PNNL-28644

Passage and Survival of Chinook Salmon at Lookout Point Dam, Fall 2017 and Spring 2018

Final Report

April 2019

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Preface

The research documented in this report 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. W66QKZ71353386) 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. 69973). PNNL is operated by the Battelle Memorial Institute for the DOE under Contract DE-AC05-76RL01830. The study was led by Eric Fischer (971-940-7103). The USACE's technical lead for the study was Fenton Khan (503-808-4777).

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Executive Summary

This report presents the results of a fish passage and survival study conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers-Portland District (USACE) at Lookout Point Dam (Lookout Point) during fall 2017 (October–February) and spring 2018 (March–July). The goal of the study was to provide biologists, engineers, resource managers, and regional decision-makers with information about the behavior, distribution, passage, and survival of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) through the Lookout Point reservoir, project, 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 Chinook salmon listed as threatened under the Endangered Species Act.

The study addressed two life-history patterns for 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 throughout the Middle Fork and Mainstem Willamette Rivers from the upper Lookout Point reservoir to Wilsonville, Oregon. An active acoustic telemetry study of fish migration and passage was conducted to meet study objectives. Research objectives for separate 2017 fall and 2018 spring sampling periods for tagged juvenile Chinook salmon were as follows:

1) For the reservoir[1], estimate distribution, behavior, and movements of study fish, including
   a) Reservoir residence time[2]
   b) Movement patterns within the reservoir
   c) Horizontal distribution at reservoir receiver arrays.
2) For the forebay[3], estimate detailed[4] distribution, behavior, and movements into and within the forebay, including
   a) Horizontal approach distributions
   b) Forebay residence time[5]
   c) Vertical distributions (day/night).
3) For Lookout Point, estimate passage metrics and survival rates, including
   a) Route distribution (turbines, spillway [if available], regulating outlets [if available] (day/night)
   b) Dam passage efficiency (DPE[6]) and fish passage efficiency (FPE[7])
   c) Dam and route-specific survival rates.
4) For the Lookout Point tailwaters,[8] estimate survival rates and travel times, including
   a) Lookout Point project survival[9]

[1] Reservoir is defined as the portion of the Lookout Point pool extending from the upper reservoir to the forebay entrance.

[2] Reservoir residence time is the duration of time from release to time of entrance into the forebay.

[3] Forebay is defined as the portion of the Lookout Point reservoir that extends from the dam-face to ~300 m upstream; it is also described as the zone of hydraulic influence from typical dam operations.

[4] "Detailed" implies three-dimensional (3D) tracking of tagged fish.

[5] Forebay residence time is the duration of time from first detection on the forebay array that is not detected subsequently on reservoir arrays upstream and the last detection on the dam-face array.

[6] DPE is the number of tagged fish known to have passed Lookout Point divided by the number known to have entered the forebay.

[7] FPE is the number of tagged fish known to have passed through the regulating outlets (ROs) and spill divided by the total number known to have passed the dam (turbines+ROs+Spill).

[8] Tailwaters include the portion of the middle-Fork Willamette and Willamette Rivers from Lookout Point to Wilsonville.

[9] Project survival encompasses the region from the Lookout Point dam-face to the Dexter tailwater.

b) Dexter reservoir survival
c) Dexter route-specific passage distributions (spillway vs. turbine passage)
d) Travel times between Lookout Point and Dexter and Lookout Point and Wilsonville.

A single-release survival model was utilized for this acoustic telemetry study (Figure S.1). Detection arrays were deployed to monitor juvenile salmon implanted with acoustic tags at nine locations in the Middle Fork and mainstem Willamette River (Figure S.2 and Figure S.3).

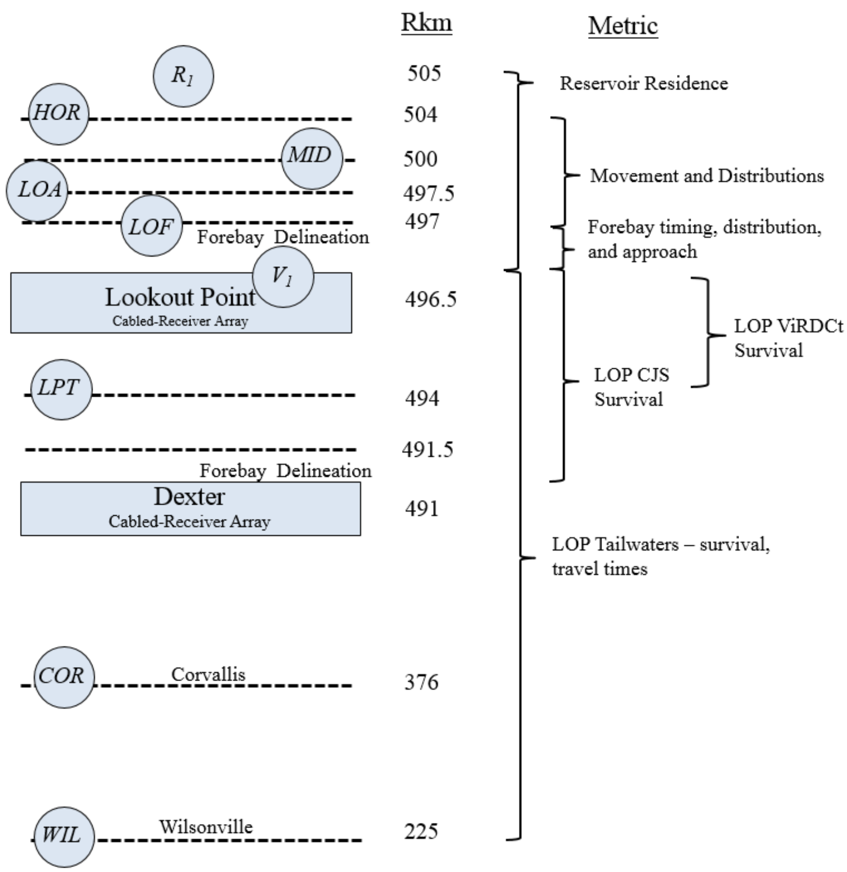

Figure S.1. Study Design Used to Estimate Project Metrics and Survival at Lookout Point and Dexter Using Juvenile Salmon Acoustic Telemetry System Cabled and Autonomous Receivers Arrays

The Oregon State University (OSU) Wild Fish Surrogate Program provided Chinook salmon reared to the approximate size of wild juveniles migrating through Lookout Point. Both acoustic tags (Advanced Telemetry Systems, Inc. [ATS] Tag model SS300; Isanti, MN) and passive integrated transponder (PIT) tags were surgically implanted in study fish. Tagged fish were released and monitored during two study periods: fall 2017 and spring 2018. During the fall period (October 17, 2017–February 19, 2018), a total of 1,507 subyearling Chinook salmon were tagged and released; 742 in mid-October and 765 in early December. During the spring period (February 20–July 9, 2018), a total of 1,527 yearling Chinook salmon were tagged and released; 750 in late February and 777 in mid-April. Detection data were used to estimate passage and survival for each of the study periods. Study fish were released in October and December of 2017 during reservoir drawdown and during spring reservoir refill in February and April 2018 (Figure S.2).

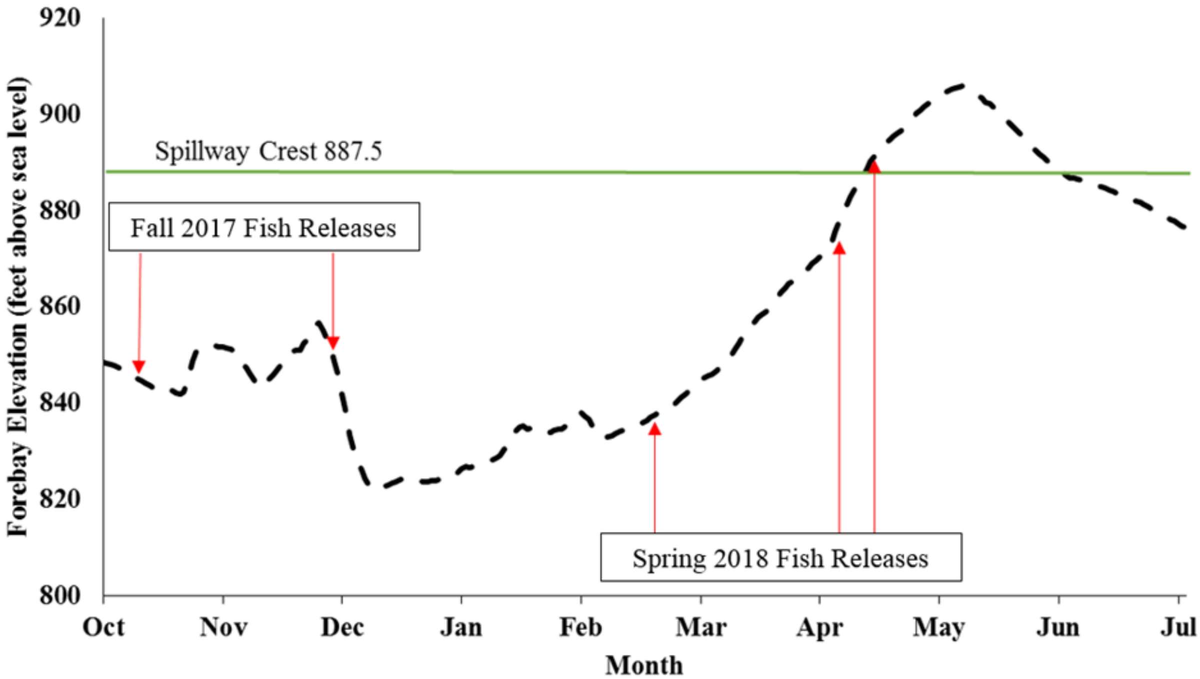

Figure S.2. Forebay Elevation (ft msl) during the Study Period (October 2017 through July 2018)

Fall 2017

During fall 2017, the turbine units were the only available route for fish passage and the units were generally operated during peak power demand; the early morning, and evening hours. Passage at Lookout Point varied between the October and December release groups, but in general most fish that passed Lookout Point did so within the first 2 weeks post-release (Figure S.3). Survival for these turbine-passed fish was estimated from the dam-face at Lookout Point (V_1) to the Lookout tailwater array (LPT) using the Virtual Release with Dead fish Correction (ViRDCt) model for the October and December release groups (Table S.1).

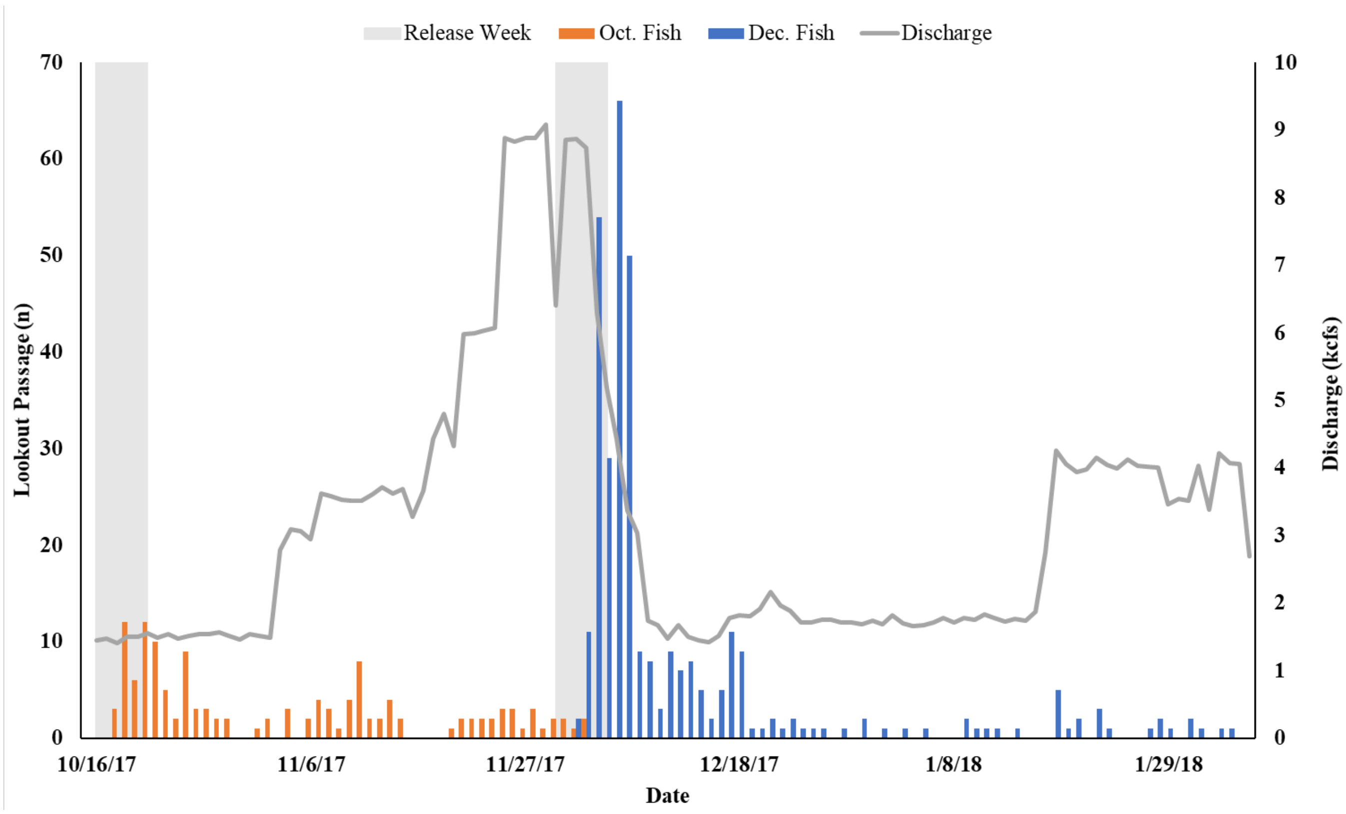

Figure S.3. Fish Passage and Daily Average Discharge through Lookout Point Turbines during the Fall of2017.

Table S.1. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\hat{S}$) from Lookout Point Passage to the Lookout Point Tailrace Array (LPT) for Acoustic-Tagged Subyearling Chinook Salmon Released into the Lookout Point Reservoir in October and December 2017. The detection probability (p) of the detection array (LPT) is also shown. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01. Superscripts indicate the model that was used to estimate survival.

	Lookout Point to Immediate Tailrace		
V_1 Group	**N**	**$\hat{S}$ (SE)**	**p**
October turbines	134	0.7788 (0.0386)	0.99
December turbines	331	0.8226 (0.0241)	1.00

Other noteworthy results include the following:

- By Day 55 post-release, a large proportion (72%) of October released fish were never detected or classified as “lost in the reservoir” and a moderate proportion (37%) of December-released fish were classified similarly.

- Horizontal distributions of both October and December-released fish arriving at the head-of-reservoir (HOR) and mid-reservoir (MID) arrays were generally evenly distributed as fish moved down reservoir to Lookout Point.
- Most study fish arriving in the Lookout Point forebay approached the dam from the southern side of reservoir and shifted northerly on approach to the dam-face, ultimately concentrating in front of the powerhouse and spillway transition area. This behavior was similar for both the October and December release groups.
- Vertical distributions of fish in the near forebay (<150 m from dam-face) at Lookout Point indicated almost all fish were observed at a depth of <2.5 m, demonstrating surface orientation.
- Very few of the October and December released fish were 3D tracked at Regulating Outlet (RO) depth.
- The spillway and ROs were not operated in fall 2017; therefore, all fish passing Lookout Point did so via the turbine units.
- Of the fish released in October (n = 742), 18% passed Lookout Point (n = 134).
- Of the fish released in December (n = 765), 43% passed Lookout Point (n = 331).
- Passage proportions for turbine-passed fish were generally similar for Units 1–3 for the October and December passed fish.
- Much greater proportions of fish from the October and December release groups passed Lookout Point at night than during the day.
- DPE was 31% for October released fish and 58% for December-released fish.
- Survival of turbine-passed fish to the Lookout Point tailwaters was 77.9% (SE = 3.9) for October released fish (n = 134) and 82.3% (SE = 3.4) for December-released fish (n = 331).
- Dexter reservoir survival, from the Lookout Point tailwaters to Dexter ranged from 93.0% (SE = 6.8) to 88.5% (SE=4.3) for the October and December release groups, respectively.
- Travel rates (rkm/day) indicated fish moved slowly through the Lookout Point reservoir and forebay, and Dexter reservoir, but traveled quickly through the Dexter tailwaters down to Wilsonville in fall 2017. Noteworthy is the delay in migration that fish experienced in the forebay at Lookout Point.

Spring 2018

In spring 2018, the turbine units were the primary route of Lookout Point discharge; however, on April 29, 2018, Spill Bay 3 was operated for approximately 6 h during the day. Only 18% of February-released fish passed Lookout Point in spring and an even smaller proportion from the April release groups (3%; Figure S.4) passed the dam. Of the February and April-released fish that passed the dam, 41% did so during the short 6 h window of spill on April 29. Survival for fish that passed Spill Bay 3 was estimated from the dam-face at Lookout Point (V_1) to the Lookout tailwater array (LPT) using the ViRDCt model for pooled February and April spill-passed fish (Table S.2).

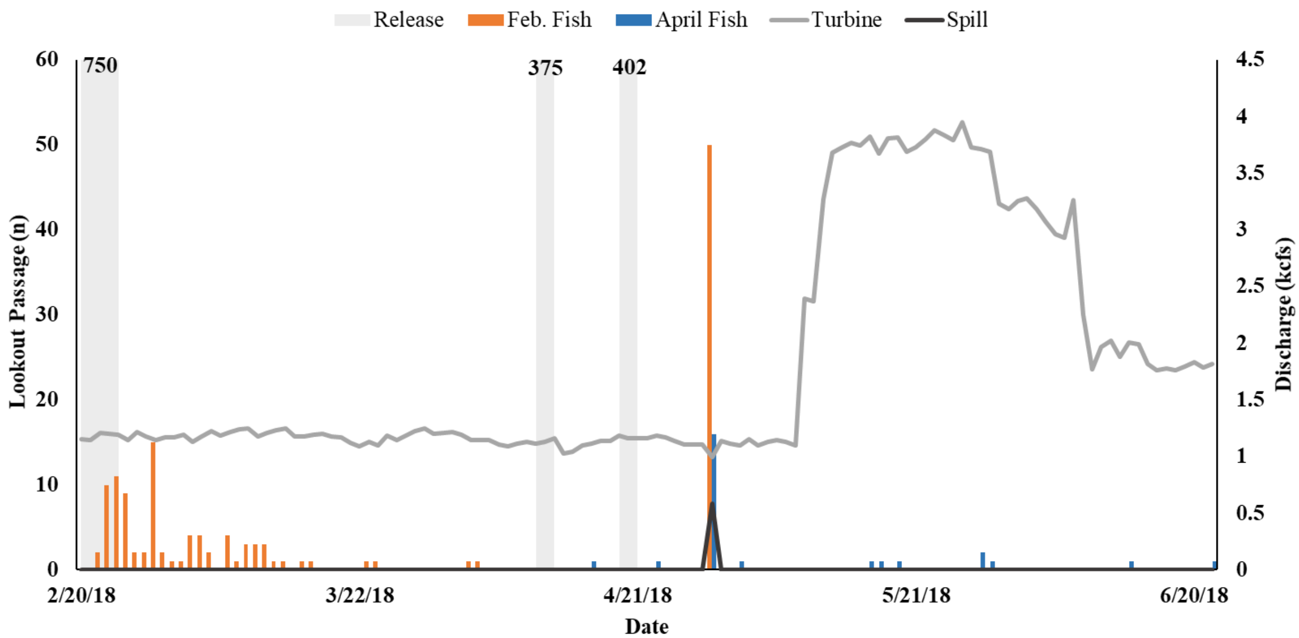

Figure S.4. Fish Passage and Daily Average Discharge through Lookout Point during the Spring of 2018

Table S.2. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\widehat{S}$) from Lookout Point Passage to the Lookout Point Tailrace Array (LPT) for Acoustic-Tagged Subyearling Chinook Salmon Released into the Lookout Point Reservoir in February and April 2018. Detection probability (p) of the detection array (LPT) is also shown. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01. Superscripts indicate the model that was used to estimate survival.

	Lookout Point to Immediate Tailrace		
V_1 Group	**N**	**$\widehat{S}$ (SE)**	**p**
February turbines	83	0.7844 (0.0473)	1.00
April turbines	11	0.6537 (0.1893)	1.00
February & April spillway	66	0.9872 (0.0553)	1.00

Other noteworthy results include the following:

- For the February release group, a majority of fish (66%) were never detected or classified as “lost in the reservoir” by the time spill occurred on April 29, 2018—approximately 70 days post-release.
- By Day 55 post-release, a very large proportion (85%) of April-released fish were never detected or classified as “lost in the reservoir.”
- Horizontal distributions of both February and April-released fish arriving at the HOR and MID detection arrays were generally evenly distributed as fish moved down reservoir to Lookout Point.
- For fish arriving in the Lookout Point forebay the approach pattern was primarily northerly vs. southerly as observed with the fall study fish. In general, fish arrived in the forebay evenly

distributed, bank-to-bank. However, as fish approached the dam-face, they concentrated in front of the powerhouse and spillway transition area, similar to the October and December release groups.

- Vertical distributions of fish in the near forebay (<150 m from the dam-face) indicated most fish were observed at a depth of <2.5 m, demonstrating a surface orientation for both release groups. In general, even proportions of fish were observed during both day and nighttime hours in the forebay.
- Very few February and April-released fish were 3D tracked at RO depth.
- The spillway was operated on April 29, 2018, from 10:30–16:45 h. The ROs were not operated in spring.
- Of the fish released in February (n = 750), 18% passed Lookout Point (n = 133). Of the 133 fish that passed the dam, 38% passed via Spill Bay 3 (n = 50) during 6 consecutive hours of spill on April 29th and 62% passed via the turbine units (n = 83).
- Of the fish released in April (n = 777), 3% passed Lookout Point (n=27). Of the 27 fish that passed the dam, 59% passed via Spill Bay 3 (n = 16) during 6 consecutive hours of spill on April 29th and 41% passed via the turbine units (n = 11) during the spring season.
- For both February and April release group fish passing via the turbine units, larger proportions of fish were observed passing via Turbine Unit 3 (closest to the north shore) compared to Turbine Units 1 and 2.
- DPE was 27% for February-released fish and 5% for April-released fish.
- FPE was 10% for February-released fish and 3% for April-released fish.
- Survival of turbine-passed fish (n = 83) to the Lookout Point tailrace was 78.4% (SE = 4.7) for February-released fish.
- Survival of pooled February and April-released fish passing via Spill Bay 3 on April 29, 2018 (n = 66) was 98.7% (SE = 5.5).
- Dexter reservoir survival, from the Lookout Point tailwaters to Dexter ranged from 89.1% (SE = 8.4) for February to 89.6% (SE = 8.7) for April (spill-passed fish only) release groups.

The probability of acoustic tagged fish being detected at cabled and autonomous arrays was high for both the fall 2017 and spring 2018 study periods. Juvenile Chinook salmon dispersed through the Lookout Point reservoir and as the seasons progressed, increasing numbers were lost in the reservoir (unaccounted). Long residence times and low passage efficiencies indicate that fish migrating through the Lookout Point forebay spent extended periods of time searching for passage routes at the dam with little success. Fish that passed Lookout Point did so mainly at night through the turbine units, except for a small period of spill that occurred in late spring. Survival through the turbine units was moderate (~80%) for all study periods except fish released in April, and spillway survival was very high (~99%) in spring. Extended residence times and notable mortality (10%) was observed in the Dexter Reservoir. Similar to Lookout Point, passage at Dexter occurred mainly at night through the turbine unit.

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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This research was conducted in compliance with protocols approved by PNNL’s Institutional Animal Care and Use Committee.

Acronyms and Abbreviations

µs	microsecond(s)
2D	two dimensional
3D	three dimensional
4D	four dimensional
°C	degree(s) Celsius
CF	compact flash data card
AT	acoustic telemetry
ATLAS	acoustic tag life-adjusted survival
ATS	Advanced Telemetry Systems, Inc.
BiOp	Biological Opinion
BPSK	binary phase shift keying
CENWP	U.S. Army Corps of Engineers-Portland District
cfs	cubic (foot) feet per second
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
CJS	Cormack-Jolly-Seber
COR	Corvallis
d	day(s)
DEX	Dexter Dam
DPE	dam passage efficiency
DSP	digital signal processor
FPE	fish passage efficiency
FPGA	field-programmable logic gate array
ft	foot (feet)
g	gram(s)
GPS	global positioning system
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 Forebay Approach Array
LOF	Lookout Point forebay delineation
LOP	Lookout Point Dam
LPT	Lookout Point tailwater/tailrace array

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
rkm	river kilometer(s)
RM&E	research monitoring and evaluation
RO	regulating outlet
RPA	Reasonable and Prudent Alternative
s	second(s)
SE	standard error
SPE	spill passage efficiency
USACE	U.S. Army Corps of Engineers
ViRDCt	Virtual Release with Dead fish Correction
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 passage and survival of juvenile Chinook 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 2017–2018 research effort was to provide the USACE 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 research monitoring and evaluation [RM&E]). These data will support management decisions about 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 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 Dam (Dexter). AT methodologies were used to examine juvenile Chinook salmon migration, passage, and survival through the study area under different operational and environmental scenarios to address the following research objectives:

1) For the reservoir[1], estimate distribution, behavior, and movements of study fish, including
    a) Reservoir residence time[2]
    b) Movement patterns within the reservoir
    c) Horizontal distribution at reservoir receiver arrays.
2) For the forebay[3], estimate detailed[4] distribution, behavior, and movements into and within the forebay, including
    a) Horizontal approach distributions
    b) Forebay residence time[5]
    c) Vertical distributions (day/night).
3) For Lookout Point, estimate passage metrics and survival rates, including
    a) Route distribution (turbines, spillway [if available], regulating outlets [if available] (day/night)
    b) Dam passage efficiency (DPE[6]) and fish passage efficiency (FPE[7])
    c) Dam and route-specific survival rates.
4) For the Lookout Point tailwaters,[8] estimate survival rates and travel times, including

[1] Reservoir is defined as the portion of the Lookout Point pool extending from the upper reservoir to the forebay entrance.

[2] Reservoir residence time is the duration of time from release to time of entrance into the forebay.

[3] Forebay is defined as the portion of the Lookout Point reservoir that extends from the dam-face to ~300 m upstream; it is also described as the zone of hydraulic influence from typical dam operations.

[4] “Detailed” implies three-dimensional (3D) tracking of tagged fish.

[5] Forebay residence time is the duration of time from first detection on the forebay array that is not detected subsequently on reservoir arrays upstream and the last detection on the dam-face array.

[6] DPE is the number of tagged fish known to have passed Lookout Point divided by the number known to have entered the forebay.

[7] FPE is the number of tagged fish known to have passed through the regulating outlets (ROs) and spill divided by the total number known to have passed the dam (turbines+ROs+Spill).

[8] Tailwaters include the portion of the middle-Fork Willamette and Willamette Rivers from Lookout Point to Wilsonville.

a) Lookout Point project survival[1]
b) Dexter reservoir survival
c) Dexter route-specific passage distributions (spillway vs. turbine passage)
d) Travel times between Lookout Point and Dexter, and Lookout Point and Wilsonville.

1.1.1 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, and subsequently Dexter reservoir and dam. The National Marine Fisheries Service (NMFS) 2008 Biological Opinion (BiOp) RPA contained measures for investigations of both interim reservoir survival and dam passage, future reservoir survival and dam passage, as well as investigation of 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 needed to inform decision-makers about options to improve juvenile fish survival through the highly modified rearing and migration corridor, which contains the Lookout Point flood risk management infrastructure, and under a range of feasible conditions. A study of juvenile Chinook salmon residence times, temporal and spatial distributions, passage, and survival rates for reaches from Lookout Point reservoir to below Dexter will provide important information for the Action Agencies (the Bonneville Power Administration and USACE) who are developing operational and structural alternatives per the intent of RPAs 4.8, 4.10, 4.11, 4.12, and 9.3.

1.1.2 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 occurring 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.

[1] Project survival encompasses the region from the Lookout Point dam-face to the Dexter tailwater.

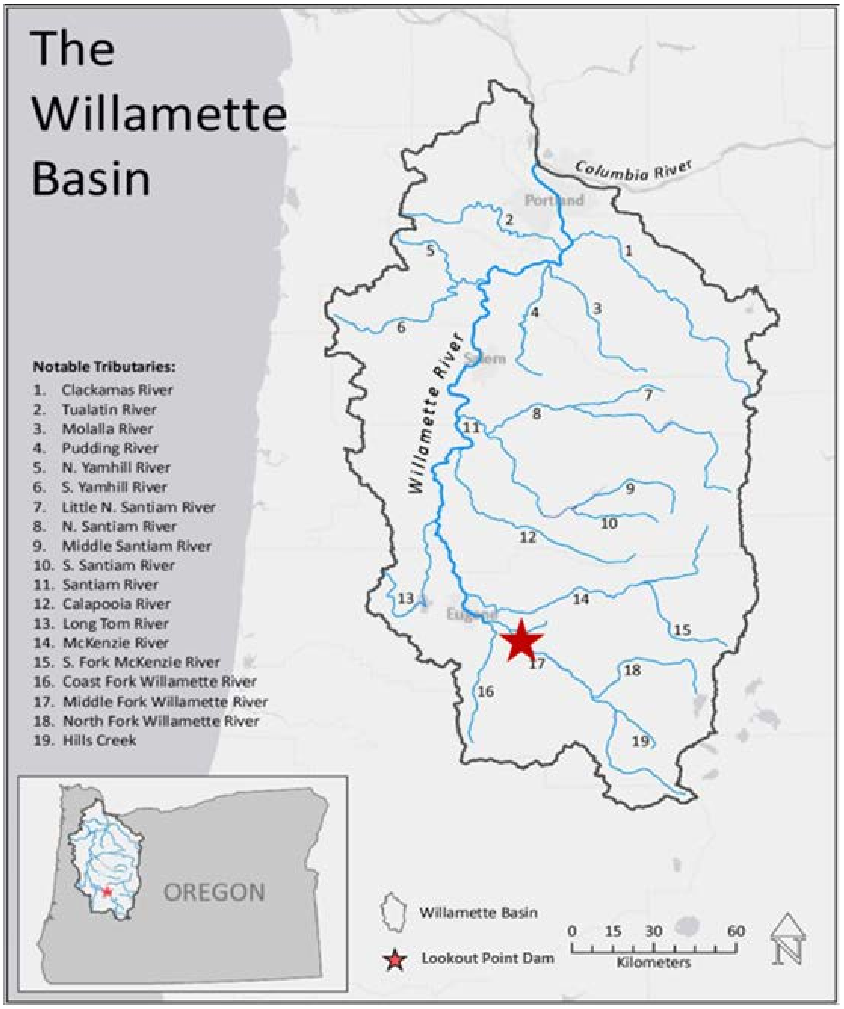


Figure 1.1. Map of the Willamette Basin Showing the Location of Lookout Point

Friesen et al. (2013) studied migration characteristics of passive integrated transponder (PIT)-tagged juvenile Chinook salmon (>60 mm fork length) 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, 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. (2012a) 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. Almost all smolt size fish passed the turbine units during December-January and very few (less than 1% or 212 individual fish) passed the RO when the turbine and RO were operated concurrently. 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. (2012b) found turbine passage rates for smolt-size fish was highest during late fall, winter, and early spring months. Similar 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 in this report is intended to help address this need.

An initial active tag (Juvenile Salmon Acoustic Telemetry System [JSATS]) study was conducted during fall 2016 and spring 2017 to obtain information about reservoir entry and survival of juvenile Chinook salmon in the Middle Fork Willamette River and Lookout Point (Fischer et al. 2018). The study addressed two life-history patterns for Chinook salmon: 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). Results from this study indicated that of 520 fish released at the head of reservoir (HOR) in the fall during minimum conservation pool elevation, 276 arrived in the forebay of Lookout Point, 31 passed the dam, and 13 fish were detected at downstream arrays at Salem and Wilsonville. An ungated spill operation was opportunistically sampled during spring 2017, during refill as a surface outlet for fish. For this study, 549 fish were released at the HOR approximately 7 days prior to the ungated spill operations, which began in March. Results indicated 475 fish arrived into the forebay of Lookout Point, 299 passed the dam, and 184 fish were detected at downstream arrays at Wilsonville in early May (Fischer et al. 2018).

1.2 Study Site Description

Lookout Point (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 management, power generation, irrigation, recreation, navigation, and to sustain the 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 1.3). 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 925 ft. (relative to mean sea level [msl]) and the minimum conservation pool is 825 ft. msl (http://www.nwd-wc.usace.army.mil/dd/common/projects/www/lop.html).

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

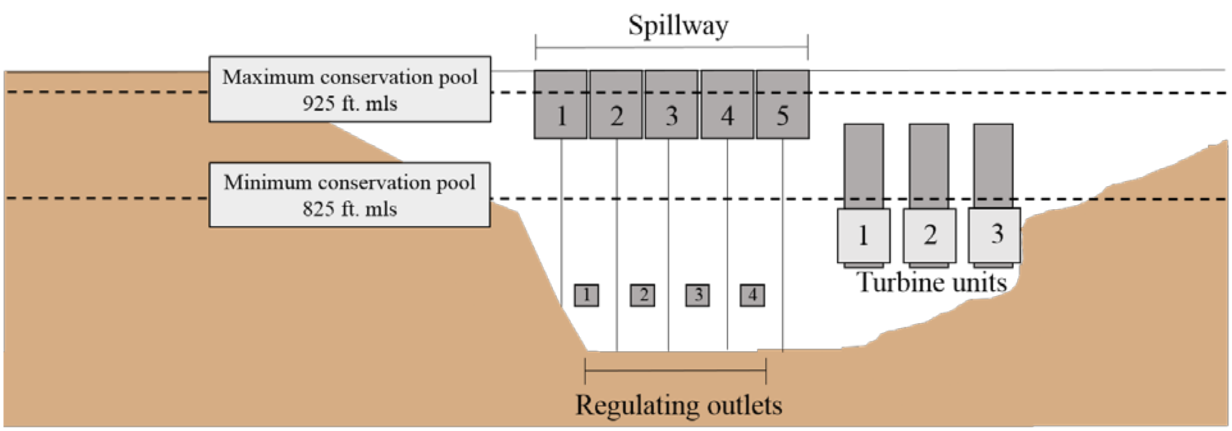


Figure 1.3. Front Elevation View of Passage Routes at Lookout Point from Upstream. Numbers designate possible fish passage routes through the spill bays, regulating outlets, and turbine units. Maximum and minimum pool elevations are indicated by the dashed line in feet above mean sea level (ft msl).

1.3 Report Contents

The ensuing sections of this report present the study methods (Section 2.0), environmental results (Section 3.0), fish passage results (Sections 4.0 and 5.0), associated 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 and Appendix B contains fish passage and travel times.

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 receiver array configuration (autonomous and cabled) to testing and final system deployment configuration:

1. Suitable locations were determined throughout the Lookout Point reservoir, Lookout Point, Dexter reservoir, Dexter, and the Willamette River.
2. Receivers were deployed at these locations in configurations to maximize the likelihood of detection.
3. All hydrophones were tested to determine detection ranges and efficiencies.
4. The optimum configuration for each array was finalized.
5. Juvenile Chinook salmon were tagged and released during fall 2017 and spring 2018 to estimate passage metrics and behavior through Lookout Point, Dexter, and tailwaters.

2.2 Release-Recapture Design and Sample Size

The single-release-recapture design was used to estimate fish 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 (HOR). The forebay entrance array (LOF) served as the forebay delineation above Lookout Point. Fish were regrouped into a virtual release group (V_1) on the Lookout Point cabled-receiver array and consisted of fish known to have arrived alive and passed Lookout Point after being released at the HOR (Figure 2.1). Survival estimates for fish included passage through Lookout Point and travel through 5 rkm of tailwaters to the primary array (Dexter; cabled-receiver array). Where applicable, the Virtual Release with Dead fish Correction (ViRDCt) model (Harnish et al. 2017) was used to estimate survival of V_1 released fish to the Lookout Point tailrace egress array (LPT). Capture histories were compiled from detections at all receiver arrays above and below Lookout Point. Detections consisted of receiver arrays at the primary array (Dexter) and secondary array (Corvallis [COR]) in combination with the tertiary array (Wilsonville [WIL]) to estimate the combined probability of detection and survival ($\hat{\lambda}$).

During the fall study period (October 17, 2017–February 19, 2018), a total of 1,507 subyearling Chinook salmon (CH0) were double-tagged (AT and PIT) and released in two groups; 742 in mid-October and 765 in early December (Table 2.1). The mean fork length and weight of released CH0 were 167.7 mm and 53.6 g, respectively. During the spring period (February 20–July 9, 2018), a total of 1,527 yearling Chinook salmon (CH1) were tagged and released; 750 in late February and 777 in mid-April (Table 2.1). The mean fork length and weight of CH1 were 183.1 mm and 66.3 g, respectively.

For each study period (fall 2017 and spring 2018), 80 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.

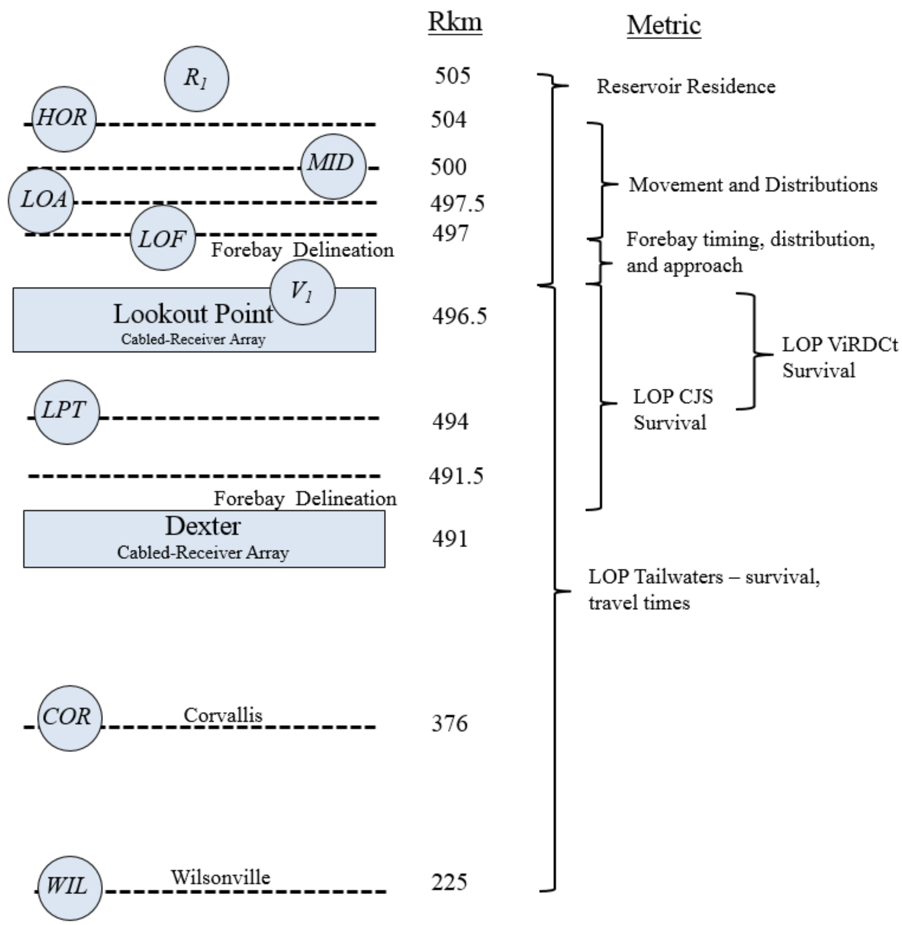


Figure 2.1. Study Design Used to Estimate Project Metrics and Survival at Lookout Point and Dexter. Cabled-receiver arrays were deployed at both Lookout Point and Dexter. All other arrays were autonomous receivers.

Table 2.1. Total Number and Mean Fork Length and Weight of Juvenile Salmonids Tagged and Released during 2017–2018. All living fish were released at three points along a transect 1 rkm upstream of the head-of-reservoir (HOR) array. All dead fish were released into the Lookout Point tailrace from the downstream end of the powerhouse at Lookout Point.

Season	Type	Release Group	Release Location	n	Mean Length (mm)	Mean Weight (g)
Fall 2017	Subyearling Chinook (CH0)	October	HOR	742	158.0	44.3
			Tailrace	41	156.4	42.8
		December	HOR	765	177.2	62.8
			Tailrace	39	177.2	61.9
		Total		1,587	167.7	53.6
Spring 2018	Yearling Chinook (CH1)	February	HOR	750	183.1	69.4
			Tailrace	40	174.6	60.4
		April	HOR	777	183.9	64.2
			Tailrace	40	175.4	55.3
		Total		1,607	183.1	66.3

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 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 5 s. Average battery life was 70.2 days and 71.1 days for fall 2017 and spring 2018, respectively. (See Section 2.8.1 for a description of the tag-life analysis.)

Figure 2.2. Acoustic Tag (ATS SS300; bottom) and PIT Tag (top) that Were Surgically Implanted in Subyearling and Yearling Chinook Salmon in 2017 and 2018

2.4 Fish-Handling, Tagging, and Release Procedures

The OSU Wild Fish Surrogate Program provided the study fish (surrogates for wild fish in the Middle Fork Willamette River). 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 for 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 Oregon Department of Fish and Wildlife (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 s, 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 h 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.

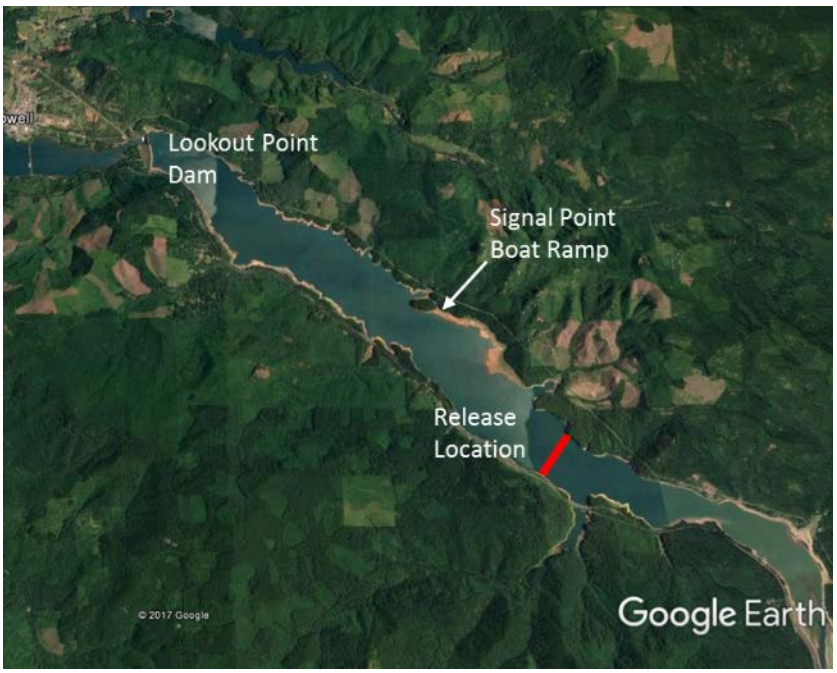


Figure 2.3. Release Location in Lookout Point Reservoir, 8.5 km from the Dam

2.5 Detection of Fish Implanted with Acoustic Tags

JSATS receivers deployed in Lookout Point reservoir and dam, Dexter reservoir and dam, 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 and receiver types used for the fall 2017 and spring 2018 AT studies at Lookout Point.

Table 2.2. Acoustic Telemetry Receiver Deployment Location, Type, and Study Purpose

Array Location	Receiver Type	Receivers per Array	Rkm	Study Purpose
Head of Reservoir (HOR)	Autonomous	6	504	Movement and distribution
Mid-Reservoir (MID)	Autonomous	7	500	Movement and distribution
Lookout Point Approach (LOA)	Autonomous	17	497.5	Movement and distribution
Lookout Point Forebay (LOF)	Autonomous	4	497	Movement and distribution; 3D behavior
Lookout Point dam-face and star arrays	Cabled Star Array	12 12	496.5	Virtual release; dam passage survival; passage efficiencies; tailrace egress and forebay residence times; vertical and horizontal distributions
Lookout Point Tailwater (LPT)	Autonomous	2	494	ViRDCt survival; project egress; travel times
Dexter dam-face	Cabled	5	491	2D passage; primary survival array; ViRDCt survival
Corvallis (COR)	Autonomous	8	376	Secondary survival array; travel times
Wilsonville (WIL)	Autonomous	4	225	Tertiary survival array; travel times

2.5.1 Cabled Receivers

The modular, time-synchronized JSATS cabled dam-face receivers used in this study were designed by PNNL for the USACE using an off-the-shelf user-build system design (Weiland et al. 2011). Each cabled-receiver system includes a computer, data-acquisition software, digital signal processing cards with field-programmable logic gate array (DSP + FPGA), a global positioning system (GPS) card, a four-channel signal-conditioning receiver with gain control, hydrophones, and cables (Figure 2.4). Components of the cabled-receiver system were tested for performance and calibrated in an anechoic tank prior to deployment (Deng et al. 2010).

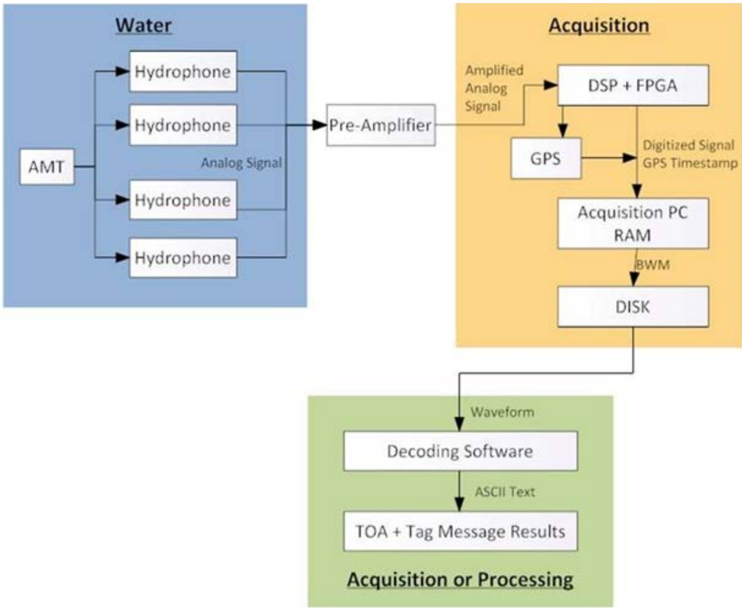


Figure 2.4. Schematic Showing the Main Components and the Direction of Signal Acquisition and Processing of a Modular Cabled-Array Receiver System. PC = personal computer; RAM = random access memory; BWM = binary waveform; TOA = time of arrival.

A cabled array was deployed along the upstream face of Lookout Point to detect the tagged migrant salmonids approaching the dam (Figure 2.5). The dam-face cabled array consisted of six cabled receivers, each supporting up to four hydrophones (Sonic Concepts, Inc.; Figure 2.6). The receivers were housed inside the penstock intake lift-gate galley on the forebay deck and the hydrophones were deployed flanking the penstock intakes and regulating outlets (ROs) in a known fixed geometry. In addition, three star arrays were deployed; one in front of the penstocks and two in front of the spillway.

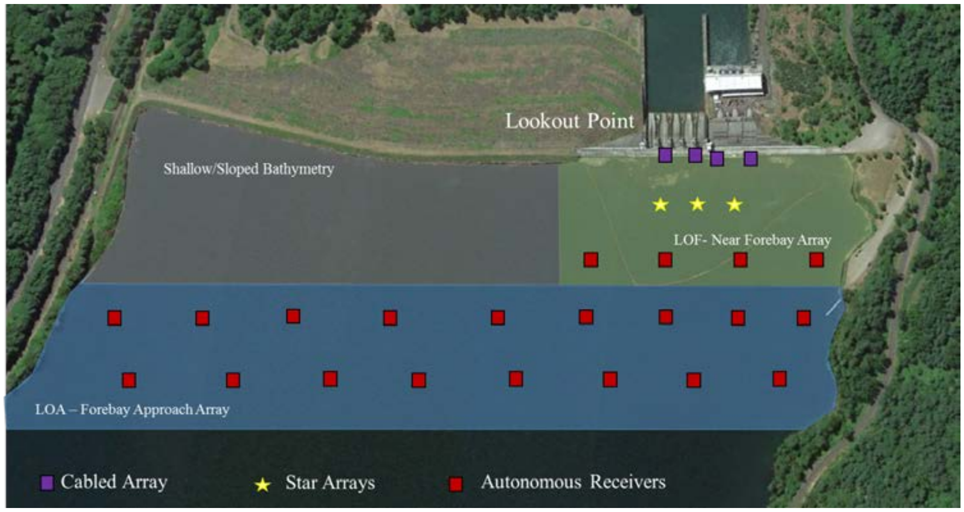


Figure 2.5. JSATS Cabled and Autonomous Receiver Array Deployment at Lookout Point, Fall 2017 and Spring 2018. The purple squares represent shallow and deep hydrophones at the dam-face, yellow stars represent star arrays in the near forebay, and red squares represent autonomous receivers in the forebay. The gray shaded “Shallow/Sloped Bathymetry” portion of the forebay upstream of earthen dam portion of Lookout Point was too shallow and its bathymetry was unsuitable for deploying autonomous receivers.

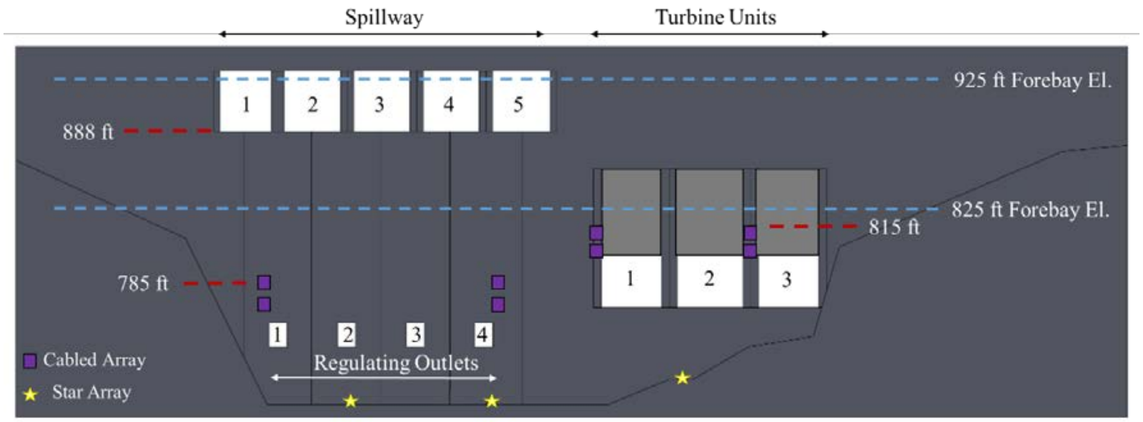


Figure 2.6. Front View Schematic of Hydrophone Deployments on the Dam-Face of Lookout Point

Twelve hydrophones were deployed on the Lookout Point dam-face. The fixed mounts used at the spillway (2) and penstocks (2) were 15 ft long and installed by divers at elevation 785 ft. (just above RO depth) and elevation 815 (just above penstock intakes; Figure 2.7). Each mount had two shallow and two deep baffled hydrophones for redundancy. All eight hydrophones at the penstocks were used for real-time data collection; only four of the eight hydrophones at the ROs were used for real-time data acquisition as the other four were used for backup purposes. Anechoic material was used to line a plastic cone surrounding the hydrophone to reduce the level of sound radiating from or reflected by the dam from reaching the hydrophone.

Figure 2.7. Diver-Installed Mounts at Lookout Point, Fall 2017 and Spring 2018

In addition to the hydrophones at the spillway and powerhouse, "star" arrays of hydrophones (3) were deployed in the near forebay of Lookout Point to allow for detailed 3D positioning. (Figure 2.8). The star arrays functioned as a stand-alone cabled-receiver system. The arrays consisted of four baffled hydrophones positioned in a specific fixed configuration on a steel frame, which were deployed ~75 m upstream of the Lookout Point dam-face. The three outer hydrophones were set in a plane equidistant from each other, while the interior hydrophone in the star array was offset from the plane of the other hydrophones but equidistant from them. Spacing between all four hydrophones was approximately 2 m to permit 3D position estimation and 4D tracking of tagged fish (Deng et al. 2011). Star arrays were deployed at the center of the spillway, between the spillway and powerhouse, and center of the powerhouse (Figure 2.5).

Figure 2.8. Star Arrays Deployed in Lookout Point Forebay, 2017–2018

At Dexter, similar mounts were used to install a 2D cabled array on the dam-face (Figure 2.9). Mounts were installed by boat on spillway piers 1–2, 3–4, and 5–6, and on either side of the powerhouse. A hydrophone of last detection was used to determine the route of passage through Dexter and only fish that were detected at a downstream survival array were used for this purpose. The Dexter forebay was delineated using the maximum range of detections of underwater hydrophones (~175 m) to determine entry time of study fish into the Dexter forebay.

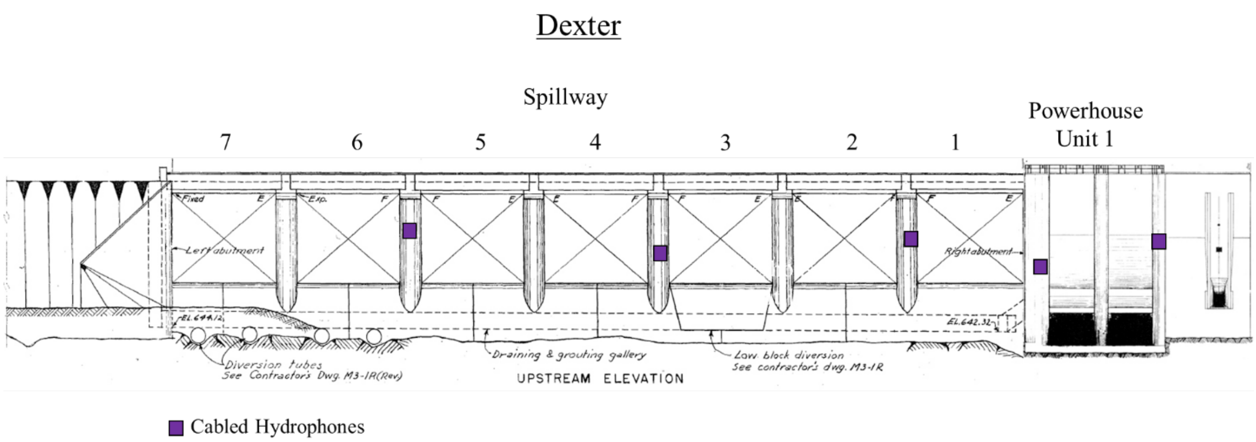


Figure 2.9. Diagram of Cabled Arrays Deployed at Dexter

2.5.2 Autonomous Receivers

The autonomous receivers used for this study (referred to as “autonomous receivers” or “receivers”), were designed by ATS for detection of acoustic tags in a riverine environment. Each receiver—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 2.10). 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 receiver, 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 2.10. Outer (left) and Internal (right) Views of an Autonomous Receiver

Seven autonomous receiver arrays were deployed for the Lookout Point study (Figure 2.11 and Figure 2.12). In most cases the receiver arrays consisted of a series of autonomous receivers 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 receivers 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.

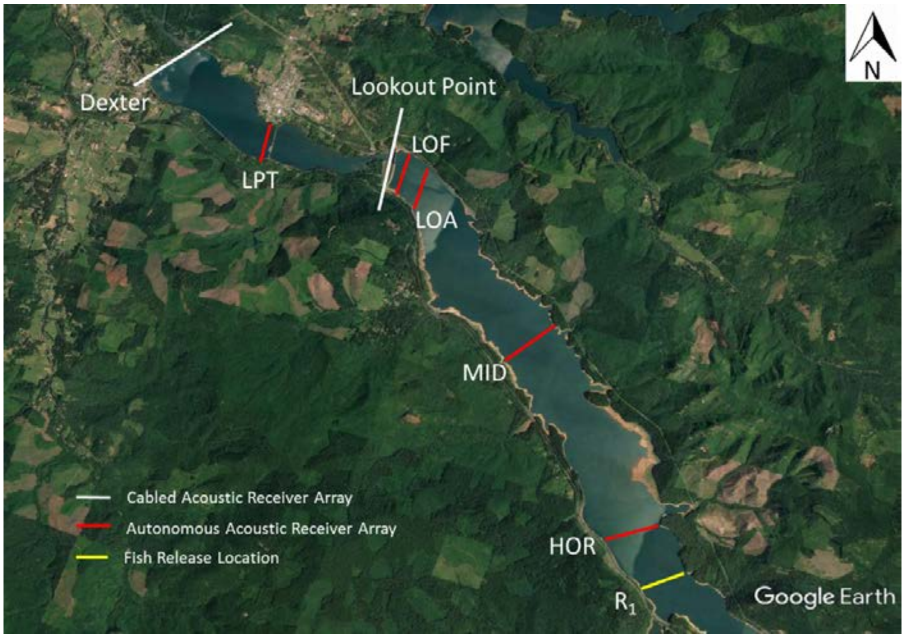


Figure 2.11. Location of Receiver Arrays Deployed to Monitor Study Fish in Lookout Point and Dexter Reservoirs

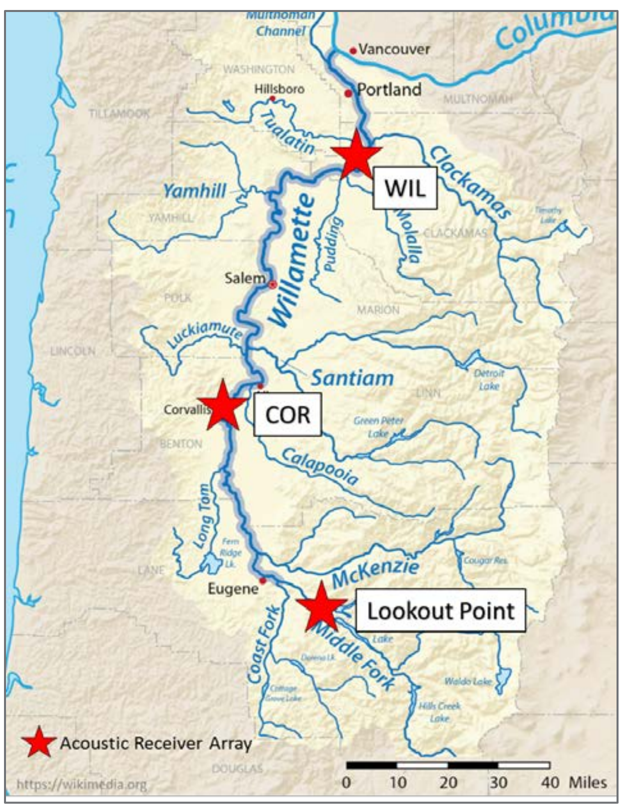


Figure 2.12. Location of Receiver Arrays Deployed to Monitor Study Fish in the Willamette River below Dexter

At the Corvallis location, four hydrophones were affixed to mounts that were strapped to wooden pilings located along the OSU rowing dock and four hydrophones were attached similarly to the Highway 34 bridges (Figure 2.13) and were used as one receiver array for the purposes of maximizing the likelihood of detection. Extensive testing indicated that this array could detect acoustic tags bank-to-bank and approximately 150 m upstream and downstream. Each hydrophone was attached to a data cable that ran up the bank to a box containing the battery-controlled receiver data instrumentation.

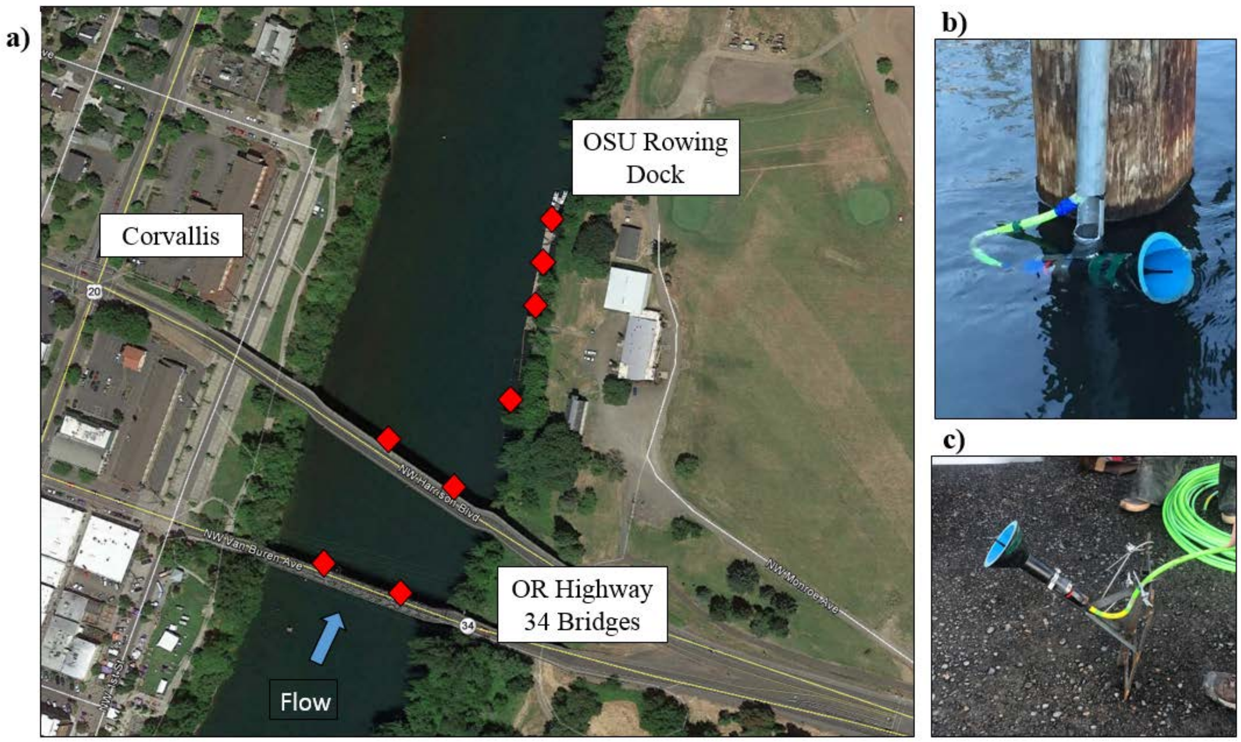


Figure 2.13. Corvallis Autonomous Receiver Array Deployment (a), Dock Receiver Deployment (b), and Bridge Recevier Depolyment (c)

The rigging used to deploy autonomous receivers was similar to that described by Titzler et al. (2010; Figure 2.14). Receivers were attached to an acoustic release (Model 111, InterOcean Systems, San Diego, CA or Model 875-T, Teledyne Benthos, North Falmouth, MA) using a 1.5 m section of rope with three 2.7 kg buoyancy floats. The rope was secured to the receiver via an eyebolt located on a compression strap around the receiver 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.

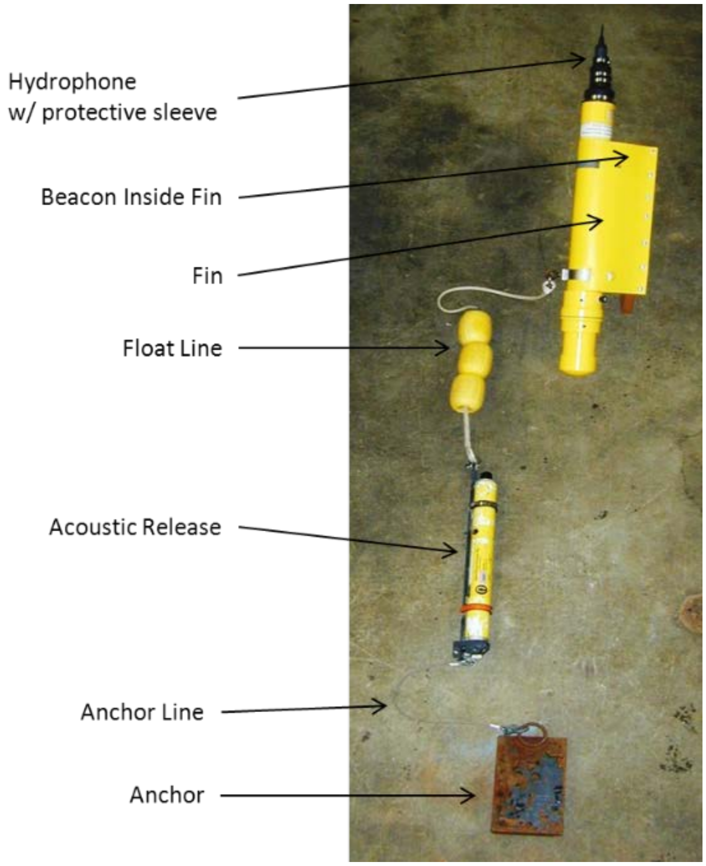


Figure 2.14. Autonomous Receiver Deployment Rigging with an InterOcean Acoustic Release

Autonomous receivers were recovered, serviced, and redeployed individually once every 3 weeks. The boat crew recovered the receivers 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 receiver convey the receiver, acoustic release, and upper rigging to the water surface. After recovery, receivers were serviced using the following process: 1) any deviation in the internal clock time for the deployment period was noted, 2) collected data were downloaded, 3) the battery pack was replaced, and 4) the receiver clock was synchronized to the correct satellite time. After confirming the proper functionality of each receiver, an anchor was attached, and the receiver 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 receiver was removed from service and replaced with a properly functioning receiver; the removed receiver was tested for performance after return to shore and repaired if necessary prior to future use. The most common problems experienced in 2017–2018 were damage to the receiver's exposed hydrophone tip, water intrusion, or occasional acoustic release malfunctions.

During the studies, all autonomous receiver arrays were deployed and confirmed to be collecting data before any surgically implanted fish were released into the reservoir. Receivers remained in service through the end of each study period (February for the fall 2017 study and the middle of July for the spring 2018 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., ~70 days).

2.6 Data Gaps

To help minimize the loss of data on cabled systems at Lookout Point and Dexter a real-time monitoring system was installed at both projects. This allowed for the monitoring of systems and the capability of addressing problems that arise in a quick and timely manner to limit data loss. The autonomous hydrophone arrays deployed in the reservoirs and main channel of the Willamette River were spaced in such a fashion to allow for overlap of detections. All receivers were tested prior to the start of the season to assure functionality. Receivers were downloaded every 3 weeks. At each download receivers were tested and data were analyzed real time to assure receivers were functioning properly. Nonfunctioning receivers were set aside for further testing and a new receiver was deployed.

2.7 Acoustic Signal Processing

Acoustic signal processing, for the cabled arrays, consisted of decoding binary waveform data files, filtering the decoded signals, and tracking fish movements using the decoded data. Autonomous array signals were processed by filtering decoded signals and using the decoded signals to determine if tagged fish passed through the array.

2.7.1 Signal Decoding

Encoded candidate messages detected on the JSATS cabled hydrophones that met certain criteria were saved in binary time-domain waveform files (Figure 2.15). The waveform files were then processed by a decoding utility (JSATS Decoder developed by the USACE and PNNL) that identifies valid tag signals and computes the tag code and time of arrival using binary phase shift keying (BPSK). BPSK is a digital-modulation technique that transmits messages by altering the phase of the carrier wave (Weiland et al. 2011). Several filtering algorithms were then applied to the raw results from the decoding utilities to exclude spurious data and false positive detections. Encoded messages detected on the JSATS autonomous receiver hydrophones and that met the criteria were decoded in real time and the decoded signal was recorded to a compact flash (CF) card in the autonomous receiver.

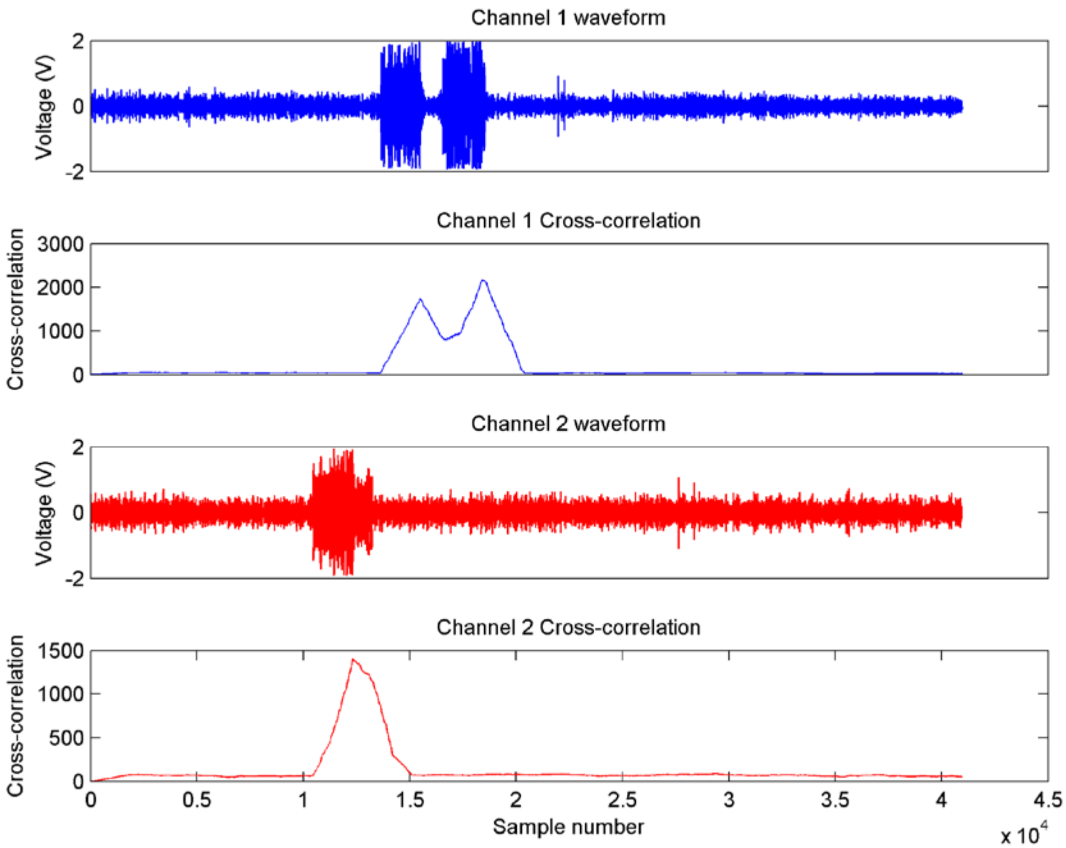


Figure 2.15. Example of Time-Domain Waveforms and Corresponding Cross-Correlations. The message portion was 1,860 samples (744 µs long). Note that multipath components were present in both channels. Decodes from the multipath components were filtered out in post-processing.

2.7.2 Filtering Decoded Data

Receptions of tag codes decoded from raw waveforms were further processed using several filtering algorithms to exclude spurious data and false positive detections and produce a data set of accepted acoustic tag detection events. For cabled arrays, detections from all hydrophones at a dam were combined for processing. The following three filters were used for cabled-array data:

- Multipath filter. For data from each individual cabled hydrophone, all acoustic tag receptions that occur within 0.156 s after an initial identical code reception were deleted under the assumption that closely lagging signals are multipath. Initial code receptions were retained. The delay of 0.156 s was the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and was computed as 2 (PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment were set at 0.006 s, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.
- Multi-detection filter. Receptions were retained only if the same acoustic tag code was received at another hydrophone in the same array within 0.3 s because receptions on separate hydrophones within 0.3 s (about 450 m of range) were likely from a single acoustic tag transmission.

- PRI filter. Only those series of receptions of an acoustic tag code (or “messages”) consistent with the pattern of transmissions from a properly functioning JSATS acoustic tag were retained. Filtering rules were evaluated for each code individually, and it was assumed that only a single acoustic tag would be transmitting that code at any given time. For the cabled system, the PRI filter operated on a message, which included all receptions of the same transmission on multiple hydrophones within 0.3 s. Message time was defined as the earliest reception time across all hydrophones for that message. Detection required that at least six messages were received with an appropriate time interval between the leading edges of successive messages.

Like the cabled-array data, receptions of acoustic tags recorded to the CF card in the autonomous node are processed to produce a data set of accepted acoustic tag detection events. A single file is processed at a time, and no information about receptions at other nodes is used. The following two filters are used during processing of autonomous node data:

- Multipath filter. Same as for the cabled-array data.
- PRI filter. Only the series of receptions of an acoustic tag code (or “hits”) that were consistent with the pattern of transmissions from a properly functioning acoustic tag were retained. Each tag 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 for an acceptable detection event.

The output of the filtering processes for both cabled and autonomous hydrophones was a data set of events that summarized accepted acoustic tag detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that indicated the unique identification number of the fish, the first and last detection time for the event, the location of detection, and the number of messages detected within the event. This list was combined with accepted acoustic tag detections from PIT detections for additional quality assurance/quality control measures prior to survival analysis. Additional fields also captured specialized information where available. One such example was route of passage, which was assigned a value for events that immediately precede passage at a dam based on spatial tracking of tagged fish movements to a location of last detection. Multiple receptions of messages within an event were used to triangulate successive acoustic tag positions relative to hydrophone locations.

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 60 5 s tags for both fall 2017 and spring 2018, 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 2017 and spring 2018, dead fish with active tags were released daily during fish releases from the lower powerhouse deck at Lookout Point. 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 Analysis of Survival

Survival was estimated for several river reaches, including dam passage survival measured as Lookout Point to the immediate tailrace (2 rkm below the dam) LPT and Lookout Point to Dexter, and Dexter reservoir survival, measured as LPT to Dexter. In addition, because some fish may not be active migrants, we report the joint probability of migration and survival from Lookout Point to Corvallis (COR). For fish released in the fall, survival was evaluated by timing of release (October or December). For fish released in the spring, survival was evaluated by release timing (February or April), Lookout Point passage timing (February and March or April and May), and Lookout Point passage route (spillway or turbine).

The standard single-release Cormack-Jolly-Seber (CJS) mark-recapture model (Cormack 1964; Jolly 1964; Seber 1965) provided the basis for all survival estimates and is expressed as

$$\hat{S}_{CJS} = \frac{\left(\frac{(n_{10} + n_{11})}{V_1}\right)}{\left(\frac{n_{11}}{n_{01} + n_{11}}\right)}$$

where n_{10} is the number of tagged fish from the virtual release group (V_1) that are detected at the primary survival array but not at downstream arrays, n_{11} is the number of tagged fish from V_1 that are detected at the primary survival array and at least one downstream array, and n_{01} is the number of tagged fish from V_1 that are not detected at the primary survival array but are detected by at least one downstream array. The V_1 group includes only those fish detected passing the array the marks the upstream boundary of the river reach over which survival is being estimated.

2.8.3.1 Tag-Life Corrected Estimates

Due to the potential for tagged fish to remain in the Lookout Point and/or Dexter reservoirs for a period of time following release, it was possible for fish to pass Lookout Point and downstream arrays near or after the end of their tag life, biasing standard CJS survival estimates low. Therefore, CJS estimates were adjusted for tag life using the methods of Townsend et al. (2006) and program ATLAS (Acoustic Tag Life-Adjusted Survival; Columbia Basin Research, University of Washington). Sixty acoustic tags were retained from the fall 2017 and spring 2018 tag lots to estimate the probability of tag failure over time.

2.8.3.2 ViRDCt Survival Estimation

Because Dexter is located just 5.5 km downstream of Lookout Point, tagged fish that die during passage through Lookout Point, but still have an active tag may be detected at Dexter; thus biasing the survival estimate. Therefore, the ViRDCt mark-recapture model (Harnish et al. 2017) was used to adjust the Lookout Point to Dexter CJS survival estimate for the bias that occurs from misidentifying dead fish as alive on the Dexter dam-face array. An estimate of this bias was obtained as the proportion of dead tagged fish released into the immediate tailrace of Lookout Point that were detected by the Dexter dam-face array. A simplified version of the ViRDCt model can be written as

$$\hat{S}_{ViRDCt} = \frac{\left(\frac{(n_{10}+n_{11})}{V_1}\right)-\frac{d}{D}}{\left(\frac{n_{11}}{n_{01}+n_{11}}\right)-\frac{d}{D}} \tag{2.1}$$

where n_{10}, n_{11}, V_1, and n_{01} are as described above for the CJS model and $\frac{d}{D}$ is the proportion of dead released fish that are detected at the primary survival array. However, maximum likelihood estimation was used to estimate Lookout Point passage survival with the ViRDCt model.

2.8.3.3 ViRDCt Reduced Model

Two alternative joint likelihood ViRDCt models were used throughout this study. The first model, the so-called reduced model, allows for detection of dead released fish on a single downstream array. For estimating Lookout Point to LPT survival, the reduced ViRDCt model can be written as

$$L = \binom{V_1}{n}(S_D p_1 + (1-S_D)\phi)^n \left(S_D(1-p_1) + (1-S_D)(1-\phi)\right)^{V_1-n} \cdot \binom{D_1}{m}\phi^m(1-\phi)^{D_1-m} \cdot \binom{n_{11}+n_{01}}{n_{11}} {p_1}^{n_{11}}(1-p_1)^{n_{01}} \tag{2.2}$$

where

- V_1 = the number of acoustic-tagged fish included in the virtual release group formed from fish detected passing Lookout Point,
- n = the number of V_1 fish detected at the LPT array,
- S_D = Lookout Point to LPT survival,
- p_1 = probability of an alive V_1 fish being detected at the LPT array,
- ϕ = the joint probability of a dead released fish (D_1) arriving at the LPT array and being detected at that array,
- m = the number of D_1 dead released fish detected at the LPT array,
- n_{11} = the number of V_1 fish detected at the LPT array and the Dexter dam-face array, and
- n_{01} = the number of V_1 fish not detected at the LPT array that were detected at the Dexter dam-face array.

Iterative procedures from Program USER (Columbia Basin Research, University of Washington) were used to estimate the model parameters and associated variances.

The reduced ViRDCt model was utilized in both October and February to estimate turbine survival from Lookout Point to the LPT array located 2.5 km downstream as well as estimating survival from the LPT array to the Dexter dam-face array located 2 km downstream.

2.8.3.4 ViRDCt Full Model

The second model utilized in this report is the full ViRDCt model. This model was also used to estimate Lookout Point passage survival from the time of passage to the LPT array located 2.5 km downstream of Lookout Point to reduce the amount of Dexter reservoir mortality that was included in the Lookout Point passage survival estimate. However, the so-called full model, which allows for detection of dead tagged fish on two downstream arrays, was used instead of the reduced model described above to estimate survival of fish passing through the turbine units in April. For the full model with possible dead fish detections at both the Lookout Point tailrace (LPT) and Dexter dam-face (DEX) arrays, the likelihood can be written as follows:

$$
\begin{aligned}
L = &\binom{V_1}{\vec{n}} (S_D p_1 \lambda + (1 - S_D)\omega p_D \Psi)^{n_{11}} \\
&\cdot (S_D(1 - p_1)\lambda + (1 - S_D)\omega(1 - p_D)\Psi)^{n_{01}} \\
&\cdot \left(S_D p_1(1 - \lambda) + (1 - S_D)\omega p_D(1 - \Psi)\right)^{n_{10}} \\
&\cdot \left[S_D(1 - p_1)(1 - \lambda) + (1 - S_D)\left((1 - \omega) + \omega(1 - p_D)(1 - \Psi)\right)\right]^{n_{00}} \\
&\cdot \binom{D}{\vec{d}} (\omega p_D \Psi)^{d_{11}} (\omega(1 - p_D)\Psi)^{d_{01}} \\
&\cdot \left(\omega p_D(1 - \Psi)\right)^{d_{10}} \left((1 - \omega) + \omega(1 - p_D)(1 - \Psi)\right)^{d_{00}}
\end{aligned}
\tag{2.3}
$$

where

- V_1 = the number of acoustic-tagged fish included in the virtual release group formed from fish detected passing Lookout Point,
- n = the number of V_1 fish detected at the Lookout Point tailrace array,
- S_D = Lookout Point to Lookout Point tailrace survival,
- p_1 = probability of an alive V_1 fish being detected at the Lookout Point tailrace array,
- λ = the joint probability of survival between the Lookout Point tailrace and Dexter dam-face arrays, and being detected at the Dexter dam-face array,
- ω = the joint probability of a dead fish from D_1 arriving at the Lookout Point tailrace array,
- p_D = the probability of detecting a dead tagged fish at the Lookout Point tailrace array,
- Ψ = the joint probability that a dead tagged fish is washed down to the Dexter dam-face array from the Lookout Point tailrace array and is detected at the Dexter dam-face array,
- n_{11} = the number of V_1 fish detected at the Lookout Point tailrace array and the Dexter dam-face array, and
- n_{01} = the number of V_1 fish not detected at the Lookout Point tailrace array that were detected at the Dexter dam-face array,
- n_{10} = the number of V_1 fish detected at the Lookout Point tailrace array but not at the Dexter dam-face array,
- n_{00} = the number of V_1 fish not detected at the Lookout Point tailrace or Dexter dam-face arrays,
- d_{11} = the number of fish from the dead release group (D_1) that were detected at the Lookout Point tailrace and Dexter dam-face arrays,
- d_{01} = the number of D_1 fish not detected at the Lookout Point tailrace array that were detected at the Dexter dam-face array,
- d_{10} = the number of D_1 fish detected at the Lookout Point tailrace array but not at the Dexter dam-face array, and
- d_{00} = the number of D_1 fish not detected at the Lookout Point tailrace or Dexter dam-face arrays.

Again, iterative procedures from Program USER (Columbia Basin Research, University of Washington) were used to estimate the model parameters and associated variances of the full ViRDCt model.

Estimating survival from Lookout Point (LOP) to the Lookout Point tailrace array (LPT) and from Lookout Point to the Dexter dam-face array (DEX) using the ViRDCt model allows for the estimation of survival in the lower half of the Dexter reservoir, between the LPT array and Dexter as follows:

$$\hat{S}_{LPT\ to\ DEX} = \frac{\hat{S}_{LOP\ to\ DEX}}{\hat{S}_{LOP\ to\ LPT}}. \tag{2.4}$$

Variances of LPT to Dexter survival estimates were calculated as follows:

$$\mathrm{Var}\left(\hat{S}_{LPT\ to\ DEX}\right) = \left(\frac{\hat{S}_{LOP\ to\ DEX}}{\hat{S}_{LOP\ to\ LPT}}\right)^2 \cdot \left(\mathrm{CV}\left(\hat{S}_{LOP\ to\ DEX}\right)^2 + \mathrm{CV}\left(\hat{S}_{LOP\ to\ LPT}\right)^2\right) \tag{2.5}$$

Route-specific survival was estimated from the time of passage through turbines and the spillway at Lookout Point to the Dexter dam-face array and from Lookout Point to the LPT array using the ViRDCt model. Route-specific survival was estimated by forming virtual release groups of fish that passed through each route and each route-specific estimated included only those fish that passed through the route. Route-specific virtual release groups were identified by using detections of fish on the Lookout Point cabled array to track their approach and passage in 3D.

2.8.3.5 Tag Life-Adjusted ViRDCt Survival Estimation

When delays in downstream migration occurred, (ie. December turbine and February spillway passed fish), survival estimates were adjusted for tag life and the bias of detecting dead tagged fish by applying the dead tagged fish detection rate $\left(\frac{d}{D}\right)$ to the ATLAS survival estimate:

$$\hat{S} = \frac{\left(\frac{\left(\frac{n_{10} + n_{11}}{V_1}\right)}{\hat{P}\left(L_{ij}\right)}\right) - \frac{d}{D}}{\left(\frac{n_{11}}{n_{01} + n_{11}}\right) - \frac{d}{D}} \tag{2.6}$$

where n_{10}, n_{11}, V_1, n_{01}, and $\frac{d}{D}$ are as described above for the CJS and ViRDCt models and $\hat{P}\left(L_{ij}\right)$ is an estimate of the probability a tag from the *i*th release group was operational at the *j*th detection array obtained from program ATLAS. The variance was estimated using the delta method (Seber 1982):

$$\widehat{\mathrm{Var}}(S) = \widehat{\mathrm{Var}}\left(\hat{S}_{ATLAS}\right) + \widehat{\mathrm{Var}}(\hat{p}_D)\left(\frac{\left(\frac{n}{V_1} - \hat{p}\right)}{(\hat{p} - \hat{p}_D)^2}\right)^2 + \widehat{\mathrm{Var}}(\hat{p})\left(\frac{\left(\frac{n}{V_1} - \hat{p}_D\right)}{(\hat{p} - \hat{p}_D)^2}\right)^2 \tag{2.7}$$

where

$\widehat{\mathrm{Var}}\left(\hat{S}_{ATLAS}\right) = \widehat{\mathrm{SE}}\left(\hat{S}\right)^2$ from the ATLAS model,

$\widehat{\mathrm{Var}}(\hat{p}_D) = \widehat{\mathrm{Var}}\left(\frac{d}{D}\right) = \frac{\frac{d}{D}\left(1-\frac{d}{D}\right)}{D}$ (i.e., binomial variance), and
$\widehat{\mathrm{Var}}(\hat{p}) = \widehat{\mathrm{SE}}(\hat{p})^2$ from the ATLAS model.

In addition to the assumptions of single-release mark-recapture studies (Skalski et al. 1998) and the tag-life correction model (Townsend et al. 2006), the following assumptions apply to the ViRDCt model:

- The estimated dead tagged fish detection rate is representative of the probability of detecting fish from the virtual release group that die during dam passage.
- Dead tagged fish are released into each route in similar proportions to the distribution of mortality of fish from the virtual release group.

Both assumptions are related to the representativeness of the dead tagged fish releases to fish from the virtual release group that die during dam passage. To make the dead tagged fish releases as representative as possible, dead tagged fish were to be released downstream of the powerhouse and spillway depending on which routes were operational at the time of release. In addition, dead tagged fish were released daily during the period of live fish releases in an attempt to capture the variability in environmental and operational conditions that could influence survival. Due to the short duration of spill that occurred during the study (~6 hours), dead tagged fish were only released in the powerhouse tailrace during periods of no spill and therefore it is assumed that dead fish detection rates for both powerhouse and spill tailrace-released fish are similar.

2.8.4 Estimation of Distributions

Based on detections on the Lookout Point dam-face array and 3D tracking results, the horizontal distribution of passage of fish at Lookout Point was estimated according to the individual turbine and spill bay of passage. The same 3D tracking data set allowed for evaluation of the vertical distribution of fish within 150 m of the dam.

Vertical distributions of tagged fish upon approach to Lookout Point can be useful in determining the effectiveness of a surface-flow outlet for entraining juvenile salmonids in its flow field. All references in this report to vertical distributions are related to the depth of the tagged fish relative to the forebay elevation at the time of detection (0 ft).

2.8.5 Estimation of Passage Efficiencies

DPE is the proportion of total fish passing the dam relative to the number of total fish detected in the near forebay of the dam (<150 m) and available to pass. DPE was estimated by the fraction

$$DPE = \frac{\hat{N}_{Turbine} + \hat{N}_{Spill} + \hat{N}_{TUR}}{\hat{N}_{NearForebay}}. \tag{2.8}$$

FPE is the proportion of fish passage via a non-turbine route relative to the number of total fish detected in the near forebay of the dam (<150 m) and available to pass. FPE was estimated by the fraction

$$FPE = \frac{\hat{N}_{Spill} + \hat{N}_{RO}}{\hat{N}_{NearForebay}} \tag{2.9}$$

Spill passage efficiency (SPE) is the proportion of fish passing Spill Bays 1–5 relative to the number of total fish passing Lookout Point. SPE was estimated by the fraction

$$SPE = \frac{\hat{N}_{Spill}}{\hat{N}_{Turbine} + \hat{N}_{Spill} + \hat{N}_{RO}}, \tag{2.10}$$

where $\hat{N}_i$ is the estimated abundance of tagged fish that passed through via a general route.

2.8.6 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.,

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n}, \tag{2.11}$$

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

$$Var(\bar{t}) = \frac{\sum_{i=1}^{n} \left(t_i - \bar{t}\right)^2}{n(n-1)}, \tag{2.12}$$

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

3.0 Results

Study results cover the following seasonal reservoir conditions; "fall drawdown" and "winter pool" in fall 2017 and "spring refill" in spring 2018 (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 2017 and Spring 2018 Study Periods

Season	Pool Elevation (ft msl)	Study Period
Fall	Drawdown (856-841)	10/17/17–11/30/18
	Winter Pool (841-822)	12/01/18–2/19/18
Spring	Spring Refill (837-905)	2/20/18–7/09/18

3.1 Environmental Conditions

Data collected about 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 reservoir elevation follows a rule curve managed by the USACE Reservoir Control Center. The rule curve dictates lowering the reservoir elevation in fall to prepare for storage and flood risk management 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 2017, the fall drawdown started the beginning of August. When the first fall fish were released into the Lookout Point reservoir on October 17, 2017, the reservoir had dropped to an elevation of 843 ft msl. The forebay fluctuated between 841 and 856 ft msl during the months of October and November. The second group of fall fish were released between December 1, 2017 and December 5, 2017. The reservoir continued to drop and reached a low pool of 822 ft msl on December 10, 2017. The forebay fluctuated between 822 and 837 ft msl through the rest of the winter pool season that ended on February 19, 2018. In spring, the first study fish were released from February 20–24, 2018, when the reservoir elevation was at 837 ft msl and refill started. By the time the second group was released (April 10–12, 2018) the reservoir had risen to an elevation of 879 ft msl. The reservoir reached the peak forebay elevation on May 12, 2018, (906 ft msl) before slowly releasing water almost exclusively through the powerhouse. By the end of the study on July 9, 2018, the reservoir had dropped to an elevation of 876 ft. msl (Figure 3.1).

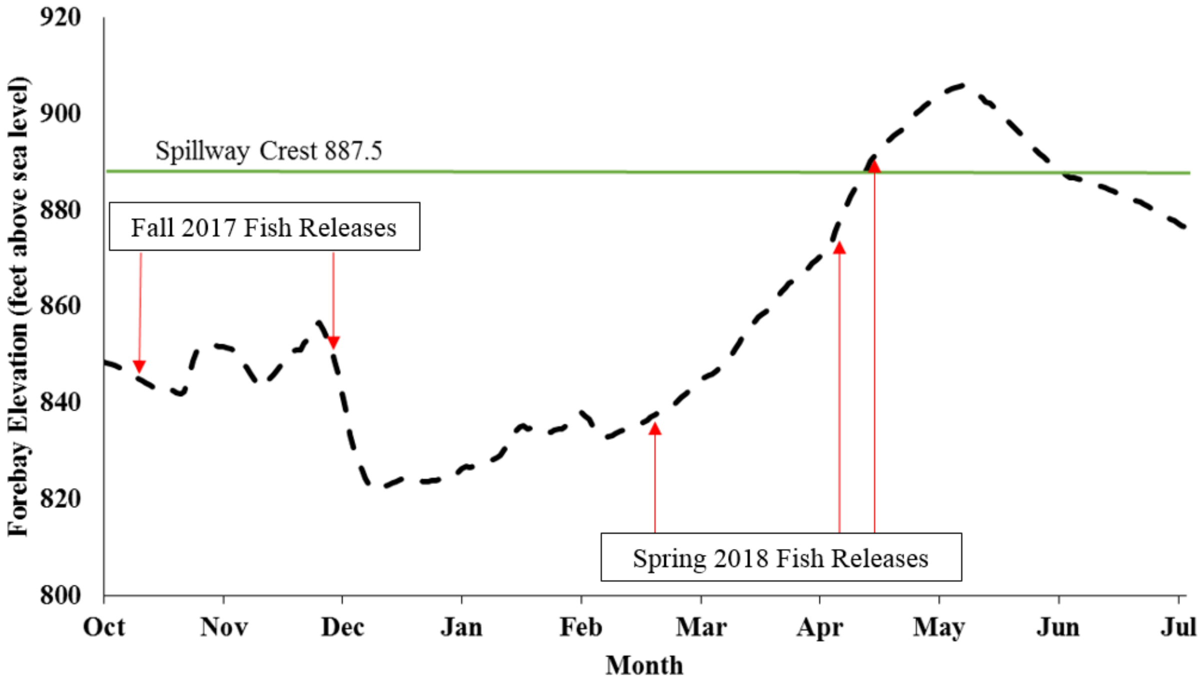


Figure 3.1. Lookout Point Reservoir Elevation (ft. msl) during the Study Period (October 2017 through July 2018)

Forebay temperature string data that recorded hourly temperature data at depths ranging from 0.5–200 ft. were obtained from http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tempstrings (Figure 3.2). From October 2017–July 2018, temperatures throughout the water column ranged from 1–19.5°C. The reservoir was still stratified at the beginning of October 2017, 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.

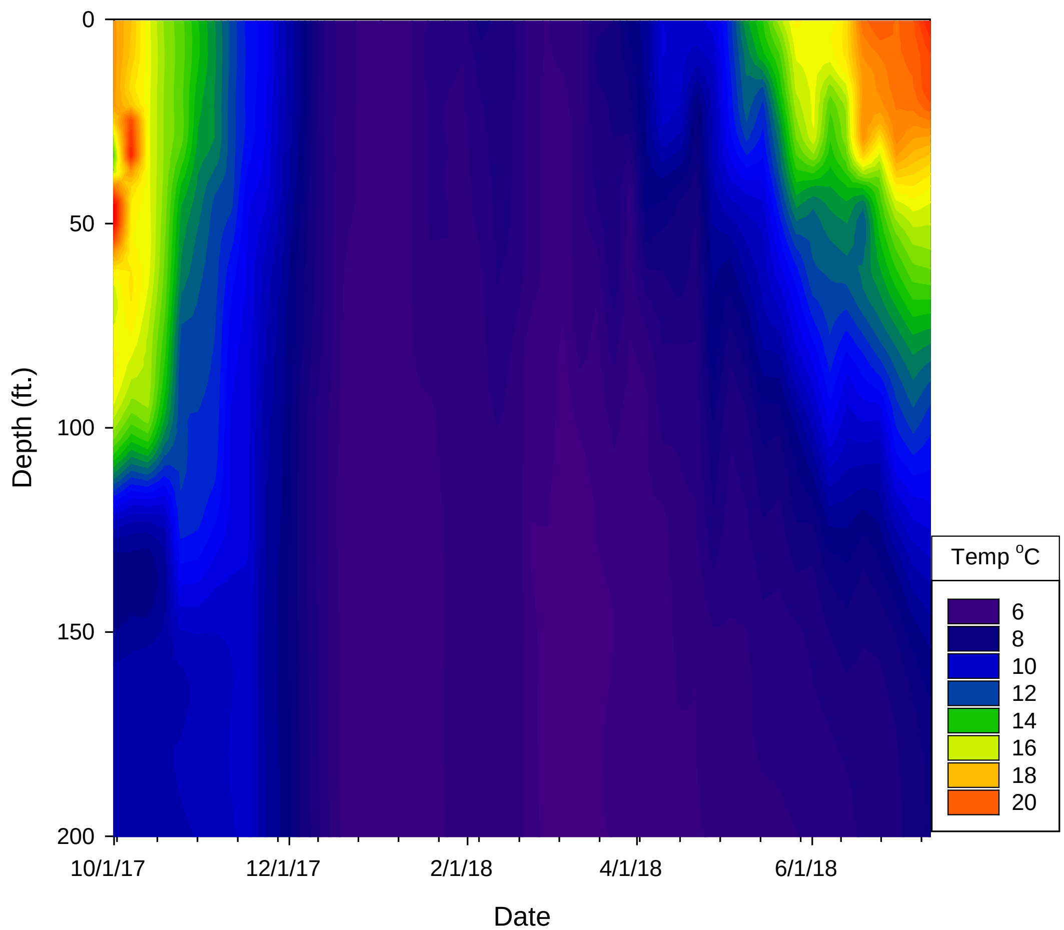


Figure 3.2. Daily Average Temperature (°C) at Depth in the Forebay at Lookout Point Reservoir from October 1, 2017 through July 9, 2018

3.1.2 Lookout Point Project Discharge and Operations

Turbine operations at Lookout Point 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 kcfs to a peak of 10.2 kcfs in November 2017 (Figure 3.3). During the spring study period, warm dry conditions persisted, which caused the Lookout Point reservoir to fill slower than normal. During these times, powerhouse generation fluctuated and discharge was between 0 kcfs and a peak in April of 7.9 kcfs. On two occasions during the spring, additional water was also released through the spillway (April 29 and July 3) in an effort to maintain appropriate reservoir and tailwater elevations (Figure 3.4).

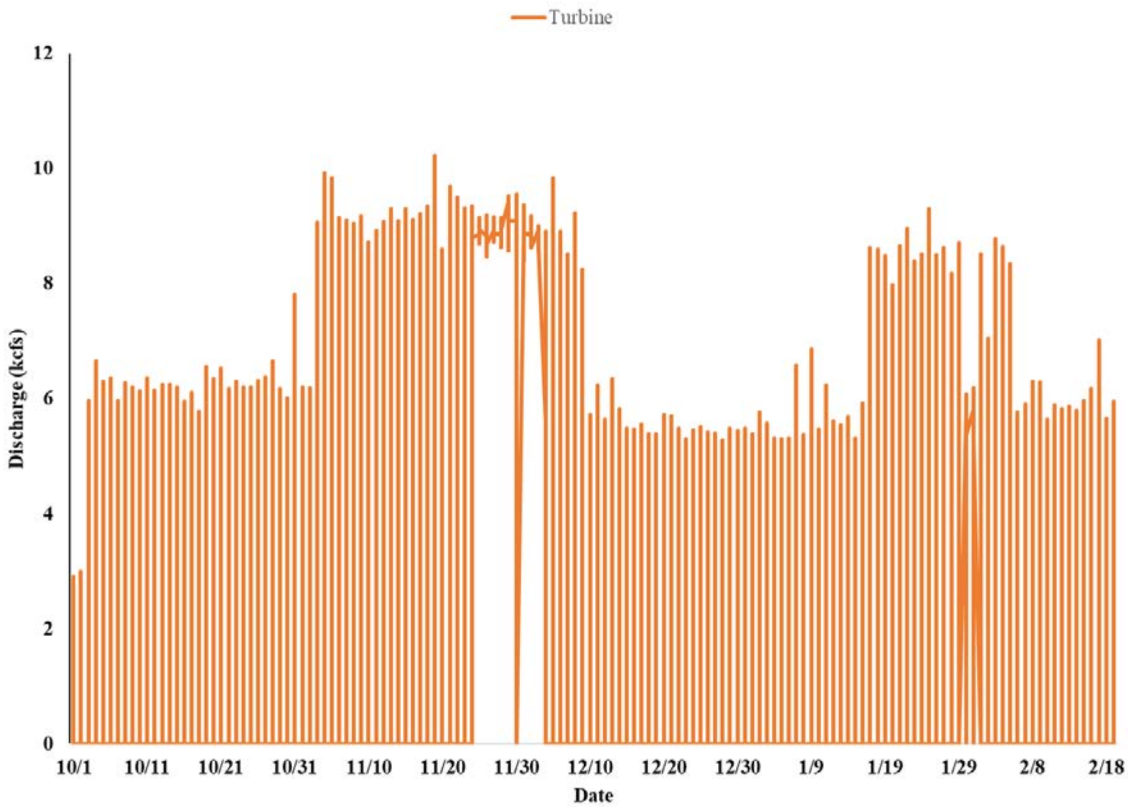


Figure 3.3. Daily Average Powerhouse Discharge for the Fall Study Period (October 1, 2017 through February 19, 2018)

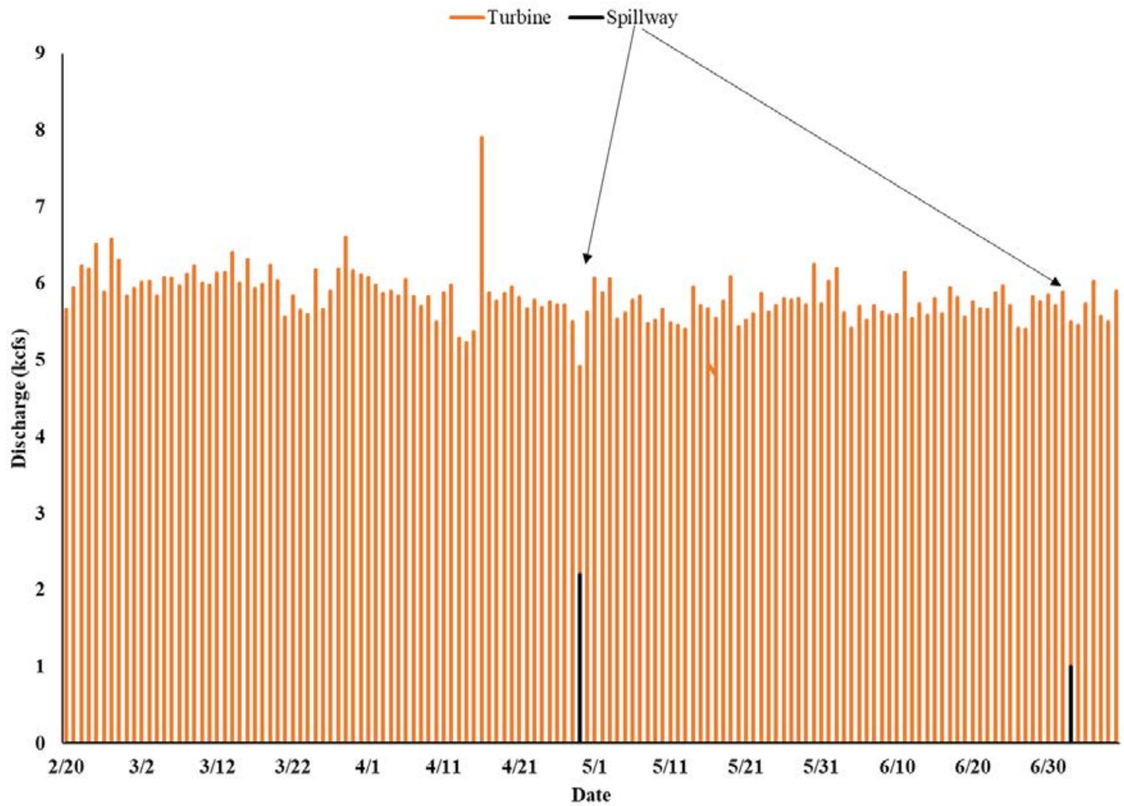


Figure 3.4. Daily Average Powerhouse and Spillway Discharge for the Spring Study Period (February 20, 2018 through July 9, 2018)

Forebay elevation fluctuated throughout fall 2017 and spring 2018 (Figure 3.5). Discharge increased the beginning of November during the fall drawdown period and remained high until the forebay reached minimum conservation pool (825 ft). Discharge then decreased in an effort to maintain the minimum conservation pool during the winter months. Forebay elevation increases during January and the beginning of February, due to rain and snow events, caused an increase in discharge to maintain forebay elevations. Discharge again dropped during the early part of February as the forebay elevation increased during the spring refill period. Discharge increased the middle of May through the end of the study causing the forebay elevation to drop.

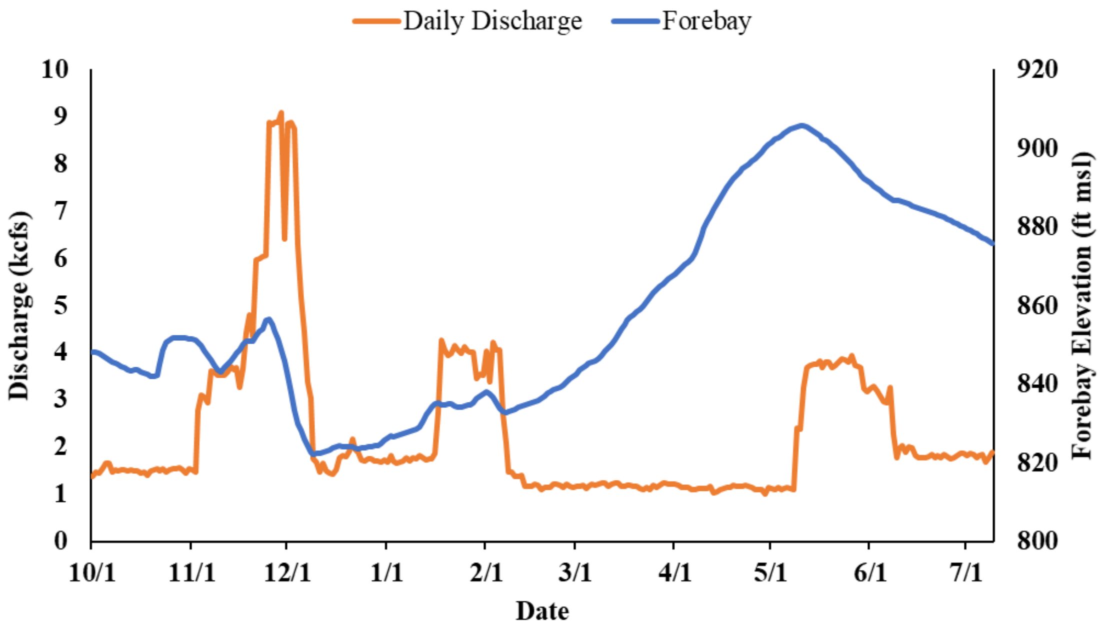


Figure 3.5. Daily Average Project Discharge (kcfs) and Daily Average Forebay Elevation (ft msl) at Lookout Point during the Fall and Spring Study Periods

3.1.3 Dexter Project Discharge and Operations

Operations at Dexter also varied throughout the year depending on power demand, water availability, and maintenance schedules. Unlike Lookout Point, turbine operations at Dexter are more uniform during a given 24 h period. The turbine unit is the priority route for passing water at the dam. The spillway at Dexter was used at sporadic times to pass water. During the fall study period, turbine hourly discharge ranged from 1.3 kcfs to a peak of 4.2 kcfs in December 2017 Figure 3.6 and spillway discharge ranged from 0 kcfs to a peak of 5.2 kcfs in November 2017 (Figure 3.6). During the spring study period, as noted above, warm and dry conditions persisted throughout the Willamette River Basin, which kept flows lower than what was seen in previous years. During these times at Dexter, powerhouse generation fluctuated and discharge was between 0 kcfs and a peak in May of 4.0 kcfs, and at times water was also released through the spillway in an effort to maintain appropriate forebay and tailrace elevation (Figure 3.7).

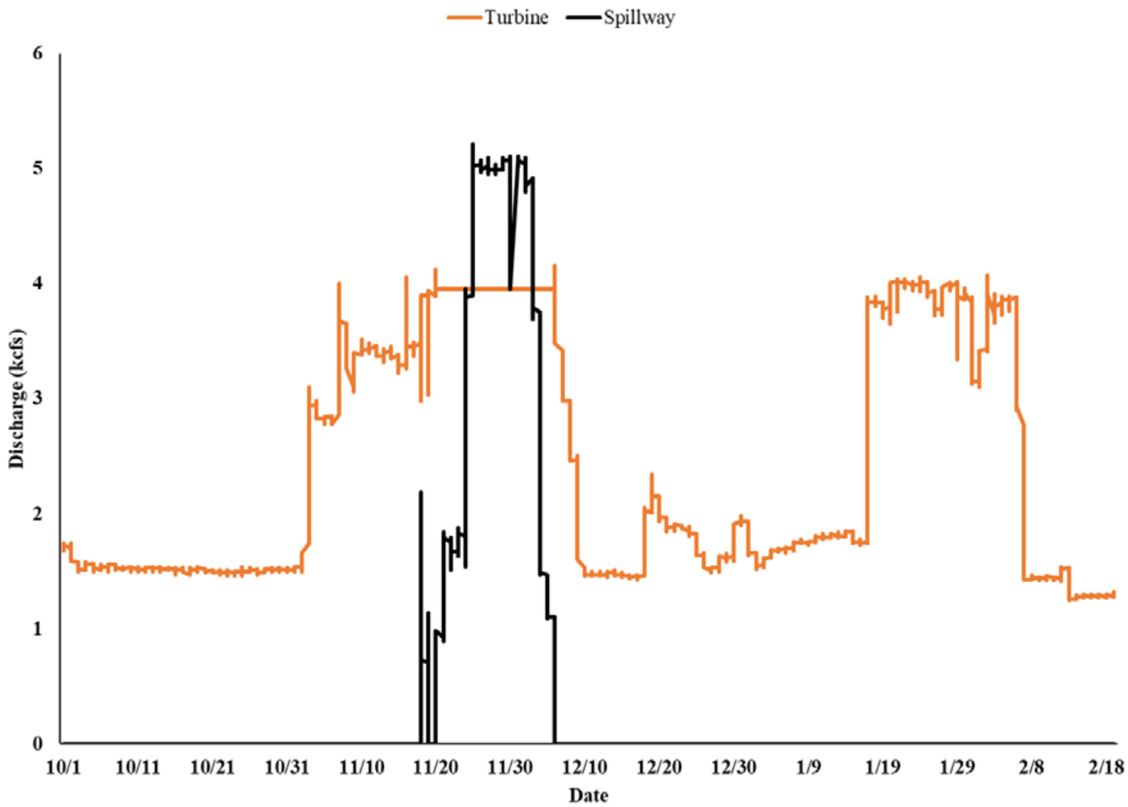


Figure 3.6. Daily Average Powerhouse and Spillway Discharge for Each Day of the Fall 2017 Study Period at Dexter (October 1, 2017 through February 19, 2018)

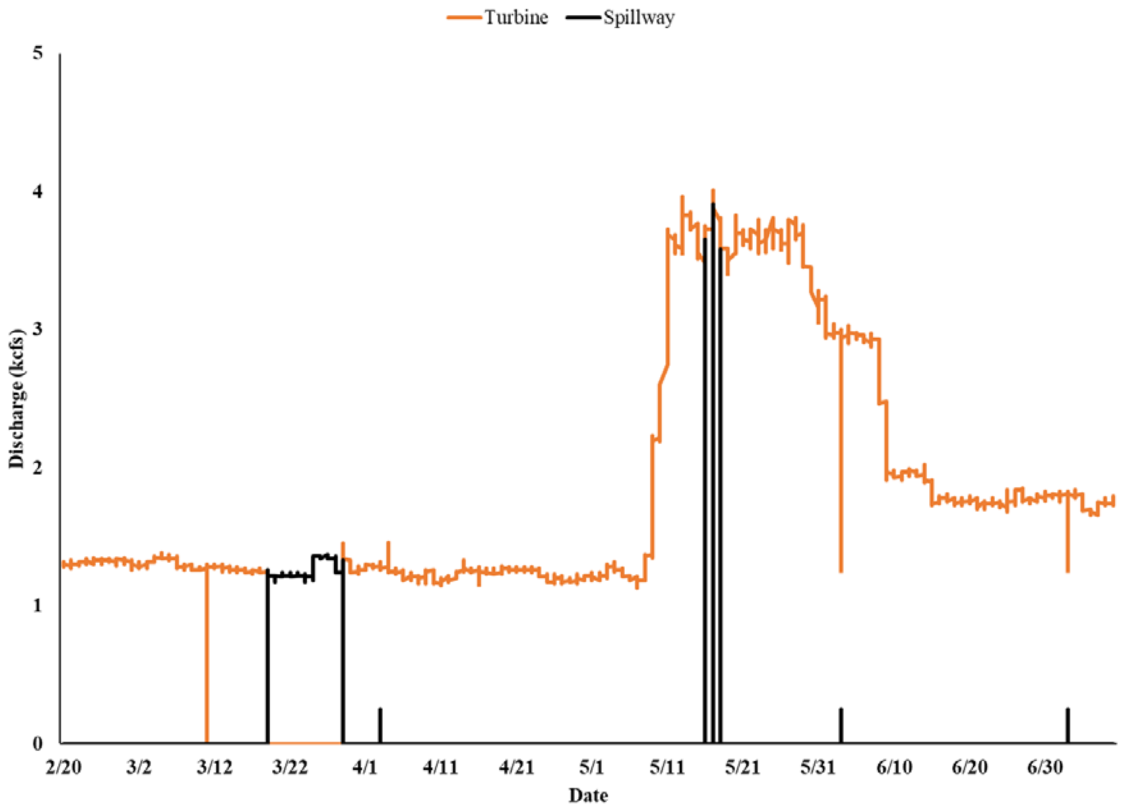


Figure 3.7. Daily Average Powerhouse and Spillway Discharge for Each Day of the Spring 2018 Study Period at Dexter (February 20 through July 9, 2018)

3.2 Tag-Life Analysis

Tag life was evaluated by randomly sampling 60 tags from a single production lot during fall 2017 and a single lot for spring 2018 (Table 3.2). Tags were activated and monitored continuously until tag failure. All tags used during the 2017–2018 study had a PRI of 5 s to better assist with 3D tracking of fish in the Lookout Point forebay and assigning route of passage. The mean tag life of tags sampled during fall 2017 was 70.2 days ± 0.95 d (mean±SE), while the mean tag life during spring 2018 was 71.7 days ± 0.76 d (mean±SE).

Table 3.2. Fall 2017 and Spring 2018 Tag-Life Results

Season	n	Min (d)	Max (d)	Mean (d)	SE (d)
Fall 2017	60	56.4	86.3	70.2	0.95
Spring 2018	60	60.3	82.8	71.7	0.76

The Weibull 3-parameter model was fit to both the fall 2017 and spring 2018 tag-life data (Figure 3.8). No tag-life adjustment was required for fish released in October 2017, because all detections of fish from this release group occurred before the first tag life study transmitter expired (Figure 3.9; Table 3.3). A small tag life adjustment was necessary for the December 2017 release, from which several fish were detected after the first tag-life study transmitter expired (Figure 3.9; Table 3.3).

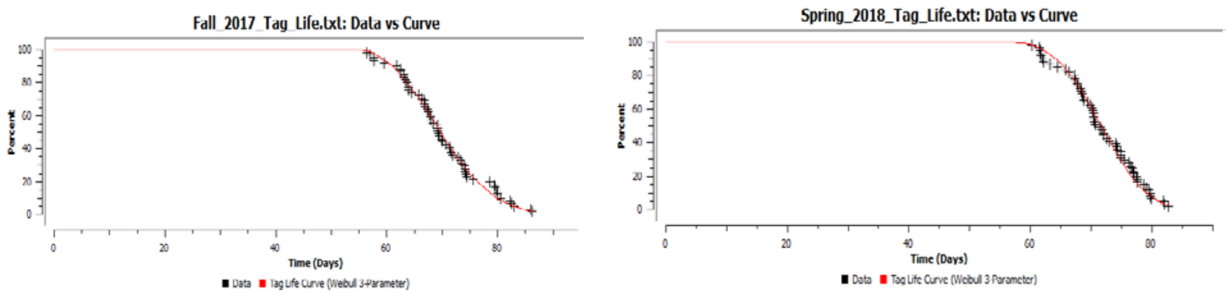


Figure 3.8. Weibull 3-Parameter Model Fit to the Fall 2017 (left) and Spring 2018 (right) Tag-Life Data

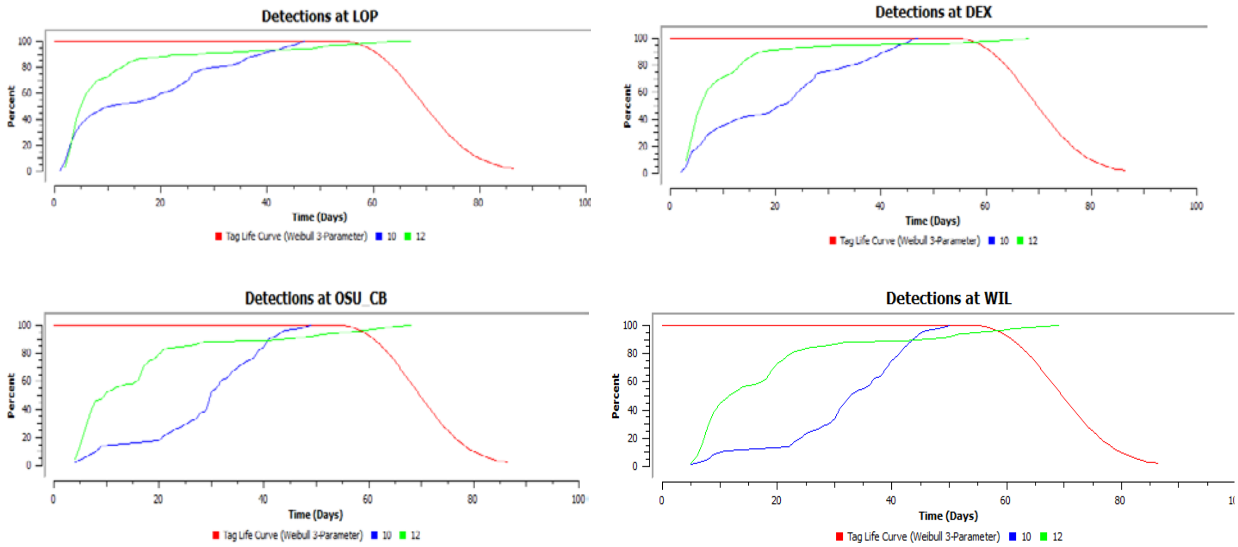


Figure 3.9. Cumulative Passage Distributions at Detection Arrays Located on the Upstream Dam-Face of Lookout Point (LOP), the Upstream Dam-Face of Dexter (DEX) near Corvallis, Oregon (OSU_CB), and near Wilsonville, Oregon (WIL) for Acoustic-Tagged Fish Released in the Lookout Point Reservoir in October 2017 (10, blue) and December 2017 (12, green). The red line is the Weibull 3-parameter model fit to the fall 2017 tag-life data and depicts the probability of tag failure over time.

Table 3.3. Detection Array-Specific Tag-Life Adjustments Applied to Lookout Point Passage Survival Estimates for Acoustic-Tagged Chinook Salmon Released into the Lookout Point Reservoir in October and December 2017. Detection arrays: LOP = Lookout Point dam-face array; LPT = Lookout Point tailrace array; DEX = Dexter dam-face array; COR = Corvallis array; WIL = Wilsonville array.

V_1 Group	LOP	LPT	DEX	COR	WIL
October	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
December	0.997 (0.001)	0.999 (0.000)	0.994 (0.001)	0.991 (0.002)	0.991 (0.002)

In the spring, 50 fish released in February did not pass Lookout Point until April 29 when spill occurred for a short period of time (~6 h). Therefore, tag-life adjustments were applied by release group and route of passage. Fish released in February that passed through the turbines and those released in April that passed via the spillway at Lookout Point required no tag-life adjustment, because all detections of these fish occurred before the first tag-life transmitter died (Figure 3.10; Table 3.4). As mentioned, fish released in February that passed Lookout Point via the spillway required a substantial tag-life adjustment, because they migrated past the detection arrays near the end of the estimated tag life (Figure 3.10; Table 3.4). This tag life correction increased Lookout Point to LPT survival estimate by 0.189 and increased the LPT to Dexter survival estimate by 0.242. No tag-life adjustment was possible for this group downstream of the Corvallis array, because none of these fish were detected at the Wilsonville array.

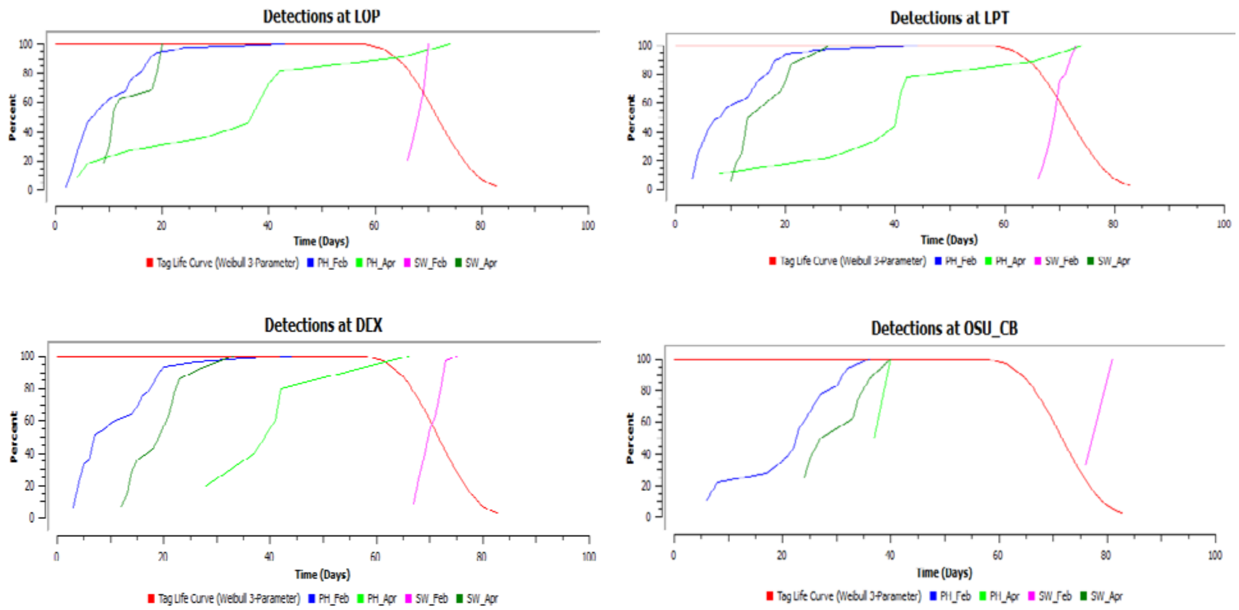


Figure 3.10. Cumulative Passage Distributions at Detection Arrays Located on the Upstream Dam-Face of Lookout Point (LOP), the Lookout Point Tailrace (LPT), the Upstream Dam-Face of Dexter (DEX), and near Corvallis, Oregon (OSU_CB) for Acoustic-Tagged Fish Released in the Lookout Point Reservoir in February 2018 that Passed Lookout Point through Turbines (blue) or the Spillway (pink) and in April 2018 that Passed through Turbines (light green) or the Spillway (dark green). The red line is the Weibull 3-parameter model fit to the spring 2018 tag-life data and depicts the probability of tag failure over time.

Table 3.4. Detection Array-Specific Tag-Life Adjustments Applied to Lookout Point Passage Survival Estimates for Acoustic-Tagged Chinook Salmon Released into the Lookout Point Reservoir in February and April 2018 by Route of Lookout Point Passage. NA indicates a lack of sufficient data to estimate tag-life corrections. Standard errors are shown in parentheses. Detection arrays: LOP = Lookout Point dam-face array; LPT = Lookout Point tailrace array; DEX = Dexter dam-face array; COR = Corvallis array; WIL = Wilsonville array.

V_1 **Group**	**LOP**	**LPT**	**DEX**	**COR**	**WIL**
February turbines	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
February spillway	0.702 (0.060)	0.868 (0.020)	0.786 (0.028)	NA	NA
April turbines	0.928 (0.008)	NA	NA	NA	NA
April spillway	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	NA	NA

3.3 Dead Fish Releases

In fall 2017 and spring 2018, dead fish with active tags were released daily during fish releases from the lower powerhouse deck at Lookout Point (Table 2.1). Of the 41 dead tagged fish released into the Lookout Point tailrace during October 2017, only 1 was detected by the LPT array ($\frac{d}{D} = 0.024$) and none were detected at Dexter. Of the 39 dead tagged fish released during December 2017, 8 were detected at the LPT array ($\frac{d}{D} = 0.205$) and none were detected at Dexter. In February 2018, 40 dead tagged fish were released into the Lookout Point tailrace. Of those, two were detected at the LPT array ($\frac{d}{D}$ = 0.050) and none were detected at Dexter. Of the 40 dead tagged fish released in April, 19 were detected at the LPT array ($\frac{d}{D}$ = 0.475) and 1 was detected at Dexter ($\frac{d}{D}$ = 0.025). Due to the detection of dead fish at LPT and in some cases Dexter, we used a combination of ViRDCt and CJS models to estimate survival as appropriate.

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 2017. Appendices A and B provide additional information in fish-tagging/release tables, and about fish passage and travel times, respectively.

4.1 Reservoir Movement and Behavior

The following sections provide results related to fish movement and behavior in the Lookout Point reservoir.

4.1.1 Fish Movement in the Reservoir

During the fall 2017 study period a total of 1,507 subyearling Chinook salmon were released into Lookout Point reservoir 8.5 km upstream of the dam and approximately 1 km upstream of the HOR array (Figure 2.1). A total of 742 fish were released in October and 765 fish were released in December. In-reservoir detection of released fish was high for both October and December with 92.5% and 98.0% of individuals, respectively, being detected on at least one in-reservoir autonomous receiver array.

In October, detections occurred at all arrays, and similar numbers of individuals were detected on HOR, MID, and forebay arrays on Day 1 post-release. Fish continued to distribute throughout the reservoir as the season progressed; some individuals moved from the HOR, down to the lower reservoir, and then were observed again at the HOR. This cycle of upstream-downstream movement repeated itself for a portion of the October released fish (Figure 4.1). Another portion of October released fish was detected in the forebay throughout the first 2 weeks post-release and, although some did pass Lookout Point, a large portion did not. In contrast to downstream movement, 36.0% of fish were never detected below the MID array and never migrated to the lower end of the reservoir near Lookout Point. The numbers of fish disappearing in the reservoir ("no detect" [ND]; Figure 4.1) increased throughout the season and 71.9% were classified as "disappearing" by day 55 post-release.

For December-released fish, detections occurred at all arrays; many fish passed or approached Lookout Point within the first week of being released (Figure 4.1). By Day 1 post-release, more December fish were detected at the MID array compared to all other arrays and in larger numbers than Day 1 October released fish. Larger proportions of December fish moved downstream (mid-reservoir and forebay) and ultimately passed Lookout Point compared to the October release. The upstream-downstream-upstream movement cycle was notable throughout the fall study period and for both the October and December release groups. In contrast to downstream movement, 19.2% of fish were never detected below the MID array and did not migrate to the lower end of the reservoir near Lookout Point. Similar to October, large numbers of December fish were never detected or disappeared as the study period progressed. By Day 55 post-release, 36.6% of December-released fish had disappeared and were never detected again in the reservoir.

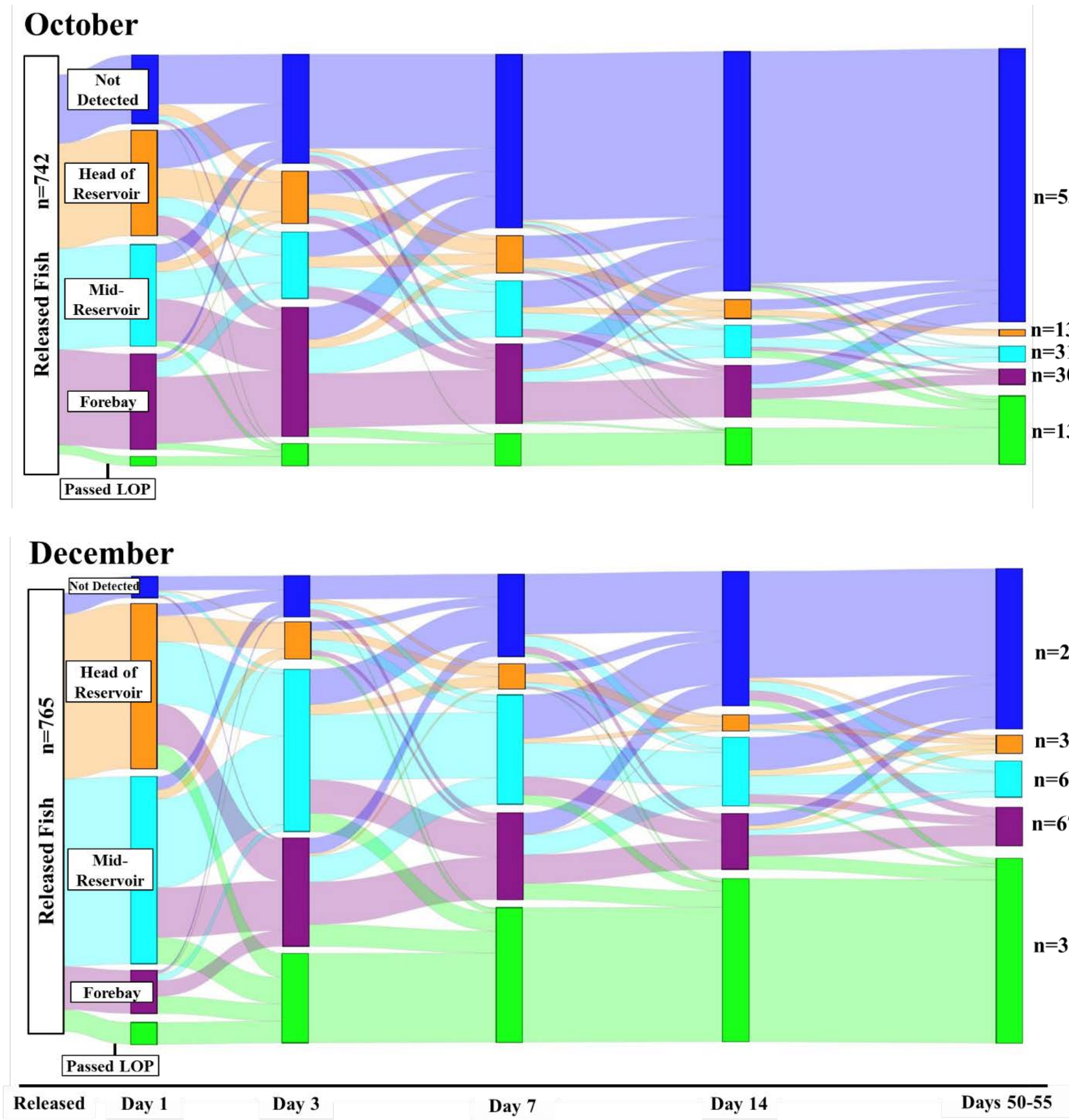


Figure 4.1. Sankey Diagrams Showing Reservoir Distribution of CH0 Released in October (Top) and December (Bottom) 2017 at Days 1, 3, 7, 14, and Days 50–55. Fish counts are determined using the most downstream (rkm) array at which a fish was detected within the given time period. Passed LOP indicates fish that have passed Lookout Point.

4.1.2 Reservoir Horizontal Distribution

As tagged fish moved through the Lookout Point reservoir, capture histories were formed for each of the receiver arrays (HOR, MID) to determine where across the reservoir fish were first detected. Using the first detection and the signal-to-noise ratio from each receiver to determine proximity, fish were assigned a horizontal position of first detection at each array. At the HOR array, located 1 km downstream from the release site, fish were dispersed across the array; receivers at positions 1, 2, and 5 detected higher percentages of first detections for fish released in October (Figure 4.2), while receivers 3, 4, and 6 each had fewer of the first detections. Similar to October, fish released during December were distributed across the receiver array and the receiver at position 1 had the highest percentage of first detections. Receivers 2–6 each accounted for 10–15% of first fish detections (Figure 4.2). Refer to Figure 2.11 for locations of each array within the reservoir. At the MID array, fish released in October were detected at all receivers in the array, and the receivers at positions 1 and 2 had the highest percentages of first detections (Figure 4.3). Fish released in December exhibited similar trends to those released in October with study fish distributed across the array (Figure 4.3).

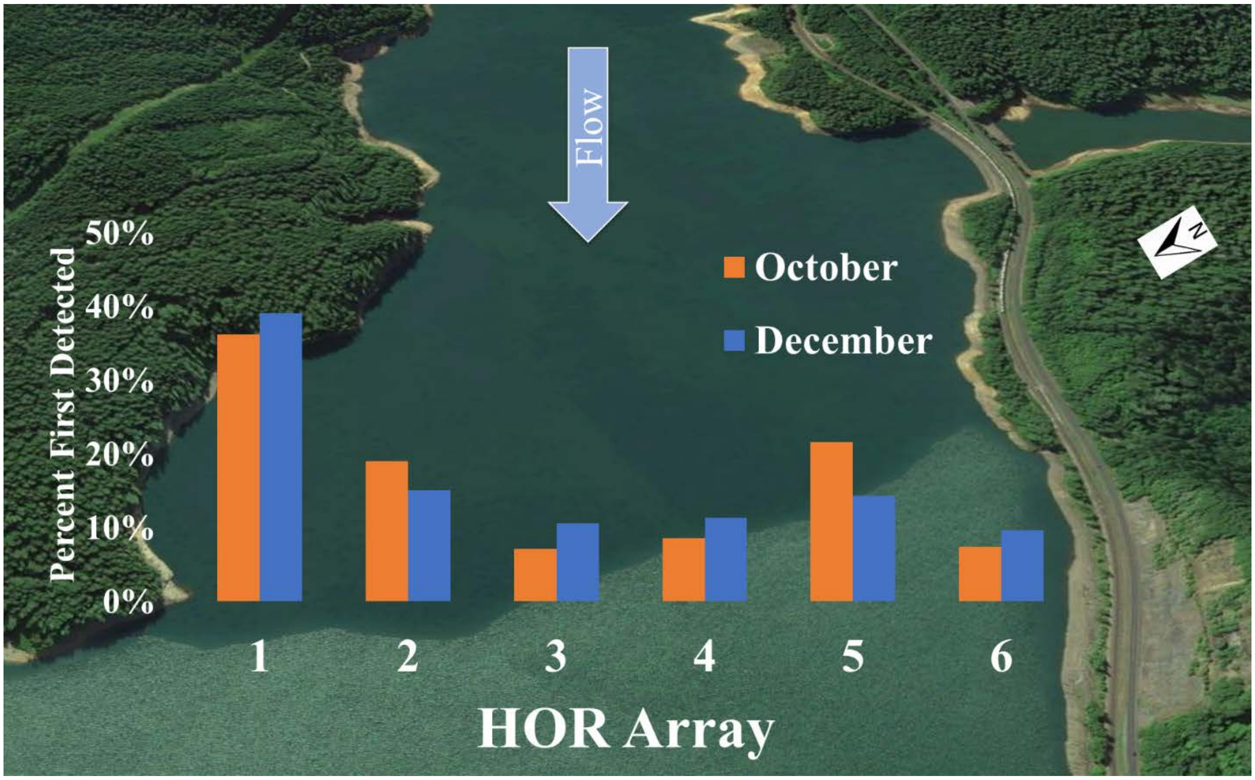


Figure 4.2. Head of River (HOR) Horizontal Distribution by Receiver Using the First Detection of CH0 Passing by the Array for October and December 2017 Released Fish. Receiver 1 is located near the northeast shoreline, and Receiver 6 is located near the southwest shoreline.

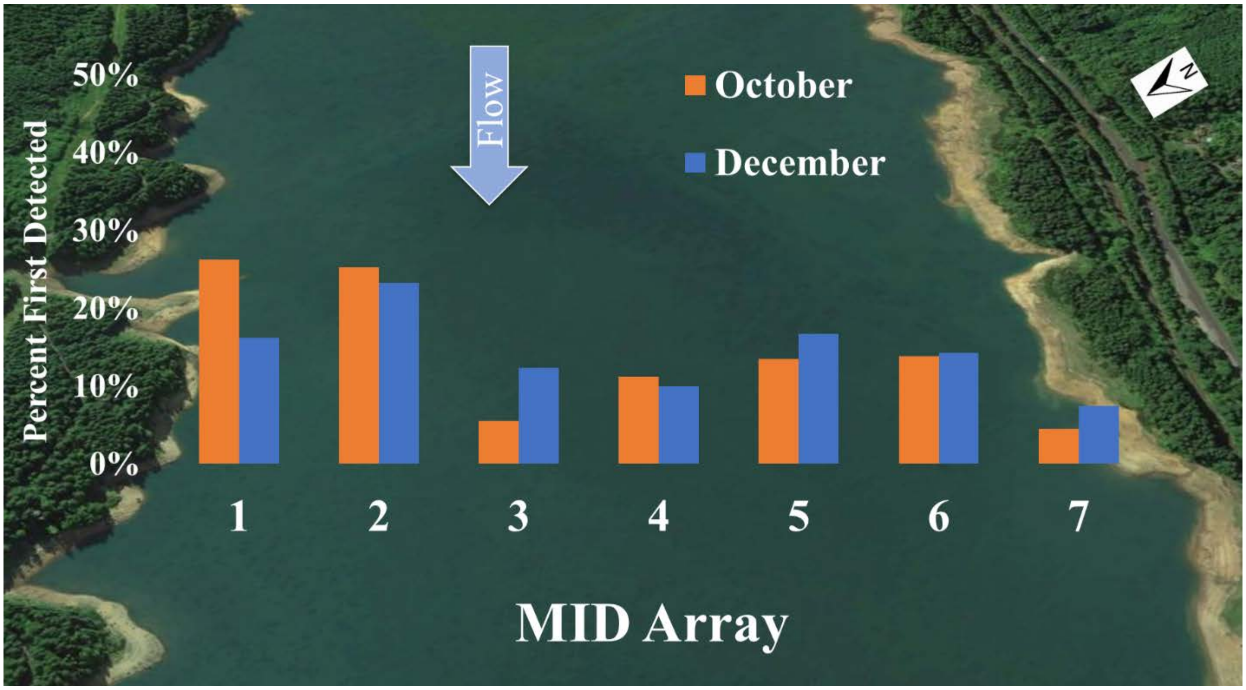


Figure 4.3. Mid-Reservoir (MID) Horizontal Distribution by Receiver Using the First Detection of CH0 Passing by the Array for October and December 2017 Released Fish. Receiver 1 is located near the Northeast shoreline, and Receiver 7 is located near the southwest shoreline.

4.2 Lookout Point Forebay

Using both cabled and autonomous receiver array data, the first-approach detection densities of fish were evaluated for the Lookout Point forebay. Contour plots were developed for October and December-released fish by using first detections in horizontal (bank-to-bank) sections throughout the forebay (Figure 4.4 and Figure 4.5). These horizontal sections were then compiled to form contour plots of the overall approach to the dam itself. The plots show fish generally first approaching the forebay (~300 m upstream of dam) and dam by using the center, deepest portion of the reservoir, with slightly more detections occurring on the southern shoreline than on the northern shoreline. In the near forebay area (<150 m from dam), fish first-approach detections increased due to a narrowing of the reservoir and downstream movement toward the dam. First-approach detection densities were greatest at the front of the dam, showing that fish most often first approach the most downstream portion of the reservoir directly in front of the dam rather than the earthen portion. Although October and December plots are very similar, results indicate higher numbers of fish using an approach at the northern end of the dam in December compared to the approach path used in October, where detections of fish were more dispersed across the near forebay area. Most notable for both the October and December release groups is the density of detections at the center of the concrete portion of Lookout Point, indicating that fish have a tendency to first encounter this area of the dam.

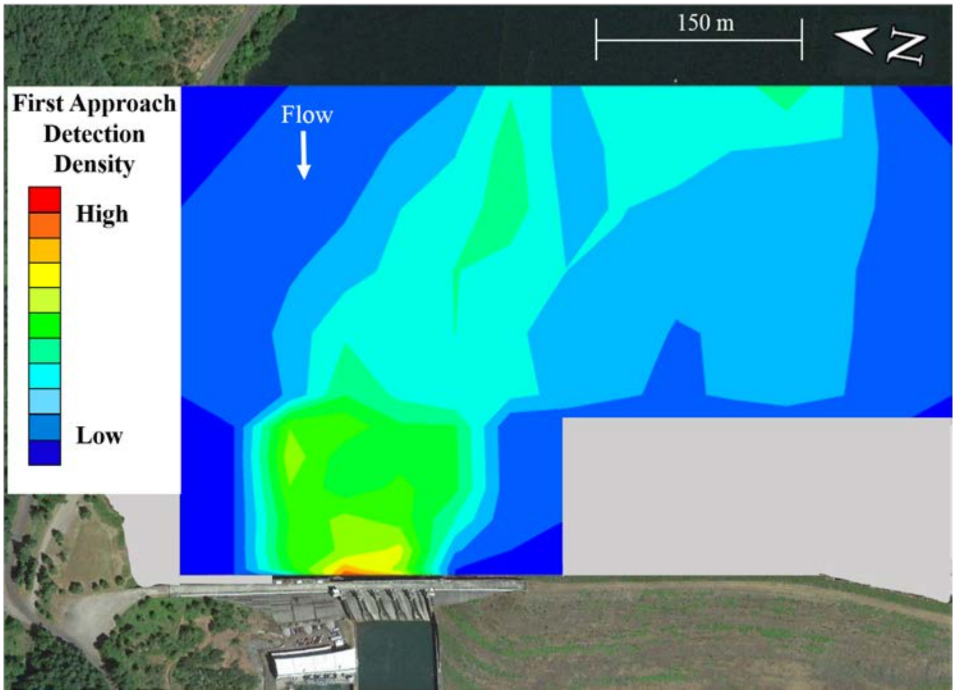


Figure 4.4. Contour Plot of Lookout Point Approach and Forebay Showing Detection Densities for October 2017 Released Fish. Detections are from both autonomous and cabled arrays. Gray fill indicate areas where fish cannot be three-dimensionally tracked due to shallow water depths.

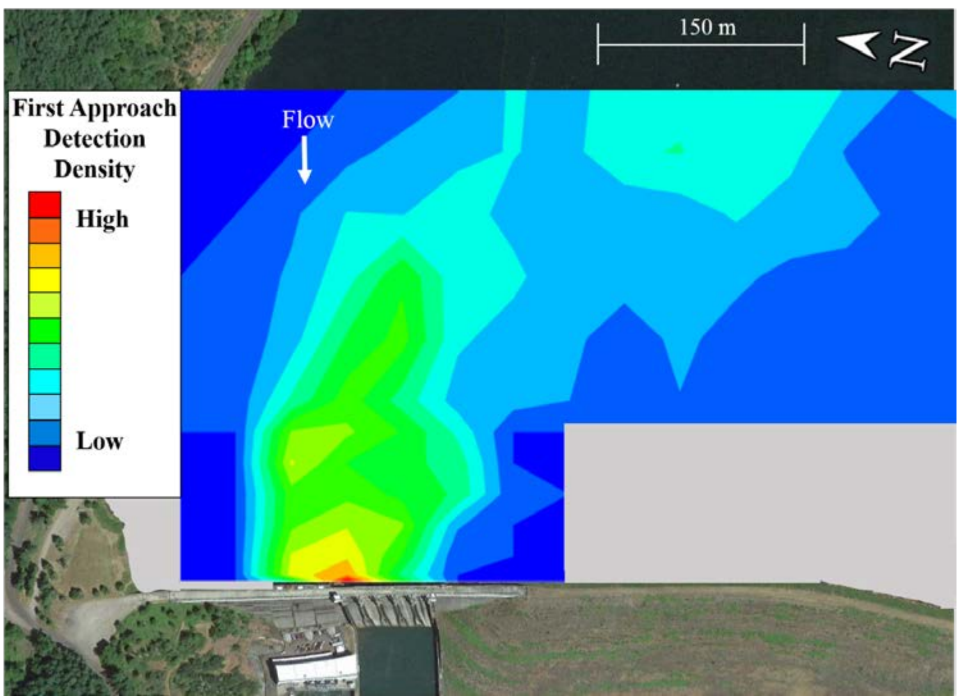


Figure 4.5. Contour Plot of Lookout Point Approach and Forebay Showing Detection Densities for December 2017 Released Fish. Detections are from both autonomous and cabled arrays. Gray fill indicates areas where fish cannot be three-dimensionally tracked due to shallow water depths.

Vertical distributions of fish were determined for individuals <150 m from the dam in order to assess where in the water column fish tended to congregate in the forebay and near the dam-face. Overall, fish were surface oriented; most fish resided within the first 2.5 m of the water column and appeared during the night hours (Figure 4.6 and Figure 4.7). In October, fish were detected nearly equally during day and night hours (slightly more fish were detected at night) in the first 2.5 m of the water column (Figure 4.6). At a depth of 15 m (penstock intake depth), more fish were detected during the day than night. Very few fish were detected at RO depth both during day and night hours. In December, fish were detected almost exclusively in the first 2.5 m depth during the night (Figure 4.7). At the penstock depth of 15 m, slightly more fish were detected at night. Similar to October released fish, very few detections occurred at the RO depth.

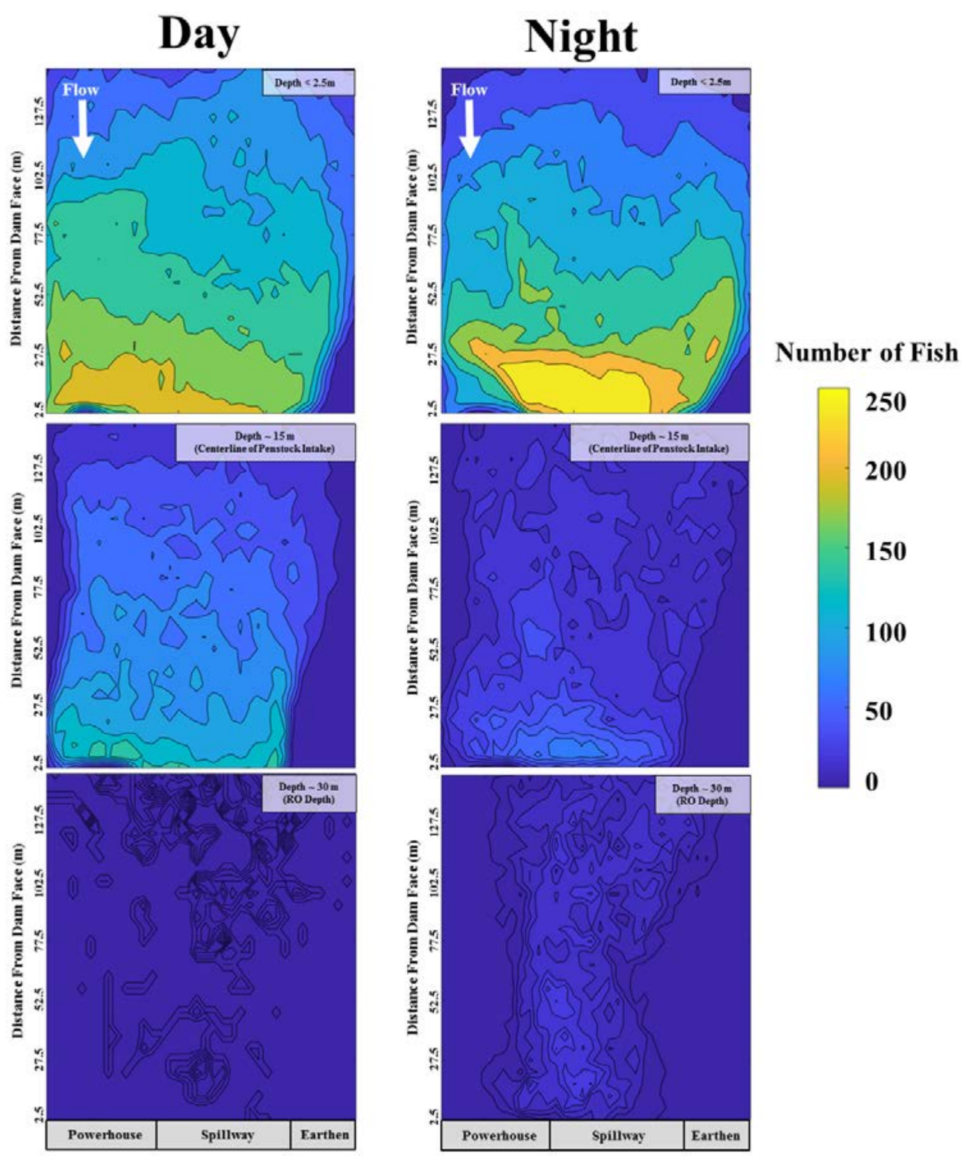


Figure 4.6. October 2017 Released CH0 Detection Densities at Three Depths along the Dam-Face of Lookout Point Using the Cabled-Array System

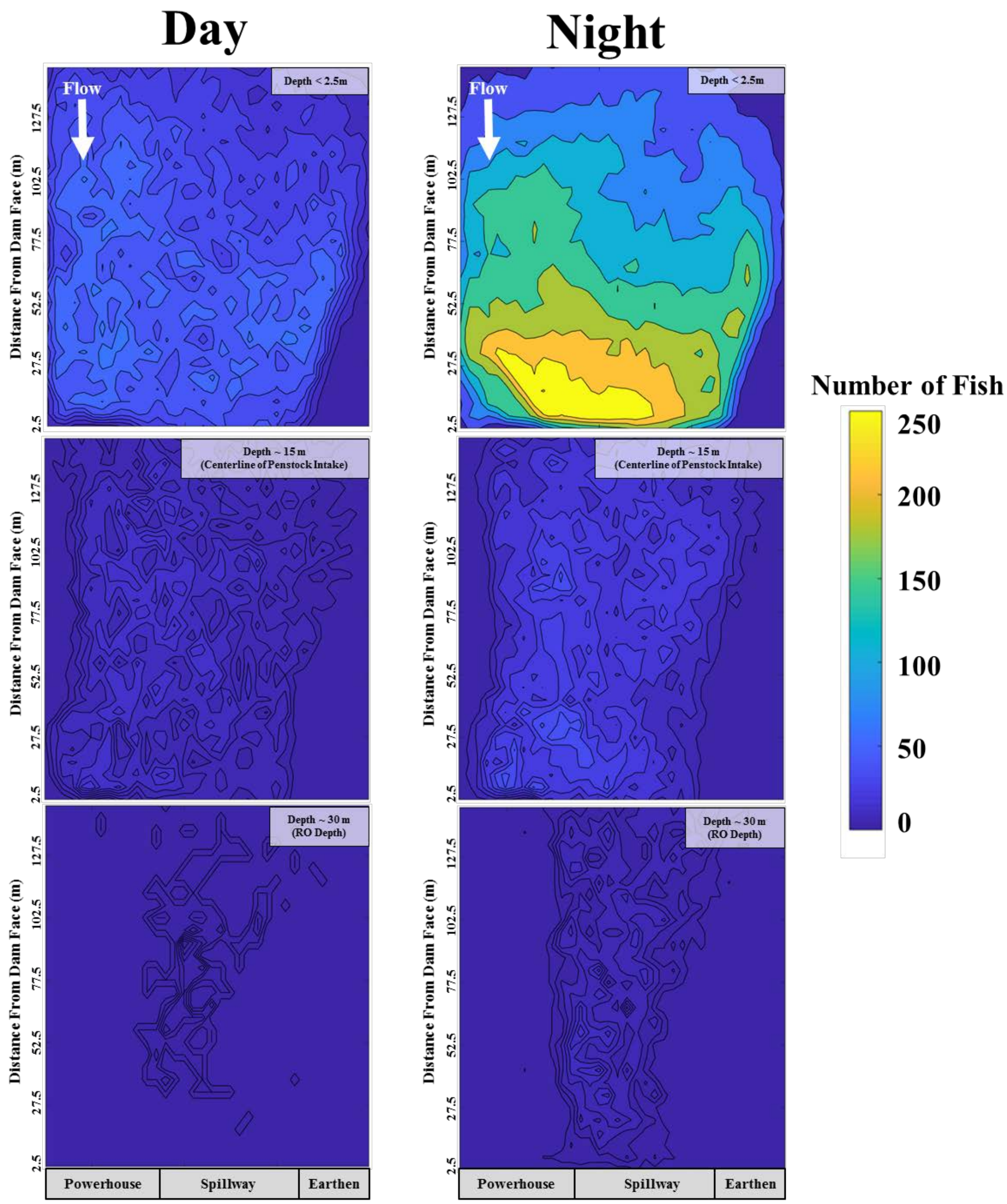


Figure 4.7. December 2017 Released CH0 Detection Densities at Three Depths along the Dam-Face of Lookout Point Using the Cabled-Array System

4.3 Lookout Point Passage and Survival

4.3.1 Passage Distributions

A total of 438 study fish released in October (n = 742) were detected at Lookout Point. Of those fish, 134 passed downstream (Figure 4.8). Fish released in December (n = 765) migrated downstream in higher numbers; a total of 573 fish were detected at Lookout Point and 331 passed downstream.

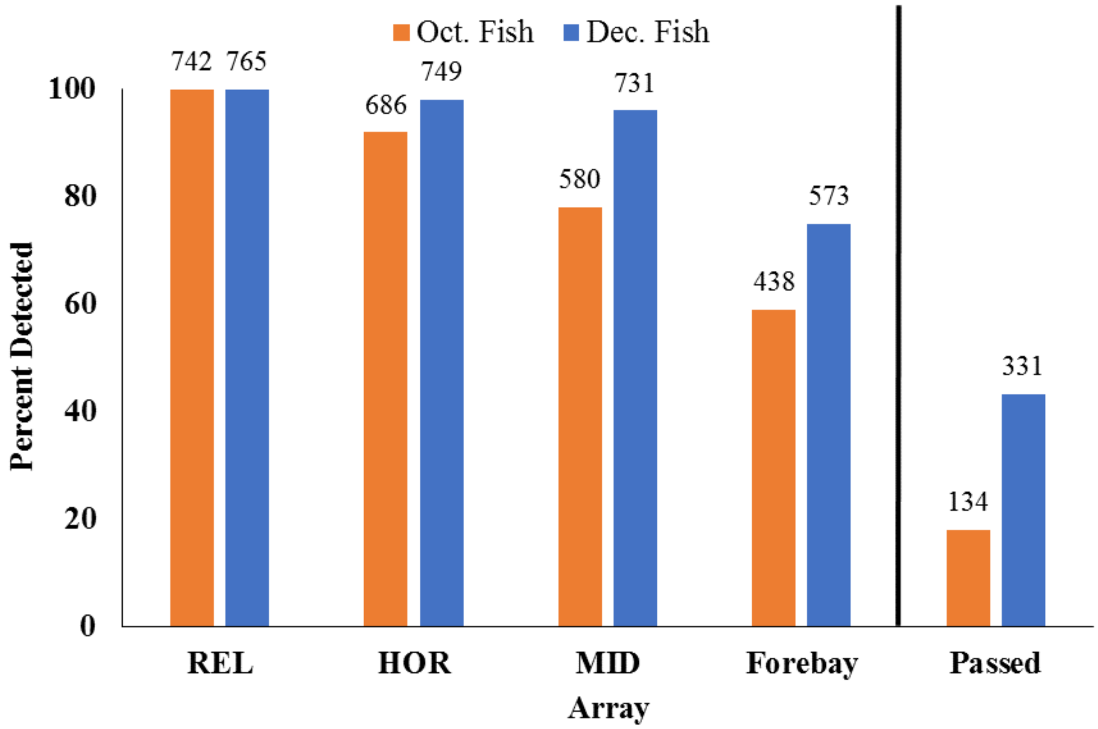


Figure 4.8. Percentage of Fall 2017 Subyearling Chinook Salmon Detected and Passed at Receiver Arrays in the Lookout Point Reservoir

During fall 2017, the only potential passage route for CH0 was through the turbines at Lookout Point. The ROs were not operated. Study fish were 3D tracked and assigned to one of three turbine units. Of the fish released during October, a total of 134 study fish passed Lookout Point: Turbine Unit 2 passed the greatest proportion (41.0%), followed by Turbine Unit 3 (31.3%), and Turbine Unit 1 (27.6%), even though discharge proportions were similar (Figure 4.9). Study fish released in December migrated downstream in much greater numbers—331 CH0 passed Lookout Point. Turbine Unit 3 passed the greatest proportion of fish (51.1%), Turbine Unit 2 passed 31.4% of fish, and Turbine Unit 1 passed 17.5% of fish; each unit had similar discharge proportions (Figure 4.9).

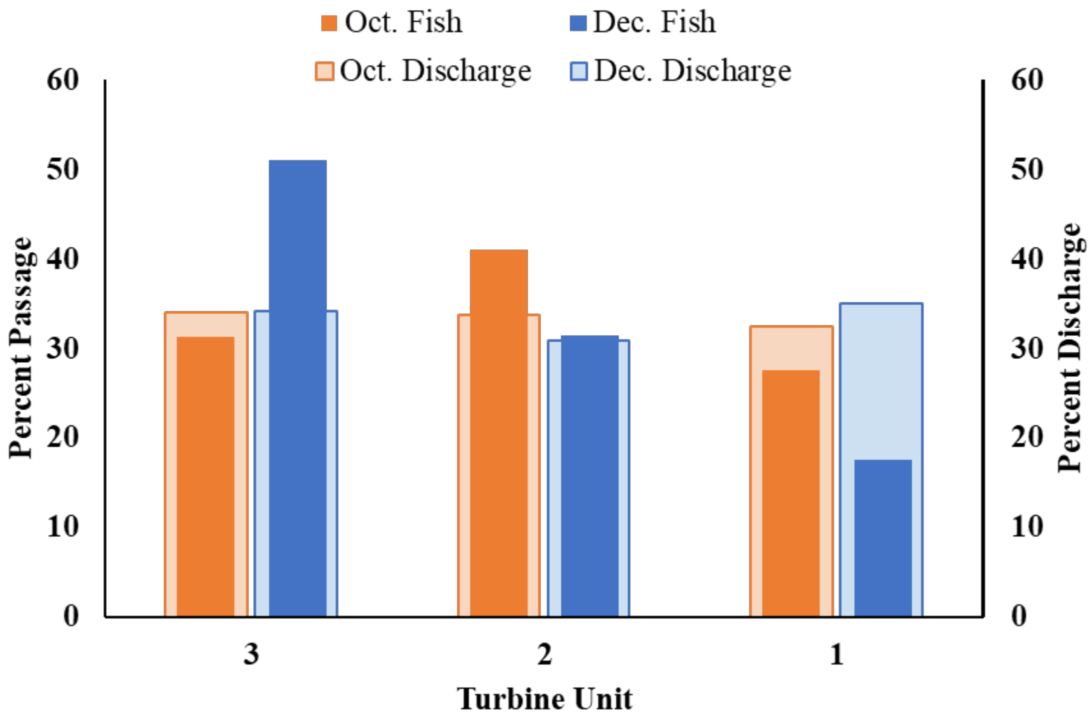
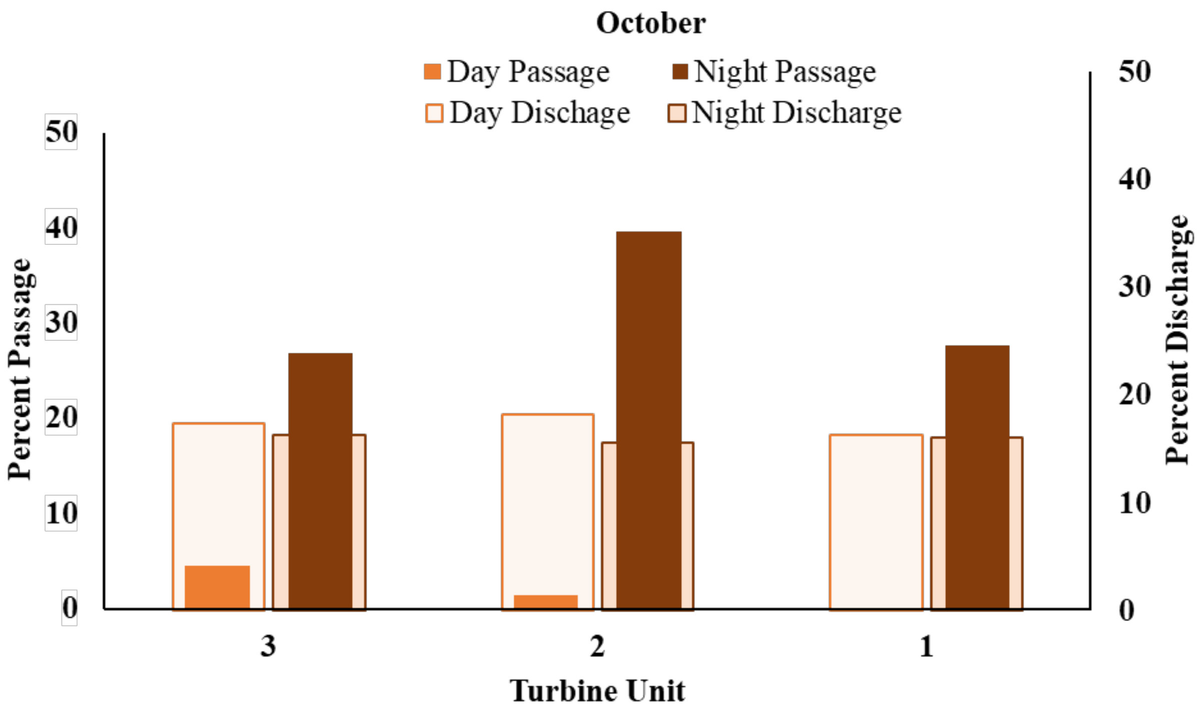


Figure 4.9. Passage and Discharge Percentages of CH0 through Penstocks at Lookout Point

Using civil twilight to estimate diel passage proportions, similar diel passage trends between the October and December fish releases were found (Figure 4.10). More than 90% of all study fish passed Lookout Point during the nighttime hours. Turbine operations were similar between daytime and nighttime hours. In October, the greatest number of fish passed through turbine unit 2 during the night (39.6%), while in December, turbine unit 3 passed the most study fish during the night (47.7%, Figure 4.10).



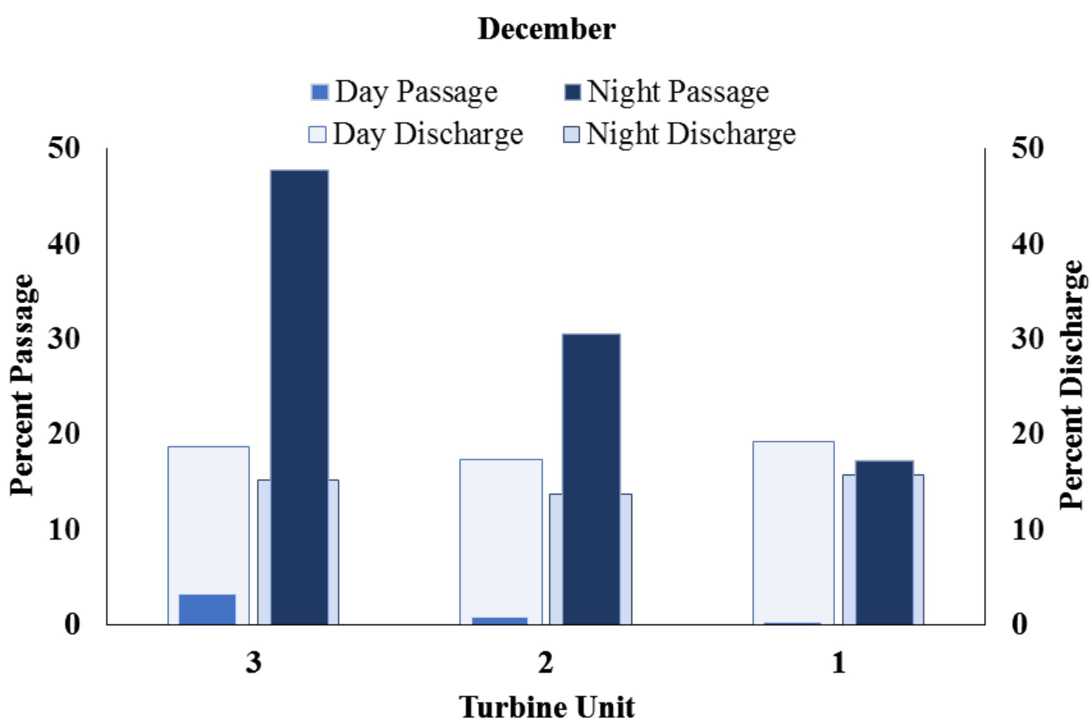


Figure 4.10. Diel Passage and Discharge Percentages through Lookout Point in Fall 2017 (October release on top and December release on bottom)

Discharge varied throughout the fall study period; a minimum daily discharge of 34 kcfs occurred on October 18, 2017 and a maximum daily discharge of 218 kcfs occurred on November 29, 2017. Passage timing at Lookout Point varied between the October and December release groups, but in general most fish that passed Lookout Point did so within the first 2 weeks post-release (Figure 4.11).

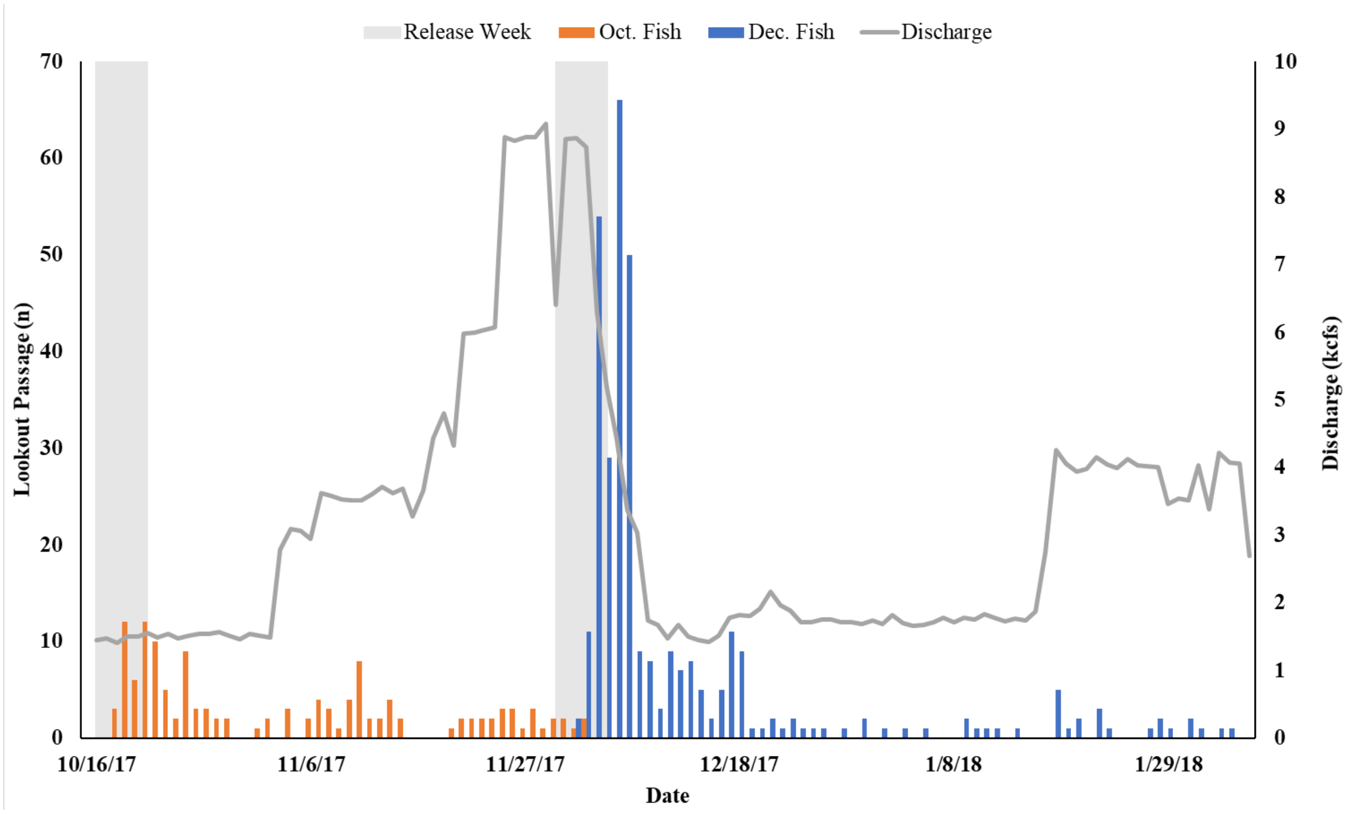


Figure 4.11. Fish Passage and Daily Average Discharge through Lookout Point during Fall 2017

Turbine units at Lookout Point were operated during peak power demand times during fall 2017. Two distinct peaks in operations occurred (Figure 4.12); one during the morning hours (6–9 am) and one during the evening (4–9 pm). The majority of fish passage also occurred during this time frame; over 90% of all fish passed between the hours of 6–9 am (24.6% in October, 13.9% in December) and 4–9 pm (67.9% in October, 77.6% in December).

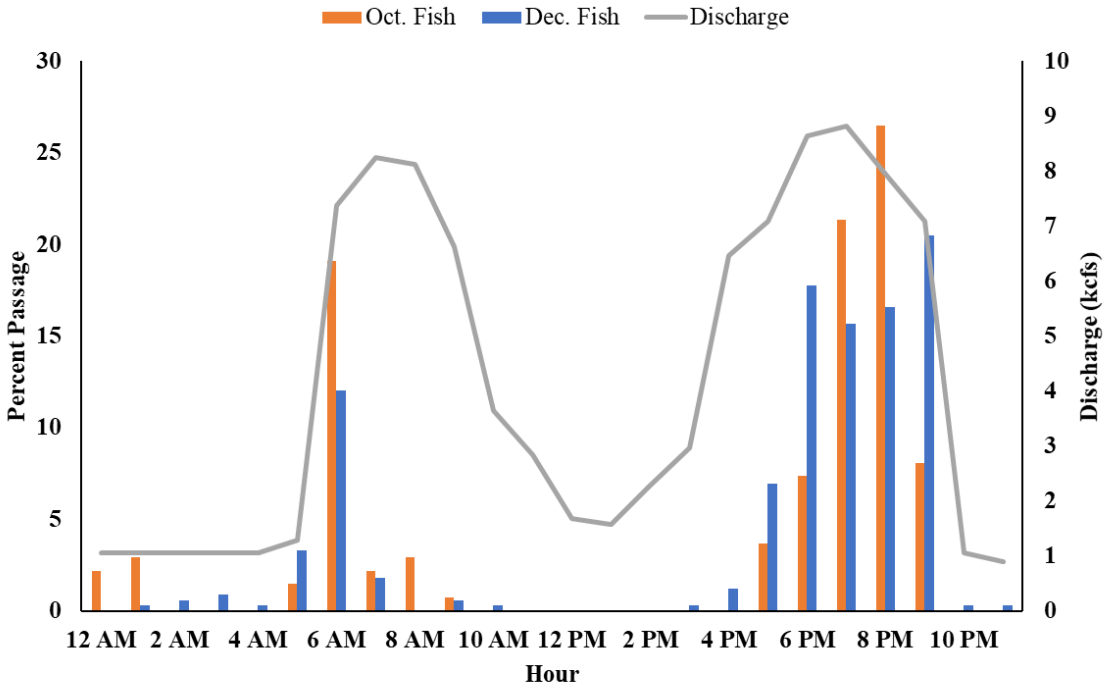


Figure 4.12. Average Hourly Passage and Turbine Discharge at Lookout Point during Fall 2017

4.3.2 Project Passage Metrics

Fish released in October migrated down to the Lookout Point near forebay in moderate numbers; 438 fish were detected in the near forebay (<150 m upstream of the dam-face). The DPE of the fish released in October was low (0.306), indicating that it was difficult for fish that made it to the forebay to pass the dam (Table 4.1).

In December, fish migrated downstream in higher numbers; 573 fish were detected in the near forebay at Lookout Point. Passage of fish released in December was also much higher and had a DPE of 0.578, indicating that just over half of the fish that encountered the Lookout Point forebay eventually passed the dam (Table 4.1).

Table 4.1. DPE for CH0 at Lookout Point in Fall 2017

Release	Forebay Detections (N)	Passage (N)	DPE
October	438	134	0.306
December	573	331	0.578

4.3.3 Survival

Of the 41 dead tagged fish released into the Lookout Point tailrace during October 2017, only one was detected in the immediate tailrace (LPT array; $\frac{d}{D}$ = 0.02) and none were detected at Dexter. Because there was not a tag-life adjustment for the group of CH0 released in October, the reduced ViRDCt model (unadjusted for tag-life) was used to estimate Lookout Point to immediate tailrace survival (LPT array) and the standard CJS model was used to estimate Lookout Point to Dexter survival (Table 4.3). Survival of fish released in October that passed Lookout Point and traveled through the entire Dexter reservoir was 0.724 (SE = 0.039, standard CJS estimate). Using the reduced ViRDCt model to estimate survival, which removes 2 km of the Dexter reservoir, the survival estimate was 0.779 (SE = 0.039).

Of the 39 dead tagged fish released during December 2017, 8 were detected in the immediate tailrace (LPT array; $\frac{d}{D}$ = 0.205) and none were detected at Dexter. Because there was a slight tag-life adjustment for the December-released group, the tag life-adjusted ViRDCt model was used to estimate survival from Lookout Point to the immediate tailrace (0.823, SE = 0.024) and the tag life-adjusted CJS model (in program ATLAS) was used to estimate survival from Lookout Point to Dexter (0.727, SE = 0.025, Table 4.2).

Table 4.2. Sample Sizes (*N*) and Estimated ViRDCt Survival Probabilities ($\hat{S}$) from Lookout Point to the Lookout Point Immediate Tailrace Array (LPT array) and to Dexter for Acoustic-Tagged CH0 Released into the Lookout Point Reservoir in October and December 2017. Detection probabilities (*p*) of each detection array (LPT and Dexter) are also shown. Virtual release groups (V_1) were formed by release month and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01. Superscripts indicate the model that was used to estimate survival.

		Lookout Point to Immediate Tailrace		**Lookout Point to Dexter**	
V_1 group	***N***	**$\hat{S}$ (SE)**	***p***	**$\hat{S}$ (SE)**	***p***
Oct turbines	134	0.779 (0.039)[a]	0.99	0.724 (0.039)[b]	1.00
Dec turbines	331	0.823 (0.024)[c]	1.00	0.727 (0.025)[d]	1.00

(a) Reduced ViRDCt model
(b) CJS model
(c) Tag life-adjusted ViRDCt model
(d) Tag life-adjusted CJS model

4.4 Dexter

4.4.1 Reservoir Passage and Survival

Unlike Lookout Point, which is a peak power generating dam, Dexter is a run-of-river project that requires constant water passage through the turbine unit, the spillway, or some combination of both. Discharge through Dexter during fall 2017 was primarily through the turbines with some spill occurring during the second half of November into early December (Figure 4.13). Study fish released in October and December arrived at and passed Dexter throughout the fall, and peak passage occurred on December 8. Fish that passed Lookout Point and migrated to Dexter passed through the turbine in high proportions (Figure 4.14); 65.5% of the fish released in October and more than 90% of fish released in December passed through this route.

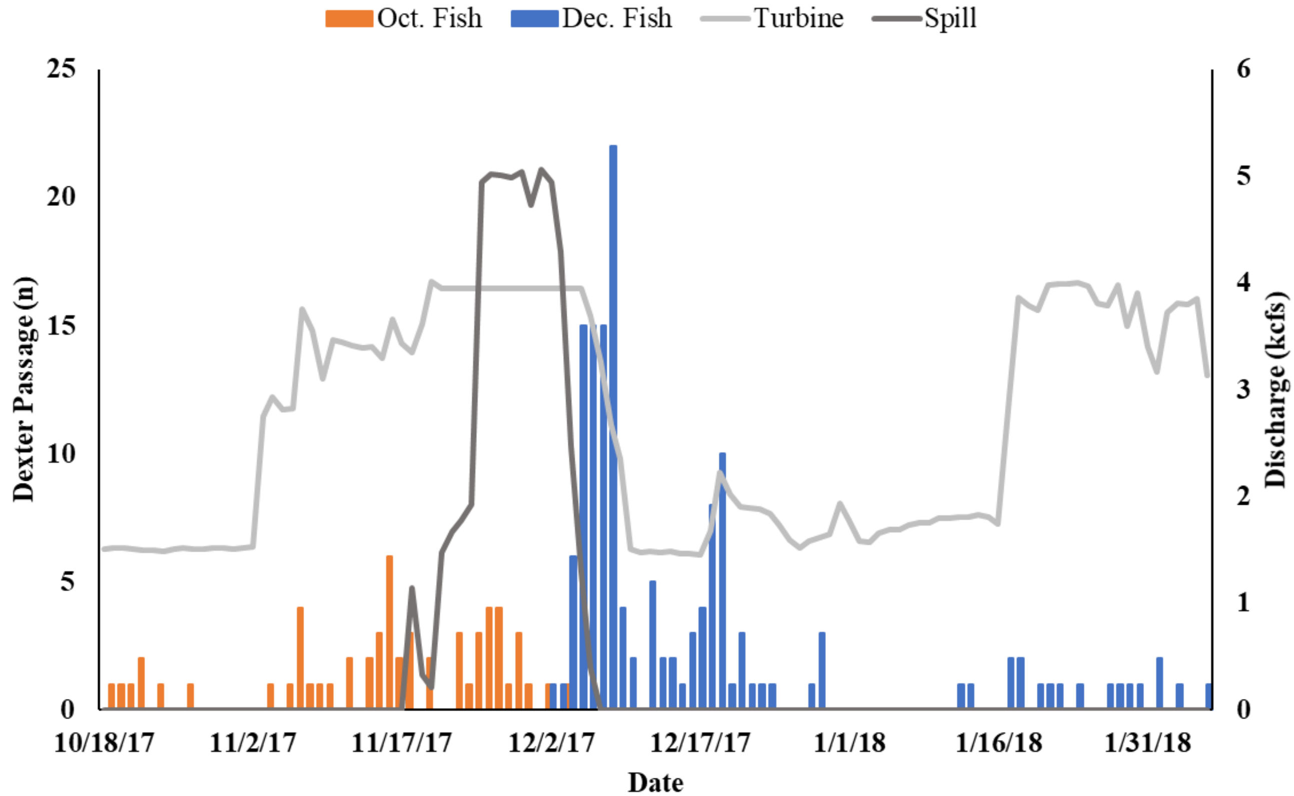


Figure 4.13. Fish Passage and Daily Average Discharge through Dexter during Fall 2017

The diel patterns of fish passing Dexter were similar to those of Lookout Point. The majority of fish released in both October and December passed Dexter during the nighttime hours, and the majority passed through the turbines (Figure 4.14).

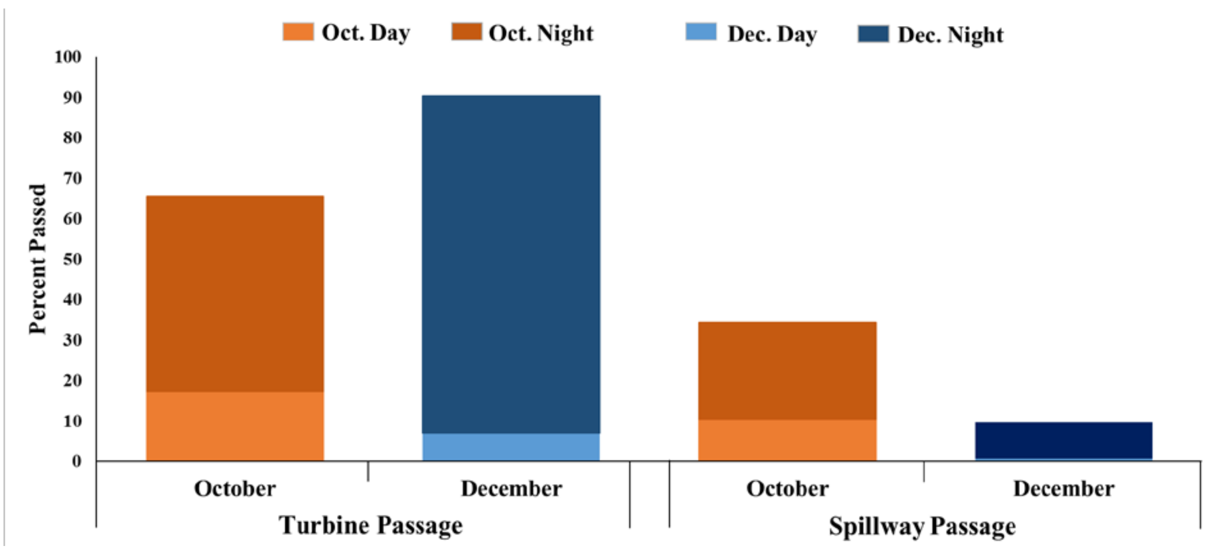


Figure 4.14. Passage of October and December 2017 Released Fish at Dexter during Night and Day Hours through Both the Turbine and Spillway

Estimating survival using the ViRDCt model, which uses the tailrace array below Lookout Point (LPT), survival could also be estimated from the immediate Lookout Point tailrace to the primary detection array at Dexter (Table 4.3). Survival through the 2 km of Dexter reservoir was 0.930 (SE = 0.068) for fish released in October and 0.885 (SE = 0.043) for fish released in December.

Table 4.3. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\widehat{S}$) from the Lookout Point Tailrace to Dexter for Acoustic-Tagged CH0 Released into the Lookout Point Reservoir in October and December 2017. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01.

		Lookout Point Tailrace to Dexter
V_1 Group	**N**	**$\widehat{S}$ (SE)**
October turbines	134	0.930 (0.068)
December turbines	331	0.885 (0.043)

4.4.2 System Migration and Travel Times

During fall 2017, fewer and fewer tagged CH0 were detected at subsequent downstream locations (Figure 4.15). This was more evident during October when 59.0% of fish were detected at Lookout Point, 18.0% were detected below Lookout Point, and 7.8% were detected below Dexter. Fish released in December migrated downstream in higher proportions; 74.9% of study fish were detected at Lookout Point, 43.3% were detected below Lookout Point, and 18% were detected below Dexter. A total of 742 tagged CH0 were released at the head of the reservoir in October 2017; of those fish, 134 migrated through the reservoir and passed Lookout Point (Figure 4.15) and had a mean reservoir residence time of 11.0 days (Figure 4.16). Average residence time between Lookout Point and the LPT arrays (for fish that passed Lookout Point and were subsequently detected downstream) was 5.1 days. Tagged fish resided between the cabled array at Lookout Point and the cabled array at Dexter (primary array) for an average of 7.0 days. Fastest travel rates were in the mainstem Willamette River (Figure 4.17); mean travel rate for CH0 from the secondary array to the tertiary array was 111.9 rkm per day. For more detailed travel time estimates, see Appendix B.

In December, an additional 765 tagged CH0 were released into the head of the reservoir. These fish migrated in much higher numbers; 331 fish were detected at and passed Lookout Point (Figure 4.18) with a mean residence time of 7.3 days, which is similar to fish released in October (Figure 4.16). Travel times between Lookout Point (last detection at cabled array) and the primary array were also similar with a mean of 6.7 days in late fall. The total travel time of December fish from passage at Lookout Point to the array in Wilsonville was 11.0 days. Similar to October, December travel rates were fastest in the mainstem Willamette River and slowest in the forebay of Lookout Point (Figure 4.17).

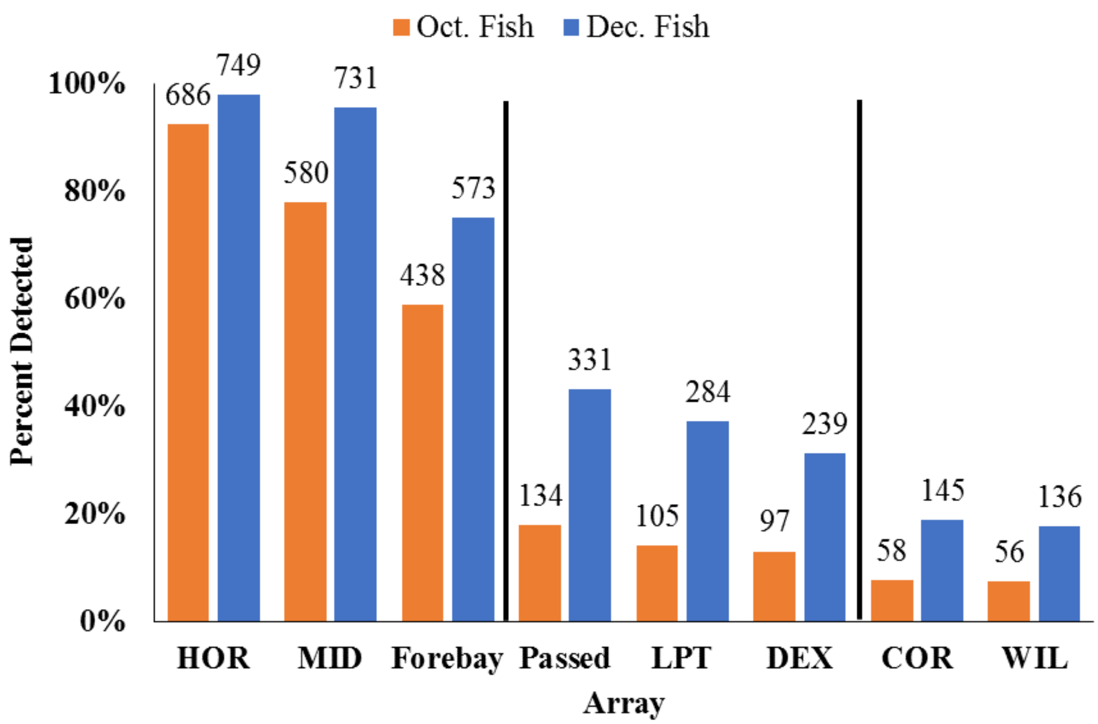


Figure 4.15. Percentage of CH0 Detected at Each Array Location in Fall 2017. The number of fish detected at each array is noted above the bars.

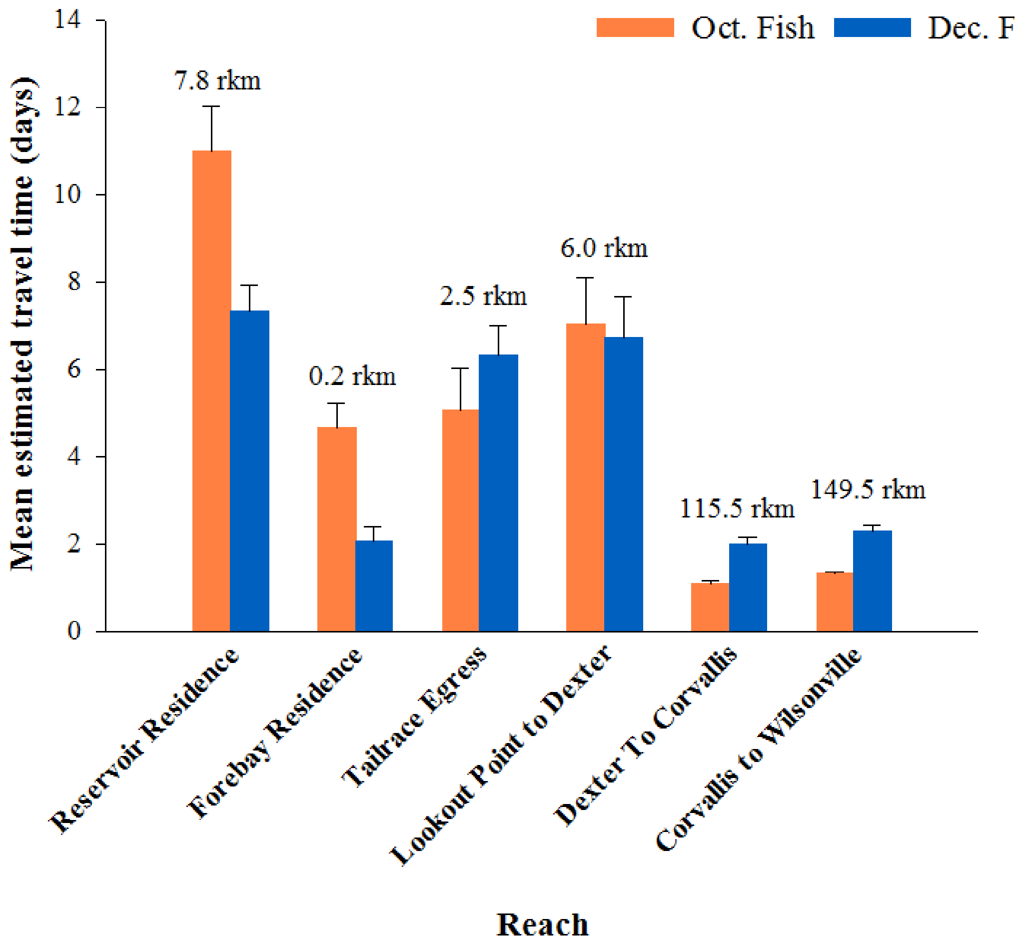


Figure 4.16. Estimated Mean Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH0 that Passed Lookout Point in Early (October) and Late Fall (December) 2017. Reach distances (rkm) are noted above the bars. Reach descriptions can be found in Appendix B.

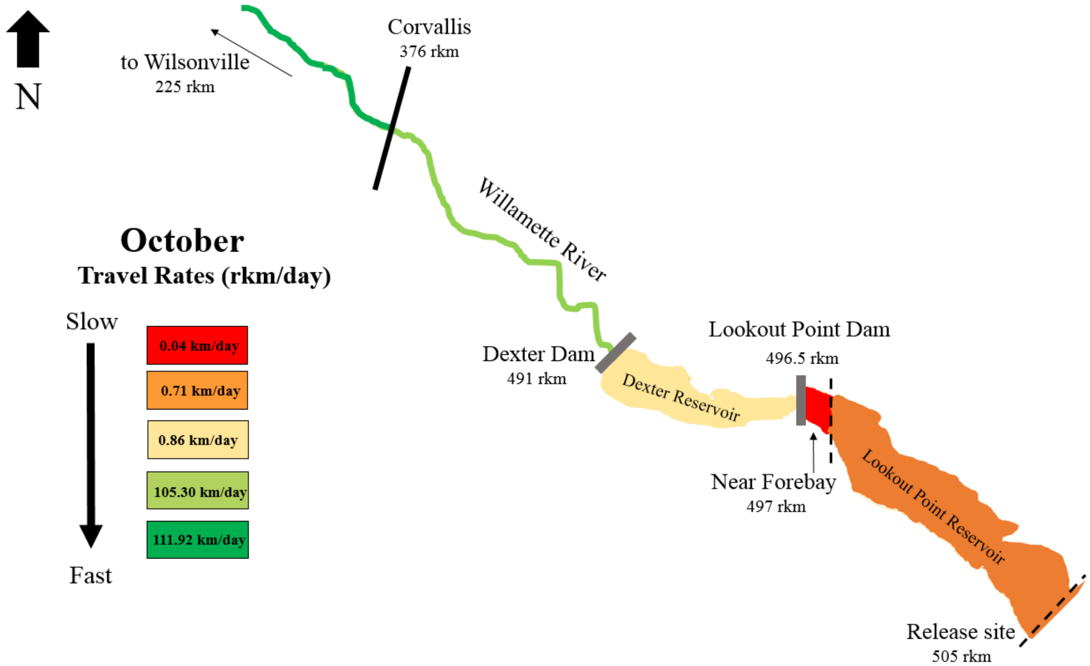


Figure 4.17. Mean Travel Rates (rkm/day) for October 2017 Released CH0 from the Release Site at Lookout Point Reservoir to Wilsonville, Oregon. Map is not to scale.

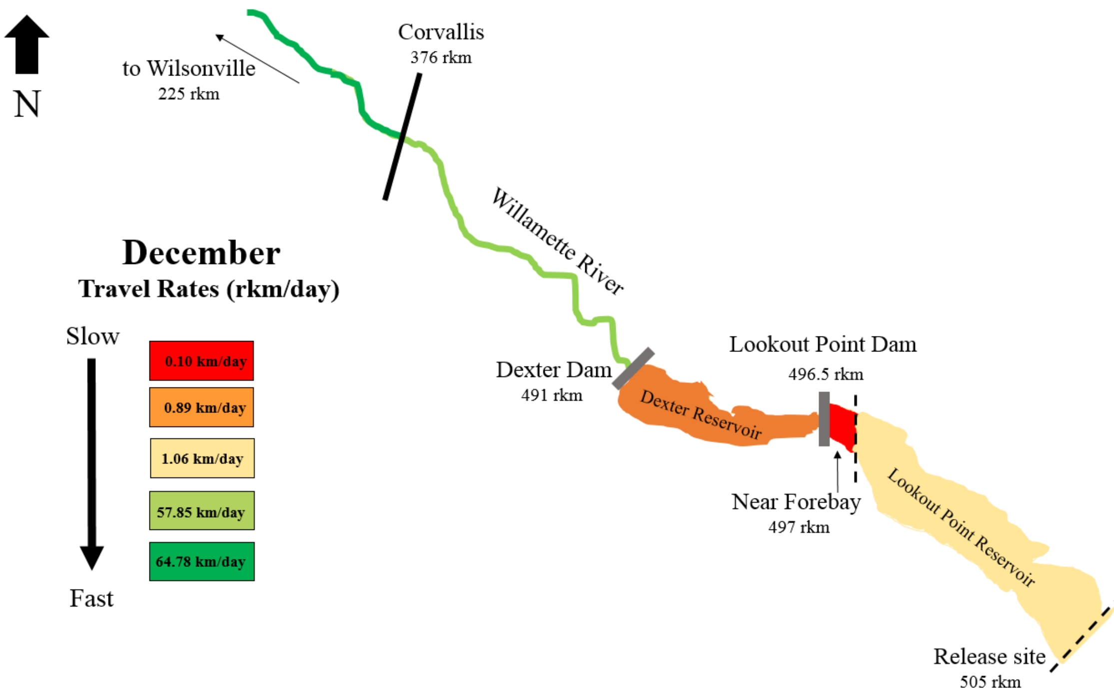


Figure 4.18. Mean Travel Rates (rkm/day) for December 2017 Released CH0 from the Release Site at Lookout Point Reservoir to Wilsonville, Oregon. Map is not to scale.

Using the downstream detection array in Corvallis we were able to calculate the joint probability of migration and survival from Lookout Point to the Corvallis array using either the standard CJS model (if no tag-life adjustment was required) or the tag life-adjusted CJS estimate (Table 4.4). For fish released in

October and December, the joint probability of migration and survival to the Corvallis array was 0.435 and 0.443, respectively.

Table 4.4. Sample Sizes (*N*) and Estimated Joint Probabilities of Migration and Survival ($\hat{S}$) from Lookout Point Passage to the Corvallis Array for Acoustic-Tagged CH0 Released into the Lookout Point Reservoir in October and December 2017. Detection probabilities of the Corvallis array are also shown. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) are shown in parentheses.

V_1 Group	*N*	$\hat{S}$ (SE)	*p* (SE)
October fish	134	0.435 (0.043)	0.875 (0.044)
December fish	331	0.443 (0.028)	0.978 (0.013)

5.0 Results – Yearling Chinook Salmon

This chapter contains information about reservoir movement, behavior, travel times, downstream migration, and survival of yearling Chinook salmon (CH1) at Lookout Point in spring 2018. Appendices A and B provide additional information about fish-tagging/release tables and fish passage and travel times, respectively.

5.1 Reservoir Movement and Behavior

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

5.1.1 Fish Movement in the Reservoir

During the spring 2018 study period, a total of 1,527 tagged yearling Chinook salmon were released into Lookout Point reservoir 8.5 km upstream of the dam and approximately 1 km upstream of the HOR array (Figure 2.1). A total of 750 fish were released in February and 777 fish were released in April. In-reservoir detection of released fish was high for both February and April periods: 93.3% and 98.1% of individuals, respectively, were detected on at least one in-reservoir autonomous receiver array.

In February 2018, detections occurred at all arrays, and a large portion of individuals were detected on HOR or MID arrays on Day 1 post-release. Fish continued to distribute throughout the reservoir as the season progressed; some individuals moved from the HOR down to the lower reservoir, then were again observed at the HOR. This cycle of movement repeated itself for a portion of the February-released fish (Figure 5.1). February fish also were observed to steadily travel from upstream locations (HOR) to the forebay, and the numbers of fish passing Lookout Point increased at each time point. In contrast to those fish that passed, approximately 30% were never detected below the MID array and never migrated to the lower end of the reservoir near Lookout Point. The numbers of fish disappearing in the reservoir (“no detect” [ND]; Figure 5.1) increased throughout the season, and 50.2% ultimately had disappeared by Day 55 post-release. Between Day 64-67 post release, the spillway at Lookout Point was operated for 6 continuous hours (April 29th, 2018). During this time an additional 50 fish that were released in February passed Lookout Point. Due to this large number of fish passing the dam an additional group was added to the plot (Spill Day) to coincide with this event.

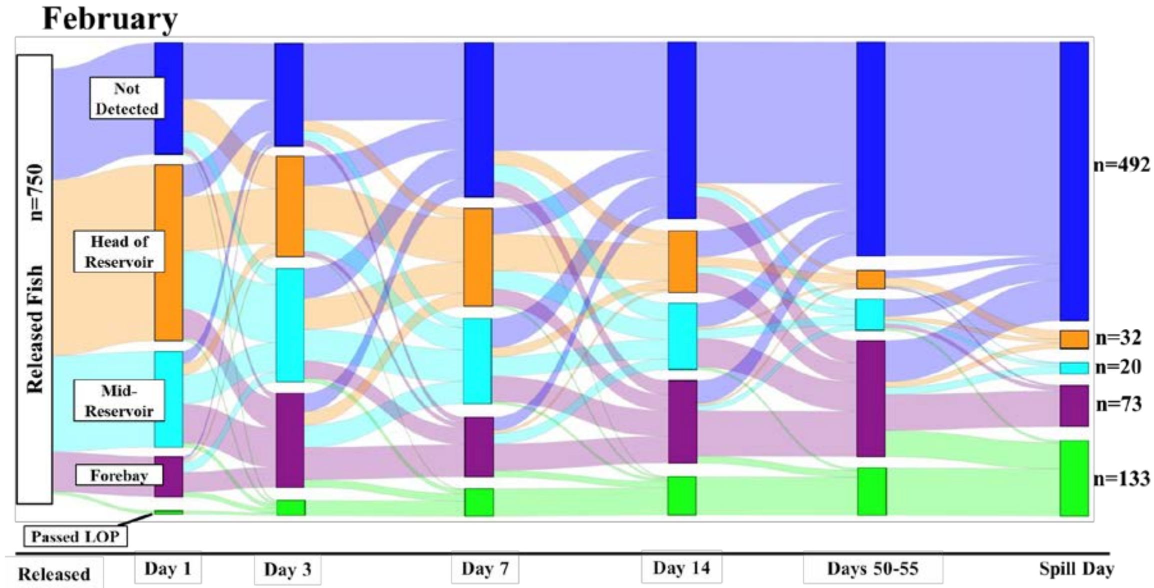


Figure 5.1. Sankey Diagram Showing Reservoir Distribution of Fish Released in February 2018 at Days 1, 3, 7, 14, Days 50–55, and Spill Day (April 29, 2018 from 10:30:00–16:45:00). Fish counts are determined using the most downstream (rkm) array at which a fish was detected within the given time period. Passed LOP indicates fish that have passed Lookout Point.

Detections occurred at all arrays for fish released in April 2018, with more fish approaching the forebay within 1 day of release compared to fish released in February (Figure 5.2). Although many fish traveled to the forebay, very few passed Lookout Point, no fish passed until Day 3, and very few passed overall (Figure 5.2). In general, many April fish traveled through the reservoir to the forebay within the first week of release and were available to pass Lookout Point, but did not ultimately do so. More than 50% of fish that passed did so through Spill Bay 3 on April 29 during the short spill period. In April, 27.1% of fish were never detected below the MID array and never migrated to the lower end of the reservoir near Lookout Point, similar to the 29.7% of February-released fish. By Day 55 post-release, 85.3% of April-released fish had disappeared from the reservoir and 3.5% had passed Lookout Point.

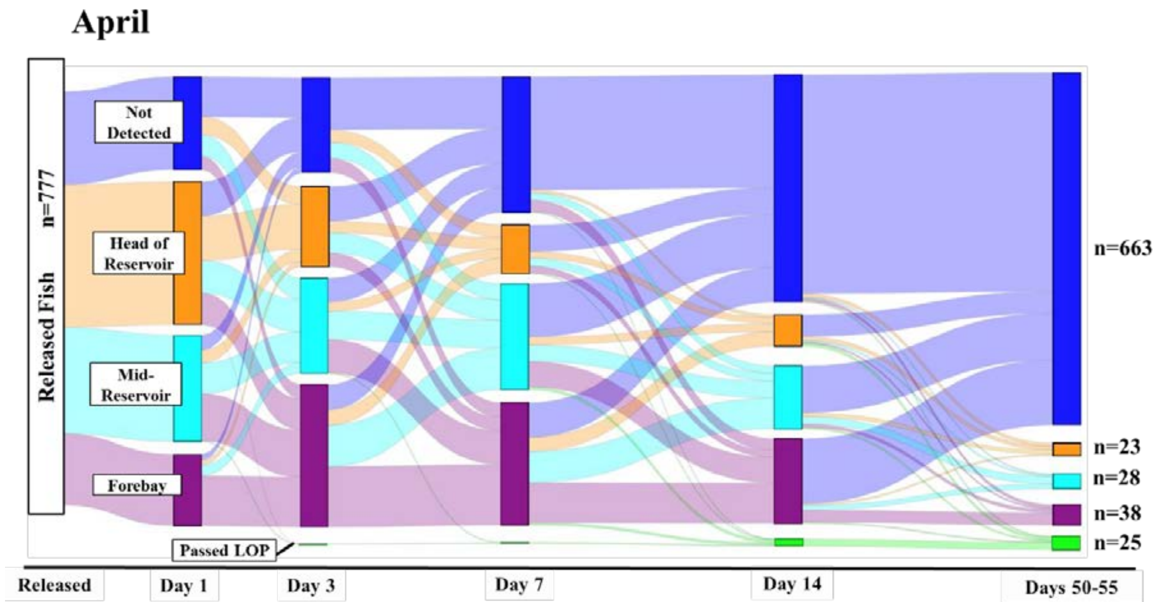


Figure 5.2. Sankey Diagram Showing Reservoir Distribution of Fish Released in April 2018 at Days 1, 3, 7, 14, and Days 50–55. Fish counts are determined using the most downstream (rkm) array a fish was detected at within the given time period. Passed LOP indicates fish that have passed Lookout Point.

5.1.2 Reservoir Horizontal Distribution

As fish moved through the Lookout Point reservoir, capture histories were formed for each of the receiver arrays (HOR, MID) to determine where across the reservoir fish were first detected. Using the first detection and the signal-to-noise ratio from each receiver to determine proximity, fish were assigned a horizontal position of first detection at each array. At the HOR array, located 1 km downstream from the release site, study fish were detected at all receivers in the array, and receivers at positions 1, 5, and 6 accounted for a greater percentage of first detections than receivers 2, 3, and 4 (Figure 5.3). Fish released during April were more uniformly distributed across the receiver array (Figure 5.3; refer to Figure 2.11 for locations of each array within the reservoir). At the MID array, fish released in February 2018, were again detected on all receivers in the array; the greatest percentage of detections occurred at receiver 2 and the remaining fish were distributed across the remaining receivers (Figure 5.4). Fish released in April 2018 distributed across the array and receiver 2 had the highest first-detection percentage (Figure 5.4).

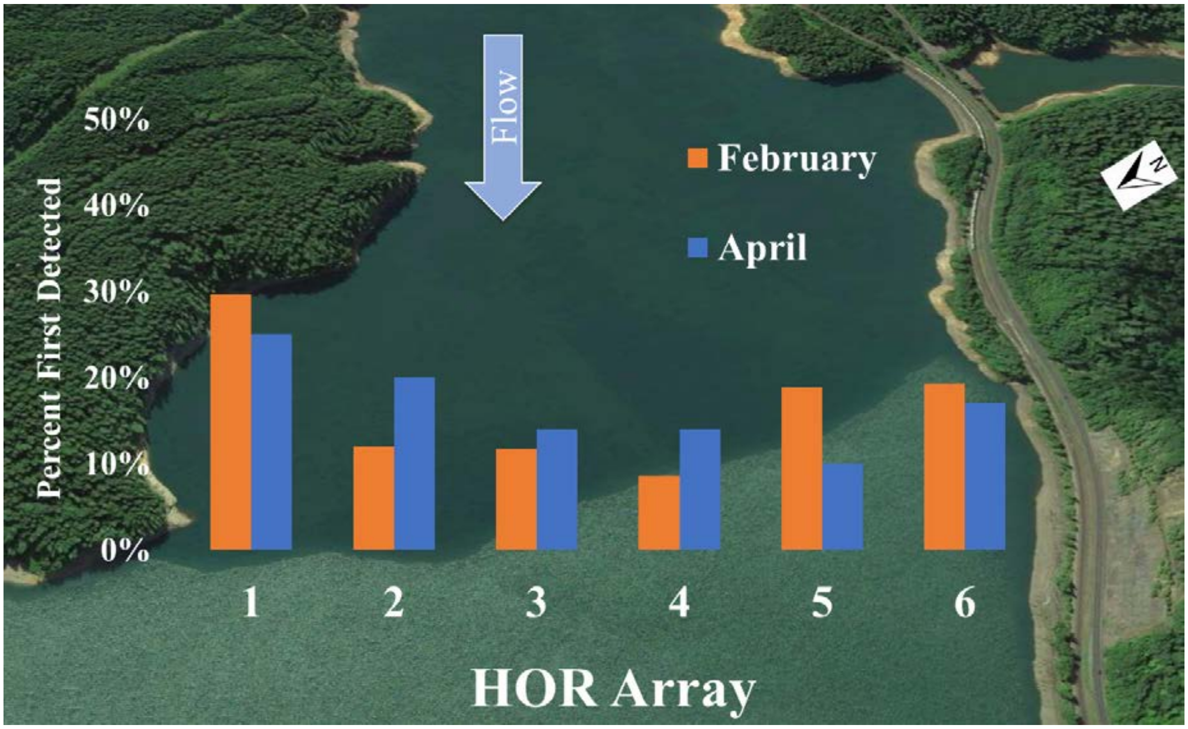


Figure 5.3. Head-of-Reservoir (HOR) Horizontal Distribution by Receiver Using the First Detection of CH1 Passing by the Array for February and April 2018 Released Fish. Receiver 1 is located near the northeast shoreline, Receiver 6 is located near the southwest shoreline.

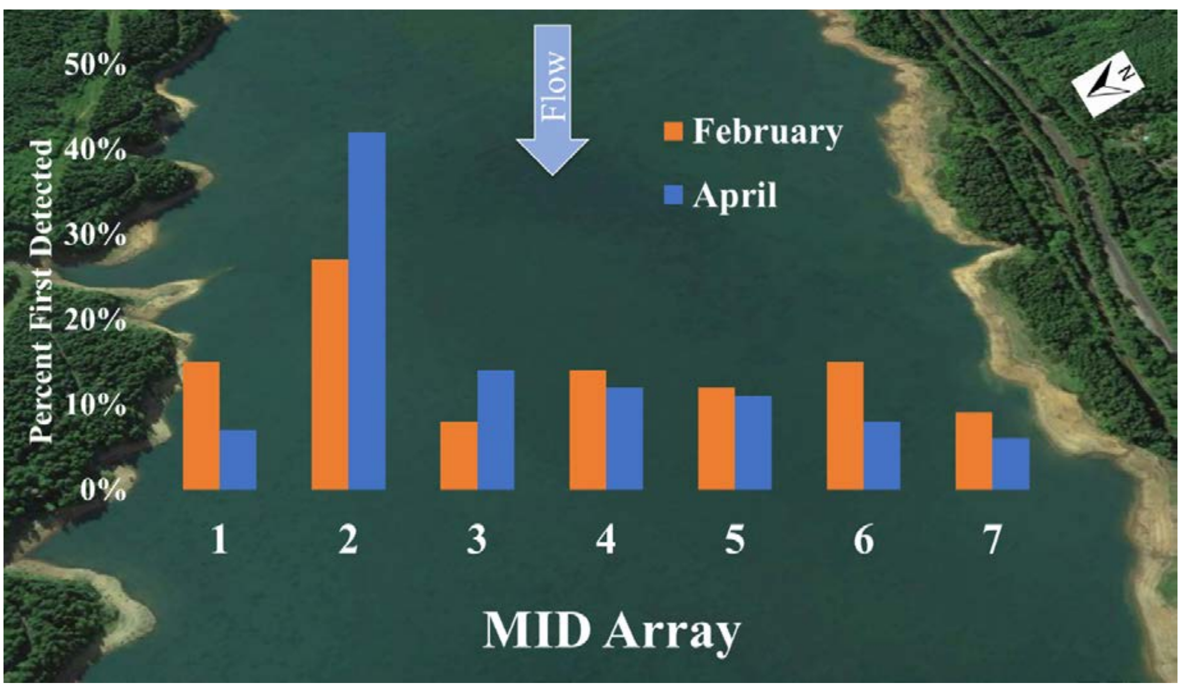


Figure 5.4. Mid-Reservoir (MID) Horizontal Distribution by Receiver Using the First Detection of CH1 Passing by the Array for February and April 2018 Released Fish. Receiver 1 is located near the northeast shoreline, Receiver 7 is located near the southwest shoreline.

5.2 Lookout Point Forebay

Detection densities of CH1 released in the spring were evaluated in the near forebay and forebay areas using cabled and receiver array data (Figure 5.5 and Figure 5.6). Distribution and movement of fish in and around the forebay area were different than the patterns of fall released fish. The contour plots suggest that fish in the spring were somewhat evenly dispersed on approach to Lookout Point . In particular, fish released in April were dispersed across the reservoir from bank-to-bank. The majority of fish first detected at the forebay array were located on the southern side of the array, closest to the earthen portion of the dam. Similar to fish movements in the fall, detection densities were greatest in front of the dam, indicating that fish mill in this area regardless of whether or not they pass through the turbine units or remain in the forebay.

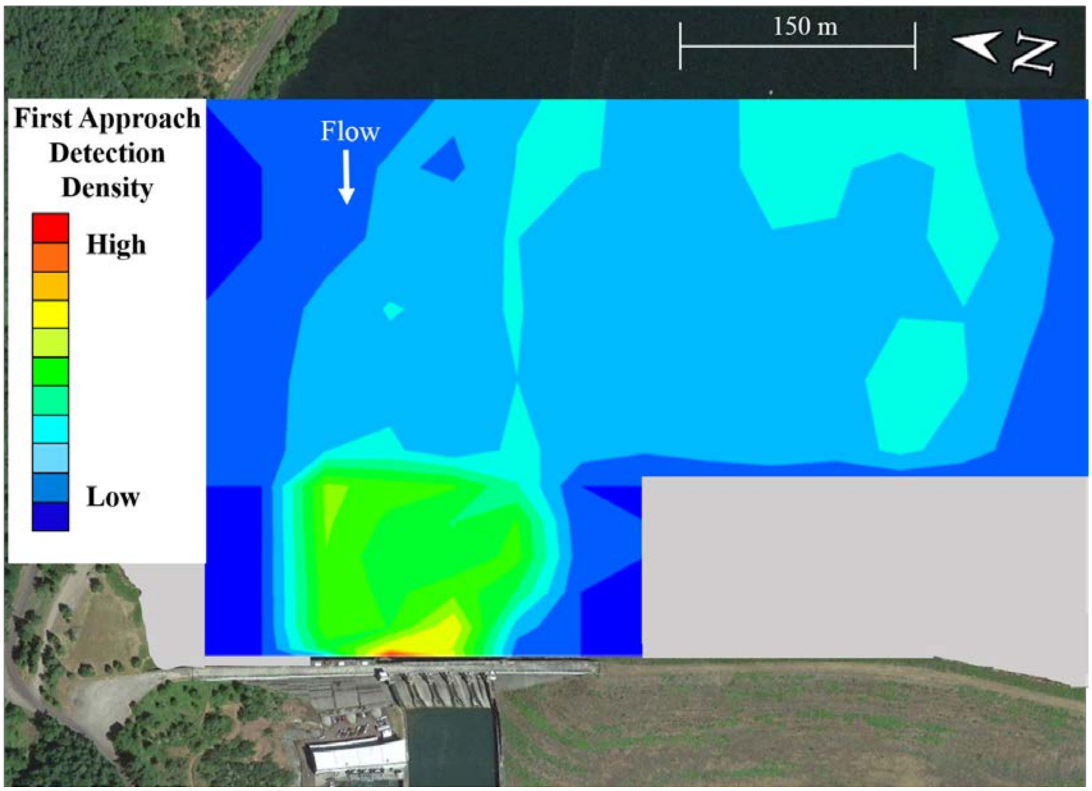


Figure 5.5. Contour Plot of Lookout Point Approach and Forebay Showing Detection Densities for February 2018 Released Fish. Detections are from both autonomous and cabled arrays. Gray fill indicates areas where fish cannot be three-dimensionally tracked due shallow water depths.

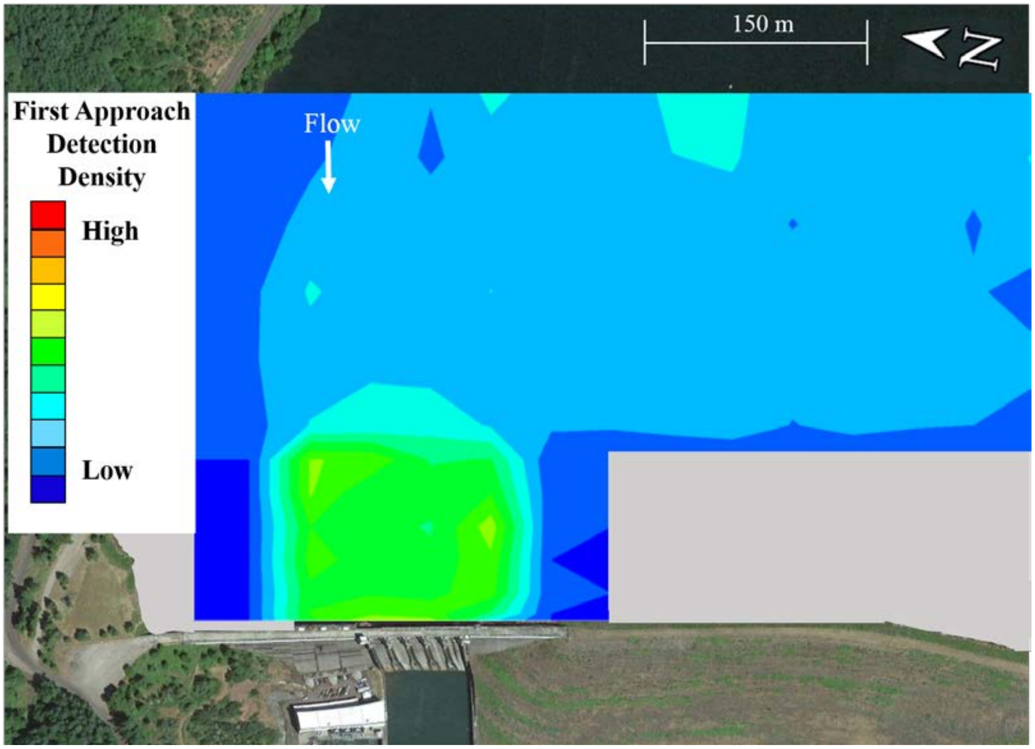


Figure 5.6. Contour Plot of Lookout Point Approach and Forebay Showing Detection Densities for April 2018 Released Fish. Detections are from both autonomous and cabled arrays. Gray fill indicates areas where fish cannot be three-dimensionally tracked due shallow water depths.

Vertical distributions of fish were determined for individuals <150 m from the dam. Overall, fish were surface oriented and most fish resided within the first 2.5 m of the water column during both day and night hours (Figure 5.7 and Figure 5.8). In February 2018, fish were detected nearly equally in day and night hours (with slightly more fish being detected at night) in the first 2.5 m of the water column. At a depth of 15 m (penstock intake depth), few fish were detected during the day or night. Very few fish were detected at RO depth during day or night hours. In April, fish were detected almost exclusively in the first 2.5 m depth during day and night, and the greatest proportion of fish were observed during the day. At penstock intake depth (15 m), slightly more fish were detected during the day. Similar to February-released fish, very few detections occurred at RO depth.

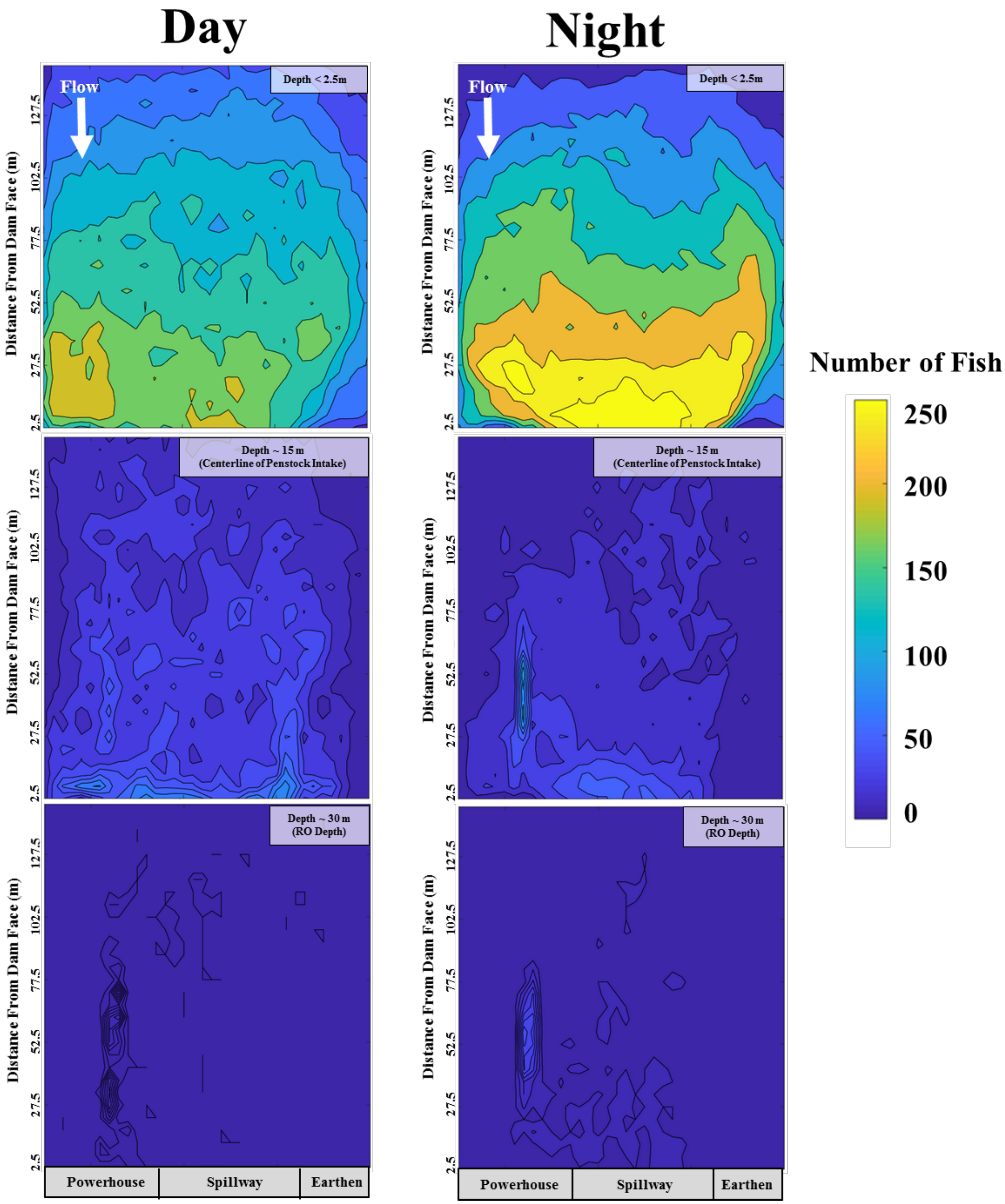


Figure 5.7. Detection Densities of February 2018 CH1 at Three Depths along the Dam-Face of Lookout Point Using the Cabled-Array System

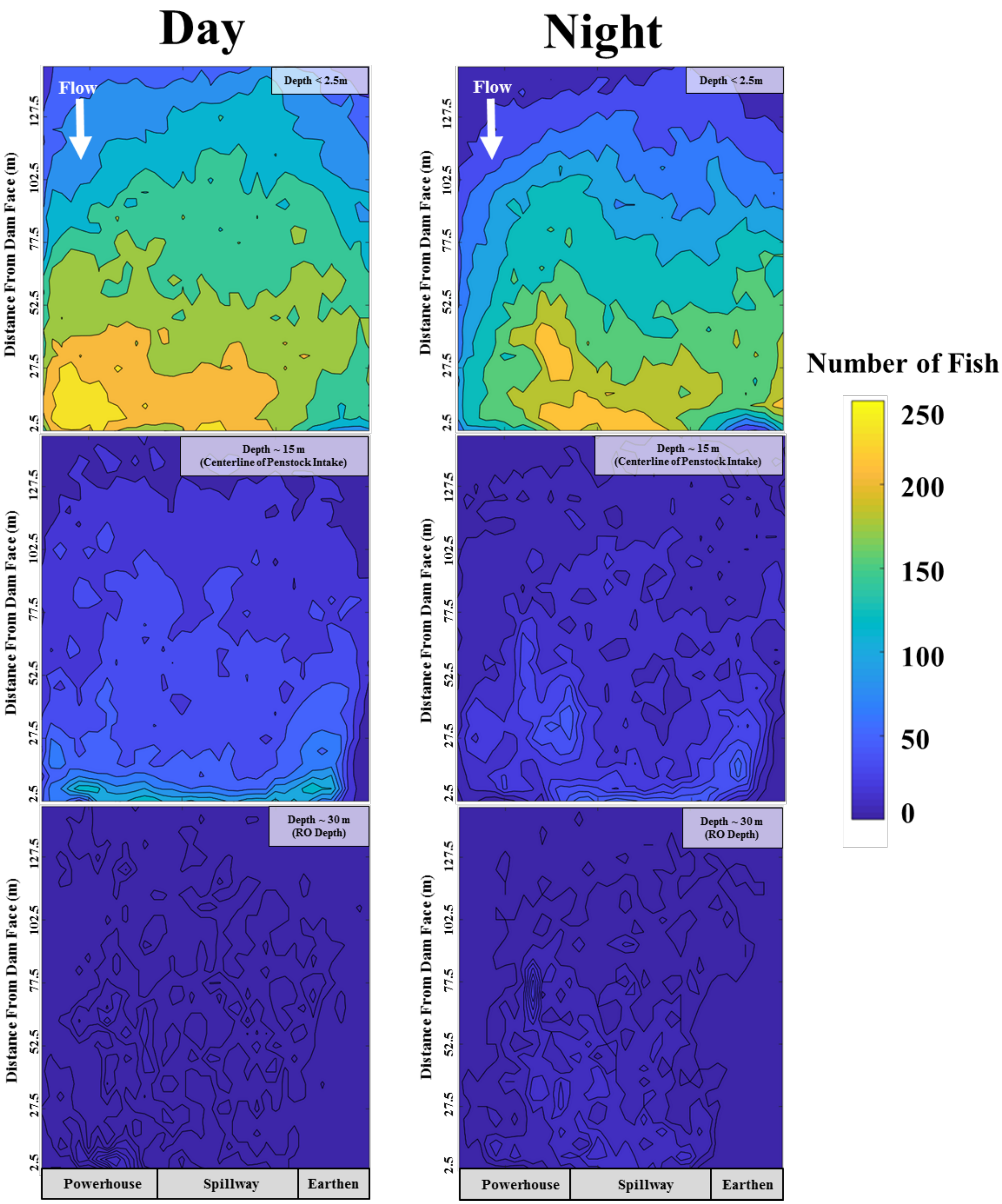


Figure 5.8. Detection Densities of April 2018 CH1 at Three Depths along the Dam-Face of Lookout Point Using the Cabled-Array System

5.3 Lookout Point Passage and Survival

5.3.1 Passage Distributions

A total of 509 fish released in February 2018 (n = 750) were detected at Lookout Point. Of those fish, 133 successfully passed downstream (Figure 5.9). Fish released in April 2018 (n = 777) migrated through the Lookout Point reservoir in similar numbers: a total of 530 fish were detected at Lookout Point. However, very few fish released in April successfully passed Lookout Point; only 27 study fish passed downstream.

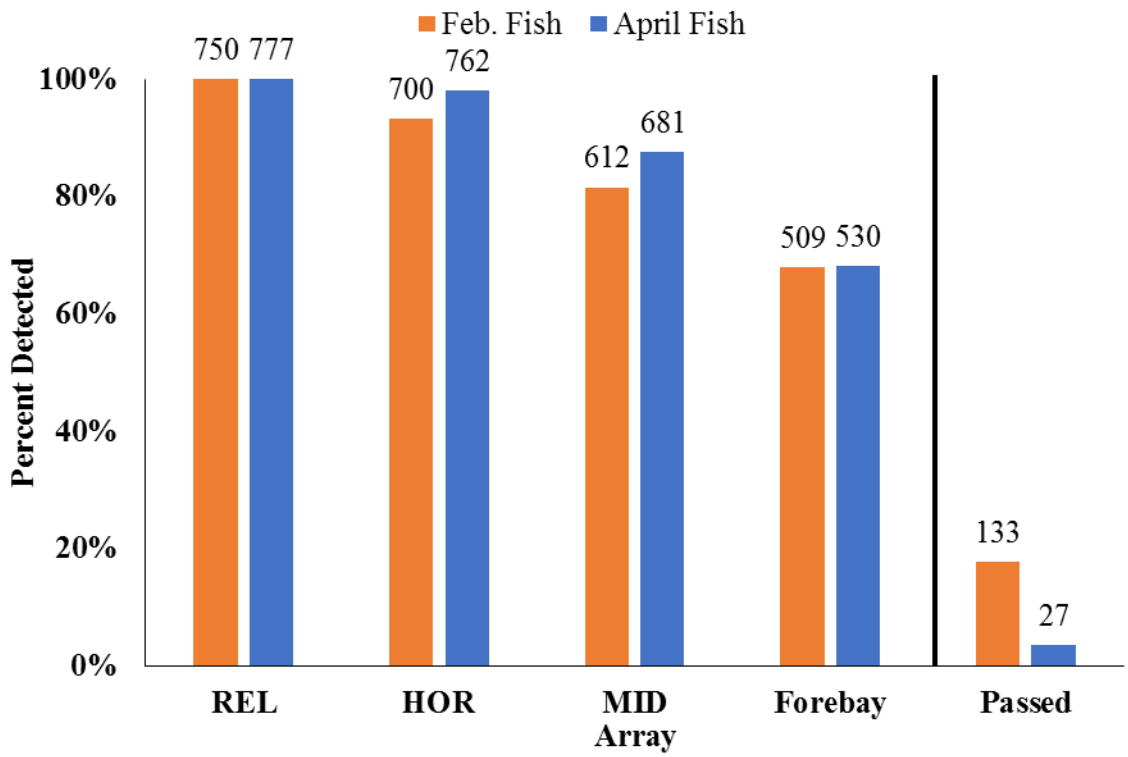


Figure 5.9. Percentage of Spring 2018 CH1 Detected and Passed at Receiver Arrays in the Lookout Point Reservoir. Black vertical line represents Lookout Point.

During spring 2018, the only potential passage route for CH1 at Lookout Point was through the turbines, with the exception of spillway passage on April 29, when 6 h of spill occurred. Study fish were tracked and assigned to one of the three turbine units or to Spill Bay 3. Of the fish released during February, a total of 133 study fish passed Lookout Point, and Spill Bay 3 and Turbine Unit 3 passed similar proportions of fish (37.6% and 36.8%, respectively); however, Turbine Unit 3 had much higher discharge than Spill Bay 3 (Figure 5.10). Turbine Units 1 and 2 passed similar proportions of fish following their February release (13.5% and 12.0%, respectively) and had similar proportions of discharge. Study fish released in April 2018 migrated through the reservoir in similar numbers, but only 27 (3.5%) fish passed Lookout Point (Figure 5.9). Spill Bay 3 passed the largest number of fish (n = 16; 59.2%) and had the least discharge (Figure 5.10). At the powerhouse, passage and discharge varied between turbine units; more fish passed via Unit 3, but Unit 2 had the highest discharge.

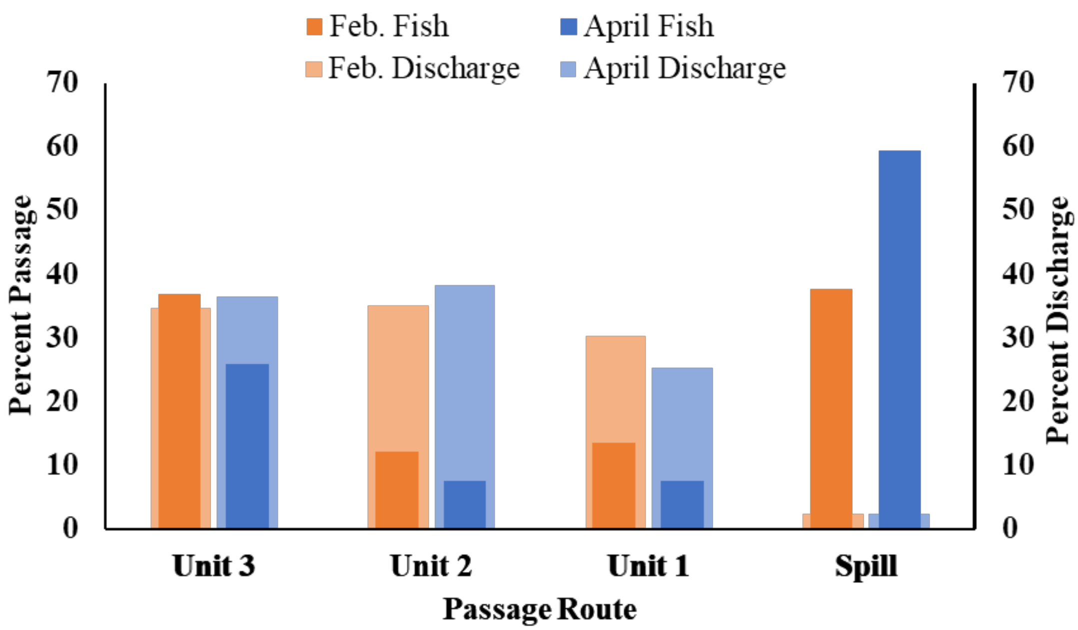


Figure 5.10. Passage and Discharge Percentages of Spring 2018 CH1 through Lookout Point.

For fish released in February, just over 50% passed Lookout Point during the nighttime hours even though a greater percentage of discharge occurred during the day (Figure 5.11). Turbine Unit 3 passed the largest proportion of fish at night (31.6%) with similar proportions of seasonal discharge between the three turbine units. During the day, the spillway at Lookout Point was used for 6 h on April 29 and a large proportion of February released fish passed through that route (37.6%).

For fish released in April, the vast majority (81.5%) passed during the daytime hours. Turbine discharge was higher during the daytime hours and Turbine Unit 3 passed the greatest proportion of fish with similar discharge between the three units. The greatest passage of April released fish occurred when the spillway was operated on April 29th, which led to very high proportions of fish passing during that time (59.3%).

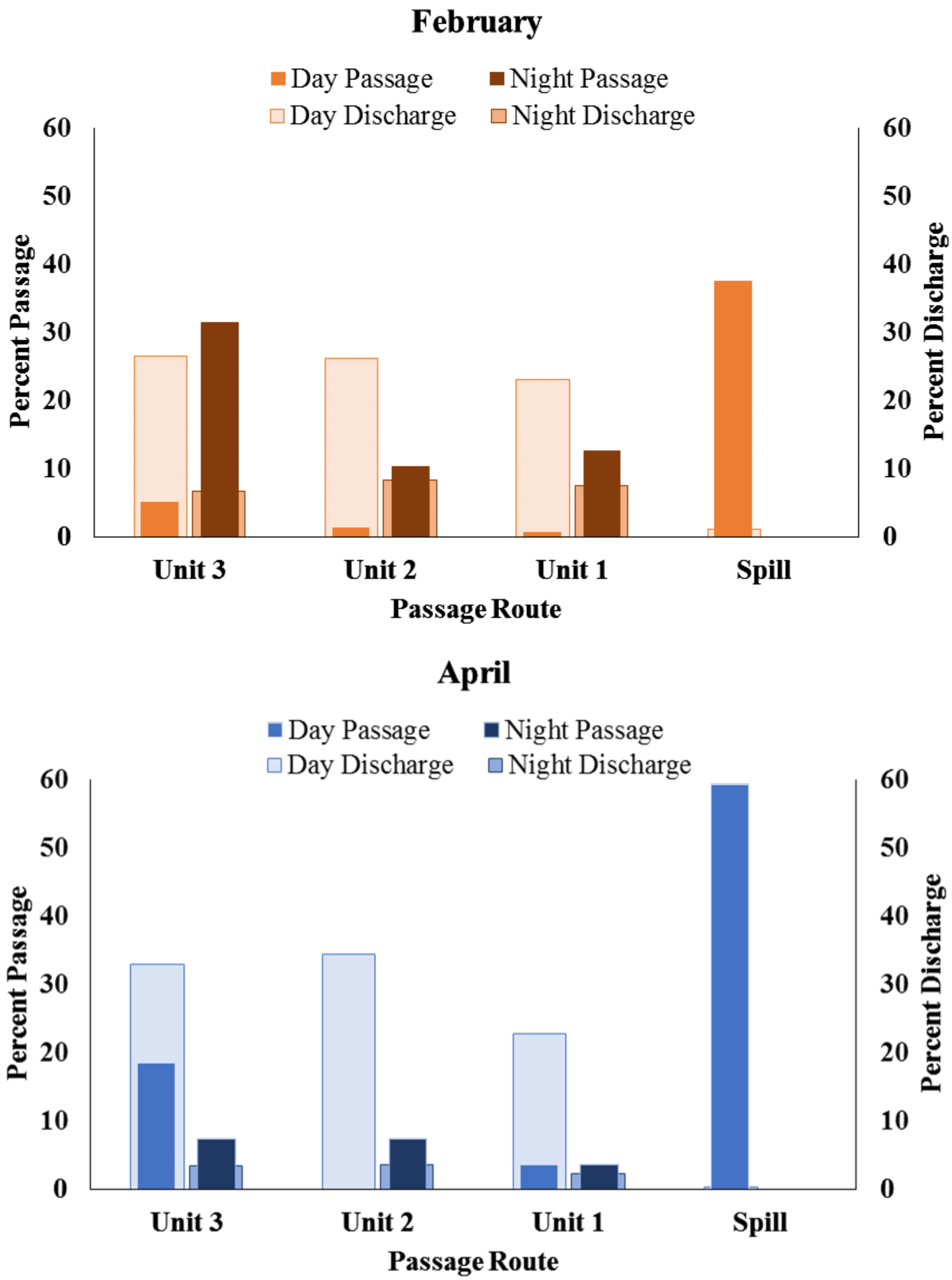


Figure 5.11. Diel Passage and Discharge Percentages through Lookout Point in Spring 2018 (February release on top and April release on bottom)

Discharge varied throughout the spring study period; a minimum daily discharge of 24 kcfs occurred on April 29, 2018 and a maximum daily discharge of 95 kcfs occurred on May 26, 2018. Fish passed Lookout Point throughout the early spring, and the largest percentage of passage occurred during the short 6 h of spill that occurred on April 29 (Figure 5.12).

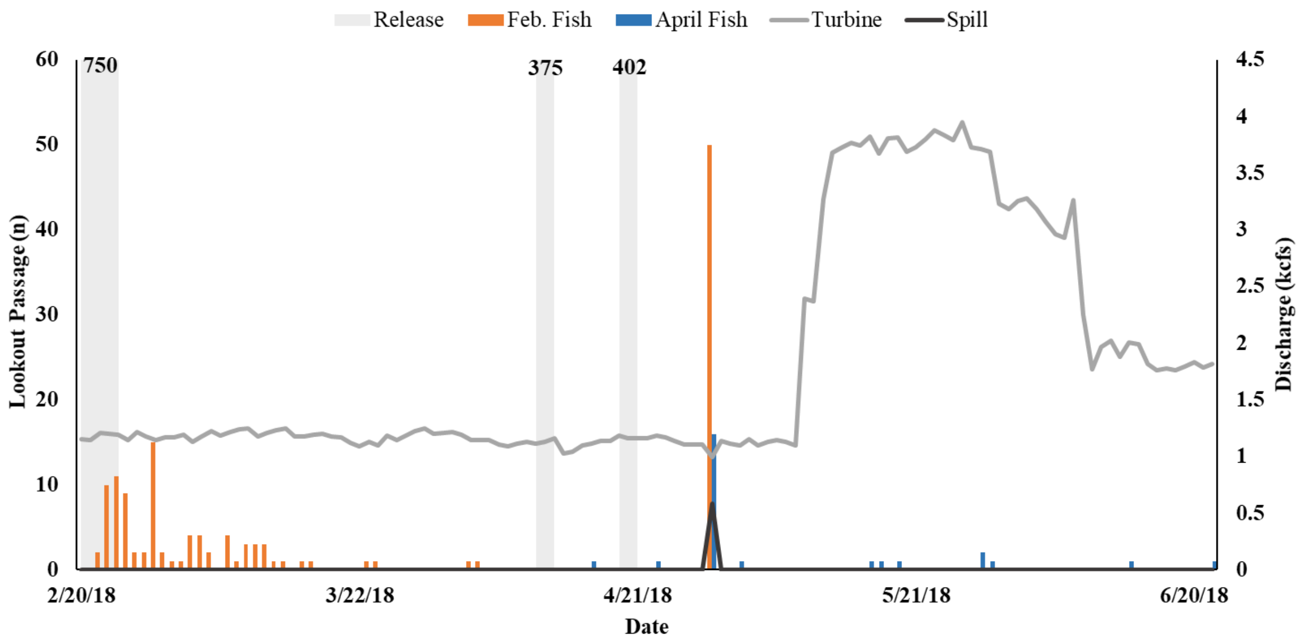


Figure 5.12. Fish Passage and Daily Average Discharge through Lookout Point during Spring 2018

Turbine units at Lookout Point were operated during peak power demand times during spring 2018. Two distinct peaks in operations (discharge) occurred (Figure 5.13) then, one during the morning (6–8 am) and one during the evening (5–8 pm). Fish passed in moderate proportions during this time; 40% of all fish passed between the hours of 6–8 am (15.0% in February, 11.1% in April) and 5-8 pm (30.1% in February and 3.7% in April). The majority of April-released fish that passed during the daytime hours did so when Spill Bay 3 was open for ~6 h (10:30 am to 4:45 pm) on April 29. During this short 6 h block of time, 37.6% of February-released fish compared to 66.7% of all April-released fish passed.

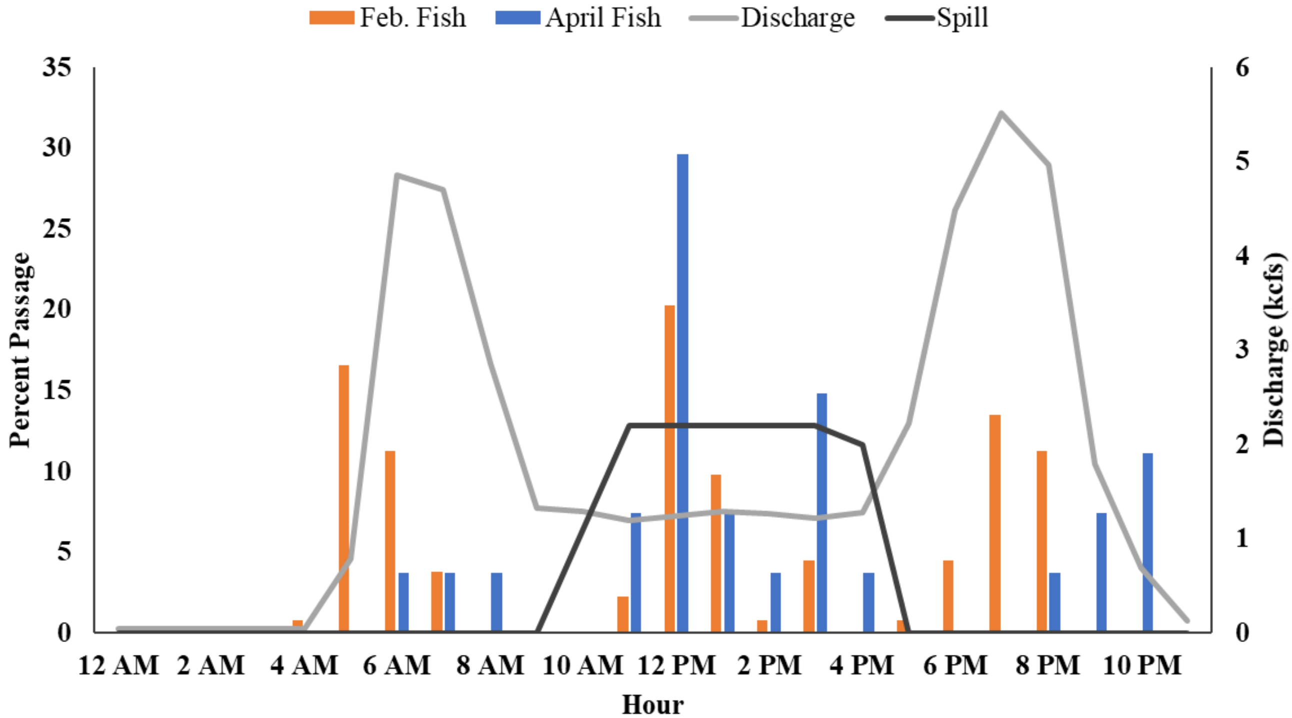


Figure 5.13. Average Hourly Passage and Discharge at Lookout Point during Spring 2018. The solid black line indicates actual spill discharge, which only occurred for 6 hours on April 29th during the Spring 2018 study period.

5.3.2 Project Passage Metrics

Study fish released in February 2018 migrated down to the Lookout Point forebay in moderate numbers—498 fish were detected in the near forebay (<150 m upstream of the dam-face). DPE was low at 0.267, indicating that it was difficult for fish in the forebay to pass the dam. The spillway was used during the spring at Lookout Point for 6 h on April 29; several fish released in February passed this route as indicated with an FPE of 0.100 (Table 5.1).

In April, study fish migrated in similar numbers, and 520 fish were detected in the near forebay at Lookout Point. Passage of fish released in April was much lower (DPE of 0.052), indicating the majority of fish that approached Lookout Point did not pass. Fish released in April were detected passing through the spillway at Lookout Point on April 29 with an FPE of 0.031 (Table 5.1).

Table 5.1. DPE and FPE for CH1 at Lookout Point in Spring 2018

Release	Forebay Detections (N)	Passage (N)	DPE	FPE
February	498	133	0.267	0.100
April	520	27	0.052	0.031

5.3.3 Survival

In February 2018, 40 dead tagged fish were released into the Lookout Point tailrace. Of those, two were detected at the LPT array ($\frac{d}{D}$ = 0.050) and none were detected at Dexter. No tag life adjustment was required for February 2018-released fish that passed through the turbines. Therefore, the reduced ViRDCt model was used for estimating Lookout Point to immediate tailrace (LPT array) survival, and the standard CJS model was used for estimating Lookout Point to Dexter survival (Table 5.2). Survival was 0.699 (SE = 0.050) for fish released in February that passed the Lookout Point turbines and traveled through the entire Dexter reservoir. Using the reduced ViRDCt model to estimate survival, which removes 2 km of the Dexter reservoir, the survival estimate was 0.784 (SE = 0.047).

Because February-released CH1 passed Lookout Point via the spillway in April, these fish were pooled with April-released CH1 that passed via the spillway (though separate tag-life corrections were made for each group) and the dead tagged fish detection rate measured in April was used to estimate Lookout Point spillway passage survival. Of the 40 dead tagged fish released in April, 19 were detected at the LPT array ($\frac{d}{D}$ = 0.48) and 1 was detected at Dexter ($\frac{d}{D}$ = 0.03). Therefore, the tag life-adjusted full ViRDCt model was used to estimate Lookout Point to the immediate tailrace (LPT array) survival, and the tag life-adjusted reduced ViRDCt model was used to estimate Lookout Point to Dexter survival for spillway-passed fish (Table 5.2). Pooled dam passage survival for fish released in April and the addition of the spillway-passed fish from February was 0.822 (SE = 0.047) to the primary detection array downstream. Using the ViRDCt survival model and the Lookout Point tailrace array (LPT), pooled survival was 0.942 (SE = 0.057). Survival of fish released in April that passed the Lookout Point turbines and traveled through the Dexter reservoir was 0.441 (SE = 0.143), while survival of the pooled February and April fish that passed the spillway was 0.884 (SE = 0.070). Using the Lookout Point tailrace array and the ViRDCt model, survival through the turbines was 0.654 (SE = 0.189), while survival through the spillway for the pooled February and April-released fish was 0.987 (0.055).

As mentioned previously (Section 3.2), tag-life corrections were not possible downstream of Lookout Point for April 2018-released, turbine-passed fish. However, based on the timing of Lookout Point passage in relation to the tag-life curve, it appeared as though any tag-life adjustment would have been fairly small. Therefore, the observed dead tagged fish detection rates from April (described in the preceding paragraph) were used with the full and reduced ViRDCt models for estimating survival to the Lookout Point tailrace and to Dexter, respectively, for April-released, turbine-passed fish.

Table 5.2. Sample Sizes (*N*) and Estimated ViRDCt Survival Probabilities ($\widehat{S}$) from Lookout Point Passage to the Lookout Point Immediate Tailrace (LPT Array) and to Dexter for Acoustic-Tagged CH1 Released into the Lookout Point Reservoir in February and April 2018. Detection probabilities (*p*) of each detection array (LPT and Dexter) are also shown. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01. Superscripts indicate the model used to estimate survival.

		Lookout Point to Immediate Tailrace		**Lookout Point to Dexter**	
V_1 Group	***N***	**$\widehat{S}$ (SE)**	***p***	**$\widehat{S}$ (SE)**	***p***
February turbines	83	0.784 (0.047)[a]	1.00	0.699 (0.050)[b]	1.00
April turbines	11	0.654 (0.189)[e]	1.00	0.441 (0.143)[a]	1.00
Feb & April spillway	66	0.987 (0.055)[c]	1.00	0.884 (0.070)[c]	1.00
Spill and April Pooled	77	0.942 (0.057)[c]	1.00	0.822 (0.047)[c]	1.00

(a) Reduced ViRDCt model
(b) CJS model
(c) Tag life-adjusted ViRDCt model
(e) Full ViRDCt model

5.4 Dexter

5.4.1 Reservoir Passage and Survival

Unlike Lookout Point, which is a peak power generating dam, Dexter is a run-of-river project that requires constant water passage through the turbine unit, the spillway, or some combination of both. Discharge through Dexter during spring 2018 was primarily through the turbine with some spill occurring in late March and the middle of May (Figure 5.14). Study fish released in February 2018 arrived at and passed Dexter throughout the spring, and peak passage occurred on March 9. Fish that passed Lookout Point and migrated to Dexter passed through the Dexter turbine in high proportions for both February (81.0%) and April (90.0%) released fish (Figure 5.15). As in fall 2017, the majority of fish passing Dexter did so at night for both the February and April release groups.

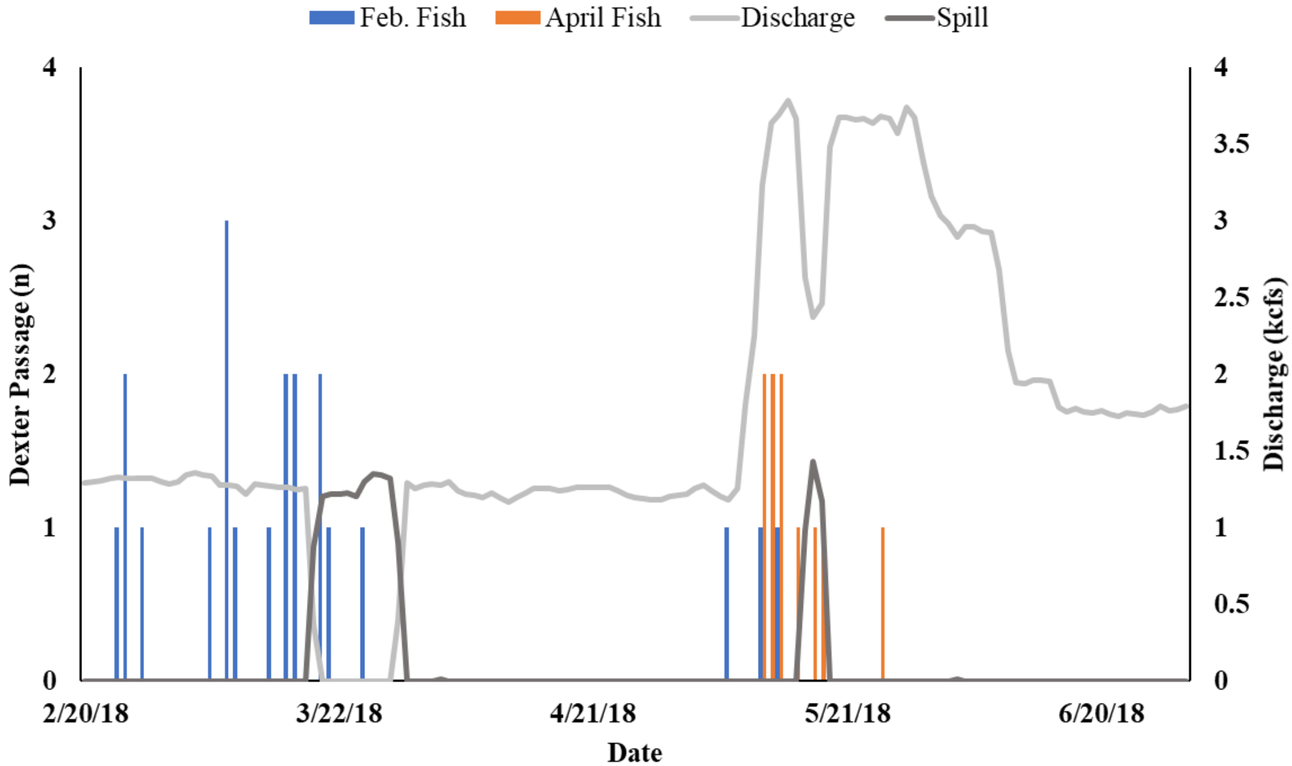


Figure 5.14. Fish Passage and Daily Average Discharge through Dexter during Spring 2018

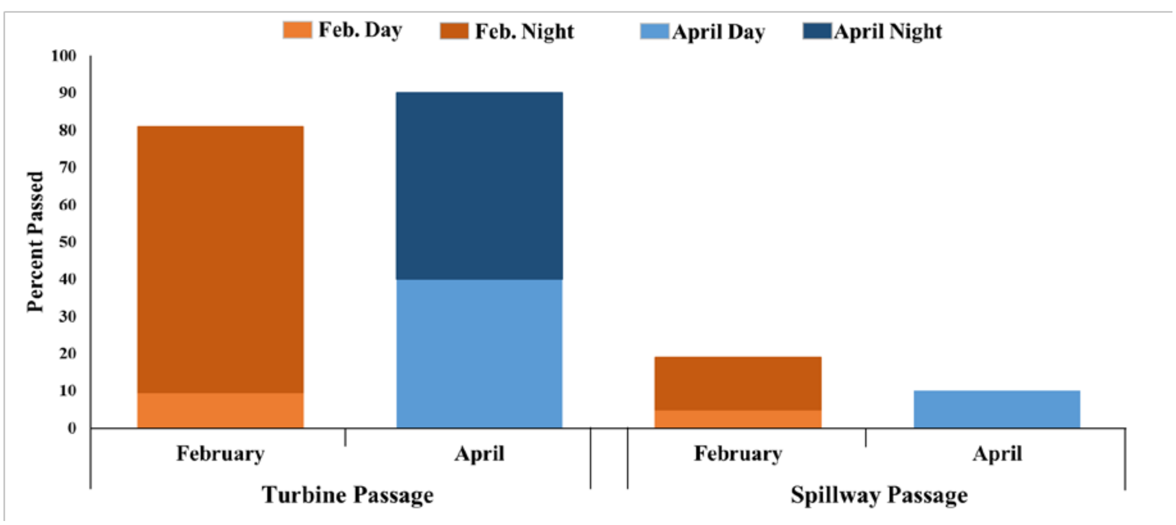


Figure 5.15. Passage of February and April 2018 Released CH1 at Dexter during Night and Day Hours through Both Turbine and Spillway Routes

Using the ViRDCt model, which uses the immediate tailrace array below Lookout Point (LPT), survival could also be estimated from the immediate Lookout Point tailrace to the primary detection array at Dexter (Table 5.3). Survival through the 2 km of Dexter reservoir (Lookout Point tailrace to Dexter) was approximately 0.891 (SE = 0.084) for fish released in February that passed through the turbine, and survival was very similar for the pooled April and February spillway fish (0.896, SE = 0.087). Survival for turbine-passed fish released in April was lower (0.674, SE = 0.293).

Table 5.3. Sample Sizes (N) and Estimated ViRDCt Survival Probabilities ($\hat{S}$) from the Lookout Point tailrace (LPT array) to Dexter or Acoustic-Tagged CH1 Released into the Lookout Point Reservoir in February and April 2018. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point. Standard errors (SEs) of survival estimates are shown in parentheses. All detection probability SEs were ≤0.01.

		Lookout Point Tailrace to Dexter
V_1 Group	***N***	**$\hat{S}$ (SE)**
February turbines	83	0.891 (0.084)
April turbines	11	0.674 (0.293)
February and April Spillway	66	0.896 (0.087)
Spill and April Turbines Pooled	77	0.872 (0.073)

5.4.2 System Migration and Travel Times

During spring, fewer tagged CH1 were detected at subsequent downstream locations (Figure 5.16). Fish released in both February and April traveled through Lookout Point reservoir in similar numbers and 68% of the fish were detected in the Lookout Point forebay. However, fewer fish released in April passed Lookout Point (3.5%) compared to fish released in February (17.7%).

A total of 750 tagged CH1 were released at the head of the reservoir in February; of those fish, 133 migrated through the reservoir and passed Lookout Point (Figure 5.17), with a mean reservoir residence time of 28.9 days (Figure 5.17). Tagged fish resided in the Dexter reservoir for an average of 9.0 days. The fastest travel times were in the mainstem Willamette River (Figure 5.18); mean travel time for CH1 from Lookout Point to Wilsonville, Oregon was 11.6 days.

In April, an additional 777 tagged CH1 were released into the head of the reservoir. These fish migrated in similar numbers; 530 fish were detected at Lookout Point, but only 27 fish successfully passed Lookout Point (Figure 5.18) with a mean reservoir residence time of 19.9 days. Travel times through the Dexter reservoir were similar with a mean of 12.1 days. Total passage time of late spring fish from Lookout Point to the array in Wilsonville was 19.3 days. Similar to February, April travel rates were fastest in the mainstem Willamette River and slowest in the forebay of Lookout Point (Figure 5.18).

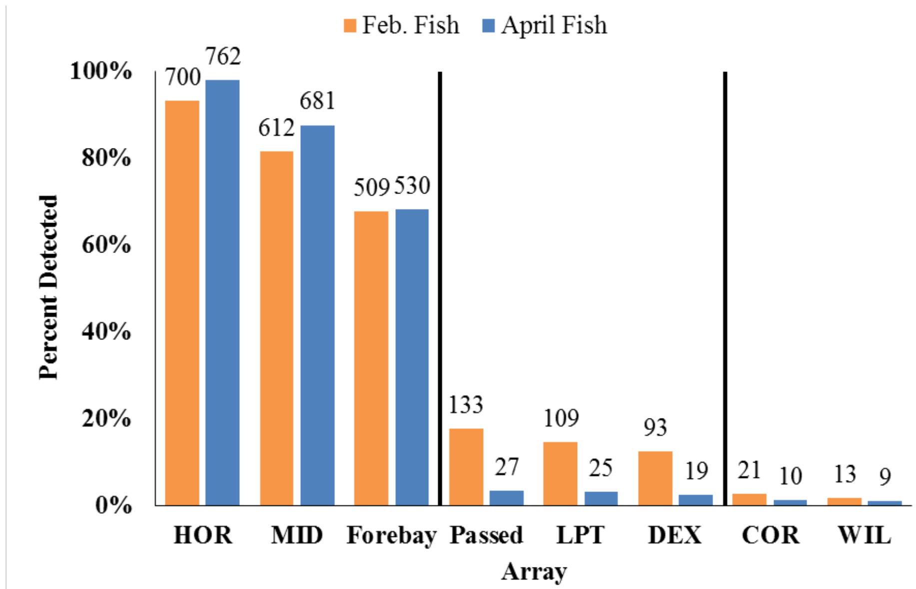


Figure 5.16. Percentage of CH1 Detected at Each Array Location in Spring 2018. The number of fish detected at each array is noted above the bars. Black vertical lines indicate Lookout Point and Dexter.

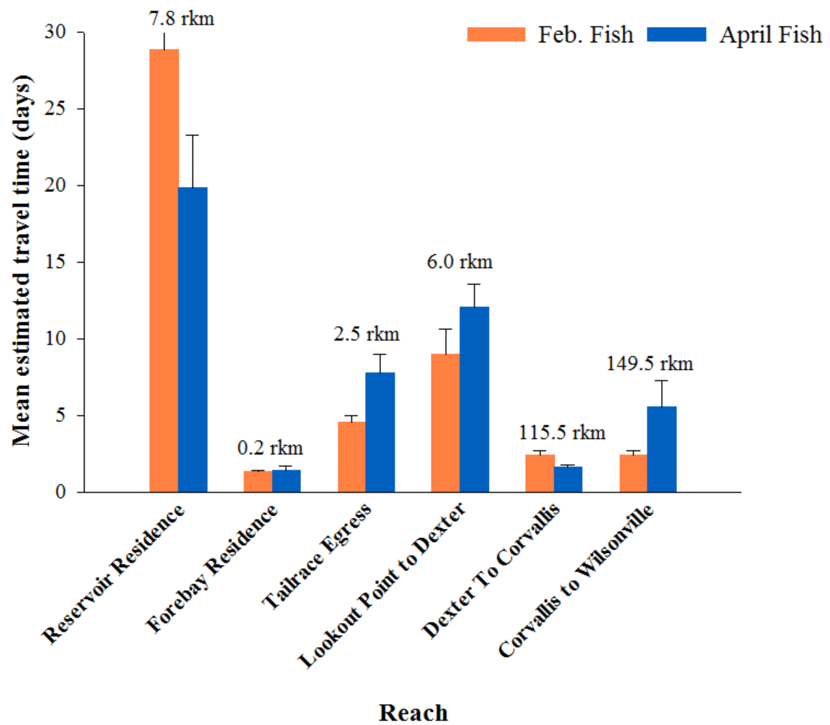


Figure 5.17. Estimated Mean Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH1 that Passed Lookout Point in Early (February) and Late Spring (April) 2018. Reach distances (rkm) are noted above the bars. Reach descriptions can be found in Table B.5 in Appendix B.

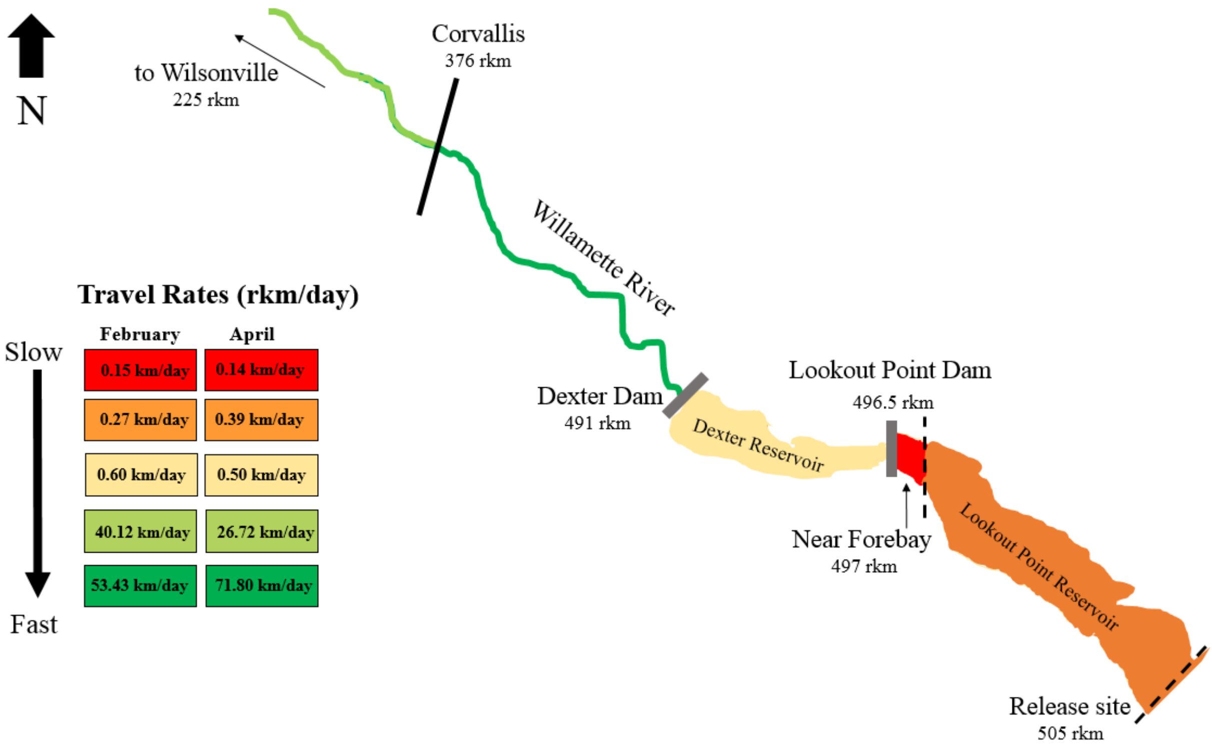


Figure 5.18. Mean Travel Rates (rkm/day) for February and April 2018 Released CH1 from the Release Site at Lookout Point Reservoir to Wilsonville, Oregon. Map is not to scale.

Using the downstream detection array in Corvallis the joint probability of migration and survival from Lookout Point to the Corvallis array was calculated by using either the standard CJS model (if no tag life adjustment was required) or the tag life-adjusted CJS estimate (Table 5.4).The exception was February-released fish that passed Lookout Point in April due to insufficient detections at the Corvallis and Wilsonville arrays, likely because they were migrating at or near the end of their tag life. For fish released in February, the joint probability of migration and survival to the Corvallis array was 0.217 (SE = 0.045). Due to the low migration success of fish released in April, pooled estimates for turbine and spillway-passed fish were calculated with a joint probability of migration and survival of 0.370 (SE = 0.093). There were insufficient data available to calculate the February-released fish that passed through the spillway in April due to inadequate tag-life.

Table 5.4. Sample Sizes (N) and Estimated Joint Probabilities of Migration and Survival ($\hat{S}$) from Lookout Point Passage to the Corvallis Array for Acoustic-Tagged CH1 Released into the Lookout Point Reservoir in February and April 2018. Detection probabilities of the Corvallis array are also shown. Virtual release groups (V_1) were formed by month of release and route of passage at Lookout Point Dam. Standard errors (SEs) are shown in parentheses. NA indicates insufficient data were available to estimate survival.

V_1 Group	N	$\hat{S}$ (SE)	p (SE)
Feb turbines	83	0.217 (0.045)	1.000 (0.000)
Feb spillway	50	NA	NA
April turbines & spillway	27	0.370 (0.093)	1.000 (0.000)

6.0 Discussion

This chapter discuss the results of the study, including fish movement through the reservoir and forebay, downstream migration, survival and travel times, use of the spillway during spring 2018, and future research considerations.

6.1 Lookout Point Reservoir

Many fish displayed a pattern of inconsistent movement within the Lookout Point reservoir. During both seasons, but especially during spring, large numbers of individuals did not travel downstream, did not pass Lookout Point, and subsequently were ultimately classified as “non-detect” or “disappearing” fish. Previous studies also observed similar patterns of movement from the forebay to upstream areas and downstream to Lookout Point (Fischer et al. 2018; Monzyk et al. 2014). Monzyk et al. (2014) found that fish tended to travel the reservoir’s length at least once after being released. Monzyk et al (2014) also found that in spring, parr were most frequently captured toward the head of the reservoir, and in fall they were most frequently captured in the forebay, indicating that fish move between areas in the reservoir depending on the season. The lack of emigration from Lookout Point, and the subsequent high amount of movement within the reservoir, are most likely due to a combination of circumstances, including suboptimal passage conditions at Lookout Point, rearing ability in the reservoir, the lentic reservoir environment, and other unknown reasons. Suboptimal passage conditions at Lookout Point could include variable reservoir levels and limited surface passage options. High water in spring during the current study likely deterred fish from passing through turbine units, especially fish released in April. Keefer et al. (2012) found that salmonid fry migrate into reservoirs in spring but can emigrate months later in fall when reservoir levels drop, making access to deep-water passage routes easier. Reduced emigration in spring, likely due to high or full reservoir, was also seen in the Foster reservoir (Hughes et al. 2017). In-reservoir rearing and overwintering have also been described as possible explanations for delayed fish migrations (Khan et al. 2012a; Schroeder et al. 2016). This delay to pass Lookout Point increases the movement displayed by fish within the reservoir. Delay periods, which may be longer than tag life, may have led to high numbers of disappearing fish.

Predation may also contribute to the disappearing fish phenomenon in the Lookout Point reservoir. Predation of juvenile salmonids in Lookout Point reservoir by both avian and piscivorous predators has been well documented (Johnson et al. 2016; Monzyk et al. 2014). Although the mean fork lengths of fish were often larger during the current study (fall 167.7 mm, spring 183.1 mm) than those preyed upon as reported in the Monzyk et al. (2014) study, predation should still be considered a possible fate of released fish.

Travel times for passage through Lookout Point reservoir during the current evaluation were similar to trends observed in previous studies—reservoir residence travel times being longer during periods of high reservoir elevations (Fischer et al. 2018; Hughes et al. 2016). In spring at high reservoir elevation, travel time to the Lookout Point forebay was much longer (mean 27.4 days) than in fall during periods of low reservoir elevations (mean 8.4 days). Longer periods of reservoir residence during high reservoir periods has been documented in previous studies in this reservoir as well as others (Brandt et al. 2016; Hughes et al. 2016; Fischer et al. 2018). Using all fish that were released and detected at the Lookout Point forebay, regardless of final passage fate, we calculated an initial travel time to Lookout Point (Appendix B). Fish released during the spring high pool periods took longer to travel to Lookout Point (mean 7.2 days) compared to initial travel times during fall low pool periods (mean 4.0 days). Although sample sizes vary greatly between seasons, a trend in slow reservoir movement is apparent during the spring and may be due to lower discharge during this period.

6.2 Lookout Point Forebay

Forebay approach was evaluated using a combination of detection data from the 3D autonomous receiver array located 0.5 km upstream of Lookout Point (LOA; Figure 2.1) and the cabled array deployed on Lookout Point. In general, for both the fall and spring study periods, CH0 and CH1 exhibited similar movement patterns. Fish moved downstream in a fairly uniform distribution from the reservoir, but approached the forebay from the south before swimming north on the final approach to the dam-face. This was most evident for fall 2017 released fish; spring released fish tended to arrive in the Lookout Point forebay more evenly dispersed across the width of the reservoir. For fall 2017, more than 50% of first detections occurred on the southern side of the forebay >150 m from dam-face. Results were similar to those from the 2016–2017 Lookout Point reservoir study, which reported more than 83% of fish used the earthen side to approach the dam (Fischer et al. 2018). For both fall 2017 and spring 2018, fish moved relatively quickly through the far forebay (>150 m from the dam-face), and appeared to mill in the near forebay (<150 m from the dam-face) by the powerhouse and spillway transition areas in a small zone with a high concentration of detections noted near Spill Bay 5 and turbine unit 1 (approximately middle of the dam).

Overall, travel times through Lookout Point reservoir and the near forebay were slow and differed between the fall and spring months. In the fall, study fish had a mean Lookout Point reservoir residence time of 11.0 days in October and 7.3 days in December. During the spring, fish had a mean reservoir residence time of 28.9 days in February and 19.9 days in April. Extended reservoir residence times could increase susceptibility to predation and decrease downstream migration success, and influence the number of fish that pass the dam, especially during the spring when longer residence times were observed. Travel times were faster in the fall when fish passage was highest and reservoirs were drawn down near annual lows. Similar results have been documented at other high-head dams (e.g., Cougar, Detroit) with long residence times (Hansen at al. 2017). Juvenile Chinook salmon that reside in reservoirs for long periods of time are susceptible to reservoir residualizing, avian and piscivorous fish predation, and parasitic copepod *Salmincola californiensis* infections (Keefer et al. 2012; Monzyk et al. 2013, 2014; Hansen et al. 2017). Additionally, differences in travel times between the fall and spring study seasons could be attributed to reservoir elevations and spill operations at the dam. Fish movement through reservoirs and dams is often constrained by operational conditions, causing travel times to be opportunistic rather than attuned to life-history strategies (Keefer et al. 2012).

Vertical distributions of tagged Chinook salmon were skewed toward the surface in the near forebay of the dam; peak densities occurred at shallow depths during both study periods. The majority of fish were detected in the upper water column at depths less <2.5 m. Only a few fish were detected at deep depths (i.e., >30 m), near the ROs. The relatively cool surface water temperatures during the spring and fall study seasons could explain the patterns in vertical distribution. Monzyk et al. (2012, 2013, 2014) sampled juvenile salmonids in deeper sections of the water column at Lookout Point and Detroit reservoirs during maximum water temperatures in the late summer using gill nets. Fish were found in the upper water column (i.e., <9 m) in late fall, as temperatures decreased. Additional studies conducted at Lookout Point also reported fish traveling at shallow depths in the fall and spring months (Khan et al. 2012a; Fischer et al. 2018). Similarly, in a study conducted at Lower Granite Dam on the Snake River, in Idaho, Kofoot et al. (1996) reported juvenile Chinook salmon as predominantly surface-oriented. Variation in vertical distribution between night and day hours has been observed throughout the Columbia River (Smith et al. 2010). The diel component of the current study was weighted toward nighttime hours; fish approached the forebay in greater numbers at night and fish densities in front of the dam were highest during the night during both the fall and spring study periods.

6.3 Lookout Point Passage and Survival

Though over half of all study fish released into the Lookout Point reservoir migrated down to the Lookout Point forebay (Figure 4.8 and Figure 5.9), passage through Lookout Point varied greatly throughout fall 2017 and spring 2018. DPE was highest in December at 58% and much lower in October (31%), February (10%), and April (3%). These results are similar to what was observed by Keefer et al. (2013), who noted the highest proportions of fish passing Lookout Point did so between November and February. Beeman et al. (2014) saw similar DPE estimates at Cougar Dam with a spring estimate of 11% and a fall estimate between 58% and 65%. During the fall, a combined total of 26% of study fish were detected below Lookout Point and 9% were detected there during the spring. These results differ from the study that was conducted in 2016–2017 (Fischer et al. 2018), which saw much higher proportions of fish pass in spring (54%) and lower passage in the fall (6%). These results could be attributed to the differences in reservoir water availability and dam operations between years. During the fall of 2016, study fish were released after the reservoir had reached minimum pool while during the fall of 2017 fish were released at two periods while the reservoir was still being drawn down. This drawdown, with increased discharge and lower reservoir elevations may have contributed to the increase in fish passage (Figure 4.11). During the spring of 2017, several prolonged spill discharge events occurred that may have led to increased passage at Lookout Point; however, during 2018 drought conditions persisted in the region which lead to lower water elevations in the reservoir and little use of the spillway. These factors may have contributed to the low passage numbers in the spring of 2018.

Differences in diel passage were observed throughout the fall and spring. Fish released in October, December, and February that passed through the turbines did so almost exclusively during the nighttime hours, and more than 90% of all fish passed during civil twilight. This is similar to findings by Khan et al. (2012a) and Romer et al. (2013), where the predominant trend was night passage of Chinook salmon during winter. Findings for fish released in April 2018 differed; the few fish that passed through the turbine generally did so during the day. With the warm and dry spring that occurred in 2018 the use of the spillway at Lookout Point was limited. However, when the spillway was used for 6 h on April 29, a large proportion of fish passed. Those few hours of spill had a large effect on spring passage—37% of all February fish and 59% of April study fish passed during that time. Romer et al. (2013, 2014) and Fischer et al. (2018) saw high rates of spring passage in 2012, 2013, and 2017 when spill occurred during the spring and summer. A spill study was planned for spring 2018 to test the effects of spill on passage, but the warm dry conditions did not allow for that component of the study to be implemented.

Survival through Lookout Point was estimated using two different models. The standard CJS estimate, which is commonly used to estimate survival in the Columbia River system, assumes receiver arrays are distant enough downstream that only living fish can be detected. This could require receiver arrays to be located a fair distance downstream of the dam. A newer model, ViRDCt, takes into account dead fish that are detected on downstream receiver arrays and minimizes the inclusion of tailwater mortality in its estimate and also requires a much smaller sample size, in some cases, to produce more precise estimates. This allows receiver arrays located in the tailwaters below a dam (sometimes <2 rkm) to be used to estimate survival. ViRDCt survival estimates for the spillway in spring assumed that dead fish detection rates were similar between powerhouse and spillway tailrace-released dead fish, because only the powerhouse was operated during fish release periods in spring and therefore only dead fish were released into its tailwaters and not the spillway. The impact of this assumption on spillway survival estimates is unknown. If dead fish detection rates on the Lookout Point tailrace array were higher for spill tailrace-released fish than powerhouse tailrace-released fish, then ViRDCt spillway survival estimates presented in this report are biased upward. The opposite is true (survival biased downward) if spillway dead fish detection rates were lower than powerhouse tailrace-released dead fish. Future studies may take this into account and plan on releasing fish below any potential passage route; however, with the irregular pattern of spillway operations at Lookout Point, this could prove challenging. Also, few fish released in April passed through the turbines during the study period and this would account for large standard errors. Some survival estimates are also underestimated because several fish passed late in the study when tag life would have been problematic. This inability to correct for tag failure could have affected the ability of late spring study fish to be detected passing Lookout Point and could have biased survival estimates.

Survival using the ViRDCt model ranged from 78–82% for turbine-passed fish, and spillway survival was 98%. Turbine survival for fish released in April was very different from other survival estimates; this may be due to the small sample size and corresponding large standard errors for the estimate. Little is known about route-specific passage and survival at Lookout Point; however, Keefer et al. (2013) estimated mortality rates of 25% with increased mortality as fish size and reservoir elevation increased. Chinook salmon survival estimated by Beeman and Adams (2015) at Detroit Dam (spring 72% and fall 62%) was slightly lower than estimates observed at Lookout Point.

High survival of fish passing through spillways has been well documented at hydro-electric facilities in the Pacific Northwest (Weiland et al. 2015; Hughes et al. 2016 and 2017; Ploskey et al. 2012). The challenge for water and fisheries managers is balancing water availability, power production, flood risk management, and fish passage to ensure the safest route available for fish passage during peak migration periods is available for downstream migrants. Spillways at high-head dams, such as Lookout Point, present unique challenges because high-head reservoirs often must refill to or just below maximum conservation pool for the spillway to become available for fish passage. This refill is highly dependent upon water availability (snow pack, runoff, etc.). There is no simple resolution to this complex situation; however, prioritizing spill as a safe passage alternative for downstream migrating juvenile salmonids would have clear and direct benefits, as indicated by the survival of spill-passed fish at Lookout Point in spring when 98% survival was observed.

6.4 Dexter Reservoir and Passage

Movement of fish within the Dexter reservoir varied between the fall and spring seasons. Travel times through the Lookout Point tailwaters averaged 1–1.5 days during the fall study period and 3–7 days during the spring study period. Similar trends were seen in the movement between the Lookout Point tailrace array and the Dexter cabled array; travel times during the fall averaged 2–3 days, while during the spring they averaged 8–12 days. Survival estimates of the Dexter reservoir (Lookout Point tailwaters to Dexter—2 rkm) using the ViRDCt model showed survival estimates between 88 and 92% for all fish except turbine-passed fish in April (67%), which had a limited sample size (n = 11) and large standard errors (SE ±29%). Predation could be a concern associated with longer travel times in spring; Monzyk et al. (2014) noted a large presence of piscivorous fish located in the Dexter reservoir (estimates of >20,000 northern pikeminnow).

Dexter is operated as a run-of-river dam (re-regulating dam for Lookout Point), which has flow passing through the powerhouse, spillway, or some combination of both at all hours. During 2017 and 2018, 90% of all discharge at Dexter occurred through the turbine unit and 10 percent passed through the spillway. Passage of study fish through Dexter followed that trend; the majority of fish passed through the single turbine unit. Diel patterns were similar to those at Lookout Point; most fish passed during the nighttime hours. These results are similar to those Hughes et al. (2016, 2017) observed at Foster Dam, another run-of-river project (re-regulating dam for Green Peter Dam) on the South Santiam River; a vast majority of Chinook salmon passed the dam during the night.

6.5 Future Research Considerations

The fish released into the reservoir during the current study were intended to be similar in size to wild juveniles passing the dam, and were therefore substantially larger than the wild fry entering the reservoir in spring. The mean fork length of tagged fish was 167.7 mm in the fall and 183.1 mm in the spring; no fish was smaller than 95 mm. Upon initial entry to the reservoir, the majority of wild fish are far smaller than 95 mm—some are as small as 31 mm (Romer et al. 2013, 2014 and 2015, as reviewed in Hansen et al. 2017), too small to be tagged using conventional AT technology. For this reason, information about their in-reservoir movement patterns and survival is somewhat lacking. Trapping and netting efforts have revealed that fry are less evenly distributed in the reservoir than larger fish (Monzyk and Romer 2013; Monzyk et al. 2014), and that they are more likely to survive dam passage (Keefer et al. 2012). However, management decisions require more specific information (Kock et al. 2016; Hansen et al. 2017). To this end, efforts are under way to estimate spring and summer fry survival in the reservoir using a release-recapture method that does not require active tagging (Kock et al. 2016). Additionally, PNNL is currently evaluating the effects of a miniature acoustic telemetry tag on fry-sized fish. These specialized tags, developed to track juvenile eels and lamprey, have a mass of only 0.088 g, less than a quarter of the mass of those used to tag juvenile Chinook salmon for Lookout Point. The results of this latter assessment will be available by January 2019.

To improve rates of fish passage, operational changes at Lookout Point or the installation of a surface collector have been suggested. Operational changes could include: greater use of the spillway during spring and summer (water availability dependent), holding the reservoir at a higher elevation in fall and utilizing spill during the early fall (water availability dependent), and a deep draw down of the reservoir and use of the regulating outlets to pass fish safely. Two locations have been proposed for the placement of a surface collector at Lookout Point: in the forebay near the dam or at the head of the reservoir (Kock et al. 2016). The preferred location is dependent on the distribution of the fish in the reservoir, and the extent to which reservoir residence time is thought to be minimized (Kock et al. 2016).

Longer residence time in reservoirs increases both risk of predation and opportunity for growth (Hansen et al. 2017). In comparison to other reservoirs in the region, predation risk in the Lookout Point reservoir is exceptionally high (Monzyk et al. 2012). Upon initial entry to the reservoir in the spring, fry congregate in the shallower areas of its upper third (Monzyk and Romer 2013; Monzyk et al. 2014), which contains a high density of northern pikeminnow, a piscivore estimated to consume more than 100,000 Lookout Point reservoir Chinook salmon annually (Monzyk et al. 2012 and 2013). The proportion of fry that succumb to predation on their journey to the dam-face is unknown. Of the smolt-sized fish we released at the head of the reservoir, 19–36% did not reach the forebay within the study period. Whether this is due to residualization or predation cannot be determined. Additionally, Schroeder et al. (2016) recognizes that reservoir rearing may not be beneficial if it artificially restricts life history diversity by limiting outmigration timing. Reducing life history types within a population may reduce resilience to variable environmental conditions and increase the extinction risk of a given population. A collector placed near the head of the reservoir would reduce fish loss from in-reservoir predation and preemptively collect fish, which if not collected would later become stalled at the dam, delaying outmigration.

In addition, complete bypass of the reservoir would greatly decrease the risk of branchial copepod infection, which increases as fish spends longer periods of time in the reservoir (Monzyk et al. 2015a), and which is likely to negatively affect fitness (Kabata and Cousens 1977; Sutherland and Wittrock 1985). A potential disadvantage to bypass of the reservoir is the lost opportunity for growth, because growth rates in reservoirs are higher than those in rivers (Brandt et al. 2016; Hansen et al. 2017). Currently, fry which enter the reservoir in the spring do not begin to arrive in the near forebay before early summer (Monzyk et al. 2014, 2015b). Generally, larger size is advantageous for migration, because larger fish can move faster, are less vulnerable to predation, and may be better foragers (Poirier and Olsen

2017). There is some evidence from the Snake River that a disproportionate number of returning adults reared in-reservoir (Connor et al. 2005; Hegg et al. 2013). Furthermore, Muir et al. (2006) found that barge transportation around a series of high-mortality dams did not improve the rate of adult returns, likely because expedited passage reduced opportunity for growth. Whether the benefits of residence in Lookout Point reservoir ultimately outweigh its costs cannot be determined without more information about the survival and movements of fry-sized fish.

Operational changes such as greater use of the spillway when water availability allows or a deep draw down of the reservoir and utilization of the RO's or a well-placed forebay surface collector would gather fish that arrive at the dam seeking to pass but are unable to find a route. Within the near forebay, for every group of fish released during the current study, the greatest number of detections occurred just in front of Spill Bay 5 (Figure 4.4, Figure 4.5, Figure 5.5, Figure 5.6). This spill bay is located in the approximate center of dam, and so it would be frequently passed by fish displaying a circular milling behavior. It is also the closest spill bay to the turbines, which are the most consistent source of attractant flow for fish, but provide a passage route with comparatively low survival (Table 5.2). Ideal collector placement might be at the powerhouse-spillway junction, where fish are most likely to encounter it, and where it can capitalize on the attractant flow through the turbines, while reducing the proportion of fish passing through them. The surface collector would not have to be deeper than about 2.5 m below the surface, because the majority of fish (63%) are found in this upper layer of water (Figure 4.6, Figure 4.7, Figure 5.7, Figure 5.8). The optimal schedule on which to operate the spillway, RO's, or a collector is less evident . Peak migration out of the reservoir occurs in the winter, when reservoir elevation level is low, the spillway is out of water, RO's are still relatively deep and turbine passage routes are more easily accessed; however, if a deep drawdown occurred the RO's would act as a near surface passage route potentially increasing downstream migration. In the spring and summer, high reservoir levels largely impede passage except when spillway routes become available (Keefer et al. 2013; also corroborated by our results). The use of the spillway at times of high water or as a surface collector may therefore have the greatest effect during the warmer months, when easily accessible routes of passage are rare. Diel variation in the density of fish in the near forebay is consistent throughout the fall and spring—densities are higher at night (Figure 4.6, Figure 4.7, Figure 5.7, Figure 5.8). Far more fish pass through the turbine units at night, even when turbine usage is greater during the day, but when the spillway was briefly operated once in the daytime, it passed an enormous quantity of fish in a very short time period. It is therefore unclear whether there is a preferred time of day at which to operate the spillway or a collector, and this would likely require some study.

7.0 Conclusions and Recommendations

This report presents an evaluation of juvenile Chinook salmon passage and survival at Lookout Point on the Middle Fork Willamette River in Oregon during fall 2017 and spring 2018 utilizing active tags. The acoustic arrays and transmitters used for the study performed well. The probability of fish bearing acoustic tags being detected at cabled-receiver arrays (Lookout Point and Dexter) was >99% and for autonomous receiver arrays it was >87% for all study periods.

Data derived from the evaluation of juvenile salmonid passage at Lookout Point in 2017 and 2018 support the following conclusions:

- Detection efficiencies at all receiver arrays was high for both the fall 2017 and spring 2018 study periods.
- For Chinook salmon that did not pass Lookout Point, within-reservoir movement was random and indicated that large proportions of Chinook salmon moved down reservoir, back upstream, etc. (HOR→MID→FOREBAY→MID→FOREBAY, etc.).
- Very large proportions of Chinook salmon disappeared in the reservoir and were never detected again during all study periods.
- Fall 2017 fish arriving in the Lookout Point forebay approached the dam from the south and shifted northerly on approach to the dam-face. In spring, horizontal dispersal across the forebay for approaching fish was more evenly distributed. Ultimately, both fall and spring fish concentrated in front of the powerhouse and spillway transition area.
- Vertical distributions of Chinook salmon in the near forebay of Lookout Point (<150 m from the dam-face) indicated most fish were surface-oriented (<2.5 m) and few fish were observed at RO depth. This observation was true for fall 2017 and spring 2018 release groups.
- Of the fish that arrived in the Lookout Point forebay, small to moderate proportions passed the dam (lower DPE and FPE) during all study periods.
- During all study periods, turbine survival was reasonably high (~78–82%) with the exception of the April 2018 release groups when the sample size was inadequate.
- Survival was high for spring 2018 spill-passed fish (~99%).
- For study fish passing the Lookout Point turbines, the majority of fish passed at night.
- Dexter reservoir mortality (survival from Lookout Point immediate tailwaters to Dexter, ~2 rkm) was notable (~10%) for all study periods.
- The majority of study fish passing Dexter did so via the turbines during nighttime hours.
- Travel rates (rkm/day) through the Middle Fork Willamette indicated that downstream migrating fish travel slowly through the Lookout Point and Dexter reservoirs, extremely slowly through Lookout Point forebay, and quickly through Dexter tailwaters down to Wilsonville, Oregon.

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:

- Continue to explore options for tagging fry-sized Chinook salmon with acoustic tags to ensure a more representative population of fish migrating through the Middle Fork Willamette is studied.
- Consider releasing Chinook salmon farther down reservoir and closer to Lookout Point to facilitate larger proportions of study fish passing the dam and to minimize the disappearance of fish.
- Consider operational patterns that maximize spillway discharge to facilitate downstream passage in fall, winter, and spring.
- Further assess the efficacy of spill as an alternative to facilitate downstream passage of fry-sized fish by using a block/treatment test design (turbines vs. spill and north spill vs. south spill).
- If a surface collector is considered for deployment in the Lookout Point forebay, consider placing it near the center of the dam to coincide with the concentration of fish detections near the powerhouse and spillway transition area. Also, focus entrainment on the top few meters of the water column.
- Consider evaluating spill at Dexter as an alternative to facilitate downstream passage of juvenile Chinook salmon.
- Future telemetry studies should include hydrophones in the immediate tailwaters of Dexter (within 1 rkm of the dam) to aid in better understanding dam passage survival.

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Appendix A

Fish-Tagging and Release Tables

Appendix A

Fish-Tagging and Release Tables

Table A.1. Number of Acoustic-Tagged Subyearling Chinook Salmon Released Alive and Dead (highlighted gray) at Lookout Point in October 2017. Mean fork length (mm) and weight (g) of fishes at each release date with standard deviations in parentheses.

Release Date	*N*	Fork Length (mm)	Weight (g)
10/17/2017	149	158.0 (9.0)	43.2 (7.2)
	8	154.9 (8.4)	41.8 (5.4)
10/18/2017	139	156.0 (11.7)	42.0 (9.0)
	8	153.0 (8.4)	39.2 (5.4)
10/19/2017	147	159.3 (10.2)	46.5 (8.5)
	9	160.0(8.0)	45.8 (6.9)
10/20/2017	155	159.6 (11.6)	46.8 (9.5)
	7	155.3 (15.91)	43.7 (12.4)
10/21/2017	152	156.9 (10.9)	42.7 (8.3)
	9	158.1(11.1)	43.3(8.5)
October total	**742**	**158.0 (11.0)**	**44.3 (8.7)**
	41	**156.4 (11.1)**	**42.8 (9.0)**

Table A.1. Number of Acoustic-Tagged Subyearling Chinook Released Alive and Dead (highlighted gray) at Lookout Point in December 2017. Mean fork length (mm) and weight (g) for fishes at each release date with standard deviations in parentheses.

Release Date	*N*	Fork Length (mm)	Weight (g)
12/1/2017	150	178.8 (13.7)	64.9 (12.7)
	7	181.1 (7.7)	66.5 (9.4)
12/2/2017	156	178.3 (11.4)	64.0 (10.3)
	8	180.9 (12.1)	65.2 (13.1)
12/3/2017	156	174.9 (12.1)	60.6 (11.7)
	8	162.0 (23.9)	48.2 (20.4)
12/4/2017	156	174.5 (11.7)	61.2 (11.3)
	8	180.2 (8.3)	66.1 (9.6)
12/5/2017	147	179.8 (10.9)	63.4 (10.4)
	8	182.1 (7.3)	63.9 (6.6)
December total	**765**	**177.2 (11.9)**	**62.8 (11.4)**
	39	**177.2 (12.0)**	**61.9 (11.2)**

Table A.3. Number of Acoustic-Tagged Yearling Chinook Released Alive and Dead (highlighted gray) at Lookout Point in February 2018. Mean fork length (mm) and weight (g) for fishes at each release date with standard deviations noted in parentheses.

Release Date	*N*	Fork Length (mm)	Weight (g)
2/20/2018	150	188.8 (19.3)	76.6 (20.9)
	8	183.6 (17.2)	71.1 (18.8)
2/21/2018	150	180.5 (18.4)	66.2 (18.5)
	8	167.5 (15.5)	52.3 (14.0)
2/22/2018	150	183.3 (19.0)	68.8 (19.9)
	8	170.6 (12.9)	53.7 (9.3)
2/23/2018	150	184.1 (20.1)	70.8 (20.9)
	8	175.9 (20.3)	61.9 (17.7)
2/24/2018	150	178.6 (22.6)	64.4 (21.4)
	8	175.4(27.1)	63.0 (25.3)
February total	**750**	**183.1 (20.2)**	**69.4 (20.7)**
	40	**174.6 (19.0)**	**60.4 (18.2)**

Table A.4. Number of Acoustic-Tagged Yearling Chinook Released Alive and Dead (highlighted gray) at Lookout Point in April 2018. Mean fork length (mm) and weight (g) for fishes at each release date with standard deviations noted in parentheses.

Release Date	*N*	Fork Length (mm)	Weight (g)
4/10/2018	124	183.3 (16.1)	62.8 (16.2)
	7	180.1 (19.1)	57.6 (15.6)
4/11/2018	125	177.8 (20.3)	58.2 (19.5)
	7	167.4 (24.7)	50.3 (20.8)
4/12/2018	126	177.9 (21.3)	61.1 (20.7)
	6	171.0 (31.2)	55.1 (25.6)
4/19/2018	136	186.7 (18.8)	66.7 (19.2)
	7	176.1 (24.3)	54.4 (18.2)
4/20/2018	134	188.6 (18.8)	67.7 (20.1)
	7	170.3 (12.5)	49.7 (9.4)
4/21/2018	132	188.3 (15.3)	68.3 (16.1)
	6	188.3 (15.2)	66.0 (19.4)
April total	**777**	**183.9 (19.7)**	**64.2 (19.0)**
	40	**175.4 (21.7)**	**55.3 (18.2)**

Appendix B

Fish Passage and Travel Times

Appendix B

Fish Passage and Travel Times

Table B.1. Diel Passage Numbers through Lookout Point for CH0 Released in October and December of 2017

Passage Route	Release	Passage Numbers			Percent Daily Discharge	
		Day	**Night**	**Total**	**Day**	**Night**
Turbine Unit 1	Oct	0	37	37	16.3%	16.1%
	Dec	1	57	58	19.3%	15.8%
Turbine Unit 2	Oct	2	53	56	18.2%	15.6%
	Dec	3	101	104	17.4%	13.7%
Turbine Unit 3	Oct	6	36	42	17.4%	16.4%
	Dec	11	158	169	18.7%	15.2%
Total	Oct	8	126	134	52.0%	48.1%
	Dec	15	316	331	55.4%	44.7%

Table B.2. Diel Passage Numbers through Lookout Point for CH1 Released in February and April of 2018.

Passage Route	Release	Passage Numbers			Percent Daily Discharge	
		Day	**Night**	**Total**	**Day**	**Night**
Turbine Unit 1	Feb	1	17	18	23.2%	7.7%
	April	1	1	2	22.8%	2.4%
Turbine Unit 2	Feb	2	14	16	26.2%	8.4%
	April	0	2	2	34.4%	3.6%
Turbine Unit 3	Feb	7	42	49	26.6%	6.8%
	April	5	2	7	32.9%	3.5%
Spill Bay 3	Feb	50	0	50	1.2%	0.0%
	April	16	0	16	0.4%	0.0%
Total	Feb	60	73	133	77.2%	22.8%
	April	22	5	27	90.5%	9.5%

Table B.3. Passage Numbers of Juvenile Chinook Salmon through Dexter during Both Study Periods (i.e., Fall 2017, Spring 2018)

Release Month	Turbine	Spillway	Total
October	38	20	58
December	131	14	145
February	83	50	133
April	11	16	27

Table B.4. Diel Passage Numbers of Juvenile Chinook Salmon through Dexter (Turbine and Spillway) during Both Study Periods (i.e., Fall 2017, Spring 2018)

Release Month	Day	Night	Total
October	16	42	58
December	11	134	145
February	50	83	133
April	18	9	27

Table B.5. Estimated Mean and Median Reservoir Residence, Tailrace Egress, and Travel Times (Days) between Arrays for CH0 Released in October 2017 at Lookout Point Reservoir, Oregon

			Travel Time (days)		
Reach	**Distance (rkm)**	***n***	**Median**	**Mean**	**SE**
Initial Travel Time to Lookout Point [a]	7.8	452	1.8	3.4	0.2
Lookout Point Reservoir Residence [b]	7.8	134	5.8	11.0	1.0
Forebay Residence Time [c]	0.2	134	2.0	4.7	0.6
Tailrace Egress [d]	2.5	104	0.9	5.1	1.0
Dexter Reservoir Residence [e]	6.0	58	2.8	7.0	1.1
Primary to Secondary [f]	115.5	46	1.0	1.1	0.1
Secondary to Tertiary [f]	149.5	44	1.2	1.3	0.0
Lookout Point to Wilsonville [f]	271.0	56	5.6	10.0	1.2

(a) Difference in time from release to first detection for all fish arriving in the Lookout Point forebay regardless of passage fate.
(b) Difference in time from release to time of first detection entering the forebay array immediately prior to dam passage.
(c) Difference in time from first detection on the forebay array and the last detection on Lookout Point cabled array immediately prior to dam passage.
(d) Difference in time from last detection on Lookout Point cabled array to last detection at the Egress Array (LPT).
(e) Difference in time from last detection at the Lookout Point cabled array to last detection at the Dexter cabled array prior to dam passage.
(f) Difference in time from last detection at the upstream array to last detection at the downstream array.

Table B.6. Estimated Mean and Median Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH0 Released in December 2017 at Lookout Point Reservoir, Oregon

			Travel Time (days)		
Reach	**Distance (rkm)**	***n***	**Median**	**Mean**	**SE**
Initial Travel Time to Lookout Point [a]	7.8	590	3.0	4.5	0.2
Lookout Point Reservoir Residence [b]	7.8	331	3.3	7.3	0.6
Forebay Residence Time [c]	0.2	331	0.3	2.1	0.3
Tailrace Egress [d]	2.5	284	1.5	6.3	0.7
Dexter Reservoir Residence [e]	6.0	145	2.0	6.7	0.9
Primary to Secondary [f]	115.5	139	1.3	2.0	0.2
Secondary to Tertiary [f]	149.5	130	1.9	2.3	0.1
Lookout Point to Wilsonville [f]	271.0	136	5.9	11.0	1.0
LOP to Willamette Falls [e]	291.0	1	6.7	6.7	0.0

(a) Difference in time from release to first detection for all fish arriving in the Lookout Point forebay regardless of passage fate.
(b) Difference in time from release to time of first detection entering the forebay array immediately prior to dam passage.
(c) Difference in time from first detection on the forebay array and the last detection on Lookout Point cabled array immediately prior to dam passage.
(d) Difference in time from last detection on Lookout Point cabled array to last detection at the Egress Array (LPT).
(e) Difference in time from last detection at the Lookout Point cabled array to last detection at the Dexter cabled array prior to dam passage.
(f) Difference in time from last detection at the upstream array to last detection at the downstream array.

Table B.7. Estimated Mean and Median Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH1 Released in February 2018 at Lookout Point Reservoir, Oregon

Reach	Distance (rkm)	*n*	Travel Time (days) Median	Mean	SE
Initial Travel Time to Lookout Point [(a)]	7.8	515	4.5	10.2	0.6
Lookout Point Reservoir Residence [(b)]	7.8	133	12.6	28.9	2.5
Forebay Residence Time [(c)]	0.2	133	1.0	1.3	0.1
Tailrace Egress [(d)]	2.5	109	3.1	4.6	0.4
Dexter Reservoir Residence [(e)]	6.0	21	8.1	9.0	1.7
Primary to Secondary [(f)]	115.5	21	2.1	2.4	0.3
Secondary to Tertiary [(f)]	149.5	13	2.0	2.4	0.3
Lookout Point to Wilsonville [(f)]	271.0	13	9.7	11.6	2.1

(a) Difference in time from release to first detection for all fish arriving in the Lookout Point forebay regardless of passage fate.
(b) Difference in time from release to time of first detection entering the forebay array immediately prior to dam passage.
(c) Difference in time from first detection on the forebay array and the last detection on Lookout Point cabled array immediately prior to dam passage.
(d) Difference in time from last detection on Lookout Point cabled array to last detection at the Egress Array (LPT).
(e) Difference in time from last detection at the Lookout Point cabled array to last detection at the Dexter cabled array prior to dam passage.
(f) Difference in time from last detection at the upstream array to last detection at the downstream array.

Table B.8. Estimated Mean and Median Reservoir Residence, Tailrace Egress, and Travel Times (days) between Arrays for CH1 Released in February 2018 at Lookout Point Reservoir, Oregon

Reach	Distance (rkm)	*n*	Travel Time (days) Median	Mean	SE
Initial Travel Time to Lookout Point (a)	7.8	543	2.8	4.3	0.2
Lookout Point Reservoir Residence (b)	7.8	27	16.0	19.9	3.4
Forebay Residence Time (c)	0.2	27	1.1	1.5	0.3
Tailrace Egress [(d)]	2.5	25	7.2	7.8	1.2
Dexter Reservoir Residence [(e)]	6	10	12.6	12.1	1.6
Primary to Secondary [(f)]	115.5	10	1.5	1.6	0.1
Secondary to Tertiary [(f)]	149.5	9	3.2	5.6	1.7
Lookout Point to Wilsonville [(f)]	271	9	17.1	19.3	1.7

(a) Difference in time from release to first detection for all fish arriving in the Lookout Point forebay regardless of passage fate.
(b) Difference in time from release to time of first detection entering the forebay array immediately prior to dam passage.
(c) Difference in time from first detection on the forebay array and the last detection on Lookout Point cabled array immediately prior to dam passage.
(d) Difference in time from last detection on Lookout Point cabled array to last detection at the Egress Array (LPT).
(e) Difference in time from last detection at the Lookout Point cabled array to last detection at the Dexter cabled array prior to dam passage.

(f) Difference in time from last detection at the upstream array to last detection at the downstream array.

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