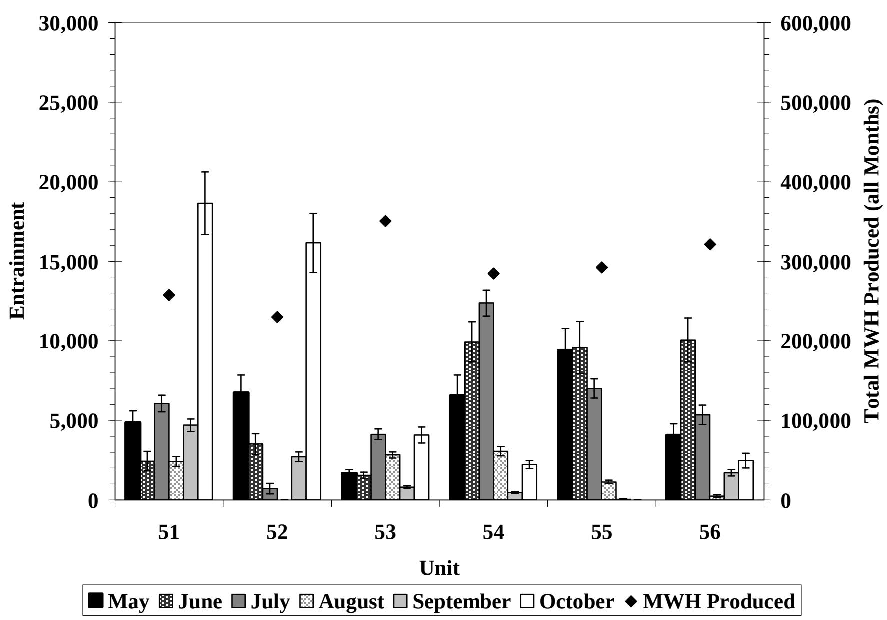

Figure 5.1-6. Horizontal distribution of estimated hydroacoustic target entrainment at each turbine unit on a monthly basis over the May 2 through October 15, 2007 study period, with 90 percent CI. Total MWH for each unit is presented on the secondary Y-axis. Note: Unit 52 did not operate in August. Unit 55 operated minimally during September and did not operate in October.

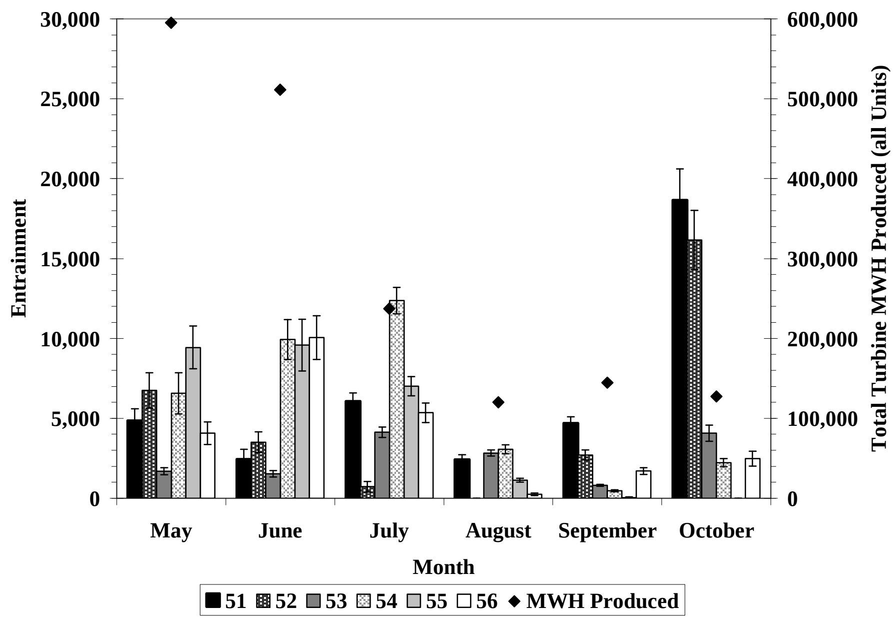

Figure 5.1-7. Monthly hydroacoustic target entrainment estimates by turbine unit over the May 2 through October 15, 2007 study period, with 90 percent CI. Total MWH (all units combined) for each month is presented on the secondary Y-axis. Note: Unit 52 did not operate in August. Unit 55 operated minimally during September and did not operate in October.

Table 5.1-5. Total estimated monthly hydroacoustic entrainment by unit over the May 2 through October 15, 2007 study period, with 90 percent CI. Total MWH produced at each unit and entrainment rates (targets per MWH and targets per hour of unit operation) are also presented on a monthly basis. Note: Unit 52 did not operate in August. Unit 55 operated minimally during September and did not operate in October.

Month	Unit	Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour Operations
May	51	4,860	306	745	81,351	0.06	8.18
May	52	6,750	456	1,100	95,014	0.07	9.84
May	53	1,695	131	223	90,176	0.02	2.50
May	54	6,571	551	1,284	84,276	0.08	10.38
May	55	9,433	685	1,337	122,423	0.08	13.93
May	56	4,069	295	711	121,987	0.03	6.03
June	51	2,436	168	617	69,212	0.04	4.69
June	52	3,510	247	649	83,863	0.04	5.61
June	53	1,539	116	202	85,998	0.02	2.30
June	54	9,930	963	1,253	82,119	0.12	15.50
June	55	9,583	771	1,621	98,140	0.10	16.77
June	56	10,053	750	1,376	91,821	0.11	18.69
July	51	6,069	327	526	40,645	0.15	16.56
July	52	720	41	334	6,396	0.11	11.84
July	53	4,128	228	328	55,544	0.07	7.91
July	54	12,371	685	817	52,921	0.23	24.47
July	55	7,010	382	609	48,637	0.14	21.67
July	56	5,354	291	613	33,116	0.16	24.56
August	51	2,413	131	312	13,135	0.18	18.77
August	52	0	0	0	0	0.00	0.00
August	53	2,825	151	194	39,264	0.07	7.38
August	54	3,062	170	286	36,673	0.08	8.58
August	55	1,133	61	118	21,959	0.05	7.30
August	56	250	14	79	9,109	0.03	3.94
September	51	4,697	260	397	26,542	0.18	19.07
September	52	2,708	158	304	19,527	0.14	15.54
September	53	812	46	63	50,221	0.02	1.75
September	54	458	27	60	11,566	0.04	4.16
September	55	38	2	39	1,140	0.03	4.45
September	56	1,705	98	208	35,812	0.05	6.97
October	51	18,652	1,012	1,969	26,680	0.70	84.11
October	52	16,152	917	1,857	25,172	0.64	76.55
October	53	4,074	226	500	29,401	0.14	16.82
October	54	2,222	126	255	17,053	0.13	15.35
October	55	0	0	0	0	0.00	0.00
October	56	2,471	149	462	29,054	0.09	13.56

Comparisons of estimated entrainment as a function of unit MWH loading (entrained targets per MWH) for the entire study period is presented in Figure 5.1-8. Unit 51 had the highest entrainment rate (0.15 targets per MWH) over the study period. Unit 52 had the next highest rate (0.13 targets per MWH), followed by Unit 54 (0.12 targets per MWH). Units 55, 56 and 53 had progressively lower rates 0.09, 0.07, and 0.04 targets per MWH, respectively.

Figure 5.1-9 shows entrainment rates per hour of turbine unit operation for the entire study period. The general trend between turbines was similar to that observed in the comparisons of targets per MWH in Figure 5.1-8, except that the relative hourly rates at Units 55 and 56 were slightly elevated due to the higher capacity of these units. Units 51 and 52 had the highest rates of target entrainment per operating hour (18.84 and 16.98, respectively) over the 2007 study period. The lowest rate of hourly entrainment (5.09 targets per hour) was observed at Unit 53.

As discussed above, the elevated entrainment rates at Units 51-52 over the 2007 study period were due to the spike in estimated entrainment that occurred at these locations in September and October. Based on the May-August monitoring period, the highest entrainment rates were observed at Unit 54, as reported in the Study 12 Fyke Net Placement Memorandum Report submitted to SCL and dated November 2, 2007.

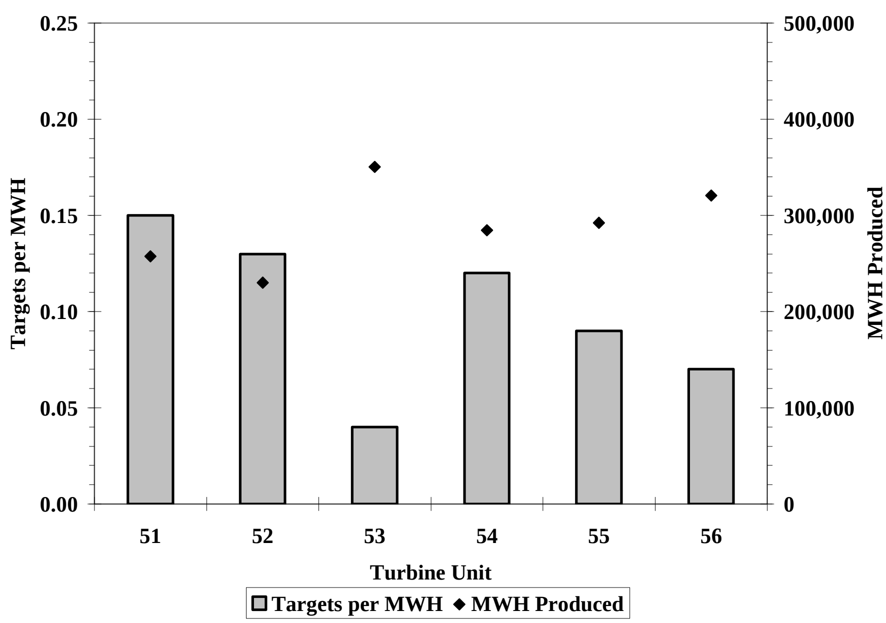

Figure 5.1-8. Total estimated hydroacoustic target entrainment per MWH of operation at each turbine unit and total MWH produced at each unit over the May 2 through October 15, 2007 study period.

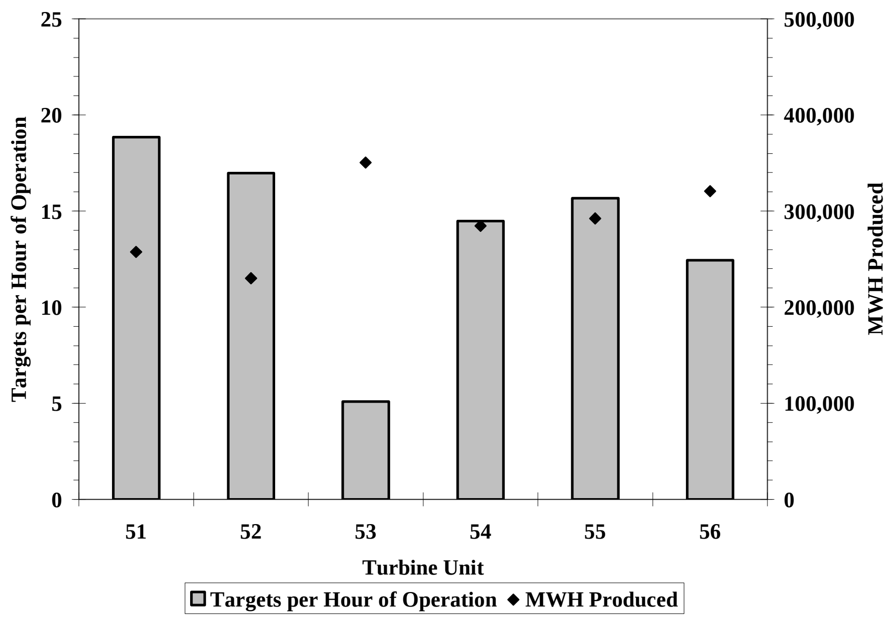

Figure 5.1-9. Total estimated hydroacoustic target entrainment per hour of unit operation at each turbine and total MWH produced at each unit over the May 2 through October 15, 2007 study period.

5.1.4. Temporal Entrainment Distributions

Temporal (mean entrainment over a 24 h period) distributions of hydroacoustic target entrainment for all turbines combined were summarized over the entire May 2 through October 15, 2007 study period. These results are shown in Figure 5.1-10 and 5.1-6. The hours designate the start time of each sample, i.e., 0600 h passage occurred between 0600-0700 h.

Over a 24 h period, hydroacoustic target entrainment was highest in the early afternoon through the early evening hours. Approximately 53 percent of all targets entrained at the powerhouse passed over the 8 h period between 1200 h and 1900 h. A peak in entrainment was observed during the early morning at 0600 h, coinciding with an increase in project generation. About 6 percent of total Project entrainment occurred during the 0600 h. Increased numbers of targets were observed to pass the powerhouse as units came on-line to meet morning power demands. On a per MWH basis, the 0600 h had the highest number of targets per MWH (0.17, Table 5.1-6). The second highest period of entrainment during the day occurred between 1200-1900 h, when generally uniform rates of between 0.10-0.12 targets per MWH. Rates of entrainment per operating unit hour were 21.67 targets per hour during the 0600 h and 14.33-17.42 targets per hour between 1200-1900 h.

The magnitude of total hourly target entrainment over the 2007 study period was observed to generally follow patterns of generation at the Project. Relatively fewer turbine units are operated during nighttime hours at Boundary Dam (from approximately 2200-0600 h), than during the day. Fewer targets were observed passing via the Boundary Dam turbines during the night than the day, presumably due to decreased unit operations during the former period.

There appeared to be a strong relationship between MWH produced and target counts. This relationship may interfere with identifying the temporal distribution of fish passage, although Project operations do typically follow a consistent pattern over a 24 h period. In order to evaluate temporal patterns of passage that were minimally influenced by differences in Project generation, 24 h total target passage distributions were estimated for a 5 day period from June 7-11, 2007. Inflow to the reservoir was relatively high during this time period and all six turbine units operated at essentially full capacity over this period. The temporal distribution of target passage through the entire Boundary powerhouse from June 7-11, 2007 is shown in Figure 5.1-11 and Table 5.1-7. Mean sunrise (0456 h) and sunset (2046 h) times for the period are shown in the graphic.

For the 5 day period in June with relatively consistent generation, hourly target passage was generally higher during daylight hours than was observed at night. The pronounced spike in passage observed at 0600 h for the entire 2007 study period (Figure 5.1-10) was less evident during the period of consistent 24 h generation (Figure 5.1-11), indicating that this increase in entrainment was primarily due to the increase in Project generation that occurs around this time. During the June 7-11 period of uniform generation, 81 percent of total target passage occurred during the approximately 18 hours of daylight (75 percent of the 24 h day) and 19 percent of total passage occurred during the six nighttime hours (25 percent of the 24 h day). On average, the proportion of targets passing via the turbine units per hour was slightly higher during daylight hours than at night, but the magnitude of this difference was relatively small.

Patterns of turbine unit operation appeared to influence the magnitude of powerhouse entrainment over a 24 h period. During a period of generally uniform turbine operation across the powerhouse, a higher proportion of entrained targets were observed per hour during daylight hours than at night, indicating that day/night period also had an effect on passage rates.

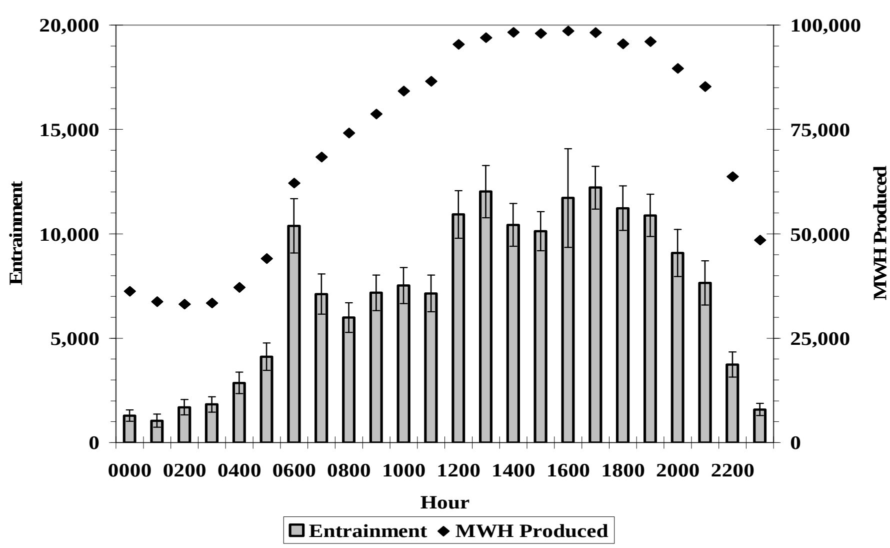

Figure 5.1-10. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) over the May 2 through October 15, 2007 study period, with 90 percent CI. Total MWH produced at the Project by hour over the period is displayed on the secondary Y-axis.

Table 5.1-6. Diel (24 h) distribution of hydroacoustic targets entrained at the powerhouse (all units combined) over the May 2 through October 15, 2007 study period, with 90 percent CI. Total MWH produced at all turbine units and entrainment rates (targets per MWH and targets per hour of unit operations) are shown for each hour.

Hour	Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour of Operation
0000	1,288	97	274	36,264	0.04	4.47
0100	1,046	79	315	33,748	0.03	4.10
0200	1,694	122	372	33,177	0.05	6.74
0300	1,829	140	370	33,453	0.05	7.15
0400	2,859	215	510	37,192	0.08	10.05
0500	4,115	294	660	44,052	0.09	11.19
0600	10,383	716	1,297	62,131	0.17	21.67
0700	7,114	456	961	68,408	0.10	13.76
0800	5,981	389	710	74,145	0.08	10.79
0900	7,176	471	853	78,671	0.09	12.38
1000	7,524	481	866	84,172	0.09	12.39
1100	7,143	491	880	86,509	0.08	11.33
1200	10,931	692	1,140	95,401	0.11	15.99
1300	12,023	764	1,256	96,967	0.12	17.42
1400	10,427	697	1,020	98,270	0.11	14.89
1500	10,125	637	940	98,015	0.10	14.33
1600	11,716	714	2,362	98,564	0.12	16.54
1700	12,212	730	1,028	98,186	0.12	17.22
1800	11,232	675	1,065	95,483	0.12	16.01
1900	10,883	655	1,012	96,070	0.11	15.70
2000	9,081	566	1,125	89,624	0.10	13.85
2100	7,648	507	1,061	85,256	0.09	12.39
2200	3,735	235	605	63,721	0.06	7.31
2300	1,586	118	286	48,469	0.03	4.04

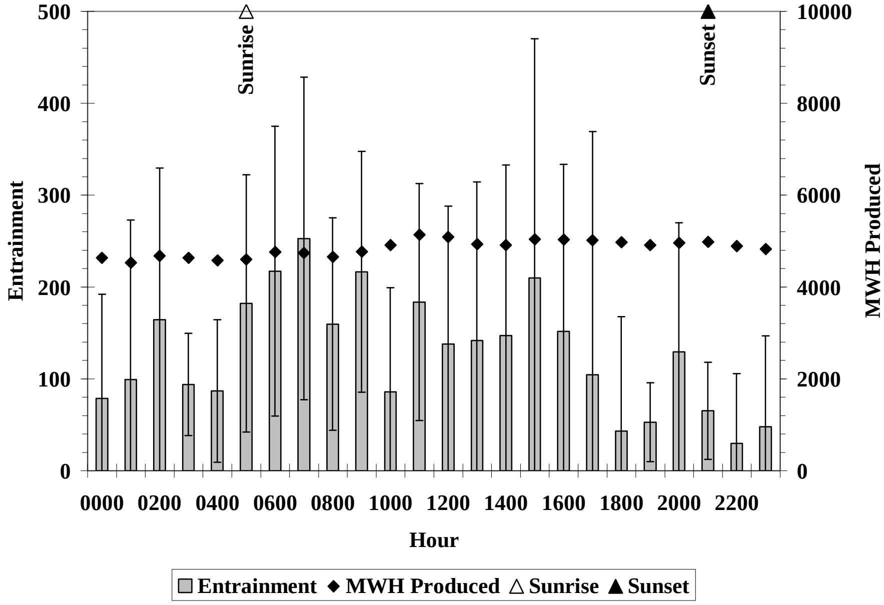

Figure 5.1-11. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) from June 7-11, 2007, with 90 percent CI. Turbine unit operations were relatively consistent over the period. Total MWH produced at the Project by hour over the period is displayed on the secondary Y-axis.

Table 5.1-7. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) from June 7-11, 2007, with 90 percent CI. Hourly turbine unit operations (MWH produced) were consistent over the 5 day period. Entrainment rates are shown for each hour as targets per MWH and targets per hour of unit operations.

Hour	Entrainment	N	CI 90 percent (+/-)	MWH Produced	Targets per MWH	Targets per Hour of Operation
0000	79	7	114	4,635	0.02	2.62
0100	99	7	173	4,530	0.02	3.31
0200	164	13	165	4,680	0.04	5.48
0300	94	8	56	4,632	0.02	3.13
0400	87	8	78	4,575	0.02	2.89
0500	182	13	140	4,597	0.04	6.07
0600	217	16	158	4,761	0.05	7.24
0700	253	17	176	4,739	0.05	8.43
0800	160	11	116	4,654	0.03	5.32
0900	217	14	131	4,773	0.05	7.22
1000	86	7	113	4,914	0.02	2.86
1100	184	17	129	5,135	0.04	6.12
1200	138	11	150	5,090	0.03	4.60
1300	142	14	173	4,933	0.03	4.72
1400	147	14	186	4,914	0.03	4.90
1500	210	19	261	5,036	0.04	6.99
1600	152	15	182	5,035	0.03	5.06
1700	105	10	265	5,015	0.02	3.49
1800	43	7	124	4,975	0.01	1.44
1900	53	6	43	4,912	0.01	1.76
2000	129	12	141	4,961	0.03	4.31
2100	65	5	53	4,979	0.01	2.17
2200	30	4	76	4,890	0.01	1.00
2300	48	6	99	4,823	0.01	1.59

Total hydroacoustic target entrainment data at the powerhouse over the reported May 2-October 15, 2007 study period was segregated into four groups, defined as daytime (0800-1759 h), nighttime (2200-0459 h), sunrise (0500-0759), and sunset (1800-2159 h) for the purpose of examining potential diel differences in entrainment (Figure 5.1-12; Table 5.1-8). To minimize the effect of the different day/night patterns of generation that typically occur at the Project, entrainment rates per hour of unit operation were compared. Entrainment rates per hour of unit operation were observed to be lower during nighttime than during the day, sunrise and sunset time periods. Entrainment rates during the latter three periods were generally equivalent. These findings were consistent with the diel patterns of total entrainment observed when all units were operated consistently over a 24 h period (Figure 5.1-11).

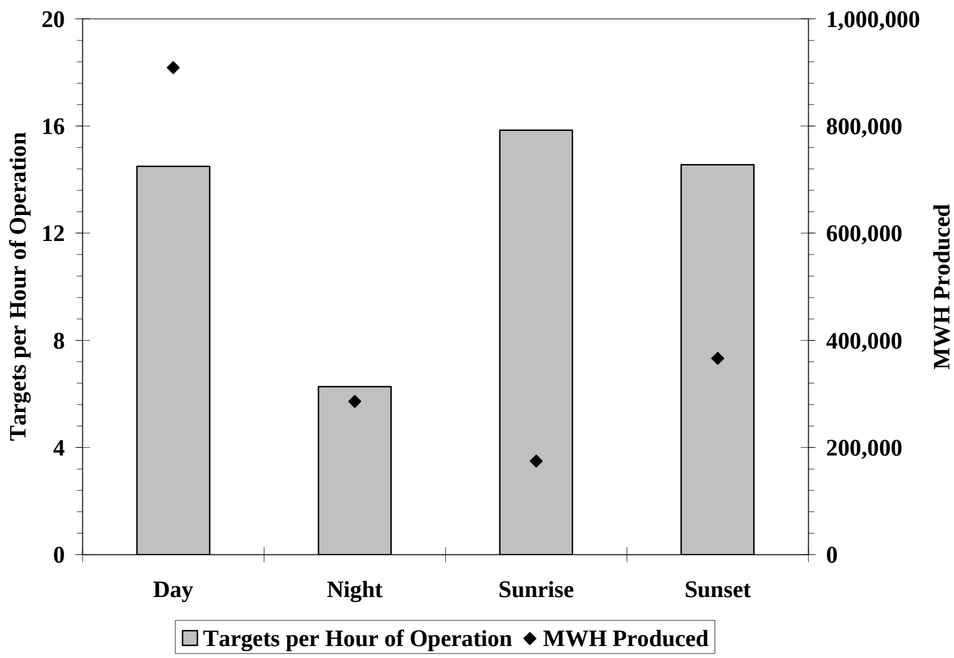

Figure 5.1-12. Diel (24 h) distribution of hydroacoustic target entrainment on a per hour of unit operation at the powerhouse (all units combined) from May 2-October 15, 2007. Total MWH produced at the Project is displayed on the secondary Y-axis.

Table 5.1-8. Diel (24 h) distribution of hydroacoustic target entrainment at the powerhouse (all units combined) from May 2-October 15, 2007, with 90 percent CI. Entrainment rates are shown for each hour as targets per hour of unit operations.

	Hours	Entrainment	N	CI 90% (+/-)	Targets per Hour of Operation
Day	0800-1759	95,257	6,066	3,759	14.50
Night	2200-0459	14,038	1,006	1,042	6.27
Sunrise	0500-0759	21,614	1,466	1,742	15.85
Sunset	1800-2159	38,844	2,403	2,069	14.56

5.1.5. Target Strength Distributions

Target strength (TS) is a measure of the ratio of reflected sound energy to the energy incident on the target, and is related to fish length. In general, physically-larger targets reflect greater proportions of the transmitted sound, resulting in higher TS values. Mean TS values were transformed to estimated fish lengths in cm using an equation published by Love (1971), which considered multiple fish species monitored in dorsal-aspect. Length frequency distributions, median and mean target strength values of all entrained detections were calculated for each turbine unit on a monthly and study period (May 2 through October 15, 2007) basis. As the fyke net sampling had not been successful as of the end date of the data presented in this report, the hydroacoustic targets have not been validated as fish. The fish length measures derived from the mean TS estimates are presented for reference only.

Comparisons of mean TS were used to evaluate if significant (α=0.10) differences in the mean size of entrained targets were observed between turbine units. If significant differences were observed, and were consistent over time, this might indicate potential differences in the size composition of targets entrained at different intakes. These differences may bias species apportionment of the hydroacoustic counts based on fyke net samples collected at a single turbine location.

Length frequency distributions calculated from the hydroacoustic TS measurements for the powerhouse (all units combined) were summarized by month (Figure 5.1-13; Table 5.1-9), on a weekly basis (Figure 5.1-14; Table 5.1-10), and by turbine unit over the entire 2007 sampling period (Figure 5.1-15; Table 5.1-11). In addition, TS was evaluated by turbine unit on a monthly basis to assess potential changes in target strength by location over time (Figure 5.1-16; Table 5.1-12). Diel (24 h) distributions of target strength for all turbine units combined over the May 2 through October 15, 2007 study period, are given in Figure 5.1-17 and Table 5.1-13. The 90 percent confidence intervals surrounding each TS and length estimate are shown (where appropriate) in each figure and table.

Length frequency histogram distributions at the turbine units were similar on a seasonal basis (Figure 5.1-13; Table 5.1-9). Median length values ranged from 13.46 cm (5 inches) in July, to 15.89 cm (6 inches) in October.

For all turbines combined, mean TS of hydroacoustic detections at the powerhouse was similar between May-August and then showed a minor (but significant) increase during September-October (Table 5.1-9). This indicated an increase in mean fish size in the late summer/early fall period.

As discussed above, positive identification of the entrained hydroacoustic targets has not yet been accomplished, and is pending successful fyke net sampling. If the hydroacoustic targets are assumed to be fish, the mean monthly TS values would result in estimated mean fish lengths of approximately 16-21 cm (6-8 inches), with a median estimated fish length of 18 cm (7 inches).

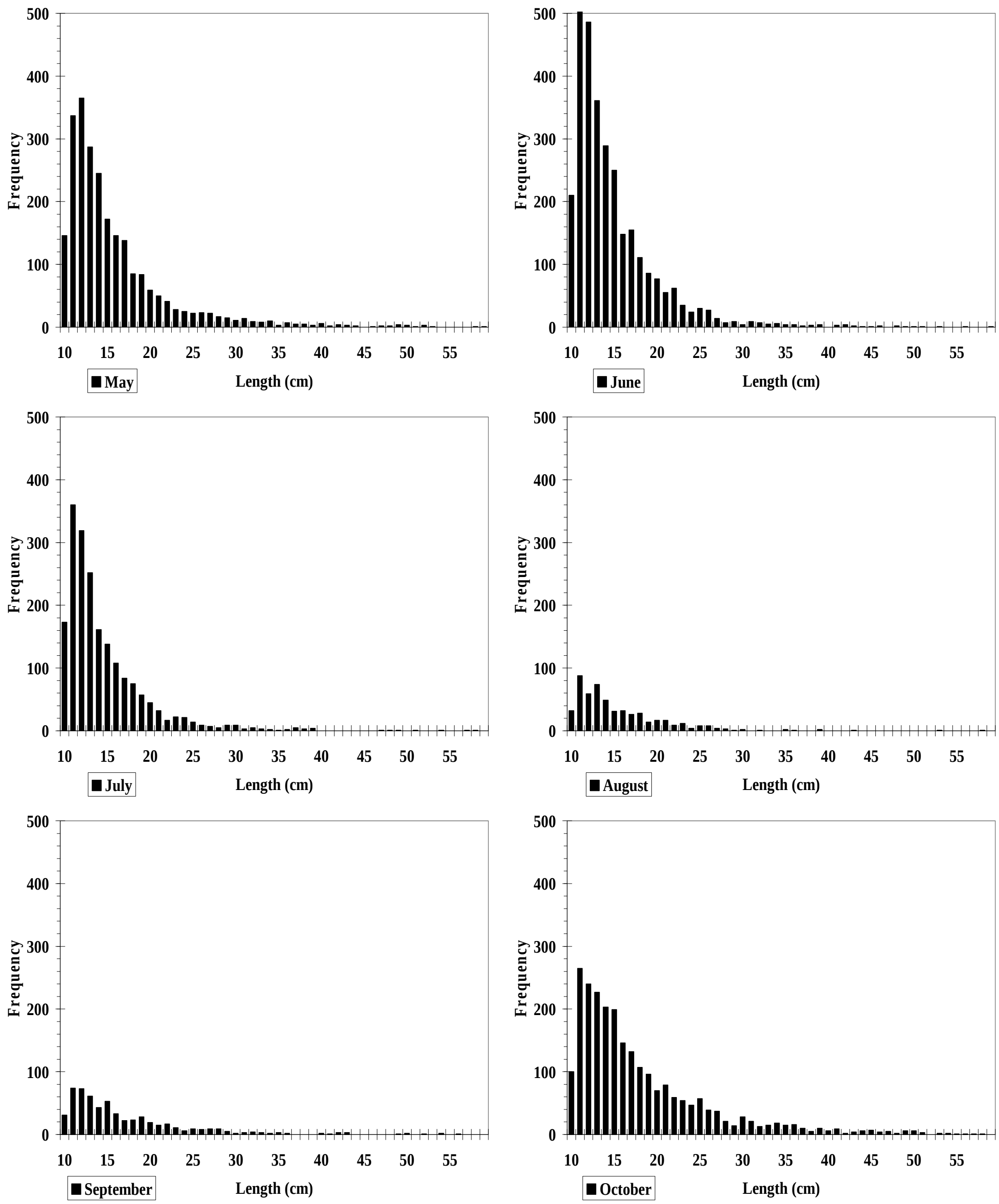

Figure 5.1-13. Monthly estimated fish length frequency (based on Love 1971) distributions of all entrained hydroacoustic targets, for all turbine intakes combined over the entire May 2 through October 15, 2007 study period.

Table 5.1-9. Monthly median and mean target strength (TS) estimates and corresponding estimated mean fish length (based on Love 1971) for all turbine units combined over the May 2 through October 15, 2007 study period. The 90 percent CI bounds surrounding each monthly TS and length estimates are included.

Month	N	Median TS (dB)	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Median Length (cm)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
May	2,430	-41.99	-39.82	0.47	14.32	18.61	1.09
June	3,019	-42.27	-40.85	0.21	13.85	16.44	0.43
July	1,955	-42.51	-41.04	0.28	13.46	16.06	0.54
August	528	-42.08	-40.55	0.49	14.17	17.04	1.04
September	592	-41.47	-38.85	0.69	15.26	20.91	1.81
October	2,430	-41.13	-38.82	0.30	15.89	21.00	0.78

On a weekly basis, mean TS was generally consistent over the 2007 study period, approximately -40 to -41 dB. These mean TS values were equivalent to estimated fish lengths of 16-18 cm, or 6-7 inches, based on Love (1971). Minor, but significant, increases in the mean TS of acoustic detections occurred during Week 21 (May 27 through June 2), and Weeks 36-40 (September 2 through October 6). During these weeks, mean TS was approximately -38 to -39 dB, equivalent to estimated fish lengths of 20-24 cm (8-9 inches) based on Love (1971). Hydroacoustic targets have not yet been verified as fish, and the length values are presented for reference only.

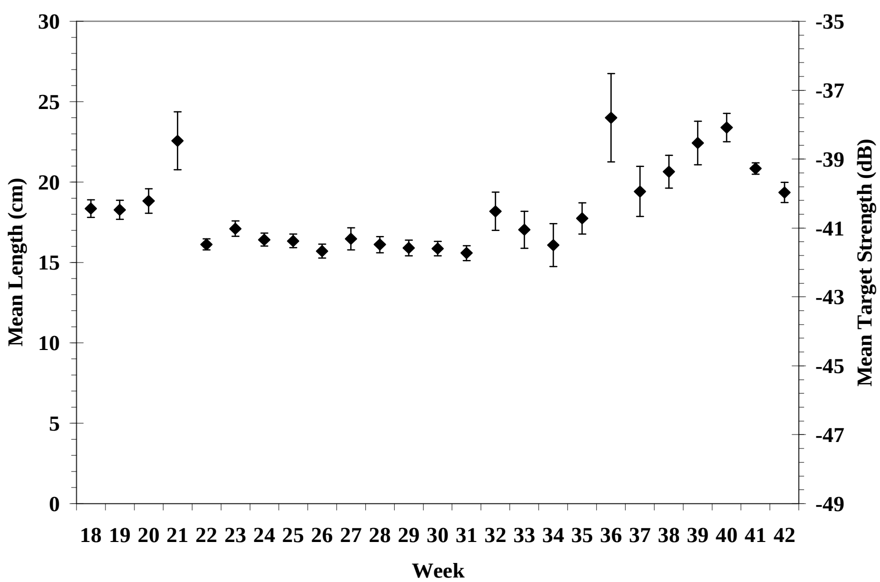

Figure 5.1-14. Weekly mean target strength (TS) and corresponding estimated mean fish length (based on Love 1971) for all turbine units combined over the May 2 through October 15, 2007 study period. The 90 percent CI bounds surrounding each weekly TS and length estimate are shown.

Table 5.1-10. Weekly mean target strength (TS) and corresponding estimated mean fish length (based on Love 1971) for all turbine units combined over the May 2 through October 15, 2007 study period. The 90 percent CI bounds surrounding each weekly TS and length estimate are shown.

Week	Date	N	Mean TS (dB)	TS CI 90 percent (+/-)	Mean Length (cm)	Length CI 90 percent (+/-)
18	5/2-5/5	594	-39.93	0.56	18.35	1.27
19	5/6-5/12	591	-39.97	0.59	18.27	1.34
20	5/13-5/19	513	-39.72	0.76	18.83	1.81
21	5/20-5/26	297	-38.22	1.80	22.56	5.48
22	5/27-6/2	673	-41.01	0.34	16.12	0.68
23	6/3-6/9	686	-40.52	0.48	17.10	1.02
24	6/10-6/16	894	-40.86	0.41	16.42	0.83
25	6/17-6/23	766	-40.90	0.42	16.34	0.86
26	6/24-6/30	435	-41.23	0.44	15.70	0.85
27	7/1-7/7	504	-40.83	0.69	16.47	1.43
28	7/8-7/14	496	-41.01	0.50	16.11	1.01
29	7/15-7/21	365	-41.13	0.49	15.90	0.98
30	7/22-7/28	452	-41.14	0.45	15.86	0.88
31	7/29-8/4	281	-41.29	0.47	15.58	0.90
32	8/5-8/11	110	-40.01	1.19	18.18	2.80
33	8/12-8/18	114	-40.55	1.15	17.03	2.53
34	8/19-8/25	57	-41.03	1.33	16.08	2.79
35	8/26-9/1	132	-40.22	0.97	17.74	2.21
36	9/2-9/8	19	-37.71	2.74	24.00	9.38
37	9/9-9/15	79	-39.47	1.56	19.42	4.01
38	9/16-9/22	293	-38.95	1.02	20.65	2.71
39	9/23-9/29	161	-38.27	1.35	22.43	3.98
40	9/30-10/6	282	-37.92	0.88	23.39	2.62
41	10/7-10/13	1,877	-38.88	0.35	20.85	0.91
42	10/14-10/15	283	-39.50	0.63	19.35	1.53

The mean TS of hydroacoustic targets entrained at each turbine intake was similar on a study period basis (Figure 5.1-15, Table 5.1-11). The mean TS values were between approximately -39 to -41 dB, equivalent to estimated mean fish lengths of 17-20 cm, or about 7 inches. Mean TS at Unit 53 was slightly, but significantly, higher than at the other turbine units (-39 dB, equivalent to an estimated mean fish length of 20 cm, or 8 inches). The decrease in the frequency of targets with estimated lengths of 10-11 cm in Figure 5.1-15 and Table 5.1-11 is caused by the 4 inch minimum target size "cutoff" applied to the hydroacoustic entrainment data set to exclude targets smaller than the minimum size of interest. A length of 4 inches is equivalent to 10.2 cm, resulting in a reduced total bin size relative to the remaining 1 cm length bins. The length frequency distribution of the 2007 Boundary Dam hydroacoustic data set was evaluated without applying a 4 inch minimum target size threshold to confirm the threshold effect, and the frequency of entrained targets was observed to increase with diminishing target size for estimated lengths at and below 4 inches.

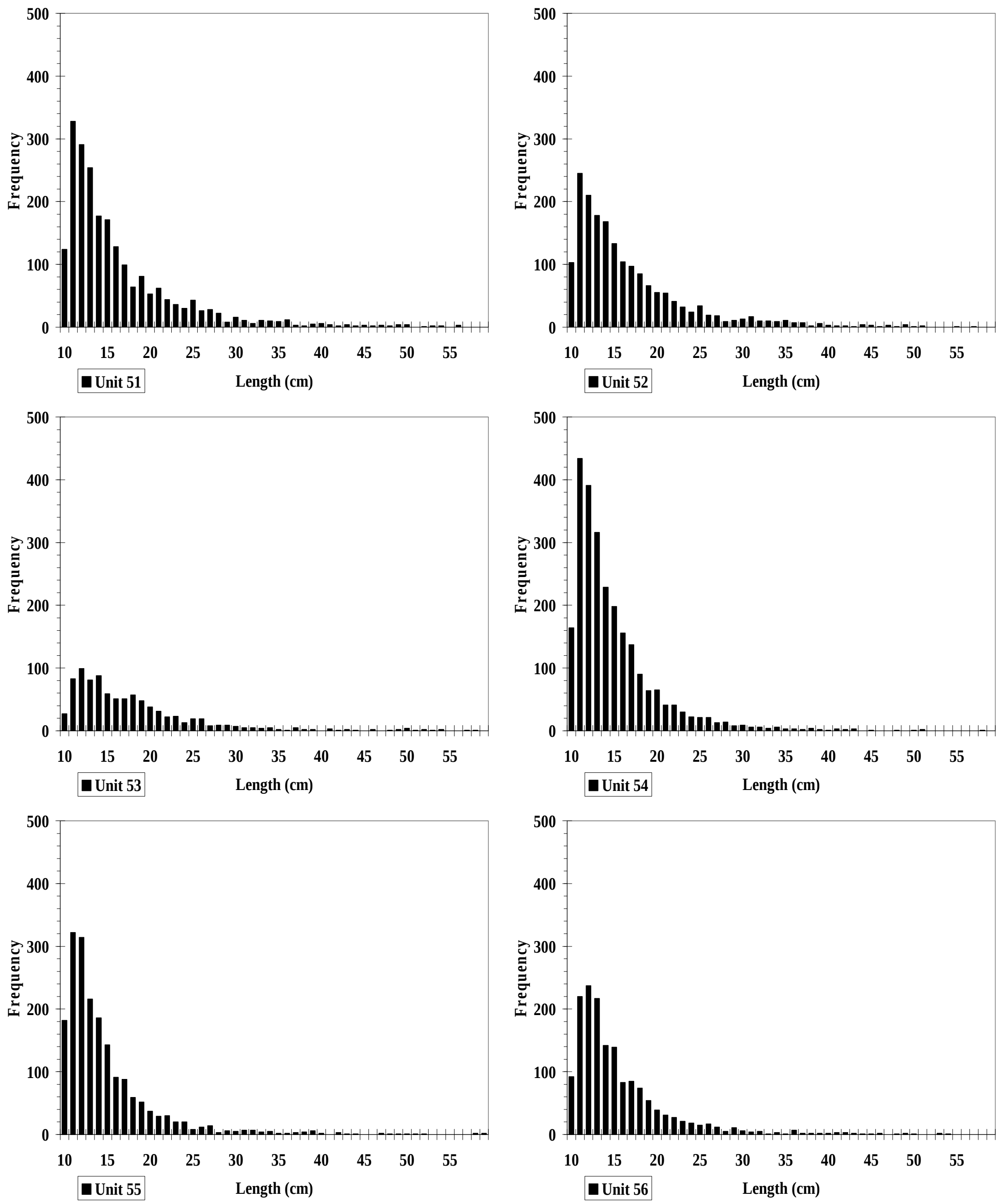

Figure 5.1-15. Estimated fish length frequency distributions (based on Love 1971), of all entrained hydroacoustic targets, at each turbine intake opening over the entire May 2 through October 15, 2007 study period.

Table 5.1-11. Median, mean target strength and calculated mean length (based on Love 1971) with corresponding 90 percent CI, by unit, at the powerhouse for the May 2 through October 15, 2007 study period.

Unit	N	Median TS (dB)	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Median Length (cm)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
51	2,206	-42.05	-39.69	0.32	14.22	18.89	0.74
52	1,822	-42.11	-39.43	0.34	14.12	19.51	0.83
53	901	-42.31	-39.05	0.47	13.79	20.42	1.18
54	2,522	-42.47	-40.78	0.25	13.51	16.57	0.51
55	1,904	-41.46	-40.24	0.59	15.27	17.69	1.30
56	1,599	-41.11	-40.25	0.36	15.93	17.66	0.78

Figure 5.1-16 and Table 5.1-12 show mean TS by turbine unit on a monthly basis over the study period. Length frequency histograms by turbine unit on a monthly basis over the study period are given in Appendix 2. Mean TS by unit was similar between May-August, with slightly higher mean TS observed at Unit 53 relative to the other turbines. Mean TS generally increased at all units in September and October. Turbine Units 53 and 54 exhibited increased mean TS during the month of September relative to the other units, but these differences were not significant at α=0.10. Observed differences in mean TS between turbine units on both a monthly and study period basis were deemed to be minor and unlikely to indicate a potential difference in the size composition of targets entrained at different intakes.

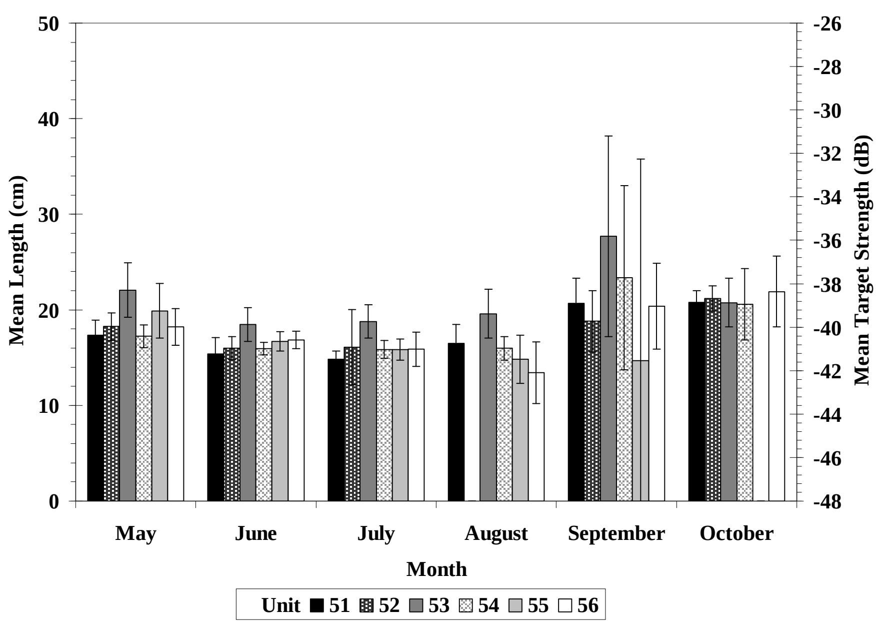

Figure 5.1-16. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the May 2 through October 15, 2007 study period. The 90 percent CI bounds surrounding each estimate are shown. Note: Unit 52 did not operate in August and Unit 55 was not operational during the October sampling period.

Table 5.1-12. Monthly mean target strength (TS), and corresponding estimated mean length based on Love (1971) by turbine unit over the May 2 through October 15, 2007 study period. The 90 percent CI bounds surrounding each estimate are shown. Note: Unit 52 did not operate in August and Unit 55 was not operational during the October sampling period.

Month	Unit	N	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
May	51	307	-40.40	0.72	17.35	1.58
May	52	457	-39.99	0.63	18.24	1.44
May	53	132	-38.41	1.01	22.07	2.84
May	54	551	-40.45	0.55	17.24	1.18
May	55	687	-39.27	1.11	19.88	2.85
May	56	296	-40.00	0.83	18.21	1.91
June	51	169	-41.41	0.89	15.37	1.73
June	52	249	-41.08	0.60	15.99	1.20
June	53	116	-39.89	0.76	18.46	1.78
June	54	963	-41.10	0.33	15.96	0.65
June	55	771	-40.72	0.49	16.69	1.02
June	56	751	-40.65	0.43	16.84	0.90
July	51	327	-41.71	0.46	14.82	0.85
July	52	41	-41.03	1.81	16.09	3.92
July	53	228	-39.74	0.74	18.79	1.74
July	54	685	-41.15	0.47	15.86	0.93
July	55	383	-41.15	0.57	15.84	1.13
July	56	291	-41.13	0.89	15.89	1.79
August	51	131	-40.81	0.93	16.51	1.97
August	52	0	0	0	0	0
August	53	152	-39.39	1.01	19.60	2.53
August	54	170	-41.08	0.62	15.98	1.24
August	55	61	-41.70	1.30	14.83	2.52
August	56	14	-42.53	1.79	13.43	3.23
September	51	260	-38.94	0.99	20.70	2.62
September	52	158	-39.73	1.31	18.81	3.21
September	53	47	-36.52	2.66	27.70	10.48
September	54	27	-37.93	2.86	23.36	9.63
September	55	2	-41.78	7.38	14.68	21.08
September	56	98	-39.07	1.65	20.37	4.48
October	51	1,012	-38.90	0.48	20.78	1.23
October	52	917	-38.74	0.49	21.19	1.29
October	53	226	-38.92	0.96	20.75	2.55
October	54	126	-38.99	1.38	20.57	3.73
October	55	0	0	0	0	0
October	56	149	-38.46	1.30	21.92	3.71

Hydroacoustic target data at the powerhouse was segregated into four groups, defined as daytime (0800-1759 h), nighttime (2200-0459 h), sunrise (0500-0759), and sunset (1800-2159 h) for the purpose of examining diel differences in entrainment. Length frequency histograms for each of these periods are given in Figure 5.1-17. The estimated mean lengths are based on the TS-length relationship published by Love (1971). From May 2 to the conclusion of the reported 2007 study period on October 15, the time of sunrise varied by 1 h 37 min, and sunset by 2 h 1 min (as measured at Spokane). The periods defining sunrise and sunset used for these analyses encompassed the actual times of these events over the study

Over the May 2 through October 15, 2007 study period, significant differences in mean TS and the corresponding estimated target lengths were not observed on a diel (24 h) basis for all turbine units combined (Table 5.1-13). On average, the estimated length distribution of entrained targets at the powerhouse was similar over a 24 h period.

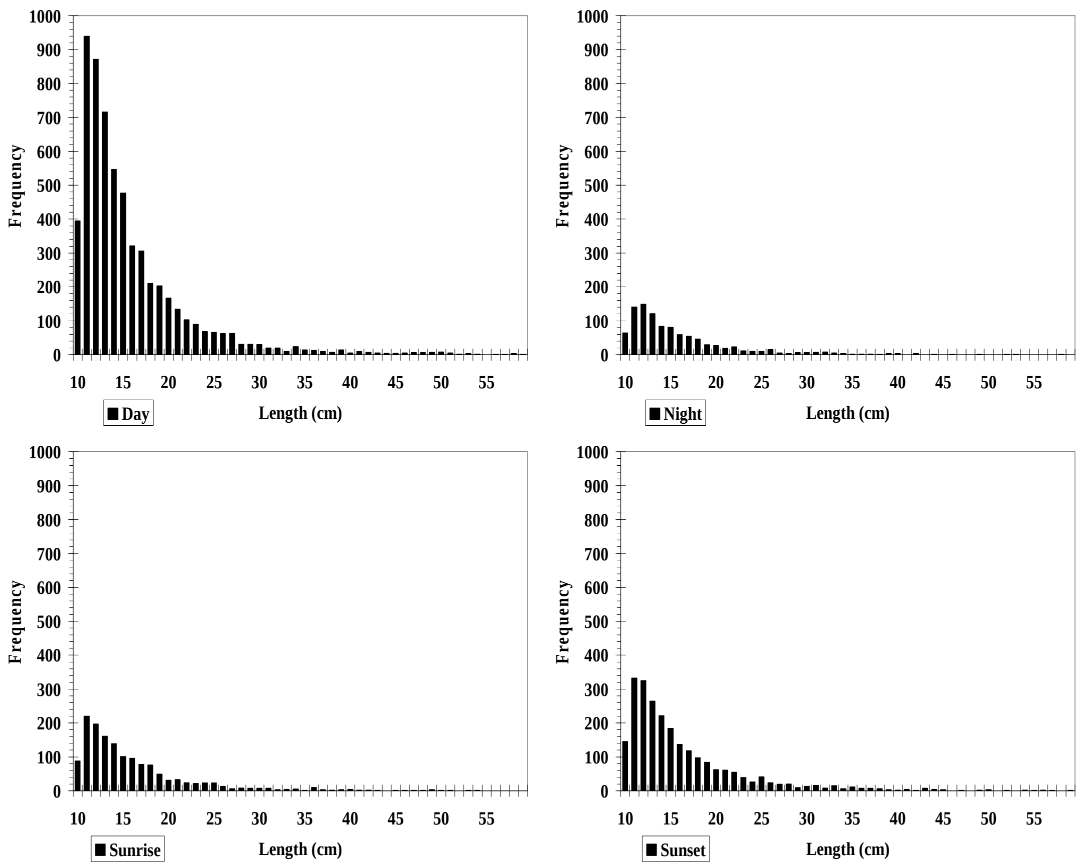

Figure 5.1-17. Estimated length frequency distributions for the daytime, nighttime, sunrise and sunset periods computed from the mean TS of all hydroacoustic targets at the powerhouse over the May 2 through October 15, 2007 study period. The estimated mean lengths are based on the TS-length relationship published by Love (1971).

Table 5.1-13. Diel (24 h) distribution of the median and mean TS of hydroacoustic targets at all turbine units combined over the May 2 through October 15, 2007 study period, with surrounding 90 percent CI. The estimated mean lengths are based on the TS-length relationship published by Love (1971).

	Hours	N	Median TS (dB)	Mean TS (dB)	Mean TS CI 90 percent (+/-)	Median Length (cm)	Mean Length (cm)	Mean Length CI 90 percent (+/-)
Day	0800-1759	6069	-42.07	-40.06	0.11	14.19	18.07	0.24
Night	2200-0459	1012	-41.99	-40.22	0.16	14.33	17.72	0.36
Sunrise	0500-0759	1468	-41.96	-40.00	0.16	14.38	18.20	0.36
Sunset	1800-2159	2405	-41.77	-39.71	0.14	14.70	18.86	0.32

5.1.6. Target Approach Distributions

The manner in which entrained targets were distributed in the monitored area immediately upstream of the turbine intakes was quantified using percent vertical distributions, target approach vectors with depth, and horizontal distributions of targets across the intake openings.

5.1.6.1. Vertical Distributions

The vertical distributions of entrained hydroacoustic targets entrainment are summarized by turbine unit over the May 2 through October 15, 2007 sampling period in Figures 5.1-18 and 5.1-19. These distributions show the percentage of total target entrainment by 3.3 foot (1-m) range (depth) strata at each turbine intake over the entire study period (Figure 5.1-18) and for all turbine units combined on a monthly basis (Figure 5.1-19). For reference, the top of each turbine intake was located 30.8 feet (9.4 m) below the monitoring transducers, and the bottom of each intake was located at a range of between 59.0-65.6 feet (18-20 m). The vertical distributions represent the percentage of all targets observed in each 3.3 foot (1-m) depth stratum within the acoustic sampling volumes, which were aligned with the centerline of each turbine unit. All targets were weighted to account for spreading of the acoustic volume with range, as described in Section 4.1.1.

The percent vertical distribution of targets entering the intakes was similar for all six turbines over the entire May 2 through October 15, 2007 study period. The majority of targets entered the intake in the upper 13-16 feet (4-5 m) of the intake openings, and percent entrainment gradually decreased with increasing depth below that point. The relative decrease in percent entrainment observed in the 29 foot (9 m) stratum at all intakes (relative to the deeper 33 foot (10 m) stratum) was due to the reduced size of the uppermost stratum. Targets above 30.8 feet (9.4 m) range (the top of each intake) were not included in the acoustic counts, resulting in an approximately 2 foot (0.6 m) tall area in Stratum 9, relative to a 3.3 foot (1-m) area for the remaining strata. The skewed percent vertical distributions observed at all turbine intakes are consistent with entrainment of surface-oriented targets.

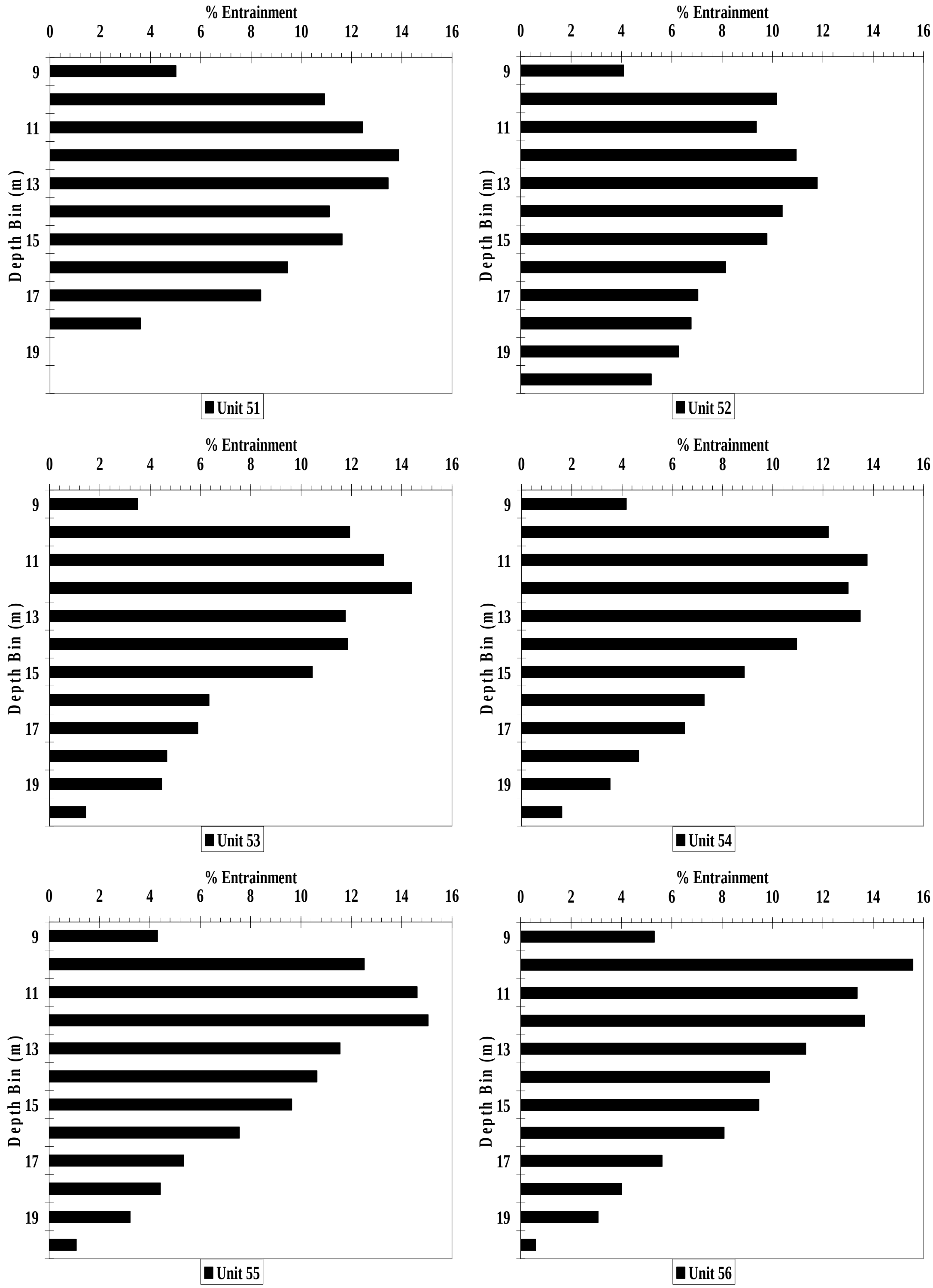

Figure 5.1-18. Percent vertical distribution of all entrained hydroacoustic targets at each turbine intake opening over the entire May 2 through October 15, 2007 study period. Estimates represent the percentage of all targets passing each 1-m range stratum from the top to bottom of each intake. Note: The 9 m range stratum only extends from 9.4 – 10.0 m, encompassing only a 0.6 m high sample.

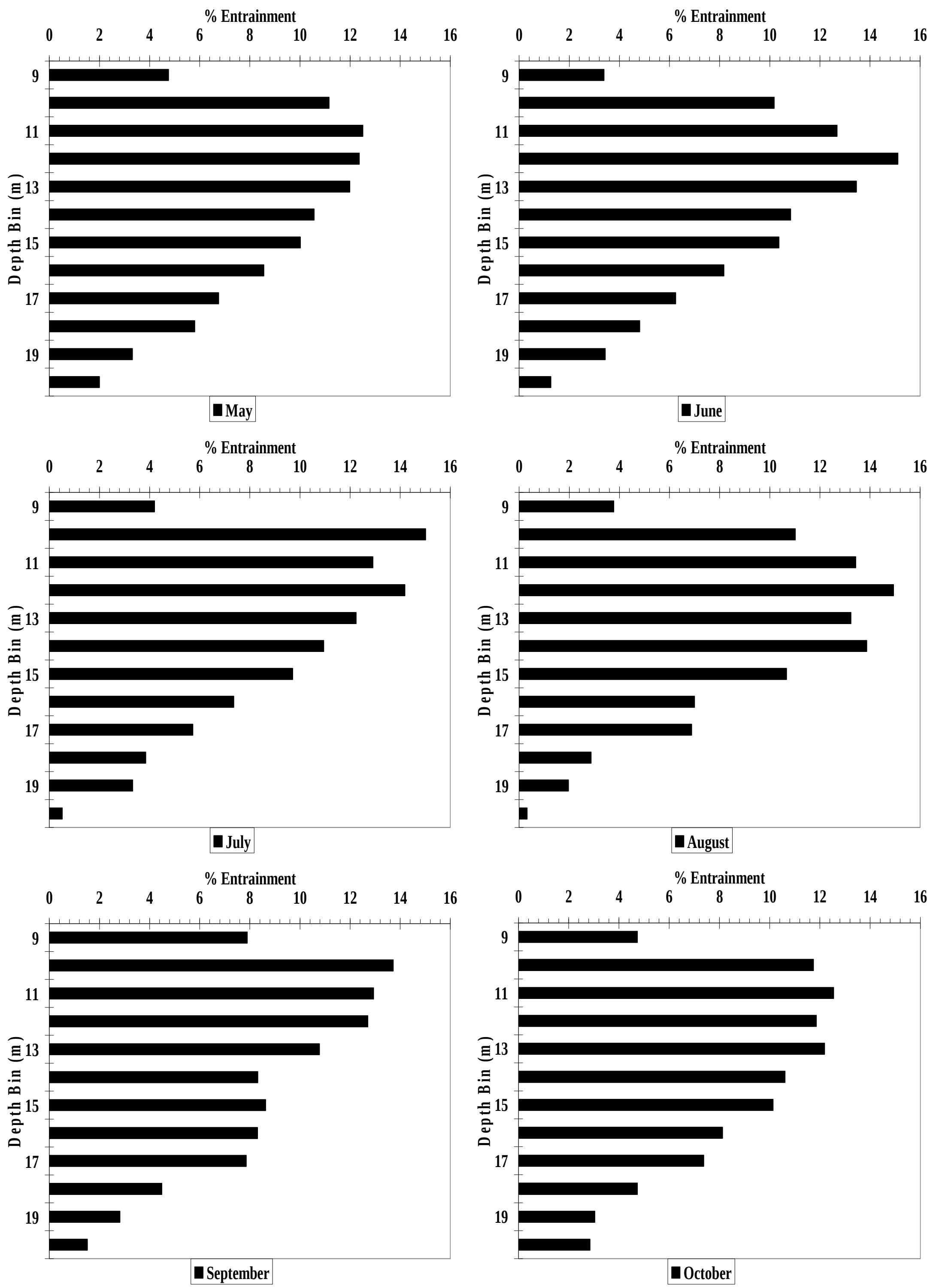

Figure 5.1-19. Percent vertical distribution of all entrained hydroacoustic targets at all turbine units combined on a monthly basis over the May 2 through October 15, 2007 study period. Estimates represent the percentage of all targets passing each 1-m range stratum from the top to bottom of each intake. Note: The 9 m range stratum only extends from 9.4 – 10.0 m, encompassing only a 0.6 m high sample.

5.1.6.2. Intake Approach Vectors

The mean vertical approach vectors of targets transiting the acoustic sampling volumes at each turbine intake are summarized for each 3.3 foot (1-m) range stratum in Figures 5.1-20 to 5.1-25. The target approach angles perpendicular to the intake face (transducer Y-axis) were summarized with depth (transducer Z-axis) to quantify the approach patterns of entrained detections. Each color coded vector represents the corresponding percentage of targets within a given stratum approaching at the shown angle.

Target approach vectors with depth were generally similar at all turbine intakes. Targets observed near the top of each intake tunnel tended to descend in the water column, consistent with movement from the surface into the intake. Detections entering the intake at intermediate depths tended to have little vertical movement, as evidenced by their relatively horizontal approach vectors. Targets moving into the intake at depth, near the bottom of each intake (at ranges exceeding approximately 56 feet (17 m)) tended to have ascending vectors, consistent with movement up into the intake from near the bottom of the forebay intake channel. Maximum sampling ranges to the bottom were approximately 69 feet (21 m) for all intakes, with the exception of Unit 51. The sampling range at Unit 51 was 59 feet (18 m), presumably due to debris accumulation at the base of that intake, which is located at the terminal end of the forebay intake channel.

The approach distributions were consistent with targets entrained in flow, and probably describe the hydraulic conditions present in the area immediately upstream of the intake openings.

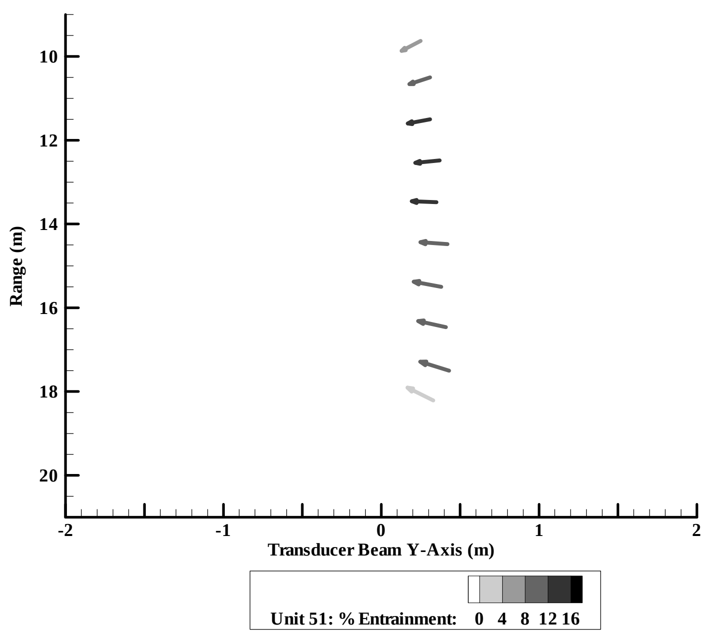

Figure 5.1-20. Target approach vectors considering all targets entrained at Unit 51 over the May 2 through October 15, 2007 study period. The X-axis units are in meters relative to the transducer axis, with positive values indicating increasing distance upstream from the intake opening.

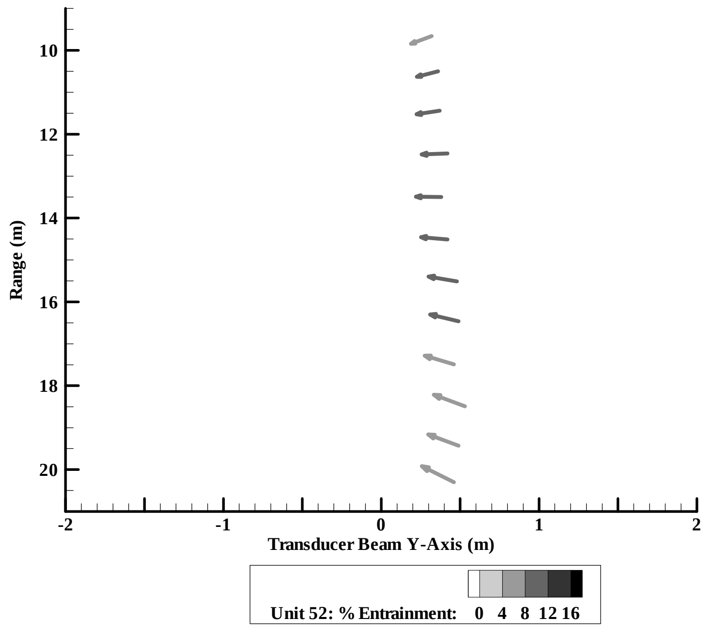

Figure 5.1-21. Target approach vectors considering all targets entrained at Unit 52 over the May 2 through October 15, 2007 study period. The X-axis units are in meters relative to the transducer axis, with positive values indicating increasing distance upstream from the intake opening.

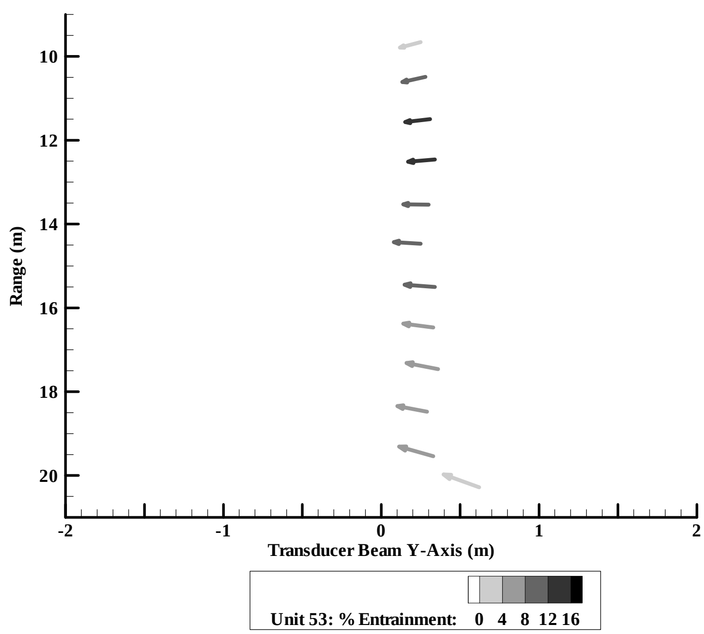

Figure 5.1-22. Target approach vectors considering all targets entrained at Unit 53 over the May 2 through October 15, 2007 study period. The X-axis units are in meters relative to the transducer axis, with positive values indicating increasing distance upstream from the intake opening.

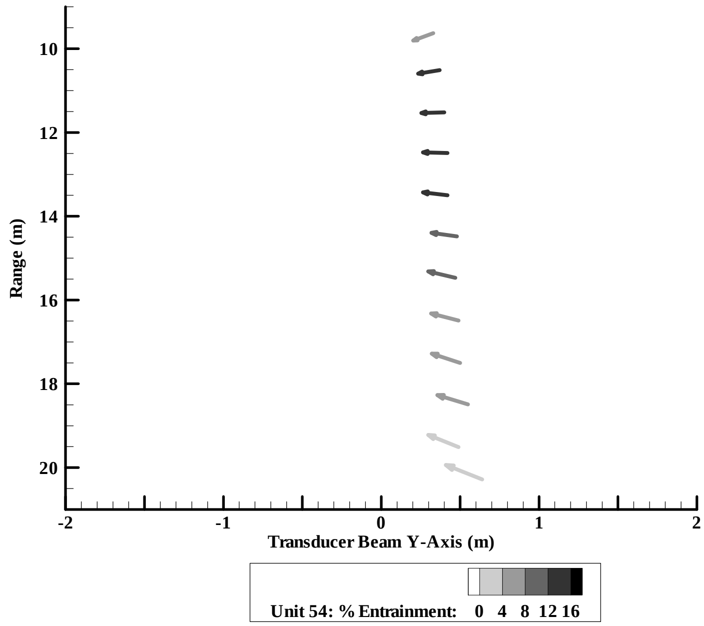

Figure 5.1-23. Target approach vectors considering all targets entrained at Unit 54 over the May 2 through October 15, 2007 study period. The X-axis units are in meters relative to the transducer axis, with positive values indicating increasing distance upstream from the intake opening.

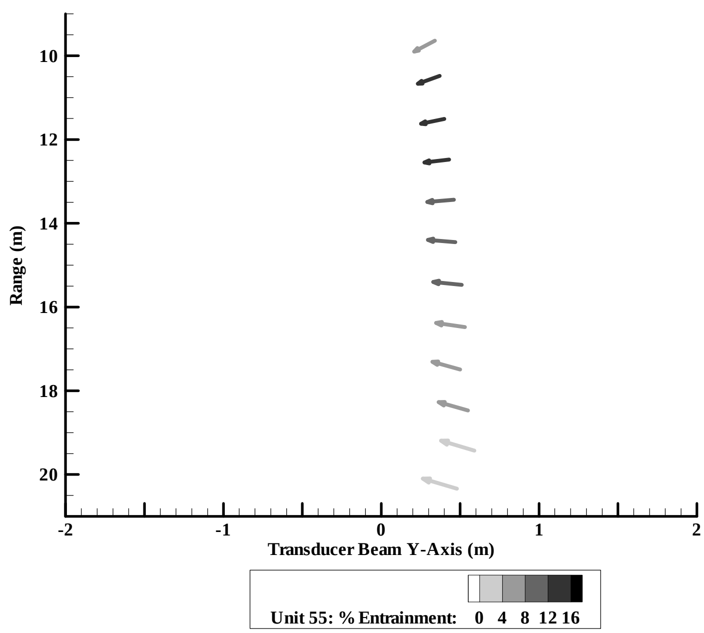

Figure 5.1-24. Target approach vectors considering all targets entrained at Unit 55 over the May 2 through October 15, 2007 study period. The X-axis units are in meters relative to the transducer axis, with positive values indicating increasing distance upstream from the intake opening.

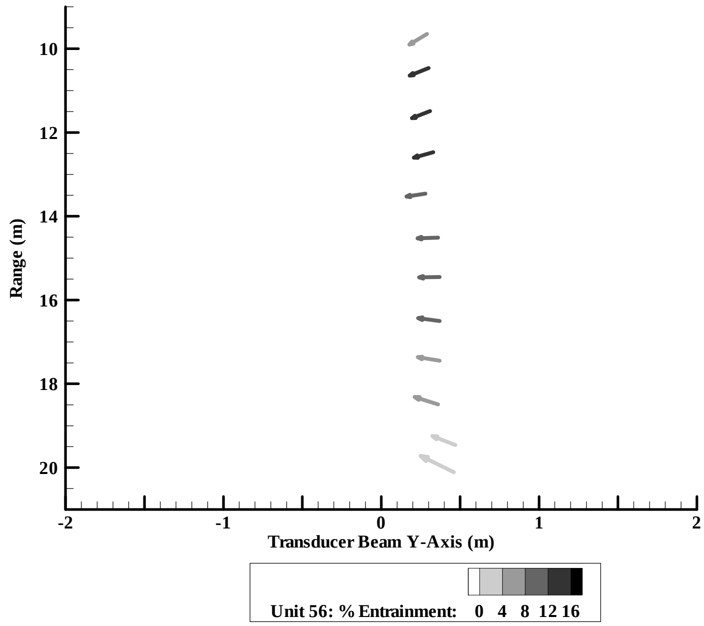

Figure 5.1-25. Target approach vectors considering all targets entrained at Unit 56 over the May 2 through October 15, 2007 study period. The X-axis units are in meters relative to the transducer axis, with positive values indicating increasing distance upstream from the intake opening.

5.1.6.3. Spatial Distribution of Turbine Entrainment

Distributions of target entrainment in the transducer X-axis (horizontal or left-right position relative to the transducer centerline) were evaluated to assess if detections passed into the units in a uniform manner, or were skewed within the intake opening. Each hydroacoustic detection was positioned in three-dimensional space as it entered the turbine intakes. The mean X-axis position of all targets entered each turbine was calculated and compared with a normal (random) distribution. The objective of this evaluation was to determine if the assumption of normal distribution of targets across the turbine intakes used to weight hydroacoustic detections to total unit passage was valid. The results of the analysis could be used to refine the spatial weighting assumptions used to extrapolate the hydroacoustic detections to total entrainment, which currently assume uniform target distribution across the total turbine intake width.

Figure 5.1-26 and Table 5.1-14 present a cumulative percent distribution of all entrained hydroacoustic targets observed at all six turbine intakes over the May 2 through October 15, 2007 study period. The X-axis represents the intake width, with the origin located at the left side of the intake opening, facing upstream (e.g., the side of the intake closest to the forebay trash racks). The Y-axis represents the cumulative percentage of all entrained targets that passed into the intake at any given point moving from left-to-right across the intake. The dotted line represents the expected distribution if fish entered the intakes in a randomly-distributed manner across the X-axis, i.e., 50 percent of all targets were entrained on either side of the unit centerlines. The vertical line represents the transducer axis, which was oriented with the unit centerlines.

The cumulative percent distribution suggests that the distribution of acoustic targets entering the turbine intakes is slightly skewed to the upstream or eastern side of the intakes, with approximately 62 percent of all targets being detected in the left side of the acoustic beam. The results shown in Figure 5.1-26 indicate that most targets are passing into the turbine intakes in the upstream left-hand side of the intakes. These results are consistent with the contour plot of target entrance into the turbine intakes shown in Figure 5.1-27. This latter figure presents relative densities of targets in 100 spatial bins across each intake opening. The X-axis represents horizontal distance across each turbine intake, with the origin located at the eastern edge of the intakes, and the Y-axis represents range from the transducer (with the top of each intake located at a depth of 29.5 feet (9 m)). The contour plot indicates that the largest percentage of targets entered the turbines in the upper half of the intakes and was skewed toward the eastern (upstream) side.

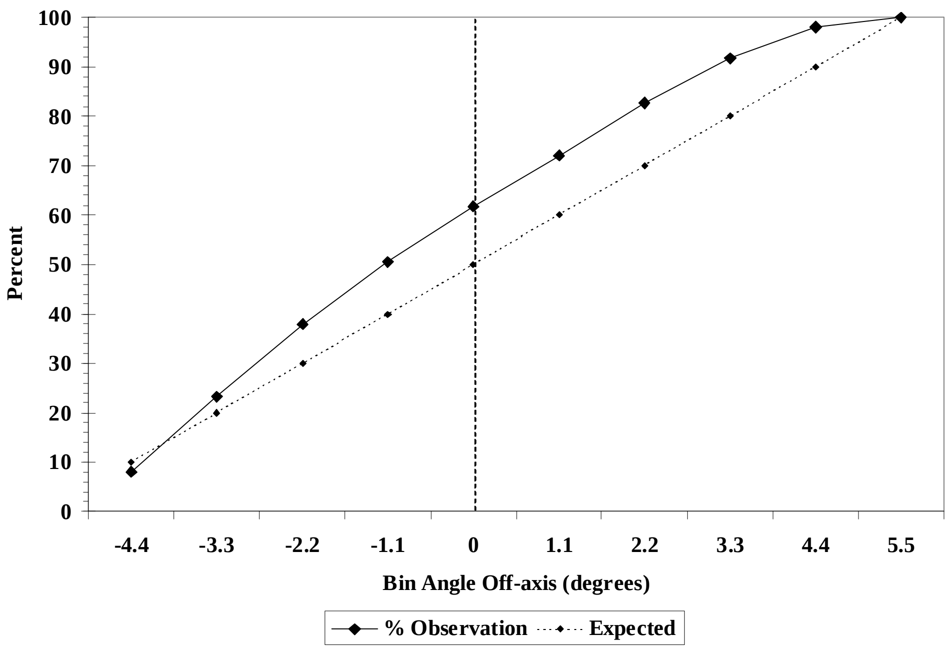

Figure 5.1-26. Cumulative percent distribution of entrained hydroacoustic targets, and expected distribution of targets at the powerhouse for the May 2 through October 15, 2007 study period.

Table 5.1-14. Horizontal distribution (angle off X-axis) of hydroacoustic targets entering all turbine intakes over the May 2 through October 15, 2007 study period. The percent and cumulative percent of all targets within each horizontal bin are given. The -5.5 degree bin represents the eastern (upstream) edge of the transducer beams and the 5.5 degree bin the western (downstream edge).

Bin Angle Off-axis (degrees)	-5.5	-4.4	-3.3	-2.2	-1.1	0	1.1	2.2	3.3	4.4	5.5
Actual Observations	0	799	1536	1475	1260	1133	1028	1063	914	638	191
Percent Observation	0.00	7.96	15.30	14.70	12.55	11.29	10.24	10.59	9.11	6.36	1.90
Cumulative percent Observation	0.00	7.96	23.26	37.96	50.51	61.80	72.04	82.63	91.74	98.10	100.00

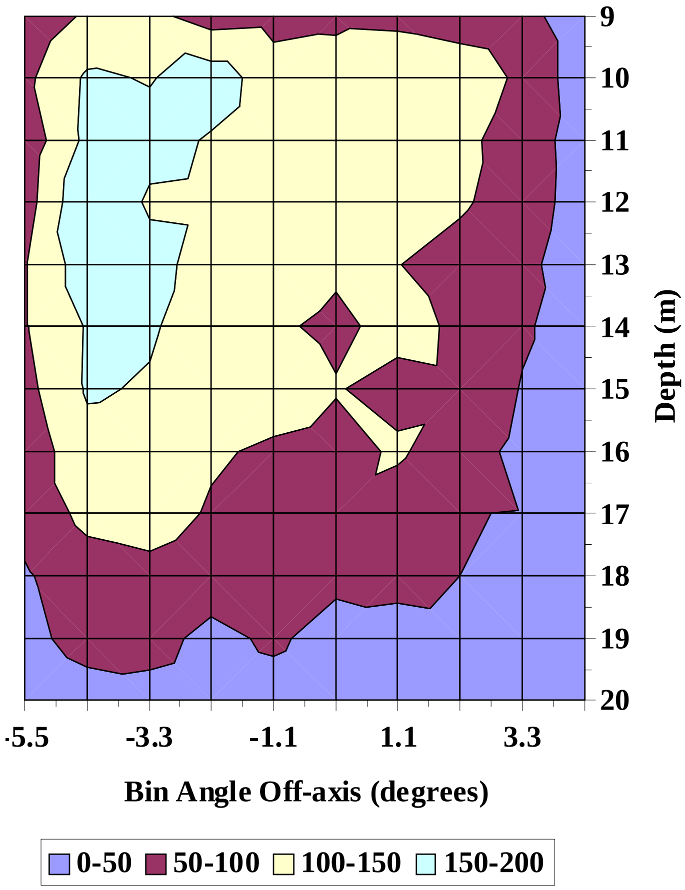

Figure 5.1-27. Density distribution plot of all hydroacoustic targets entrained at the powerhouse (all turbines combined) across the X-axis (left-right across the intakes) and with depth (Z-axis). All observations over the May 2 through October 15, 2007 study period are considered. Projection is looking out to the forebay from inside of the turbine intake openings, with the plot origin located on the eastern edge.

5.2. Hydroacoustic Spillway Distributions

Spillway entrainment distributions based on the hydroacoustic monitoring are presented below in Sections 5.2.1 to 5.2.3. The results of the spillway gill net sampling are summarized in Section 5.2.4 of this report, and described in greater detail in the Study No. 9 Fish Distribution, Timing, and Abundance Study interim report (SCL 2008).

5.2.1. Total Estimated Entrainment

Estimated total hydroacoustic target entrainment was summarized for each spill event by individual spill bay and examined for trends in relative entrainment. To evaluate potential effects of variable spill levels on target entrainment by spill gate, entrainment rates per unit of flow were also calculated and compared. The number of targets per hour of spill gate operation was evaluated as a relative measure of passage per unit of water volume.

Nine spill events occurred during June 2007, totaling 37 hours of spill (Table 5.2-1). Various spill patterns were examined, using different spill levels at the two gates. These spill levels varied from 1,000 to 10,000 cfs per gate. Spill generally occurred concurrently from both spill gates during the nine spill events, but was restricted to a single gate in some tests. A total of 29 hours of spill occurred at Spill Gate 1 (the west gate, closest to the powerhouse) and 28 hours occurred at Spill Gate 2 (closest to the east shore of the reservoir).

Table 5.2-1. Time, duration and spill target level (cfs) for each spill gate, for all spill events at Boundary Dam, June 2007.

Test No.	Start Date	Start Time	End Date	End Time	Spill Gate #1	Spill Gate #2	Hours of Spill
1	8 June	00:00	8 June	04:00	---	10,000	4.0
2	8 June	23:00	9 June	03:00	2,000	8,000	4.0
3	9 June	03:00	9 June	07:00	5,000	5,000	4.0
4	9 June	07:00	9 June	11:00	10,000	---	4.0
5	13 June	11:00	13 June	16:00	5,000	---	5.0
6	17 June	19:00	17 June	23:00	---	5,000	4.0
7	17 June	23:00	18 June	03:00	1,000	4,000	4.0
8	18 June	03:00	18 June	07:00	2,500	2,500	4.0
9	15 June	00:00	15 June	04:00	7,500	7,500	4.0

5.2.2. Spillway Entrainment Distributions

Figure 5.2-1 shows total estimated target passage at each spill gate relative to the total gate spill passing that gate (in mcf) for the nine 2007 spill events. A linear relationship is fitted to the data for reference. Although there was a generally positive correlation between increased spill volume and entrainment, the two variables were not significantly associated (α=0.10). Spillway entrainment was variable between tests during the relatively short period of spill evaluated in 2007.

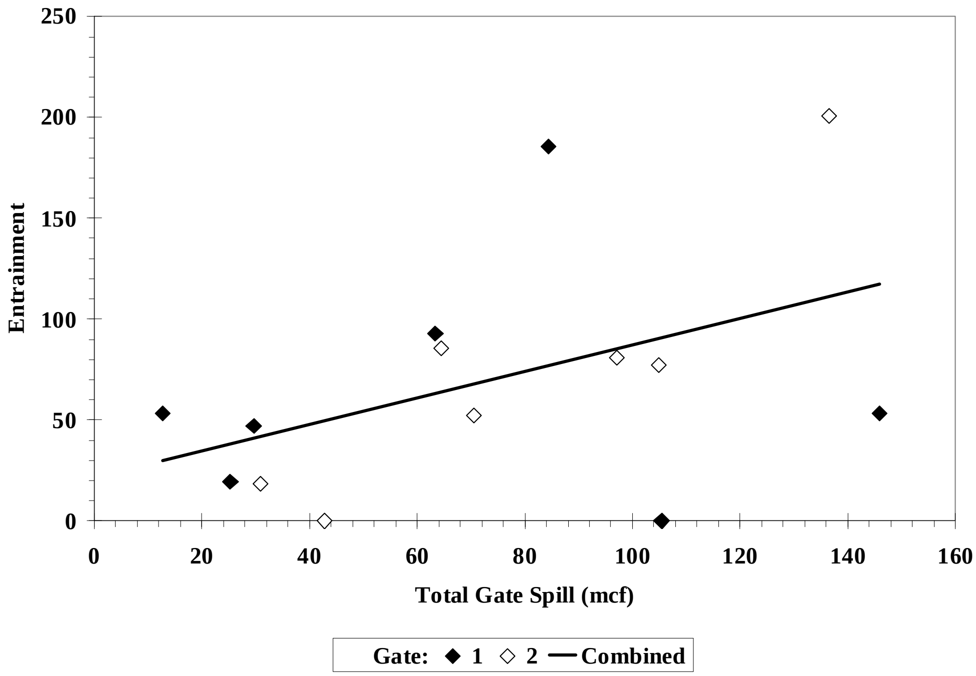

Figure 5.2-1. Estimated spillway entrainment by total gate spill volume (mcf) for all nine spill tests conducted at Boundary Dam, June 2007.

A total of 967 targets were estimated to have passed downstream through both spill gates in 2007 (Figure 5.2-2 and Table 5.2-2). On a per gate basis, this was equivalent to 16.96 targets per operating gate hour (57 total spill gate operating hours, 29 hours at Spill Gate 1 and 28 hours at Spill Gate 2). This mean rate was higher than the passage rates observed at the powerhouse during June 2007 (10.4 targets per operating turbine hour). Mean spillway entrainment per unit flow for both gates combined was estimated as 0.95 targets per million cubic feet (mcf) of water passed (Table 5.2-2).

Total hydroacoustic target entrainment was similar between Spill Gates 1 and 2 over the entire spill period, with 47 percent of entrained targets passing through Gate 1 and 53 percent passing through Gate 2 (Figure 5.2-2; Table 5.2-2). Estimated entrainment per unit volume of spill was also similar between the two gates, with 0.97 targets per million cubic feet (mcf) passing through Gate 1 and 0.94 targets per mcf, passing through Gate 2.

Estimated mean entrainment rates per hour of spill were higher at Spill Gate 2 (18.39 targets/h) than at Spill Gate 1 (15.58 targets/h). For both gates combined, mean passage was estimated as 16.96 targets per hour of gate spill.

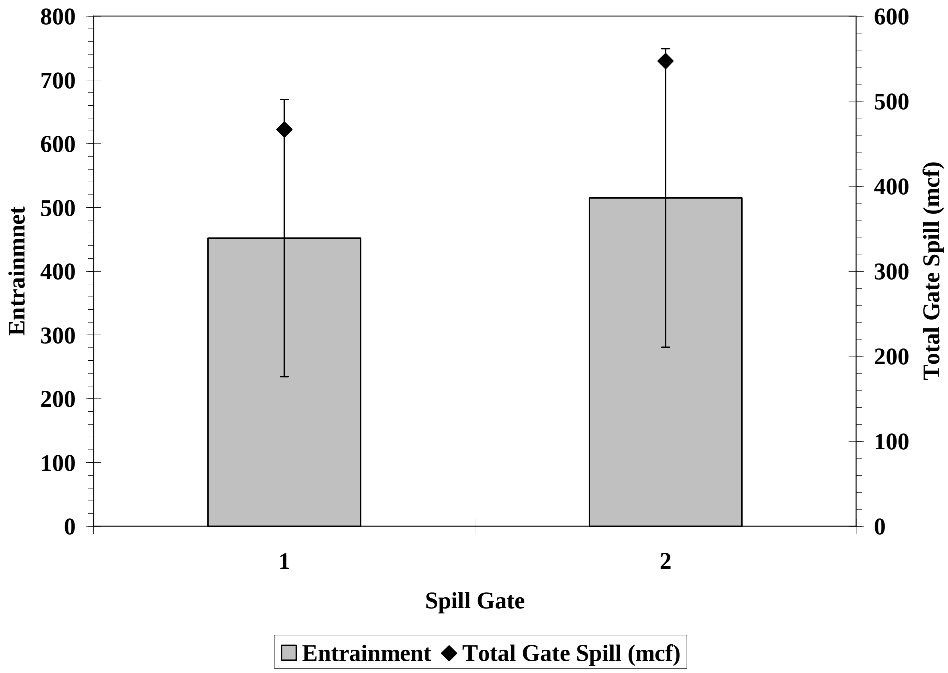

Figure 5.2-2. Total estimated number of entrained hydroacoustic targets, with 90 percent CI, and mean discharge (cfs) at each spill gate in June 2007.

Table 5.2-2. Total estimated target entrainment by spill gate, with 90 percent CI, entrainment per million cubic feet (mcf) of spill, total entrainment per hour of spill, and mean discharge (cfs) for all spill events in June 2007.

Gate	N	Entrainment	CI 90 percent Entrainment (+/-)	Mean Gate Opening (feet)	Total Gate Spill Volume (mcf)	Mean Gate Spill (cfs)	Entrainment /mcf	Entrainment /Hour of Spill
1	36	452	217	3.12	467	4,724	0.97	15.58
2	46	515	234	3.81	547	6,000	0.94	18.39
Combined	82	967	317	3.46	1,014	5,350	0.95	16.96

Hydroacoustic target entrainment through the spillway did not appear to be directly correlated with volume of spill during the limited testing conducted in June 2007 (Figure 5.2-3; Table 5.2-3). The highest hydroacoustic target entrainment through the spillway occurred at Spill Gate 2 during Test 5, with 201 targets passing at a mean gate spill level of 9,480 cfs, or an estimated entrainment rate of 50.15 targets per hour of spill. The highest passage estimate, per unit volume of spill (4.19/mcf), was observed during Test 7 at Gate 1, when the mean gate spill level was 881 cfs.

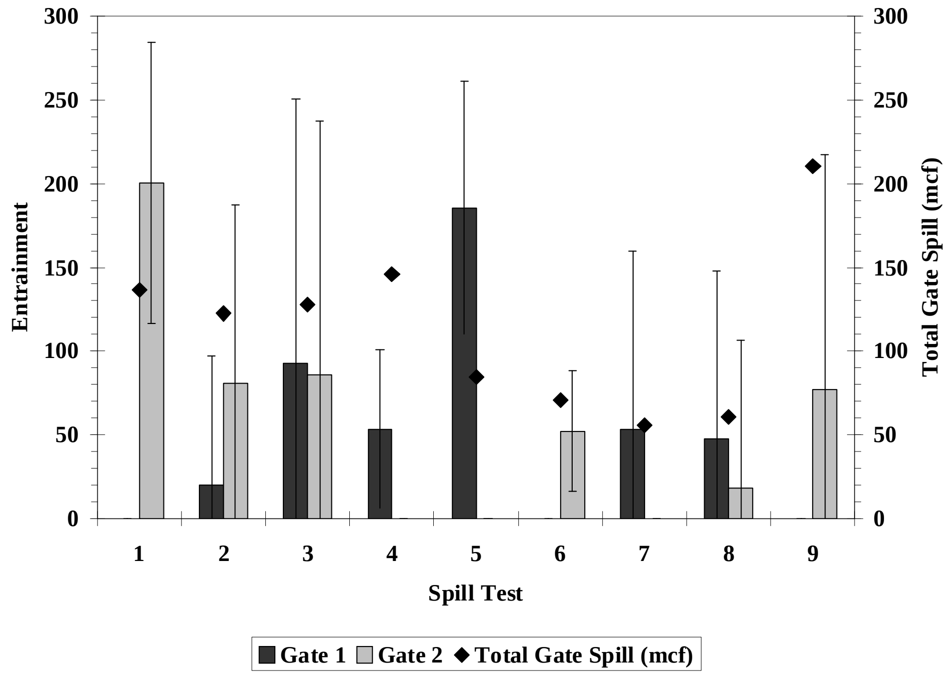

Figure 5.2-3. Total estimated entrainment at the spill gates for each spill test, conducted in June 2007. Total gate spill (mcf) is shown on the secondary y-axis.

Table 5.2-3. Total estimated number of hydroacoustic targets entrained with 90 percent CI, entrainment per million cubic feet (mcf), entrainment per hour of spill, and mean discharge (cfs) by spill test for each spill gate in June 2007.

Gate	Spill Test	N	Entrainment	CI 90 percent Entrainment (+/-)	Mean Gate Opening (ft)	Total Gate Spill (mcf)	Mean Gate Spill (cfs)	Entrainment /mcf	Entrainment /Hour of Spill
1	1	0	0	0	0	0	0	0	0
1	2	2	20	77	1.25	25	1,756	0.77	4.90
1	3	5	93	158	3.08	63	4,401	1.47	23.23
1	4	5	53	47	6.73	146	10,136	0.36	13.30
1	5	21	186	76	3.31	84	4,686	2.20	37.15
1	6	0	0	0	0	0	0	0	0
1	7	2	53	107	0.75	13	881	4.19	13.30
1	8	1	47	100	1.69	30	2,057	1.59	11.80
1	9	0	0	0	4.99	105	7,320	0.00	0.00
2	1	17	201	84	6.15	137	9,480	1.47	50.15
2	2	10	81	107	4.78	97	6,744	0.83	20.25
2	3	8	86	152	3.13	64	4,477	1.33	21.43
2	4	0	0	0	0	0	0	0	0
2	5	0	0	0	0	0	0	0	0
2	6	2	52	36	3.4	71	4,901	0.74	13.04
2	7	0	0	0	2.51	43	2,969	0.00	0.00
2	8	2	18	88	1.76	31	2,141	0.59	4.56
2	9	7	77	140	4.96	105	7,290	0.74	19.29

5.2.3. Target Strength Distributions by Spill Bay

Mean target strength (TS) values were calculated for all entrained detections at each spill bay for all spill events. Mean TS and calculated mean length (cm), with associated 90 percent CI, for each spill gate is given in Figure 5.2-4 and Table 5.2-4.

Estimated mean TS at Spill Gate 1 was higher than at Spill Gate 2, but the difference was not significant at α=0.10 (Table 5.2-4). Mean TS estimates for each individual test conducted at the spillway in June 2007 are given for each spill gate in Table 5.2-5. Mean TS was observed to be variable across spill tests and gates, possibly due to the relatively small sample sizes observed during the abbreviated spill periods.

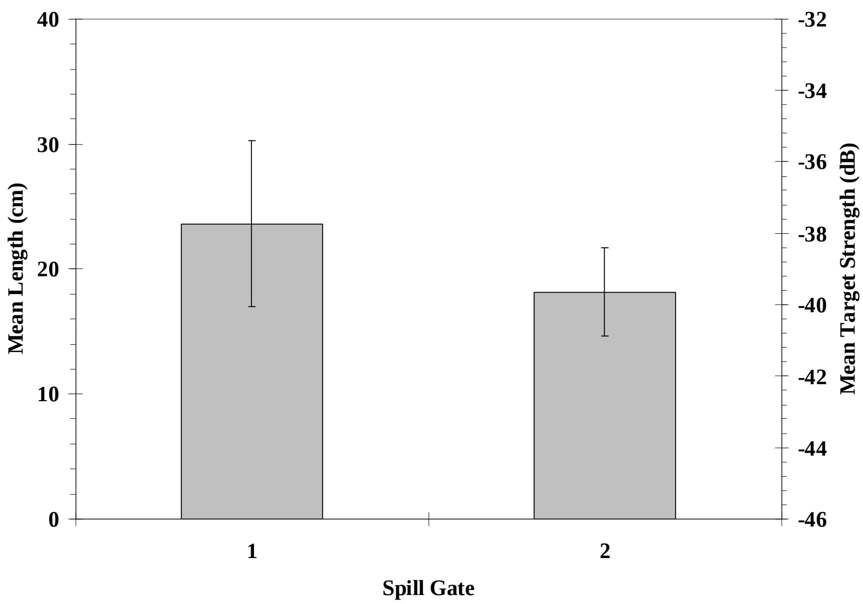

Figure 5.2-4. Mean target strength (dB) and mean length (cm), with corresponding 90 percent CI, at the two spill gates during spill tests conducted in June 2007.

Table 5.2-4. Mean target strength and mean length, with corresponding 90 percent confidence intervals at the two spill gates during spill testing conducted in June, 2007.

Gate	N	Mean TS (dB)	CI 90 percent TS (+/-)	Mean Length (cm)	CI 90 percent Mean Length (+/-)
1	36	-37.84	2.05	23.63	6.62
2	46	-40.03	1.48	18.15	3.54
Combined	82	-38.93	1.32	20.72	3.57

Table 5.2-5. Mean target strength (TS) and estimated mean length, with corresponding 90 percent CI, for each spill gate and test combination evaluated during June, 2007.

Gate	Spill Test	N	Mean TS (dB)	CI 90 percent TS (+/-)	Mean Length (cm)	CI 90 percent Mean Length (+/-)
1	1	0	0	0	0	0
1	2	2	-43.76	0.82	11.58	1.21
1	3	5	-37.09	6.35	25.86	29.77
1	4	5	-33.87	4.19	38.12	25.03
1	5	21	-39.24	2.76	19.96	7.87
1	6	0	0	0	0	0
1	7	2	-43.18	0.19	12.42	0.29
1	8	1	-36.76	0.00	26.91	0.00
1	9	0	0	0	0	0

2	1	17	-41.66	2.32	14.91	4.81
2	2	10	-41.19	2.38	15.78	5.25
2	3	8	-40.22	2.27	17.73	5.59
2	4	0	0	0	0	0
2	5	0	0	0	0	0
2	6	2	-36.48	33.42	27.83	1,535.68
2	7	0	0	0	0	0
2	8	2	-34.91	1.10	33.64	4.79
2	9	7	-39.44	2.64	19.47	7.28

5.2.4. Results of Spillway Gill Netting

During the monthly spillway gillnet sampling, a total of 35 separate gill net sets were deployed for a combined effort of 219 hrs per 1,000 ft^2 net (Table 5.2-6). In addition, during the spill event of June 7, 11 nets were set for a combined effort of 56 hrs per 1,000 ft^2 net. Only one northern pike minnow was captured during the entire period. The specimen was captured near the surface in a net situated in the center of the log boom during the June 7 spill event.

Table 5.2-6. Summary of gillnetting efforts conducted near the spillway of Boundary Dam during March through October sampling.

Date	Number of Nets Deployed	Total Effort (hours/1,000 ft^2 net)	Fish Captured
March 11	5	15	0
May 21	5	31	0
June 7	11	56	1 (northern pike minnow)
June 12	5	42	0
July 31	5	29	0
August 15	5	23	0
September 31	5	31	0
October 20	5	48	0

5.3. Fyke Net Sampling at Turbine Unit 54

A fyke net array was deployed in the Unit 54 draft tube in early October 2007, in accordance with the study plan schedule. The net was deployed on October 6, October 27, and December 1, 2007. Technical difficulties were experienced during initial testing of the fyke net array, and the fyke nets could not be effectively fished. To date, full fyke net sampling has not taken place and no fish have been captured in the fyke net. The turbine fyke net array is being redesigned and will be re-deployed in January 2008 after Unit 54 comes back online following its annual maintenance. The results of the 2008 fyke net sampling program will be presented in the Updated Study Report. Additional details regarding the turbine fyke net sampling in 2007 and plans for modifications to the array in 2008 are discussed in Sections 4.2, 7.2 and 7.3 of this report.

6 SUMMARY

A total of 169,752 targets were estimated to have been entrained at the Boundary Dam turbine intakes over the 5.5 month monitoring period between May 2 and October 15, 2007. This was equivalent to an average entrainment of 13.2 targets per hour at each operating unit. Total target entrainment at the powerhouse was variable over time. Monthly total powerhouse entrainment was relatively consistent during the months of May through July (33,379-37,051 targets per month), decreased during August and September (9,682-10,418 targets per month), and peaked in early October (43,571 targets over a two-week period).

The magnitude of entrainment varied between turbines, but the relationship may have been affected by unit operations. Between May and August, Units 54-56 were observed to pass approximately 68 percent of the total estimated powerhouse passage. In September and October, only 13 percent of the total estimated powerhouse entrainment passed via Units 54-56. Unit 55 was not operated in September and October and may have affected patterns of flow in the forebay intake channel. Unit 53 demonstrated generally lower entrainment than the other units over the 2007 monitoring period. The minimum target size detection threshold at Unit 53 was equivalent to the other powerhouse sampling locations, based on a review of system sampling parameters and laboratory calibration data. Additional investigations into potential causes for the decreased relative entrainment at Unit 53 are ongoing, and the findings will be discussed in the Updated Study Report. Between unit variability in entrainment was observed at other times during the study. During the period of peak detections in early October, Units 51 and 52 had entrainment rates (on a per MWh basis) that were 4.6 to 7.8 times higher than Units 53, 54, and 56. Ongoing monitoring is anticipated to help understand the observed variability in detection rates among the turbine units over time.

On a diel (24 h) basis over the 2007 study period, total entrainment at the powerhouse was positively correlated with the magnitude of Project generation. Total passage was relatively low during nighttime hours (2200-0500 h), when fewer units were operating. A peak in entrainment was observed between 0600-0700 h, when generation load typically increased. However, increases in entrainment were not observed during 0500-0600 h, when additional units started to come on-line. During the day, total powerhouse entrainment was generally uniform on an hourly basis, and was greatest between 1200-1700 h, when total mean generation at the Project was highest. To assess diel patterns of entrainment independently of potential turbine operating influences, rates of powerhouse entrainment per operating unit hour were compared over four diel periods (i.e. day, night, sunrise, and sunset). Powerhouse entrainment rates were least at night, relative to the daytime, dawn and dusk periods. This pattern of lower entrainment at night was also observed during a period of uniform 24 h powerhouse operations that occurred from June 7-11, 2007, although the magnitude of the day/night differences during this period was not large.

The mean target strength (TS) of hydroacoustic detections at the powerhouse was generally consistent across units for the study period as a whole, and on a monthly basis, indicating that hydroacoustic detections entrained into all turbines were of similar mean size at any given point in time. Applying Love (1971) and assuming that the hydroacoustic detections are fish, the mean estimated length of targets entrained at individual turbine units over the 2007 monitoring period varied from 17-20 cm.

Length-frequency distributions were derived by converting the mean target strength of individual detections to estimated fish lengths using Love's (1971) relationship (Figures A.2-1 through A.2-6, Appendix 2). Estimated fish length distributions were generally consistent between turbine units on a monthly basis. Between May and July, estimated length frequency distributions generally had a single mode and the majority of entrained targets were relatively small, with length modes varying between 12-16 cm (4.7-6.3 inches). Fewer targets were observed at all turbines in August and September, and distinct length modes were less evident in the distributions. Estimated lengths during these months varied between 10 cm (4 inches) to approximately 50 cm (19.7 inches), although targets exceeding 30 cm (11.8 inches) were relatively infrequent. Entrained targets observed in October passed predominantly through Units 51 and 52, and were predominantly smaller in estimated length. Estimated length modes at Units 51 and 52 in October occurred at 12 cm, similar to the length distributions observed during May-July.

Hydroacoustic targets entrained at the powerhouse tended to enter the turbines in the upper half of the intakes and on the upstream (east) side of the openings. This distribution is consistent with surface-oriented targets moving down the face of the powerhouse from upstream (e.g., the trash rack or east end of the turbine forebay intake channel), and encountering the flow into each turbine. This skewed pattern of entrainment into the turbine intakes may indicate a review of the spatial fish weighting assumptions used to extrapolate the hydroacoustic detections to estimates of total entrainment. The applied weighting factors currently assume that targets entering the turbine intakes are uniformly distributed across the openings. These assumptions may remain valid, as increased entrainment on one half of the intake may be compensated during the weighting process by lower entrainment in the other half. The effect of entrained target distributions within the turbine intake on total entrainment estimates is currently being investigated and could result in adjustments to the total powerhouse entrainment described in this document.

Investigations of the spatial distribution of fish entering the Boundary Dam turbine intakes were also conducted using a DIDSON acoustic imaging system on June 28, 2007 (Appendix 3). The DIDSON system was deployed at Unit 54 and provided high-resolution sampling across the entire width of the upper intake area. The results of this sampling, although relatively short in duration, were consistent with the observations from the split-beam transducers deployed at the powerhouse. Targets were observed to enter the intakes primarily from the upstream (east) side, and typically increased in range as they passed into the penstock. Water movement patterns in front of the turbine intakes may be affected by pool level; i.e., the amount of water column available above the intake. The lake elevation during the June 28 sampling period was 1,989 feet NAVD 88 (1,985 feet NGVD 29) and the top apex of the turbine intake opening is located at an elevation of 1,941 feet NAVD 88 (1,937 feet NGVD 29), resulting in 48 feet of water above the intake ceiling. During the monitored period, a majority of the observed targets appeared to originate in the upper water column and descend toward the intake opening.

Spill was infrequent at Boundary Dam in 2007, relative to historical patterns of spill at the Project. Inflow rates to the reservoir during spring 2007 rarely exceeded Project generation demand. Nine spill events of relatively brief duration (4-5 hours each) occurred between June 8-

18, 2007, all of which were monitored by the acoustic system. In aggregate, 967 hydroacoustic targets were estimated to have passed downstream via both spillways during all 2007 spill events, resulting in a mean estimate of 16.96 targets per hour of individual spill gate operation. Over approximately equal periods of spill gate operation, Spill Gate 1 (the west gate closest to the powerhouse) was estimated to have passed 452 targets (15.6 targets per operating hour) and Spill Gate 2 (closest to the east shoreline of the reservoir) was estimated to have passed 515 targets (18.39 targets per operating hour). However, these differences in estimated passage were not significant between spill gates at $\alpha=0.10$.

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Appendix 2: Fish Entrainment Study Methods Outline Report

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 12
Fish Entrainment Study
Methods Outline Report

Prepared for
Seattle City Light

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Final Report: July 17, 2007

TABLE OF CONTENTS

1 Introduction.....1

2 Study Objectives.....1

3 Study Area.....2

4 Data Collection Methods.....2

4.1. Turbine Entrainment.....3
4.2. Fyke Net Array within the Draft Tube Gatewell Slot.....4
4.3. Hydroacoustic Sampling Methods.....5
4.4. Fyke Net Sampling Plan.....7
4.4.1. Fyke Net Array Installation.....7
4.4.2. Fyke Net Sampling.....7
4.4.3. Fish Handling.....9

5 Data Analysis Methods.....9

5.1. Hydroacoustic Data.....9
5.1.1. Estimating Powerhouse Passage.....10
5.1.2. Estimating Spillway Passage.....12
5.2. Hydroacoustic Performance Measures.....13
5.2.1. Passage Counts.....13
5.2.2. Proportional Spillway Passage.....14
5.2.3. Fractional Spill bay Passage.....15
5.2.4. Fractional Powerhouse Passage.....15
5.2.5. Rate of Passage Through Time.....16
5.3. Fyke Net Data.....16
5.3.1. Analysis and Data Processing.....16
5.4. Fyke Net and Hydroacoustic Statistical Comparisons.....16
5.4.1. Comparison of Size Frequencies.....16
5.4.2. Comparison of Passage Abundance.....18
5.4.3. Species Composition and Abundance Estimates.....19

6 Reporting.....20

6.1. 2007 Annual Interim Study Report.....20
6.2. 2008 Annual Interim Study Report.....20
6.3. Addendum Data Report.....20

7 References.....21

LIST OF FIGURES

Figure 3-1. Plan view of the proposed Boundary Dam hydroacoustic system transducer deployment, showing the six 6°x10° transducers monitoring the powerhouse and the four 15° transducers installed at the spillway. 2
Figure 4.4-1. Proposed fyke net data entry form. 9
Figure 5.4-1. Schematic of cumulative distribution curves for fish size illustrating homogeneity of the hydroacoustic and fyke net samples. 17
Figure 5.4-2. Schematic of a 1:1 relationship between fyke net and hydroacoustic passage estimates (i.e., $\beta_1 = 1$). 19

Study No. 12: Fish Entrainment Study
Methods Outline Report
Boundary Hydroelectric Project (FERC No. 2144)

1 INTRODUCTION

Study No. 12, the Boundary Dam Fish Entrainment Study, is being conducted in support of the relicensing of the Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP) submitted by Seattle City Light (SCL) on February 14, 2007 and approved by the FERC in its Study Plan Determination letter dated March 15, 2007. This document presents the methods outline for the 2007-2009 fish entrainment study.

2 STUDY OBJECTIVES

The goal of the Fish Entrainment and Habitat Connectivity Study is to estimate the number, size, species, and timing of fish that may be entrained within the Boundary Project turbine intakes and spillways. The limited frequency, duration of use, and flow conditions associated with the use of the sluiceways, and the discontinued use of the skimmer gate, eliminates the need to estimate the number of fish potentially entrained though these pathways. Fish entrainment through the turbine and spillway pathways is being monitored at the Boundary Project to estimate total downstream fish passage at the dam. Study results will be used to estimate the effects of Boundary Project operations on hourly, daily, diel, and seasonal entrainment of fish within the Boundary Reservoir.

The Boundary Dam hydroacoustic study will monitor fish passage through the spillways and powerhouse for purposes of estimating entrainment through these routes. Passage estimates and associated confidence intervals will be calculated for various time periods within the study period, e.g., weeks, months, seasons and years. Strategic use of fyke net sampling in the draft tube gatewells will be used to determine the accuracy of the turbine passage information generated by hydroacoustics and to monitor species composition over time. Hydroacoustic data collection was initiated at Boundary Dam on May 2, 2007 and is currently scheduled to continue through May 2, 2009. Fyke net sampling is scheduled to begin in September 2007 and continue through April 2009.

As the entrainment study plan was developed there was concern that the hydroacoustic work might not be underway during spring of 2007. This would leave decision makers with only the data from one spring (spring 2008) on which to base their decisions. Consequently, data collection through May 2009 was envisioned. Because spring data was gathered in 2007 it may be possible to curtail the hydroacoustic and fyke net effort at the end of 2008. This decision, to be made in cooperation with the relicensing participants, would be taken if sufficient data has been gathered at the end of 2008 to allow an informed development of the PLP.

3 STUDY AREA

The total fish entrainment study area encompasses Boundary Dam and associated structures, the forebay and the Pend Oreille River in the vicinity of the Boundary Dam tailrace. The hydroacoustic monitoring study area is located immediately upstream of Units 51-56 in the Boundary Dam forebay, and in front of the two spill gates (Figure 3-1).

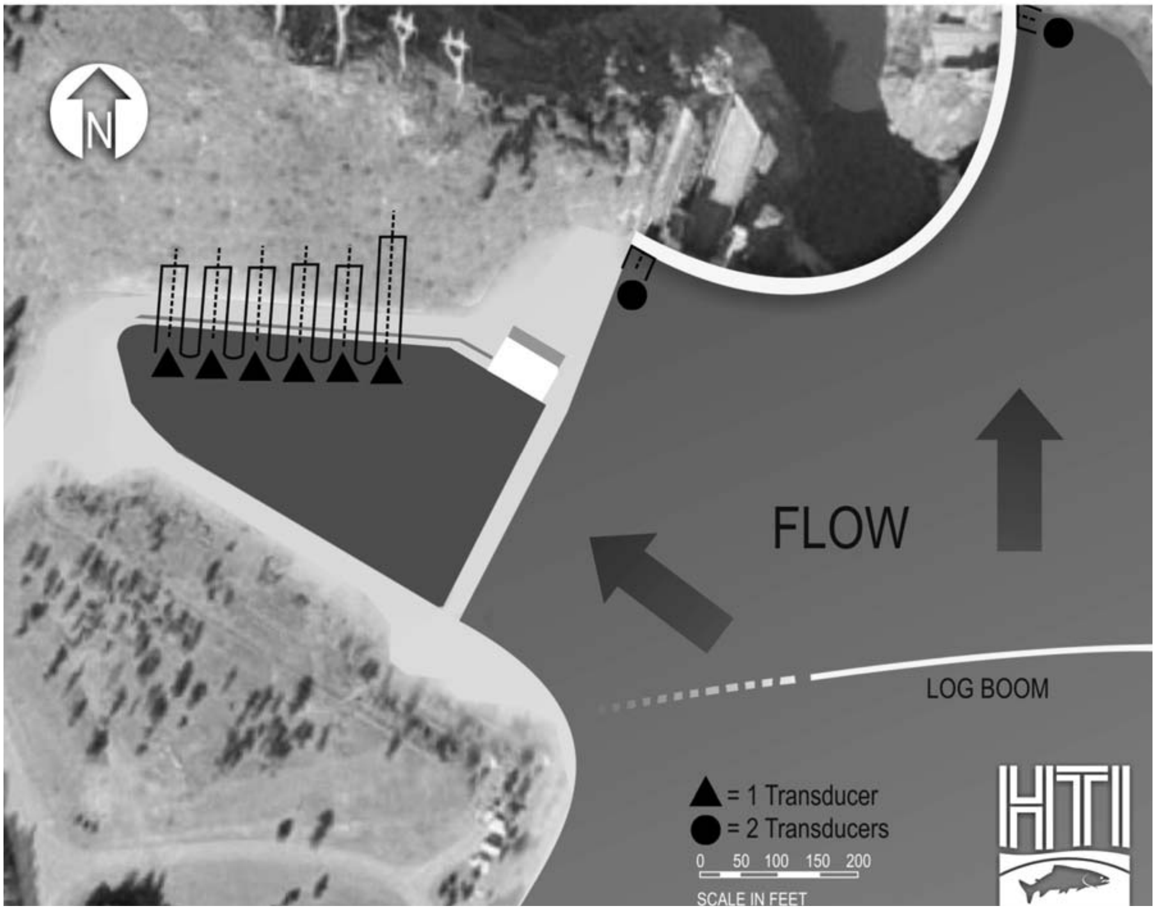

Figure 3-1. Plan view of the proposed Boundary Dam hydroacoustic system transducer deployment, showing the six 6°x10° transducers monitoring the powerhouse and the four 15° transducers installed at the spillway.

4 DATA COLLECTION METHODS

The Boundary Dam Fish Entrainment Study consists of separate turbine and spillway components, which are described below. The information from both components will be summarized to estimate fish entrainment through the Boundary Project over time. Turbine entrainment monitoring includes both hydroacoustic and fyke netting techniques. Spillway entrainment will be monitored using hydroacoustic sampling methods.

4.1. Turbine Entrainment

Hydroacoustic monitoring will be used to estimate the number, size, and timing of fish entrained within the Boundary Project turbine intakes. Fyke net sampling within the draft tube gatewells will be used to verify whether hydroacoustic targets are fish and identify the species composition of entrained fish. In addition, fish entrainment estimates derived from the fyke nets will be used to ground truth concurrent hydroacoustic passage estimates at the turbines. The fyke net will be deployed during fixed time periods and will be sampled concurrently with the ongoing hydroacoustic sampling. A one-to-one correspondence in fish entrainment estimates derived from the netting and hydroacoustic estimates is anticipated for fish sizes susceptible to capture by the fyke net. Algorithms used to distinguish fish from other hydroacoustic targets would be reassessed in the event that the correspondence between the hydroacoustic and the fyke net data is not one-to-one. The fyke nets will select for fish larger than 4.0 inches because the net design calls for a 1 inch mesh size. This mesh size reflects a trade-off between capturing fish of a given size or larger and consideration of the potential for net damage and the frequency of checking and cleaning nets that would be required to sample smaller fish. Fyke net capture results will be statistically-evaluated relative to the hydroacoustic target counts and target strength (acoustic fish size) information over the study period.

Gill nets deployed in the Forebay Reach as part of the Fish Distribution, Timing and Abundance Study (Study No. 9) will indicate the relative number, size and species of fish in the general vicinity of the spillway and trash rack structures. However, they will not identify whether those fish were likely to have passed downstream through the dam. Fyke net arrays deployed downstream (i.e., the draft tube gatewells) of selected turbine intake(s) are expected to be the most effective method of collecting fish that have been entrained into the turbines. Four potential fyke net locations were described in the RSP:

1) in front of the turbine intake tunnel
2) within the intake gatewell slot,
3) within the draft tube gatewell slot and;
4) at the turbine outfall.

The objective was to design the fyke net array to subsample all portions of the water column. Engineering, operational, safety and sample design assessments of each location were considered for each of the potential sampling sites. The draft tube gatewell slot location (Option 3) was selected for the following reasons.

All of the sites considered for fyke net deployment present engineering, operational and logistical challenges. Three of the four potential locations had limitations that precluded effective sampling.

1) The sampling location in front of the turbine intake tunnel (Option 1) was rejected because water velocities were insufficient to ensure fish capture over the range of Project turbine operational conditions.

2) The intake gatewell slot (Option 2) was rejected due to Project safety considerations. This slot must be kept accessible for a bulkhead gate designed for emergency turbine shutdown in the event of wicket gate failure. Obstructing the intake gatewell slot with a fyke net sampling frame would prevent the ability to shut down the unit under such conditions.

3) The turbine outfall site (Option 4) was rejected due to physical structures that could interfere with net sampling and safety concerns. Overhanging rock presents the danger of rock fall injuries to personnel manning the nets. Metal structure (rubble and rebar) left in the tailrace after the initial construction near the outfall of the draft tube presents a high likelihood of net snagging, which would interfere with effective net sampling.

4.2. Fyke Net Array within the Draft Tube Gatewell Slot

Fyke net deployment within the turbine draft tube gatewell slot (Option 3) provides the best opportunity for effective fish sampling This location was deemed to have the highest probability of providing unbiased entrained fish estimates for comparison with the hydroacoustic sampling results. Deploying a fyke net in the draft tube gatewell slot presents challenges related to personnel access, high water velocities and turbulence. It is anticipated that these challenges can be addressed in the engineering and planning processes.

If estimates of fish abundance and size are found to differ between the hydroacoustic and fyke net methods, the netting results will be considered to better represent actual entrainment rates. Both hydroacoustic and fyke net sampling provide imperfect estimates of fish entrainment. Statistical comparisons between the results of both sampling methods will be conducted to identify potential biases and will improve overall sampling effectiveness.

A single turbine intake will be monitored with two fyke net frames (one in each draft tube gatewell slot) beginning in September 2007. Sampling will be conducted during four 24-hour periods each month. Selection of the turbine intake will be based on physical site constraints, project operational considerations, frequency of turbine use, and distribution of fish between turbine intakes based on earlier hydroacoustic sampling results.

Units 51 and 56 present physical site constraints. Unit 51 has a sump pump deck that blocks the work area needed to store the draft tube gate and to fish the fyke nets. Unit 56 is constrained by circulation patterns in the tailrace that deposit rock at the gate sill during spill events. This can keep the gate or fyke net frame from properly seating. Additionally, Unit 56 has a TDG measuring well pipe installed in the gate slot. Another site constraint for consideration is the higher flows in the two larger units (55 and 56). The flow to these units is 30 percent higher than the other units. The flow area however is the same. Consequently the velocities are higher, and the turbulence greater in the larger units. The fishing conditions will be worse in the larger units than in the smaller units. Project operational considerations include scheduled maintenance outages. According to conversations with the Boundary Project Chief Operator, turbine use is for the most part uniform. Units 55 and 56 are usually turned on first, while Unit 51 is turned on last. Hydroacoustic target analysis is currently underway. Decisions on fyke net placement will be made in cooperation with the relicensing participants and will be fully documented in the first initial study report.

If the ongoing hydroacoustic monitoring reveals a significant shift in the passage distribution across the intakes by season, and if a non one-to-one correspondence between the hydroacoustic targets and fyke net data is unexplainable, a second fyke net may be installed at another turbine intake in May-June, 2008. This decision, made in cooperation with the relicensing participants, will be taken in the first quarter of 2008, using data gathered through December 2007. The decision on installation of a second fyke net will be fully documented in the 2008 study report.

4.3. Hydroacoustic Sampling Methods

Hydroacoustic fish entrainment data will be collected and analyzed using split-beam target tracking techniques (Ehrenberg and Torkelson 1996) and following the acoustic sampling principles outlined in MacLennan and Simmonds (1992). Fixed-location hydroacoustics has been used to evaluate fish passage at dams for over 25 years. Hydroacoustics provides high sampling coverage that is difficult to obtain with more traditional means of fish sampling. The principle of fixed-location, split-beam hydroacoustic techniques is based on placing one or more transducers on a fixed structure and sampling fish as they pass through the insonified acoustic beams. The fish produce characteristic echo returns that can be processed to produce estimates of fish passage rates, direction of movement, size, velocity, and other parameters.

The hydroacoustic equipment required for a quantitative fixed-location study includes a scientific-quality echo sounder/transceiver, transducers, and a PC-based echo processor. The primary component of a hydroacoustic data collection system is the scientific echo sounder. When triggered, the echo sounder emits a short electrical pulse of known frequency, duration, and transmit power. The transducer then converts the electrical pulse into mechanical energy (i.e., a sound pulse with the same characteristics as the electrical pulse). In fixed-location applications, the transducers typically have relatively narrow beam widths so they can be aimed close to confined areas of interest.

When the sound waves encounter fish, echoes are reflected back to the transducer. The transducer then converts the sound energy back into electrical energy and sends it back to the receiver portion of the echo sounder. The echo signals are relayed to a computer-based echo processor, which records each detection to a computer file for subsequent analysis.

The Boundary Dam powerhouse consists of six turbine units, numbered Units 51-56. A vertically-oriented 6˚x10˚ nominal beam width transducer is placed on the centerline of each turbine intake at elevation 1968 ft and aimed down to monitor the water column immediately upstream of each turbine opening. The transducers operate at a sampling frequency of 200 kHz and use split-beam technology to track the direction of individual fish in three-dimensional space. Only fish exhibiting movement into the intake are considered to be entrained. The six transducer turbine monitoring array is sampled continuously, 24 h/d. Individual transducers at each turbine are sequentially-sampled in 2.5-min increments across the powerhouse within each 1-hour data replicate, such that each location is sampled 10 min/h. All entrained fish detections are weighted for unsampled time and space, such that the resulting estimates represent total fish passage at each location. Turbine unit operations are considered during the analyses, such that only fish moving into the intakes of operating turbines are included in the hydroacoustic entrainment estimates.

Boundary Dam has two spill bays, which are monitored using two 15˚ nominal beam width split-beam transducers at each location (four transducers in total). Two transducers are deployed equidistantly at each spill bay to maximize spatial sampling coverage of fish passing the openings during spill. Each spill bay was conceptually subdivided vertically into two halves with one down-looking split-beam transducer located in each half. Each transducer will randomly sample six 5-min time intervals per hour, 24-hour/day, during all periods when spill is occurring at the Project. This sampling design provides 60 min of sampling time within each spill bay per hour.

Acoustic sampling (ping) rates of 12.5 pings per second (pps) are used at the turbine units. Ping rates of 15 pps are implemented for the spillway monitoring. These relatively high ping rates are used to provide high acoustic detectability of individual entrained fish at both locations. Fish detectability was modeled before the data collection period at the turbine and spillway locations, based on the transducer beam widths, sampling ranges, and water velocities at the site. The higher potential water velocity in the spillways relative to the turbine intakes indicated use of a relatively higher ping rate at the former location. A minimum on-axis echo detection threshold of -52 decibels (dB) is used for monitoring at the Boundary Dam powerhouse and spillways, equivalent to a minimum on-axis fish detection length of 86 mm (2.8 inches) across the full nominal beam width, based on Love (1971). Hydroacoustic data are subsequently filtered in post-processing to only include detections equivalent to 100 mm (4 inches) in length or greater. A relatively narrow broadcast pulse width (PW) of 0.2 ms is used to optimize detection of closely-spaced individual fish targets.

The installation is configured to allow remote control of the hydroacoustic systems for monitoring and data transfer purposes. The hourly hydroacoustic fish passage data files are transferred on a daily basis to Seattle for ongoing data review and analysis.

4.4. Fyke Net Sampling Plan

The fyke net sampling within the draft tube of a turbine will be used to verify hydroacoustic targets and identify the species composition of entrained fish. Fyke net sampling will be conducted for four 24-hour periods each month using a stacked fyke net assembly consisting of an array of multiple fyke nets within the turbine draft tube.

During a sampling period, three types of information will be collected:

1) Total fish numbers by net location and full array.
2) Fish length data by net location and full array.
3) Species composition by net location and full array.

It is anticipated that fish numbers will differ by net location. It is less clear whether size and species composition will be net-dependent. If estimates of fish numbers derived from the fyke net and hydroacoustics are consistent and fish size and composition are homogeneous across nets, the number of nets in the array may be reduced in the future for purposes of monitoring species composition. These decisions will be made in cooperation with relicensing participants. Decision criteria for possible modifications to the fyke net sampling plan are described in Section 4.4.2.

4.4.1. Fyke Net Array Installation

A stacked fyke net assembly, consisting of an array of multiple net frames, will be used to sample one turbine draft tube concurrently with the hydroacoustic monitoring. Access to the Boundary Project intakes will be gained through the draft tube gatewell slot. Based on the success of the initial fyke net installation and comparisons with the hydroacoustic data record, modifications to the 2008 fyke net sampling plan may occur. This decision will be made in coordination with relicensing participants.

4.4.2. Fyke Net Sampling

As discussed in Section 4.2, selection of the turbine intake for fyke net installation will be based on entrainment trends at the Boundary Dam Powerhouse in May-June, 2007, physical site constraints, project operational considerations, and turbine frequency of use. Fyke netting at a single turbine intake is scheduled to begin in September, 2007, and may continue through April, 2009. A second fyke net may be installed at another turbine intake, based on the results of the 2007 hydroacoustic monitoring and demonstrated effectiveness of the initial fyke net deployment. This decision will be made in January, 2008, based on results from the aggregated May- December, 2007 monitoring period. These decisions will be made in cooperation with the relicensing participants and be fully documented in the annual reports.

Two arrays of fyke nets will sample 100 percent of the flow in both slots of a single turbine draft tube. These arrays will consist of two rows of four vertically-stacked nets. Sampling is expected to occur for at least four 24-hour periods per month. Fyke net operation will require that the sampled turbine be shut down during deployment and recovery of the array. The length of time of exposure to flows will initially be set at 1-hour, but may vary based on concurrent estimates of fish entrainment by hydroacoustic system and the degree of debris loading on the nets. Depending on the rate of fish and debris build-up in the cod end of the fyke nets, nets may be fished continuously for multiple hour periods, or split into shorter time intervals. Initially the nets will be fished continuously, except during periods when the turbine units are shut down to remove and deploy the net frames for sample recovery and cleaning. Planned nighttime generation and planned spill events may be required during some months to provide adequate comparisons between daytime and nighttime periods and evaluation of spillway hydroacoustic passage. Sampling may not be possible during periods of maintenance or repair of the turbine(s) selected for fyke net sampling.

The fyke net sampling design will be adaptive because of uncertainties related to fish passage distributions over time and equipment performance. For maximum statistical power, the target total fish counts of all nets per sampling period will be a minimum of 30 fish, with 50 fish preferred (> 100 mm total length for all species) per sampled temporal strata. Initial sampling strata will be one 24-hour period per week. To obtain the minimum required number of captured fish per 24-hour sampling period, the number and/or the length of net samples may be increased within 24-hour sampling periods. Sampling regimes may be aggregated into two 2-day periods or four continuous days per month, based on ongoing review of the hydroacoustic counts, associated target strengths and temporal changes in fyke net catches. If these data suggest little temporal variability in species and size composition, sampling regimes may be simplified. The results of the first two months of routine fyke net sampling (eight 24-hour sample periods) will be used to determine if aggregating fyke net sampling is appropriate during subsequent monitoring. If the four weekly 24-hour fyke net sample entrainment estimates are not significantly different, future sampling may occur on adjacent days. If 24-hour samples differ significantly within a month, weekly sampling spacing will be maintained. This evaluation process may be continued on a seasonal basis for the duration of the study period, as differing patterns of river flow and fish movement over the year may require changes in sampling frequency over time.

In the same manner, the number of individual net frames sampled within each fyke net array may be reduced in 2008, if fish distribution within each turbine intake slot is shown to be statistically equivalent. For example, nets might be sampled in four of the eight frames in 2008, based on the results observed during the September-December 2007 fyke netting sampling period. Reduced net coverage within an intake slot will be considered only if:

a. Adequate numbers of fish (a minimum of 30-50 fish per sample) can be captured within a reduced set of nets to estimate entrainment rates and surrounding confidence intervals,
b. Significant (α=0.10) differences in spatial patterns of fish capture within the eight nets in each array are not observed within the initial September-December 2007 netting period, and

c. Logistical considerations, such as high net debris loading or the magnitude of total fish entrainment, restrict the ability to effectively sample with fyke nets.

This adaptive fyke net sampling approach will allow in-season flexibility to quantify fish entrainment under variable environmental conditions.

4.4.3. Fish Handling

All fish collected during fyke net sampling will be identified to species and their total length will be measured to the nearest millimeter (mm). All captured salmonids will be scanned for tags, including passive integrated transponder (PIT) tags. Protocols for handling and disposition of any bull trout carcasses that may be collected are described in the US Fish and Wildlife Service scientific collecting permit. An example of the proposed fyke net data entry form is shown in Figure 4.4-1.

page_____ of ______

Boundary Dam Fyke Net Data Form

Date:
Sample Location:
Personnel On-site:
Sample Number:
Net Deployment Time:
Unit Start Time:
Unit Shutdown Time:
Net Removal Time (on deck):

Comments:

Top of net frame

net number 1	2
3	4
5	6
7	8

Turbine Slot #1 Frame (upstream)

Net Number	**Species Code**	**Total Length** (mm)	**Comments**

Figure 4.4-1. Proposed fyke net data entry form.

5 DATA ANALYSIS METHODS

5.1. Hydroacoustic Data

Data are automatically transferred from the Boundary Dam hydroacoustic monitoring systems on a daily basis and manually-processed. Each data file is manually-reviewed and individual fish detections are marked and entered into Microsoft ACCESS® data files for subsequent analyses. Unit operations and other ancillary data (e.g., TDG, fyke net data, etc.) are also downloaded on a regular basis.

The hydroacoustic data analyses are conducted within a SQL/ACCESS database software framework and final data summaries for reporting are conducted in EXCEL® spreadsheet files.

Individual entrained targets must meet fixed criteria to be counted as fish. Each target must return a minimum of four consecutive echo returns as it passes through the acoustic volume at each turbine intake opening. To be considered an entrained fish, the target must demonstrate consistent movement into the intake tunnel and return a mean target strength (TS) value > -45 dB. This minimum TS value is equivalent to a minimum fish length of 10 cm (4 inch), based on Love (1971), a published formula relating fish TS and length. These minimum number of echo return, TS and direction-of-movement criteria are used to minimize the potential of counting debris or non-entrained fish in the acoustic counts.

Reported fish passage distributions will describe total fish passage per monitored location over varying time scales. In addition, fish acoustic size (target strength) and diel (day/night) passage distributions will be presented for the same periods. Target strength estimates will be converted to estimated fish lengths using Love (1971).

The hydroacoustic monitoring system covers slightly over 40% of the cross-sectional area of each turbine and spillway opening. Total fish passage is extrapolated to the full intake and spillway widths based on the hourly observations within the sampled areas. Hydroacoustic sub sampling also occurs over time. Each turbine intake location is sampled for four 2.5 minute periods each hour, or 10 minutes total. These samples are weighted to account for unsampled time at each location within each hour. The hourly fish passage estimates account for unsampled time and area at each monitored location. The specific details of the hydroacoustic fish entrainment weighting and data analysis procedures are described below in Sections 5.1.1-5.1.8.

5.1.1. Estimating Powerhouse Passage

Hydroacoustic fish passage into the turbine units considers 1-hour sampling block replicates. Each turbine location is sampled four times within each 1-hour replicate. Daily fish passage is estimated by summarizing the hourly samples from 0000-2359 h.

The sampling at the powerhouse can be envisioned as stratified random sampling within unit-hours. Fish passage is independently estimated within each unit-hour, and these unit-hours are summed over time and location to estimate total passage. The formula used to estimate total fish passage at the Boundary Dam Powerhouse is given below.

x_{ijkl} = expanded fish count in the *i*th sample $(i = 1, \ldots, a)$ in the *j*th hour $(j = 1, \ldots, 24)$ of the *k*th day $(k = 1, \ldots, D)$ at the *l*th turbine unit $(l = 1, \ldots, 6)$;

a = number of samples monitored per hour at a turbine unit (nominally, a = 4);

A = total number of possible sampling units within an hour at a turbine unit (nominally, A = 24).

Then, total fish passage at the powerhouse over D days, across all six turbine units, is estimated by:

$$\hat{P} = \sum_{i=1}^{6}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{A}{a}\sum_{i=1}^{a} x_{ijkl}\right]. \quad (1)$$

Special cases of $\hat{P}$ may include estimating passage at a single turbine unit over time, i.e.,

$$\hat{P}_l = \sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{A}{a}\sum_{i=1}^{a} x_{ijkl}\right]. \quad (2)$$

The variance of $\hat{P}$ can be expressed as:

$$\text{Var}\left(\hat{P}\right) = \sum_{l=1}^{6}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{A^2\left(1-\frac{a}{A}\right)S_{x_{jkl}}^2}{a}\right]$$

and estimated by:

$$\widehat{\text{Var}}\left(\hat{P}\right) = \sum_{l=1}^{6}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{A^2\left(1-\frac{a}{A}\right)s_{x_{jkl}}^2}{a}\right], \quad (3)$$

where:

$$s_{x_{jkl}}^2 = \frac{\sum_{i=1}^{a}\left(x_{ijkl}-\overline{x_{jkl}}\right)^2}{(a-1)} \quad (4)$$

and where:

$$\overline{x_{jkl}} = \frac{\sum_{i=1}^{a} x_{ijkl}}{a}. \quad (5)$$

5.1.2. Estimating Spillway Passage

Two equidistantly-spaced transducers are used to sample each spillway, due to the relatively wide (15.2 m, or 50 ft) horizontal extent of the gates. Fish detected by each transducer are weighted to account for unsampled area to the midpoint of each spill gate, and the two estimates are summed to provide total entrainment values. As at the turbine intakes, 1-hour time blocks are used as the basic data replicate. The two halves of the spillway are considered to be different spatial strata and a stratified random sampling design is used to estimate passage variance. The formula used to estimate total spill bay passage is given below:

y_{ijklm} = expanded fish count in the *i*th sample $(i=1,\ldots,a)$ in the *j*th hour $(j=1,\ldots,24)$ of the *k*th day $(k=1,\ldots,D)$ at the *l*th vertical stratum $(l=1,2)$ within the *m*th spillbay $(m=1,2)$;

b = number of samples monitored per hour at a spill bay location (nominally, $b = 6$);

B = total number of possible sampling units within an hour at a spill bay location (nominally $B = 12$).

The total fish passage at the spillway over D days, across all locations, is estimated by:

$$\hat{S}=\sum_{m=1}^{2}\sum_{l=1}^{2}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{B}{b}\sum_{i=1}^{b}y_{ijklm}\right]. \qquad (6)$$

Special cases of $\hat{S}$ may include estimating passage at a single spill bay over time, i.e.,

$$\hat{S}_m=\sum_{l=1}^{2}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{B}{b}\sum_{i=1}^{b}y_{ijklm}\right]. \qquad (7)$$

The variance of $\hat{S}$ can be expressed as:

$$\text{Var}(\hat{S}) = \sum_{m=1}^{2}\sum_{l=1}^{2}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{B^2\left(1-\frac{b}{B}\right)S^2_{y_{jklm}}}{b}\right]$$

and estimated by:

$$\widehat{\text{Var}}(\hat{S}) = \sum_{m=1}^{2}\sum_{l=1}^{2}\sum_{k=1}^{D}\sum_{j=1}^{24}\left[\frac{B^2\left(1-\frac{b}{B}\right)s^2_{y_{jklm}}}{b}\right], \qquad (8)$$

where:

$$s^2_{y_{jklm}} = \frac{\sum_{i=1}^{b}\left(y_{ijklm} - \overline{y_{jklm}}\right)^2}{(b-1)} \qquad (9)$$

and where:

$$\overline{y_{jklm}} = \frac{\sum_{i=1}^{b} y_{ijklm}}{b}. \qquad (10)$$

5.2. Hydroacoustic Performance Measures

Over the course of the investigation, various salient summaries of fish passage at Boundary Dam are required. This section summarizes some of the more important metrics that may be estimated from the hydroacoustic investigation.

5.2.1. Passage Counts

The estimator $\hat{P}$ [Eq. (1)] and associated variance estimator (3) provide information on total fish passage at the powerhouse for a selected length of time. Similarly, estimator $\hat{S}$ [Eq. (6)] and associated variance estimator (8) provide information on total fish passage at the spillway for a selected length of time. Total project passage (T) can then be estimated by:

$$\hat{T} = \hat{P} + \hat{S} \qquad (11)$$

with associated variance estimator

$$\widehat{\text{Var}}(\hat{T}) = \widehat{\text{Var}}(\hat{P}) + \widehat{\text{Var}}(\hat{S}). \quad (12)$$

Asymptotic $(1-\alpha)$ 100% confidence interval can be calculated as

$$\hat{\theta} \pm Z_{1-\frac{\alpha}{2}} \sqrt{\widehat{\text{Var}}(\hat{\theta})}$$

For any parameter θ and where $Z_{1-\frac{\alpha}{2}}$ is a standard normal deviate defined by:

$$P\left(|Z| > Z_{1-\frac{\alpha}{2}} \right) = 1 - \alpha .$$

For example, for a 90% confidence interval, $Z_{0.975} = 1.645$.

5.2.2. Proportional Spillway Passage

The proportion of the total fish passage at Boundary Dam that goes through the spillway (*PS*) is estimated by the quantity:

$$\widehat{PS} = \frac{\hat{S}}{\hat{S} + \hat{P}} . (13)$$

with associated variance estimator

$$\widehat{\text{Var}}(\widehat{PS}) = \widehat{PS}^2 (1 - \widehat{PS})^2 \left[\frac{\widehat{\text{Var}}(\hat{S})}{\hat{S}^2} + \frac{\widehat{\text{Var}}(\hat{P})}{\hat{P}^2} \right]. \qquad (14)$$

5.2.3. Fractional Spill bay Passage

The fraction of total spillway passage that goes through a specific spill bay $\left(FS_m\right)$ can be estimated by:

$$\widehat{FS}_m = \frac{\hat{S}_m}{\hat{S}}, \quad (15)$$

where $\hat{S}$ is the estimated total spillway passage and $\hat{S}_m$ is the estimated passage for the *m*th spill bay $(m = 1, 2)$. The response $\widehat{FS}_m$ has the variance estimator:

$$\widehat{\text{Var}}\left(\widehat{FS}_m\right) = \left(\widehat{FS}_m\right)^2 \left(1 - \widehat{FS}_m\right)^2 \left[\frac{\widehat{\text{Var}}\left(\hat{S}_1\right)}{\hat{S}_1^2} + \frac{\widehat{\text{Var}}\left(\hat{S}_2\right)}{\hat{S}_2^2}\right]. \qquad (16)$$

5.2.4. Fractional Powerhouse Passage

Similarly, the fraction of total powerhouse passage through the *g*th turbine unit $\left(FP_g\right)$ can be estimated by:

$$\widehat{FP}_g = \frac{\hat{P}_g}{\hat{P}}, \quad (17)$$

where $\hat{P}$ is the estimated total powerhouse passage and $\hat{P}_g$ is the estimated passage for the *g*th turbine unit. The response $\left(\widehat{FP}_g\right)$ has the variance estimator:

$$\left(\widehat{FP}_g\right) = FP_g^2 \left(1 - FP_g\right)^2 \left[\frac{\widehat{\text{Var}}\left(\hat{P}_g\right)}{\hat{P}_g^2} + \frac{\sum_{\substack{h=1 \\ h \neq g}}^{6} \widehat{\text{Var}}\left(\hat{P}_h\right)}{\sum_{\substack{h=1 \\ h \neq g}}^{6} \hat{P}_h}\right]. \quad (18)$$

5.2.5. Rate of Passage Through Time

Total passage estimates can be converted to a passage number per unit of time by dividing the total fish passage by total time (t) of monitoring, e.g.,

$$\widehat{\text{rate}} = \frac{\hat{S}}{t} \qquad (19)$$

with associated variance estimator:

$$\widehat{\text{Var}}\left(\widehat{\text{rate}}\right) = \frac{\widehat{\text{Var}}\left(\hat{S}\right)}{t^2}. \qquad (20)$$

5.3. Fyke Net Data

The size, number and species of fish entrained within the Project intakes will be correlated with the duration, timing and magnitude of generation. Hydroacoustic target counts and target strengths will be translated into the number and size of entrained fish using the results of the fyke net sampling if abundance numbers from the two sampling methods are similar. If the abundance numbers are dissimilar, the algorithms used to distinguish fish from other hydroacoustic targets would be reassessed. The results of fyke net sampling will also be used to identify the relative proportion of species entrained into the intakes.

5.3.1. Analysis and Data Processing

Data analysis will be conducted by HTI with raw data counts and operations data transferred in a MS ACCESS database following data entry and QA/QC procedures.

5.4. Fyke Net and Hydroacoustic Statistical Comparisons

5.4.1. Comparison of Size Frequencies

Within a sampling period, the fish length distribution from fyke net and hydroacoustics sampling will be compared over a length range of 4 inches to 39 inches (10 cm to 1 meter). This fish length comparison range is based on the fish size detection threshold of the hydroacoustic system and the capture efficiency of the fyke net arrays. Both methods are designed to have comparable fish detection/capture within this fish length range. Cumulative size frequency curves will be plotted for both fyke net and hydroacoustic data (Figure 5.4-1). Statistical comparison of the size distribution data will be based on a Kolmogorov-Smirnov (KS) test for equal distributions (Conover 1980). The results across periods will be summarized using a meta-analysis where the overall *P*–value is calculated from:

$$\lambda = -2\sum_{i=1}^{k} \ln P_i$$

where:

P_i = P-value for the ith analysis,

k = number of trials,

and where λ is chi-square distributed with $2k$ degrees of freedom, such that the overall significance is:

$$P = P\left(\chi^2_{2k} \geq \lambda\right). \quad (21)$$

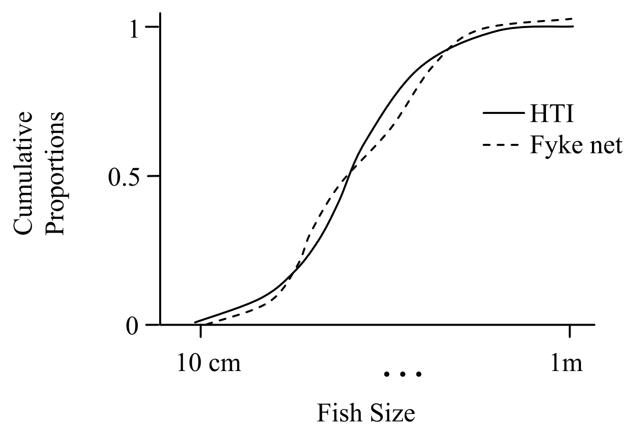

Figure 5.4-1. Schematic of cumulative distribution curves for fish size illustrating homogeneity of the hydroacoustic and fyke net samples.

Comparison of size distributions among the different fyke nets within the array can be compared using an R × C contingency table test of homogeneity of the size-class data. The comparison of fyke net data with the hydroacoustic target-strength information will be based on the pooled netting data. Homogeneity of size distributions among the nets within the array may permit eventual entrainment monitoring using only a subset of the full array. For comparison of size frequencies, the fyke net sampling should be performed such that a minimum of 30-50 fish per trial are captured.

5.4.2. Comparison of Passage Abundance

The hydroacoustic monitoring will estimate passage abundance on an hourly basis. Fyke net sampling will be carefully coordinated with the hydroacoustic monitoring to ensure passage estimates are calculated over identical time periods. Using multiple sampling periods within a day and across days within a month, a regression analysis will compare passage counts between hydroacoustic and fyke net techniques of the form:

$$y_i = \beta_1 x_i + \varepsilon_i \qquad (22)$$

where:

y_i = hydroacoustic passage estimate for the *i*th sampling period,

x_i = fyke net passage count for the *i*th sampling period,

ε_i = random error term.

The test of equality of passage counts between methods is then equivalent to a test of slope, where:

$$\mathrm{H_o}: \beta_1 = 1$$

vs.

$$\mathrm{H_a}: \beta_1 \neq 1 .$$

If the null hypothesis is true, a data plot of hydroacoustic counts vs. fyke net counts should produce a 45° line through the origin (Figure 5.4-2). Across seasons, results of tests of equality can be combined using the meta-analysis equation (21).

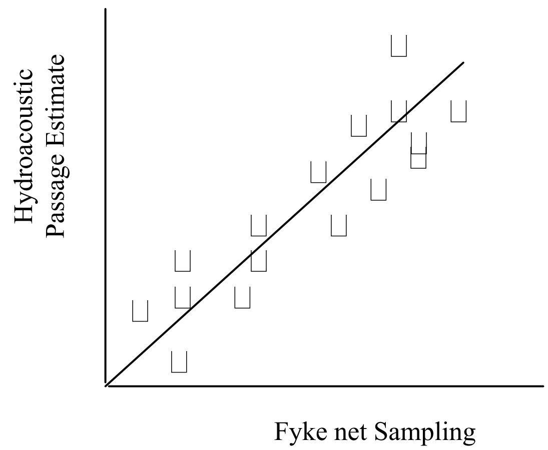

Figure 5.4-2. Schematic of a 1:1 relationship between fyke net and hydroacoustic passage estimates (i.e., $\beta_1 = 1$).

5.4.3. Species Composition and Abundance Estimates

Species composition data collected from the fyke net sampling will be summarized on a monthly basis. The percentage of each species within the total fyke net capture for the month will be used to apportion the total hydroacoustic estimates. For any monthly time period, the proportion of fish of a specific species group will be estimated by:

$$\hat{p}_i = \frac{x_i}{n} \qquad (23)$$

where:

x_i = number of fish belonging to species i,

n = total number of fish collected by fyke net.

The estimates of species proportions (22) will have an associated standard error of:

$$\widehat{SE}\left(\hat{p}_i\right) = \sqrt{\frac{\hat{p}_i\left(1-\hat{p}_i\right)}{n-1}}. \qquad (24)$$

An asymptotic $(1-\alpha)100\%$ confidence interval will be calculated for p_i as follows:

$$\hat{p}_i \pm Z_{1-\frac{\alpha}{2}} \sqrt{\frac{\hat{p}_i\left(1-\hat{p}_i\right)}{n-1}}. \qquad (25)$$

Bar charts or pie charts will be used to illustrate species composition over time.

An estimate of entrainment abundance for a particular species using the hydroacoustic estimate of total entrainment $\left(\hat{N}\right)$ and the fyke net estimate of species proportions $\left(\hat{p}_i\right)$ can be computed as the product:

$$\hat{N} \cdot \hat{p}_i \quad (26)$$

with the associated variance estimator:

$$\hat{\text{V}}\text{ar}\left(\hat{N} \cdot \hat{p}_i\right) = \hat{N}^2 \cdot \hat{\text{V}}\text{ar}\left(\hat{p}_i\right) + \hat{p}_i^2 \cdot \hat{\text{V}}\text{ar}\left(\hat{N}\right) - \hat{\text{V}}\text{ar}\left(\hat{p}_i\right) \cdot \hat{\text{V}}\text{ar}\left(\hat{N}\right). \quad (27)$$

6 REPORTING

6.1. 2007 Annual Interim Study Report

The draft Annual Interim Study Report for 2007 will be completed and shared with relicensing participants in January 2008. It will be submitted to FERC in March 2008.

6.2. 2008 Annual Interim Study Report

The Annual Interim Study Report for 2008 will be completed and shared with relicensing participants in December 2009. It will be submitted to FERC in March 2009.

6.3. Addendum Data Report

If a decision is taken as described in Section 2, to extend the data collection efforts into the spring of 2009, an addendum report will be available in July of 2009. In the addendum report, fish passage distributions from the final 8.5 months of data collection will be summarized and compared to those in the final 2008 Annual Interim Report. Significant differences in results between the two sampling periods will be noted.

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Appendix 3: Fyke Net Fish Passage Estimator with Variance

Estimator and Variance

for Fish Passage at Boundary Dam

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15 September 2008

An estimator for fish passage at Boundary Dam can be constructed using the fyke-net data only.

The estimator of total fish passage can be expressed as

$$\hat{N}_2 = \sum_{i=1}^{12} R_{F/M_i} \cdot \sum_{j=1}^{D_i} M_{ij} \quad (1)$$

where R_{F/M_i} = the ratio of fish per megawatt hour for the *i*th month $(i = 1, \ldots, 12)$. This method allows for monthly difference in entrainment rates but the precision of R_{F/M_i} is degraded because of smaller sample sizes.

For the estimator (1), the variance would be calculated as follows:

$$\widehat{\text{Var}}\left(\hat{N}_2\right) = \sum_{i=1}^{12}\left[\widehat{\text{Var}}\left(\hat{R}_{F/M_i} \cdot M_i\right)\right],$$

where the variances for the monthly extrapolations are summed. In turn, the within-month variances can be reexpressed such that

$$\widehat{\text{Var}}\left(\hat{N}_2\right) = \sum_{i=1}^{12}\left[\frac{\text{MSE}_i M_i^2}{\left(\sum_{j=1}^{n} m_{ij}^2\right)}\right], \quad (1a)$$

where

M_i = total megawatts for the *i*th month $(i = 1, \ldots, 12)$;

m_{ij} = megawatts during the *j*th trial $(j = 1, \ldots, n)$ in the *i*th month $(i = 1, \ldots, 12)$;

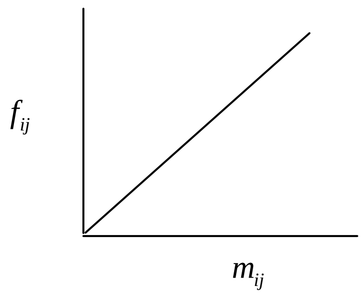
f_{ij} = number of fyke-net fish during the *j*th trial $(j = 1, \ldots, n)$ in the *i*th month $(i = 1, \ldots, 12)$;

n = number of fyke-net trials in the *i*th month $(i = 1, \ldots, 12)$;

and where

$$\text{MSE} = \frac{\left[\sum_{j=1}^{n} f_{ij}^2 - \frac{\left(\sum_{j=1}^{n} m_{ij} f_{ij}\right)^2}{\sum_{j=1}^{n} m_{ij}^2}\right]}{(n-1)}.$$

Equation (1a) assumes $\hat{R}_{F/M_i}$ was estimated by a straight-line regression through the origin of the form



such that $\hat{R}_{F/M_i} = \dfrac{\sum_{j=1}^{n} m_{ij} f_{ij}}{\sum_{j=1}^{n} m_{ij}}$

on a monthly basis.

On the other hand, if the megawatts during the *n* trials are held to a fixed constant (m_i), then

$$\hat{R}_{F/M_i} = \frac{\bar{f}_i}{m_i} = \frac{\frac{1}{n}\sum_{j=1}^{n} f_{ij}}{m_i}.$$

As such, the passage abundance estimate would have the alternative variance expression of the form:

$$\widehat{\text{Var}}\left(\hat{N}_2\right) = \sum_{i=1}^{12}\left[\frac{s_i^2 M_i^2}{m_i^2 n}\right] \qquad (1b)$$

and where

$$s_i^2 = \frac{\sum_{j=1}^{n}\left(f_{ij} - \bar{f}_i\right)^2}{(n-1)},$$

$$\bar{f}_i = \frac{1}{n}\sum_{j=1}^{n} f_{ij}.$$

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Appendix 4: Fyke Net Fish Capture Summary

Fyke Net Catch Summary Sheet - Species **2008**

		Number	Percent	Mean Length (cm)
February	Burbot	2	50	49.4
	Yellow Perch	2	50	12.6
	Total	**4**		
March				
	Brown bullhead	1	4	16.4
	Burbot	8	29	51.3
	Pumpkinseed	1	4	8.2
	Redside shiner	1	4	na
	Sucker spp.	1	4	13.0
	Unidentified	4	14	na
	Yellow perch	12	43	12.5
	Total	**28**		
April				
	Brown bullhead	1	2	6.8
	Burbot	2	5	49.5
	Rainbow trout (triploid)	6	14	23.7
	Slimy sculpin	1	2	8.0
	Sucker spp.	18	43	32.8
	Yellow perch	14	33	12.8
	Total	**42**		
May				
	Black crappie	1	1	10.4
	Brown trout	1	1	17.0
	Burbot	1	1	59.0
	Kokanee	1	1	21.6
	Northern pikeminnow	3	3	14.3
	Pumpkinseed	18	18	8.3
	Rainbow trout (triploid)	3	3	20.9
	Sucker spp.	58	59	32.7
	Tench	3	3	8.2
	Yellow perch	9	9	12.3
	Total	**98**		
June				
	Kokanee	3	15	13.7
	Pumpkinseed	4	20	8.2
	Rainbow trout (triploid)	1	5	25.0
	Sucker spp.	6	30	na
	Tench	1	5	15.5
	Unidentified	2	10	na
	Yellow perch	3	15	11.9
	Total	**20**		

July				
	Black bullhead	1	1	16.0
	Black crappie	4	4	8.5
	Brown bullhead	1	1	21.5
	Burbot	2	2	48.8
	Kokanee	7	8	13.0
	Northern pikeminnow	2	2	34.9
	Smallmouth bass	3	3	20.4
	Sucker spp.	61	67	31.5
	Unidentified	1	1	na
	Yellow perch	9	10	15.5
	Total	**91**		
August				
	Black crappie	5	6	8.5
	Brown bullhead	5	6	17.4
	Burbot	3	4	50.7
	Kokanee	4	5	13.3
	Pumpkinseed	40	48	7.7
	Rainbow trout (triploid)	3	4	34.4
	Smallmouth bass	6	7	16.0
	Sucker spp.	15	18	34.6
	Unidentified	1	1	na
	Walleye	1	1	9.2
	Total	**83**		
September				
	Burbot	2	7	49.5
	Pumpkinseed	26	87	9.6
	Rainbow trout (triploid)	1	3	15.3
	Smallmouth bass	1	3	13.4
	Sucker spp.	8	27	36.6
	Total	**30**		
October				
	Black crappie	1	10	14.0
	Burbot	1	10	63.0
	Kokanee	1	10	13.2
	Sucker spp.	6	60	32.0
	Yellow perch	1	10	6.0
	Total	**10**		
November				
	Black crappie	1	50	58.0
	Burbot	1	50	61.3
	Total	**2**		