PNNL-27022

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Behavior, Distribution, and Passage Metrics of Juvenile Chinook Salmon Above and Below Lookout Point Dam, Fall 2016 and Spring 2017

Final Report

April 2018

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US Army Corps
of Engineers

Prepared for the U.S. Army Corps of Engineers,
Portland District, under a Government Order with
the U.S. Department of Energy
Contract DE-AC05-76RL01830

U.S. DEPARTMENT OF
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Pacific Northwest National Laboratory
Richland, Washington 99352

Preface

The research reported herein was performed under the auspices of the Willamette Basin Research, Monitoring, and Evaluation Program (study code JPL-15-04-LOP). The study was funded by the U.S. Army Corps of Engineers, Portland District (USACE) (Ref. No. W66QKZ61889194) under an agreement with the U.S. Department of Energy (DOE) for work by Pacific Northwest National Laboratory (PNNL). The data are archived at PNNL offices in Richland, Washington. This final report is a project deliverable (PNNL Project No. 65456). PNNL is operated by the Battelle Memorial Institute for the DOE under Contract DE-AC05-76RL01830. The study was led by James Hughes (509-371-6802). The USACE's technical lead for the study was Fenton Khan (503-808-4777).

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Summary

This report presents the results of a fish behavior, distribution, and passage study conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers-Portland District (USACE) at Lookout Point Dam (or Lookout Point) during the fall of 2016 (October–December) and spring of 2017 (March–June). The goal of this study was to provide biologists, engineers, resource managers, and regional decision-makers with information about the behavior, distribution, and passage of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) through the Lookout Point reservoir and tailwaters. The results of this study are intended to inform decision-making about long-term structural and operational measures to help rebuild populations of Upper Willamette River spring Chinook salmon listed as threatened under the Endangered Species Act.

The study addressed two life-history patterns for spring Chinook salmon in the Middle Fork Willamette River: reservoir-rearing with outmigration past Lookout Point Dam in fall (subyearling Chinook salmon) and natal-stream rearing with outmigration past Lookout Point in spring (yearling Chinook salmon). The study area stretched from the upper Lookout Point reservoir to below Dexter Dam (Dexter). An active acoustic telemetry study of tagged fish migration and passage was conducted to meet study objectives. Research objectives for separate 2016 fall and 2017 spring sampling periods for tagged juvenile Chinook salmon were as follows:

- Estimate seasonal and diel passage metrics (residence times and survival rates [data permitting]) for tagged fish in reaches between telemetry receiver arrays, including:
  - Lookout Point reservoir[1]
  - Lookout Point project (forebay+tailrace)[2]
  - Dexter project (forebay+tailrace).[3]
- Characterize entrance and exit timing, residence time, and horizontal distribution for tagged fish detected at each array.

We employed a single-release survival model for this acoustic telemetry study at Lookout Point (Figure S.1). Detection arrays were deployed to monitor juvenile salmon implanted with acoustic tags at eight locations in the Middle Fork and mainstem Willamette River (Figure S.2 and Figure S.3).

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[1] For purposes of this study, the Lookout Point reservoir is the reach from the Head of Reservoir array to the Lookout Point Forebay (LOP) array.

[2] For purposes of this study, Lookout Point project is the reach from the LOP array to the array in the Dexter forebay. There was no cabled receiver array on the face of the dam.

[3] For purposes of this study, Dexter project is the reach from the Dexter forebay to the first array below Dexter.

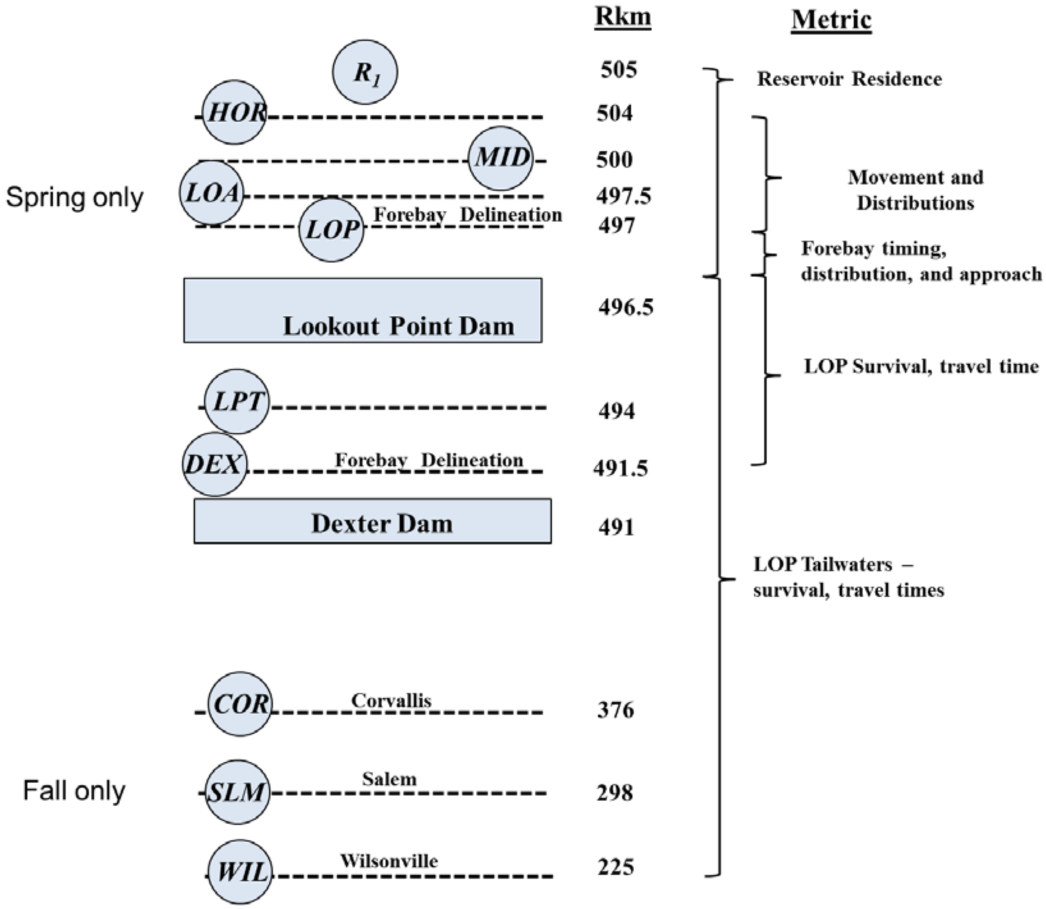

Figure S.1. Schematic of the Study Design Used to Estimate Project Metrics at Lookout Point

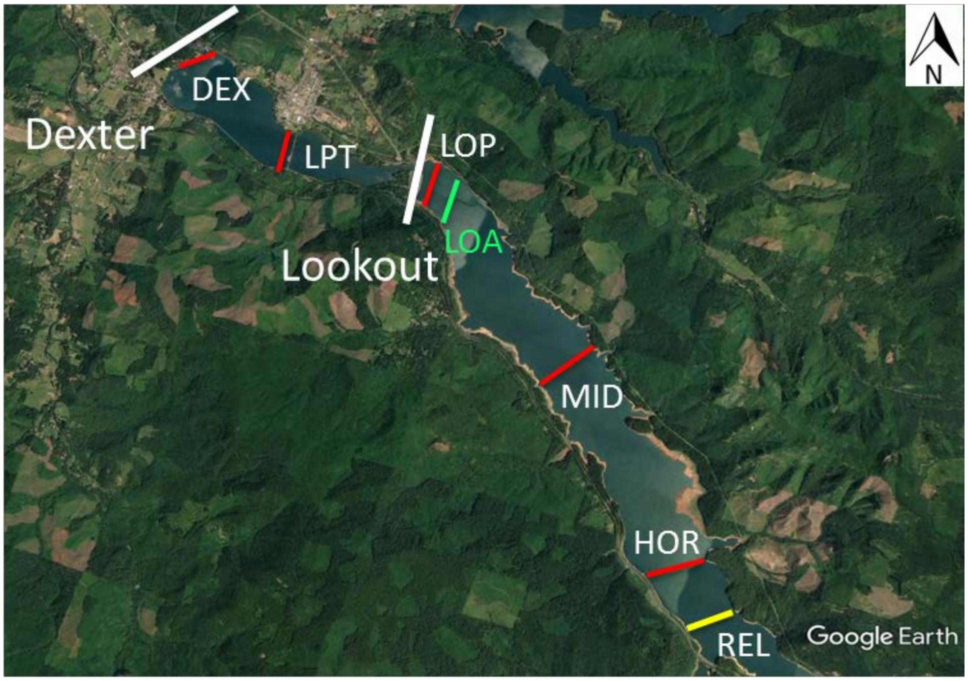

Figure S.2. Location of Receiver Arrays Deployed to Monitor Study Fish in Lookout Point and Dexter Reservoirs. The Lookout Point Approach (LOA [green legend]) array was added in spring 2017.

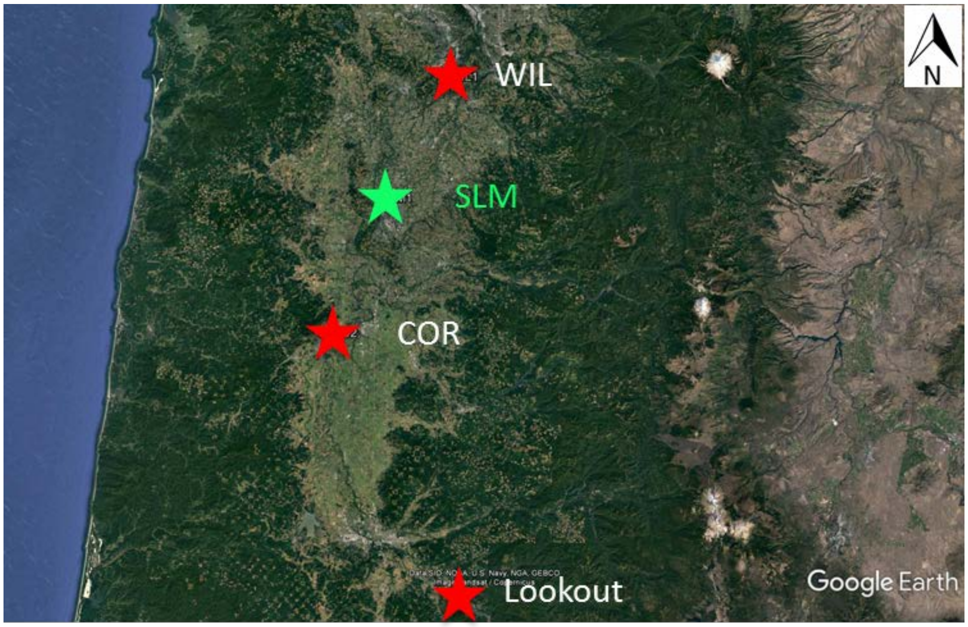

Figure S.3. Location of Receiver Arrays Deployed to Monitor Study Fish in the Willamette River below Dexter Dam. The Salem (SLM [green legend]) array was only deployed in fall 2016.

The Oregon State University (OSU) Wild Fish Surrogate Program provided study fish reared to the approximate size of wild juveniles migrating through Lookout Point. We surgically implanted both acoustic tags (Advanced Telemetry Systems, Inc. [ATS] Tag modelSS300; Isanti, MN) and passive integrated transponder (PIT) tags in study fish. Tagged juvenile Chinook salmon were released and monitored during two study periods: fall 2016 and spring 2017. During the fall period (October 3, 2016–December 30, 2016), a total of 520 subyearling Chinook salmon were tagged and released. During the spring period (March 6–June 30, 2017), a total of 549 yearling Chinook salmon were tagged and released. Detection data were used to estimate migration and passage metrics for each of the study periods. Percent detection decreased as distance from the head of the reservoir (HOR) increased during fall 2016 and spring 2017 (Figure S.4) indicating a dispersion of study fish from the point of release above HOR down to Lookout Point and Dexter Dams.

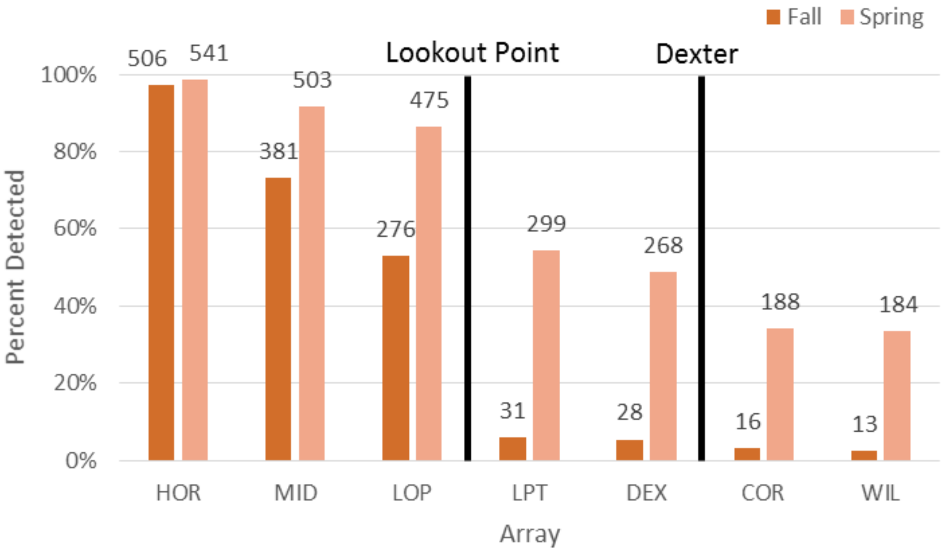

Figure S.4. Percent Detection of Tagged Juvenile Chinook Salmon during Fall 2016 and Spring 2017. The numbers of fish detected at each array are listed above the bars.

Noteworthy results include the following:

- Overall numbers of fish detected in the reservoir peaked days after release (fall and spring), but slowly diminished as the study period progressed, indicating a lack of movement.
- The horizontal distribution of study fish in fall 2016 was uniform across the HOR and Mid-reservoir (MID) arrays. During spring 2017 the north bank of both the HOR and MID arrays had the highest detection percentages (68 and 47%, respectively).
- The majority of study fish first approached Lookout Point Dam from the southern, earthen portion of the dam in both fall (87%) and spring (83%).
- Except for reservoir residence time, the forebay residence, tailrace egress, and travel times to Wilsonville were shorter for yearlings in spring than subyearlings in fall (Table S.1).
- Percent detection of subyearling Chinook salmon released in fall 2016 was low at LPT (6%) and DEX (3%).
- Spring 2017 yearling Chinook salmon percent detections were relatively high at Lookout Point Tailwater (LPT) (54%) and Dexter (DEX) (34%) compared to fall 2016 estimates.

- Low numbers of subyearling Chinook salmon passed Lookout Point and Dexter during fall 2016 (31 and 16, respectively), whereas spring study fish passed Lookout Point and Dexter in relatively high numbers (299 and 188, respectively).
- Detection efficiencies at all receiver arrays exceeded 95% for both fall 2016 and spring 2017, with the exception of the Corvallis (COR) array due to high-water events.
- Increased flows and the use of the spillway from March 14 to June 5, 2017 may have contributed to the increased passage of fish in spring 2017 compared to fall 2016.
- During spring, spill and spill + turbine accounted for the passage 37 and 145 study fish, respectively.

Table S.1. Estimated Mean Reservoir Residence, Forebay Residence, Tailrace Egress, and Travel Times in days for Study Fish for Each Study Period

Reach	**Distance (rkm)**	**Fall – Subyearling Chinook Salmon (days)**				**Spring – Yearling Chinook Salmon (days)**			
		n	**Mean**	**Median**	**SE**	**n**	**Mean**	**Median**	**SE**
Reservoir Residence[(a)]	8.5	31	8.0	3.4	2.6	299	10.8	8.0	0.6
Forebay Residence Time [(b)]	1.0	31	21.0	8.0	4.6	299	15.1	4.4	1.2
Tailrace Egress[(c)]	2.5	30	8.9	2.4	3.0	280	1.2	0.3	0.7
LOP to Primary[(d)]	6.0	15	17.3	11.2	5.4	188	1.1	1.3	0.6
Primary to Secondary [(e)]	115.5	14	1.3	1.0	0.2	106	1.2	0.8	0.1
LOP to Wilsonville[(f)]	271.0	13	13.3	12.1	3.1	184	3.9	3.6	0.7

Difference in time from:
(a) Release time to first detection at the LOP array.
(b) First detection at the LOP array to last detection at the LOP array.
(c) Last detection at the LOP array to last detection at the LPT array.
(d) Last detection at the LOP array to last detection at the DEX array.
(e) Last detection at the DEX array to last detection at the COR array.
(f) Last detection at the LOP array to last detection at the WIL array.

Acknowledgments

This study was the result of hard work by dedicated scientists from Pacific Northwest National Laboratory (PNNL), Oregon State University (OSU), the U.S. Army Corps of Engineers-Portland District (USACE), and USACE Willamette Valley Project Office (USACE WVP). Their teamwork and attention to detail, schedule, and budget were essential for the study to succeed in providing high-quality and timely results to decision-makers.

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- OSU: K Cogliati, R Coulture, C Schreck, D Noakes, R Chitwood, and the Wild Fish Surrogate Team.
- USACE: F Khan, Engineering, and Reservoir Control staff.
- USACE WVP: G Taylor, J Barrowcliff, A Naidu, C Helms, D Garletts, and operations and maintenance staff at Lookout Point Dam.

We also acknowledge the manufacturer of the tags and acoustic telemetry receivers and equipment and hardware required to accomplish this evaluation:

- Advanced Telemetry Systems (Isanti, MN) manufactured the acoustic telemetry tags, receivers and hydrophones.

Acronyms and Abbreviations

°C	degree(s) Celsius
CF	compact flash data card
AT	acoustic telemetry
ATS	Advanced Telemetry Systems, Inc.
BiOp	Biological Opinion
cfs	cubic (foot) feet per second
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
COR	Corvallis
d	day(s)
DEX	Dexter
ft	foot (feet)
g	gram(s)
h	hour(s)
HOR	head-of-reservoir
JSATS	Juvenile Salmon Acoustic Telemetry System
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
LOA	Lookout Point Approach
LOP	Lookout Point Forebay
LPT	Lookout Point Tailwater
m	meter(s)
mg	milligram(s)
mm	millimeter(s)
MID	mid-reservoir
msl	mean sea level
MW	megawatt(s)
n	number
N	absolute abundance
NMFS	National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
OSU	Oregon State University
PIT	passive integrated transponder
PITAGIS	PIT Tag Information System
PNNL	Pacific Northwest National Laboratory

PRI	pulse repetition intervals
psi	pound(s) per square inch
R	release
rkm	river kilometer(s)
RPA	Reasonable and Prudent Alternative
SE	standard error
sec or s	second(s)
SLM	Salem
USACE	U.S. Army Corps of Engineers
WIL	Wilsonville
WVP	Willamette Valley Project

Contents

Figures

Tables

1.0 Introduction

This report presents the results of an acoustic telemetry (AT) evaluation of the behavior, distribution, and passage of juvenile salmon at Lookout Point Dam (or Lookout Point) on the Middle Fork Willamette River in Oregon. The study was conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers-Portland District (USACE). The goal of this 2016–2017 research effort was to provide Action Agencies with decisional information related to Reasonable and Prudent Alternative (RPA) measures 4.8 (interim downstream fish passage through reservoirs and dams), 4.10 (downstream juvenile fish passage through reservoirs), 4.11 (downstream juvenile fish passage through dams), 4.12 (long-term fish passage solutions) and 9.3 (fish passage RM&E). These data will support management decisions on long-term measures and operations to help rebuild populations of Upper Willamette River spring Chinook salmon listed as threatened under the Endangered Species Act.

1.1 Objectives

The study addressed two life-history patterns for spring Chinook salmon in the Middle Fork Willamette River: reservoir-rearing with outmigration past Lookout Point in fall (subyearling Chinook salmon) and natal-stream rearing with outmigration past Lookout Point in spring (yearling Chinook salmon). The study area stretched from the upper Lookout Point reservoir to below Dexter. We used AT methodologies to examine juvenile Chinook migration behavior through the study area under different operational and environmental scenarios to address the following research objectives:

- Estimate seasonal and diel passage metrics (residence times and survival rates [data permitting]) for tagged fish in reaches between telemetry receiver arrays, including:
  - Lookout Point reservoir[1]
  - Lookout Point project (forebay+tailrace)[2]
  - Dexter project (forebay+tailrace).[3]
- Characterize entrance and exit timing, residence time, and horizontal distribution for tagged fish detected at each receiver array.

1.2 Background and Literature Review

The USACE is currently assessing operational and structural alternatives for downstream fish passage in the Middle Fork Willamette River, especially at Lookout Point (Figure 1.1). Most Chinook salmon enter Lookout Point reservoir as fry and must then pass Lookout Point dam, and subsequently Dexter reservoir and dam. The National Marine Fisheries Service (NMFS) 2008 Biological Opinion (BiOp) RPA contained measures for investigations for both interim reservoir survival and dam passage, future reservoir survival and dam passage, as well as investigation of head-of-reservoir collection and bypass at Lookout Point (NMFS 2008).

With respect to downstream fish passage at Lookout Point, the 2008 Willamette Project BiOp requires USACE to develop interim operations, investigate alternative structures and operations, and complete construction of feasible structures or implement passage operations by 2021 (NMFS 2008). Studies are

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[1] For purposes of this study, the Lookout Point reservoir is the reach from the HOR array to the Lookout Point Forebay (LOP) array.

[2] For purposes of this study, Lookout Point project is the reach from LOP array to the array in the Dexter forebay. There was no cabled receiver array on the face of the dam.

[3] For purposes of this study, Dexter project is the reach from the Dexter forebay to the first array below Dexter.

needed to inform decision-makers about management options that are meant to improve juvenile fish survival through the highly modified rearing and migration corridor that contains the Lookout Point flood damage reduction infrastructure under a range of feasible conditions. Specifically for 2016, a study of juvenile Chinook salmon residence times (migration rates), temporal and spatial distributions, and survival rates for reaches from Lookout Point reservoir to below Dexter will provide important information for the action agencies who are developing operational and structural alternatives per the intent of RPAs 4.8, 4.10, 4.11, 4.12 and 9.3.

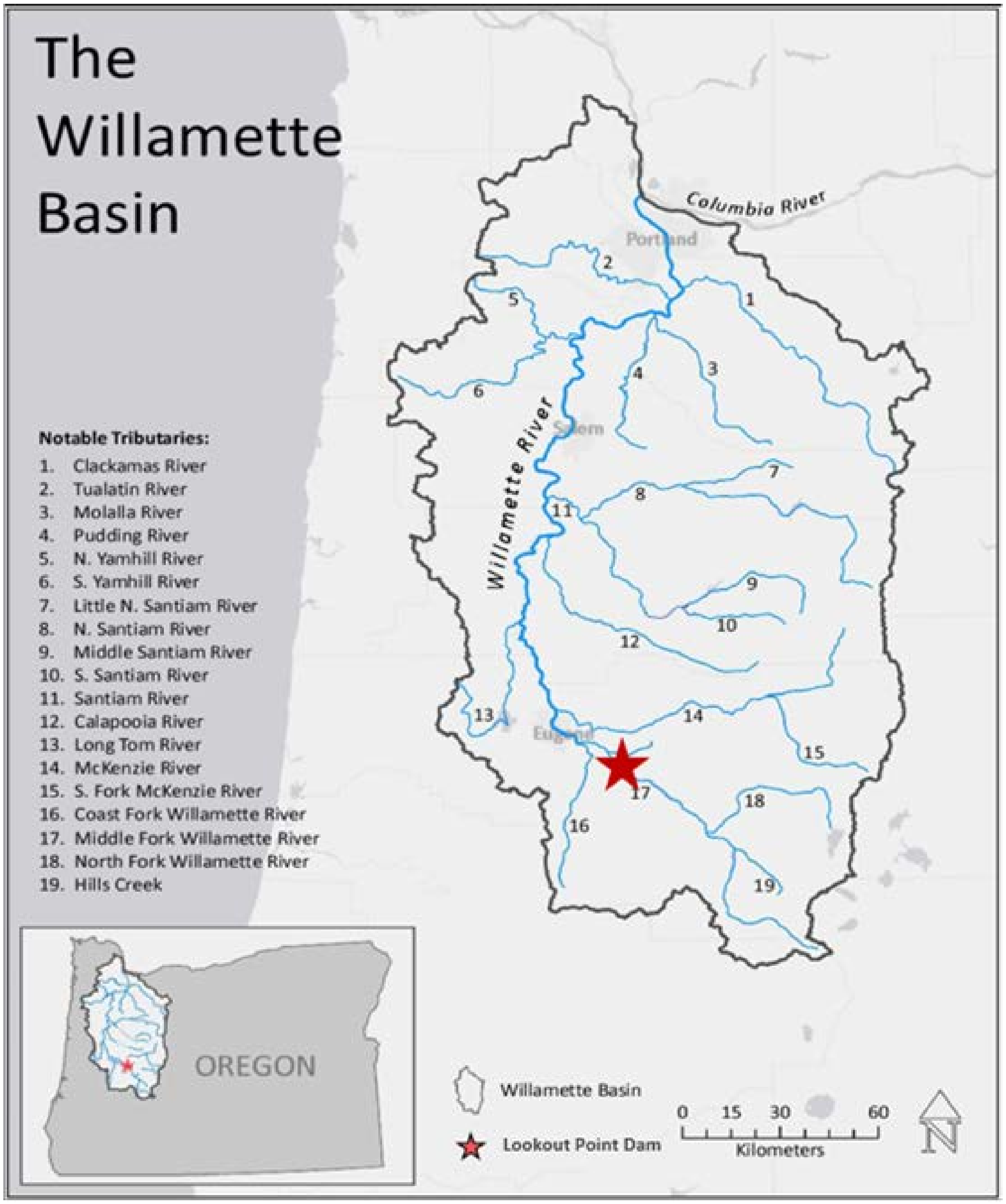

Figure 1.1. Map of the Willamette Basin Showing the Location of Lookout Point Dam

1.2.1 Previous Research at Lookout Point

Bourett et al. (2013) used analysis of isotopic ratios and natural elemental tracers in otoliths to characterize the life-history patterns of Upper Willamette River spring Chinook salmon. In the Middle Fork Willamette River in particular, their data indicated that 90% and 10% of the total adult fish studied reared in Lookout Point reservoir and in natal streams above the reservoir, respectively. They also noted other outmigration variations interpreted from isotope analysis of otoliths, such as rearing in natal streams with outmigration the following spring as yearlings, and rearing in reservoirs with outmigration in fall/winter as subyearlings.

Monzyk and Romer (2013) investigated the timing and size of juvenile Chinook salmon entering and distributing in Lookout Point reservoir during 2012. They found migration into the reservoir peaked in spring and was composed of fry-size fish. They sampled with nearshore box traps and found these fish dispersed throughout the reservoir, although catches were typically highest in the upper third of the reservoir. During 2011, Monzyk et al. (2014) applied direct capture methods and observed a skewed spatial distribution of Chinook salmon fry with the highest abundance in the upper part of Lookout Point reservoir, whereas subyearling parr and yearling fish were more uniformly distributed throughout the reservoir. The authors noted juvenile salmonids in Lookout Point reservoir were at risk of predation based on the abundance and species of predators sampled within the reservoir.

Friesen et al. (2013) studied migration characteristics of passive integrated transponder (PIT)-tagged juvenile Chinook salmon (>60 mm) released during 2012 at the head of Lookout Point reservoir and at the tailrace below Dexter. Detections at Willamette Falls were 4.5 times higher for the tailrace-released fish than for those released at the head of Lookout Point reservoir. These data, while not survival estimates per se, because the joint probabilities of surviving and being detected are confounded, do indicate substantial mortality could be occurring between the head of Lookout Point reservoir and the Dexter tailrace. This hypothesis was supported by incidental recoveries of PIT tags from study fish consumed by predators in Lookout Point reservoir.

Using the fixed-aspect hydroacoustic technique, Khan et al. (2012) found fish passage rates for smolt-size fish (approximately 90–300 mm fork length) were lowest in mid-summer through early fall and highest during December–January. Passage peaks were also evident in early spring and early summer at Lookout Point. Run timing for small-size fish (approximately 65–90 mm) peaked in December. Downstream passage of small-size juvenile fish was variable and most of them passed during late fall and winter. In a similar year-long study during 2011 at Detroit Dam on the North Santiam River, Khan et al. (2012) found turbine passage rates for smolt-size fish was highest during late fall, winter, and early spring months. Similarly to Lookout Point, dam passage at Detroit Dam was lowest during summer months.

Keefer et al. (2013) hypothesized that reservoir/dam operations during spring and summer for annual refill of the reservoir inhibited downstream movements of juvenile salmonids. In general, juvenile salmon migration rates into reservoirs from natal areas were highest in late winter to early summer, whereas passage rates through the dams were highest in late fall and winter. Keefer et al. (2013) noted that better understanding of cues or environmental conditions that influence residualism and outmigration timing in this reservoir will directly inform passage options. The study described herein is intended to help address this need.

1.3 Study Site Description

Lookout Point Dam (Figure 1.2) is located on the Middle Fork Willamette River approximately 22 miles southeast of Eugene, Oregon. The congressionally authorized purpose of Lookout Point is to provide for and ensure flood risk reduction, power generation, irrigation, recreation, navigation, and water quality of the river. The dam has a powerhouse with three Francis turbine units each with one penstock, a total generating capacity of 120 MW, and a total hydraulic capacity of 9,300 cfs. The dam has a spillway with five spill bays and four regulating outlets (Figure 1.2). Operation of the spill bays (spillway crest 887.5 ft) and regulating outlets depends on forebay pool elevation, turbine operations, runoff conditions, season, and other factors. The maximum forebay pool elevation is rated at 929 ft (relative to mean sea level [msl]) and the minimum conservation pool is 825 ft (http://www.nwd-wc.usace.army.mil/report/lop.htm).

Figure 1.2. Aerial Photograph of Lookout Point Dam (courtesy of the USACE [http://www.nwd-wc.usace.army.mil/dd/common/projects/www/pics/lop.jpg])

1.4 Report Contents

The ensuing sections of this report describe the study methods (Section 2.0), environment results (Section 3.0), fish passage results (Sections 4.0 and 5.0), discussion (Section 6.0), conclusions and recommendations (Section 7.0), and a list of the literature cited (Section 8.0). Appendix A contains fish-tagging and release tables.

2.0 Methods

The general approach; release and recapture design and sample sizes; tag specifications; fish handling, tagging, and release procedures; study fish detection capabilities; and data processing and statistical methods pertinent to the study are described in the following sections.

2.1 General Approach

Acoustic telemetry technology was applied to accomplish the objectives of this study. The general approach involved a multi-step process from autonomous receiver configuration, mount design, and testing through final system deployment configuration. First, suitable locations were determined throughout the Lookout Point reservoir, Dexter reservoir and Willamette River. Second, receivers were deployed at these locations. Third, all hydrophones, were tested to determine detection ranges and efficiencies. Fourth, the optimum configuration for each array was established. Finally, juvenile Chinook salmon were tagged and released during fall 2016 and spring 2017 to estimate passage metrics and behavior through Lookout Point.

2.2 Release-Recapture Design and Sample Size

The single-release-recapture design was used to estimate passage metrics and behavior for this study. Fish were double-tagged with acoustic and PIT tags and released into the head of the Lookout Point reservoir. The forebay entrance array (LOP) served as the detection array above Lookout Point to regroup fish into a virtual release group of fish known to have arrived alive after being released at the head of the reservoir (Figure 2.1). Survival of fish included passage through the immediate Lookout Point forebay, Lookout Point Dam, and travel through 5 rkm of tailwaters to the primary array. Capture histories were compiled from detections at all receiver arrays above and below Lookout Point. Tailwater detections consisted of arrays of receivers at the primary array (DEX) and secondary array (COR) in combination with the tertiary arrays (SLM and WIL) to estimate the combined probability of detection and survival ($\hat{\lambda}$).

A total of 520 double-tagged (AT and PIT) subyearling Chinook salmon (CH0) were released during the fall 2016 study period (Table 2.1). The mean fork length and weight of released CH0 were 148.1 mm and 38.6 g, respectively. A total of 549 yearling Chinook salmon (CH1) were released during the spring 2017 study period (Table 2.1). The mean fork length and weight of CH1 were 199.9 mm and 82.6 g, respectively.

For each study period (fall 2016 and spring 2017), 60 dead fish with active AT transmitters were released into the Lookout Point tailrace. These fish were released to test the assumption that downstream detection arrays were distant enough from Lookout Point, so fish passage mortalities at Lookout Point would not be misidentified as active migrants if dead fish were carried by river flow through downstream arrays where their transmitters would be detected. Such detections would upwardly bias survival estimates.

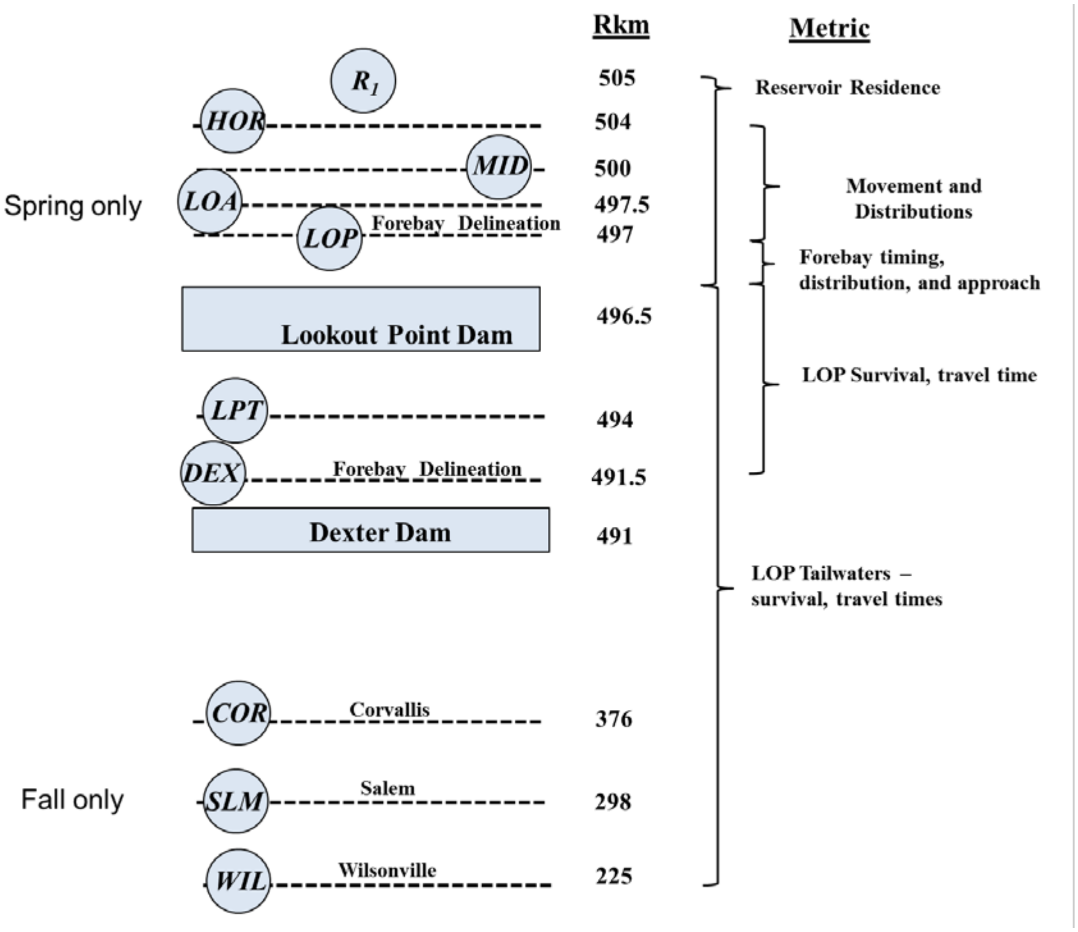

Figure 2.1. Schematic of the Study Design Used to Estimate Project Metrics at Lookout Point. The release (R_1) was tracked at three locations in the Lookout Point reservoir to assess movement and behavior (HOR, MID, LOA [Spring], and LOP) and the LOP array served as the final detection array above Lookout Point. Downstream detection arrays in the Lookout Point reservoir were used to estimate tailrace egress (LPT) and reservoir travel times. Detection arrays in Corvallis (COR), Salem (SLM [Fall]), and Wilsonville (WIL) were used to account for fish moving through the Middle Fork and mainstem Willamette River.

Table 2.1. Total Number and Mean Fork Length and Weight of Juvenile Salmonids Tagged and Released during 2016–2017. All living fish were released at three points along a transect at the head of the reservoir (HOR) All dead fish were released into the Lookout Point Tailrace from the downstream end of the powerhouse at Lookout Point Dam.

Season	Type	Release Date	Release Location	n	Mean Length (mm)	Mean Weight (g)
FALL 2016	Subyearling Chinook (CH0)	October 4	HOR	108	147.6	38.9
			Tailrace	12	147.9	38.9
		October 5	HOR	106	148.1	38.3
			Tailrace	14	147.3	36.9
		October 6	HOR	108	148.8	39.1
			Tailrace	11	151.2	41.4
		October 7	HOR	108	147.3	38.2
			Tailrace	12	148.8	38.1
		October 8	HOR	90	149.0	38.6
			Tailrace	11	145.6	36.0
		Total		580	148.1	38.6
SPRING 2017	Yearling Chinook (CH1)	March 7	HOR	136	197.2	81.6
			Tailrace	16	189.9	70.3
		March 8	HOR	137	200.8	83.1
			Tailrace	15	193.5	72.5
		March 9	HOR	137	199.0	80.4
			Tailrace	15	204.1	82.1
		March 10	HOR	139	202.3	85.2
			Tailrace	14	196.9	77.1
		Total		609	199.5	81.9

2.3 Tag Specifications and Radio Frequencies

Advanced Telemetry Systems (ATS) tags, SS300 (model 379; Isanti, MN) and PIT tags (Figure 2.2) were used for both the fall and spring studies. The physical dimensions of the SS300 acoustic tag were 6.3 × 3.6 × 11.7 mm (width, height, length); the in-air weight was 0.42 g. Tags had a nominal pulse repetition interval (PRI) of 7 s; a subset of 50 tags had PRIs 10 s. The latter allowed us to extend the monitoring time during fall 2016 for the subyearling fish. Average battery life was 102 days and 142 days, respectively. (See Section 2.8.2 for a description of the tag-life analysis.)

Figure 2.2. Acoustic Tag (ATS SS300; bottom) and PIT Tag (top) Surgically Implanted in Subyearling and Yearling Chinook Salmon in 2016 and 2017

2.4 Fish Handling, Tagging, and Release Procedures

The OSU Wild Fish Surrogate Program provided the study fish. The fish were reared to the approximate size of wild juveniles migrating through Lookout Point and were tagged at OSU facilities to alleviate the stress of pre-surgery transport and holding.

The study fish were surgically implanted with both an ATS model SS300 (Isanti, MN) tag and a PIT tag. The research team used the protocols set forth by the Columbia River Basin surgical protocols steering committee (Axel et al. 2011). The use of AQUI-S® as a fish anesthetic in this research was approved by the U.S. Fish and Wildlife Service's Aquatic Animal Drug Approval Partnership Program (study number 11-741-14-209F) in cooperation with the U.S. Food and Drug Administration's Investigational New Animal Drug program. Both federal and state take permits were obtained for this study and all requirements of said permits were abided by (Federal–NMFS permit PNNL217 and ODFW permit 20677/21144).

Steps were taken to minimize the impacts of handling the study fish during surgical procedures. First, fish were netted in small groups from pre-surgery holding tanks and placed in 10 L of river water containing a 350 mg/L solution of AQUI-S®20E (Aqui-S New Zealand Ltd, Lower Hutt, New Zealand), which provided fish with a 35 mg/L anesthetic dose of the active ingredient, eugenol. Once a fish lost equilibrium, it was transferred to a data collection/processing table in a small transfer container of river water and anesthetic. Using a multi-step process, each fish was weighed and measured, assigned a bucket and release location, assigned an acoustic tag and PIT tag, then returned to the small transfer container. Tagging information was added automatically to the tagging database using "P3" software from the PIT Tag Information System (PITAGIS). Finally, fish were transferred to their assigned surgeons for tag implantation.

During surgery, each fish was placed ventral side up and a gravity-fed supply of fresh river water was provided through tubing into the fish's mouth. As necessary, "maintenance" anesthetic (up to 15 mg/L of eugenol; 150 mg/L Aqui-S 20E) was administered through the same gravity-fed supply line. Using a 15º, 3.0 mm-depth microsurgical stab blade, a 5–7 mm long incision was made on the linea alba, 5 to 10 mm anterior of the pelvic girdle. A PIT tag was inserted, followed by the acoustic tag with the acoustic element pointing posteriorly. The incision was closed with two interrupted stitches using 4-0 Ethicon Monocryl® monofilament sutures with a reverse cutting needle. Stitches were secured with a knot consisting of four single-wrap throws in alternating directions.

An established protocol, described herein, was used to help minimize any potential negative impacts of surgical procedures and handling. All metal surgical tools (needle holders and forceps) were autoclaved prior to the start of each tagging day. After using the surgical tools on a single fish, the tools were disinfected or autoclaved prior to reuse. Needle holders and forceps were disinfected in a hot bead sterilizer for 30 seconds, while suture material and needles were disinfected with ultraviolet light for 2 minutes (Walker et al. 2013). Blades were disinfected with ultraviolet light for 5 minutes. PolyAqua® was applied liberally on all surfaces that came in direct contact with the fish to protect the fish's mucus membrane, reduce the possibility of infection, and to aid in healing. Water in both the anesthesia and recovery buckets was refreshed when necessary to maintain temperatures within ±2°C of the freshwater source.

The tagging process required a team of four to five people to conduct daily operations and all strived to ensure that tagged fish were handled as efficiently and carefully as possible. Tagged fish were held approximately 18 hours post-surgery to ensure short-term effects of the surgical process had dissipated.

Prior to releasing the fish, transport buckets were removed from the post-surgery holding tanks and placed in Bonar transportation totes, which hold up to 18 fish buckets. A network of valves and plastic tubing was attached to a 2,000 psi oxygen tank to deliver oxygen to the totes during transport. A YSI meter was used to monitor dissolved oxygen concentrations and water temperatures in the totes before and during transport to ensure that those parameters remained within acceptable limits (80–110% for dissolved oxygen, ±2°C for fresh water supply). If measurements approached unacceptable limits, staff adjusted the flow of oxygen to the tanks or added ice to the river water in the tanks to reduce the temperature.

Upon arriving at the reservoir, fish buckets were transferred to a boat for transport to in-river release locations at each release cross section. Fish were released at one transect upstream of the Signal Point Boat Ramp in the Lookout Point reservoir (Figure 2.3). The transect consisted of three equidistant points. At each release point, all buckets to be released were set apart and the lids were scanned using a Biomark HPR Plus PIT-tag reader, which recorded the global positioning system coordinates and time of release. Just before fish were released in the river, the buckets were opened to check for dead or moribund fish. If dead or moribund fish were observed, they were removed and their PIT codes were noted on the release sheet. All remaining fish were then lowered in the bucket over the side of the boat into the water and allowed to swim out of the bucket into the reservoir.

Figure 2.3. Release Location at Lookout Point Reservoir, 9.5 km from the Dam

2.5 Detection of Fish Implanted with Acoustic Tags

Juvenile Salmon Acoustic Telemetry System (JSATS) receivers deployed in Lookout Point reservoir, Dexter reservoir, and in downstream locations enabled the detection of tagged fish throughout the Lookout Point reservoir, downstream into the Dexter reservoir, and throughout the Middle Fork and mainstem Willamette River. Table 2.2 lists the array locations used for the fall 2016 and spring 2017 AT studies at Lookout Point.

Table 2.2. Acoustic Telemetry Receiver Deployment Location and Study Purpose

Array Location	Receivers per Array	Rkm	Study Purpose
Head-of-Reservoir (HOR)	6	504	Movement and distribution
Mid-Reservoir (MID)	7	500	Movement and distribution
Lookout Point Approach (LOA)[a]	5	497.5	Movement and distribution
Lookout Point Forebay (LOP)	7	497	Movement and distribution
Lookout Point Tailwater (LPT)	2	494	Survival and travel times
Dexter Forebay (DEX)	3	491.5	Survival and travel times
Corvallis (COR)	4	376	Survival and travel times
Salem (SLM)[b]	4	298	Survival and travel times
Wilsonville (WIL)	4	225	Survival and travel times

(a) The Lookout Point Approach array was added for the spring study period only.
(b) The Salem array was removed during fall due to debris loading.

The autonomous receivers used for this study (referred to as an “autonomous node” or “node”), were designed by ATS for detection of acoustic tags in a riverine environment. Each node—an independent, self-contained data-acquisition instrument that may be anchored in the river where necessary—consists of a top section that houses a hydrophone (Sonic Concepts, Inc.), a data processing circuit board, a compact flash card for data storage, an internal battery housing and battery, and USB cable connectors (Figure 2.4). An external beacon (an acoustic tag with a larger battery in a cylindrical housing) and stabilizing fin were attached to the outside of the housing to stabilize the node, shed turbulence, and to maintain positioning of the hydrophone tip toward the water surface. All hydrophones and receivers were calibrated and tested for acceptable detection performance in a specialized anechoic testing tank prior to deployment.

Figure 2.4. Outer (left) and Internal (right) Views of an Autonomous Node

Eight autonomous node arrays were deployed for the Lookout Point study. One array in Salem was deployed during early fall, but as river levels rose, heavy debris loads and dangerous river conditions forced the removal of that array prior to the late fall and spring study. In most cases the node arrays consisted of a series of autonomous nodes deployed on the riverbed, across the entire width of the river cross section, perpendicular to the river flow, and spaced to detect the tagged fish as they approached, crossed, and moved downstream through the cross section containing the array. Each array acts as a "passage gate," detecting tagged fish as they pass. Autonomous nodes were typically deployed at 150 m intervals and less than about 75 m from each shore. In general, the maximum range for efficient detection of acoustic tags is approximately 150 m. Each array was named by the location of the array or its intended purpose. At the Corvallis location, four hydrophones were affixed to mounts that were strapped to wooden pilings located along the OSU rowing dock (Figure 2.5). Extensive testing of this array indicated that this array could detect acoustic tags bank-to-bank and approximately 150 m upstream and downstream. These hydrophones were spaced 15–30 m apart and ran parallel to the river flows. Each hydrophone was attached to a data cable that ran up the bank to a box containing the battery-controlled receiver data instrumentation.

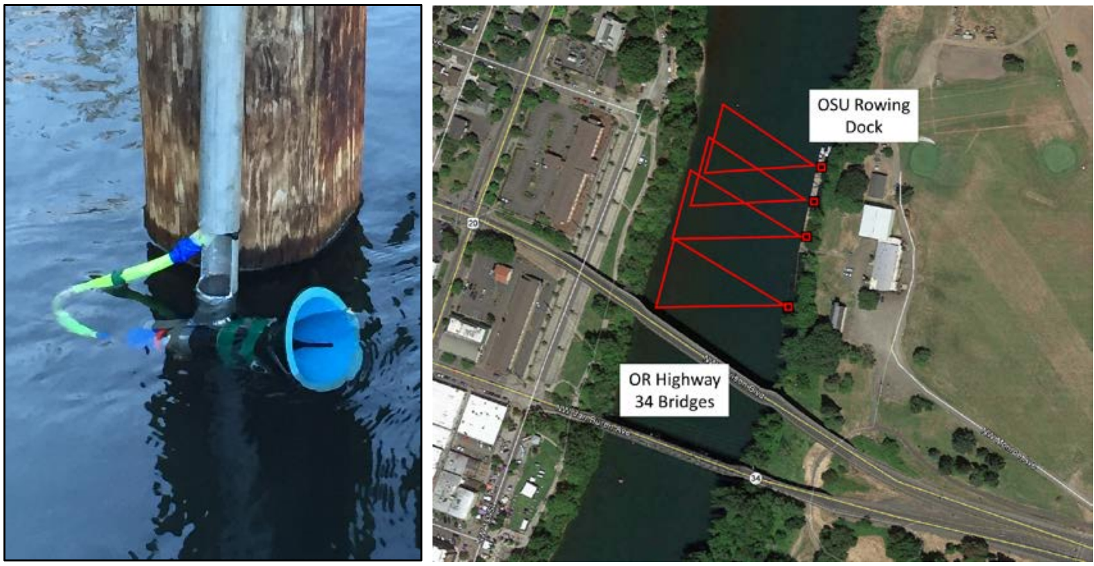

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Figure 2.5. Mount Used to Hold Acoustic Hydrophone to Pilings (Left) at the OSU Rowing Docks (Right) on the Willamette River with Detection Zones (outlined in red)

The rigging used to deploy autonomous nodes was similar to that described by Titzler et al. (2010; Figure 2.6). Nodes were attached to an acoustic release (Model 111, InterOcean Systems, San Diego, CA) using a 1.5 m section of rope with three 2.7 kg buoyancy floats. The rope was secured to the node via an eyebolt located on a compression strap around the node housing at its balance point. A length of wire rope measuring 0.3, 1.0, or 2.0 m connected the acoustic release to a 34 kg steel anchor. The 0.3 m length of wire rope is used in depths less than approximately 7.0 m; the 1.0 m length is used in depths between 7.0 and 20.0 m; and the 2.0 m length is used in deeper locations.

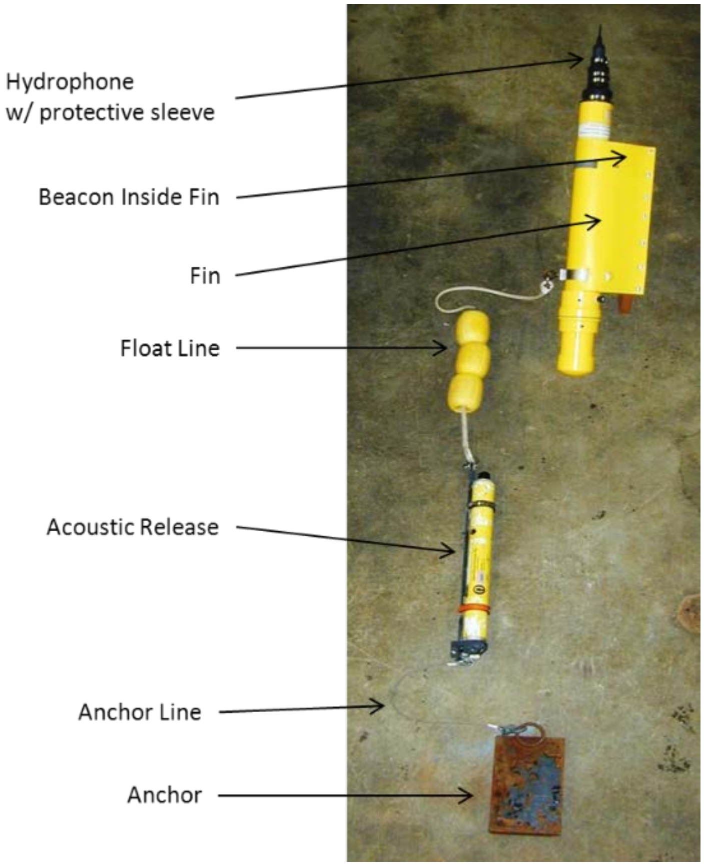

Figure 2.6. Autonomous Node Deployment Rigging with an InterOcean Acoustic Release

Autonomous nodes were recovered, serviced, and redeployed individually once every 3 weeks. The boat crew recovered the nodes by transmitting a command signal to the acoustic release, which caused a latch mechanism attached to the anchor line to open. Once the anchor is released, the rigging floats and the positive buoyancy of the node conveys the node, acoustic release, and upper rigging to the water surface. After recovery, nodes were serviced using the following process: 1) any deviation in the internal clock time for the deployment period was noted, 2) collected data was downloaded, 3) battery pack was replaced, and 4) node clock was synchronized to the correct satellite time. After confirming the proper functionality of each node, an anchor was attached and the node was redeployed. Data files were reviewed to verify that information was collected during the entire deployment, records were continuous, and that the records included correct date/time stamps and beacon detections. If operational issues or data corruption were noticed, the node was removed from service and replaced with a properly functioning node; the removed node was tested for performance after return to shore and repaired if necessary prior to future use. The most common problems experienced in 2016–2017 were damage to the node’s exposed hydrophone tip, water intrusion, or occasional acoustic release malfunctions.

During the studies, all autonomous node arrays were deployed and confirmed to be collecting data before any surgically implanted fish were released into the reservoir. Nodes remained in service through the end of each study period (December for the fall 2016 study and the end of June for the spring 2017 study), to ensure that any tagged fish that might still be migrating would be detected up until the expected depletion of the battery life of the acoustic tags (i.e., ~100 days).

2.6 Data Acquisition

All data acquired during fall 2016 and spring 2017 came from trident receivers from Advanced Telemetry Systems equipped with hydrophones from Sonic Concepts. Data from all receivers were downloaded every 3 weeks from compact flash (CF) cards and checked for data consistencies. Data were copied from the CF cards to a computer and immediately backed up to an external hard drive while in the field. All data sheets were scanned once back in Richland, Washington, and all scanned sheets and data were backed up to a server at PNNL. Once all data were confirmed to be backed up, the CF cards were then wiped of all data and prepared for reuse.

2.7 Data Processing

Autonomous array signals were processed by filtering decoded signals and then using the decoded signals to determine if tagged fish had passed through the array. Reception of the tags' encoded signals to the CF card in the autonomous node was processed to produce a data set of acceptable (true positive) detection events. A single file was processed at a time, and no information about reception at other nodes was used. The following filters were used during processing of autonomous node data:

- Multipath Filter: Tag code receptions that occur within 0.156 s after an initial identical tag code reception on an individual hydrophone were deleted. This was done assuming that repetitive reception of the same coded signal spaced closely in time is the result of the sequential arrival of an encoded signal from a single transmission by a tag for which the first reception is the signal that traveled via a direct path from the transmitter to the receiver and any closely spaced identical signal was a signal that traveled along a longer path that included reflection from the water surface or bottom. Initial code receptions, assumed to be direct path signals, were retained.
- PRI Filter: Only the series of receptions of a tag code that were consistent with the pattern of transmissions from a properly functioning tag were retained. Each code was processed individually, and it was assumed that only a single tag would be transmitting that code at any given time. At least four messages passing the PRI filter were required to form an acceptable (true positive) detection event.

The results of applying data processing filters to autonomous receivers was events of accepted tag detections for all times and locations when autonomous nodes were operating. Each unique event record in a data set was annotated with information that included the unique identification number of the tag carried by a fish, the first and last detection time of the tag in the event, the location where the detection occurred, and the messages within the event. An important quality control step was examination of the chronology of detections of tagged fish on arrays to locate any detection sequences that deviated from the expected movement of fish through receiver arrays.

During spring, to compensate for the lack of hydrophones on the face of Lookout Point, we used the last detection of fish at the LOP receiver array and the first detection at the LPT array to assign a passage route at Lookout Point. This method required consistency of dam operations at the project during the time period between last detection at the LOP array and first detection at the LPT array.

2.8 Statistical Methods

Statistical methods used for this investigation are summarized in the following sections.

2.8.1 Tag-Life Analysis

JSATS tags were randomly sampled from one production lot (ATS SS300 [model 379]) of 20 tags, 15 tags with a PRI of 7 seconds and 5 tags with a PRI of 10 seconds for an assessment of tag operational life. The tags were activated and monitored continuously until their batteries no longer provided enough power to transmit signals. Post-processing software calculated the number of hourly decodes for each transmitter, allowing the times that transmitters stopped working to be determined within ± 1 h.

2.8.2 Detection of Dead Fish on Downstream Arrays

In fall 2016 and spring 2017, dead fish with active tags were released daily during fish releases from the lower powerhouse deck at Lookout Point Dam. They were released to test the assumption that downstream detection arrays were distant enough from Lookout Point that fish mortalities at Lookout Point would not be misidentified as active migrants if they were carried by river flow through downstream arrays where their tags would be detected.

2.8.3 Estimation of Travel Times

The estimated travel times were based on the time from the first detection at any given array to the last detection at the next array. Both the arithmetic average and the median were calculated for all travel times. Travel times associated with reservoir residence, project egress, etc., were estimated using arithmetic averages, i.e.,

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n}, \qquad (2.1)$$

with the variance of $\bar{t}$ estimated by

$$Var(\bar{t}) = \frac{\sum_{i=1}^{n} \left(t_i - \bar{t}\right)^2}{n(n-1)}, \qquad (2.2)$$

where t_i was the travel time of the i^{th} fish $(i = 1,\ldots,n)$.

2.8.4 Analysis of Survival

Survival through Lookout Point and Dexter could not be estimated due to the lack of fish passage at the two projects. Few fish were detected below Lookout Point and Dexter. These low numbers would not allow for estimates to be calculated within the acceptable confidence limits. Equally as important, the total number of fish passing the LOP array (dead or alive) could not be confirmed without JSATS hydrophones being deployed on the Lookout Point dam face. Without this confirmation, the exact number of fish passing Lookout Point is unknown (all that is known are the numbers of live fish passing the LOP array) and therefore survival could not be estimated.

3.0 Results

Study results cover “winter pool” in fall 2016 and “spring refill” in spring 2017 (Table 3.1). Fish passage study results presented in Sections 4.0 and 5.0 also pertain to these seasonal study periods.

Table 3.1. Fall 2016 and Spring 2017 Study Periods

Season	Pool Elevation (ft)	Study Period
Fall	Winter Pool	10/4–12/31/16
Spring	Spring Refill	3/7–6/30/17

3.1 Environmental Conditions

Data collected on environmental conditions included forebay elevation by operational/seasonal periods, forebay temperature, and project discharge. Discharge and forebay temperature data were provided courtesy of the USACE Willamette Valley Project operations office.

3.1.1 Forebay Elevation and Temperature

The Lookout Point forebay elevation follows a rule curve managed by the USACE Reservoir Control Center. The rule curve dictates lowering the forebay pool elevation in fall to prepare for storage and flood damage reduction during winter months. Generally, the fall drawdown begins on or after September 1 and refill begins on or around February 1. Any deviations in the timing of refill and drawdown periods are coordinated through the Reservoir Control and local stakeholders.

During spring 2016, warm, dry conditions persisted over much of the Willamette Valley; these conditions did not allow most of the reservoirs in the Willamette Valley to fill to normal summer pool elevations. When the fall drawdown started in September 2016, water levels were already very low. By the time the fish releases occurred in October the Lookout Point reservoir had reached the winter pool elevation of 825 ft (Figure 3.1). The Lookout Point reservoir remained low until the beginning of February, when water levels started to rise. When fish releases occurred in early March the reservoir was filling rapidly. Several large rain and late seasonal snow events in early spring caused the reservoir to fill quicker than anticipated, and efforts to maintain water levels close to the rule curve required several days of additional spill. The Lookout Point reservoir reached summer full pool (926 ft) in early May and was maintained throughout the remainder of the spring study.

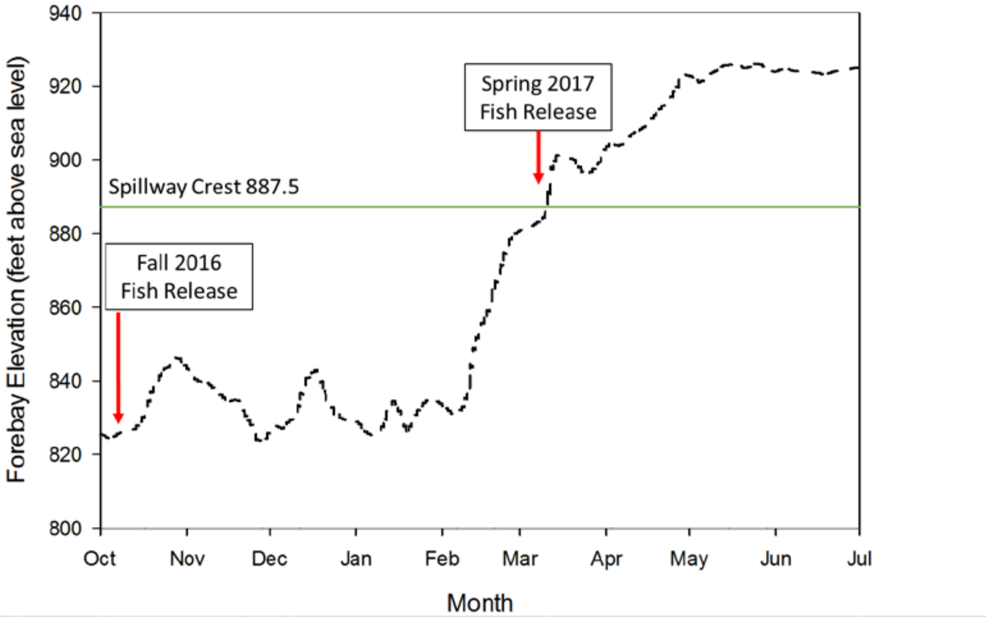

Figure 3.1. Forebay Elevation (msl) during the Study Period (October 2016 through June 2017)

Forebay temperature string data that recorded hourly temperature data at depths ranging from 0.5–200 ft were obtained (Figure 3.2). From October 2016–June 2017, temperatures throughout the water column ranged from 1–19.5°C. The reservoir was still stratified at the beginning of October 2016, began to mix in November, and had “turned over” by December. Water temperatures remained isothermal throughout the water column until late April–May, when surface temperatures began to increase.

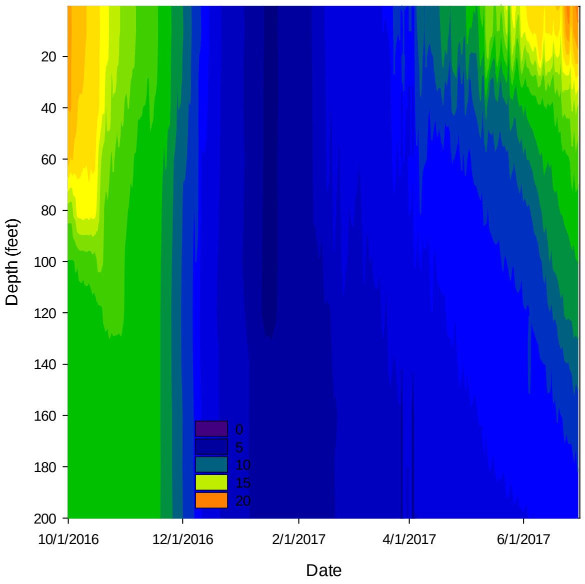

Figure 3.2. Daily Average Temperature (°C) at Depth in the Forebay at Lookout Point Reservoir from October 1, 2016 through June 30, 2017

3.1.2 Lookout Point Project Discharge and Operations

Turbine operations at Lookout Point Dam generally vary throughout the year depending on power demand, maintenance schedules, and forebay fluctuations. Turbine operations also vary greatly during a given 24 h period; it is common for power generation to fluctuate on and off daily. During the fall study period, turbine hourly discharge ranged from 0 cfs to a peak of 9,510 cfs in December 2016 (Figure 3.3). During the spring study period several large rain and snow events occurred, which caused the Lookout Point reservoir to fill rapidly and, at times, exceed the rule curve. During these times, powerhouse generation fluctuated with discharge between 0 cfs and a peak in April of 9,100 cfs and at times excess water was also released through the spillway in an effort to maintain approved water levels (Figure 3.4)

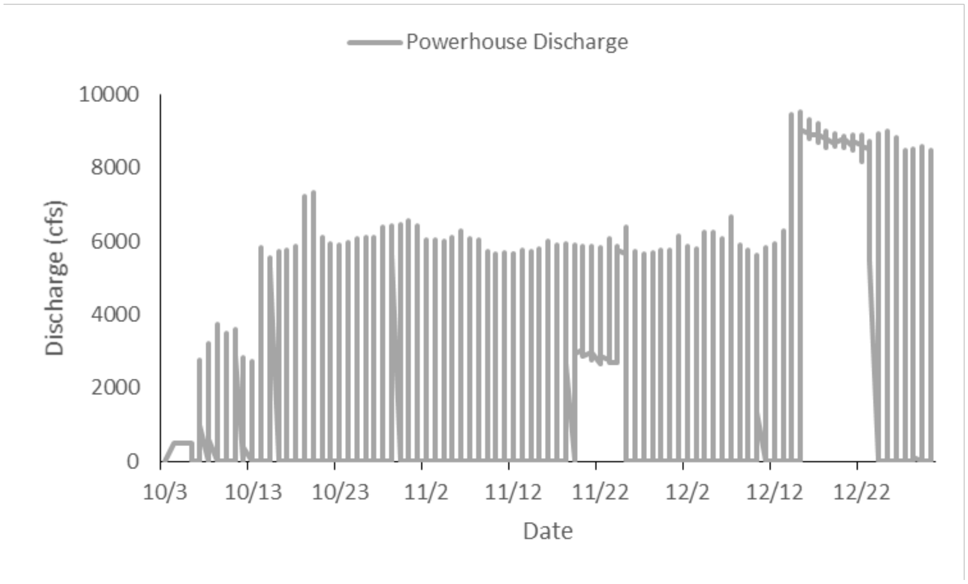

Figure 3.3. Average Hourly Powerhouse Discharge for Each Day of the Fall Study Period (October 4 through December 31, 2016)

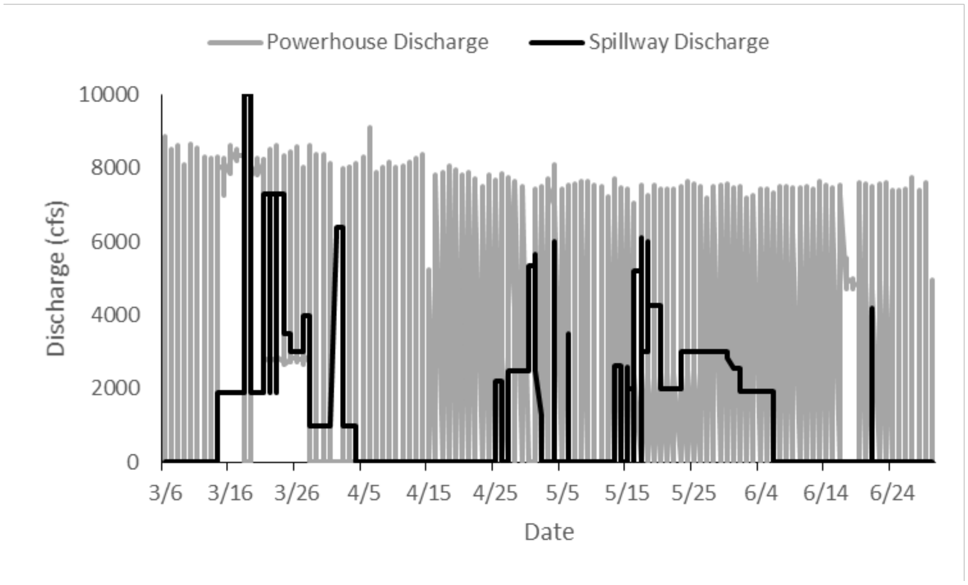

Figure 3.4. Average Hourly Powerhouse Discharge and Average Hourly Spillway Discharge for Each Day of the Spring Study Period (March 7 through June 30, 2017)

3.1.3 Dexter Project Discharge and Operations

Operations at Dexter Dam also varied throughout the year depending on power demand, water availability and maintenance schedules. Unlike Lookout Point Dam, turbine operations at Dexter Dam are more uniform during a given 24 h period. The spillway at Dexter was also used at sporadic times to pass excess water downstream. During the fall study period, turbine hourly discharge ranged from 0 cfs to a peak of 4,400 cfs in December 2016 with spillway discharge ranging from 0 cfs to a peak of 5,970 in December 2016 (Figure 3-5). During the spring study period, as noted above, several large rain and snow events occurred, which caused excess water to be passed through both Lookout Point and Dexter Dams. During these times at Dexter Dam, powerhouse generation fluctuated with discharge between 0 cfs and a peak in April of 6,400 cfs and at times excess water was also released through the spillway in an effort to maintain appropriate forebay elevation (Figure 3.6).

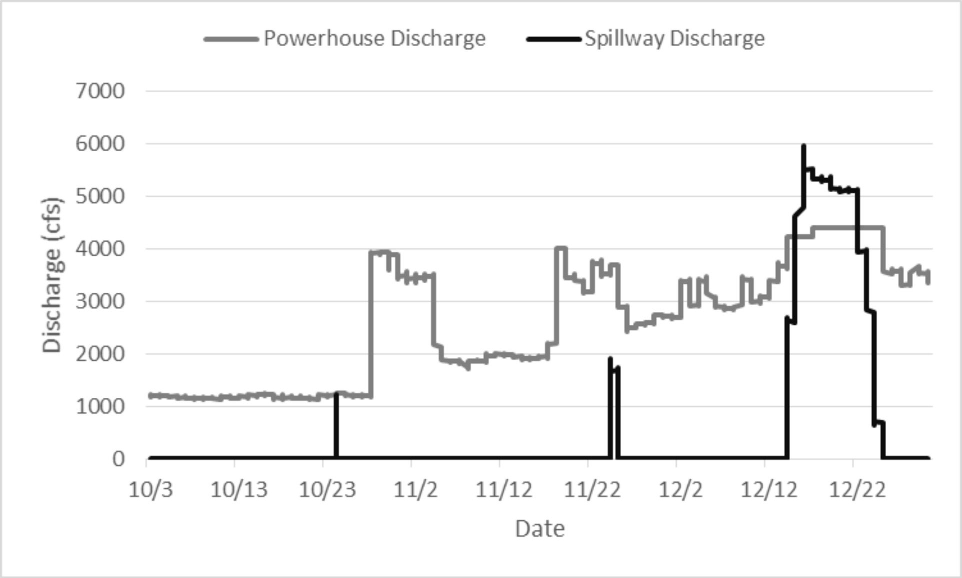

Figure 3.5. Range of Hourly Powerhouse and Spillway Discharge for Each Day of the Fall Study Period (October 4 through December 31, 2016)

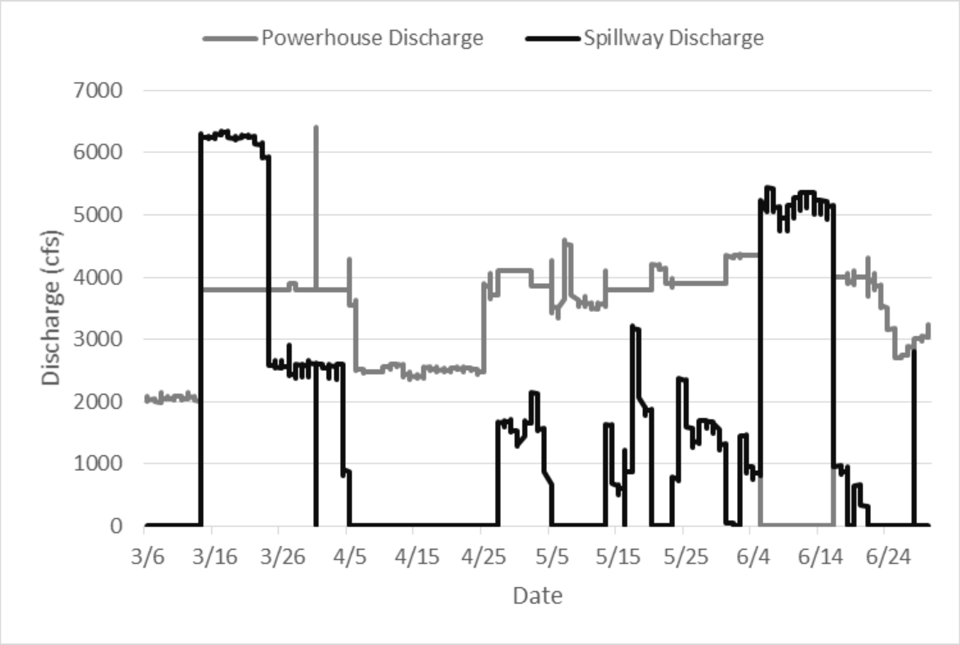

Figure 3.6. Range of Hourly Powerhouse and Spillway Discharge for Each Day of the Spring Study Period (March 7 through June 30, 2017)

3.2 Tag Life Analysis

In the fall of 2016, tag life was evaluated by randomly sampling tags from one production lot and monitoring them continuously until tag failure. As this was the first acoustic telemetry study conducted in the Lookout Point reservoir, two separate PRIs were selected. The majority of fish tagged (969) utilized the 7 sec PRI with a small subset (100) of 10 sec tags. The mean tag life of the 15–7 sec PRI tags was determined to be 101.7 ± 1.4 d (mean ± SE), while the mean tag life of the 5–10 sec PRI tags was 142.2 ± 3.5 d (mean ± SE).

3.3 Dead Fish Releases

In fall 2016 and spring 2017, dead fish with active tags were released daily during fish releases from the lower powerhouse deck at Lookout Point Dam (Table 2.1). Of the 120 fish released into the tailrace of Lookout Point Dam none were detected on the DEX primary survival array located 4 km downstream of Lookout Point Dam.

4.0 Results – Subyearling Chinook Salmon

This chapter contains information about reservoir movement, behavior, travel times, downstream migration, and survival of subyearling Chinook salmon (CH0) at Lookout Point in fall 2016. Appendix A provides additional information about fish-tagging/release tables.

4.1 Reservoir Movement and Behavior

The following sections provide results on movement and behavior in the Lookout Point reservoir.

4.1.1 Daily Reservoir Movement.

In fall (October–December) 2016, a total of 520 CH0 were released into Lookout Point reservoir, 9.5 km upstream of the dam. Most of fish (97%) were detected at the HOR array early in October before distributing throughout the reservoir. Relatively consistent proportions were detected at each of the two downstream arrays in the reservoir in subsequent weeks (Figure 4.1). Fish detection numbers declined dramatically 20 days into the study and gradually decreased thereafter. During the fall, fish movement within the Lookout reservoir varied between individual fish. The overall trend in movement of study fish was from upstream to downstream with just over 50% of all fish released being detected on the Lookout forebay array (LOP). However, upstream movement of study fish was also observed. Three random fish were chosen to create plots of movement within the Lookout reservoir (Figure 4.2) to illustrate the varied movement. This upstream-downstream-upstream movement of fish within the reservoir was typical in-reservoir behavior for most study fish, in particular those that did not pass Lookout Point.

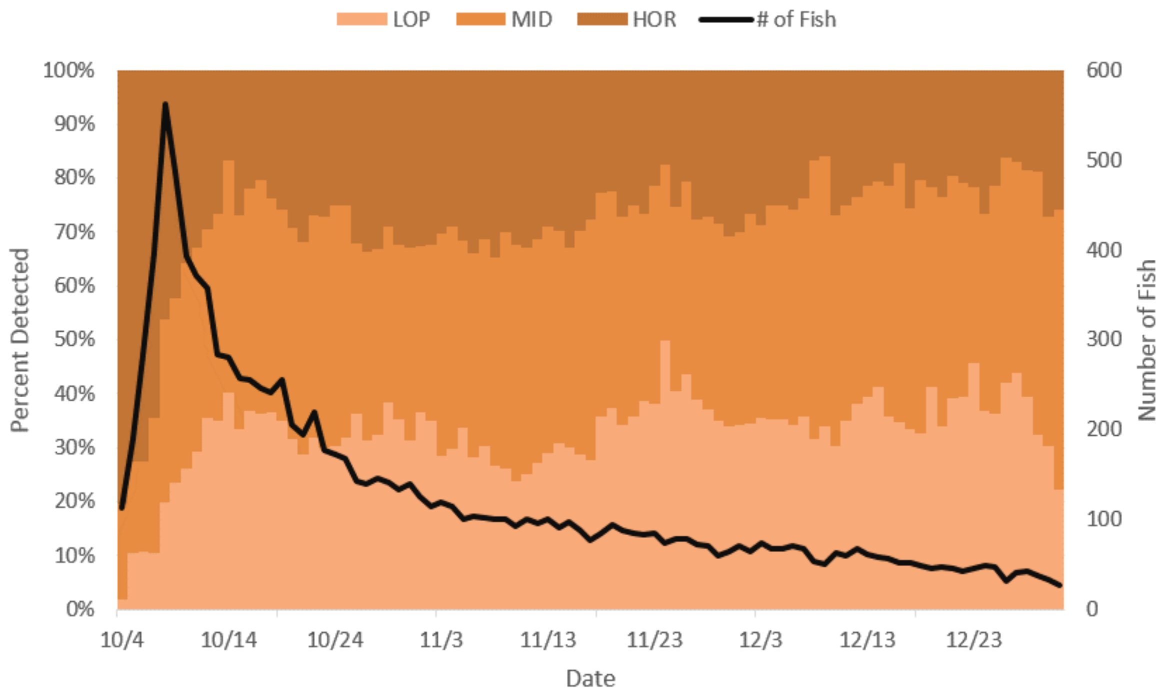

Figure 4.1. Daily Reservoir Distribution of CH0 Released into the Lookout Point Reservoir in Fall 2016

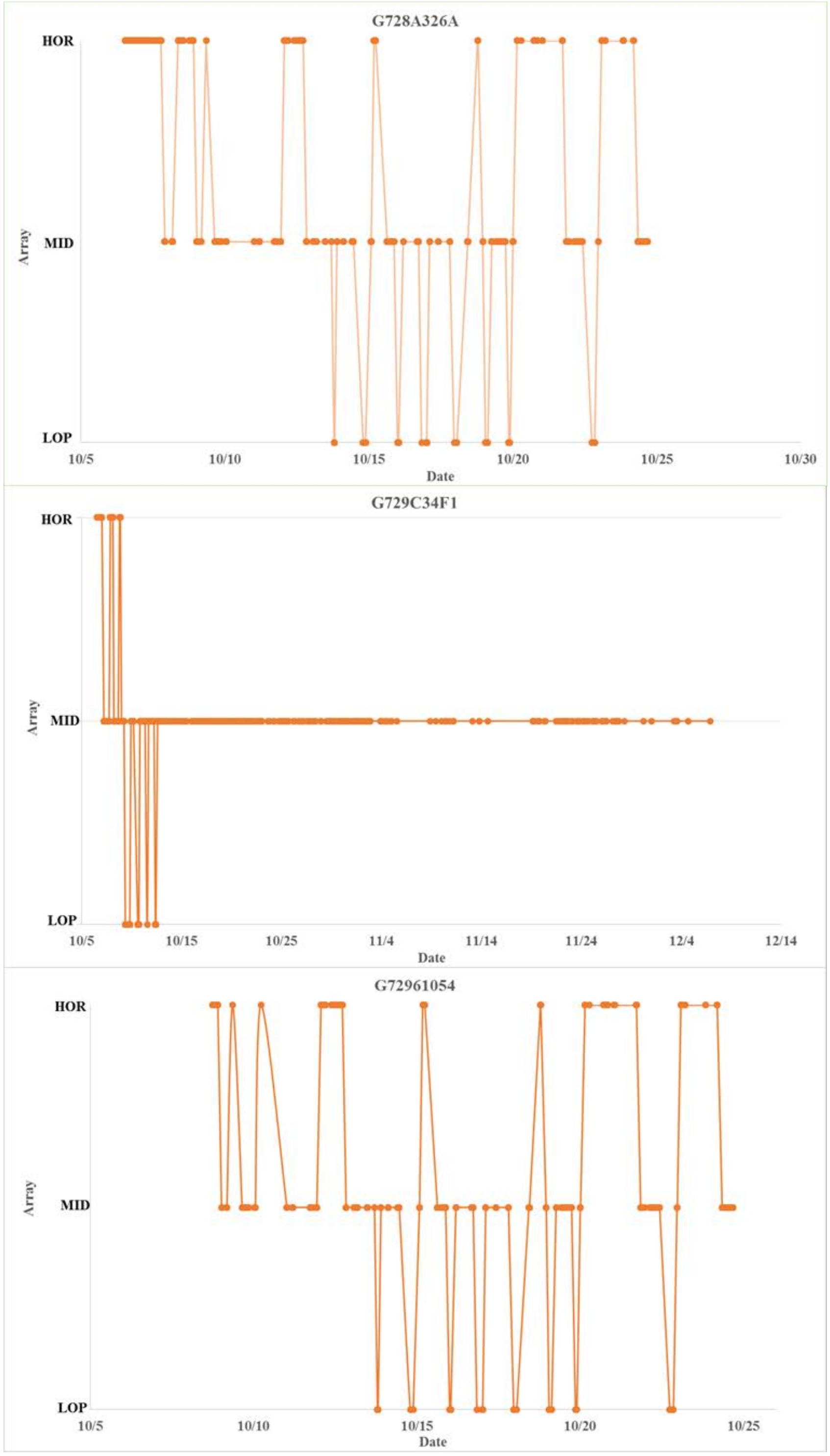

Figure 4.2. Movement of Randomly Selected Study Fish Within the Lookout Point Reservoir during Fall 2016

4.1.2 Reservoir Horizontal Distribution

As tagged fish moved through the Lookout Point reservoir, capture histories were formed for each of the detection arrays (HOR, MID). Using the first detection and the signal-to-noise ratio from each receiver, fish were assigned a horizontal position at each array. At the HOR array, located 1 km downstream from the release site, the receivers at positions 1, 2, and 5 each had over 20% of the first detentions of each fish (Figure 4.3), while receivers 3 and 6 each had fewer than 15% of the first detections. Receiver 4 malfunctioned during the early study period; therefore, no data were collected.

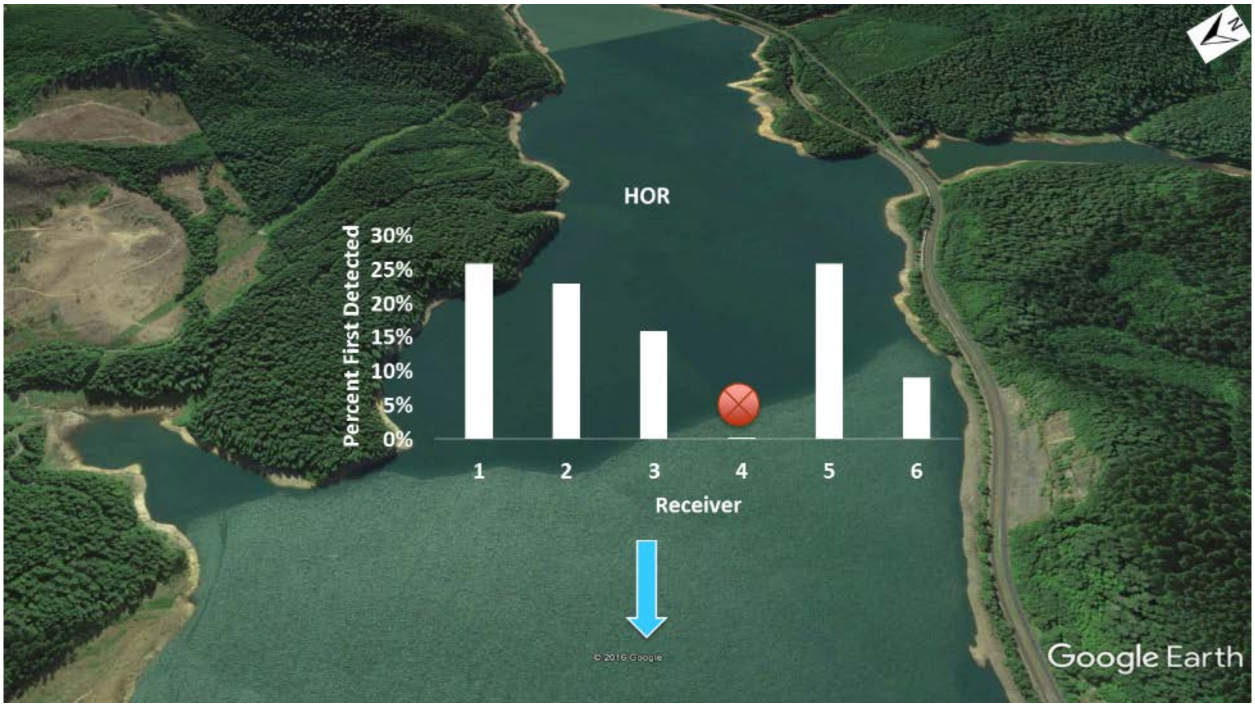

Figure 4.3. Head-of-Reservoir (HOR) Horizontal Distribution by Receiver Using the First Detection of CH0 Passing by Array (blue arrow represents river flow direction, red dot indicates malfunctioning receiver)

At the MID array, fish were evenly distributed across most of the array and receivers 1, 2, 4, 5, and 6 each had between 15% and 20% of the fish detected (Figure 4.4). Receiver 7, located on the southern bank, had the lowest percentage of first detections (8%) and receiver 3 malfunctioned during the early part of the study and did not collect data.

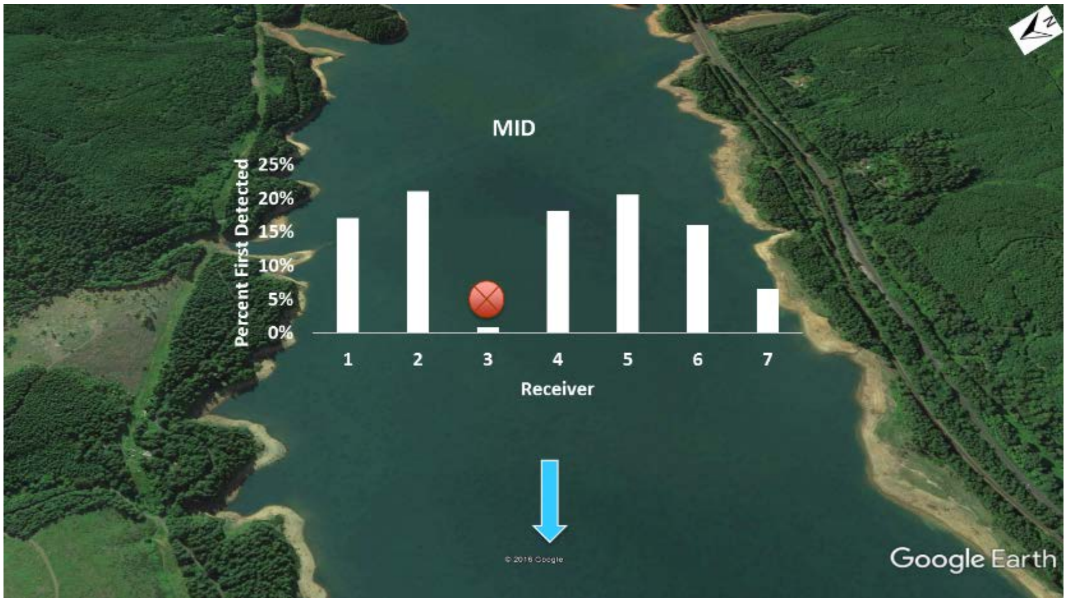

Figure 4.4. MID Horizontal Distribution by Receiver Using the First Detection of CH0 Passing by Array (blue arrow represents river flow direction, red dot indicates malfunctioning receiver)

4.1.3 Forebay Approach

Fish distributions at the LOP receiver array, located just upstream of Lookout Point, was much different than those at the HOR and MID arrays. The majority of fish first detected at the LOP array were located on the southern side of the array, closest to the earthen portion of the dam (Figure 4.5). Receiver 5 and 6 each had over 30% of the first detections and receivers 4 and 3 had 19% and 10%, respectively. Receivers 2 and 1 had few to no first detections.

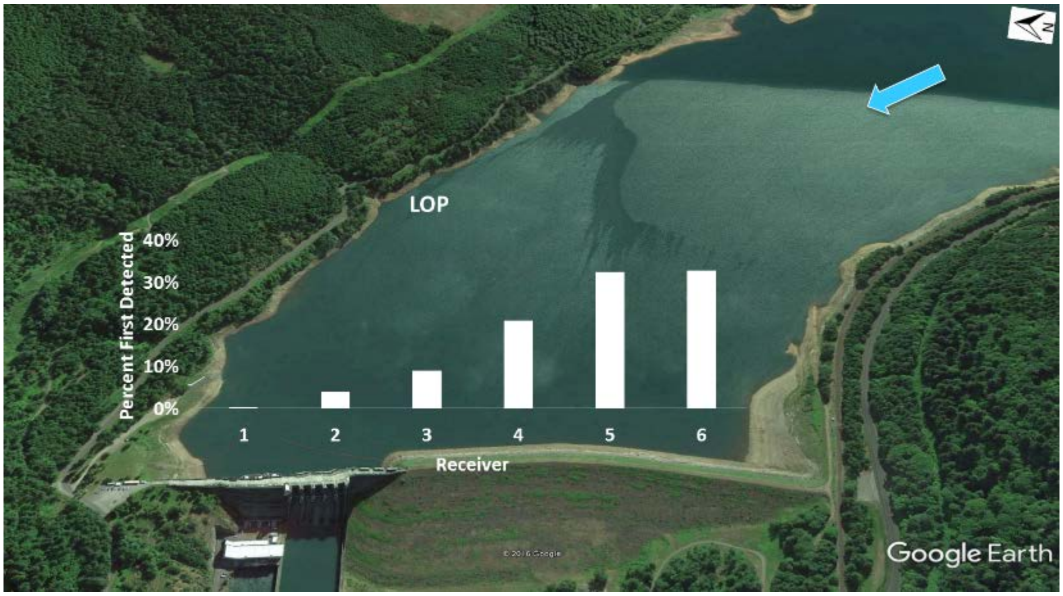

Figure 4.5. LOP Horizontal Distribution by Receiver Using the First Detection of CH0 Passing by Array (blue arrow represents river flow direction)

The LOP array was used to determine the approach and timing of fish that entered the Lookout Point forebay. A large majority of fish (87%) first approached Lookout Point from the earthen south side of the dam, while a small proportion (13%) approached the concrete portion of Lookout Point (Table 4.1). The fish that made it to the forebay of Lookout Point did so at all hours of the day and night; 58% of fish arrived during the nighttime hours and 42% arrived during the day (Table 4.2). Hourly arrival distributions at the LOP array indicated that fish were first arriving in the forebay at all hours; peaks were during early morning hours and late evening (Figure 4.6).

Table 4.1. Forebay First Approach of CH0 at Lookout Point for Fall 2016

Concrete Approach		**Earthen Approach**	
n	Percentage	n	Percentage
37	13%	239	87%

Table 4.2. Lookout Point Forebay First Approach of CH0 during Day and Night for Fall 2016

Day		**Night**	
n	Percentage	n	Percentage
115	42%	161	58%

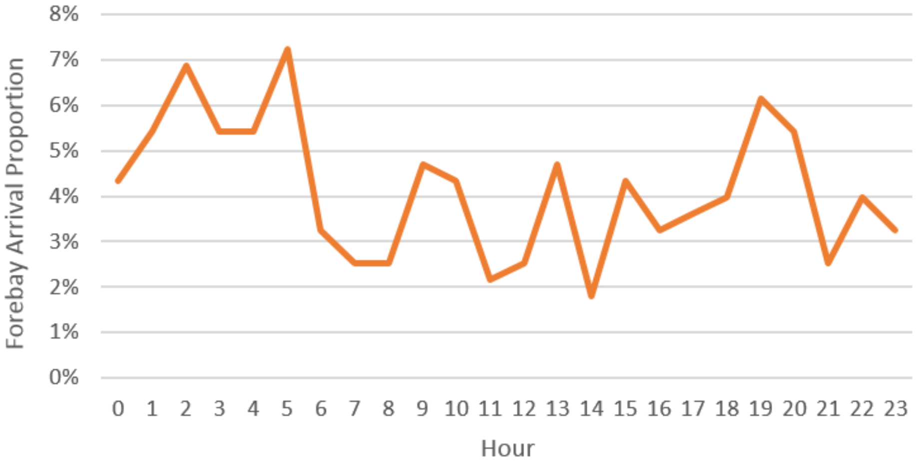

Figure 4.6. Diel Arrival Distributions of First Detection of CH0 at the LOP Forebay Array in Fall 2016

4.2 Downstream Migration and Travel Times

During fall, fewer and fewer tagged CH0 were detected at subsequent downstream locations (Figure 4.7). Only 6% (31 fish) of the total number of fish released were detected below Lookout Point and only 3% of released fish (16 fish) were detected below Dexter.

A total of 520 tagged CH0 were released at HOR; of those fish, 31migrated through the reservoir and passed Lookout Point, with a mean reservoir residence time of 8.0 days (Table 4.3). Tagged fish resided between the LOP array and DEX array for an average of 8.9 days. Fastest travel times were in the mainstem Willamette River; mean travel time for CH0 from the LOP array to the WIL array was 13.3 days.

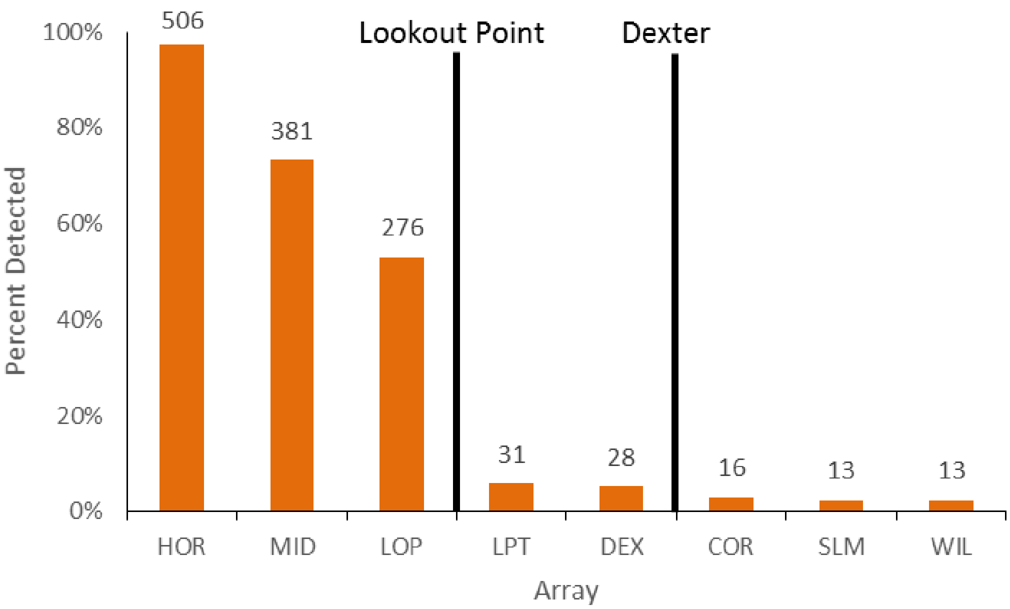

Figure 4.7. Percentage of CH0 Detected at Each Array Location in Fall 2016. The number of fish detected at each array is noted above the bars.

Table 4.3. Estimated Mean and Median Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH0 in Fall 2016

		Fall			
Reach	**Distance (rkm)**	**Median (d)**	**Mean (d)**	**SE**	**n**
Reservoir Residence[(a)]	8.5	3.4	8.0	2.6	31
Forebay Residence[(b)]	1.0	8.0	21.0	4.6	31
Tailrace Egress[(c)]	2.5	2.4	8.9	3.0	30
LOP to DEX[(d)]	6.0	11.2	17.3	5.4	15
DEX to COR[(e)]	115.5	1.0	1.3	0.2	14
COR to SLM[(f)]	77.5	0.6	0.6	0.0	12
SLM to WIL[(g)]	72.0	0.7	0.7	0.0	13
LOP to WIL[(h)]	271.0	12.1	13.3	3.1	13

Difference in time from:
(a) release time to first detection at the LOP array.
(b) first detection at the LOP array to last detection at the LOP array.
(c) last detection at the LOP array to last detection at the LPT array.
(d) last detection at the LOP array to last detection at the DEX array.
(e) last detection at the DEX array to last detection at the COR array.
(f) last detection at the COR array to last detection at the SLM array.
(g) last detection at the SLM array to last detection at the WIL array.
(h) last detection at the LOP array to last detection at the WIL array.

4.3 Survival

As noted in the methods section, survival through Lookout Point and Dexter could not be estimated due to the lack of fish passage at the two projects. Only 31 fish were detected below Lookout Point and only 16 fish were detected below Dexter. These low numbers would not allow for estimates to be calculated that fall within the acceptable confidence limits. Equally as important, the total number of fish passing LOP (dead or alive) could not be confirmed without JSATS hydrophones deployed on the Lookout Point dam face. Without this confirmation, the exact number of fish passing Lookout Point is unknown (all that is known are the numbers of live fish passing LOP) and therefore survival could not be estimated.

5.0 Results –Yearling Chinook Salmon

This chapter contains information about reservoir movement, behavior, travel times, downstream migration and survival of CH1 at Lookout Point in spring 2017. Appendix A provides additional information about fish-tagging/release tables.

5.1 Reservoir Movement and Behavior

The following sections provide results on movement and behavior in the Lookout Point reservoir.

5.1.1 Daily Reservoir Movement

In spring (March–June) 2017, a total of 549 CH1 were released into the upper end of Lookout Point reservoir. The majority of these fish were detected at the HOR array (99%) early in March before distributing relatively evenly throughout the reservoir in subsequent weeks (Figure 5.1). The daily number of CH1 detected at any of the reservoir arrays generally declined during the March through June study period. During spring, movement of study fish within the Lookout reservoir varied between individual fish. Four randomly tagged fish were selected during spring and tracked through the Lookout reservoir (Figure 5.2). During the fall 2016 study, the overall trend in movement of test fish was from upstream to downstream. However, spring migrants traveled downstream in much greater numbers; 87% of all study fish were detected in the Lookout forebay (LOP).

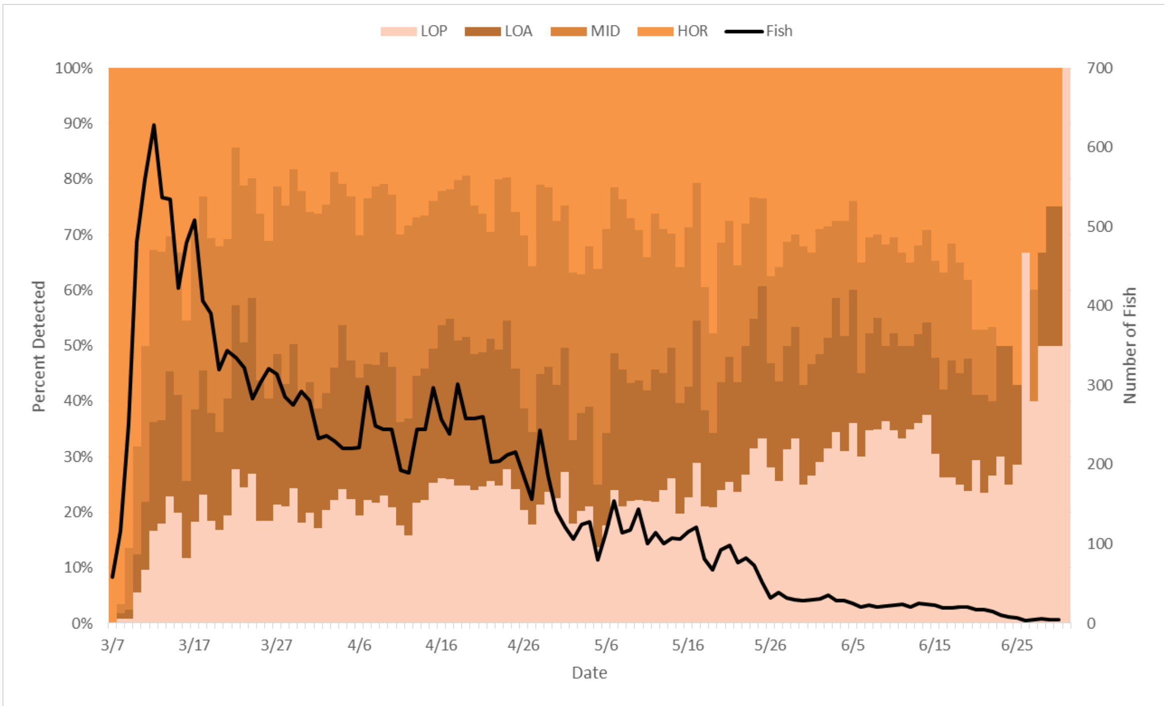

Figure 5.1. Daily Reservoir Movement of CH1 Released into the Lookout Point Reservoir in spring 2017

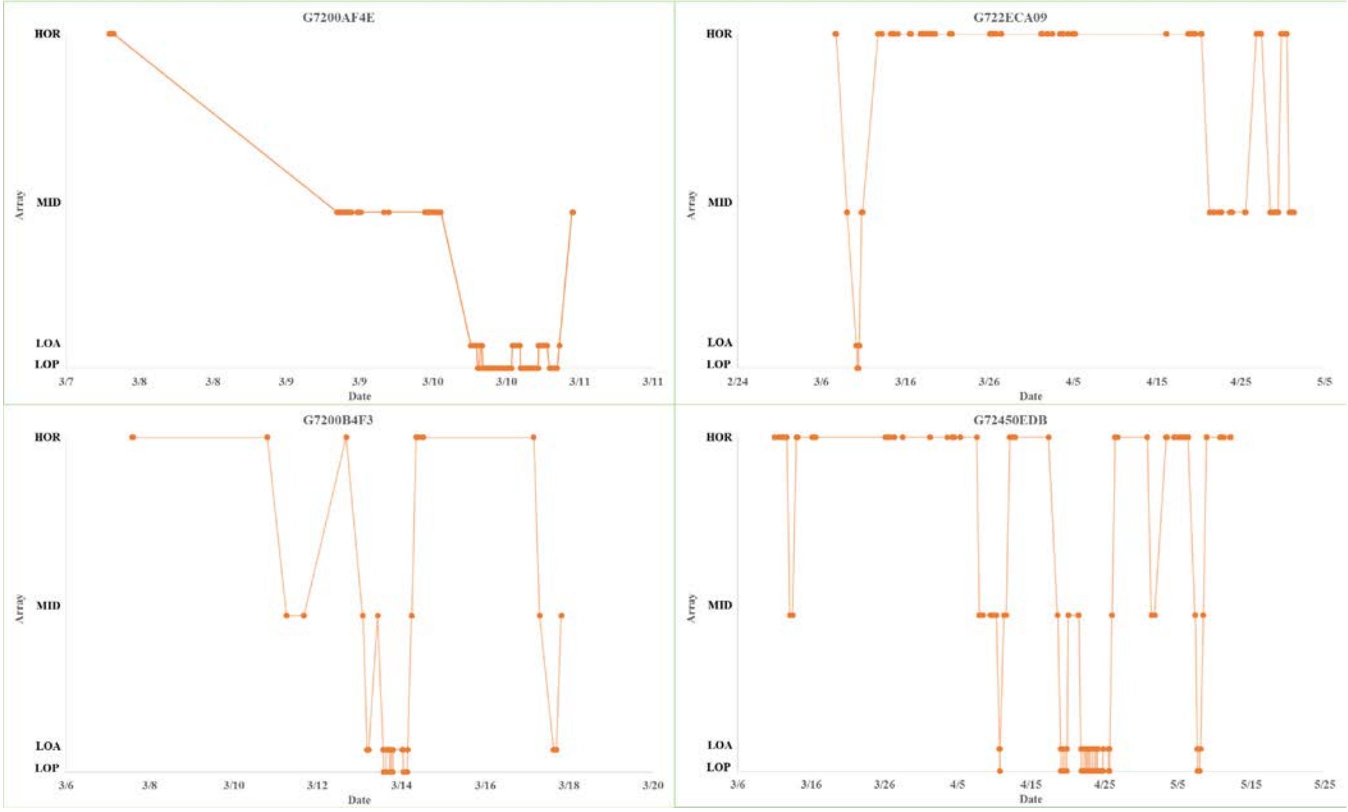

Figure 5.2. Movement of Randomly Selected Study Fish Within the Lookout Point Reservoir during Spring 2017

5.1.2 Reservoir Horizontal Distribution

As study fish moved through the Lookout Point reservoir, capture histories were formed at each of the detection arrays (HOR, MID). Using the first detection and the signal-to-noise ratio from each receiver, fish were assigned a position at each array. At the HOR array, 68% of the first detections for each fish were detected at the receiver at position 2 (Figure 5.3), while receiver 6 had 13% of all first detections, and all other receivers had fewer than 8%. At the MID detection array, receivers at positions 1 and 2 accounted for 47% of first detections (Figure 5.4). All remaining receivers had fairly even distributions of first detections, ranging between 7% and 12%.

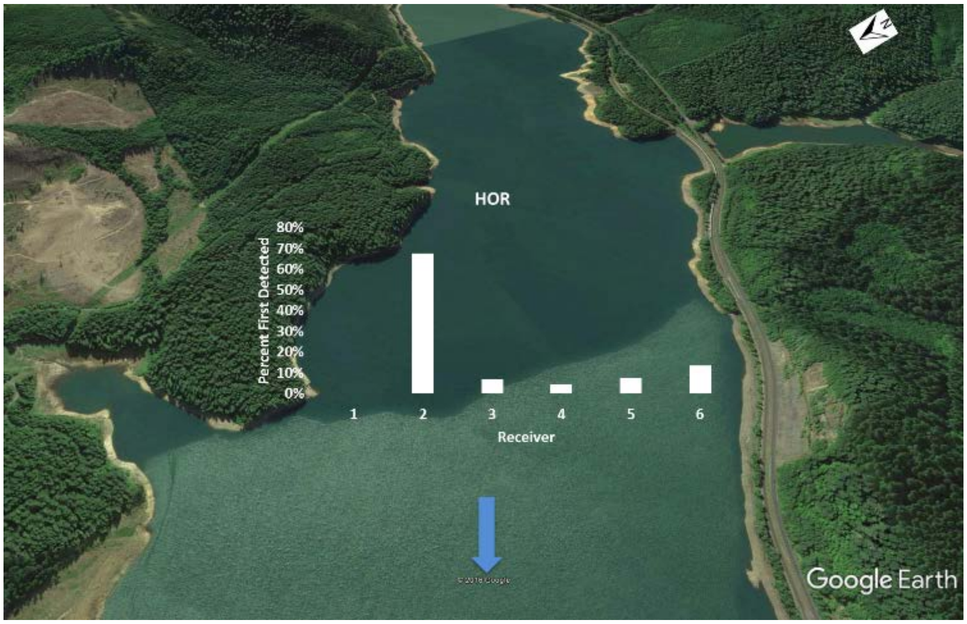

Figure 5.3. Head-of-Reservoir (HOR) Horizontal Distribution by Receiver Using the First Detection of CH1 Passing by Array (blue arrow represents river flow direction)

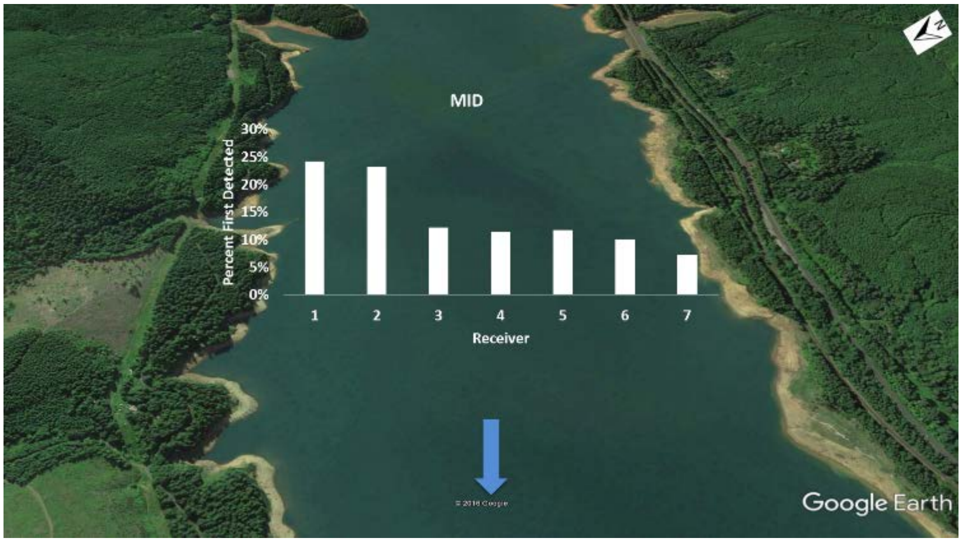

Figure 5.4. MID Horizontal Distribution by Receiver Using the First Detection of CH1 Passing by Array (blue arrow represents river flow direction)

5.1.3 Forebay Approach

During spring, an additional array (the Lookout Point Approach [LOA] array) was deployed 0.5 rkm upstream of the LOP array to enhance the data on fish approach into the near forebay of Lookout Point. The majority of fish first detected at the LOA array (Figure 5.5) were located on the southern side of the reservoir, where receiver 5 detected 35% of the fish and receiver 4 detected 23% of the fish. This trend continued as fish approached the dam. The detection array located just upstream of Lookout Point (the LOP array) had a similar trend—a majority of first detections of fish occurred on the southern earthen side of the reservoir (Figure 5.6).

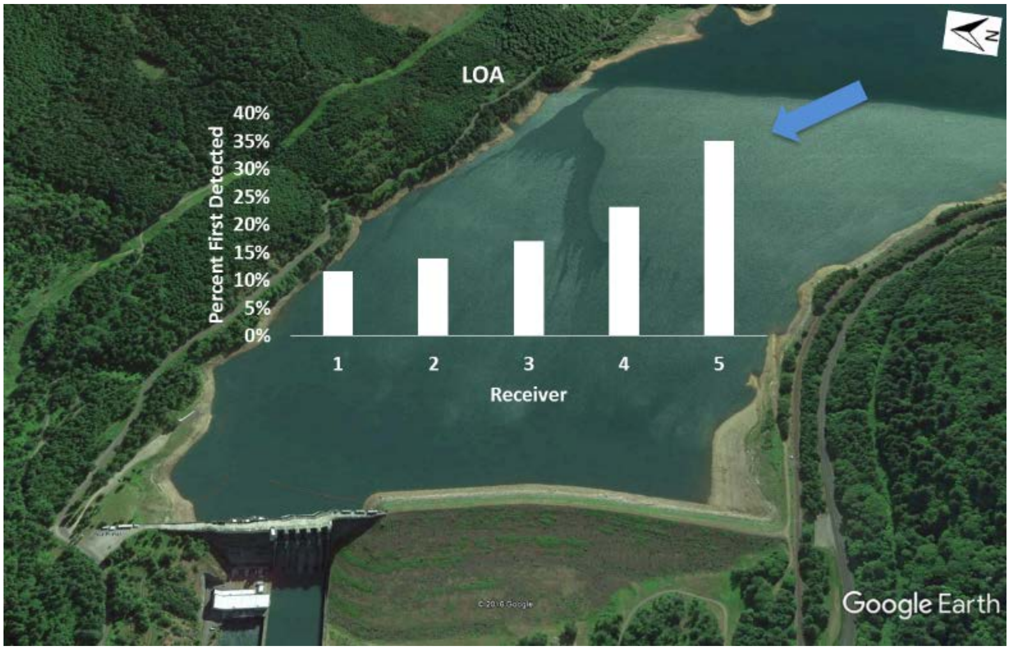

Figure 5.5. LOA Horizontal Distribution by Receiver Using the First Detection of CH1 Passing by Array (blue arrow represents river flow direction)

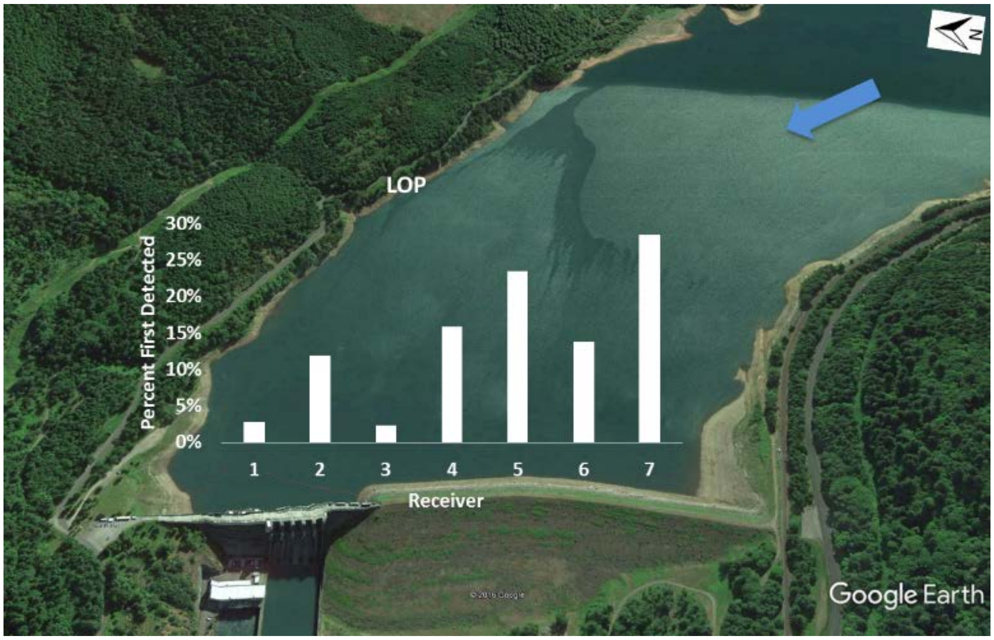

Figure 5.6. LOP Horizontal Distribution by Receiver Using the First Detection of CH1 Passing by Array (blue arrow represents river flow direction)

The LOP array was used to determine the approach and timing of fish that entered into the Lookout Point forebay. A large majority of fish (83%) first approached Lookout Point from the earthen south side of the dam, while fewer (17%) approached the concrete portion of Lookout Point (Table 5.1). The fish that made it to the Lookout Point forebay did so at all hours of the day and night; 45% of fish arrived during the nighttime hours and 55% arrived during the day (Table 5.2). Hourly arrival distributions at the LOP array indicated that fish were first arriving in the forebay at all hours; arrival times peaked during the mid-day hours and at night (Figure 5.7).

Table 5.1. Forebay First Approach of CH1 at Lookout Point Dam in Spring 2017

Concrete Approach		**Earthen Approach**	
n	Percentage	n	Percentage
79	17%	394	83%

Table 5.2. Lookout Point Dam Forebay First Approach of CH1 during Day and Night of Spring 2017

Day		**Night**	
n	Percentage	n	Percentage
259	55%	214	45%

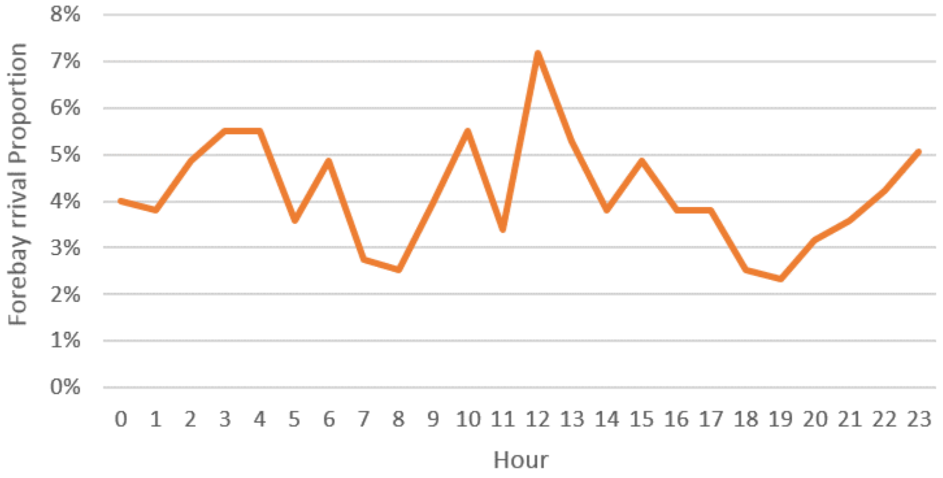

Figure 5.7. Diel Arrival Distributions of First Detection of CH1 at the LOP Forebay Array in Fall 2016

5.2 Downstream Migration and Travel Times

During spring, 99% of all CH1 releases into the Lookout Point reservoir were detected at the HOR array (Figure 5.8). As the study fish moved through the Lookout Point reservoir fewer fish were detected at each downstream location. Approximately 92% of fish released were detected at the MID array in Lookout Point reservoir and 87% of fish were detected at the LOP array. Unlike during the fall 2016 study, where only a small portion of fish passed Lookout Point, 54% of fish were detected below Lookout Point in spring and 34% of fish were detected below Dexter.

Reservoir movement and travel times for CH1 released in spring are presented in Table 5.3. A total of 549 tagged CH1 were released at HOR, of these fish, 299 migrated through the reservoir and passed Lookout Point with a mean reservoir residence time of 10.8 days. Mean travel time for CH1 from the LOP array to the WIL array was 3.9 days.

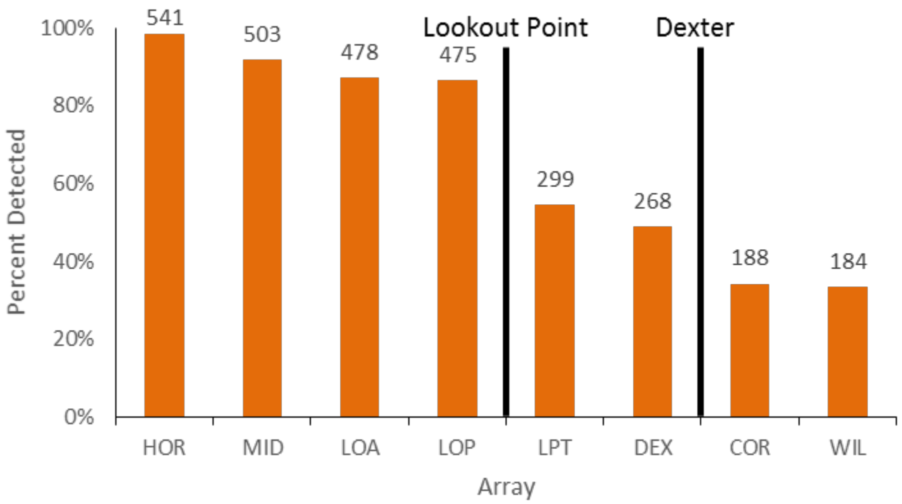

Figure 5.8. Percentage of CH1 Detected at Each Array in Spring 2017. The numbers of fish detected at each array are listed above the bar.

Table 5.3. Estimated Mean and Median Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH1 in Spring 2017

	Spring				
Reach	Distance (rkm)	Median (d)	Mean (d)	SE	n
Reservoir Residence[(a)]	8.5	8.0	10.8	0.6	299
Forebay Residence[(b)]	1.0	4.4	15.1	1.2	299
Tailrace Egress[(c)]	2.5	0.3	1.2	0.7	280
LOP to DEX[(d)]	6.0	1.3	1.1	0.6	188
DEX to COR[(e)]	115.5	0.8	1.2	0.1	106
COR to WIL[(f)]	149.5	1.3	1.7	0.1	102
LOP to WIL[(g)]	271.0	3.6	3.9	0.7	184

Difference in time from:
(a) release time to first detection at the LOP array.
(b) first detection at the LOP array to last detection at the LOP array.
(c) last detection at the LOP array to last detection at the LPT array.
(d) last detection at the LOP array to last detection at the DEX array.
(e) last detection at the DEX array to last detection at the COR array.
(f) last detection at the COR array to last detection at the WIL array.
(g) last detection at the LOP array to last detection at the WIL array.

5.3 Spill Passage

During the spring 2017 study period, several snow and rain events occurred, causing the reservoir levels to exceed the rule curve for Lookout Point. Due to the large volume of water in the reservoir, use of the spillway was required to manage the water levels. To compensate for the lack of hydrophones on the face of Lookout Point, we used the last detection of fish at the LOP receiver array and the first detection at the LPT array to assign a passage route at Lookout Point. This method required consistency of dam operations at the project during the time period between the last detection at the LOP array and first detection at the LPT array. Of the 299 fish that were detected downstream of Lookout Point, 191 fish met the criteria above and were assigned a route of spill, turbine, or spill + turbine passage (Table 5.4). The remaining 108 fish that were detected downstream of Lookout Point could not be assigned a route due to several different operations having occurred during the time between detections.

Table 5.4. Estimated Spill, Turbine, Spill + Turbine and Unassigned Passage Routes during Spring 2017

Route	n
Spill	37
Turbine	9
Spill + Turbine	145
Unassigned	108

5.4 Survival

As noted above, survival through Lookout Point and Dexter could not be performed because the total number of fish passing the LOP array (dead and alive) could not be confirmed without JSATS hydrophones deployed on the Lookout Point dam face. Without this confirmation, the exact number of fish passing Lookout Point is unknown (all that is known are the numbers of live fish passing LOP) and therefore survival could not be estimated.

6.0 Discussion

This chapter discusses the results obtained during the studies, including fish movement through the reservoir and forebay, downstream migration and travel times, use of the spillway during spring 2017, and an overview of the study design configurations and results during the fall 2016 and spring 2017.

6.1 Reservoir and Forebay Distributions

Little is known about movement of juvenile Chinook salmon in Lookout Point reservoir. Information is needed to determine the most feasible ways to meet the requirements of the RPA that calls for improving juvenile downstream survival. The use of acoustic tags implanted in Chinook salmon during fall 2016 and spring 2017 allowed for the tracking of fish as they passed telemetry arrays throughout the reservoir.

Movement patterns of study fish in Lookout Point reservoir differed between the spring 2017 and fall 2016 study periods. During spring 2017, the proportions of fish detected at the MID (92%) and LOP (87%) arrays were much higher than was observed during the fall 2016 study period (73% and 53%, respectively). Similarly at Foster reservoir in the South Santiam River, for fall 2015 and 2016, Hughes et al (2016) reported large numbers of fish tagged and released into the reservoir were either never detected or were detected but not observed to have passed Foster Dam. The relative lack of downstream movement during fall compared to spring raises the question of why. These fish may have moved upstream or reared between receiver arrays. Given that all fish tagged for this study were double-tagged with acoustic and PIT tags, we queried the PITAGIS database for detections of study fish at PIT interrogation sites downstream of Lookout Point. At press time, no fall or spring fish had been detected downstream.

Predation is another possible reason for numbers of study fish declining through time in Lookout Point reservoir. Johnson et al. (2016) noted a large presence of avian predators and piscivorous fish in the Lookout Point reservoir. Monzyk et al. (2014) estimated juvenile Chinook salmon losses (37.7–66.5 mm in size) to northern pikeminnow in the Lookout Point reservoir exceeded 100,000 fish during spring 2013. However, mean fork length of our acoustic tagged fish in fall 2016 was 148 mm and in spring 2017 was 147 mm, lending little credence to the hypothesis that study fish were preyed upon. A large potential for predation, along with the propensity of fish to overwinter in the reservoir (Schroeder et al. 2016), may have contributed to the decline in the number of tagged fish that moved downstream through the Lookout Point reservoir during fall 2016 and to a lesser extent during spring 2017.

Detections at individual autonomous receivers in each array allowed us to determine horizontal distribution of fish movements. In fall, the horizontal distributions of fish at the HOR and MID arrays were quite similar; they had generally similar detection percentages across each array (bank-to-bank) for study fish moving downstream to Lookout Point (Figure 4.3 and Figure 4.4). In the spring however, the horizontal distribution of fish migrating downstream to Lookout Point differed greatly from the fall distribution (Figure 5.3 and Figure 5.4). At HOR, almost 70% of all detections occurred at one receiver location, HOR-2 indicating a north-bank downstream migration in spring. At the MID detection array, 47% of all fish were detected on the northern two receivers and each of the remaining receivers detected between 7–12% of the fish. In general, CH1 had a north-bank migration downstream to Lookout Point, in contrast to an even horizontal (bank-to-bank) downstream migration observed for CH0. We examined the bathymetry of the Lookout Point reservoir, but saw no clear indicator of a cause of the difference of observed migration behavior (Figure 6.1).

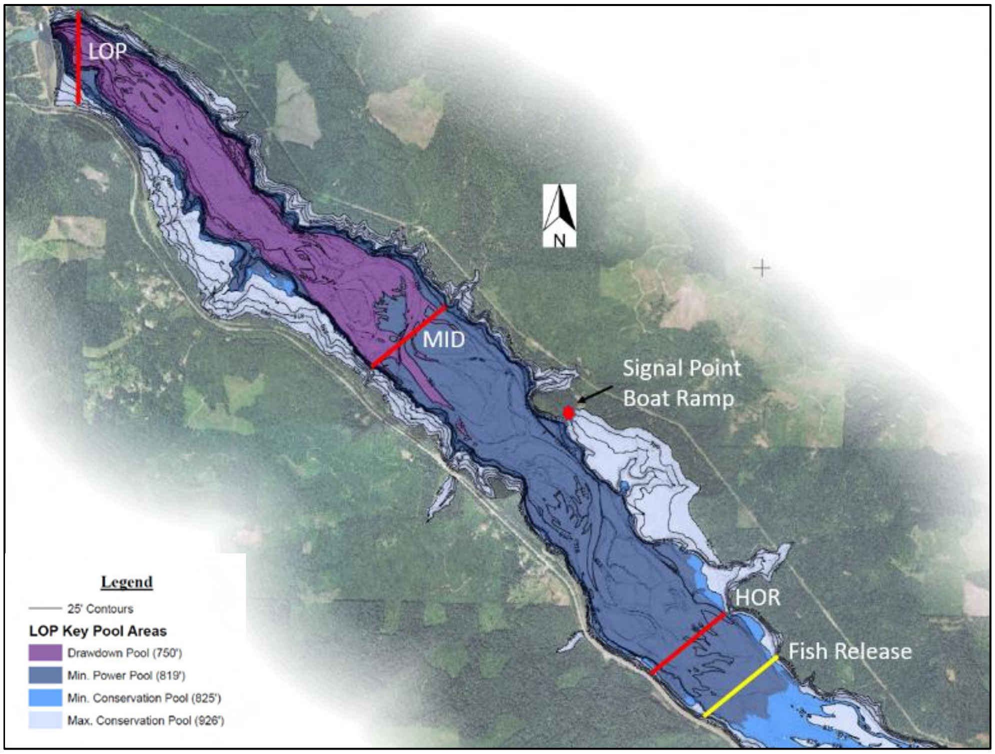

Figure 6.1. Lookout Point Reservoir Autonomous Receiver Arrays with Bathymetry. The red lines indicate a receiver array and the yellow line indicates the fish release transect. Bathymetry data were provided by USACE.

We used the farthest downstream array in the Lookout Point reservoir (LOP), 0.5 km upstream of the dam, as the forebay approach array. During both the fall and spring study periods, juvenile Chinook salmon followed similar trends by first approaching the forebay of Lookout Point from the south forebay at the earthen side of the dam. This trend was most evident in the fall when the majority (87%) of study fish first approached the southern side of the dam. The trend continued in spring when 83% of fish approached the earthen side of the dam. With such a large proportion of fish using the southern side of the reservoir near Lookout Point during fall, in spring we deployed an additional receiver array (LOA) 0.5 rkm upstream of the LOP array to substantiate Lookout Point forebay approach distributions. The LOA array showed similar trends—75% of all detections occurred on the southern side of the array. These results indicate that when considering a location for a surface collector in the Lookout Point forebay, the most advantageous placement appears to be in the near forebay just upstream of the earthen portion of Lookout Point Dam.

In fall 2016, the diel distribution of fish approaching Lookout Point showed over half of all fish (58%) first approached Lookout Point during the night. These results were different during spring, when 45% of fish first approached during night. However, in general both CH0 and CH1 arrived in the Lookout Point forebay during all hours of the day but peak arrival times occurred during the early morning, mid-day, and early evening depending upon study the period (Figure 6.2). Diel first approach results indicate no clear diel management advantage to operating a surface collector during the day versus night.

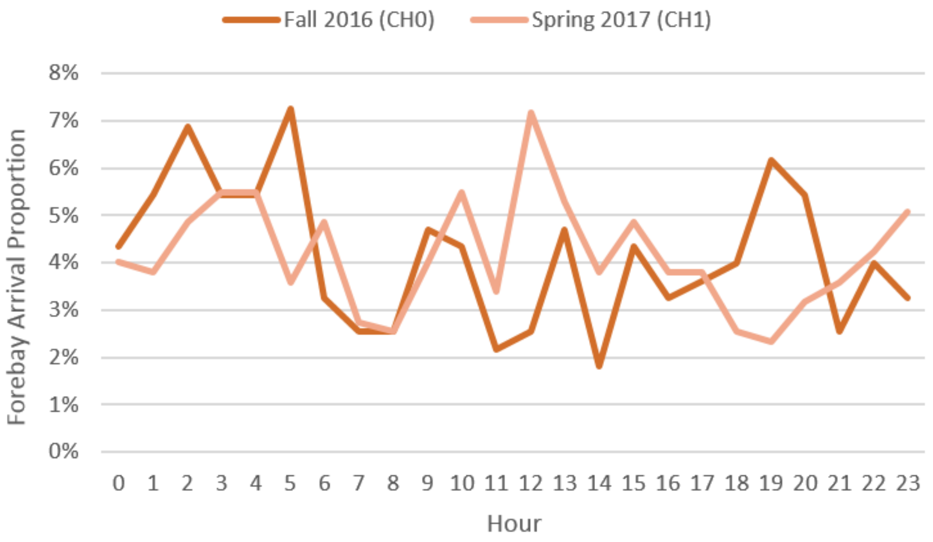

Figure 6.2. Diel Arrival Distributions of First Detection of CH0 and CH1 at the LOP Forebay Array in Fall 2016 and Spring 2017

6.2 Downstream Migration and Travel Times

We analyzed the downstream migration past Lookout Point and found that during fall 6% of tagged fish released in the reservoir passed Lookout Point, compared to 54% of total fish tagged and released during spring. Fall discharge (Figure 3.3) and spring discharge (Figure 3.4) show similar trends: discharge ranged from 0 cfs to 9,510 cfs in fall and 0 cfs to 9,100 cfs in spring. With discharges similar between fall and spring, but the passage proportions between fall and spring varying by 48%, the magnitude of project discharge probably did not contribute to diminished downstream movement through the dam in fall 2016. Keefer et al. (2013) estimated that Chinook salmon migration occurs from September to May with peak migration from November to January, based on rotary screw trap captures below Lookout. Fish from this study were not released during these peak periods; however, they were released well within the historical run timings for Chinook salmon in the Middle Fork Willamette. The absence of migration observed for our study fish is similar to behavior exhibited by radio tagged Chinook salmon in the South Santiam (Hughes et al. 2016 and 2017). The authors reported large proportions of Chinook salmon that did not migrate past Foster dam in both the spring (8% – 42%) and fall (25% – 29%) for 2015 and 2016.

Travel times throughout the study area differed greatly between fall 2016 and spring 2017 (Table 6.1). Fall study fish had a mean reservoir travel time of 8 days (SE = 2.6), while spring fish had a mean reservoir travel time of 10.8 days (SE = 0.6). Spring travel times through the forebay (15.1 days) and tailrace (1.2 days) were much quicker than fall travel times (21.0 days and 8.9 days, respectively). The same holds true for the Dexter reservoir; mean spring travel times were much quicker than during the fall (1.1 days in spring vs. 17.3 days in fall). Travel times throughout the free-flowing Willamette River below Dexter were similar in both spring and fall. Comparing travel times from the LOP array to the WIL array, spring travel times were again much quicker than fall travel times (3.9 days vs. 13.3 days, respectively), which could indicate that yearling Chinook salmon were more inclined to actively migrate through the Middle Fork Willamette than subyearling Chinook salmon.

Brandt et al. (2016) and Johnson et al. (2016) used PIT-tag data at Willamette Falls to look at the travel times of juvenile Chinook salmon. While a direct comparison is not possible between the two PIT-tag studies and this acoustic study, differences in travel times between the HOR releases and subsequent detections at either Willamette Falls (PIT) or Wilsonville (AT) (18.8 km upstream of Willamette Falls) may help validate study design or bring to life any changes that may be required in future studies. Table 6.1 presents travel times for PIT tagged Chinook salmon fry (2011–2014) and yearling and subyearling Chinook salmon that were acoustically tagged (2016–2017). Travel times between fry-sized and juvenile Chinook salmon were notably different. Chinook salmon fry traveled from the LOP reservoir to Willamette Falls in 59–113 days, whereas juvenile sized Chinook salmon took an average of 28 days to reach Willamette Falls in fall of 2016 and spring of 2017. The quicker travel times for the much larger yearling and subyearling Chinook are expected of fish that are more actively migrating downstream through the mainstem Willamette River.

Table 6.1. Estimated Mean and Median Travel Times for Fish Released into the Head of the Lookout Point Reservoir and Detected at Willamette Falls (PIT) from 2011 through 2014 and Wilsonville (AT) during 2016 and 2017

Year	Tag Type	Class	n	Mean (Days)	SE	Median (Days)	Range (Days)
2011	PIT	Fry	201	59.7	1.67	50	34–207
2012	PIT	Fry	534	77.4	1.94	66	25–351
2013	PIT	Fry	383	112.0	3.56	81	25–352
2014	PIT	Fry	28	113.0	9.21	111	13–212
Fall 2016	AT	Subyearling	13	28.8	3.93	26	12–56
Spring 2017	AT	Yearling	184	28.7	1.79	15	6–88

6.3 Spring Spill

Due to the rainy spring of 2017, water levels in the Lookout Point reservoir exceeded the reservoir control rule curve. This large amount of water led to the release of excess water through the spillway for an extended period of time. The use of the spillway has not been studied at Lookout Point Dam; most research has focused on turbine and regulating outlet passage. While spill is usually considered the most benign way to pass fish, Schilt et al. (2007) and Keefer et al. (2013) noted there are still risks associated with spill, including high dissolved gas levels, spillway height, plunge pool configuration, and predation. However, the spillway is only a viable non-turbine passage option when the water elevation exceeds 887.5 ft (spillway crest elevation), which usually occurs during the end of the spring refill and during the summer high pool season. Because Lookout Point is a flood damage reduction dam, years with drought conditions and little precipitation mean water levels can remain low during the spring and summer. We used the last detection of fish at the LOP receiver array and the first detection at the LPT array to assign a passage route at Lookout Point only when dam operations at the project during that time period were consistent. A total of 191 fish met that criteria and were assigned a route of spill, turbine, or spill + turbine passage. Of those 191 fish, 145 fish passed while the turbine and spillway were operating, 37 fish passed when just the spillway was operating, and 9 fish passed through the turbine. The remaining 108 fish that were detected downstream of Lookout Point could not be assigned a route due to a lack of consistent operations during the time between detections. With no hydrophones located on the dam face to detect fish and estimate route of passage little additional information is known about these fish. Future studies conducted at Lookout Point should use dam-mounted equipment to get more fine-scale information to estimate route-specific passage. Our 2016/2017 study, though, showed that CH1 can use the spillway to pass the dam.

The implications of spill operations at LOP are not completely understood. The perception that we have of operations (turbine and turbine+spill) vs. passage is rudimentary since we were not able to assign route of passage for study fish that passed during the turbine+spill operations. What can be concluded from the spring 2017 spill is that to an extent the turbine + spill operation did facilitate downstream passage of juvenile Chinook salmon, meaning large proportions of study fish passed LOP during this operation. The question that remains unanswered is what route of passage did these fish utilize and without that understanding firm conclusions cannot be drawn. The 2017–2018 study, in which a 3D cabled-array will be deployed on the dam face at LOP, will help more clearly define these types of conclusions.

6.4 First-Year Study Design

This was the first AT study conducted in the Lookout Point and Dexter reservoirs. We were able to apply experience from similar studies at both Foster Dam on the South Santiam (radio telemetry) by Hughes et al. (2016, 2017), and Detroit Dam on the North Santiam (acoustic telemetry) by Beeman and Adams (2015) to ensure receiver arrays were deployed in optimal configurations. Data acquired during the fall of 2016 and spring of 2017 allowed us to achieve study objectives with the exception of survival. Moreover, we made the following observations during this study that will lead to changes in study design in future work at Lookout Point.

- Detection efficiencies were very high at all reservoir locations (greater than 99%) and also at the WIL array. The COR array performed well during low water levels but as water levels rose the detection efficiency dropped lower than expected and will require additional equipment to maximize the likelihood of detection.
- With only autonomous receiver arrays deployed above and below dams, the ability to track fish in the immediate forebay and assign a route of passage was not feasible. In future studies, the use of JSATS cabled arrays at both Lookout Point and Dexter will allow for more fine-scale tracking of study fish in the immediate forebay of both projects and determine specific routes of passage and survival.
- Deployment and testing of a 3D autonomous array occurred during the fall of 2016. This array was capable of tracking JSATS tags deployed from a mobile platform to an accuracy of ±5 m. Additional information from this analysis determined that receiver placement should be decreased from 100 m spacing to 75 m spacing to increase the detection efficiency and increase the ability to track fish in 3D.

7.0 Conclusions and Recommendations

This report presents the AT evaluation of fish passage and survival at Lookout Point Dam on the Middle Fork Willamette River in Oregon during 2016–2017. The AT arrays and transmitters performed well. The probability of fish bearing AT tags being detected at all receiver arrays was >95% for all study periods, with the exception of the array located in Corvallis, for which detection varied by season, discharge, and fish stock.

Data derived from the AT evaluation of juvenile salmonid passage at Lookout Point in 2016 and 2017 support the following conclusions:

- Of the CH0 and CH1 that did not pass Lookout Point, reservoir detections decreased as the study period progressed, indicating a lack of in-reservoir movement.
- CH0 distribution was reasonably uniform horizontally across the reservoir compared to CH1, which had a north-bank preference.
- For CH1 and CH0, the majority of fish arriving in the near forebay of Lookout Point did so on the south side of the reservoir nearest the earthen dam.
- CH0 migrated downstream past Lookout Point in low proportions in fall 2016; however, CH1 migrated past Lookout Point in moderately high proportions in spring 2017.
- Though travel times between CH0 and CH1 were similar from release to furthest downstream array, individual reach travel times between arrays varied considerably among seasons.
- Detection efficiencies at all receiver arrays was high for both the fall 2016 and spring 2017 study periods during high-water events, with the exception of the COR array in Corvallis.
- CH1 used the spillway in moderate proportions to pass Lookout Point.
- Lookout Point survival estimates could not be determined for either CH1 or CH0 because the total number of fish passing Lookout Point (dead or alive) could not be determined due to no receivers being deployed on the dam face.

We offer the following recommendations for future research at Lookout Point to support the design of fish passage structures or dam operations to protect downstream migrants:

- Consider releasing fall study fish during reservoir drafting to maximize the likelihood of fish passage at Lookout Point (based on Keefer et al. 2013).
- Consider operational patterns that maximize spillway discharge to facilitate downstream passage in spring.
- Adding hydrophones located in the immediate forebay and affixed to the face of the dam at Lookout Point could provide additional data to track study fish and estimate survival and specific routes of passage.
- Increase downstream detection efficiencies by bolstering receiver arrays.
- Further assess the efficacy of spill as an alternative to facilitate downstream passage by utilizing a block/treatment test design (turbines vs spill and north spill vs south spill).

8.0 Literature Cited

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Appendix A

Fish-Tagging and Release Tables

Appendix A

Fish-Tagging and Release Tables

Table A.1. AT-Implanted Subyearling Chinook Salmon Size, Weight, Release Dates, and Numbers in Fall 2016

Release Date (Fall 2016)	Species	n	Mean Size (mm)	Weight (g)
October 4	Subyearling Chinook	108	147.6	38.9
	Dead Fish Release	12	147.9	38.9
October 5	Subyearling Chinook	106	148.1	38.3
	Dead Fish Release	14	147.3	36.9
October 6	Subyearling Chinook	108	148.8	39.1
	Dead Fish Release	11	151.2	41.4
October 7	Subyearling Chinook	108	147.3	38.2
	Dead Fish Release	12	148.8	38.1
October 8	Subyearling Chinook	90	149.0	38.6
	Dead Fish Release	11	145.6	36.0
Total	Subyearling Chinook	520	148.1	38.6
	Dead Fish Release	60	148.1	38.2

Table A.2. AT-Implanted Yearling Chinook Salmon Size, Weight, Release Dates, and Numbers in Spring 2017

Release Date (Spring 2017)	Species	n	Mean Size (mm)	Weight (g)
March 7	Yearling Chinook	136	197.2	81.6
	Dead Fish Release	16	189.9	70.3
March 8	Yearling Chinook	137	200.8	83.1
	Dead Fish Release	15	193.5	72.5
March 9	Yearling Chinook	137	199.0	80.4
	Dead Fish Release	15	204.1	82.1
March 10	Yearling Chinook	139	202.3	85.2
	Dead Fish Release	14	196.9	77.1
Total	Yearling Chinook	549	199.9	82.6
	Dead Fish Release	60	196.0	75.4

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