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Passage Distribution and Federal Columbia River Power System Survival for Steelhead Kelts Tagged Above and at Lower Granite Dam, Year 2

Final Report

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March 2014

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Pacific Northwest National Laboratory
Richland, Washington 99352

Preface

The study reported herein was funded as part of the Anadromous Fish Evaluation Program (AFEP), which is managed by the U.S. Army Corps of Engineers (USACE). The AFEP study code is ADS-W-12-1: Steelhead kelt passage distributions and Federal Columbia River Power System survival and return rates for fish tagged above and at Lower Granite Dam. Pacific Northwest National Laboratory (PNNL) was the prime contractor for the USACE Walla Walla District. The USACE technical lead was Chris Pinney. The PNNL project manager was Alison Colotelo (509-371-7248). Study data are archived at PNNL offices in Richland, Washington.

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Abstract

Steelhead (*Oncorhynchus mykiss*) populations have declined throughout their range in the last century and many populations, including those of the Snake River Basin are listed under the *Endangered Species Act of 1973*. The reasons for their decline are many and complex, but include habitat loss and degradation, overharvesting, and dam construction. The 2008 Biological Opinion calls for an increase in the abundance of female steelhead through an increase in iteroparity (i.e., repeat spawning) and this can be realized through a combination of reconditioning and in-river survival of migrating kelts. The goal of this study is to provide the data necessary to inform fisheries managers and dam operators of Snake River kelt migration patterns, survival, and routes of dam passage. Steelhead kelts (n = 487) were captured and implanted with acoustic transmitters and passive integrated transponder (PIT)-tags at the Lower Granite Dam (LGR) Juvenile Fish Facility and at weirs located in tributaries of the Snake and Clearwater rivers upstream of LGR. Kelts were monitored as they moved downstream through the Federal Columbia River Power System (FCRPS) by 15 autonomous and 3 cabled acoustic receiver arrays. Cabled receiver arrays deployed on the dam faces allowed for three-dimensional tracking of fish as they approached the dam face and were used to determine the route of dam passage. Overall, 27.3% of the kelts tagged in this study successfully migrated to Martin Bluff (rkm 126, as measured from the mouth of the Columbia River), which is located downstream of all FCRPS dams. Within individual river reaches, survival per kilometer estimates ranged from 0.958 to 0.999; the lowest estimates were observed in the immediate forebay of FCRPS dams. Steelhead kelts tagged in this study passed over the spillway routes (spillway weirs, traditional spill bays) in greater proportions and survived at higher rates compared to the few fish passed through powerhouse routes (turbines and juvenile bypass systems). The results of this study provide information about the route of passage and subsequent survival of steelhead kelts that migrated through the Snake and Columbia rivers from LGR to Bonneville Dam in 2013. These data may be used by fisheries managers and dam operators to identify potential ways to increase the survival of kelts during their seaward migrations.

Executive Summary

Steelhead (*Oncorhynchus mykiss*) populations throughout the Pacific Northwest have declined during the last century and many populations, including Snake River steelhead, are listed as threatened under the *Endangered Species Act of 1973*. The causes of population declines are many and complex but include habitat loss and degradation, overharvesting, and dam construction. The 2008 Biological Opinion calls for a 6% increase in Snake River B-run female steelhead abundance through an increase in iteroparity rates. Improving survival of post-spawn downstream migrants (known as kelts) through Federal Columbia River Power System (FCRPS) dams may contribute to an increase in iteroparity rates and improve population abundance and productivity. The goal of the study reported herein is to provide the data necessary to inform fisheries managers and dam operators of Snake River steelhead kelt migration patterns, survival, and dam passage routes. The data may be used to adaptively manage the configuration and operation of FCRPS dams to maximize kelt survival.

Objectives

In this report, we present demographic summaries, survival estimates, and passage metrics of Snake River steelhead kelts tagged with acoustic transmitters at Lower Granite Dam (LGR) and several tributary sites within the Snake River basin upstream of LGR. The field study period was from 11 April through 26 August 2013. The objectives were as follows:

- Estimate the proportion of kelts that passed through each dam passage route and estimate route-specific survival probabilities at each FCRPS dam where acoustic transmitter detection capabilities existed.
- Estimate the following passage metrics and timing of kelts implanted with acoustic transmitters:
  - **forebay residence time**: travel time between the entrance to the forebay of the dam and passage through the dam. In this study, the forebay included the river reach 1 km upstream of the dam.
  - **tailrace egress time**: travel time between passage through the dam and exit from the tailrace of the dam. In this study, the tailrace included the river reach 1 to 2 km downstream of the dam.
  - **project passage time**: travel time between the entrance to the forebay and exit from the tailrace of the dam. In this study, the project included the river reaches 1 km upstream of the dam and 1 to 2 km downstream of the dam.
- Estimate the annual population abundance of kelts that arrived at and passed LGR in 2013.

Methods

The study area spanned the lower Snake and Columbia rivers as well as selected tributary sites within the Snake River basin upstream of LGR. Steelhead kelts were captured and tagged at the LGR Juvenile Fish Facility (JFF; rkm 695 measured from the mouth of the Columbia River) and at weirs located on Asotin Creek (rkm 761), Joseph Creek (rkm 800), the Potlatch River (rkm 836), and Fish Creek (rkm 944).

The objectives of this study were accomplished using the Juvenile Salmon Acoustic Telemetry System (JSATS), which enables researchers to monitor the movement of fish that are tagged with acoustic

transmitters using a series of acoustic receivers. For this study, JSATS transmitters were surgically implanted into the coelom of each kelt. After they recovered from surgery, kelts were released into the LGR tailrace or downstream of the tributary weir where they could continue their seaward migrations. In 2013, tagged kelts could have been detected on up to 3 cabled and 15 autonomous receiver arrays that were deployed in the Snake and Columbia rivers. Cabled receiver arrays were located on the dam faces of LGR, Little Goose Dam (LGS), and Lower Monumental Dam (LMN) in the lower Snake River and allowed for three-dimensional tracking of fish as they approached the dam face and for determining the dam passage route. Autonomous receiver arrays were located in the forebays, tailraces, and reservoirs of these dams, as well as at strategic locations in the lower Snake and Columbia rivers, including downstream of Bonneville Dam (BON; the most downstream FCRPS dam).

Survival estimates were calculated for each river reach between acoustic receiver arrays and for each main dam passage route (i.e., spillway weir, traditional spill, turbine, juvenile bypass system [JBS]) using detections on downstream arrays. In addition, elapsed times for forebay residence (forebay to dam-face array), tailrace egress (dam face to tailrace array), and project passage (forebay to tailrace array) were calculated for each kelt tagged with an acoustic transmitter detected on both the upstream and downstream arrays.

Results

Survival Estimates and Passage Proportions

Overall, 27.3% (n = 133 of 487) of kelts that were tagged in this study successfully migrated to Martin Bluff (rkm 126), which is located downstream of all FCRPS dams. Within individual river reaches, survival probability estimates ranged from 0.657 (SE = 0.042) to 0.978 (SE = 0.013). Because river reaches varied in length, the survival per kilometer was also calculated and found to be lowest in the immediate forebay of FCRPS dams. The LGS forebay reach (rkm 636 to 635) had the lowest survival per kilometer (0.9580). Survival per kilometer was generally highest in the upstream- and downstream-most reaches of the study area (tributaries to LGS forebay [rkm 636] and Burbank [rkm 525] to Martin Bluff [rkm 126]).

Tagged kelts passed through the spillway routes (spillway weirs or traditional spill bays) in greater proportions during this study, whereas few fish passed through the powerhouse routes (turbines or JBS). Survival estimates of fish that passed via the spillway weir at LGS (0.936; SE = 0.016) and LMN (0.927; SE = 0.018) were high compared to other routes. Route-specific survival estimates were also high for kelts that passed through the JBS at LMN (0.938; SE = 0.061); however, very few fish passed through this route (n = 16, or and 5.4%).

Passage Times and Travel Rates

Forebay residence and tailrace egress times were consistent among LGR, LGS, and LMN in 2013. Median forebay residence times were less than 2.00 hours at all dams and median tailrace egress times were approximately 0.50 hours. Median project passage time in this study ranged from 2.00 (LMN) to 3.06 (LGR) hours. Overall, passage times were lowest for fish that passed LMN.

Of the kelts captured and tagged in the tributaries, those released in Fish Creek, which migrated the greatest distance through fluvial habitats, travelled fastest to Red Wolf Bridge (rkm 743; median = 88.2

km/day). Once kelts reached rkm 743, travel rates through river reaches tended to increase as tagged kelts moved downstream. Median travel rates were noticeably lower when kelts moved through the dam forebays (12.5 to 17.8 km/day), than through fluvial habitats such as dam tailraces (46.2 to 130.0 km/day). Overall travel time from the LGR tailrace (rkm 693) to rkm 126 ranged from 7.3 to 23.5 days for the 133 tagged kelts that successfully migrated all the way through the FCRPS in 2013. These travel times represent travel rates that ranged from 24.2 to 77.7 km/day.

Annual Kelt Abundance at LGR

Two independent estimates of LGR kelt abundance were derived from the available data. Dividing the number of kelts sampled on the LGR JFF separator by the probability of tagged kelts passing LGR via the JBS produced a population estimate of 19,630 kelts that passed LGR. Calculating the population abundance separately for marked and unmarked kelts produced an estimated 7,819 marked and 11,811 unmarked kelts that passed LGR in 2013. Using the Lincoln-Petersen mark-recapture method on kelts marked at the tributary weirs and recaptured at the LGR JFF separator, an estimated 14,022 kelts were present at the time of tagging. Multiplying this estimate by the pooled survival probability from the tributary weirs to LGR, we obtained an estimate of 11,750 unmarked kelts that arrived at LGR. Agreement of these two independent estimates of the number of unmarked kelts leads us to believe they are relatively accurate and precise. These estimates indicate that 18% (n = 19,630) of the 110,675 adult steelhead estimated to have passed LGR on their way to spawning grounds and hatcheries located upstream of LGR in 2012, survived the spawning event, and migrated back downstream to LGR as kelts in 2013.

Conclusions

The results of this study provide information about the route of passage and subsequent survival of steelhead kelts that migrated through the Snake and Columbia rivers from LGR to BON in 2013. Specifically, this study builds on information collected in 2012, which was the first to document these metrics since the installation of spillway weirs at many of the dams in the FCRPS. Similar to 2012, spillway weirs were the primary route of passage for steelhead kelts in the Snake River in 2013. Spillway weirs provided the highest estimated survival at LGS and LMN, which is also consistent with the results from the 2012 study. Overall, very few fish passed through the turbine and JBS routes at any of the dams. Therefore, estimates of turbine and JBS survival should be interpreted with caution. Mean river discharge was lower in 2013 compared to 2012 and likely contributed to differences in migration success, survival estimates, and travel rates between years.

Although the results of this study contribute to understanding the effect of dam configuration and operations on steelhead kelt migration in the FCRPS, future research is warranted. Future studies should focus on sampling throughout the full kelt emigration period, specifically prior to the opening of the spill bays, and on tagging a larger proportion of kelts in fair and poor condition. Such studies should also collect kelts from additional locations in the Snake River basin to acquire information that is applicable to a larger proportion of the Snake River steelhead population.

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Acronyms and Abbreviations

3D	three-dimensional
AFEP	Anadromous Fish Evaluation Program
B2CC	Bonneville Dam second powerhouse corner collector
BiOp	Biological Opinion
BON	Bonneville Dam
°C	degree(s) Celsius or centigrade
cfs	cubic feet per second
cm	centimeter(s)
CR	Columbia River
CRB	Columbia River Basin
DART	Data Access in Real Time
ESA	*Endangered Species Act of 1973*
FCRPS	Federal Columbia River Power System
ft	foot(feet)
GPS	Global Positioning System
IHR	Ice Harbor Dam
JBS	juvenile bypass system
JDA	John Day Dam
JFF	juvenile fish facility
JSATS	Juvenile Salmon Acoustic Telemetry System
kcfs	thousand cubic feet per second
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
LGR	Lower Granite Dam
LGS	Little Goose Dam
LMN	Lower Monumental Dam
m	meter(s)
mm	millimeters(s)
MCN	McNary Dam
mg	milligram(s)
min	minute(s)
MS-222	tricaine methanesulfonate
N	population
n	sample
NGVD29	National Geodetic Vertical Datum of 1929

NMFS	National Marine Fisheries Service
NPT	Nez Perce Tribe
NOAA	National Oceanic and Atmospheric Administration
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PTAGIS	PIT Tag Information System
RPA	reasonable and prudent alternative
rkm	river kilometer(s)
SE	standard error
TDA	The Dalles Dam
USACE	U.S. Army Corps of Engineers

Contents

Preface iii
Abstract iv
Executive Summary v
Acknowledgments viii
Acronyms and Abbreviations ix
1.0 Introduction 1.1
1.1 Background 1.1
1.2 Research Objectives 1.2
1.3 Study Area 1.3
1.3.1 FCRPS Dams 1.3
1.3.2 Steelhead Kelt Capture Sites 1.7
1.4 Report Contents 1.7
2.0 Materials and Methods 2.1
2.1 Environmental Conditions 2.1
2.2 Definitions 2.1
2.3 Fish Capture, Tagging, and Release 2.2
2.3.1 Capture Sites 2.2
2.3.2 Federal and State Permitting 2.2
2.3.3 Sampling Methods 2.3
2.3.4 Implantation of Passive Integrated Transponder Tags and Acoustic Transmitters 2.4
2.3.5 Recovery, Holding, and Release 2.5
2.4 Detection of Tagged Fish 2.5
2.4.1 Cabled Receiver Arrays 2.6
2.4.2 Autonomous Receiver Arrays 2.7
2.5 Data Processing and Validation 2.8
2.6 Statistical Methods 2.9
2.6.1 Tests of Assumptions 2.9
2.6.2 Tag-Life Study 2.9
2.6.3 Survival Estimation 2.9
2.6.4 Determination of Passage Proportion 2.11
2.6.5 Estimation of Passage Times and Travel Rates 2.11
2.6.6 Estimation of Population Abundance Arriving at Lower Granite Dam 2.11
2.7 Dam-Passage Characteristics 2.12
2.7.1 Dam Passage versus Flow 2.12
2.7.2 Diel Distribution 2.12
3.0 Results 3.1

3.1 Environmental Conditions 3.1
3.2 Kelt Migration Timing and Demographics 3.1
3.3 Estimates of Survival Rates 3.3
3.3.1 Migration Success Through the FCRPS 3.3
3.3.2 Survival Estimates Through the FCRPS 3.5
3.3.3 Passage Proportions and Survival Estimates Through Each FCRPS Dam 3.8
3.4 Passage Times and Travel Rates 3.10
3.4.1 Forebay Residence 3.10
3.4.2 Tailrace Egress 3.12
3.4.3 Project Passage Times 3.12
3.4.4 Travel Rates 3.14
3.5 Estimation of Population Abundance Arriving at Lower Granite Dam 3.15
3.6 Iteroparity Rates 3.16
3.7 JSATS Performance 3.16
3.7.1 Detection Probabilities at Cabled and Autonomous Arrays 3.16
3.7.2 Multiple Detections on Autonomous Arrays 3.16
3.7.3 Tag Life 3.16
3.8 Dam-Passage Characteristics 3.17
3.8.1 Dam Passage versus Flow 3.17
3.8.2 Diel Distribution 3.17
4.0 Discussion and Conclusions 4.1
4.1 Migration Success 4.1
4.2 Reach Survival 4.1
4.3 Passage Proportions and Route-Specific Survival 4.6
4.4 Travel Rates 4.9
4.5 Population Abundance 4.10
4.6 Conclusions 4.12
5.0 References 5.1
Appendix A – Hydrophone and Autonomous Node Deployment Tables and Locations of Fish Collection Sites A.1
Appendix B – Steelhead Kelt Data Collected at Tagging B.1
Appendix C – Timing of Juvenile Salmon Acoustic Telemetry System-Tagged Kelts Passage versus Dam Discharge C.1
Appendix D – Discharge versus Spill at Each Dam D.1
Appendix E – Timing of Kelt Passage versus Temperature E.1
Appendix F – Timing of Kelts Captured and Tagged at Tagging Sites F.1
Appendix G – Juvenile Salmon Acoustic Telemetry System Performance G.1
Appendix H – Juvenile Salmon Acoustic Telemetry System-Tagged Kelts Dam Passage versus Flow H.1

Appendix I – Diel Distribution and Dam Passage I.1
Appendix J – Routes of Passage through Multiple Federal Columbia River Power System Dams J.1

Figures

1.1. Locations of acoustic telemetry receiver arrays used to detect acoustic-tagged steelhead kelts that migrated through the Federal Columbia River Power System in 2013 ..... 1.4
1.2. Sites where steelhead kelts were captured and tagged with acoustic transmitters in 2013 including Lower Granite Dam, Asotin Creek, Potlatch River, Joseph Creek, and Fish Creek 1.5
1.3. Aerial photograph of Lower Granite Dam 1.5
1.4. Aerial photograph of Little Goose Dam 1.6
1.5. Aerial photograph of Lower Monumental Dam. The spillway weir is located on the north side of the spillway 1.6
2.1. Photograph of a steelhead kelt that was in good condition at the time of tagging 2.4
2.2. Photograph of a steelhead kelt that was in fair condition at the time of tagging 2.4
2.3. Photograph of the incision area of a female steelhead kelt implanted with an acoustic transmitter. 2.5
2.4. The autonomous acoustic receiver system used in 2013, including the hydrophone, acoustic receiver, acoustic release, and anchor. 2.8
3.1. Standardized reach survival probability estimates for all tagged steelhead kelts detected in the Federal Columbia River Power System in 2013. ..... 3.6
3.2. Cumulative survival probabilities of steelhead kelts from the Little Goose Dam forebay array to rkm 126 by tagging location 3.8
3.3. Frequency distribution of forebay residence times for steelhead kelts that passed Lower Granite, Little Goose, and Lower Monumental dams in 2013. ..... 3.11
3.4. Frequency distribution of tailrace egress times for steelhead kelts that passed Lower Granite, Little Goose, and Lower Monumental dams in 2013. ..... 3.13
3.5. Frequency distribution of project passage times for steelhead kelts that passed Lower Granite, Little Goose, and Lower Monumental dams in 2013. ..... 3.14
3.6. Median travel rates of steelhead kelts through various reaches of the Snake and Columbia rivers from rkm 743 to 113 in 2013. ..... 3.15
4.1. Total daily discharge from McNary Dam in years that steelhead kelt telemetry studies occurred in the Federal Columbia River Power System. 4.4
4.2. Total daily discharge from Lower Granite Dam in years that steelhead kelt telemetry studies occurred in the Federal Columbia River Power System. 4.4
4.3. Daily temperatures recorded at McNary Dam in years that steelhead kelt telemetry studies occurred in the Federal Columbia River Power System. 4.5
4.4. Standardized reach survival probability estimates for all tagged steelhead kelts detected in the Federal Columbia River Power System in 2012 and 2013 ..... 4.5

4.5. (A) Cumulative survival estimates from release to the forebay of Little Goose Dam for good and fair condition kelts tagged in the tributaries of the Snake and Clearwater rivers in 2013. (B) Cumulative survival estimates from the forebay of Little Goose Dam to the forebay of Bonneville Dam for good and fair condition kelts tagged in the tributaries and at the Lower Granite Dam Juvenile Fish Facility in 2013 ..... 4.6

4.6. Tailrace egress time of steelhead kelts that passed Lower Granite, Little Goose, and Lower Monumental dams over time in 2013..... 4.11

Tables

1.1. Distances between locations referenced in this study. 1.4

2.1. Total river kilometers from each acoustic receiver array to the mouth of the Columbia River, along with the description, location, name, and function of each array deployed in 2013..... 2.6

2.2. Assumptions of the virtual single-release model and tests of the assumptions..... 2.10

3.1. Mean, maximum, and minimum discharge values and percentage spill at Lower Granite, Little Goose, and Lower Monumental dams for the time period between the tagging of the first kelt and the last detection of a kelt at any acoustic array in the Snake River..... 3.1

3.2. Dates of first and last kelt captured and tagged at Lower Granite Dam, Asotin Creek, Potlatch River, Joseph Creek, and Fish Creek, and the dates when 10%, 25%, 50%, 75%, and 90% of the kelt at each location had been tagged..... 3.2

3.3. Dates that the first and last kelts implanted with an acoustic transmitters passed Lower Granite, Little Goose, and Lower Monumental dams and dates when 10%, 25%, 50%, 75%, and 90% of the kelt had passed each dam..... 3.4

3.4. Sex ratios and total number of kelts tagged at Lower Granite Dam, Asotin Creek, Potlatch River, Joseph Creek, and Fish Creek along with total number tagged, median fork length, and weight of males and females tagged at each site. 3.4

3.5. Reach survival estimate for all steelhead kelts implanted with acoustic transmitters that were detected in 2013 throughout the Federal Columbia River Power System..... 3.7

3.6. Passage percentages and route-specific survival estimates of tagged kelts that passed through Lower Granite, Little Goose, and Lower Monumental dams during the 2013 season 3.9

3.7. Distance of travel and median forebay residence time for steelhead kelts implanted with acoustic transmitters at Lower Granite, Little Goose, and Lower Monumental dams in 2013..... 3.11

3.8. Number of kelts last detected on the forebay array after detection on the dam-face cabled array at Lower Granite, Little Goose, and Lower Monumental dams..... 3.12

3.9. Distance of travel and median tailrace egress time for steelhead kelts implanted with acoustic transmitters at Lower Granite, Little Goose, and Lower Monumental dams in 2013..... 3.12

3.10. Distance of travel and median project passage time for steelhead kelts implanted with acoustic transmitters at Lower Granite, Little Goose, and Lower Monumental dams in 2013..... 3.12

4.1. Summary of studies examining the downstream migration success of steelhead kelts in the Federal Columbia River Power System 4.3
4.2. The percentage and route-specific survival estimates of tagged kelts that passed through Lower Granite, Little Goose, and Lower Monumental dams during the 2012 and 2013 seasons 4.8
4.3. The percentage and route-specific survival estimates of fair and good condition kelts that passed through Lower Granite Dam during the 2013 season..... 4.9

1.0 Introduction

This report documents the results from the second year of a steelhead kelt migration and FCRPS dam passage study conducted by Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers (USACE), Walla Walla District, during spring and summer 2013. The goal of this study was to quantify migration patterns and estimate dam passage metrics of Snake River steelhead kelts passing through hydroelectric facilities in the FCRPS. These data may be used to understand sources of mortality and inform managers and dam operators of potential ways to increase the survival of kelts during their seaward migrations. The data presented here will allow for comparisons of kelt migration and survival with respect to annual differences in environmental conditions and a larger range of fish physical condition.

1.1 Background

Adult summer steelhead (*Oncorhynchus mykiss*) enter freshwater during the summer months and, once mature, spawn in the Snake River basin the next spring (March to May). Post-spawn kelts migrate downstream in an attempt to return to the ocean to restore their energy reserves (Busby et al. 1996). Steelhead sometimes exhibit iteroparity (i.e., repeat spawning), thus population fitness and reproductive success are highly dependent on survival between spawning events. Estimated annual iteroparity rates for Snake River steelhead range from 0.5 to 1.2%, a lower rate compared to the 2.9 to 9.0% repeat spawners documented in the lower Columbia River (Keefer et al. 2008). Over the past few decades, steelhead populations in the Columbia River basin (CRB) have been greatly diminished and several stocks are listed for protection under the *Endangered Species Act of 1973* (ESA; McClure et al. 2003; NMFS 2004). Causes for population declines are numerous and include overharvesting, loss and degradation of habitat, failed hatchery supplementation practices, predation, and various effects of dam passage (Lichatowich 2001; Budy et al. 2002; McClure et al. 2003; Brannon et al. 2004). However, the effect of these factors on steelhead iteroparity rates is not well understood. Reasonable and Prudent Alternative (RPA) 33 of the 2008 Biological Opinion (BiOp; NOAA 2008) identifies actions and requires measures to increase the survival of migrating kelts, with particular emphasis on B-run fish. B-run steelhead are primarily identified based on the timing of their upstream migration past Bonneville Dam (BON; late-August to October; Busby et al. 1996). Understanding sources of mortality and increasing the survival of kelts is an important step in improving iteroparity rates and potentially contributing to population recovery.

Repeat breeding can be advantageous and with higher adult survival the iteroparous life history strategy may be selected for genetically (Fleming and Reynolds 2004). Iteroparous species may have higher population abundance and productivity than semelparous (reproduce only once before dying) species because they are afforded multiple spawning opportunities in their lifetimes and, as a result, have increased lifetime fitness (Fleming and Reynolds 2004). Furthermore, Seamons and Quinn (2010) showed that steelhead repeat spawners produced more offspring during their second spawning run alone than did one-time spawners. Also, repeated breeding events allow for multiple breeding pairs across years, which may introduce greater genetic variability into a population. Variation in age-at-maturation and overlapping generations could reduce the risk of catastrophic population declines during years of low recruitment (Narum et al. 2008).

The energetic costs associated with migrations and spawning are high and past research suggests the probability of repeat spawning is reduced with greater migration distances (Keefer et al. 2008). During

these large-scale migrations, post-spawn adult steelhead from the Snake River basin upstream of Lower Granite Dam (LGR) must also migrate downstream through eight Federal Columbia River Power System (FCRPS) dams in the lower Snake and Columbia rivers to reach the ocean. The effects of dam passage on iteroparity rates are currently not well understood. River impoundment may indirectly affect kelt migration by altering the environmental conditions (i.e., reducing flows, increasing water temperature), thereby causing delays in migration and additional physiological impairment when fish are already in an atrophied state. In turn, direct effects, such as mortality, may be a result of dam passage or an accumulation of factors such as long migration distances under unfavorable environmental conditions for kelts during their seaward-migration (Wertheimer and Evans 2005; Wertheimer 2007). There is a clear need for continued research to examine the effects of hydropower dam design and operation on iteroparous species (Kraabol et al. 2009).

Several studies have been conducted to evaluate the passage and survival of steelhead kelts as they migrated downstream through the FCRPS (Hatch et al. 2003; Boggs and Peery 2004; Wertheimer and Evans 2005). These studies were conducted nearly a decade ago, and since then several changes to the structure and operations of FCRPS dams have occurred, including installation of spillway weirs at most dams within the system, installation of the BON second powerhouse corner collector (B2CC), and implementation of a court-ordered spill program. These modifications, generally implemented to benefit salmonid smolt survival, may also have a significant positive effect on the survival and migration success of kelts, which tend to be surface oriented and have been shown to readily pass dams via surface passage routes (i.e., spillway weirs; Colotelo et al. 2013). Understanding how kelts respond to the recent changes at the dams will allow fish managers to focus efforts on providing feasible passage routes for out-migrating adults.

In addition to structural and operational modifications at FCRPS dams, annual variation in environmental conditions may also affect steelhead kelt migration through the FCRPS. In 2012, 37.0% of the kelts survived seaward migrations through the FCRPS (Colotelo et al. 2013); this was a higher percentage than in previous studies where only 4.2% and 15.6% of kelts survived this migration in 2001 and 2002, respectively (Wertheimer and Evans 2005). Flow conditions in 2001 and 2002 were lower than average (47% and 85% of the 10-year average at LGR [1990–2000], respectively), while flows were above average in 2012 (109% of 10-year average at LGR [2002–2011]), which highlights the need for additional behavioral studies that capture greater variation in annual flow regimes and may be useful for understanding kelt migration success. The physical condition of kelts may also affect migration success. Previous studies have shown that fish in good condition are more likely to successfully migrate to the ocean and return to spawn again (Boggs and Peery 2004; Keefer et al. 2008). Therefore, interpretation of results from various studies should account for the condition of kelts.

1.2 Research Objectives

In this report, we present demographic summaries, survival estimates, and passage metrics of Snake River steelhead kelts tagged with acoustic transmitters at LGR and several tributary sites within the Snake River basin upstream of LGR. The field study period was from 11 April through 26 August 2013. The objectives were as follows:

- Estimate the proportion of kelts that passed through each dam passage route and estimate route-specific survival probabilities at each FCRPS dam where acoustic transmitter detection capabilities existed.

- Estimate the following passage metrics and timing of kelts implanted with acoustic transmitters:
  - **forebay residence time**: travel time between the entrance to the forebay of the dam and passage through the dam. In this study, the forebay included the river reach 1 km upstream of the dam.
  - **tailrace egress time**: travel time between passage through the dam and exit from the tailrace of the dam. In this study, the tailrace included the river reach 1 to 2 km downstream of the dam.
  - **project passage time**: travel time between the entrance to the forebay and exit from the tailrace of the dam. In this study, the project included the river reaches 1 km upstream of the dam and 1 to 2 km downstream of the dam.
- Estimate the annual population abundance of kelts that arrived at, and passed, LGR.

1.3 Study Area

The CRB spans the majority of Washington, Oregon, Idaho, and southeastern British Columbia, and includes additional smaller portions in four neighboring states. Historically, the CRB was home to one of the largest runs of salmon and steelhead in the world (Chapman 1986; McClure et al. 2003). However, extensive hydroelectric development, habitat loss and degradation, overharvesting, and various other anthropogenic effects have caused many populations to decline (Nehlsen et al. 1991). Currently, 13 populations of salmon and steelhead within the CRB are listed under the ESA, including the Snake River steelhead evolutionarily significant unit, which is listed as Threatened (Busby et al. 1996). Hells Canyon and Dworshak dams completely block migration of Snake River steelhead to the upper Snake and North Fork Clearwater rivers, respectively. In addition, Snake River steelhead must pass up to eight FCRPS dams in the lower Snake and Columbia rivers during their migration.

This research study focused on the lower Snake and Columbia rivers from river kilometer (rkm) 944 (the location of the weir on Fish Creek as measured from the mouth of the Columbia River) to rkm 113 (near Kalama, Washington; Figure 1.1). Steelhead kelts were collected and tagged at four weir sites upstream of the detection area in tributaries of the Snake and Clearwater rivers (Figure 1.2), and at the LGR Juvenile Fish Facility (JFF). The distance from the mouth of the Columbia River for each of the FCRPS dams within the study area and tagging sites, as well as their distances from each other, are listed in Table 1.1.

1.3.1 FCRPS Dams

LGR is the fourth dam upstream from the mouth of the Snake River, 695 rkm from the Pacific Ocean (Figure 1.3). It is the most upstream dam in the FCRPS that provides upstream fish passage. LGR consists of one powerhouse with six turbine units on the south side of the dam. The spillway has eight bays in the middle of the dam, and the southernmost bay is fitted with a spillway weir. An earthen-filled section also forms a portion of the dam. LGR is equipped with a juvenile bypass system (JBS) to route the portion of downstream migrants guided by in-turbine screens through the dam. Many of these fish are routed to monitoring and collection facilities for study and transportation.

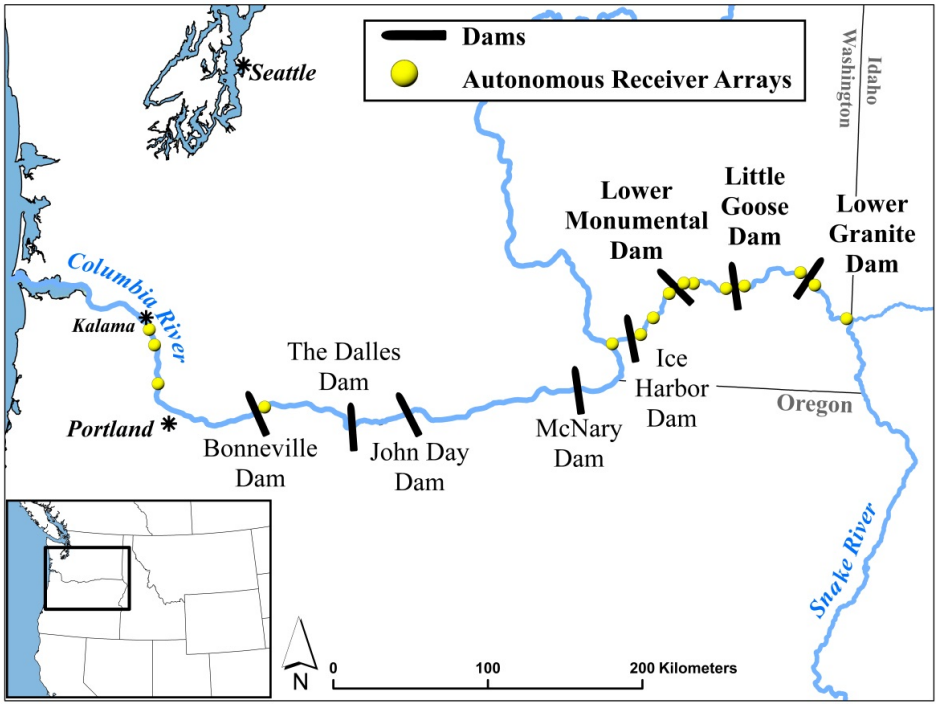

Figure 1.1. Locations of acoustic telemetry receiver arrays used to detect acoustic-tagged steelhead kelts that migrated through the Federal Columbia River Power System (FCRPS) in 2013. Cabled receiver arrays were located on the upstream dam-face of Lower Granite, Little Goose, and Lower Monumental dams (bolded text). Autonomous receiver arrays (yellow dots) were located in the forebay and tailrace of these dams and were used to estimate forebay residence, tailrace egress, and project passage times. In addition to cabled receiver arrays on the dams, autonomous receiver arrays were located at other locations in the Snake and lower Columbia rivers to detect fish for survival estimation.

Table 1.1. Distances (rkm) between locations referenced in this study.

Location	Kilometers Upstream of CR Mouth	LGR	LGS	LMN	IHR	MCN	JDA	TDA	BON
		695	635	589	538	470	349	309	234
Fish Creek	944	249	309	355	406	474	595	635	710
Joseph Creek	804	109	169	215	266	334	455	495	570
Potlatch River	797	102	162	208	259	327	448	488	563
Asotin Creek	761	66	126	172	223	291	412	452	527
LGR	695	0	60	106	157	225	346	386	461
LGS	635		0	46	97	165	286	326	401
LMN	589			0	51	119	240	280	355
IHR	538				0	68	189	229	304
MCN	470					0	121	161	236
JDA	349						0	40	115
TDA	309							0	75
BON	234								0

CR = Columbia River; LGR = Lower Granite Dam; LGS = Little Goose Dam; LMN = Lower Monumental Dam; IHR = Ice Harbor Dam; MCN = McNary Dam; JDA = John Day Dam; TDA = The Dalles Dam; BON = Bonneville Dam.

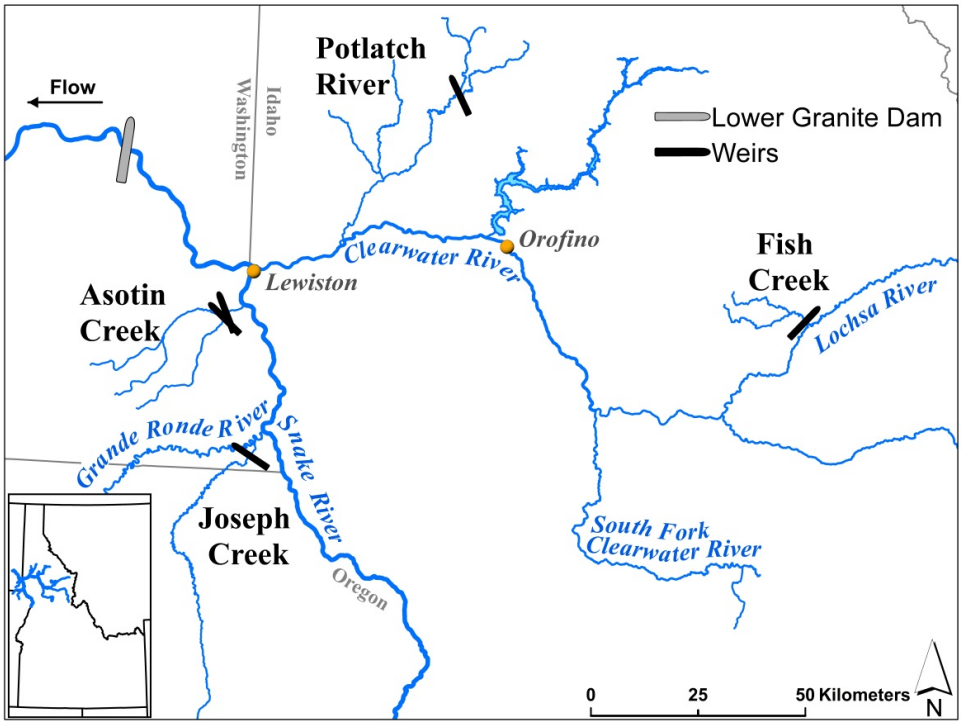

Figure 1.2. Sites where steelhead kelts were captured and tagged with acoustic transmitters in 2013 including Lower Granite Dam, Asotin Creek (and George Creek, an Asotin Creek tributary), Potlatch River, Joseph Creek, and Fish Creek.

Figure 1.3. Aerial photograph of Lower Granite Dam. The spillway weir (surface route) is located on the south side of the spillway.

Little Goose Dam (LGS) spans the Snake River at rkm 635 (Figure 1.4). It has a single powerhouse with six turbine units on the south side of the dam. It also has eight spill bays in the middle of the river,

one of which is equipped with a spillway weir to provide a surface passage route for downstream migrants, and an earthen-filled section on the north side. It is also equipped with a JBS.

Figure 1.4. Aerial photograph of Little Goose Dam. The spillway weir (surface route) is located on the south side of the spillway.

Lower Monumental Dam (LMN) is on the Snake River at rkm 589 (Figure 1.5). It consists of six turbine units in a single powerhouse on the north side of the dam; eight spill bays, including one spillway weir on the south side; and a JBS.

Figure 1.5. Aerial photograph of Lower Monumental Dam. The spillway weir (surface route) is located on the north side of the spillway.

Unlike 2012, during the 2013 study the four lower Columbia River dams were not equipped with cabled receiver systems. As in 2012, Ice Harbor Dam (IHR) was not equipped with cabled receiver systems. For a description of these five dams, refer to the report by Colotelo et al. (2013).

1.3.2 Steelhead Kelt Capture Sites

Steelhead kelts were captured from the separator of the LGR JFF (rkm 695; Figure 1.2). Similar to the 2012 study, sampling at LGR was done in conjunction with an ongoing Nez Perce Tribe (NPT) study conducted to evaluate the feasibility of reconditioning Snake River steelhead kelts captured at LGR. Steelhead were also captured and tagged at four tributaries of the Snake and Clearwater rivers, including Asotin Creek (rkm 761), Joseph Creek (rkm 804), the East Fork of the Potlatch River (rkm 835), and Fish Creek (rkm 944). Kelts in the Asotin Creek drainage were captured at two weir sites: one on the main stem of Asotin Creek and the other on George Creek (rkm 762), a tributary of Asotin Creek. Colotelo et al. (2013) provided detailed descriptions of each capture site included in this study.

1.4 Report Contents

The ensuing sections of this report present the materials and methods (Section 2.0), results (Section 3.0), and discussion and conclusion (Section 4.0). Sources cited in the text may be found in Section 5.0. Ten appendices contain hydrophone and autonomous receiver deployment tables (Appendix A), data collected at the time of fish tagging (Appendix B), the timing of kelt passage versus dam discharge (Appendix C), discharge versus spill at each dam (Appendix D), the timing of kelt passage versus temperature (Appendix E), the run timing of untagged kelts captured at tagging sites (Appendix F), Juvenile Salmon Acoustic Telemetry System (JSATS) performance (Appendix G), plots of percentages of tagged kelts that passed through different routes at FCRPS dams relative to the percentage of flow (Appendix H), diel distributions of tagged kelts that passed through FCRPS dams (Appendix I), and the routes of passage through multiple FCRPS dams (Appendix J).

2.0 Materials and Methods

The source of data about environmental conditions; relevant definitions; fish capture, tag, release, and detection methods; data processing/validation and statistical methods; and dam-passage characteristics are described below.

2.1 Environmental Conditions

Data on total discharge, spill discharge, and forebay temperature in 2013, as well as the 10-year average (2003–2012) for each FCRPS dam, were downloaded from the Data Access in Real Time (DART) website (http://www.cbr.washington.edu/dart). Additional forebay temperature data collected by temperature strings in the forebay of each dam were downloaded from the USACE Technical Management Team (TMT) website (http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tempstrings/). Daily discharge and temperature values represent the mean hourly values for each day.

2.2 Definitions

- **Forebay** is the segment of the reservoir immediately upstream of the dam where operations at the dam are the primary contributing factor to velocity and direction of water flow. The upstream boundary is the most upstream location where water velocity and direction of flow are altered by changes in dam operations (as defined for each dam by Rakowski et al. [2010]), and the downstream boundary is the upstream face of the dam. Autonomous receivers were deployed 1 km upstream of the dam face at the upstream boundary of the forebay at LGR, LGS, LMN, and IHR. The receiver array deployed at the upstream boundary of the BON forebay was located 2 km upstream of the dam face.
- **Tailrace** is the segment of the river immediately downstream of the dam where operations at the dam are the primary contributing factor to velocity and direction of flow. The upstream boundary of the tailrace is the downstream face of the dam, and the downstream boundary is where operational changes at the dam no longer affect the direction of water flow and mixing from the spillway and powerhouse is complete (as defined for each dam by Rakowski et al. [2010]). A tailrace exit array of autonomous receivers was deployed at the downstream boundary of the LGS tailrace and was located 1 km downstream of the dam face. Tailrace exit arrays of autonomous receivers were deployed at the downstream boundaries of the LGR and LMN tailraces and were located 2 km downstream of the dam face.
- The **route-specific survival estimate** is the probability of fish surviving when passing through any individual route (i.e., spillway weir, traditional spillway, turbine, JBS) to the second downstream array. In this study, the passage-route survival estimates were calculated for fish that passed through the turbines, JBS, spillway weirs, and traditional spillway, where traditional spill is passage through tainter or vertical lift gate openings and is any passage through the spillway that is not through the surface spillway weirs.
- **Survival per kilometer** is the probability of fish surviving passage through any individual reach of the river. It is calculated as $S^{1/km}$, where S is the probability of survival in the reach and km is the

length of the reach. This metric allows for comparison of survival through various river reaches that differ in length.

- **Project passage timing** is the time required to travel from the upstream boundary of the forebay to the downstream boundary of the tailrace. It is calculated as the difference in time between the first detection on the tailrace autonomous receiver array and the last detection on the forebay autonomous receiver array. The units used for reporting project passage timing are hours.
- **Forebay residence** is the time required to travel from the upstream boundary of the forebay to dam passage. It is calculated as the difference in time between the last detection on the cabled receiver array and the last detection (as the fish initially crosses the array) on the forebay autonomous receiver array. The units used for reporting forebay residence are hours.
- **Tailrace egress** is the time required to travel from the dam face to the downstream boundary of the tailrace. It is calculated as the difference in time between the last detection on the cabled receiver array and the first detection on the tailrace receiver array. The units used for reporting tailrace egress are hours.
- **Reach travel rate** is the rate of travel from the array at the upstream boundary of the reach of interest to the next downstream array. It is calculated as distance traveled divided by the difference in time between the last detection on the upstream receiver array and the first detection on the downstream receiver array. Reach travel rate is reported in kilometers per day.
- **Migration success** is the percentage of tagged kelts detected downstream of BON (the most downstream dam in the FCRPS). It is calculated by dividing the number of tagged kelts that were detected on any of the autonomous arrays downstream of BON by the number of kelts tagged. This differs from survival because it does not take into account the detection probability of arrays.

2.3 Fish Capture, Tagging, and Release

The following sections describe the methods used to capture fish; associated record-keeping related to meeting permitting requirements for fish collection and handling; sampling; acoustic transmitter and passive integrated transponder (PIT)-tag implantation; fish recovery and holding; and release.

2.3.1 Capture Sites

Overall, six capture sites were used during the 2013 study. Steelhead kelts were collected from and tagged at five capture sites on four different tributaries of the Snake and Clearwater rivers (Figure 1.2). Steelhead kelts with clipped or intact adipose fins were also collected from the LGR JFF and tagged during the study.

2.3.2 Federal and State Permitting

Records were kept on all kelts handled and tagged for permit accounting. Tagging was conducted in conjunction with routine sampling efforts at LGR and tributary sites conducted by various state and Tribal agencies in order to minimize handling impacts on the fish. A federal scientific take permit (permit number 14-13-PNNL86) was authorized for this study by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Hydropower Division's FCRPS Branch and administered by NOAA.

Scientific collection permits were also obtained from three state fish and wildlife management agencies: the Washington Department of Fish and Wildlife (permit number 13-081), the Idaho Department of Fish and Game (permit number F-12-03-13), and the Oregon Department of Fish and Wildlife (permit number 17940). All permit requirements and guidelines were met, and reports of collection and release were reported to each agency. All animals used in this study were handled in accordance with federal guidelines, and study protocols were approved by the PNNL Institutional Animal Care and Use Committee (protocol number 2013-02).

2.3.3 Sampling Methods

Kelts were removed from the separator at the LGR JFF and held in a 26,280-L (7.3- × 2.4- × 1.5-m) holding tank for up to 24 hours before sampling. Tributary weirs were checked daily, and kelts were immediately sampled. All weirs except the George Creek weir were equipped with downstream migrant trap boxes, which were used with varying levels of success to capture kelts. Because of the lack of fish voluntarily moving into the downstream migrant trap boxes, most kelts tagged in the tributaries for this study were captured by the use of seine and/or dip nets upstream of tributary weirs.

Demographic information, including sex, maturational status (pre- or post-spawn), status of adipose fin (clipped or intact), and external physical condition (good, fair, or poor), were recorded for each fish captured. Fork length (cm) and weight (kg) were also measured for each individual.

Males were identified by their characteristically longer snout and the presence of a kype. Males were also typically thinner in profile than females. Females were identified by their blunt rounded snout, the absence of a kype, and their more round abdominal profile (Buelow 2011). Maturational status was determined by evidence, or the lack thereof, of previous spawning activity. Female steelhead were readily identified as kelts by their much more slender and compressed body profile when compared to the thick egg-laden abdomen of a pre-spawn female (Buelow 2011). The downstream direction of migration was often the best identifier of male kelts versus pre-spawn males. Abrasions, especially on the caudal and anal fins, served as additional evidence of previous spawning activity.

Kelts were assessed for condition by visual external evaluation using a method similar to that of Keefer et al. (2008) and Buelow (2011). Kelts were considered to be in *good* condition if they were active with very minor or no wounds, fungus, or injuries (Figure 2.1). *Fair*-condition kelts were active with minor to moderate wounds, fungus, or injuries (Figure 2.2). *Poor*-condition kelts had low activity levels and/or moderate to severe wounds, fungus, or injuries. Only good- and fair-condition kelts were selected for surgical implantation of acoustic transmitters because those kelts have been shown to be in better physiological health and the most likely to migrate (Wertheimer and Evans 2005; Buelow 2011).

Figure 2.1. Photograph of a steelhead kelt that was in good condition at the time of tagging. Good-condition kelts are typically active with very minor or no wounds, fungus, or injuries.

Figure 2.2. Photograph of a steelhead kelt that was in fair condition at the time of tagging. Fair-condition kelts are typically active with minor to moderate wounds, fungus, or injuries.

2.3.4 Implantation of Passive Integrated Transponder Tags and Acoustic Transmitters

Prior to surgery, each kelt was anesthetized by the respective management agency at each capture site. Anesthetized fish were implanted with a 12-mm 134.2-kHz PIT tag (Biomark, Boise, Idaho) either in the dorsal sinus (fish collected from Asotin Creek, Potlatch River, and Fish Creek) or the pelvic girdle (fish collected from LGR and Joseph Creek) using a 12-gauge needle and syringe. PIT tag codes and corresponding fish information were uploaded to the PIT Tag Information System (PTAGIS) database (www.ptagis.org).

Each kelt selected for acoustic tagging was further anesthetized using a solution of 100-mg tricaine methanesulfonate (MS-222)/L of water buffered with a 200-mg/L solution of sodium bicarbonate until reaching Stage 4 anesthesia as described by Summerfelt and Smith (1990). Each kelt was then placed ventral side up on a foam surgery pad, and fresh river water (at tributary sites) or a maintenance dose of 50 mg MS-222/L of water (at LGR) was pumped into the mouth of the kelt for the duration of the surgery (~1.5–3 min).

A small incision of approximately 6 mm was made on the ventral side of the fish, halfway between the pectoral and pelvic girdles along the linea alba. A JSATS transmitter (Advanced Telemetry Systems, Inc., Insanti, Minnesota) was implanted into the coelom of each kelt. The acoustic transmitters were 11.5 mm long, 5.9 mm wide, and 4.3 mm high. The transmitters weighed 0.5 g in air. The nominal pulse rate interval for the JSATS transmitters used in this study was 4.2 seconds, and the expected tag life was 80 days. Different methods were used to implant acoustic transmitters in male and female kelts. For

male kelts, the acoustic transmitter was inserted into the body cavity and the incision closed with two simple interrupted 3-0 Monocryl stitches (Ethicon, Rahway, New Jersey). For females, a barbed suture (V-loc 90, 4-0, Covidien, Mansfield, Massachusetts) was attached to the acoustic transmitter with epoxy (days to weeks prior to tag implantation). After the incision was made, the barbed suture was passed into the body cavity and out through the body wall of the fish. The transmitter was inserted though the incision, and the barbed suture was then pulled gently until the transmitter was flush against the interior surface of the body wall; the barbed suture was then cut, leaving a tail end of approximately 2 mm of suture outside the body to help anchor the transmitter to the body wall (Figure 2.3). The incision was then closed using two stitches in the same manner as done with the males. The barbed suture method was used to decrease possible transmitter loss in females due to post-spawn swelling of the vent and the small size of the acoustic transmitter.

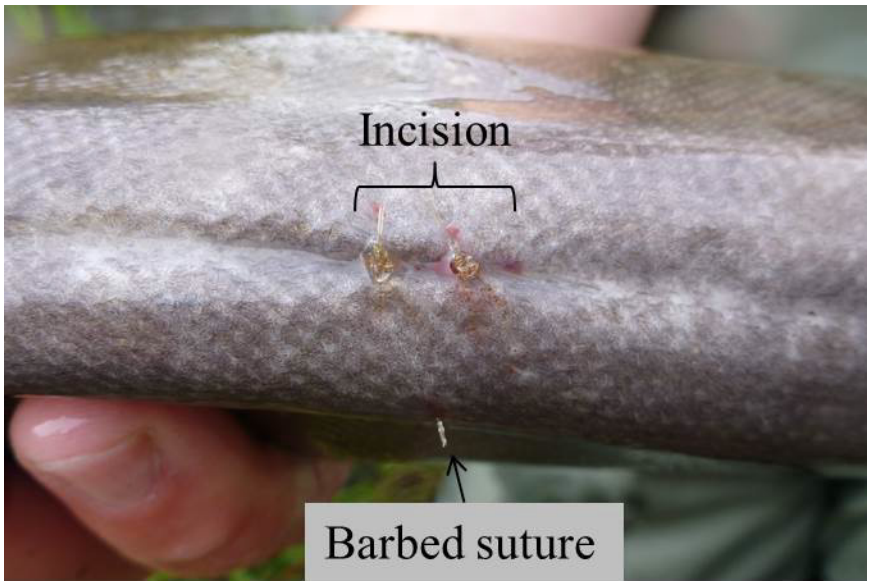

Figure 2.3. Photograph of the incision area of a female steelhead kelt implanted with an acoustic transmitter. The acoustic transmitter was attached to a barbed suture and then anchored to the body wall to decrease possible transmitter loss due to post-spawn swelling of the vent and the small size of the acoustic transmitter.

2.3.5 Recovery, Holding, and Release

After surgery, kelts tagged at LGR were held overnight in a 17,568-L (6.1- × 2.4- × 1.2-m) holding tank at the LGR JFF. The following morning, they were released into the river using a flume pipe leading directly from the holding tank to the LGR tailrace. Kelts tagged at tributary sites were allowed to recover in a 114-L plastic tote full of fresh river water. Kelts were released after regaining equilibrium and normal activity level (~10–20 min).

2.4 Detection of Tagged Fish

Two types of receiver arrays, cabled and autonomous, were deployed to detect fish tagged with acoustic transmitters as they passed downstream through the study area between the upstream end of the LGR pool (rkm 743) and downstream of BON at rkm 113 (Table 2.1). The cabled receiver arrays at

LGR, LGS, and LMN were used to estimate the route of passage at the dam using three-dimensional (3D) tracking and last-detection data (Deng et al. 2011). Dam passage survival was estimated from detection on the cabled receiver arrays to the second downstream autonomous receiver array (generally in the reservoir of the next downstream dam). The autonomous receiver array that marked the downstream boundary of the tailrace (located 1 to 2 km downstream from the dam) was not used for survival estimation because kelts that died during dam passage may be detected on these arrays and falsely classified as alive. The global positioning system (GPS) positions of individual dam-face hydrophones, autonomous receivers, and fish release locations are presented in Appendix A. All cabled hydrophones and autonomous receivers were tested in the acoustic tank located in the PNNL Bio-Acoustics and Flow Laboratory (Deng et al. 2010) prior to their deployment. The Bio-Acoustics and Flow Laboratory is accredited by The American Association for Laboratory Accreditation (A2LA) to ISO/IEC 17025:2005, which is the international standard for calibration and testing laboratories.

Table 2.1. Total river kilometers from each acoustic receiver array to the mouth of the Columbia River, along with the description, location, name, and function of each array deployed in 2013. Array Name is a concatenation "CR" for Columbia River, and the distance from the mouth of the Columbia River. For reference, the mouth of the Snake River is located at rkm 522.

Array Description	Location	Array Name	Array Function
LGR Pool Upper Boundary	Red Wolf Bridge	CR743	Detect tagged fish entering LGR pool
LGR Forebay	1 km upstream LGR	CR696	Detect tagged fish entering LGR forebay
LGR Dam Face	LGR	CR695	Regroup fish for route-specific assignments
LGR Tailrace	2 km downstream LGR	CR693	Detect tagged fish to estimate egress rate
LGS Forebay	1 km upstream LGS	CR636	Detect tagged fish entering LGS forebay
LGS Dam Face	LGS	CR635	Regroup fish for route-specific assignments
LGS Tailrace	1 km downstream LGS	CR634	Detect tagged fish to estimate egress rate
LMN Pool	Ayer's Boat Basin	CR602	Detect tagged fish migrating through LMN pool
LMN Forebay	1 km upstream LMN	CR590	Detect tagged fish entering LMN forebay
LMN Dam Face	LMN	CR589	Regroup fish for route-specific assignments
LMN Tailrace	2 km downstream LMN	CR587	Detect tagged fish to estimate egress rate
IHR Pool	24 km upstream IHR	CR562	Detect tagged fish migrating through IHR pool
IHR Forebay	1 km upstream IHR	CR539	Detect tagged fish entering IHR forebay
Mouth of Snake River	3 km upstream CR	CR525	Detect tagged fish migrating out of SR
BON Forebay	2 km upstream BON	CR236	Detect tagged fish entering BON forebay
Lower CR	Knapp	CR152	Detect tagged fish migrating through Lower CR
Lower CR	Martin Bluff	CR126	Detect tagged fish migrating through Lower CR
Lower CR	Kalama	CR113	Detect tagged fish migrating through Lower CR

CR = Columbia River; SR = Snake River; LGR = Lower Granite Dam; LGS = Little Goose Dam; LMN = Lower Monumental Dam; IHR = Ice Harbor Dam; BON = Bonneville Dam.

2.4.1 Cabled Receiver Arrays

The cabled receivers were acquired from Advanced Telemetry Systems, Inc. Each cabled receiver consisted of a computer, data-acquisition software, digital signal-processing cards with field-programmable logic gate array (DSP+FPGA), GPS card, and a four-channel signal-conditioning receiver

with gain control, hydrophones, and cables. The software that controls data acquisition and signal processing is the property of the USACE.

Cabled receiver arrays were deployed along the upstream face of LGR, LGS, and LMN to detect kelts tagged with acoustic transmitters as they approached and passed the dams. Cabled receiver arrays at all dams consisted of hydrophones mounted on each main pier. Hydrophones for each cabled receiver were deployed on trolleys in pipes attached to the main piers at the powerhouse and spillways in a known fixed geometry. The fixed geometry and precisely synchronized clocks allowed the tag position to be computed from the differences in arrival timing among hydrophones of each transmitted tag message. Two hydrophones were deployed at each main pier, one at a shallow elevation and the other at a deep elevation to provide acceptable geometries for tracking tagged fish in three dimensions and to assign routes of passage through the dam. The elevations and physical locations (latitude and longitude) of each cabled receiver hydrophone are presented in Appendix A.

One- and two-cluster arrays were deployed in the forebay of LGR and LMN, respectively. These arrays were deployed on the bottom of the reservoir approximately 50 m upstream from the spillway weir to assist 3D tracking of kelts as they approached each dam. Each cluster array consisted of a non-planar configuration of four hydrophones attached to a metal frame. Hydrophones were cabled to receivers, which were housed in trailers on the forebay deck of the dams, with the exception of LGR where some of the receivers were housed in the gallery of the dam.

2.4.2 Autonomous Receiver Arrays

Autonomous acoustic telemetry receivers were deployed in arrays at strategic sites throughout the lower Snake and Columbia rivers (Figure 1.1). Fifteen arrays of autonomous receivers were used in this study. An array is defined as a group (between 2 and 10 receivers) of autonomous acoustic receivers deployed across the entire width of a river to detect tagged fish that move past the array. Most arrays consisted of receivers deployed within 120 m of each other and less than 90 m from the shore.

Autonomous receiver arrays were located in the forebays of LGR, LGS, LMN, IHR, and BON and in the tailraces of LGR, LGS, and LMN. Additional mid-reservoir arrays were also located in the pools of LMN, and IHR. An array was deployed near the upstream extent of the LGR pool, and three arrays were deployed downstream of BON. See Appendix A for approximate GPS coordinates of autonomous receivers used in this study.

Autonomous receivers were rigged with the configuration shown in Figure 2.4 and presented in detail by Titzler et al. (2010). In brief, a rope with three floats connected the receiver housing to an acoustic release device (Model 111, InterOcean Systems, Inc., San Diego, California). A second rope connected the acoustic release device to a steel anchor and the rope length (up to 2 m) was adjusted to account for water depth and substrate condition.

Autonomous receivers were retrieved by boat and downloaded at least once per month. A pre-activated receiver was immediately deployed in the same location as the recovered receiver (Snake River) or data from the receiver were downloaded and the receiver was redeployed in the same location (Columbia River). The data were downloaded from the memory card to a laptop computer and checked

to verify that data were collected during the entire deployment, records were continuous, and records included time stamps and tag detections. The memory card was replaced and batteries changed when needed.

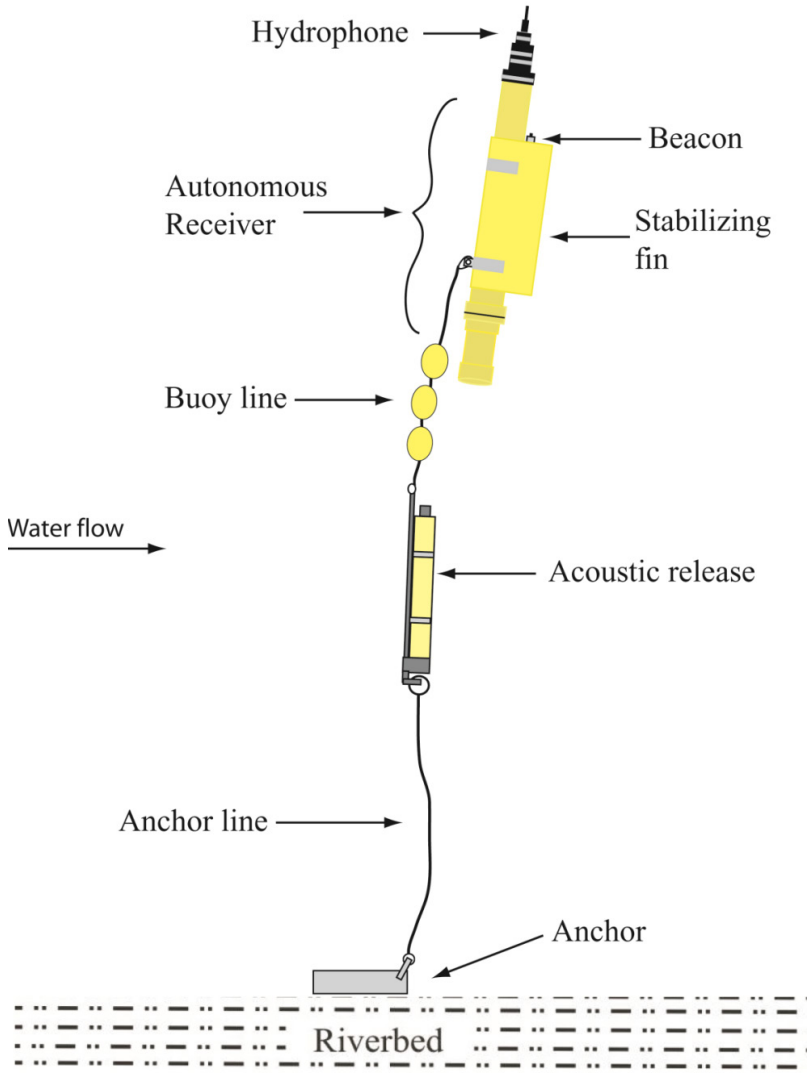

Figure 2.4. The autonomous acoustic receiver system used in 2013, including the hydrophone, acoustic receiver, acoustic release, and anchor.

2.5 Data Processing and Validation

Data collected by the cabled hydrophones were encoded candidate messages saved in binary time-domain waveform files (Weiland et al. 2011). 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 using binary phase shift keying, a digital-modulation technique that transmits messages by altering the phase of the carrier wave. The decoding process also computed the time of arrival for the tag message at each hydrophone. Several filtering algorithms were then applied to the raw results from the decoding utilities to exclude spurious data and false positives.

To produce accepted detection events, raw data were processed through a series of filters that removed detections arising from noise. The output of the filtering process is a data set that summarizes accepted tag detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that indicated the fish identification, the event first and last detection time, the location of detection, and the number of hits detected within the event. Additional fields were added to an event record to capture specialized information, where available. An example is route of passage, which is assigned a value for the event that immediately precedes dam passage based on the spatial tracking of tagged fish movements to the location of last detection on the cabled receiver array.

Fish were tracked in three-dimensions within the cabled array reception areas in the near-dam forebays of LGR, LGS, and LMN. Multiple receptions of messages within an event were used to triangulate successive tag positions relative to hydrophone locations. Dam passage routes were assigned based upon the paths taken by fish during the final event prior to dam passage.

2.6 Statistical Methods

The statistical methods included tests of assumptions and estimation of dam-passage survival, travel times, and estimates of the population abundance arriving at and passing LGR.

2.6.1 Tests of Assumptions

Several assumptions of the virtual single-release survival model could be readily tested. Table 2.2 describes survival model assumptions and subsequent sections describe assumption testing conducted in 2013.

2.6.2 Tag-Life Study

All tags used for this study were located at PNNL prior to the beginning of tagging (11 April 2013), including any leftover tags from the 2012 study. A total of 45 tags (20 tags from 2012 and 25 tags from 2013) were randomly selected to assess tag failure; premature tag failure would violate Assumption A6 (see Table 2.2). The reception of messages from these tags was continuously monitored from their activation to their failure in water. The failure times were fit with the four-parameter vitality model of Li and Anderson (2009), the two- or three-parameter Weibull model, or a non-parametric model. Because the possibility of acoustic-tag failure before the fish exits the study area depends on travel time relative to battery life, we plotted tag-life curves and the cumulative percentage of tags passing the most downstream survival-detection array (rkm 126) as a function of time since tag activation.

2.6.3 Survival Estimation

A virtual single-release study design was used to estimate overall dam passage and route-specific survival at each dam that was fitted with a cabled array and reach survivals for river reaches located between the dams. Virtual release groups, which are groupings of fish based on detection at a similar location independent of when or where those fish were released, were formed at the array that marked the upstream boundary of each reach. For route-specific survival estimation, virtual release groups consisted of all fish that passed a specific dam through the same route (i.e., JBS, spillway weir, traditional spill,

turbines). Survival from the array that marked the upstream boundary of the reach to the next downstream (primary) array was estimated for each virtual release group. Detections of fish on the primary array and all cabled and autonomous arrays located downstream from the primary array (secondary arrays) were used to construct detection histories for each fish in the virtual release group. With two opportunities for detection, the possible detection histories for tagged fish were as follows:

00 = not detected on the primary or secondary arrays

10 = detected on the primary array but not on any of the secondary arrays

01 = detected on at least one secondary array but not on the primary array

11 = detected on both the primary array and on at least one secondary array.

Table 2.2. Assumptions of the virtual single-release model and tests of the assumptions (based on Skalski et al. 2010).

Assumption	Test
A1. Individuals marked for the study are a representative sample from the population of inference.	Compare run timing distributions for the test fish versus the steelhead kelt monitoring data. Compare fish size and other fitness measures between tagged fish and run-at-large.
A2. Survival and recapture probabilities are not affected by tagging or sampling. That is, tagged animals have the same probabilities as untagged animals.	No test; commonly accepted as true in tagging studies. Tag burdens were very low in this study, and acoustic detections of kelts do not involve physical recapture of individuals.
A3. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling events.	No test; the time a tagged fish spends at a sampling array is relatively brief compared to the time of travel between arrays.
A4. The fate of each tagged individual is independent of the fate of all others.	No test; commonly accepted as true in tagging studies.
A5. All tagged individuals alive at a sampling location have the same probability of surviving to the next sampling location.	No test; the high detection probabilities present in acoustic-tag studies preclude testing.
A6. All tagged individuals alive at a sampling location have the same probability of being detected at that location.	No test; this assumption is satisfied by placing hydrophone arrays across the breadth of the river so that all fish, regardless of location, have the same probability of detection. Lab-derived tag-life data will be used to assess this assumption.
A7. All tags are correctly identified and the status of each kelt (i.e., alive or dead) is correctly assessed.	Laboratory tag-life assessments are conducted because tag loss or failure would violate this basic assumption. In addition, survival arrays were located sufficiently far downstream from the dams to minimize the probability of dead kelts being detected and incorrectly identified as alive.
A8. The virtual release group is constructed of tagged fish known to have passed through the dam.	A double-detection array in the forebay increases detection probabilities close to 1.0 and will be used to test for homogeneous detection rates.
A9. All fish arriving at the dam have an equal probability of inclusion in the virtual release group, independent of the passage route through the dam.	This assumption is met by having very high detection probabilities on dam-face arrays. Thus, we will estimate array detection probabilities.

The detection history of each virtual release group was loaded into SURPH Version 3.5.2[1] to estimate overall dam passage, route-specific, and reach survivals as well as detection probabilities for each array. It is possible for model-derived survival estimates to exceed 1.0, because estimates of survival from Cormack-Jolly-Seber single-release models are random variables subject to sampling variability. This is particularly likely when true survival probabilities are close to 1.0 or when sampling variability is high (Muir et al. 2001; Smith et al. 2002; Skalski et al. 2009).

2.6.4 Determination of Passage Proportion

Passage proportions were calculated for traditional spill, spillway weirs, turbines, and the JBS. For fish that entered the JBS, the PIT-tag detection system was used to provide a tally of that passage abundance, with the assumption of 100% detection efficiency. Routes of passage for fish that passed through the traditional spillways, spillway weirs, and turbines were determined by 3D tracks and last detection location based on acoustic telemetry data.

2.6.5 Estimation of Passage Times and Travel Rates

Travel times associated with forebay residence, tailrace egress, and project passage were calculated for each kelt tagged with an acoustic transmitter that passed LGR, LGS, and LMN in 2013 and was detected on both the upstream and downstream arrays. Travel rates were also calculated for all other river reaches encompassed by receiver arrays.

2.6.6 Estimation of Population Abundance Arriving at Lower Granite Dam

Assuming the proportion of tributary-tagged kelts we observed passing LGR through the JBS was representative of all kelts originating from upstream of LGR, the annual kelt abundance at LGR was estimated as:

$$\widehat{N}_{LGR} = \frac{n_{\mathrm{m}}+n_{\mathrm{u}}}{p_{JBS}} \tag{2.1}$$

where $\widehat{N}_{LGR}$ = marked and unmarked kelt population estimate at LGR
n_{m} = total number of marked (adipose-clipped) kelts sampled at the LGR JFF separator
n_{u} = total number of unmarked (unclipped) kelts sampled at the LGR JFF separator (including recaptures)
p_{JBS} = proportion of acoustic-tagged kelts that passed LGR through the JBS.

We attempted to verify the precision of this estimate by calculating the abundance of unmarked kelts using the Lincoln-Petersen mark-recapture method (Petersen 1896; Lincoln 1930) and comparing it to the unmarked kelt abundance estimate obtained using the equation $\widehat{N}_u = \frac{n_{\mathrm{u}}}{p_{JBS}}$ (similar to the approach described above). To estimate unclipped kelt abundance using the Lincoln-Petersen method, kelts captured and tagged with acoustic transmitters and PIT tags at tributary weirs were used as the first sample, and unclipped acoustic-tagged kelts that were sampled at the LGR JFF separator were used as the second sample.

[1] http://www.cbr.washington.edu/paramest/surph/ (December 2012).

$$\widehat{N}_{trib} = \frac{n_1 n_2}{m_2}$$

$$\widehat{SE} = \sqrt{\frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2)^2(m_2+2)}} \tag{2.2}$$

where $\widehat{N}_{trib}$ = unmarked kelt population estimate at the time of tagging
n_1 = number of unclipped kelts caught, marked, and released at tributary weirs
n_2 = total number of unclipped kelts that passed through the LGR JFF and were sampled on the separator (including recaptures)
m_2 = number of acoustic-tagged kelts sampled in the LGR JFF (i.e., recaptures)

2.7 Dam-Passage Characteristics

We examined passage characteristics for all kelts that passed each dam in the system relative to flow and time of day.

2.7.1 Dam Passage versus Flow

The cross-dam distributions of kelt passage at LGR, LGS, and LMN were analyzed using data collected from the cabled receiver arrays. Each cross-dam distribution was calculated by dividing the number of kelts that passed through each opening in the dam (e.g., Turbine Unit 1, Spill Bay 5, etc.) by the total number of fish that passed through the dam. The proportion was multiplied by 100 for presentation as a percentage. Percentages were then plotted against the location of each opening in the dam. The percentage of flow that passed through each opening in the dam during the time when tagged kelts passed each dam (LGR, 14 April to 17 June; LGS, 17 April to 22 June; LMN, 19 April to 24 June) was also plotted.

2.7.2 Diel Distribution

The diel distributions of kelt passage through each dam were determined using the cabled receiver array detections at LGR, LGS, and LMN. For each cabled array, the number of kelts last detected on the cabled array during each hour of the day was divided by the total number of kelts that passed through the dam. This proportion was multiplied by 100 for presentation as a percentage. Plots of the percentage of kelts last detected each hour were created for each cabled receiver array. Bars indicating approximate hours of darkness were placed beginning 1 hour after sunset and ending 1 hour before sunrise. Average sunrise and sunset times for each cabled receiver array were calculated from the sunrise and sunset times of the first and last day of detection for each cabled receiver array, based on data downloaded from the U.S. Naval Observatory website (available at http://aa.usno.navy.mil/data/docs/RS_OneYear.php). Average sunrise and sunset times for Pullman, Starbuck, and Kahlotus, Washington, were used for the cabled receiver arrays at LGR, LGS, and LMN, respectively.

3.0 Results

The study results related to environmental conditions, survival estimates, and fish passage summaries are presented in the following sections.

3.1 Environmental Conditions

Total discharge and spill discharge at FCRPS dams in 2013 was generally less than the 10-year average (2003–2012), with the exception of a brief period in mid-May (Appendix D). For the entire study period, from the time the first fish was released to the time the last fish was detected in the Snake River (11 April through 27 June 2013), total daily discharge in the Snake River (as measured at LGR) ranged from 40.4 to 137.3 kcfs with a mean of 66.0 kcfs (Table 3.1; Figure C.1). Spillways were in use during the entire study period at all three FCRPS dams outfitted with cabled receivers in the Snake River, and the mean percentage spill during that time ranged from 30.3% at LGS to 41.2% at LMN (Table 3.1). Water temperatures in the Snake River fluctuated around or slightly above the 10-year average (2003–2012) during the study period (Appendix E).

Table 3.1. Mean, maximum, and minimum discharge values (kcfs) and percentage spill at Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams for the time period between the tagging of the first kelt (11 April 2013) and the last detection of a kelt at any acoustic array in the Snake River (27 June 2013). Also shown are the 10-year averages (2003–2012) for the same dates. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

	2013				10-Year Average	
	Mean Discharge (kcfs)	Max. Discharge (kcfs)	Min. Discharge (kcfs)	Mean % Spill	Mean Discharge (kcfs)	Mean % Spill
LGR	66.0	137.3	40.4	33.3	96.2	28.4
LGS	64.9	130.1	40.8	30.3	93.4	27.1
LMN	66.9	131.5	41.5	41.2	95.6	28.3

3.2 Kelt Migration Timing and Demographics

Tagging began on 12 April 2013 at LGR and continued until 17 June 2013 (Table 3.2). Kelts were captured and tagged at Asotin Creek, Potlatch River, and Joseph Creek between 11 April and 19 May 2013, and tagging at Fish Creek occurred between 22 May and 13 June 2013. After tagging began, kelts were sampled throughout their migration at all tagging sites to ensure our sample represented all stages of the run.

Functionality of the weirs at all tributary sites was related to spring runoff, and kelts were captured only when the water levels were low enough to allow for operation and maintenance of the weirs. High runoff conditions in the Potlatch River and Fish Creek delayed the onset of tagging; however, after

Table 3.2. Dates of first and last kelt captured and tagged at Lower Granite Dam (LGR), Asotin Creek, Potlatch River, Joseph Creek, and Fish Creek, and the dates when 10%, 25%, 50%, 75%, and 90% of the kelt at each location had been tagged.

Location	Kelts Tagged	First Capture	First Tagging	Percentage of Fish Tagged by Date					Last Tagging	Last Capture
				10%	25%	50%	75%	90%		
LGR	316	7 April	12 April	29 April	6 May	12 May	21 May	1 June	17 June	10 July
Asotin Creek	50	21 Feb	11 April	12 April	12 April	16 April	22 April	23 April	24 April	28 May
Potlatch River	17	24 April	25 April	25 April	26 April	3 May	5 May	8 May	15 May	29 May
Joseph Creek	63	15 March	11 April	11 April	12 April	18 April	23 April	13 May	19 May	7 June
Fish Creek	41	20 May	22 May	23 May	24 May	2 June	7 June	9 June	13 June	28 June

tagging began at all tributary sites, flows were low enough to allow continuous operation of all weirs for the remainder of the tagging season. The timing of kelt capture at each collection site and the timing of tagging for this study are presented in Appendix F.

Although untagged kelts were first collected by Nez Perce personnel from the JFF at LGR on 7 April, the period of passage at LGR, LGS, and LMN for kelts implanted with acoustic transmitters was from 14 April through 24 June 2013 (Table 3.3). The date by which 50% of kelts had passed each dam ranged from 28 April at LGR to 15 May at LMN. The majority (90%) of tagged kelts passed through all three Snake River dams by early June, although several kelts were detected at autonomous receiver arrays in the lower Columbia River in early July.

Kelts implanted with acoustic transmitters ranged in fork length from 48.3 to 90.0 cm. Median fork length was smaller for males (53.2 cm to 70.5 cm) than for females at all sites (62.0 cm to 79.0 cm; Table 3.4). Kelts collected and tagged at Fish Creek, which supports what is considered a B-run steelhead population, were generally larger than fish tagged at other sites. Females at all sites (1.7 kg to 3.6 kg) were typically heavier than males (1.3 kg to 2.8; Table 3.4). Overall, 46.5% (n = 147 of 316) of the kelts tagged at LGR had a clipped adipose fin, indicating they were of hatchery origin and 53.5% (n = 169 of 316) had an intact adipose fin suggesting they were of wild origin. These percentages were similar to those of all the fish handled at LGR (i.e., 40.0% clipped adipose fin [n = 366 of 914] and 60.0% intact adipose fin [n = 548 of 914]). Only 1 of 171 kelts (0.6%) tagged in tributaries had a clipped adipose fin; all others had an intact adipose fin.

3.3 Estimates of Survival Rates

Migration success rates, reach survival estimates, passage proportions, and route-specific survival estimates for kelts tagged with acoustic transmitters that passed through the FCRPS in 2013 are presented below.

3.3.1 Migration Success Through the FCRPS

Overall, 133 of 487 (27.3%) steelhead kelts implanted with JSATS transmitters were detected on the array located in the tidal freshwater portion of the Columbia River estuary at Martin Bluff (rkm 126), indicating successful migration through the FCRPS. Of the fish that successfully migrated, 40.6% (n = 54) had a clipped adipose fin (denoting hatchery origin) and 59.4% (n = 79) had an intact adipose fin. The migration success rate for kelts tagged at LGR with a clipped adipose fin was 36.5% (n = 54 of 148), and 31.4% (n = 53 of 169) for kelts with an intact adipose fin. The migration success rate of fish tagged in the tributaries was 16.4% (n = 28 of 171). Males had a higher migration success rate (33.9%; n = 37 of 109) than females (25.4%; n = 96 of 378). Kelts in good and fair condition at the time of tagging differed in their migration success rates; kelts in good condition migrated successfully at a rate of 33.8% (n = 124 of 367), whereas 7.5% (n = 9 of 120) of fair condition kelts were detected at Martin Bluff (rkm 126).

Table 3.3. Dates that the first and last kelts implanted with an acoustic transmitters passed Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams and dates when 10%, 25%, 50%, 75%, and 90% of the kelt had passed each dam.

Dam	Kelt Passed	First Kelt Passed	Percentage of Kelt Passed by Date					Last Kelt Passed
			10%	25%	50%	75%	90%	
LGR	144	14 April	17 April	23 April	28 April	21 May	5 June	17 June
LGS	364	17 April	28 April	5 May	13 May	24 May	6 June	22 June
LMN	294	19 April	2 May	11 May	15 May	25 May	7 June	24 June

Table 3.4. Sex ratios and total number of kelts tagged at Lower Granite Dam (LGR), Asotin Creek, Potlatch River, Joseph Creek, and Fish Creek along with total number tagged, median fork length (range), and weight (range) of males and females tagged at each site.

Site	M:F Ratio Handled Fish	Total Tagged	M:F Ratio Tagged Fish	Males			Females		
				n	Fork Length (cm)	Weight (kg)	*n*	Fork Length (cm)	Weight (kg)
LGR	0.3:1	316	0.4:1	90	57.5 (49.0 – 77.0)	1.4 (0.96 – 3.47)	226	62.0 (52.0 – 84.0)	1.7 (0.82 – 4.30)
Asotin Creek	0.3:1	50	0.2:1	8	55.4 (48.3 – 65.2)	1.3 (1.24– 2.16)	42	66.4 (52.3 – 76.7)	2.2 (1.14 – 3.14)
Potlatch River	0.4:1	17	0.2:1	3	68.8 (53.4 – 74.0)	2.5 (1.20– 2.54)	14	72.4 (58.2 – 79.0)	2.9 (1.50 – 3.57)
Joseph Creek	0.1:1	63	0.1:1	6	53.2 (49.2– 59.8)	1.3 (0.78 – 1.80)	57	67.2 (48.7 – 76.7)	2.2 (1.02 – 3.88)
Fish Creek	0.1:1	41	0.1:1	2	70.5 (59.0 – 82.0)	2.8 (1.64 – 3.96)	39	79.0 (59.0 – 90.0)	3.6 (1.66 – 5.90)

3.3.2 Survival Estimates Through the FCRPS

Survival to Red Wolf Bridge (rkm 743) varied by release location for kelts captured and tagged in the tributaries. Kelts tagged and released in Fish Creek (rkm 944; $n = 41$) had an estimated survival probability of 0.902 (SE = 0.046) to Red Wolf Bridge. Those tagged and released in the East Fork Potlatch River (rkm 835; $n = 17$) had the lowest probability of surviving to Red Wolf Bridge ($S = 0.824$; SE = 0.093) of all the tributary release groups. Conversely, kelts tagged and released in Joseph Creek (rkm 800; $n = 55$) had the highest probability of survival to Red Wolf Bridge ($S = 0.964$; SE = 0.025). Finally, kelts from Asotin Creek (rkm 760; $n = 45$) had an estimated survival probability of 0.956 (SE = 0.031) to Red Wolf Bridge. Pooled together, kelts tagged in the tributaries had a 0.930 (SE = 0.020) probability of surviving from release to Red Wolf Bridge.

Because of the large differences in the distance to Red Wolf Bridge from each tributary, differences in survival among tributary groups are more accurately depicted by survival/kilometer estimates. Kelts captured and tagged in Fish and Joseph creeks had the highest rates of survival per kilometer: 0.9995 and 0.9994, respectively. Survival per kilometer was similar among kelts captured and tagged in the East Fork Potlatch River (0.9979) and Asotin Creek (0.9973).

Dam passage survival (cabled receiver array to survival array located 27 to 59 rkm downstream) was lowest at LGR ($S = 0.657$; SE = 0.042) and highest at LMN ($S = 0.891$; SE = 0.018; Table 3.5). Evaluated on a per kilometer basis (reaches differed in length and for this reason, reach survival is best compared on a per kilometer basis; Table 3.5, Figure 3.1), survival was lowest at LGR ($S/km = 0.9929$) and highest at LGS ($S/km = 0.9963$). However, the opposite was true of survival in the immediate forebay (from 1 km upstream of the dam to the dam face) of the three dams. Forebay survival was lowest at LGS ($S = 0.958$; SE = 0.010) and highest at LGR ($S = 0.978$; SE = 0.013). Survival per kilometer was substantially lower in the immediate forebays of the three dams compared to any other reach (Figure 3.1). Survival per kilometer estimates exceeded 0.99 in all other reaches and was highest in the most upstream (tributary release to rkm 743 and rkm 743 to rkm 696) and downstream reaches (rkm 525 to rkm 236 and rkm 236 to rkm 126) of the study area.

The cumulative survival probability of all tagged kelts from the forebay array at LGS (rkm 636) to Martin Bluff (rkm 126) was 0.384 (SE = 0.025; Figure 3.2). Relatively small sample sizes of fish collected and tagged at the tributary weirs and the large error associated with survival estimates for these groups precluded an in-depth comparison of cumulative survival probabilities by release location. However, we did observe some apparent differences in kelt survival to Martin Bluff (rkm 126) by tagging locations. Kelts tagged and released in the East Fork Potlatch River had the highest estimated survival ($S = 0.500$); however, this estimate included only 10 fish. Therefore, the error associated with this estimate was quite high (SE = 0.158). The next highest cumulative survival probability to rkm 126 was observed for kelts collected and tagged at the LGR JFF ($S = 0.396$; SE = 0.029). The lowest cumulative survival probability was observed for kelts tagged in Fish Creek ($S = 0.273$; SE = 0.095).

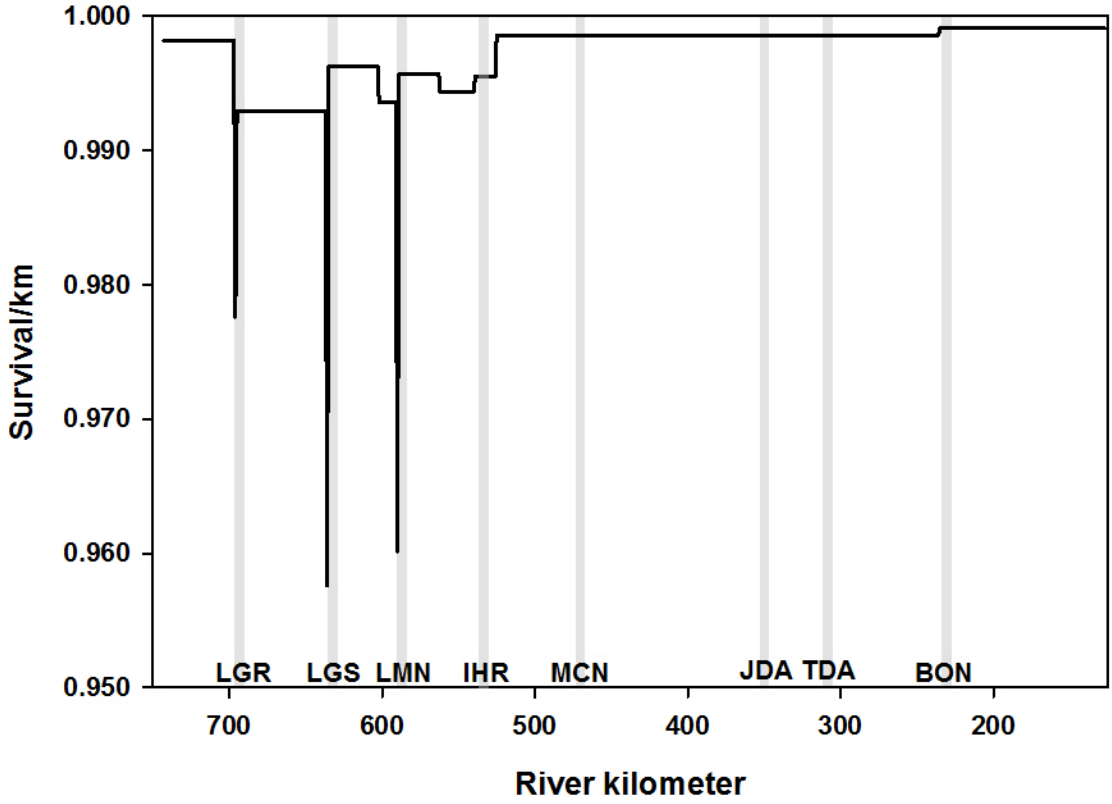

Figure 3.1. Standardized reach survival probability estimates for all tagged steelhead kelts detected in the Federal Columbia River Power System in 2013.

Table 3.5. Reach survival estimate for all steelhead kelts implanted with acoustic transmitters that were detected in 2013 throughout the Federal Columbia River Power System (LGR = Lower Granite Dam, LGS = Little Goose Dam, LMN = Lower Monumental Dam, BON = Bonneville Dam).

Location	Upstream Array	Downstream Array	Distance (km)	n	Survival (SE)	Survival / km
LGR reservoir	A1CR743	A2CR696	47	147	0.919 (0.023)	0.9982
LGR forebay to LGR	A2CR696	D1CR695	1	134	0.978 (0.013)	0.9780
LGR to LGS forebay	D1CR695	A4CR636	59	131	0.657 (0.042)	0.9929
LGR tailrace to LGS forebay	A3CR693	A4CR636	57	307	0.912 (0.016)	0.9984
LGS forebay to LGS	A4CR636	D2CR635	1	375	0.958 (0.010)	0.9580
LGS to LMN forebay	D2CR635	A7CR590	45	368	0.818 (0.021)	0.9955
LGS to mid-LMN reservoir	D2CR635	A6CR602	33	368	0.886 (0.017)	0.9963
mid-LMN reservoir to LMN forebay	A6CR602	A7CR590	12	326	0.926 (0.015)	0.9936
LMN forebay to LMN	A7CR590	D3CR589	1	301	0.960 (0.011)	0.9600
LMN to IHR forebay	D3CR589	A10CR539	50	293	0.782 (0.024)	0.9951
LMN to mid-IHR reservoir	D3CR589	A9CR562	27	293	0.891 (0.018)	0.9957
Mid-IHR reservoir to IHR forebay	A9CR562	A10CR539	23	262	0.878 (0.021)	0.9944
IHR forebay to Burbank	A10CR539	A11CR525	14	230	0.939 (0.016)	0.9955
Burbank to BON forebay	A11CR525	A12CR236	289	216	0.667 (0.032)	0.9986
BON forebay to rkm 126	A12CR236	A14CR126	110	144	0.910 (0.024)	0.9991

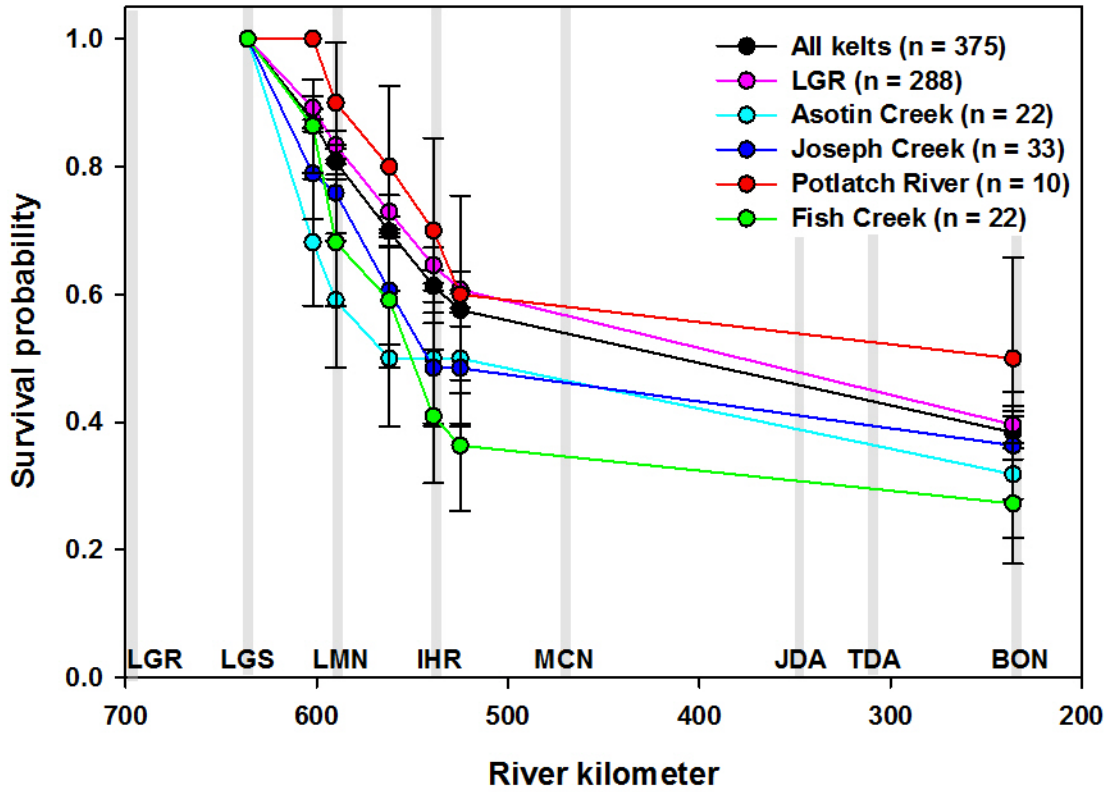

Figure 3.2. Cumulative survival probabilities of steelhead kelts from the Little Goose Dam (LGS) forebay array (rkm 636) to rkm 126 by tagging location (i.e., Lower Granite Dam Juvenile Fish Facility [LGR], Asotin Creek, Potlatch River, Joseph Creek, and Fish Creek). Survival probabilities are presented for the autonomous arrays that were deployed in the Federal Columbia River Power System in 2013 (LGR = Lower Granite Dam, LMN = Lower Monumental Dam, IHR = Ice Harbor Dam, MCN = McNary Dam, JDA = John Day Dam, TDA = The Dalles Dam, BON = Bonneville Dam).

3.3.3 Passage Proportions and Survival Estimates Through Each FCRPS Dam

Overall, at each individual FCRPS dam monitored in this study, the largest proportion of steelhead kelts passed through the spillway (range: 86.9% [LGS] – 92.4% [LGR]; Table 3.6). Specifically, spillway weirs were the most commonly used route of passage (>70%) for tagged kelts at LGR, LGS, and LMN. The least-used route of passage was through the turbines at LGR and LGS, whereas the JBS was the least-used route at LMN. In total, less than 10% of tagged kelts that passed through each dam used a turbine or JBS route. A total of nine fish passed through LGR, LGS, and LMN (n = 2, 5, and 2, respectively) but were not assigned to a specific route, so the route was denoted as "unknown." These fish may have passed through the navigation lock or other parts of the dam that were not equipped with cabled receivers (e.g., adult fish ladders). This is plausible because kelts were observed in the navigation locks of several FCRPS dams by the authors of this report on several occasions. In addition, seven kelts (1.4% of total tagged fish) were detected at the forebay array after being detected at the dam face and were not detected again on that cabled receiver array or on any other downstream arrays, indicating these fish migrated upstream upon encountering the dam. Although these fish were included in the forebay-to-

Table 3.6. Passage percentages and route-specific survival (± SE) estimates of tagged kelts that passed through Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams during the 2013 season. Single-release survival estimates were based on pooled data for each major route of passage (i.e., traditional spillway, spillway weir, turbine, juvenile bypass systems [JBS], unknown) at each dam. The number of kelts that passed through each route and the sample size used for survival estimation are shown for each route. These numbers do not always match because kelts tagged with transmitters from 2012 were included in passage proportion estimates but not in survival estimates due to tag life issues.

		Route									
Dam	Measure	*n*	Traditional Spill	*n*	Spillway Weir	*n*	Turbine	*n*	JBS	*n*	Unknown
LGR	Passage percentage	18	12.5%	115	79.9%	2	1.4%	7	4.9%	2	1.4%
	Survival (SE)	17	0.706 (0.111)	105	0.667 (0.046)	2	1.000 (0.000)	6	0.333 (0.193)	1	0.000 (0.000)
LGS	Passage percentage	57	15.9%	255	71.0%	19	5.3%	24	6.7%	4	1.1%
	Survival (SE)	56	0.821 (0.051)	250	0.936 (0.016)	19	0.842 (0.084)	24	0.875 (0.068)	3	1.000 (0.000)
LMN	Passage percentage	47	16.0%	209	71.1%	20	6.8%	16	5.4%	2	0.7%
	Survival (SE)	46	0.826 (0.056)	206	0.927 (0.018)	19	0.842 (0.084)	16	0.938 (0.061)	2	0.500 (0.354)

dam face survival estimates, they were not included in the dam passage or route-specific survival estimates. Appendix J outlines the routes of passage through multiple dams in the FCRPS taken by individual kelts.

The relatively small sample sizes of kelts that passed through turbine, JBS, or traditional spill routes precluded an in-depth comparison of survival probabilities by passage route at all dams. Only eight kelts (6.3%) were included in the survival estimation for JBS and turbine routes at LGR, and only about 12% of kelts passed through the JBS and turbine routes at LGS and LMN. Kelts (n = 2) that passed through the turbines at LGR survived to the LGS forebay array (rkm 636; S = 1.000; SE = 0.000; Table 3.6); whereas the estimated survival to the LGS forebay array was just 0.333 (SE = 0.193) for the six kelts that passed through the LGR JBS. The survival probability for kelts that passed the traditional spill and spillway weir routes at LGR was estimated to be 0.706 (SE = 0.111) and 0.667 (SE = 0.046), respectively. Kelts that passed through traditional spill routes had the lowest estimated survival at LGS (0.821; SE = 0.051) and at LMN (0.826; SE = 0.056). Turbine-passed kelts experienced the next-lowest survival at LGS and LMN (at both dams S = 0.842; SE = 0.084). At LGS, the estimated survival probability was 0.875 (SE = 0.068) for kelts that passed through the JBS and 0.936 (SE = 0.016) for kelts that passed through the spillway weir. Conversely, at LMN, survival was highest through the JBS (S = 0.938; SE = 0.061), followed by the spillway weir (S = 0.927; SE = 0.018).

3.4 Passage Times and Travel Rates

Passage times through forebays, tailraces, and projects, as well as travel rates for river reaches are reported below.

3.4.1 Forebay Residence

The distance between forebay and cabled receiver arrays was 1 km for each FCRPS dam investigated in this study. Median forebay residence times ranged from 1.35 hours (at LMN) to 1.92 hours (at LGS; Table 3.7). The shortest measured forebay residence time was 0.13 hours at LMN, and the longest was 89.47 hours, also at LMN. Plots of the frequency distribution of forebay residence times at LGR, LGS, and LMN demonstrate that most kelts (~90%) moved through the forebay in less than 14 hours (Figure 3.3). As previously mentioned, seven kelts were detected at the forebay array after being detected at the dam face of LGS and LMN and were not detected again on that cabled receiver array or on any other upstream or downstream arrays, indicating these fish migrated upstream and remained within the reservoir upon encountering one of these dams (Table 3.8). These seven fish were included in the forebay survival estimates, but were excluded from the forebay residence, route-specific survival, and dam passage survival calculations because it could not be confirmed that they passed the dam.

Table 3.7. Distance of travel and median forebay residence time for steelhead kelts implanted with acoustic transmitters at Lower Granite, Little Goose, and Lower Monumental dams in 2013.

Dam	*n*	Distance (km)	Forebay Residence Time (Hours) Median (Range)
Lower Granite	144	1	1.87 (0.26–59.91)
Little Goose	365	1	1.92 (0.26–50.25)
Lower Monumental	294	1	1.35 (0.13–89.47)

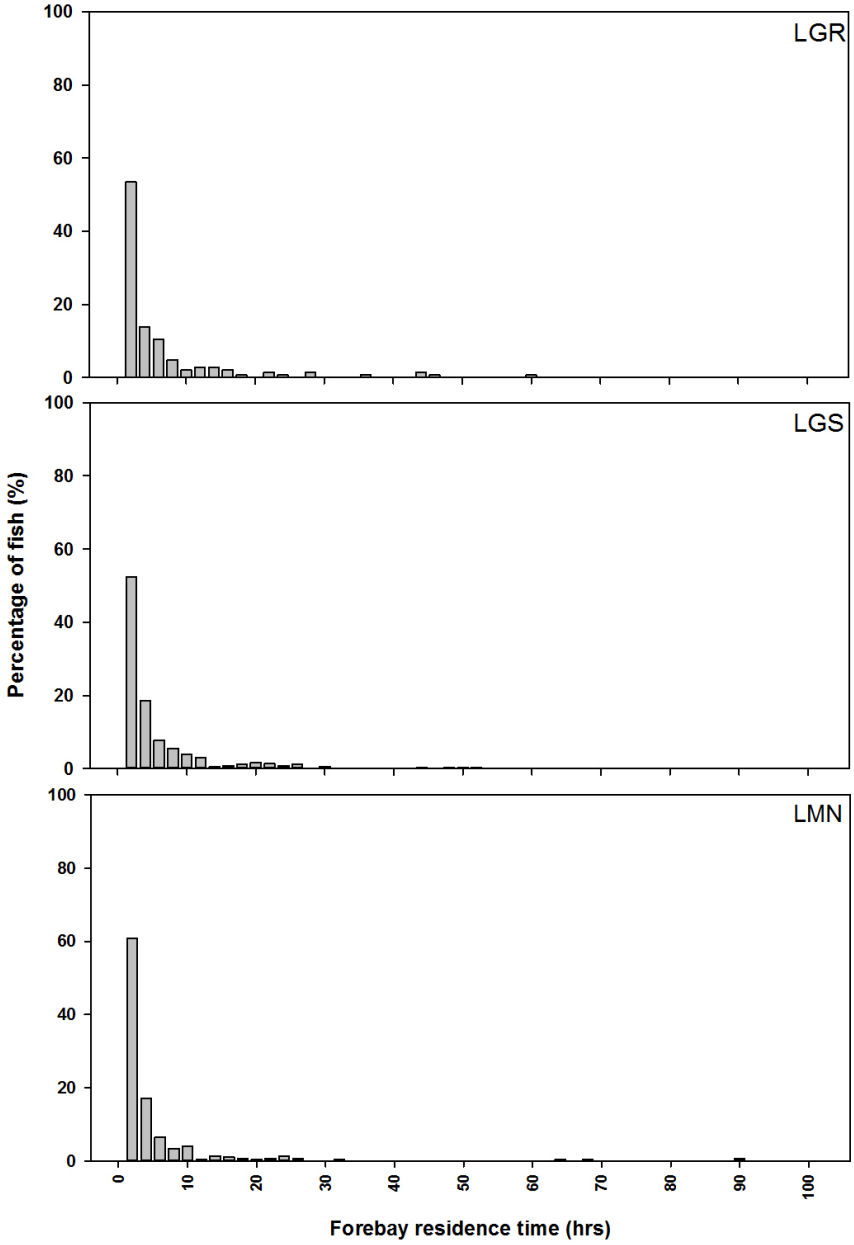

Figure 3.3. Frequency distribution of forebay residence times (hours) for steelhead kelts that passed Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams in 2013.

Table 3.8. Number of kelts last detected on the forebay array after detection on the dam-face cabled array (i.e., moving upstream) at Lower Granite, Little Goose, and Lower Monumental dams.

Dam	Number of Kelts Detected on Cabled Array	Kelts Last Detected Moving Upstream from Dam Face	
		n	%
Lower Granite	144	0	0.0
Little Goose	375	3	0.8
Lower Monumental	298	4	1.3

3.4.2 Tailrace Egress

The distance between the cabled receiver arrays and tailrace arrays ranged from 1 to 2 km for each FCRPS dam monitored (Table 3.9). Median tailrace egress times ranged from 0.37 hours (at LMN) to 0.60 hours (at LGR). The shortest recorded tailrace egress time was 0.18 hours (at LGS), and the longest was 99.19 hours (at LGR). Over 85% of the kelts that moved through the tailraces of LGR, LGS, and LMN did so within 2 hours (Figure 3.4).

Table 3.9. Distance of travel and median tailrace egress time (hours) for steelhead kelts implanted with acoustic transmitters at Lower Granite, Little Goose, and Lower Monumental dams in 2013.

Dam	*n*	Distance (km)	Tailrace Egress Time (Hours)
			Median (Range)
Lower Granite	135	2	0.60 (0.22–99.19)
Little Goose	359	1	0.52 (0.18–57.59)
Lower Monumental	289	2	0.37 (0.19–46.79)

3.4.3 Project Passage Times

The distance between the forebay and tailrace arrays ranged from 2 to 3 km for each FCRPS dam investigated in this study (Table 3.10). Median project passage times ranged from 2.00 hours (at LMN) to 3.06 hours (at LGR). The shortest recorded project passage time was 0.36 hour (at LMN) and the longest was 103.42 hours (at LGR). Project passage times for more than 80% of all kelts that passed LGR, LGS, or LMN was less than 12 hours (Figure 3.5).

Table 3.10. Distance of travel and median project passage time (hours) for steelhead kelts implanted with acoustic transmitters at Lower Granite, Little Goose, and Lower Monumental dams in 2013.

Dam	*n*	Distance (km)	Project Passage Time (Hours)
			Median (Range)
Lower Granite	135	3	3.06 (0.77–103.42)
Little Goose	359	2	2.78 (0.49–58.30)
Lower Monumental	289	3	2.00 (0.36–93.72)

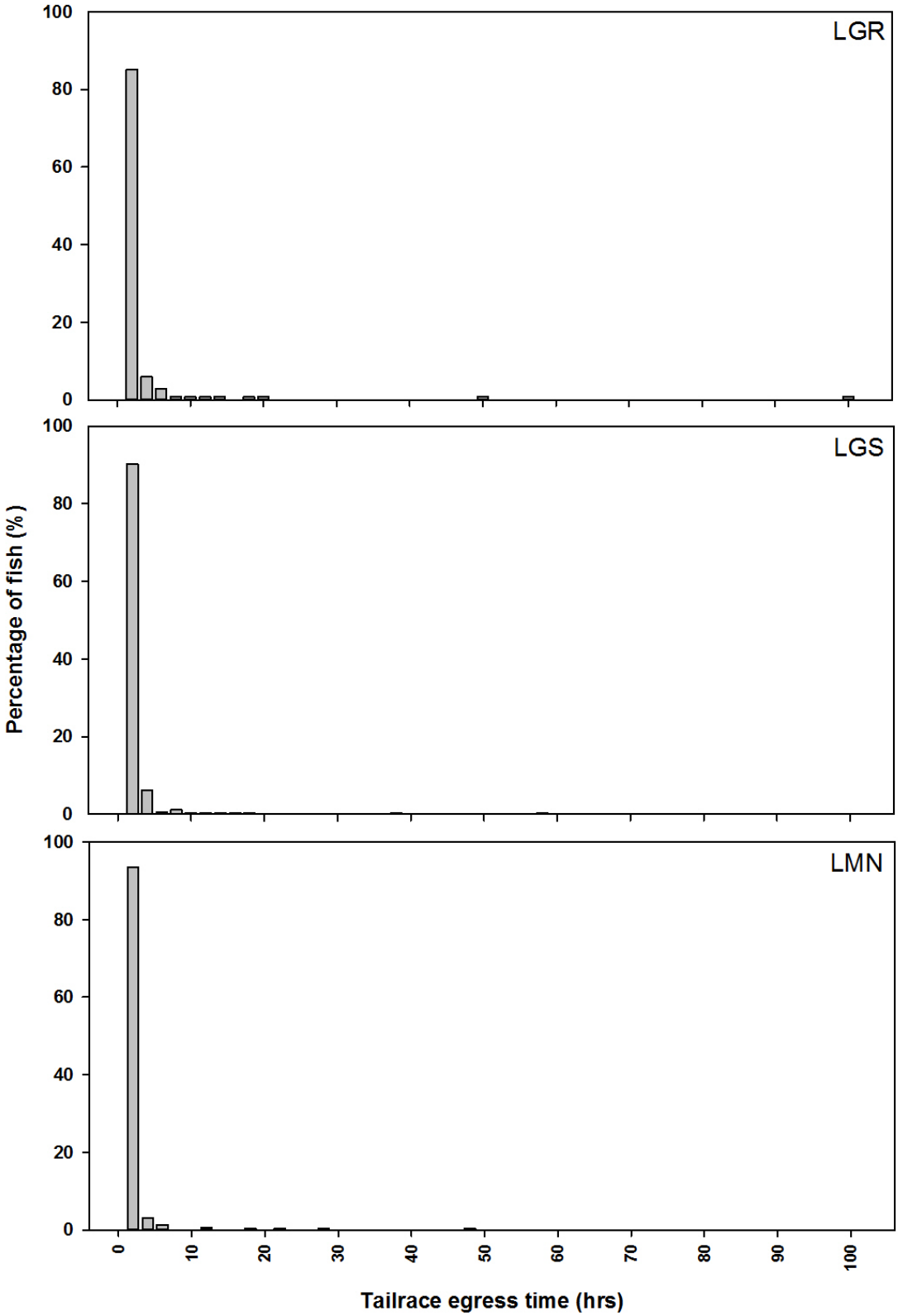

Figure 3.4. Frequency distribution of tailrace egress times (hours) for steelhead kelts that passed Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams in 2013.

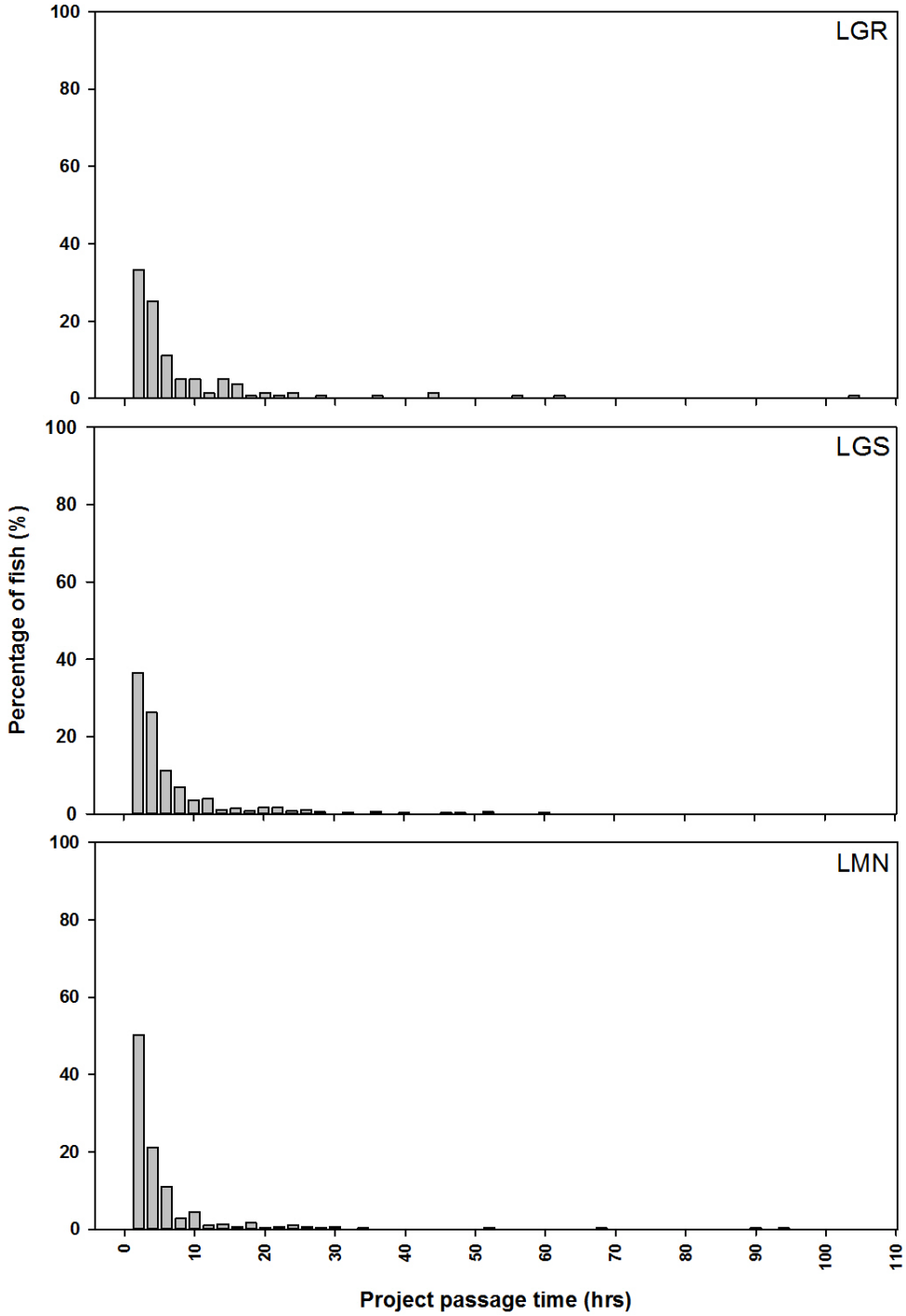

Figure 3.5. Frequency distribution of project passage times (hours) for steelhead kelts that passed Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams in 2013.

3.4.4 Travel Rates

Travel rates were calculated from release to first downstream array and for river reaches located between detection locations. Of the kelts captured and tagged in the tributaries, those released in Fish

Creek had the highest median travel rate (88.2 km/day) from release to rkm 743. Kelts captured and tagged in Joseph Creek and the East Fork Potlatch River had similar median travel rates of 16.7 km/day and 16.6 km/day, respectively. Kelts released in Asotin Creek had the slowest median travel rate (10.5 km/day) of all tributary groups. Once kelts reached rkm 743, travel rates generally increased as fish migrated downstream; the lowest median travel rates occurred in the Snake River (20.0 km/day from rkm 743 to 696; Figure 3.6) and the highest median travel rates occurred in the Columbia River (129.1 km/day from rkm 126 to rkm 113). Median travel rates were generally highest in the tailrace of each dam and lowest in the forebay of the dams (46.2 to 130.0 km/day).

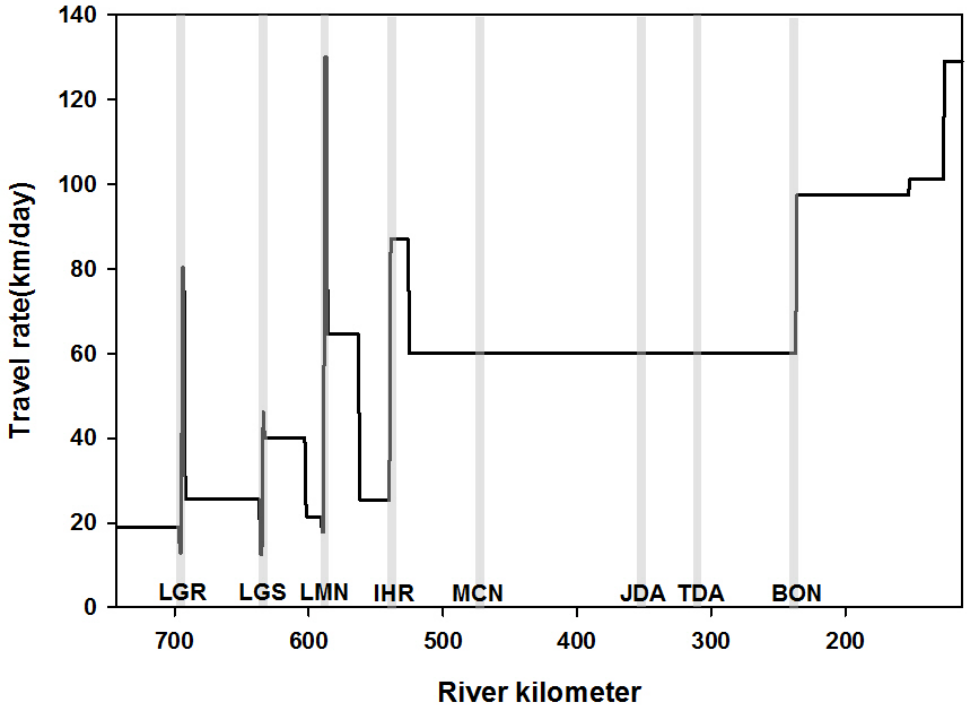

Figure 3.6. Median travel rates (km/day) of steelhead kelts through various reaches of the Snake and Columbia rivers from rkm 743 to 113 in 2013.

3.5 Estimation of Population Abundance Arriving at Lower Granite Dam

A total of 954 steelhead kelts were sampled at the LGR JFF separator. By dividing this number by the proportion of acoustic-tagged kelts that passed LGR through the JBS (0.0486), we estimated that 19,630 steelhead kelts passed LGR in 2013. Calculating the population abundance separately for adipose-clipped and unclipped kelts produced an estimated 7,819 clipped and 11,811 unclipped kelts that passed LGR in 2013.

Using the Lincoln-Petersen method, we estimated that 14,022 (SE = 4,567) unclipped kelts were present in the tributaries at the time of tagging. Multiplying this estimate by the estimated survival from release to LGR for all kelts tagged in tributaries (S = 0.838) resulted in an estimate of 11,750 unclipped kelts that passed LGR. Agreement between the estimates of unclipped kelts using the JBS passage

proportion and the Lincoln-Petersen methods indicates that we may be relatively confident in our kelt population abundance estimate.

3.6 Iteroparity Rates

PTAGIS (www.ptagis.org) was queried for the detection histories of all kelts included in this study, as well as those included in the 2012 study. These detection histories were examined to determine the migration behavior of kelts prior to their inclusion in this study and to determine if any kelts made upstream movements after their inclusion in this study. No kelts included in this study had PIT-tag detection histories consistent with spawning events in prior years. At the time of this report (31 March 2014), no kelts that were tagged in 2013 had been detected moving back upstream in the FCRPS.

Four of the 324 (1.2%) kelts that were tagged with acoustic transmitters in 2012 were detected making upstream migrations in the summer and fall of 2013. One of the returning fish, a female, was tagged in 2012 at the Joseph Creek weir, and the remaining three were tagged at LGR. The kelt tagged at Joseph Creek was detected in August 2013 at the PIT-tag detection array near the mouth of the Deschutes River (at rkm 328). The Deschutes River is a tributary of the Columbia River and Snake River steelhead commonly use it as a thermal refuge during summer months because it generally has cooler water temperatures than the Columbia River (High et al. 2006). This kelt was later detected in November 2013 as it passed LGR. The other three fish (two females and one male) were detected moving upstream through the FCRPS and in the LGR adult fish ladder in August (female) and September (male and female) 2013. The female detected in the LGR adult fish ladder in September was detected in Joseph Creek in March 2014.

3.7 JSATS Performance

JSATS performance was evaluated in terms of detection probabilities of autonomous and cabled receiver arrays, fish distribution at autonomous arrays, and tag failure.

3.7.1 Detection Probabilities at Cabled and Autonomous Arrays

Detection probabilities of all cabled and autonomous receiver arrays used for survival estimation exceeded 0.99 for the 2013 season (Table G.1 and Table G.2).

3.7.2 Multiple Detections on Autonomous Arrays

Tagged kelts were generally detected on two or more autonomous receivers within an array during their seaward migrations (Table G.3). The median percentage of fish detected on two or more receivers within an autonomous array was 97.8% (range: 69.2%–100.0%).

3.7.3 Tag Life

In total, 20 tags from the 2012 tag lot and 25 tags from the 2013 tag lot were used to estimate tag life. Of the 2012 tags, 4 of 20 (20.0%) tags died within 24 hours of their activation. Due to the high initial tag failure, only 13 tags from the 2012 tag lot were used in the field portion of the 2013 study, which was an

insufficient sample size to adjust for tag failure of survival estimates. Therefore, fish implanted with 2012 transmitters were not included in the survival estimation. However, these fish were used to estimate travel time and passage proportions. In comparison, all 25 of the 2013 tags lasted at least 60 days. During 2013, all of the kelts tagged with acoustic transmitters passed the final survival detection array at Martin Bluff (rkm 126) in 30.8 days or fewer (Figure G.1). Therefore, there was no need to apply a tag-life correction to survival probability estimates.

3.8 Dam-Passage Characteristics

The proportions of kelts and the proportion of flow that flowed through each route in each dam, along with the diel distribution of fish passage through the dams are reported below.

3.8.1 Dam Passage versus Flow

During the time of tagged kelt passage at each dam (see Appendix H for dates for each dam), the largest percentage of flow passed through the powerhouses at LGR, LGS, and LMN (69.8%, 69.2%, 62.4%, respectively). However, the largest proportion of kelts passed through the spillways at all dams (Appendix H). Furthermore, the majority of kelts that passed LGR, LGS, and LMN (71.0%–79.9%) did so through the spillway weir, whereas less than 13% of the flow passed through this route at each dam.

3.8.2 Diel Distribution

The hourly distributions of kelt passage at LGR, LGS, and LMN were fairly consistent throughout the season in 2013 (Appendix I). At all dams studied in 2013, approximately 75% of kelts passed through the dam during daylight hours, whereas 25% of kelts passed during hours of darkness based on their last detection on the cabled receiver arrays.

4.0 Discussion and Conclusions

Discussion of steelhead kelt migration success, reach survival, passage proportions and route-specific survival, travel rates, population abundance, and associated conclusions are presented in the following sections.

4.1 Migration Success

The 2013 migration success rate of kelts (to rkm 126) was lower than the success rates observed in 2012 (to rkm 113; Colotelo et al. 2013) and 2004 (to rkm 232; Boggs and Peery 2004), but higher than the success rates observed in 2001 and 2002 (to rkm 181; Hatch et al. 2003, Wertheimer and Evans 2005; Table 4.1). River conditions may have been partially responsible for some of the observed differences in migration success between years. Related to the years of study considered here, Columbia River discharge was highest in 2012 (when the highest migration success rate was observed) and lowest in 2001 (when the lowest migration success rate was observed; Figure 4.1). In fact, discharge was so low in 2001 that no water was spilled at Snake River dams, forcing all kelts to pass via JBSs, turbine units, or navigation locks. The low flow conditions of 2001 and high flow conditions of 2012 are shown on a plot of Snake River discharges (Figure 4.2). River temperature may have also contributed to differences in migration success among study years: Columbia River water temperature was highest in 2001 and generally lower in 2012 (Figure 4.3).

The condition of kelts tagged in each study is also important to consider when comparing the results among years. For example, a higher percentage of good condition kelts (90.1%) were implanted with transmitters in 2012 than in 2013 (75.4%; Table 4.1). The location of the array to which migration success rate was measured may have also played a role in the observed differences among studies and years. However, survival of Snake River steelhead kelts appeared to be quite high in the Columbia River downstream from BON in both 2012 and 2013 (0.897 from rkm 235 to 156 in 2012 and 0.910 from rkm 236 to 126 in 2013). Therefore, the difference in array location likely had a relatively small effect on differences in migration success among studies and years.

4.2 Reach Survival

Reach survival, estimated on a per–kilometer basis (Figure 3.3) to allow for comparison among reaches of different lengths, was lowest in the immediate forebays of Snake River dams in 2013. This trend is mostly consistent with observations from the 2012 study (Figure 4.4; Colotelo et al. 2013). However, in 2012, the lowest survival per kilometer estimate occurred in the LGR forebay; whereas in 2013, the lowest survival per kilometer estimate occurred in the LGS forebay. In both 2012 and 2013, survival was generally lower through reaches that included a dam as compared to river reaches between dams (excluding the immediate forebay). Of the reaches evaluated in 2013 that contained a dam, survival per kilometer was lowest from LGR to the LGS forebay. In 2012, survival per kilometer estimates were similar among the reaches that contained LGR, LGS, and LMN (Colotelo et al. 2013).

When all kelts (from all capture and tagging locations) were combined, survival was higher in 2012 than in 2013 in all reaches that were monitored in both years. Again, it is possible that differences in river

conditions (e.g., discharge and water temperature) between years accounted for the observed differences in survival with the higher discharge and cooler water conditions of 2012 contributing to higher survival.

A higher percentage of kelts tagged in the tributaries were in fair condition in 2013 (25%) compared to 2012 (0%). It is possible that the higher proportion of fair condition kelts tagged in 2013 contributed to the lower survival estimates we observed. In general, fair condition kelts had lower survival than good condition kelts (Figure 4.5). In particular, the higher proportion of fair condition kelts implanted in the tributaries in 2013 likely contributed to the low survival we observed between the LGR forebay and the LGS forebay. Fair condition kelts had a survival probability of 0.345 in this reach compared to 0.745 for good condition kelts. In 2012, only good condition kelts were implanted in the tributaries and had a 0.882 probability of survival between the LGR forebay and the LGS forebay. Therefore, river conditions may have also contributed to the lower survival observed in this reach in 2013.

The location at which kelts were captured may have influenced survival estimates. Only good and fair condition kelts were implanted with a transmitter in the tributaries and at the LGR JFF. However, kelts tagged in good or fair condition in the tributaries may have degraded to a poorer condition by the time they arrived at the LGR forebay. Therefore, estimates of survival between the LGR forebay and the LGS forebay, which consisted entirely of kelts tagged in the tributaries, may have been biased low, relative to the other dams. This hypothesis is supported by the lower survival we observed for both good and fair condition kelts implanted in the tributaries compared to those implanted at LGR through reaches the groups shared in common (from rkm 636 to rkm 236; Figure 4.5). Overall, survival of kelts tagged in the tributaries was about 5% lower than observed for LGR JFF-tagged kelts in most Snake River reaches located between the LGS forebay and the IHR forebay.

Kelts tagged in the tributaries survived at a similar rate in the Columbia River ($S = 0.732$ from rkm 525 to rkm 236) to those tagged at the LGR JFF ($S = 0.651$; likelihood ratio test, $P = 0.32$). Overall cumulative survival estimates (from rkm 636 to rkm 236) were fairly similar between the two groups in 2013. These results are in contrast to those observed in 2012 when LGR JFF kelts survived at a much higher rate than tributary kelts in both the Snake and Columbia rivers, resulting in a 24% difference in cumulative survival between the two groups from the LGS forebay (rkm 636) to the BON forebay (rkm 236; Colotelo et al. 2013).

In 2012, kelts captured and tagged at the tributary sites located farthest upstream, specifically Fish Creek (rkm 944) and the Crooked River (rkm 961), had the lowest migration success rates of all tagged groups (Colotelo et al. 2013). These results indicated that perhaps kelt survival was negatively correlated with the distance of spawning sites from the ocean. Although kelts captured and tagged in Fish Creek in 2013 had the lowest survival rate from release to rkm 236 of all tributary groups, we did not observe this same trend among the other tributary sites. In fact, kelts captured and tagged in Asotin Creek (rkm 760), which is the tributary site located nearest to LGR, had the second-lowest survival rate from release to the BON forebay (rkm 236). As suggested by Colotelo et al. (2013), differences in migration timing among tributary groups may also affect survival, making it difficult to identify whether distance traveled, migration timing, or some other factor has the greatest effect on the survival rates of tributary groups.

Table 4.1. Summary of studies examining the downstream migration success of steelhead kelts in the Federal Columbia River Power System.

Study	Year	Telemetry Equipment[a]	Migration Success Rate (%)[b]	Fish Release Site	Downstream Array	*n* Tagged	Fish Condition		
							Good (%)	Fair (%)	Poor (%)
Wertheimer and Evans 2005	2001	Radio	4.1	LGR Tailrace	rkm 181	197	73.0 [c]	27.0 [c]	n/a
Wertheimer and Evans 2005	2002	Radio	15.4	LGR Tailrace	rkm 181	167	73.0 [c]	27.0 [c]	n/a
Hatch et al. 2003	2002	Radio	13.3	LGR Tailrace	BON Tailrace	210	51.4	27.6	21.0
Boggs and Peery 2004	2003	Radio	34.4	LGR Tailrace	rkm 232	212	66.5	33.5	n/a
Colotelo et al. 2013	2012	JSATS	37.0	Tributaries and LGR Tailrace	rkm 113	324	89.8	10.2	n/a
Current Study	2013	JSATS	27.3	Tributaries and LGR Tailrace	rkm 126	487	75.4	24.6	n/a

(a) Radio transmitters were attached externally. JSATS transmitters were implanted internally.
(b) Migration success is defined as the percentage of tagged fish detected at an array downstream of all Federal Columbia River Power System dams.
(c) Wertheimer and Evans (2005) did not report the proportion of kelts in good and fair condition for the individual years of tagging, but reported that overall 73.0% of fish were in good condition.

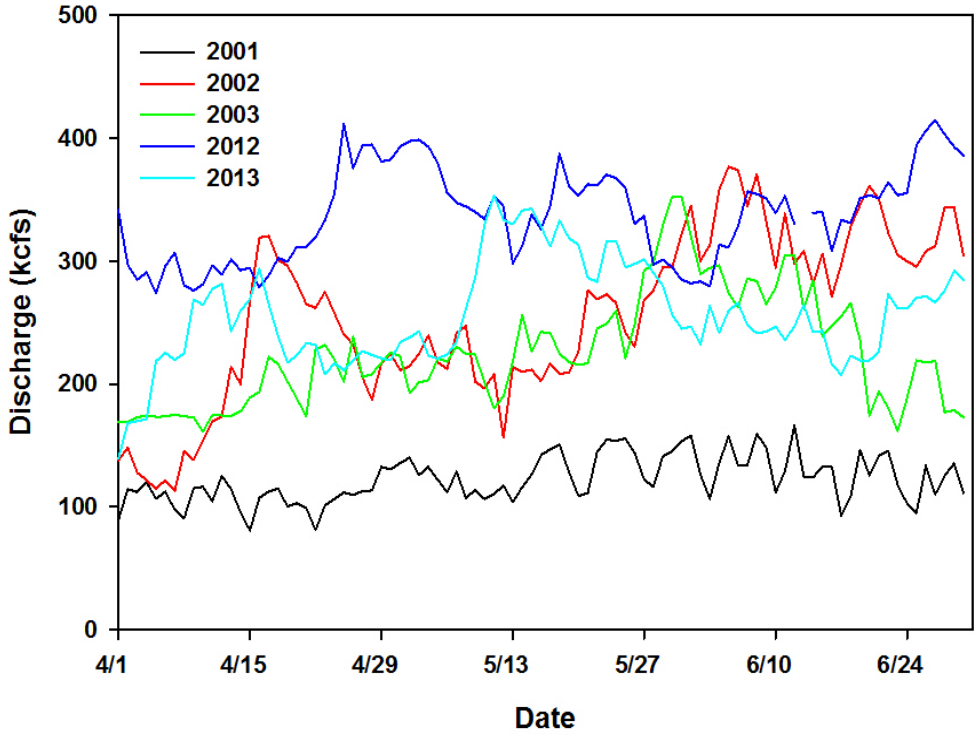

Figure 4.1. Total daily discharge (kcfs) from McNary Dam in years that steelhead kelt telemetry studies occurred in the Federal Columbia River Power System.

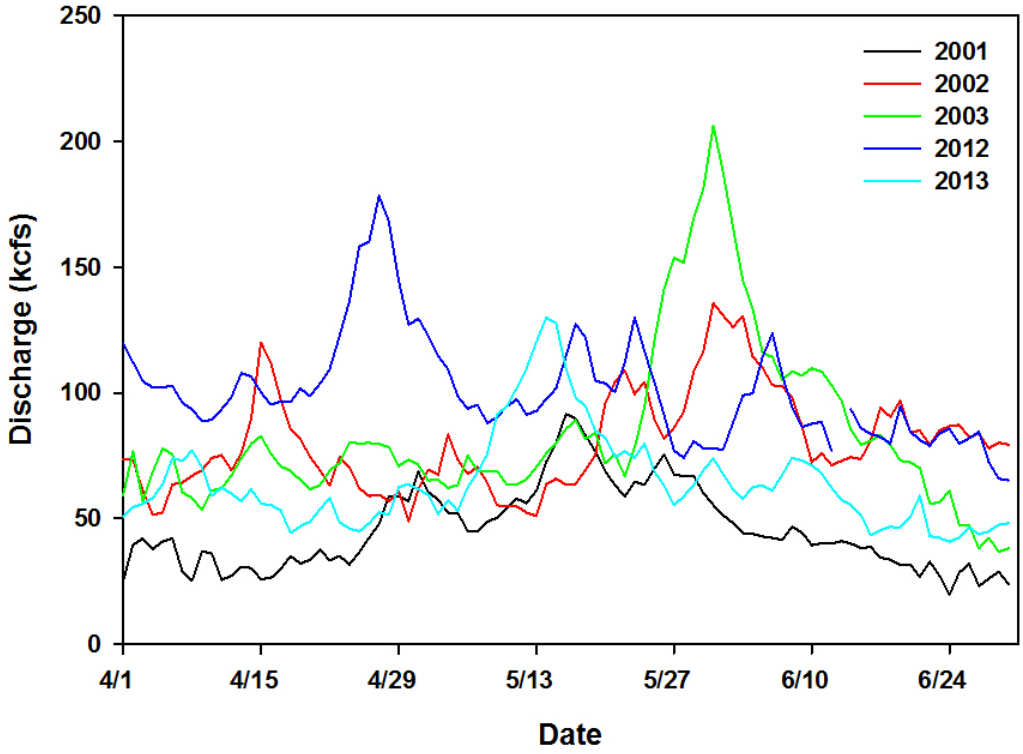

Figure 4.2. Total daily discharge (kcfs) from Lower Granite Dam in years that steelhead kelt telemetry studies occurred in the Federal Columbia River Power System.

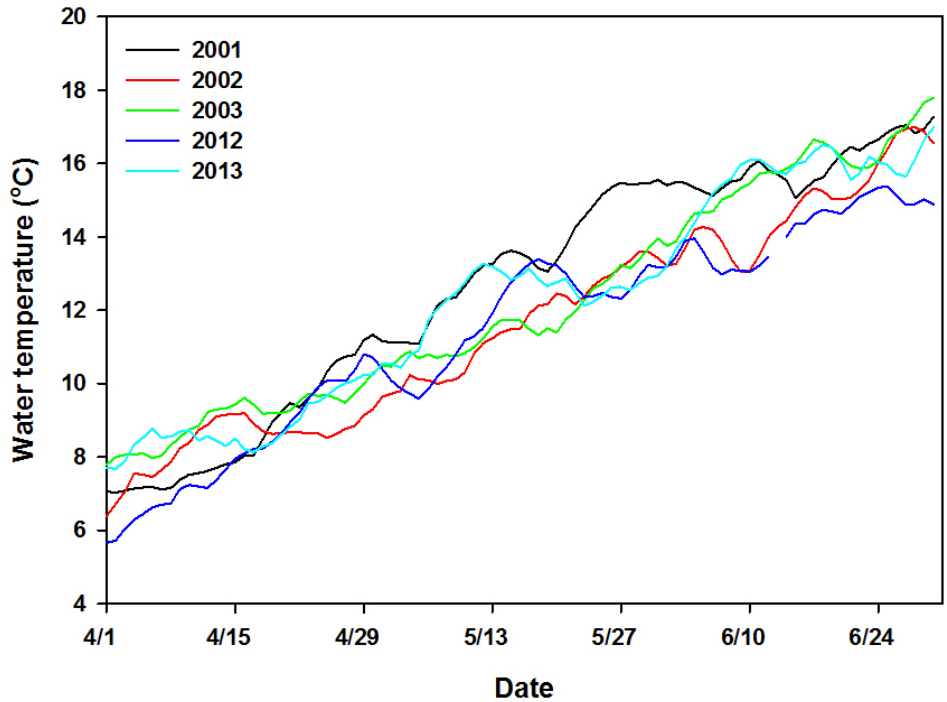

Figure 4.3. Daily temperatures (ºC) recorded at McNary Dam in years that steelhead kelt telemetry studies occurred in the Federal Columbia River Power System.

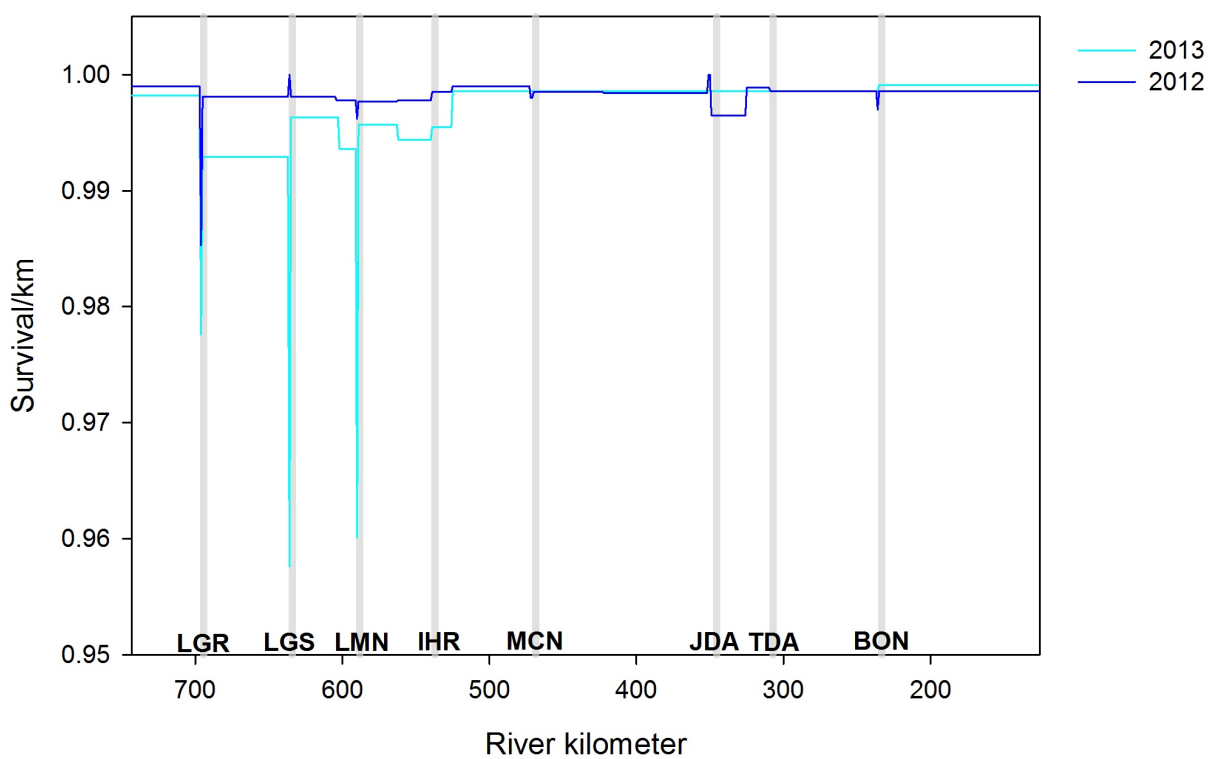

Figure 4.4. Standardized reach survival probability estimates for all tagged steelhead kelts detected in the Federal Columbia River Power System in 2012 (dark blue) and 2013 (light blue).

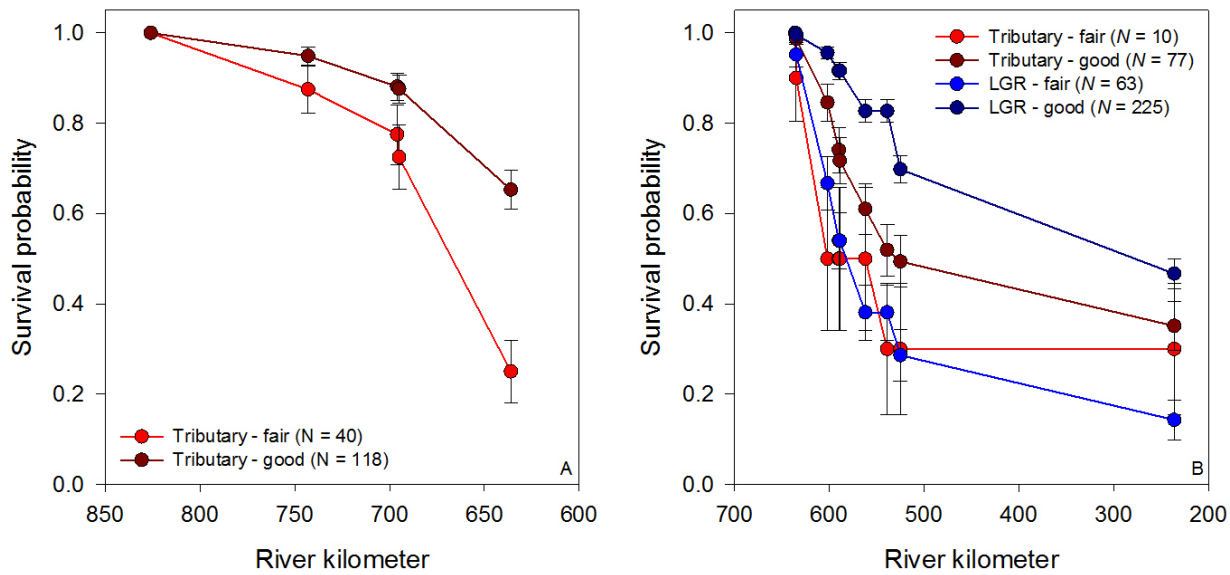

Figure 4.5. (A) Cumulative survival estimates from release to the forebay of Little Goose Dam (rkm 636) for good (dark red) and fair (red) condition kelts tagged in the tributaries of the Snake and Clearwater rivers in 2013. Kelts were tagged and released in multiple tributaries. The arithmetic mean of the tributary weir releases (rkm 826) was used to represent the starting point for all kelts tagged in the tributaries. (B) Cumulative survival estimates from the forebay of Little Goose Dam (rkm 636) to the forebay of Bonneville Dam (rkm 236) for good and fair condition kelts tagged in the tributaries (dark red and red) and at the Lower Granite Dam Juvenile Fish Facility (LGR; dark blue and blue) in 2013.

4.3 Passage Proportions and Route-Specific Survival

Spillway routes (spillway weirs and traditional spillways) were the most commonly used route of kelt passage at LGR, LGS, and LMN in 2013, which is similar to the results obtained during previous studies of kelt passage at Snake and Columbia river dams (Wertheimer and Evans 2005; Wertheimer 2007; Colotelo et al. 2013; Table 4.2). The percentage of kelts that used the weirs was even higher in 2013, particularly at LGR where the percentage increased from 57% in 2012 to 80% in 2013. A 10% increase was observed from 2012 to 2013 at LGS where spillway weir use was 61% in 2012 and 71% in 2013. Spillway weir use was similar at LMN in 2012 (68%) and 2013 (71%). The next most-commonly used route of kelt passage at all three dams was through traditional spill routes, which is consistent with 2012 results (Table 4.2). However, the percentage of kelts that passed through traditional spill routes decreased from 2012 levels at all three dams: from 26% to 13% at LGR, 25% to 16% at LGS, and 21% to 16% at LMN. Similar to previous studies, a relatively small percentage of kelts passed through the powerhouse at the dams (Wertheimer and Evans 2005; Wertheimer 2007; Colotelo et al. 2013). The percentage of kelts that passed through the turbines decreased at LGR from 7% in 2012 to 1% in 2013. One reason for this may have been the prototype overflow weir that was tested in unit 5 in 2013. Of the four kelts that entered unit 5, three (75%) were guided into the JBS. In comparison, none of the kelts (n = 2) that entered unit 5 in 2012 were guided into the JBS. The percentage of kelts that passed through the turbines remained similar at LGS (5% in both 2012 and 2013) and increased at LMN from 5% in 2012 to 7% in 2013 (Table 4.2). The percentage that passed through the JBS was lower in 2013 than we observed in

2012 at all three dams. Similar to 2012, LGS had the highest percentage of JBS passage of the three dams and LGR again had the lowest.

The amount of discharge through each route may have affected the dam passage distribution of kelts at the Snake River dams in 2012 and 2013. The percentage of discharge passed by the spillway weirs during the study period was higher in 2013 at all three dams than it was in 2012. As mentioned previously, a greater percentage of kelts passed all three dams via the spillway weirs in 2013 than in 2012. A similar trend was observed for traditional spill routes at LGR and LGS: a higher percentage of discharge through traditional spill routes correlated with a higher percentage of kelts passing through those routes in 2012 than in 2013. The opposite trend was observed in both years for powerhouse passage at all three dams: a larger percentage of kelts passed through the powerhouse when the percentage of discharge that passed through the powerhouse was lower.

Dam passage survival, which included a rather lengthy river reach downstream of each dam (27 to 59 km), differed by route of passage. At LGR, too few kelts (n = 9) passed through the powerhouse to provide a reasonable evaluation of survival for turbine- or JBS-passed fish. However, survival probabilities for kelts that passed the spillway were low through both traditional spill (0.71) and spillway weir (0.67) routes in 2013. These results are in sharp contrast to those obtained in 2012 when the probability of survival was 0.91 and 0.90 through LGR traditional spill and spillway weir routes, respectively. It is possible that the higher percentage of fair condition fish tagged in the tributaries in 2013 contributed to the lower dam passage survival observed at LGR in 2013. An evaluation of route-specific survival by condition revealed that the high proportion of fair condition fish introduced a relatively small bias on route-specific survival estimates at LGR. Although fair condition fish had substantially lower survival through all routes, survival of good condition kelts was still considerably lower through traditional spill (0.77) and spillway weir (0.76) routes in 2013 compared to 2012 (Table 4.3). These estimates are also relatively low compared to those observed at LGS and LMN, where dam passage survival was highest in 2012 and 2013 for kelts that passed via the spillway weir or the JBS. However, survival through all routes (except the turbines) was lower at both dams in 2013 than it was in 2012. The difference in turbine survival may be more apparent than real, due to the small sample size of turbine-passed fish at both dams in both years.

Table 4.2. The percentage and route-specific survival (± SE) estimates of tagged kelts that passed through Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams during the 2012 and 2013 seasons. Single-release survival estimates were based on pooled data for each major route of passage (i.e., traditional spill, spillway weir, turbine, juvenile bypass system [JBS]) at each dam.

		2012						2013					
Dam	Measure	n	Traditional Spill	Spillway Weir	Turbine	JBS	Unknown	n	Traditional Spill	Spillway Weir	Turbine	JBS	Unknown
LGR	Passage percentage	124	25.8%	57.3%	6.5%	5.6%	4.8%	144	12.5%	79.9%	1.4%	4.9%	1.4%
	Survival (SE)		0.906 (0.052)	0.901 (0.035)	0.875 (0.117)	0.857 (0.132)	0.833 (0.152)		0.706 (0.111)	0.667 (0.046)	0.750 (0.217)	0.250 (0.217)	0.000 (0.000)
LGS	Passage percentage	288	24.7%	60.8%	4.5%	10.1%	0.0%	359	15.9%	71.0%	5.3%	6.7%	1.1%
	Survival (SE)		0.943 (0.028)	0.967 (0.014)	0.779 (0.119)	0.966 (0.034)	–		0.821 (0.051)	0.936 (0.016)	0.842 (0.084)	0.875 (0.068)	1.000 (0.000)
LMN	Passage percentage	258	20.5%	68.0%	4.6%	6.9%	0.0%	294	16.0%	71.1%	6.8%	5.4%	0.7%
	Survival (SE)		0.926 (0.036)	0.983 (0.010)	0.583 (0.142)	1.000 (0.000)	–		0.826 (0.056)	0.927 (0.018)	0.842 (0.084)	0.938 (0.061)	0.500 (0.354)

Table 4.3. The percentage and route-specific survival (± SE) estimates of fair and good condition kelts that passed through Lower Granite Dam (LGR) during the 2013 season. Single-release survival estimates were based on pooled data for each major route of passage (i.e., traditional spill, spillway weir) and powerhouse routes (i.e., turbine, juvenile bypass system) were combined due to low sample sizes.

		Fair				Good			
Dam	Measure	*n*	Traditional Spill	Spillway Weir	Powerhouse	*n*	Traditional Spill	Spillway Weir	Powerhouse
LGR	Passage percentage	29	13.8%	75.9%	10.3%	101	12.9%	82.2%	5.0%
	Survival (SE)		0.500 (0.250)	0.318 (0.099)	0.333 (0.272)		0.769 (0.117)	0.759 (0.047)	0.600 (0.219)

4.4 Travel Rates

Travel rates of downstream-migrating salmonids can influence their migration and survival through a river system. This is particularly important in hydropower-influenced river systems because dams have been shown to reduce migration rates (Raymond 1969, 1979). Delays in migration can expose kelts to high water temperatures, increase the risk of predation, and deplete limited energy stores that are required for successful emigration to the ocean. This is particularly important for kelts, which have depleted energy stores because of recent spawning activity. Overall, the travel rates observed in this study follow similar trends to those reported from the 2012 FCRPS kelt passage study (Colotelo et al. 2013). The results from 2013 show a median travel rate of 48.3 km/day for tagged kelts that migrated from the LGR tailrace (rkm 693) to below BON (rkm 126). In 2012, tagged kelts migrated from the LGR tailrace (rkm 693) to the BON tailrace (rkm 233) at a median travel rate of 51.3 km/day (Colotelo et al. 2013). These travel rates are faster than those reported by Wertheimer and Evans (2005) from their 2001 and 2002 studies (19.0 and 27.3 km/day, respectively). The results of the 2012 (Colotelo et al. 2013) and 2013 studies support the idea presented by Wertheimer and Evans (2005) that river discharge is positively associated with the travel rates of kelts. In 2002 and 2012, the travel rates and mean river discharge were higher than in 2001 and 2013. Overall, the travel rates of kelts observed in 2012 and 2013 were both greater than those observed in 2001 and 2002 (Wertheimer and Evans 2005). However, the mean river discharge at LGR was not consistently higher in 2012 (101.5 kcfs) and 2013 (66.0 kcfs) compared to 2001 (47.3 kcfs) and 2002 (85.6 kcfs; Figure 4.2). In fact, travel rates observed in 2012 and 2013 were nearly double those from 2001 and 2002. These results suggest that other factors influence kelt migration rates. Dam configurations and operations have changed in the FCRPS in the years between 2002 and 2012 (e.g., installation of spillway weirs, court–ordered spill program), and these changes likely also contributed to the higher migration rates observed in recent years.

In 2013, we found similar ($P > 0.05$) forebay residence times compared to those reported in the 2012 study at all three Snake River dams. At LGS and LMN, project passage times were also similar between 2012 and 2013; however, we did observe a longer median project passage time in 2013 compared to 2012 at LGR (Mann-Whitney rank sum test, $P < 0.01$). In addition, we found longer tailrace egress times in 2013 when compared with 2012 results at all three dams (Mann-Whitney rank sum test, $P < 0.001$). As mentioned previously, mean river discharge was higher in 2012 than in 2013 and may have been

associated with differences in tailrace egress times and LGR project passage times between years; but there does not appear to be a distinct pattern in tailrace egress time throughout the duration of the study period (Figure 4.6).

4.5 Population Abundance

Using the number of tagged and untagged kelts sampled in the LGR JFF and the proportion of kelts tagged with acoustic transmitters that passed LGR through the JBS, we estimated 19,630 kelts passed LGR in 2013. This population abundance was comprised of an estimated 11,811 unclipped and 7,819 adipose-clipped steelhead kelts. From the Lincoln-Petersen method, the unclipped kelt population abundance at the time of tagging was estimated to be 14,022 (SE = 4,567). Multiplying this estimate by the pooled survival probability from release to LGR of all tributary groups (0.838), we obtained an estimate of 11,750 unclipped kelts, which substantiates the estimate we obtained using the JBS passage proportion.

Our estimate of 19,630 marked and unmarked kelts that passed LGR in 2013 is 49% of the number of kelts we estimated to have passed LGR in 2012 (N = 39,910; Colotelo et al. 2013). This difference between years is comparable to the difference observed in the numbers of adipose-clipped and unclipped adult steelhead counted passing LGR on their way to the spawning grounds in 2011 and 2012 when 183,648 and 110,675 passed LGR, respectively (Fish Passage Center; www.fpc.org). Based on these numbers alone, we would expect there to be about 40% fewer kelts returning to LGR in 2013 compared to 2012 (if all other conditions were similar between years) since there were 40% fewer steelhead adults that migrated above LGR. However, as mentioned previously, river conditions were less favorable (lower discharge, warmer water temperatures) in 2013 than in 2012, which may have contributed to the lower percentage of steelhead that returned to LGR as kelts in 2013.

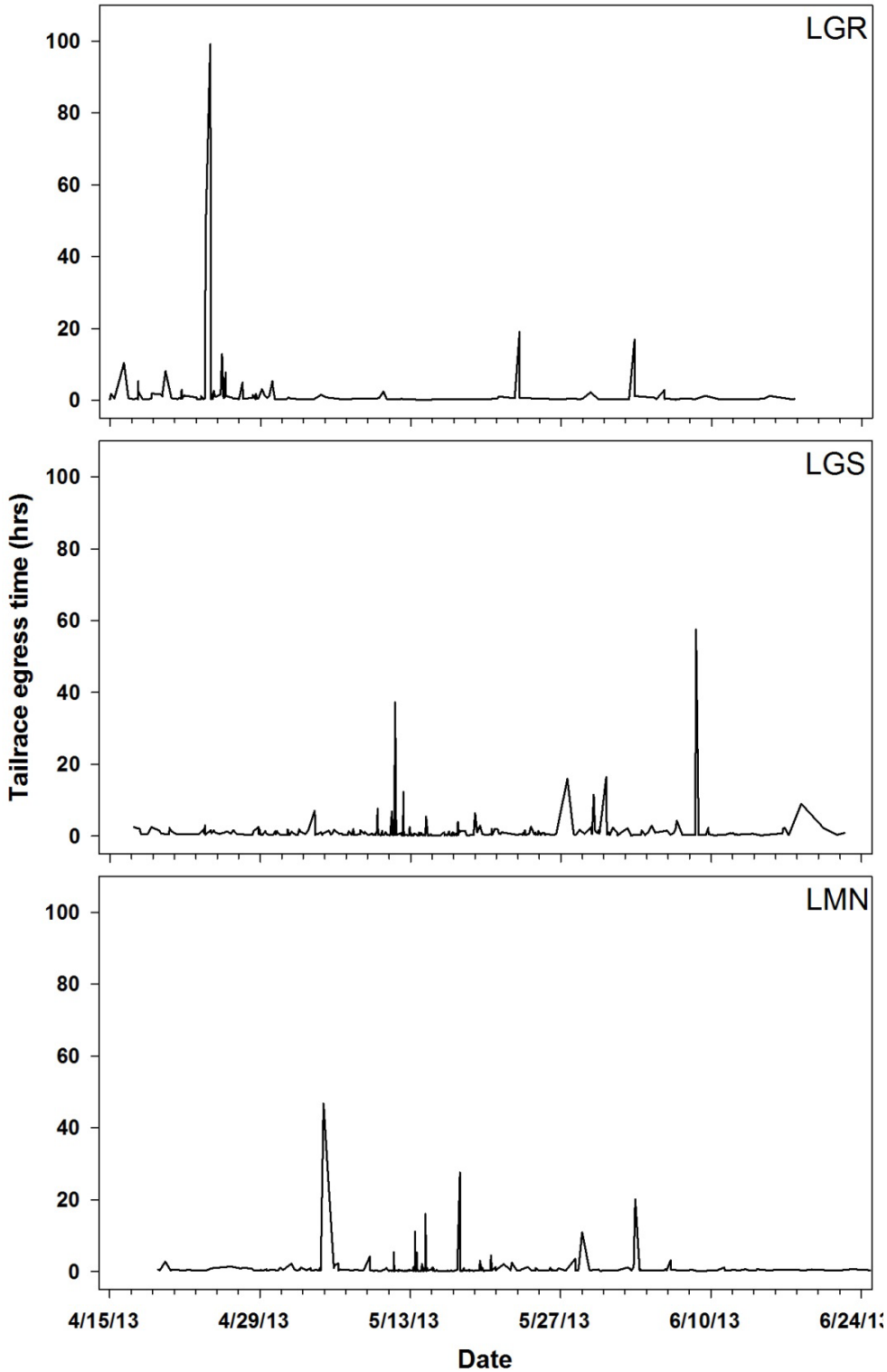

Figure 4.6. Tailrace egress time (hours) of steelhead kelts that passed Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams over time in 2013.

4.6 Conclusions

The results of this study provide information about the migration success, survival, route of passage, and route-specific survival for steelhead kelts that migrated through the Snake and Columbia rivers from Snake River tributaries to BON in 2013. This was the second year of a study conducted to measure these metrics since the installation of spillway weirs at many FCRPS dams. Migration success and survival was highest in 2012, and survival was generally higher and travel rates were faster for Snake River kelts in 2013 compared to the results obtained in 2001 and 2002. Spillway weirs were again the primary route of passage for steelhead kelts in the Snake River. Spillway weirs and the JBSs generally provided the highest estimated dam passage survival for steelhead kelts. We observed a decline in estimated survival through traditional deep spill routes from results obtained in 2012. In fact, survival was lowest through traditional spill routes at LGS and LMN. JBS- and turbine-specific survival estimates should be interpreted with caution, particularly at LGR, because of low sample sizes. Discharge was lower, water temperature was generally higher, and a higher proportion of the tagged kelts were in fair condition in 2013 compared to 2012. These factors may have contributed to the lower survival and slower travel rates observed in 2013.

The results of this two-year study have contributed to the understanding of the effects of FCRPS dams on the migration and survival of steelhead kelts in the Snake and Columbia rivers. However, additional analyses of data collected during this study may provide further insight into the conditions (e.g., dam operations) that optimize dam passage (i.e., route, travel time, and survival). Future field studies should focus on sampling over the full seaward-migration period and include additional tributaries of the Snake River to include a broader section of the Snake River steelhead population.

5.0 References

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Appendix A

Hydrophone and Autonomous Node Deployment Tables and Locations of Fish Collection Sites

Appendix A

Hydrophone and Autonomous Node Deployment Tables and Locations of Fish Collection Sites

Table A.1. Cabled hydrophone locations at Lower Granite Dam in 2013. Hydrophones were deployed on 7 March 2013.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
S08S	46.65998667	-117.4286809	722.6	Spillway
S08D	46.65998667	-117.4286809	695.3	
S07 08S	46.65984214	-117.4288243	722.6	
S07 08D	46.65984214	-117.4288243	695.4	
S06 07S	46.65969717	-117.4289683	722.7	
S06 07D	46.65969717	-117.4289683	695.7	
S05 06S	46.65955209	-117.4291110	722.9	
S05 06D	46.65955209	-117.4291110	695.8	
S04 05S	46.65940624	-117.4292554	722.9	
S04 05D	46.65940624	-117.4292554	695.8	
S03 04S	46.65926284	-117.4293973	727.3	
S03 04D	46.65926287	-117.4293973		
S02 03S	46.65911294	-117.4295452	722.8	
S02 03D	46.65911294	-117.4295452	695.5	
RSW S 01	46.65854941	-117.4292647	618.2	Spillway weir approach
RSW S 02	46.65856943	-117.4292301	618.2	
RSW S 03	46.65857960	-117.4292731	618.2	
RSW S 04	46.65856619	-117.4292560	623.6	
P06S	46.65868149	-117.4298670	723.4	Powerhouse
P06 D	46.65866020	-117.4298218	639.1	
P05 06S	46.65848276	-117.4300641	723.4	
P05 06D	46.65846147	-117.4300188	639.1	
P04 05S	46.65827777	-117.4302663	723.4	
P04 05D	46.65825648	-117.4302211	639.2	
P03 04S	46.65807321	-117.4304676	722.7	
P03 04D	46.65805192	-117.4304223	638.5	
P02 03S	46.65787033	-117.4306678	723.0	
P02 03D	46.65784913	-117.4306226	638.8	
P01 02S	46.65766579	-117.4308698	723.0	
P01 02D	46.65764450	-117.4308244	638.7	
P00 01S	46.65746829	-117.4310725	723.1	
P00 01D	46.65744690	-117.4310270	638.6	

Table A.2. Cabled hydrophone locations at Little Goose Dam in 2013. Hydrophones were deployed on 31 March 2013.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
S08S	46.58616543	-118.0273789	624.0	Spillway
S08D	46.58616543	-118.0273789	596.9	
S07 08S	46.58599119	-118.0273299	623.7	
S0 08D	46.58599119	-118.0273299	597.0	
S06 07S	46.58581759	-118.0272810	623.9	
S06 07D	46.58581759	-118.0272810	597.0	
S05 06S	46.58564690	-118.0272337	624.0	
S05 06D	46.58564690	-118.0272337	597.1	
S04 05S	46.58547392	-118.0271846	624.0	
S04 05D	46.58547392	-118.0271846	597.0	
S03 04S	46.58530149	-118.0271363	624.1	
S03 04D	46.58530149	-118.0271363	597.2	
S02 03S	46.58512963	-118.0270884	623.8	
S02 03D	46.58512963	-118.0270884	596.9	
S01 02S	46.58495583	-118.0270391	622.5	
S01 02D	46.58495583	-118.0270391	595.4	
S01S	46.58478224	-118.0269909	624.3	
S01D	46.58478224	-118.0269909	597.2	
P06S	46.58467372	-118.0268723	622.9	Powerhouse
P06D	46.58468104	-118.0268229	539.8	
P05 06S	46.58443168	-118.0268053	623.4	
P05 06D	46.58443898	-118.0267560	540.4	
P04 05S	46.58419034	-118.0267375	623.5	
P04 05D	46.58419772	-118.0266880	540.1	
P03 04S	46.58394647	-118.0266694	623.5	
P03 04D	46.58395377	-118.0266201	540.5	
P02 03S	46.58370405	-118.0266013	623.4	
P02 03D	46.58371143	-118.0265519	540.3	
P01 02S	46.58346188	-118.0265329	623.1	
P01 02D	46.58346926	-118.0264836	540.2	
P00 01S	46.58321938	-118.0264624	623.5	
P00 01D	46.58322679	-118.0264129	540.4	
FLS	46.58292047	-118.0263206	626.4	Fish ladder

Table A.3. Cabled hydrophone locations at Lower Monumental Dam in 2013. Hydrophones were deployed on 31 March 2013.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
FLN	46.56455186	-118.5401841	531.1	North fish ladder
P00 01S	46.56418889	-118.5396474	527.3	Powerhouse
P00 01D	46.56420973	-118.5396080	443.3	
P01 02S	46.56400256	-118.5394456	527.3	
P01 02D	46.56402340	-118.5394062	443.4	
P02 03S	46.56380569	-118.5392326	527.2	
P02 03D	46.56382662	-118.5391931	443.1	
P03 04S	46.56360717	-118.5390175	527.2	
P03 04D	46.56362800	-118.5389782	443.2	
P04 05S	46.56340984	-118.5388042	527.3	
P04 05D	46.56343068	-118.5387648	443.3	
P05 06S	46.56321168	-118.5385895	527.4	
P05 06D	46.56323260	-118.5385501	443.3	
P06S	46.56301499	-118.5383762	527.4	
P06D	46.56303591	-118.5383368	443.4	
RSW N 01	46.56323363	-118.5377934	425.7	Spillway weir approach
RSW N 02	46.56324192	-118.5377768	430.0	
RSW N 03	46.56323932	-118.5377650	423.7	
RSW N 04	46.56325183	-118.5377829	424.7	
RSW S 01	46.56300257	-118.5376657	429.4	
RSW S 02	46.56302216	-118.5376618	428.4	
RSW S 03	46.56301586	-118.5376513	433.6	
RSW S 04	46.56301395	-118.5376419	428.7	
S06 07S	46.56261439	-118.5380490	526.8	Spillway
S06 07D	46.56261439	-118.5380490	497.9	
S05 06S	46.56247364	-118.5378969	526.8	
S05 06D	46.56247364	-118.5378969	498.0	
S04 05S	46.56233307	-118.5377448	526.8	
S04 05D	46.56233307	-118.5377448	497.9	
S03 04S	46.56219314	-118.5375935	526.9	
S03 04D	46.56219314	-118.5375935	498.0	
S02 03S	46.56205257	-118.5374415	526.9	
S02 03D	46.56205257	-118.5374415	497.9	
S01 02S	46.56191116	-118.5372882	526.7	
S01 02D	46.56191116	-118.5372882	497.7	
S00 01S	46.56176912	-118.5371344	526.9	
S00 01D	46.56176912	-118.5371344	498.0	
FLS	46.56159715	-118.5369512	531.3	South fish ladder

Table A.4. Approximate global positioning system coordinates of autonomous hydrophone nodes deployed in the Snake, Clearwater, and Columbia rivers in 2013. Array_Node is a concatenation of array name and autonomous node number. Array name is a concatenation of river name (CR for Columbia River), and rkm from the array to the mouth of the Columbia River. Nodes within each array are generally numbered from the north shore to the south shore. Note: the CR113.0 array was removed on 5/15/2013 after which the CR152 array was deployed on 5/16/2013.

Array_Node	Array Function	Latitude (Degrees North)	Longitude (Degrees West)	rkm	Deployment Date
CR743.0_01	Clearwater mouth	46.4258896	-117.0713279	743	4/11/2013
CR743.0_02		46.42537625	-117.0707588	743	4/11/2013
CR743.0_03		46.42488335	-117.0700750	743	4/11/2013
CR696.0_01	LGR forebay	46.65861708	-117.4151533	696	4/12/2013
CR696.0_02		46.65721583	-117.4165254	696	4/12/2013
CR696.0_03		46.65579375	-117.4176846	696	4/12/2013
CR696.0_04		46.65455753	-117.4186659	696	4/12/2013
CR693.0_01	LGR tailrace	46.67293668	-117.4466009	693	4/12/2013
CR693.0_02		46.67279665	-117.4480759	693	4/12/2013
CR636.0_01	LGS forebay	46.58926112	-118.0168925	636	4/11/2013
CR636.0_02		46.58823972	-118.0162978	636	4/11/2013
CR636.0_03		46.58707195	-118.0156900	636	4/11/2013
CR636.0_04		46.58603083	-118.0155522	636	4/11/2013
CR634.0_01	LGS tailrace	46.58094222	-118.0466570	634	4/11/2013
CR634.0_02		46.58038335	-118.0457789	634	4/11/2013
CR634.0_03		46.57981638	-118.0449525	634	4/11/2013
CR602.0_01	LMN mid res.	46.58176083	-118.3940736	602	4/14/2013
CR602.0_02		46.58067722	-118.3942967	602	4/14/2013
CR602.0_03		46.57979638	-118.3942197	602	4/14/2013
CR602.0_04		46.57872498	-118.3942686	602	4/14/2013
CR590.0_01	LMN forebay	46.56752610	-118.5313650	590	4/14/2013
CR590.0_02		46.56681638	-118.5298903	590	4/14/2013
CR590.0_03		46.56591917	-118.5288292	590	4/14/2013
CR590.0_04		46.56494223	-118.5280095	590	4/14/2013
CR587.0_01	LMN tailrace	46.54741833	-118.5554108	587	4/14/2013
CR587.0_02		46.54660108	-118.5559911	587	4/14/2013
CR587.0_03		46.54699252	-118.5533978	587	4/14/2013
CR562.0_01	IHR mid res.	46.37897138	-118.6953459	562	4/14/2013
CR562.0_02		46.37867030	-118.6943131	562	4/14/2013
CR562.0_03		46.37842778	-118.6932406	562	4/14/2013
CR562.0_04		46.37836110	-118.6922853	562	4/14/2013
CR539.0_01	IHR forebay	46.25282527	-118.8700603	539	4/14/2013
CR539.0_02		46.25178195	-118.8688336	539	4/14/2013
CR539.0_03		46.25126417	-118.8684811	539	4/14/2013
CR539.0_04		46.24986057	-118.8678703	539	4/14/2013
CR525.0_01	Snake mouth	46.21617264	-119.0243824	525	4/14/2013
CR525.0_02		46.21534166	-119.0231703	525	4/14/2013

Table A.4. (contd)

Array_Node	Array Function	Latitude (Degrees North)	Longitude (Degrees West)	rkm	Deployment Date
CR525.0_03		46.21490968	-119.0225910	525	4/14/2013
CR525.0_04		46.21439918	-119.0217961	525	4/14/2013
CR236.0_01	BON forebay	45.65097400	-121.9203458	236	3/13/2013
CR236.0_02		45.65043500	-121.9198845	236	3/13/2013
CR236.0_03		45.64985990	-121.9193207	236	3/13/2013
CR236.0_04		45.64932090	-121.9188595	236	3/13/2013
CR152.0_01	CR at km 152	45.75221670	-122.7590167	152	5/16/2013
CR152.0_02		45.75200000	-122.7599833	152	5/16/2013
CR152.0_03		45.75176660	-122.7610000	152	5/16/2013
CR152.0_04		45.75156670	-122.7621167	152	5/16/2013
CR152.0_05		45.75131660	-122.7633500	152	5/16/2013
CR152.0_06		45.75100000	-122.7647000	152	5/16/2013
CR152.0_07		45.75071670	-122.7659167	152	5/16/2013
CR152.0_08		45.75039997	-122.7672500	152	5/16/2013
CR126.0_01	CR at km 126	45.97245000	-122.8251833	126	4/4/2013
CR126.0_02		45.97235000	-122.8258000	126	4/4/2013
CR126.0_02		45.97225000	-122.8260500	126	4/25/2013
CR126.0_03		45.97185000	-122.8261833	126	4/4/2013
CR126.0_04		45.97135000	-122.8269833	126	4/4/2013
CR126.0_05		45.97055000	-122.8276000	126	4/4/2013
CR126.0_06		45.97010000	-122.8284000	126	4/4/2013
CR126.0_07		45.96996670	-122.8294500	126	4/4/2013
CR126.0_08		45.96961670	-122.8301500	126	4/4/2013
CR113.0_01	CR at km 113	46.05613700	-122.8727154	113	4/4/2013
CR113.0_02		46.05933330	-122.8806833	113	4/4/2013
CR113.0_03		46.05933330	-122.8820167	113	4/4/2013
CR113.0_04		46.05916670	-122.8831167	113	4/4/2013
CR113.0_04		46.05803300	-122.8829300	113	4/29/2013
CR113.0_05		46.05911670	-122.8841000	113	4/4/2013
CR113.0_05		46.05785000	-122.8841670	113	4/29/2013
CR113.0_06		46.05903330	-122.8851500	113	4/4/2013
CR113.0_07		46.05890000	-122.8860833	113	4/4/2013
CR113.0_08		46.05878330	-122.8871167	113	4/4/2013
CR113.0_09		46.05865000	-122.8881333	113	4/4/2013
CR113.0_10		46.05851670	-122.8891000	113	4/4/2013

Table A.5. Approximate global positioning system coordinates of sites where steelhead kelts were collected for tagging in 2013.

Location	Latitude (Degrees North)	Longitude (Degrees West)	rkm
Lower Granite Dam juvenile fish facility	46.66011900	-117.4358080	695
Asotin Creek weir	46.32559167	-117.1074806	761
George Creek weir	46.31342500	-117.1113611	762
Potlatch River weir	46.79846670	-116.4193083	836
Joseph Creek weir	46.02762778	-117.0178944	804
Fish Creek weir	46.33928611	-115.3539583	944

Appendix B

Steelhead Kelt Data Collected at Tagging

Table B.1. Data collected at tagging from the steelhead kelts included in this study. Information includes tagging site (LGR = Lower Granite Dam, ASO = Asotin Creek, PEW = Potlatch River, JOS = Joseph Creek, FC = Fish Creek), PIT-tag code, JSATS tag code, condition, sex, status of the adipose fin, length, weight, release date, and the release rkm as measured from the mouth of the Columbia River).

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Clipped/Intact)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DDBF829	G722990C2	Fair	Female	Clipped	60.0	1.70	4/13/2013	695
LGR	3D9.1C2DB0BE4A	G720A3245	Fair	Female	Intact	57.0	1.20	4/14/2013	695
LGR	3D9.1C2D240B13	G721657BE	Fair	Female	Intact	68.0	2.19	4/14/2013	695
LGR	3D9.1C2DDC1C10	G72105375	Fair	Female	Clipped	69.0	2.58	4/14/2013	695
LGR	3D9.1C2DDC16D3	G72299D3F	Good	Female	Intact	59.0	1.59	4/16/2013	695
LGR	3D9.1C2D4755FE	G7209DDB8	Good	Female	Intact	62.0	1.87	4/17/2013	695
LGR	3D9.1C2D483E09	G72155D95	Good	Female	Intact	68.0	2.16	4/17/2013	695
LGR	3D9.1C2DDB8D96	G721516F3	Good	Female	Intact	67.0	2.27	4/19/2013	695
LGR	3D9.1C2DDBCACC	G721137B5	Good	Female	Intact	72.0	2.70	4/22/2013	695
LGR	3D9.1C2DDBCCF4	G7210F7BB	Good	Female	Clipped	79.0	3.40	4/22/2013	695
LGR	3D9.1C2DDBC0F7	G7209FD9B	Fair	Female	Intact	64.0	1.77	4/23/2013	695
LGR	3D9.1C2DDBD70C	G7216747F	Fair	Female	Intact	58.0	1.39	4/23/2013	695
LGR	3D9.1C2DDBF196	G7208DD7C	Good	Female	Clipped	65.0	1.72	4/23/2013	695
LGR	3D9.1C2DDC22A5	G7215D978	Fair	Female	Intact	67.0	2.11	4/24/2013	695
LGR	3D9.1C2DDBBFCF	G720A9056	Fair	Female	Clipped	65.0	2.04	4/24/2013	695
LGR	3D9.1C2DDBAFAF	G7216107B	Fair	Female	Clipped	79.0	3.47	4/24/2013	695
LGR	3D9.1C2DDBA102	G72097637	Good	Female	Intact	73.0	2.69	4/25/2013	695
LGR	3D9.1C2DDBA813	G72181865	Good	Male	Intact	61.0	1.82	4/25/2013	695
LGR	3D9.1C2D48629A	G7208CE03	Fair	Male	Intact	58.0	1.46	4/26/2013	695
LGR	3D9.1C2D4899A3	G72124C38	Good	Female	Intact	58.0	1.32	4/26/2013	695
LGR	3D9.1C2DDBCA49	G72164342	Fair	Female	Intact	71.0	2.33	4/26/2013	695
LGR	3D9.1C2DE8CB2D	G7218761F	Fair	Female	Clipped	68.0	2.23	4/26/2013	695
LGR	3D9.1C2DDBDBE3	G7210B39C	Fair	Female	Clipped	78.0	3.75	4/27/2013	695
LGR	3D9.1C2DDC0176	G72110FC9	Good	Female	Clipped	53.0	1.03	4/27/2013	695
LGR	3D9.1C2DDBBEDD	G7215FF86	Good	Male	Intact	59.0	1.67	4/28/2013	695
LGR	3D9.1C2DDC1E40	G72114613	Fair	Female	Clipped	71.0	2.57	4/28/2013	695
LGR	3D9.1C2DDBA2FC	G72176F06	Fair	Female	Clipped	77.0	3.36	4/28/2013	695
LGR	3D9.1C2DDBF7CB	G721811F9	Fair	Female	Clipped	69.0	2.68	4/28/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2D483BDC	G72094896	Fair	Female	Intact	70.0	2.37	4/29/2013	695
LGR	3D9.1C2DDB98AB	G722A4ABE	Good	Male	Intact	64.0	1.97	4/29/2013	695
LGR	3D9.1C2DDBF3D0	G722A5680	Good	Male	Intact	69.0	2.35	4/29/2013	695
LGR	3D9.1C2DE21D6E	G720F57E0	Good	Female	Clipped	77.0	3.22	4/29/2013	695
LGR	3D9.1C2DDBE543	G720FD30D	Good	Female	Clipped	68.0	2.13	4/29/2013	695
LGR	3D9.1C2DDC226F	G7212B632	Fair	Female	Clipped	69.0	2.17	4/29/2013	695
LGR	3D9.1C2DDC1E93	G7212E455	Good	Female	Intact	55.0	1.14	4/30/2013	695
LGR	3D9.1C2DDBD953	G722A13F9	Good	Female	Intact	59.0	1.34	4/30/2013	695
LGR	3D9.1C2DDBB303	G72097828	Good	Female	Clipped	55.0	1.19	4/30/2013	695
LGR	3D9.1C2DDC2278	G720AEB8E	Good	Female	Clipped	78.0	3.67	4/30/2013	695
LGR	3D9.1C2DE1D035	G72094F15	Good	Female	Intact	58.0	1.52	5/1/2013	695
LGR	3D9.1C2D4775DC	G720A4460	Fair	Female	Intact	74.0	2.68	5/1/2013	695
LGR	3D9.1C2DDBEBE7	G72176119	Fair	Female	Intact	84.0	4.07	5/1/2013	695
LGR	3D9.1C2DDBF31C	G72178932	Good	Female	Intact	55.0	1.24	5/1/2013	695
LGR	3D9.1C2DDC135E	G7217950C	Fair	Male	Intact	62.0	1.66	5/1/2013	695
LGR	3D9.1C2DDBE578	G7217E616	Good	Male	Intact	65.0	2.18	5/1/2013	695
LGR	3D9.1C2DDBE349	G72089F86	Good	Female	Clipped	61.0	1.55	5/1/2013	695
LGR	3D9.1C2DDBEA30	G720FF270	Good	Female	Clipped	65.0	2.06	5/1/2013	695
LGR	3D9.1C2DDBCF4D	G72101C72	Good	Female	Clipped	67.0	2.27	5/1/2013	695
LGR	3D9.1C2DE1B4C0	G72109E42	Fair	Female	Clipped	80.0	3.39	5/1/2013	695
LGR	3D9.1C2DDC18E0	G7211FD01	Good	Female	Clipped	68.0	2.27	5/1/2013	695
LGR	3D9.1C2DDB91A2	G720A42BD	Fair	Female	Intact	56.0	1.26	5/2/2013	695
LGR	3D9.1C2DB1B19E	G720EC874	Fair	Female	Intact	76.0	3.06	5/2/2013	695
LGR	3D9.1C2DE1FBA9	G72111989	Good	Male	Intact	59.0	1.51	5/2/2013	695
LGR	3D9.1C2DDB9256	G7211C57D	Fair	Male	Intact	55.0	1.32	5/2/2013	695
LGR	3D9.1C2DDC016B	G72084372	Good	Female	Clipped	58.0	1.64	5/2/2013	695
LGR	3D9.1C2DDC02C7	G720B13FC	Good	Female	Clipped	67.0	2.26	5/2/2013	695
LGR	3D9.1C2DE19D44	G721232DF	Good	Female	Clipped	59.0	1.50	5/2/2013	695
LGR	3D9.1C2DDC17B8	G7212A7F1	Fair	Female	Clipped	80.0	3.73	5/2/2013	695
LGR	3D9.1C2DDBEA63	G7217BF51	Fair	Female	Clipped	71.0	2.63	5/2/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DDBA2CC	G720F7A3E	Good	Male	Intact	76.0	2.94	5/3/2013	695
LGR	3D9.1C2DDC00C7	G7229A7FF	Good	Female	Intact	58.0	1.36	5/3/2013	695
LGR	3D9.1C2DDC0F14	G7208E7BC	Good	Female	Clipped	56.0	1.12	5/3/2013	695
LGR	3D9.1C2DDC064B	G720942E8	Good	Female	Clipped	74.0	2.63	5/3/2013	695
LGR	3D9.1C2DDBF335	G720A0E58	Fair	Female	Clipped	68.0	2.17	5/3/2013	695
LGR	3D9.1C2DDC04A1	G720AE0AE	Good	Female	Clipped	55.0	1.12	5/3/2013	695
LGR	3D9.1C2DDBBA31	G721213A2	Good	Female	Clipped	63.0	1.78	5/3/2013	695
LGR	3D9.1C2DDBB2B2	G721454CD	Good	Female	Clipped	81.0	3.34	5/3/2013	695
LGR	3D9.1C2DDBDBCB	G72120183	Good	Female	Intact	62.0	1.75	5/4/2013	695
LGR	3D9.1C2DCE95F7	G72178212	Good	Female	Intact	66.0	1.81	5/4/2013	695
LGR	3D9.1C2DDBDBE1	G7217CA96	Good	Male	Intact	58.0	1.30	5/4/2013	695
LGR	3D9.1C2DDBBFAB	G721238A1	Good	Female	Clipped	58.0	1.15	5/4/2013	695
LGR	3D9.1C2DDB986B	G721678DC	Good	Female	Clipped	71.0	2.37	5/4/2013	695
LGR	3D9.1C2DDBE6EB	G720837EB	Good	Female	Intact	64.0	1.56	5/5/2013	695
LGR	3D9.1C2DE1C219	G720F7CE3	Good	Female	Clipped	66.0	2.25	5/5/2013	695
LGR	3D9.1C2DE213A0	G7210D8D9	Fair	Female	Clipped	84.0	4.30	5/5/2013	695
LGR	3D9.1C2DDBF3DD	G72130F58	Fair	Female	Clipped	55.0	1.22	5/5/2013	695
LGR	3D9.1C2DDBA4D2	G720929AD	Good	Female	Intact	60.0	1.70	5/6/2013	695
LGR	3D9.1C2DDBD5AD	G7211C423	Good	Female	Intact	59.0	1.40	5/6/2013	695
LGR	3D9.1C2DB08DA4	G7213D88C	Good	Female	Intact	73.0	2.60	5/6/2013	695
LGR	3D9.1C2DDB9B50	G7214A33A	Good	Female	Clipped	65.0	2.00	5/6/2013	695
LGR	3D9.1C2DDB9164	G722A3F79	Fair	Female	Clipped	69.0	2.18	5/6/2013	695
LGR	3D9.1C2DDC0F98	G7208AF38	Good	Female	Intact	56.0	1.31	5/7/2013	695
LGR	3D9.1C2DE20760	G7208B1BA	Fair	Female	Intact	75.0	2.85	5/7/2013	695
LGR	3D9.1C2DD5CECA	G720A8BEB	Good	Male	Intact	77.0	3.47	5/7/2013	695
LGR	3D9.1C2DDBBBE3	G72161125	Good	Male	Intact	61.0	1.61	5/7/2013	695
LGR	3D9.1C2DDC10BB	G722A4EDF	Good	Female	Intact	57.0	1.16	5/7/2013	695
LGR	3D9.1C2DDBA39A	G720B4807	Fair	Female	Clipped	80.0	2.67	5/7/2013	695
LGR	3D9.1C2DDC0177	G720FA528	Fair	Male	Clipped	55.0	1.21	5/7/2013	695
LGR	3D9.1C2DDBA62D	G7210EADB	Good	Male	Clipped	49.0	0.96	5/7/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DE1FB22	G7211036A	Fair	Male	Clipped	61.0	1.92	5/7/2013	695
LGR	3D9.1C2DDBD75A	G72136A02	Good	Female	Clipped	52.0	0.82	5/7/2013	695
LGR	3D9.1C2DDB92E9	G72159340	Good	Female	Clipped	66.0	2.09	5/7/2013	695
LGR	3D9.1C2DDBCF38	G72160C45	Good	Female	Clipped	74.0	2.95	5/7/2013	695
LGR	3D9.1C2DDBBD44	G7217669A	Good	Female	Clipped	68.0	2.29	5/7/2013	695
LGR	3D9.1C2DDBB4D2	G7229C019	Good	Female	Clipped	55.0	1.08	5/7/2013	695
LGR	3D9.1C2DDC20FD	G72089805	Good	Male	Intact	57.0	1.30	5/8/2013	695
LGR	3D9.1C2DDBDD9F	G7208E6E2	Fair	Male	Intact	54.0	1.22	5/8/2013	695
LGR	3D9.1C2DAC409C	G720A2A1A	Good	Female	Intact	66.0	2.00	5/8/2013	695
LGR	3D9.1C2DB1AA5C	G7211DF9E	Good	Female	Intact	55.0	1.27	5/8/2013	695
LGR	3D9.1C2DAC5999	G72124D66	Good	Male	Intact	58.0	1.54	5/8/2013	695
LGR	3D9.1C2DDC25D3	G7213FF2C	Good	Female	Intact	58.0	1.54	5/8/2013	695
LGR	3D9.1C2DDC18C3	G7217A5B2	Good	Female	Intact	65.0	1.65	5/8/2013	695
LGR	3D9.1C2DDC146B	G72085991	Good	Female	Clipped	59.0	1.34	5/8/2013	695
LGR	3D9.1C2DDC1D53	G72088F1B	Good	Female	Clipped	53.0	0.94	5/8/2013	695
LGR	3D9.1C2DE21F88	G720895F8	Good	Female	Clipped	56.0	1.28	5/8/2013	695
LGR	3D9.1C2D7C976A	G7208F340	Good	Female	Clipped	60.0	1.71	5/8/2013	695
LGR	3D9.1C2DE1DD6A	G720ED514	Good	Female	Clipped	52.0	1.03	5/8/2013	695
LGR	3D9.1C2DDB9ACA	G7211754F	Good	Female	Clipped	57.0	1.26	5/8/2013	695
LGR	3D9.1C2DDC180F	G72175A87	Good	Female	Clipped	54.0	1.12	5/8/2013	695
LGR	3D9.1C2DDBB203	G72087B0E	Good	Female	Intact	71.0	2.89	5/9/2013	695
LGR	3D9.1C2DDC1793	G720889C6	Good	Female	Intact	54.0	1.02	5/9/2013	695
LGR	3D9.1C2D482A1C	G72109562	Good	Male	Intact	57.0	1.45	5/9/2013	695
LGR	3D9.1C2DDBE97F	G721245A4	Good	Female	Intact	59.0	1.52	5/9/2013	695
LGR	3D9.1C2DDBC9E5	G7213C750	Good	Female	Intact	64.0	1.96	5/9/2013	695
LGR	3D9.1C2DDB99E5	G7217CD15	Good	Female	Intact	63.0	1.79	5/9/2013	695
LGR	3D9.1C2DDBEC6C	G7210943C	Good	Female	Clipped	74.0	2.85	5/9/2013	695
LGR	3D9.1C2DDBCF17	G7210AEFC	Fair	Female	Clipped	69.0	2.11	5/9/2013	695
LGR	3D9.1C2DDC1BD3	G7211E383	Good	Female	Clipped	72.0	2.90	5/9/2013	695
LGR	3D9.1C2DDBA2DC	G7213BDD6	Good	Male	Clipped	58.0	1.34	5/9/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DDBAF10	G7214A75B	Good	Female	Clipped	59.0	1.53	5/9/2013	695
LGR	3D9.1C2DDC04ED	G72159721	Good	Male	Clipped	63.0	1.61	5/9/2013	695
LGR	3D9.1C2DDBE9DF	G7215BAFF	Good	Female	Clipped	72.0	3.06	5/9/2013	695
LGR	3D9.1C2DDBE51C	G7215F325	Good	Male	Clipped	59.0	1.62	5/9/2013	695
LGR	3D9.1C2DE1D103	G72099B23	Good	Male	Intact	57.0	1.23	5/10/2013	695
LGR	3D9.1C2DE20743	G720B741A	Good	Male	Intact	58.0	1.44	5/10/2013	695
LGR	3D9.1C2DDBE87D	G7210D3F9	Good	Male	Intact	61.0	1.39	5/10/2013	695
LGR	3D9.1C2DDBF86F	G7213EC53	Fair	Female	Intact	64.0	1.75	5/10/2013	695
LGR	3D9.1C2DDBB558	G72162618	Good	Female	Intact	63.0	1.75	5/10/2013	695
LGR	3D9.1C2DDC1412	G72163F19	Good	Female	Intact	68.0	2.55	5/10/2013	695
LGR	3D9.1C2DDBD8E4	G72086B93	Good	Female	Clipped	58.0	1.29	5/10/2013	695
LGR	3D9.1C2DDB9282	G7208C2A0	Good	Female	Clipped	55.0	1.24	5/10/2013	695
LGR	3D9.1C2DE1C3E9	G72095C6A	Fair	Male	Clipped	58.0	1.30	5/10/2013	695
LGR	3D9.1C2DDBC0D1	G721035CD	Fair	Female	Clipped	74.0	3.08	5/10/2013	695
LGR	3D9.1C2DDC1210	G7211F49D	Good	Female	Clipped	55.0	1.13	5/10/2013	695
LGR	3D9.1C2DDBAEE8	G72140CD4	Good	Female	Clipped	67.0	1.98	5/10/2013	695
LGR	3D9.1C2DDB9481	G72143F88	Good	Female	Clipped	67.0	2.33	5/10/2013	695
LGR	3D9.1C2DDBBE77	G721536D0	Good	Female	Clipped	69.0	2.17	5/10/2013	695
LGR	3D9.1C2DDBB1AE	G721742D8	Good	Female	Clipped	67.0	1.87	5/10/2013	695
LGR	3D9.1C2DDC27C4	G7229D659	Good	Female	Clipped	67.0	2.25	5/10/2013	695
LGR	3D9.1C2DE1EDD8	G722A0BA6	Fair	Female	Clipped	58.0	1.41	5/10/2013	695
LGR	3D9.1C2DDBB0AA	G722A53BF	Good	Female	Clipped	56.0	1.27	5/10/2013	695
LGR	3D9.1C2DDBF5B3	G72087170	Good	Female	Intact	57.0	1.40	5/11/2013	695
LGR	3D9.1C2DDBE77A	G72087E31	Good	Female	Intact	60.0	1.70	5/11/2013	695
LGR	3D9.1C2DDC172C	G72113509	Good	Female	Intact	59.0	1.43	5/11/2013	695
LGR	3D9.1C2DDC0E90	G72114BEE	Good	Male	Intact	56.0	1.29	5/11/2013	695
LGR	3D9.1C2DDC2355	G72159D5F	Good	Male	Intact	54.0	1.10	5/11/2013	695
LGR	3D9.1C2DDBD5F9	G72176B67	Good	Female	Intact	61.0	1.60	5/11/2013	695
LGR	3D9.1C2DDBDB72	G721798F1	Fair	Female	Intact	63.0	1.61	5/11/2013	695
LGR	3D9.1C2DDC2354	G722A4C63	Good	Female	Intact	64.0	1.83	5/11/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DCE3D57	G7208BA9A	Fair	Female	Clipped	62.0	1.76	5/11/2013	695
LGR	3D9.1C2DDBA424	G72091BAF	Good	Female	Clipped	68.0	2.25	5/11/2013	695
LGR	3D9.1C2DDBBFE7	G72095275	Good	Female	Clipped	65.0	2.34	5/11/2013	695
LGR	3D9.1C2DDBF362	G7210CAF8	Good	Male	Clipped	54.0	1.10	5/11/2013	695
LGR	3D9.1C2DDB9231	G7211D181	Good	Male	Clipped	55.0	1.20	5/11/2013	695
LGR	3D9.1C2DDBCCE5	G7212B48E	Fair	Female	Clipped	57.0	1.43	5/11/2013	695
LGR	3D9.1C2DDBE337	G7213B02B	Fair	Male	Clipped	56.0	1.36	5/11/2013	695
LGR	3D9.1C2DDC1AE6	G721541AB	Good	Female	Clipped	65.0	2.00	5/11/2013	695
LGR	3D9.1C2DDBA8DB	G722A7B5E	Good	Female	Clipped	54.0	1.09	5/11/2013	695
LGR	3D9.1C2DDBD92B	G720F0B98	Good	Male	Intact	54.0	1.25	5/12/2013	695
LGR	3D9.1C2DDB91C7	G72105D6A	Fair	Female	Intact	58.0	1.34	5/12/2013	695
LGR	3D9.1C2DDBAF42	G72086351	Good	Female	Clipped	53.0	1.18	5/12/2013	695
LGR	3D9.1C2DE1DE7D	G720FC6AF	Good	Male	Clipped	55.0	1.16	5/12/2013	695
LGR	3D9.1C2DDBF844	G721093BF	Good	Male	Clipped	54.0	1.13	5/12/2013	695
LGR	3D9.1C2DDBE52C	G7210A482	Good	Female	Clipped	69.0	2.58	5/12/2013	695
LGR	3D9.1C2DDC207F	G7215D0E4	Fair	Male	Clipped	58.0	1.53	5/12/2013	695
LGR	3D9.1C2DDBC0E8	G72163106	Good	Female	Clipped	62.0	1.81	5/12/2013	695
LGR	3D9.1C2DDC0841	G7217A911	Good	Female	Clipped	63.0	1.68	5/12/2013	695
LGR	3D9.1C2DDB90FD	G7208B767	Fair	Female	Intact	58.0	1.36	5/13/2013	695
LGR	3D9.1C2DDBB345	G720F2379	Good	Male	Intact	51.0	1.12	5/13/2013	695
LGR	3D9.1C2DE1ED4D	G7211A8E5	Fair	Female	Intact	55.0	1.25	5/13/2013	695
LGR	3D9.1C2DDBDC10	G7212033F	Good	Female	Intact	66.0	1.94	5/13/2013	695
LGR	3D9.1C2DDBCA3D	G72158E20	Good	Female	Intact	60.0	1.58	5/13/2013	695
LGR	3D9.1C2DB6F7AA	G721751A7	Good	Male	Intact	55.0	1.34	5/13/2013	695
LGR	3D9.1C2DDBD8EC	G72182CBA	Good	Female	Intact	64.0	1.96	5/13/2013	695
LGR	3D9.1C2DE20738	G72183084	Fair	Male	Intact	56.0	1.43	5/13/2013	695
LGR	3D9.1C2DDBE83F	G72083557	Good	Female	Clipped	54.0	1.14	5/13/2013	695
LGR	3D9.1C2DDBCA5D	G720A48C3	Fair	Male	Clipped	60.0	1.54	5/13/2013	695
LGR	384.1B796EF371	G7210DA65	Good	Female	Clipped	53.0	1.13	5/13/2013	695
LGR	3D9.1C2DDBF099	G7215A79F	Good	Female	Clipped	74.0	2.97	5/13/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DDC23BC	G72299741	Good	Female	Clipped	58.0	1.70	5/13/2013	695
LGR	3D9.1C2DDBE966	G720A331B	Fair	Male	Intact	54.0	1.28	5/14/2013	695
LGR	3D9.1C2DDC11BF	G720A55A3	Good	Male	Intact	58.0	1.58	5/14/2013	695
LGR	3D9.1C2DDBC3AA	G720B6D1B	Good	Female	Intact	60.0	1.52	5/14/2013	695
LGR	3D9.1C2DE19529	G72132505	Good	Male	Intact	66.0	2.20	5/14/2013	695
LGR	3D9.1C2DDBBC3E	G72165C9E	Good	Female	Intact	55.0	1.31	5/14/2013	695
LGR	3D9.1C2DDC2649	G72180DC7	Good	Female	Intact	61.0	1.71	5/14/2013	695
LGR	3D9.1C2DDBF7F8	G7209B29C	Good	Female	Clipped	67.0	2.01	5/14/2013	695
LGR	3D9.1C2DDBF7FF	G720A28A6	Good	Female	Clipped	59.0	1.52	5/14/2013	695
LGR	3D9.1C2DE1DD4C	G720A6C81	Good	Male	Clipped	56.0	1.49	5/14/2013	695
LGR	3D9.1C2DDBF885	G7214B7C6	Good	Male	Clipped	56.0	1.40	5/14/2013	695
LGR	3D9.1C2DDC0E19	G72185480	Good	Female	Clipped	58.0	1.45	5/14/2013	695
LGR	3D9.1C2DB2FE1D	G722A0FC7	Good	Female	Clipped	55.0	1.09	5/14/2013	695
LGR	3D9.1C2DDBD774	G722A589F	Good	Female	Clipped	56.0	1.40	5/14/2013	695
LGR	3D9.1C2DDBAD21	G720887D9	Good	Female	Intact	55.0	1.19	5/15/2013	695
LGR	3D9.1C2DDBA27A	G720A2405	Good	Female	Intact	56.0	1.38	5/15/2013	695
LGR	3D9.1C2DDC05E3	G720EC92A	Good	Male	Intact	58.0	1.42	5/15/2013	695
LGR	3D9.1C2DAC6738	G721029F3	Good	Female	Intact	61.0	1.61	5/15/2013	695
LGR	3D9.1C2DDBF846	G72165DC0	Good	Female	Intact	57.0	1.52	5/15/2013	695
LGR	384.1B796D9BDF	G7217413A	Good	Male	Intact	61.0	1.81	5/15/2013	695
LGR	3D9.1C2DE204C8	G7218003A	Good	Male	Intact	59.0	1.50	5/15/2013	695
LGR	3D9.1C2DDBF832	G7229CF58	Good	Female	Intact	61.0	1.65	5/15/2013	695
LGR	3D9.1C2DE1C3B2	G7209D887	Good	Female	Clipped	74.0	2.94	5/15/2013	695
LGR	3D9.1C2DDBB136	G7215660B	Good	Female	Clipped	60.0	1.74	5/15/2013	695
LGR	3D9.1C2DDC269A	G7217DE6A	Good	Female	Clipped	68.0	2.40	5/15/2013	695
LGR	3D9.1C2DDBD73C	G720873CC	Good	Male	Intact	73.0	2.54	5/16/2013	695
LGR	3D9.1C2DE1C120	G72099780	Good	Female	Intact	56.0	1.30	5/16/2013	695
LGR	3D9.1C2DDBFA3B	G72108ABE	Good	Male	Intact	68.0	2.17	5/16/2013	695
LGR	3D9.1C2DDC27BD	G7213D571	Good	Female	Intact	57.0	1.37	5/16/2013	695
LGR	3D9.1C2DDBA64A	G721410EA	Good	Male	Intact	64.0	1.98	5/16/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DE1A814	G7214450E	Fair	Female	Intact	83.0	4.28	5/16/2013	695
LGR	3D9.1C2DDC1143	G7217D8B7	Good	Female	Intact	68.0	2.18	5/16/2013	695
LGR	3D9.1C2DE1C4A1	G7229A41D	Good	Female	Intact	59.0	1.56	5/16/2013	695
LGR	3D9.1C2DDBE7CF	G7210A25F	Good	Female	Clipped	61.0	1.63	5/16/2013	695
LGR	3D9.1C2DDC1AEC	G72112D56	Good	Male	Clipped	56.0	1.33	5/16/2013	695
LGR	3D9.1C2DDBCF1B	G7209A201	Good	Female	Intact	58.0	1.35	5/17/2013	695
LGR	3D9.1C2DDBB243	G720B4ABB	Good	Female	Intact	61.0	1.64	5/17/2013	695
LGR	3D9.1C2DB07C71	G7210E4C4	Good	Male	Intact	54.0	1.18	5/17/2013	695
LGR	3D9.1C2DDBEC1F	G7213595E	Good	Female	Intact	64.0	2.08	5/17/2013	695
LGR	3D9.1C2DB07C44	G7214BCE6	Good	Female	Intact	57.0	1.34	5/17/2013	695
LGR	3D9.1C2DDBE7F4	G722A3C9B	Good	Male	Intact	57.0	1.43	5/17/2013	695
LGR	3D9.1C2DDC239E	G7208E03F	Good	Female	Clipped	61.0	1.41	5/17/2013	695
LGR	3D9.1C2DDBA17E	G7215C418	Fair	Male	Clipped	56.0	1.31	5/17/2013	695
LGR	3D9.1C2DDBA2D9	G722A800A	Good	Male	Clipped	52.0	1.04	5/17/2013	695
LGR	3D9.1C2DDC070E	G7209C0D8	Good	Female	Intact	64.0	2.12	5/18/2013	695
LGR	3D9.1C2DDC00F4	G720A4CA2	Good	Male	Intact	56.0	1.35	5/18/2013	695
LGR	3D9.1C2DDBAF02	G72115432	Good	Female	Intact	67.0	2.01	5/18/2013	695
LGR	3D9.1C2DDBF1DB	G721471D1	Good	Male	Intact	63.0	1.95	5/18/2013	695
LGR	3D9.1C2DDBF3CD	G72161E64	Good	Female	Intact	67.0	2.33	5/18/2013	695
LGR	3D9.1C2DDBB146	G7211FBDC	Good	Male	Intact	57.0	1.40	5/20/2013	695
LGR	3D9.1C2DF79827	G72134101	Good	Female	Intact	62.0	1.66	5/20/2013	695
LGR	3D9.1C2DDC191C	G7213AAC8	Good	Female	Intact	55.0	1.40	5/20/2013	695
LGR	3D9.1C2DDB9B49	G7216840B	Good	Female	Intact	54.0	1.17	5/20/2013	695
LGR	3D9.1C2DDC1323	G7213DCED	Good	Female	Clipped	68.0	2.15	5/20/2013	695
LGR	3D9.1C2DDC0E62	G7213F2D1	Fair	Female	Clipped	74.0	2.91	5/20/2013	695
LGR	3D9.1C2DDBCF13	G7214E643	Good	Female	Clipped	58.0	1.33	5/20/2013	695
LGR	3D9.1C2DDBCE77	G7215DFA5	Good	Male	Clipped	60.0	1.46	5/20/2013	695
LGR	3D9.1C2DDC0DA6	G7215FAB9	Good	Male	Clipped	60.0	1.48	5/20/2013	695
LGR	3D9.1C2DDBF3B0	G7211CB62	Good	Female	Intact	65.0	1.94	5/21/2013	695
LGR	3D9.1C2DB06F31	G72159FE3	Good	Male	Intact	56.0	1.25	5/21/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DDBCEF1	G7215A980	Good	Male	Intact	71.0	2.23	5/21/2013	695
LGR	3D9.1C2DB0673F	G7215F27B	Good	Male	Intact	56.0	1.27	5/21/2013	695
LGR	3D9.1C2DDBB048	G72163E47	Good	Female	Intact	62.0	1.74	5/21/2013	695
LGR	3D9.1C2DDC0545	G7212313D	Good	Female	Clipped	68.0	2.47	5/21/2013	695
LGR	3D9.1C2DDBCC67	G72141EF5	Good	Female	Clipped	69.0	2.41	5/21/2013	695
LGR	3D9.1C2DDBD8D7	G721583DD	Good	Female	Clipped	55.0	1.19	5/21/2013	695
LGR	3D9.1C2DDBFA84	G72126C1B	Good	Female	Intact	71.0	2.28	5/22/2013	695
LGR	3D9.1C2DDB9D80	G7213B297	Good	Male	Intact	57.0	1.25	5/22/2013	695
LGR	3D9.1C2DDBE62D	G721409EB	Good	Female	Intact	55.0	1.10	5/22/2013	695
LGR	3D9.1C2DDBCF7B	G7215222C	Good	Male	Intact	70.0	2.12	5/22/2013	695
LGR	3D9.1C2DDBA4C1	G7215CF38	Good	Female	Intact	70.0	2.20	5/22/2013	695
LGR	3D9.1C2DDBEA55	G72145210	Good	Male	Clipped	56.0	1.32	5/22/2013	695
LGR	3D9.1C2DDC22E3	G7215E898	Good	Female	Clipped	54.0	1.14	5/23/2013	695
LGR	3D9.1C2DDBA2ED	G7212277D	Good	Female	Clipped	55.0	1.36	5/24/2013	695
LGR	3D9.1C2DDBA340	G7212F86B	Good	Female	Clipped	52.0	1.01	5/24/2013	695
LGR	3D9.1C2DDC239D	G721311DA	Good	Female	Clipped	69.0	2.38	5/24/2013	695
LGR	3D9.1C2DDBF2EF	G72137D1C	Good	Female	Intact	59.0	1.38	5/25/2013	695
LGR	3D9.1C2DDBFA71	G72166AFD	Fair	Female	Intact	69.0	2.48	5/25/2013	695
LGR	3D9.1C2DDC1D3E	G7212081F	Good	Female	Clipped	57.0	1.19	5/25/2013	695
LGR	3D9.1C2DDBD573	G72124718	Fair	Female	Clipped	60.0	1.39	5/25/2013	695
LGR	3D9.1C2DDC0DCD	G7212AB52	Good	Female	Clipped	65.0	1.81	5/25/2013	695
LGR	3D9.1C2DDB9A48	G7211E13F	Good	Female	Intact	60.0	1.47	5/26/2013	695
LGR	3D9.1C2DDC18E4	G7212AF33	Fair	Female	Intact	75.0	3.45	5/26/2013	695
LGR	3D9.1C2DDBB2DB	G721429C8	Fair	Female	Intact	72.0	2.65	5/26/2013	695
LGR	3D9.1C2DAC61A1	G72160D1B	Fair	Female	Intact	73.0	2.54	5/26/2013	695
LGR	3D9.1C2DDBD205	G72145AD2	Good	Female	Clipped	54.0	1.07	5/26/2013	695
LGR	3D9.1C2DDBB605	G72148247	Good	Female	Clipped	66.0	2.06	5/26/2013	695
LGR	3D9.1C2DDBE542	G72155E77	Fair	Female	Clipped	53.0	1.09	5/26/2013	695
LGR	3D9.1C2DDB918B	G721517AD	Good	Female	Intact	71.0	2.35	5/27/2013	695
LGR	3D9.1C2DDB9A08	G72157F0A	Good	Female	Clipped	54.0	1.19	5/27/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DE21433	G72131FC5	Fair	Male	Intact	57.0	1.43	5/28/2013	695
LGR	3D9.1C2DDBA3BF	G72166361	Fair	Female	Intact	57.0	1.49	5/28/2013	695
LGR	3D9.1C2DDC27EC	G7211C2FE	Fair	Male	Intact	53.0	1.19	5/29/2013	695
LGR	3D9.1C2DDBFF4E	G72138C36	Fair	Male	Intact	54.0	1.08	5/29/2013	695
LGR	3D9.1C2DDB9453	G72146E0D	Fair	Female	Intact	70.0	2.31	5/29/2013	695
LGR	3D9.1C2DDBF655	G7213D693	Good	Female	Clipped	73.0	3.40	5/29/2013	695
LGR	3D9.1C2DDBFF47	G721616A6	Good	Female	Clipped	57.0	1.27	5/29/2013	695
LGR	3D9.1C2DDC269B	G72146B32	Good	Female	Intact	70.0	2.51	5/30/2013	695
LGR	3D9.1C2DDBA646	G72166700	Fair	Female	Intact	58.0	1.54	5/30/2013	695
LGR	3D9.1C2DDB9BA0	G72154969	Good	Female	Clipped	81.0	4.08	5/30/2013	695
LGR	3D9.1C2DDC0E59	G72137823	Good	Female	Intact	59.0	1.61	5/31/2013	695
LGR	3D9.1C2DDBF850	G7214B57A	Good	Female	Intact	58.0	1.49	5/31/2013	695
LGR	3D9.1C2DB1AB87	G7212D5B5	Good	Female	Intact	60.0	1.78	6/1/2013	695
LGR	3D9.1C2DDBBD23	G7213E0F0	Good	Female	Intact	71.0	2.54	6/1/2013	695
LGR	3D9.1C2DDC139E	G7214A186	Good	Male	Intact	56.0	1.38	6/1/2013	695
LGR	3D9.1C2DDBBFB9	G721618B9	Good	Female	Intact	68.0	2.30	6/1/2013	695
LGR	3D9.1C2DDC0129	G721498A4	Fair	Female	Clipped	55.0	1.19	6/1/2013	695
LGR	3D9.1C2DDBCE73	G72134682	Good	Female	Intact	60.0	1.58	6/3/2013	695
LGR	3D9.1C2DDBA5A7	G7214DB00	Good	Female	Intact	64.0	1.89	6/3/2013	695
LGR	3D9.1C2DDC0149	G7214EC3D	Fair	Male	Intact	55.0	1.14	6/3/2013	695
LGR	3D9.1C2DDC0187	G72124FDA	Good	Male	Clipped	62.0	1.72	6/3/2013	695
LGR	3D9.1C2DDBCE78	G7212C8D5	Good	Male	Clipped	57.0	1.35	6/3/2013	695
LGR	3D9.1C2DDBB267	G7212974F	Good	Male	Intact	57.0	1.70	6/5/2013	695
LGR	3D9.1C2DDBCC58	G72128430	Good	Female	Clipped	55.0	1.11	6/5/2013	695
LGR	3D9.1C2DDBFF39	G7214C660	Good	Female	Intact	58.0	1.42	6/6/2013	695
LGR	3D9.1C2DDBA305	G7215ACBF	Fair	Female	Intact	64.0	1.76	6/6/2013	695
LGR	3D9.1C2DDBC15F	G7212D848	Fair	Female	Clipped	59.0	1.38	6/6/2013	695
LGR	3D9.1C2DDBB027	G721355FD	Good	Male	Intact	53.0	1.15	6/8/2013	695
LGR	3D9.1C2DDBD998	G7215A2A0	Good	Female	Intact	62.0	1.78	6/8/2013	695
LGR	3D9.1C2DDBF64D	G72165E22	Fair	Male	Clipped	57.0	1.33	6/8/2013	695

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
LGR	3D9.1C2DDBF06E	G7214C87F	Good	Male	Intact	58.0	1.31	6/9/2013	695
LGR	3D9.1C2DDC1123	G7213B6F6	Good	Male	Clipped	57.0	1.44	6/9/2013	695
LGR	3D9.1C2DDC1B6A	G7213C94F	Good	Female	Clipped	54.0	1.12	6/9/2013	695
LGR	3D9.1C2DDB968C	G72123D9E	Good	Male	Intact	57.0	1.12	6/10/2013	695
LGR	3D9.1C2DE21366	G7212AA0C	Good	Male	Intact	60.0	1.66	6/10/2013	695
LGR	3D9.1C2DE1DFAE	G721225C1	Good	Male	Clipped	60.0	1.53	6/10/2013	695
LGR	3D9.1C2DDBCF3A	G7211B926	Good	Female	Intact	57.0	1.57	6/11/2013	695
LGR	3D9.1C2DDBE8F3	G72138648	Fair	Male	Intact	66.0	2.25	6/12/2013	695
LGR	3D9.1C2DDBDA17	G721393EA	Good	Male	Intact	65.0	2.10	6/13/2013	695
LGR	3D9.1C2DAC613B	G7213D9D2	Good	Female	Intact	64.0	1.86	6/14/2013	695
LGR	3D9.1C2DB30848	G721572F7	Fair	Male	Intact	55.0	1.20	6/14/2013	695
LGR	3D9.1C2DDBB0F9	G72157E54	Good	Female	Intact	76.0	3.04	6/14/2013	695
LGR	3D9.1C2DDBAF11	G72141976	Good	Male	Intact	72.0	2.84	6/15/2013	695
LGR	3D9.1C2DDC21A4	G72167CBD	Fair	Male	Clipped	55.0	1.36	6/15/2013	695
LGR	3D9.1C2DDBE4D1	G72162C66	Fair	Male	Intact	61.0	1.60	6/17/2013	695
LGR	3D9.1C2DDBCA5A	G72159B82	Good	Male	Clipped	60.0	1.57	6/17/2013	695
LGR	3D9.1C2DDBBE96	G72161B5B	Good	Male	Clipped	62.0	1.75	6/17/2013	695
LGR	3D9.1C2DDBA048	G7215C7FA	Good	Female	Intact	57.0	1.35	6/18/2013	695
ASO	3D9.1C2E099C5F	G720AF033	Good	Female	Intact	67.2	2.58	4/11/2013	761
ASO	3D9.1C2DB071E1	G7210EB85	Fair	Female	Intact	71.6	2.92	4/11/2013	761
ASO	3D9.1C2DCE33A7	G72135BE2	Good	Female	Intact	68.9	2.40	4/11/2013	761
ASO	3D9.1C2DCE7311	G7251BC82	Fair	Male	Intact	55.3	1.32	4/11/2013	761
ASO	3D9.1C2DCF7A65	G720883B8	Good	Female	Intact	57.1	1.46	4/12/2013	761
ASO	3D9.1C2DB2FB18	G720A0B67	Fair	Female	Intact	67.4	2.18	4/12/2013	761
ASO	3D9.1C2E09B53B	G720F3B26	Good	Female	Intact	69.4	2.42	4/12/2013	761
ASO	3D9.1C2DC881BE	G72106E36	Good	Female	Intact	62.5	1.94	4/12/2013	761
ASO	3D9.1C2E081BE9	G7212CDEA	Good	Female	Intact	69.1	2.96	4/12/2013	761
ASO	3D9.1C2E09DB03	G72150D4E	Fair	Female	Intact	70.6	2.68	4/12/2013	761
ASO	3D9.1C2E00A0CA	G7217B793	Good	Female	Intact	56.6	1.52	4/12/2013	761
ASO	3D9.1C2D858FD6	G7217F3B4	Good	Female	Intact	66.2	2.10	4/12/2013	761

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
ASO	3D9.1C2E09F4C3	G724F135C	Good	Female	Intact	63.1	1.88	4/12/2013	761
ASO	3D9.1C2DB0866D	G724F455A	Fair	Female	Intact	69.5	2.20	4/12/2013	761
ASO	3D9.1C2E0865D9	G72516A08	Fair	Female	Intact	63.4	2.04	4/12/2013	761
ASO	3D9.1C2E0894A2	G725269BF	Good	Female	Intact	65.1	2.08	4/12/2013	761
ASO	3D9.1C2E096301	G72138AEB	Good	Female	Intact	69.1		4/15/2013	761
ASO	3D9.1C2E08E76C	G72139156	Good	Male	Intact	56.4		4/15/2013	761
ASO	3D9.1C2E085827	G7213C811	Good	Female	Intact	66.5		4/15/2013	761
ASO	3D9.1C2E09E51C	G721632E4	Fair	Female	Intact	63.5		4/15/2013	761
ASO	3D9.1C2DCE1090	G720A2B44	Fair	Male	Intact	58.0	1.52	4/16/2013	761
ASO	3D9.1C2DB1F9A1	G720FCA0C	Good	Female	Intact	68.2	2.22	4/16/2013	761
ASO	3D9.1C2E090F04	G7216691F	Good	Female	Intact	71.6	2.64	4/16/2013	761
ASO	3D9.1C2E092425	G721749F8	Good	Female	Intact	69.0	2.48	4/16/2013	761
ASO	3D9.1C2E093F4A	G72178591	Good	Male	Intact	53.7	1.26	4/16/2013	761
ASO	3D9.1C2DCE2499	G7229C147	Fair	Female	Intact	63.5	1.62	4/16/2013	761
ASO	3D9.1C2E08EB1E	G7212673B	Good	Female	Intact	58.0	1.52	4/17/2013	761
ASO	3D9.1C2E01E58C	G72140A09	Good	Female	Intact	52.7	1.14	4/17/2013	761
ASO	3D9.1C2DCE64EF	G7217F9CA	Good	Female	Intact	62.4	1.82	4/17/2013	761
ASO	3D9.1C2E095583	G7229E505	Good	Female	Intact	63.5	2.28	4/17/2013	761
ASO	3D9.1C2E08A696	G720F19B9	Fair	Female	Intact	67.5	1.88	4/18/2013	761
ASO	3D9.1C2E09392F	G7209953C	Good	Female	Intact	67.0	2.28	4/19/2013	761
ASO	3D9.1C2E096835	G7215B4E0	Fair	Male	Intact	65.2	2.16	4/19/2013	761
ASO	3D9.1C2DAC6748	G7229D084	Fair	Female	Intact	76.7	3.14	4/19/2013	761
ASO	3D9.1C2E09FED8	G720F4BDE	Fair	Female	Intact	71.0	2.80	4/22/2013	761
ASO	3D9.1C2E08B6F3	G7210DDE6	Good	Female	Intact	57.5	1.40	4/22/2013	761
ASO	3D9.1C2DCE8A95	G7211E2DD	Good	Female	Intact	67.9	2.08	4/22/2013	761
ASO	3D9.1C2E0A14E1	G7213B7A8	Good	Female	Intact	65.9	2.20	4/22/2013	761
ASO	3D9.1C2E08B9A0	G7208A6A4	Good	Female	Intact	58.0	1.34	4/23/2013	761
ASO	3D9.1C2E095829	G720B259F	Fair	Female	Intact	72.3	2.86	4/23/2013	761
ASO	3D9.1C2E01F148	G720ED3C9	Good	Male	Intact	55.5		4/23/2013	761
ASO	3D9.1C2E0A07CA	G72113A48	Fair	Female	Intact	69.9	2.28	4/23/2013	761

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
ASO	3D9.1C2E01D9C2	G7214ABF8	Good	Female	Intact	65.0		4/23/2013	761
ASO	3D9.1C2DAC6049	G72162807	Good	Female	Intact	70.0	2.82	4/23/2013	761
ASO	3D9.1C2E01CB4A	G7217C0E8	Good	Female	Intact	61.8		4/23/2013	761
ASO	3D9.1C2D85B5CF	G722A4F81	Good	Female	Intact	57.7	1.24	4/23/2013	761
ASO	3D9.1C2E01A18D	G72093AD2	Good	Male	Intact	48.3	1.24	4/24/2013	761
ASO	3D9.1C2E0867DD	G720B88CD	Fair	Female	Intact	52.3	1.16	4/24/2013	761
ASO	3D9.1C2E09C4FF	G7211B358	Good	Female	Intact	64.0	1.90	4/24/2013	761
ASO	3D9.1C2E08D3A8	G7211EA1F	Good	Male	Intact	52.1	1.28	4/24/2013	761
PEW	3D9.1C2D9C22F9	G720968B5	Fair	Female	Intact	73.1	2.80	4/25/2013	836
PEW	3D9.1C2D9CC635	G7215845E	Good	Female	Intact	72.2	2.68	4/25/2013	836
PEW	3D9.1C2D9DF147	G72176A39	Good	Female	Intact	70.6	2.65	4/25/2013	836
PEW	3D9.1C2D9C5BC3	G7209FA18	Good	Female	Intact	67.3	2.94	4/26/2013	836
PEW	3D9.1C2D99D8B6	G7211AB07	Good	Female	Intact	71.8	3.04	4/26/2013	836
PEW	3D9.1C2D9CDB64	G720B24C1	Good	Female	Intact	74.6	2.98	4/27/2013	836
PEW	3D9.1C2D9C238D	G721624A4	Good	Female	Intact	72.9	3.12	4/27/2013	836
PEW	3D9.1C2D75C1AB	G720F2227	Good	Male	Intact	68.8	2.51	4/29/2013	836
PEW	3D9.1C2D9EB70C	G72097308	Fair	Female	Intact	79.0	3.57	5/3/2013	836
PEW	3D9.1C2D9BD432	G72175FB8	Fair	Female	Intact	71.6	2.45	5/3/2013	836
PEW	3D9.1C2D9EE8E3	G721315BB	Good	Male	Intact	74.0	2.54	5/5/2013	836
PEW	3D9.1C2D9DAB86	G7214B698	Good	Female	Intact	73.9	3.03	5/5/2013	836
PEW	3D9.1C2CF746F7	G722995FD	Fair	Female	Intact	72.7	3.02	5/5/2013	836
PEW	3D9.1C2D9D9CA7	G720B3DC0	Good	Female	Intact	58.2	1.50	5/8/2013	836
PEW	3D9.1C2D873A7D	G7229B823	Good	Female	Intact	69.2	2.50	5/8/2013	836
PEW	3D9.1C2D88BC4C	G72107928	Good	Male	Intact	53.4	1.20	5/9/2013	836
PEW	3D9.1C2D9BB6FC	G72087511	Good	Female	Intact	72.6	2.65	5/15/2013	836
JOS	3D9.1C2DB1ED82	G720AE673	Good	Female	Intact	65.8	2.18	4/11/2013	804
JOS	3D9.1C2D484035	G721195A6	Good	Female	Intact	68.8	2.30	4/11/2013	804
JOS	3D9.1C2D47E10E	G72182DE4	Good	Female	Intact	67.5	2.30	4/11/2013	804
JOS	3D9.1C2D4773B0	G722A4D3D	Fair	Female	Intact	55.7	1.30	4/11/2013	804
JOS	3D9.1C2D451F6A	G725079B3	Fair	Female	Intact	74.4	3.02	4/11/2013	804

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
JOS	3D9.1C2D47E9B1	G725150C8	Good	Female	Intact	70.4	2.52	4/11/2013	804
JOS	3D9.1C2D48050D	G72527AC0	Good	Female	Intact	63.9	2.02	4/11/2013	804
JOS	3D9.1C2D453CAB	G721672A2	Good	Female	Clipped	58.7	1.70	4/11/2013	804
JOS	3D9.1C2D476D2C	G72085DF0	Good	Female	Intact	74.6	3.88	4/12/2013	804
JOS	3D9.1C2D453025	G720A3624	Good	Female	Intact	67.1	2.14	4/12/2013	804
JOS	3D9.1C2D47772F	G720F01E6	Fair	Female	Intact	62.1	1.72	4/12/2013	804
JOS	3D9.1C2D451AF7	G721367FF	Good	Female	Intact	68.2	2.34	4/12/2013	804
JOS	3D9.1C2D4845EC	G724FDE6B	Good	Female	Intact	72.6	3.02	4/12/2013	804
JOS	3D9.1C2D47486C	G724FE5F5	Good	Female	Intact	55.7	1.50	4/12/2013	804
JOS	3D9.1C2D45360F	G7250D4E1	Good	Female	Intact	73.6	2.94	4/12/2013	804
JOS	3D9.1C2D482FA4	G72520B66	Good	Female	Intact	76.2	2.62	4/12/2013	804
JOS	3D9.1C2D453A85	G722A1798	Good	Female	Intact	66.2	2.06	4/14/2013	804
JOS	3D9.1C2D479F53	G724F46B8	Good	Female	Intact	57.1	1.46	4/14/2013	804
JOS	3D9.1C2D47BE21	G72085F4C	Good	Female	Intact	59.8	1.52	4/15/2013	804
JOS	3D9.1C2D4889EC	G7209E49A	Good	Female	Intact	72.2	2.70	4/15/2013	804
JOS	3D9.1C2D475F3A	G720A0119	Good	Female	Intact	59.3	1.64	4/15/2013	804
JOS	3D9.1C2D47F348	G721186D9	Good	Female	Intact	68.5	2.40	4/15/2013	804
JOS	3D9.1C2D482D61	G7211E6BC	Good	Female	Intact	68.2	2.24	4/15/2013	804
JOS	3D9.1C2D4853D9	G72151B0E	Good	Female	Intact	70.3	2.82	4/15/2013	804
JOS	3D9.1C2D4800FF	G722A0C25	Fair	Male	Intact	56.8	1.48	4/15/2013	804
JOS	3D9.1C2D487345	G72087A50	Good	Female	Intact	64.7	2.12	4/17/2013	804
JOS	3D9.1C2D4759AD	G72088687	Fair	Male	Intact	53.4	1.42	4/17/2013	804
JOS	3D9.1C2D4879E5	G720FEDAC	Good	Female	Intact	75.2	3.18	4/17/2013	804
JOS	3D9.1C2D4733AC	G72157B6B	Good	Female	Intact	65.3	2.22	4/17/2013	804
JOS	3D9.1C2D4776A3	G721775E5	Good	Female	Intact	65.7	2.24	4/17/2013	804
JOS	3D9.1C2D47E755	G7208FADC	Good	Female	Intact	76.7	3.20	4/18/2013	804
JOS	3D9.1C2D4737A2	G72107876	Good	Female	Intact	63.0	1.74	4/18/2013	804
JOS	3D9.1C2D4775B0	G72120261	Good	Female	Intact	71.5	2.64	4/18/2013	804
JOS	3D9.1C2D475850	G7216389A	Fair	Female	Intact	66.4	2.60	4/18/2013	804
JOS	3D9.1C2D4800FE	G72188874	Good	Female	Intact	70.6	2.64	4/18/2013	804

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
JOS	3D9.1C2D4826F4	G720821AB	Good	Female	Intact	48.7	1.02	4/19/2013	804
JOS	3D9.1C2D4865E0	G7229C2A5	Fair	Female	Intact	62.8	2.02	4/19/2013	804
JOS	3D9.1C2D4772DE	G720F2BBB	Good	Female	Intact	71.1	2.60	4/20/2013	804
JOS	3D9.1C2D488139	G72121F01	Good	Female	Intact	71.7	2.96	4/20/2013	804
JOS	3D9.1C2D483E8A	G721375DE	Fair	Female	Intact	67.3	2.50	4/20/2013	804
JOS	3D9.1C2D481700	G72152852	Fair	Female	Intact	57.5	1.46	4/20/2013	804
JOS	3D9.1C2D45130D	G721540F5	Fair	Female	Intact	67.6	2.26	4/20/2013	804
JOS	3D9.1C2D489343	G720A8F8A	Good	Female	Intact	66.1	2.52	4/22/2013	804
JOS	3D9.1C2DCE27C2	G7229B1BF	Good	Male	Intact	59.8	1.80	4/22/2013	804
JOS	3D9.1C2D4785AA	G7229BA9F	Good	Female	Intact	71.9	2.90	4/22/2013	804
JOS	3D9.1C2D484FAA	G720B36E0	Good	Female	Intact	70.8	2.80	4/23/2013	804
JOS	3D9.1C2DCE4BE6	G7210FF79	Good	Female	Intact	55.7	1.24	4/23/2013	804
JOS	3D9.1C2D473F5E	G7212DAF4	Good	Female	Intact	59.5	1.54	4/23/2013	804
JOS	3D9.1C2D485780	G720820F5	Good	Female	Intact	67.6	2.52	4/24/2013	804
JOS	3D9.1C2D47A069	G7215264D	Good	Female	Intact	66.5	2.12	4/24/2013	804
JOS	3D9.1C2D454142	G721625FA	Good	Female	Intact	70.3	2.66	4/24/2013	804
JOS	3D9.1C2D4841BB	G7217A1D3	Good	Female	Intact	64.3	1.94	5/7/2013	804
JOS	3D9.1C2D489A48	G72188735	Good	Female	Intact	65.2	1.92	5/7/2013	804
JOS	3D9.1C2D4809D7	G720A7662	Good	Female	Intact	60.4	1.54	5/9/2013	804
JOS		G7229CB39	Good	Female	Intact	67.2	2.34	5/9/2013	804
JOS	3D9.1C2D476B47	G721063CB	Good	Female	Intact	66.0	2.04	5/13/2013	804
JOS	3D9.1C2D47EFA2	G72179F72	Good	Male	Intact	51.8	0.78	5/13/2013	804
JOS	3D9.1C2D476364	G722A52E1	Fair	Female	Intact	70.7	2.01	5/17/2013	804
JOS	3D9.1C2DB0B3E9	G720EE909	Good	Female	Intact	67.9	2.16	5/18/2013	804
JOS	3D9.1C2D475B19	G72137EFE	Good	Female	Intact	68.2	1.84	5/18/2013	804
JOS	3D9.1C2DB0AA47	G7215D767	Fair	Female	Intact	54.7	1.06	5/18/2013	804
JOS	3D9.1C2D47F74C	G72181D5A	Good	Male	Intact	49.2	0.94	5/18/2013	804
JOS	3D9.1C2DAC3833	G7229E8F8	Fair	Male	Intact	52.9	1.24	5/19/2013	804
FC	3D9.1C2E085DA5	G720B663B	Fair	Female	Intact	90.0	5.90	5/22/2013	944
FC	3D9.1BF26B931E	G72103BD2	Fair	Female	Intact	83.0	4.28	5/22/2013	944

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
FC	3D9.1C2E084A89	G72112C08	Fair	Female	Intact	81.0	3.80	5/22/2013	944
FC	3D9.1BF26BFEFE	G72121CE3	Good	Female	Intact	80.0	4.18	5/23/2013	944
FC	3D9.1C2E08C95B	G7212B76C	Good	Female	Intact	81.0	4.16	5/23/2013	944
FC	3D9.1C2E094CA8	G7213BC88	Good	Female	Intact	80.0	3.88	5/23/2013	944
FC	3D9.1C2E08C894	G7215E9C6	Fair	Male	Intact	82.0	3.96	5/23/2013	944
FC	3D9.1C2DB08E4D	G72150EAC	Good	Female	Intact	78.0	3.45	5/24/2013	944
FC	3D9.1C2E01A23A	G7215A3FE	Good	Female	Intact	76.0	3.10	5/24/2013	944
FC	3D9.1C2DAC1646	G7215E104	Good	Female	Intact	81.0	3.68	5/24/2013	944
FC	3D9.1C2E085CE4	G7210CE99	Fair	Female	Intact	84.0	4.00	5/25/2013	944
FC	3D9.1C2E092DFC	G72153F4C	Good	Female	Intact	80.0	3.86	5/25/2013	944
FC	3D9.1C2E093BDF	G7214F8C1	Good	Female	Intact	81.0	4.36	5/27/2013	944
FC	3D9.1C2E085EFE	G72135800	Good	Female	Intact	59.0	1.66	5/28/2013	944
FC	3D9.1C2E08D370	G7211F0FC	Good	Female	Intact	80.0	3.82	5/30/2013	944
FC	3D9.1C2E08BF0B	G7215AA62	Good	Female	Intact	80.0	4.50	5/30/2013	944
FC	3D9.1C2E09228B	G7213CC70	Good	Female	Intact	80.0	3.50	5/31/2013	944
FC	3D9.1C2E01F053	G7215921E	Good	Female	Intact	81.0	3.92	5/31/2013	944
FC	3D9.1C2E01E4DD	G7211EF20	Good	Female	Intact	79.0	4.06	6/2/2013	944
FC	3D9.1C2E095972	G7212DE95	Good	Female	Intact	76.0	3.30	6/2/2013	944
FC	3D9.1C2E07F513	G72131C27	Fair	Female	Intact	83.0	4.38	6/2/2013	944
FC	3D9.1C2E08DB33	G721350C2	Fair	Female	Intact	79.0	3.54	6/2/2013	944
FC	3D9.1C2E019875	G7214AC7B	Good	Female	Intact	76.0	3.00	6/2/2013	944
FC	3D9.1C2E086BC1	G72151C8D	Good	Female	Intact	78.5	3.18	6/2/2013	944
FC	3D9.1C2E01FABC	G72154BD5	Good	Female	Intact	85.0	4.30	6/3/2013	944
FC	3D9.1C2E08D327	G721289CD	Good	Female	Intact	79.0	3.32	6/4/2013	944
FC	3D9.1C2E01D81F	G7213A0B6	Good	Female	Intact	62.0	1.70	6/4/2013	944
FC	3D9.1C2E07FEED	G72141308	Good	Female	Intact	77.0	3.28	6/4/2013	944
FC	3D9.1BF23E648E	G7213DDB3	Fair	Female	Intact	75.0	3.08	6/6/2013	944
FC	3D9.1BF263197E	G7211D33D	Fair	Female	Intact	77.0	3.16	6/7/2013	944
FC	3D9.1C2E089E21	G72122BDE	Good	Female	Intact	79.0	3.36	6/7/2013	944
FC	3D9.1C2E01A191	G7212FB89	Good	Female	Intact	81.0	3.68	6/7/2013	944

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Intact/Clipped)	Length (cm)	Weight (kg)	Release Date	Release rkm
FC	3D9.1C2E086BAE	G7213E773	Good	Male	Intact	59.0	1.64	6/7/2013	944
FC	3D9.1C2E01F34F	G721463F0	Good	Female	Intact	79.0	4.04	6/7/2013	944
FC	3D9.1C2E018ABC	G72122FBF	Good	Female	Intact	75.0	3.04	6/8/2013	944
FC	3D9.1BF26BA5AD	G72131659	Good	Female	Intact	81.0	4.30	6/8/2013	944
FC	3D9.1C2E07B38D	G7216503D	Good	Female	Intact	79.0	3.40	6/9/2013	944
FC	3D9.1C2E01A68D	G72145FED	Good	Female	Intact	77.0	3.42	6/12/2013	944
FC	3D9.1C2E01931E	G72135D3F	Fair	Female	Intact	74.0	2.64	6/13/2013	944
FC	3D9.1C2E0876FE	G72157DB6	Good	Female	Intact	76.0	2.88	6/13/2013	944
FC	3D9.1C2C94CAC0	G72158F7E	Fair	Female	Intact	80.0	3.56	6/13/2013	944

Appendix C

Timing of Juvenile Salmon Acoustic Telemetry System-Tagged Kelts Passage versus Dam Discharge

Appendix C

Timing of Juvenile Salmon Acoustic Telemetry System-Tagged Kelts Passage versus Dam Discharge

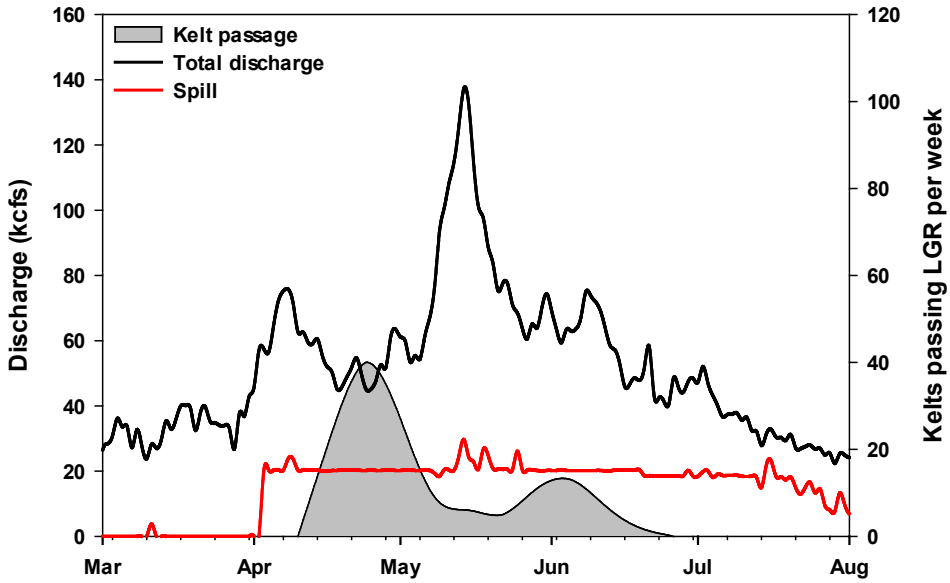

Figure C.1. Average daily total and spill discharge (kcfs) at Lower Granite Dam (LGR) from 1 March to 1 August 2013. Also shown are the numbers of kelts per week (Sunday–Saturday) detected passing LGR during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

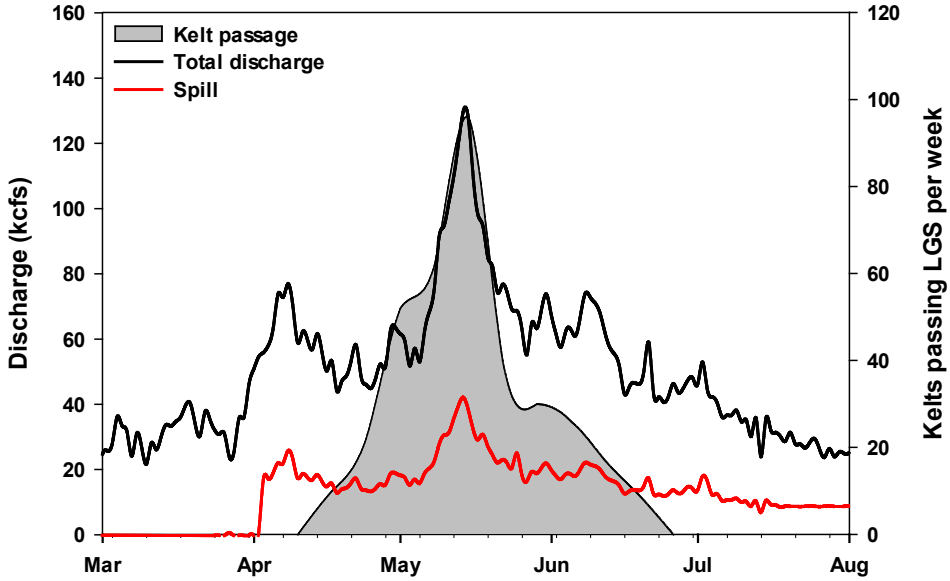

Figure C.2. Average daily total and spill discharge (kcfs) at Little Goose Dam (LGS) from 1 March to 1 August 2013. Also shown are the numbers of kelts per week (Sunday–Saturday) detected passing LGS during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

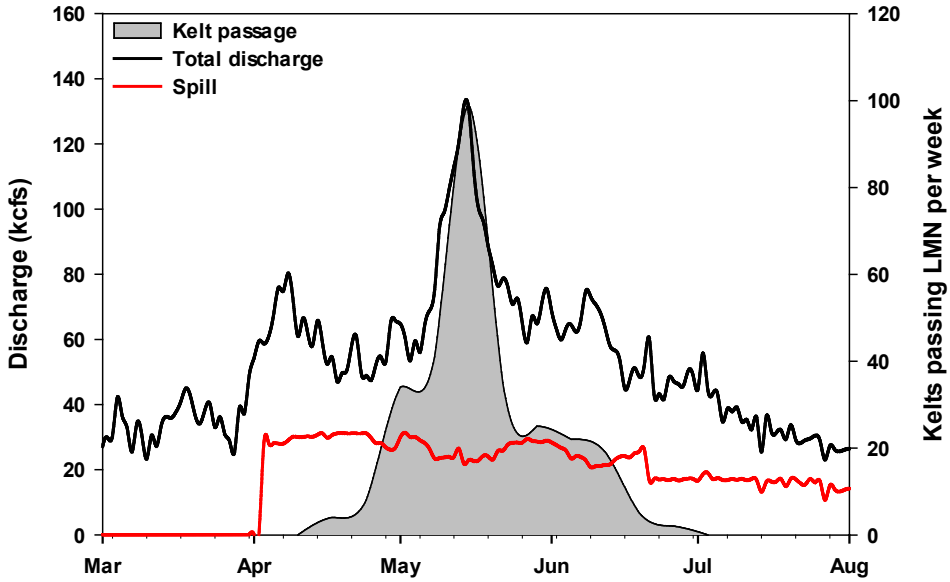

Figure C.3. Average daily total and spill discharge (kcfs) at Lower Monumental Dam (LMN) from 1 March to 1 August 2013. Also shown are the numbers of kelts per week (Sunday–Saturday) detected passing LMN during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

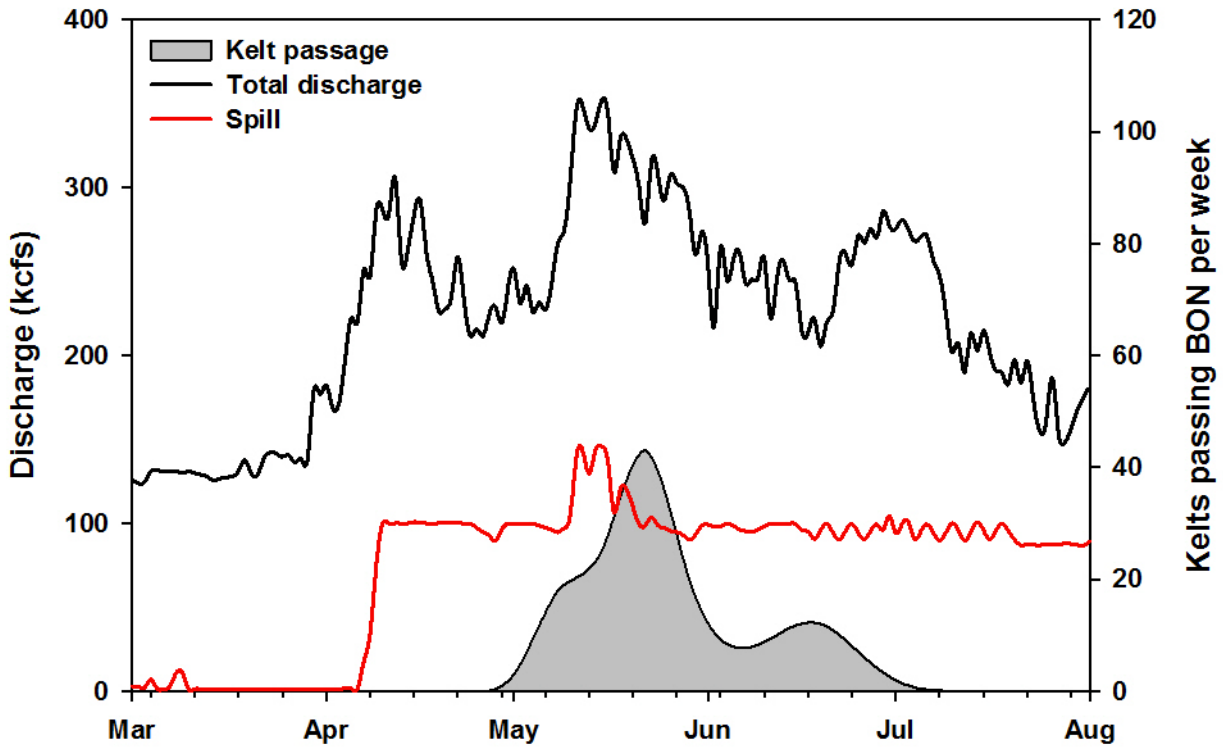

Figure C.4. Average daily total and spill discharge (kcfs) at Bonneville Dam (BON) from 1 March to 1 August 2013. Also shown are the numbers of kelts per week (Sunday – Saturday) detected passing the array in the BON forebay (rkm 236) during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

Appendix D

Discharge versus Spill at Each Dam

Appendix D

Discharge versus Spill at Each Dam

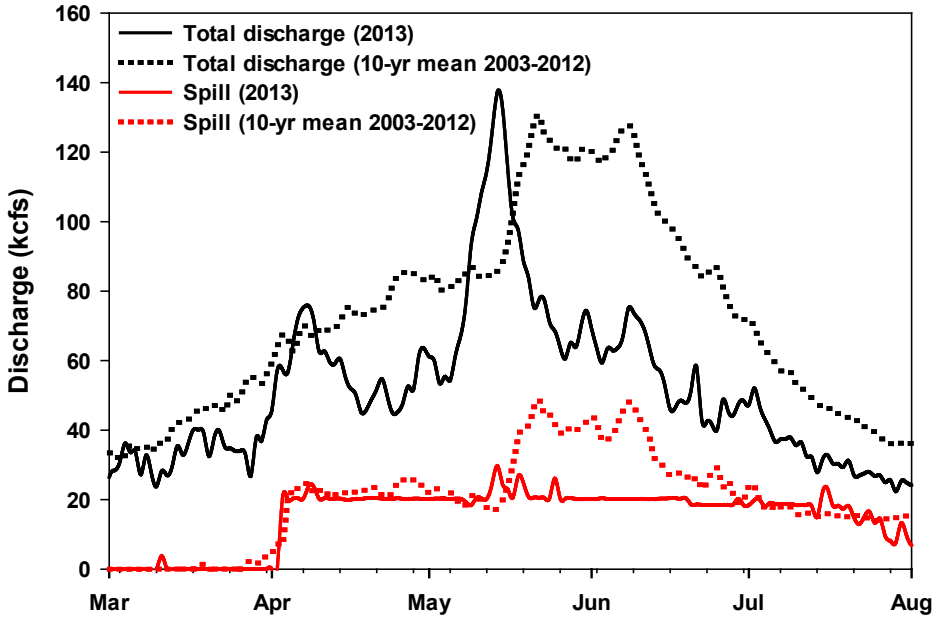

Figure D.1. The average daily total and spill discharge rates (kcfs) observed at Lower Granite Dam from 1 March to 1 August 2013, with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

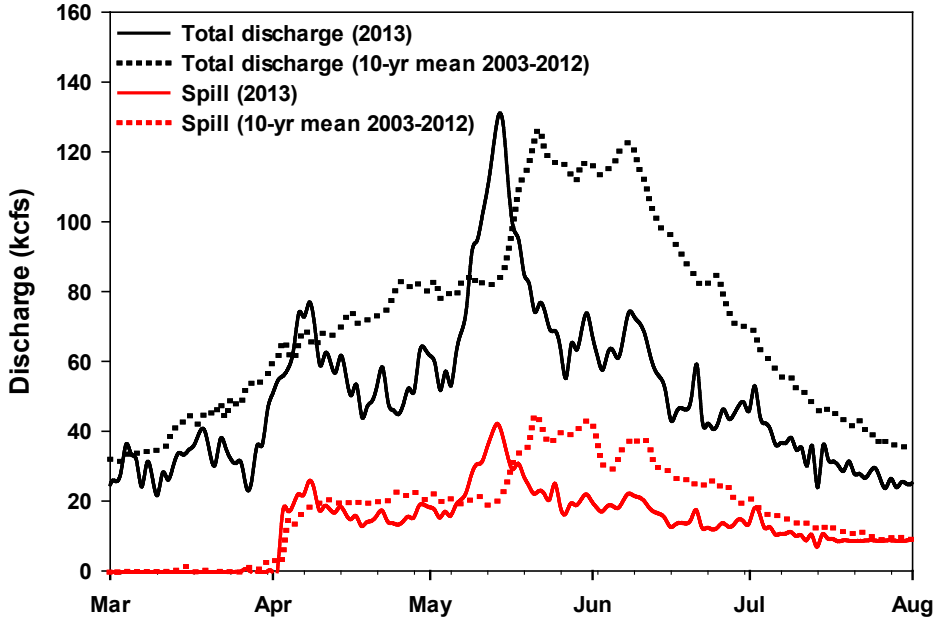

Figure D.2. The average daily total and spill discharge rates (kcfs) observed at Little Goose Dam from 1 March to 1 August 2013, with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

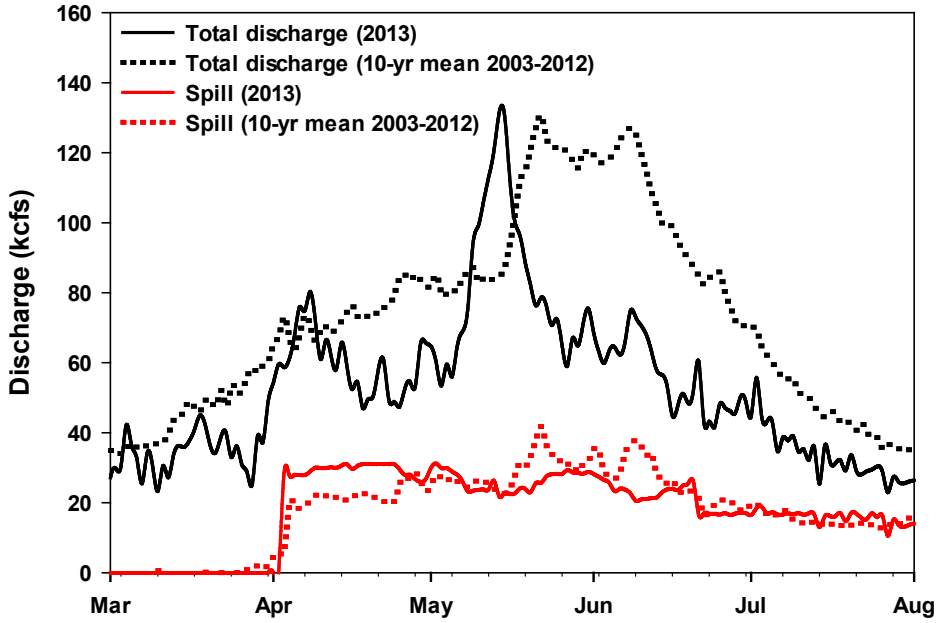

Figure D.3. The average daily total and spill discharge rates (kcfs) observed at Lower Monumental Dam from 1 March to 1 August 2013, with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

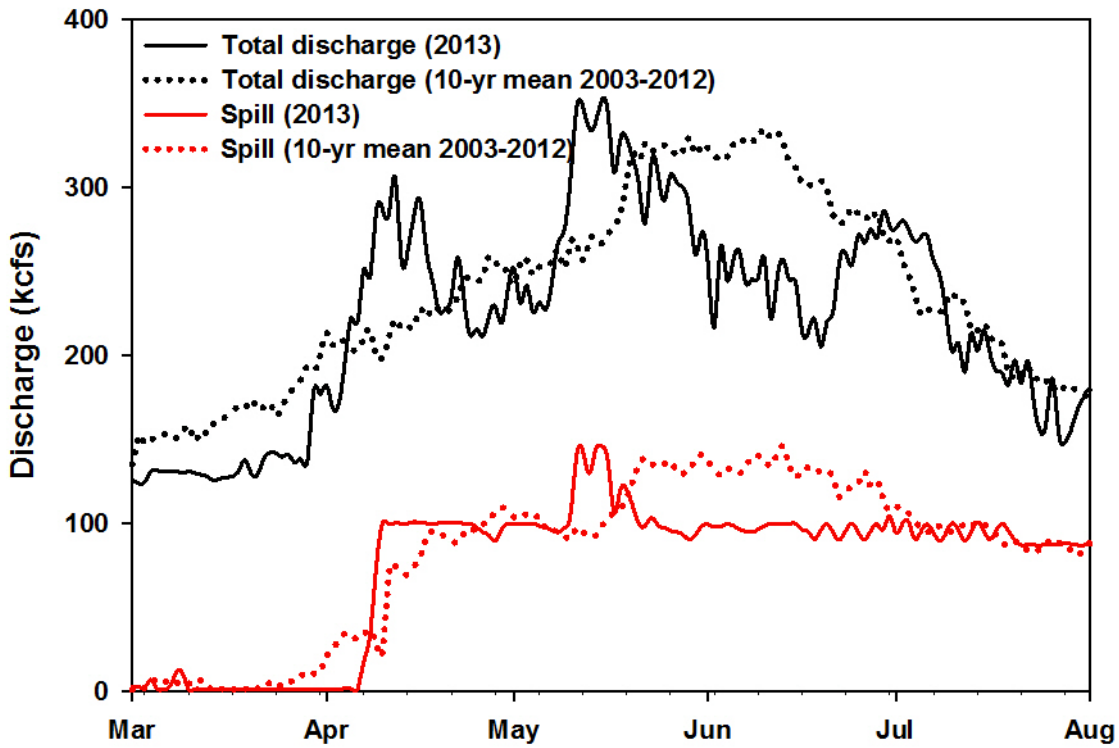

Figure D.4. The average daily total and spill discharge rates (kcfs) observed at Bonneville Dam from 1 March to 1 August 2013, with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

Appendix E

Timing of Kelt Passage versus Temperature

Appendix E

Timing of Kelt Passage versus Temperature

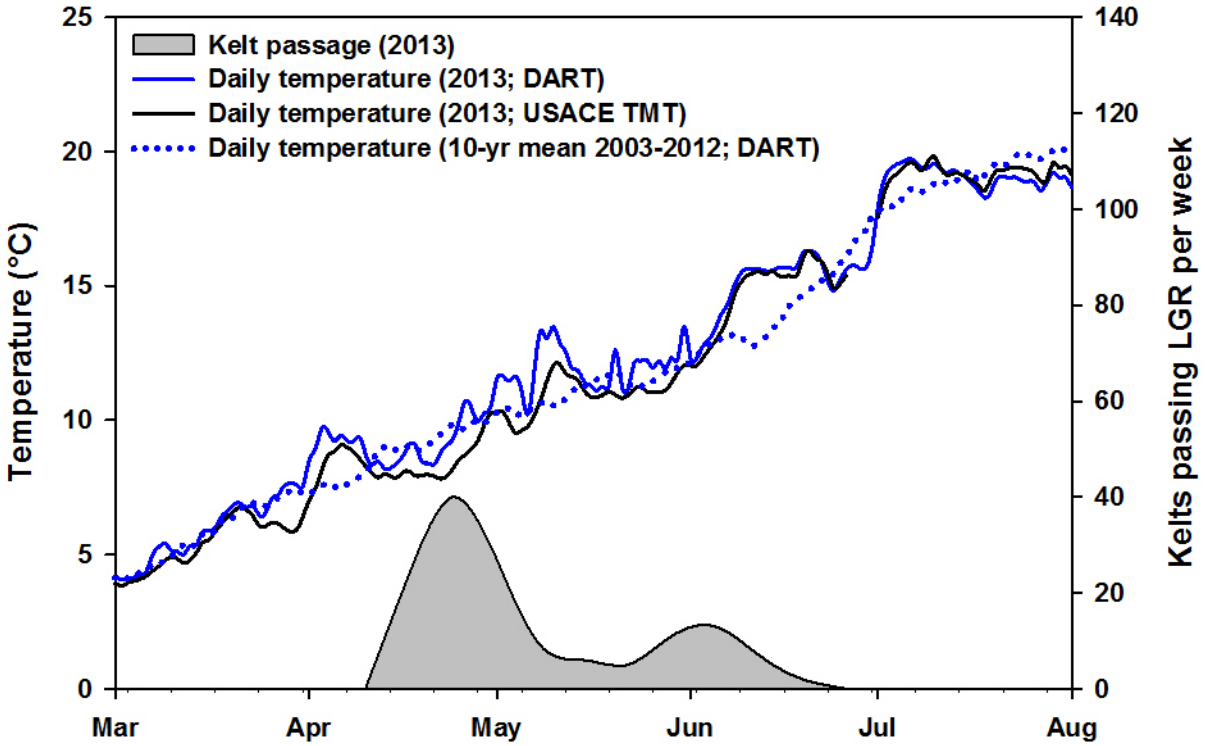

Figure E.1. Average daily forebay temperature (°C) observed at Lower Granite Dam (LGR) from 1 March to 1 August 2013, with the 10-year average. Also shown are the numbers of kelts per week (Sunday–Saturday) detected passing LGR during the same period. Reported temperatures are daily averages as recorded at forebay water-quality monitoring stations. Temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/) and the USACE TMT (U.S. Army Corps of Engineers Technical Management Team; http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tempstrings/).

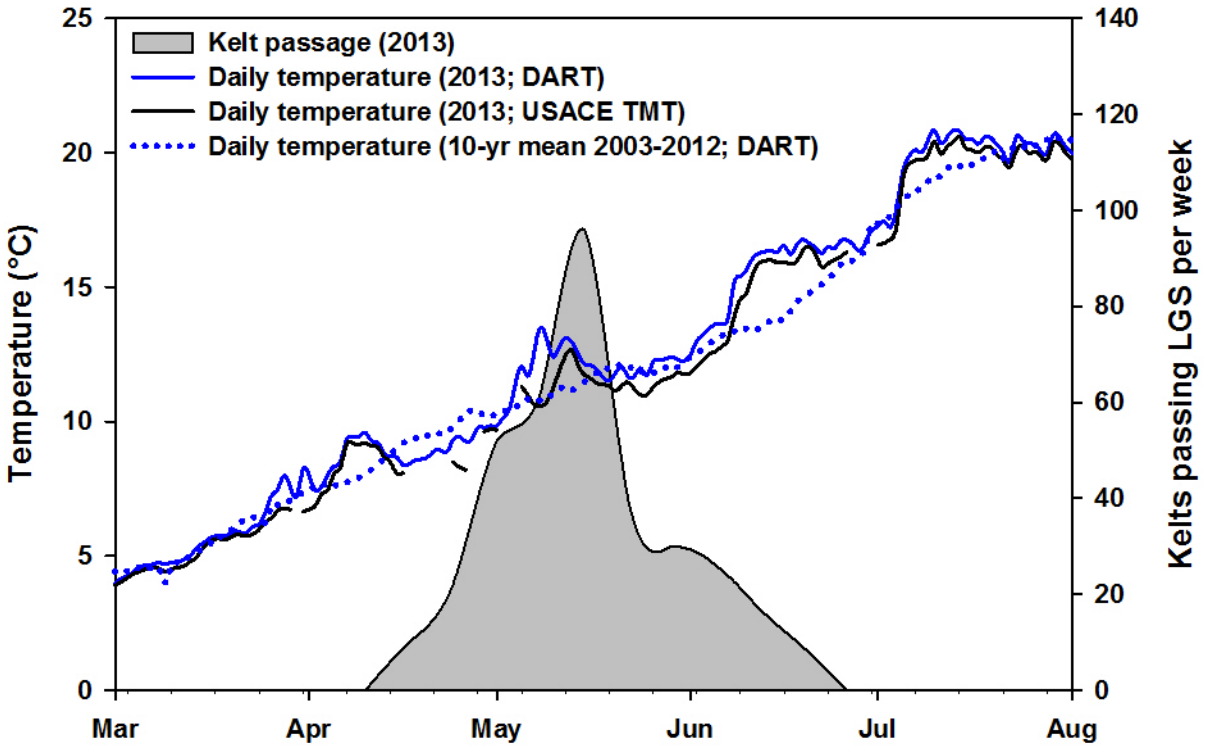

Figure E.2. Average daily forebay temperature (°C) observed at Little Goose Dam (LGS) from 1 March to 1 August 2013, with the 10-year average. Also shown are the numbers of kelts per week (Sunday-Saturday) detected passing LGS during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. Temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/) and the USACE TMT (US Army Corps of Engineers Technical Management Team; http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tempstrings/).

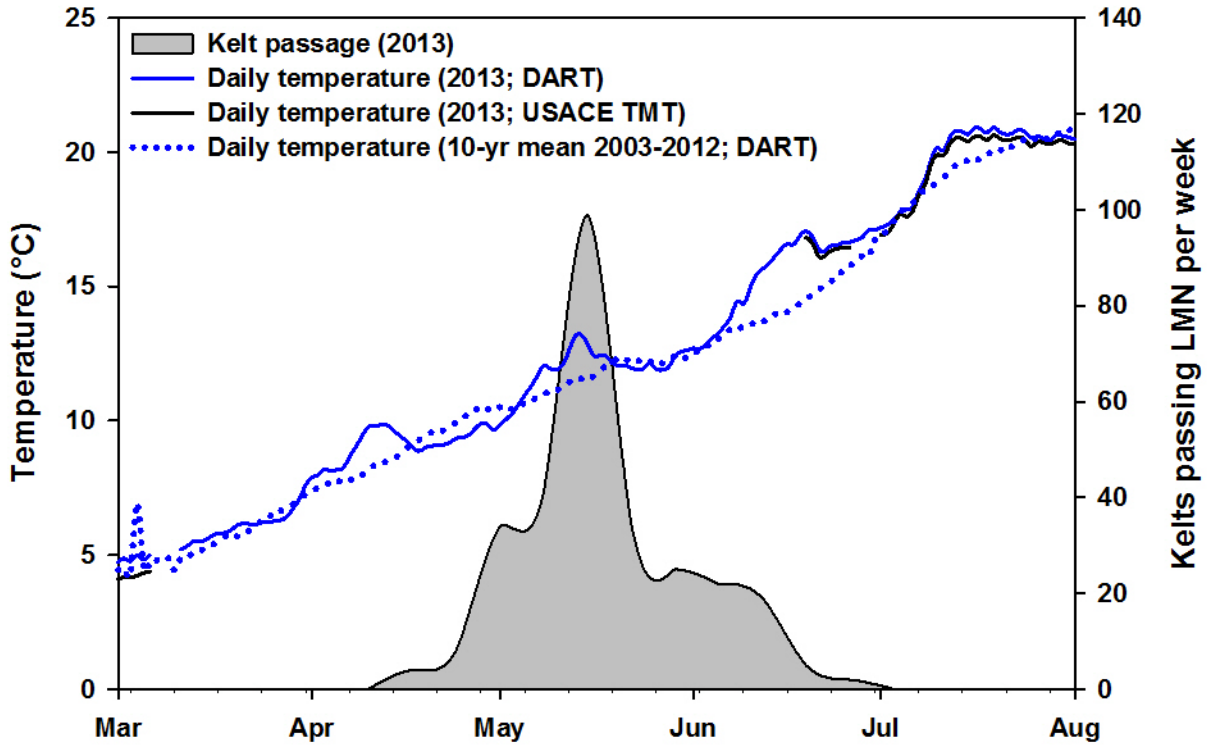

Figure E.3. Average daily forebay temperature (°C) observed at Lower Monumental Dam (LMN) from 1 March to 1 August 2013, with the 10-year average. Also shown are the numbers of kelts per week (Sunday–Saturday) detected passing LMN during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. Temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/) and the USACE TMT (US Army Corps of Engineers Technical Management Team; http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tempstrings/).

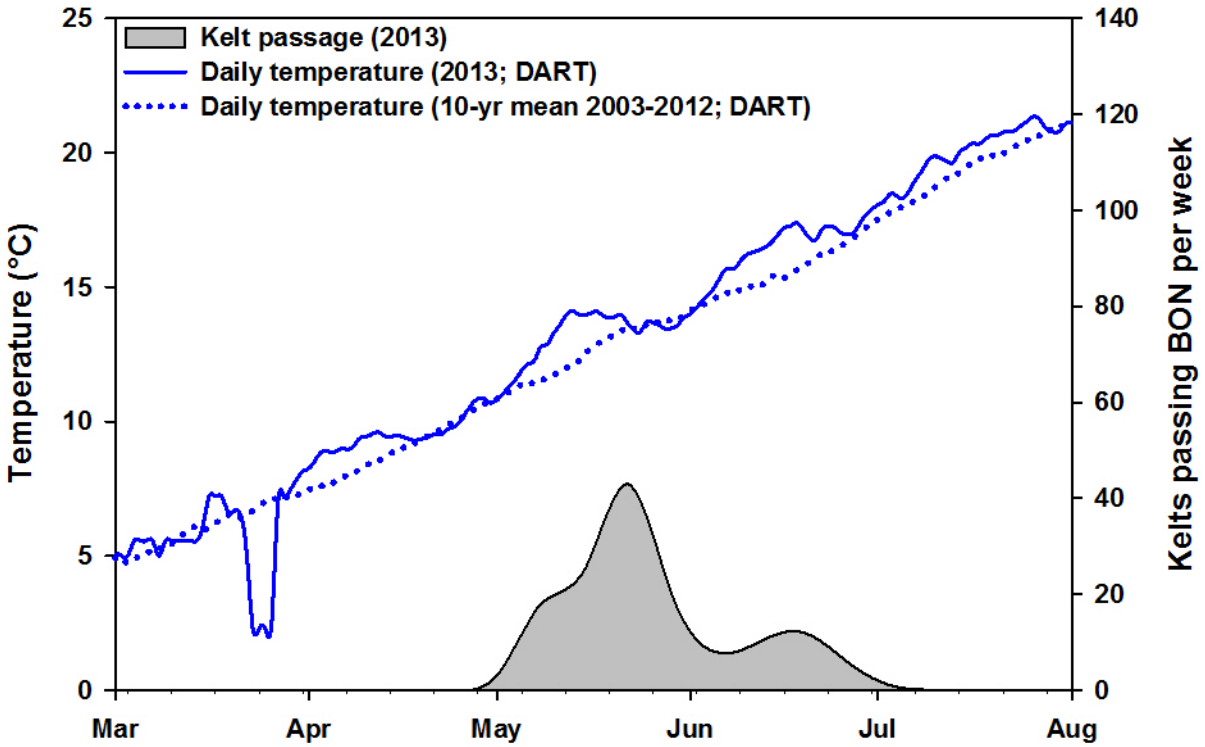

Figure E.4. Average daily forebay temperature (°C) observed at Bonneville Dam (BON) from 1 March to 1 August 2013, with the 10-year average. Also shown are the numbers of kelts per week (Sunday–Saturday) detected passing BON during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. All temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

Appendix F

Timing of Kelts Captured and Tagged at Tagging Sites

Appendix F

Timing of Kelts Captured and Tagged at Tagging Sites

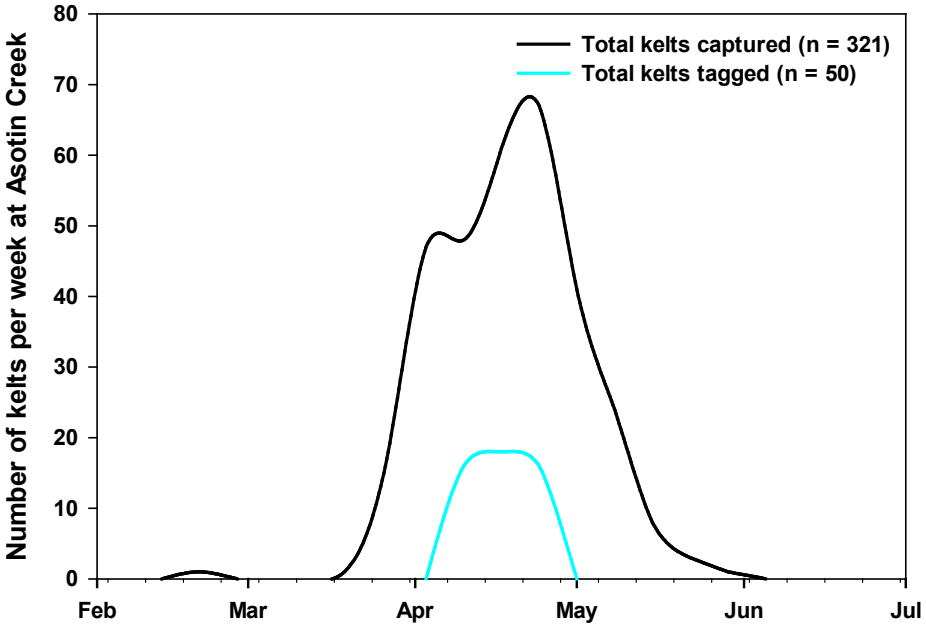

Figure F.1. Number of kelts surgically implanted with acoustic transmitters per week at Asotin Creek compared to the number of kelts captured by Washington Department of Fish and Wildlife at the weir in 2013. Kelts captured and tagged at the George Creek weir are also included in this figure.

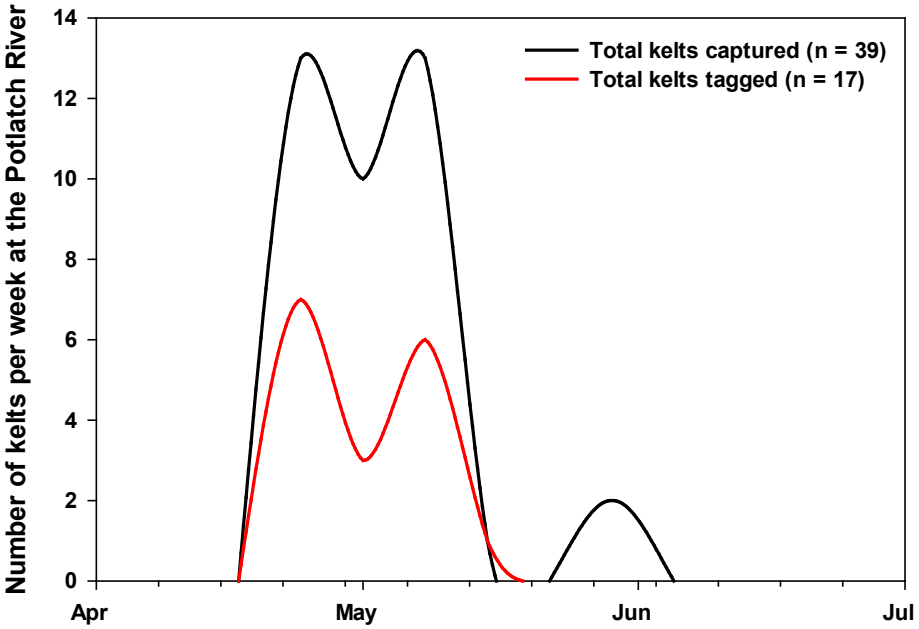

Figure F.2. The number of kelts surgically implanted with acoustic transmitters per week at the Potlatch River compared to the number of kelts captured by Idaho Department of Fish and Games at the weirs in 2013.

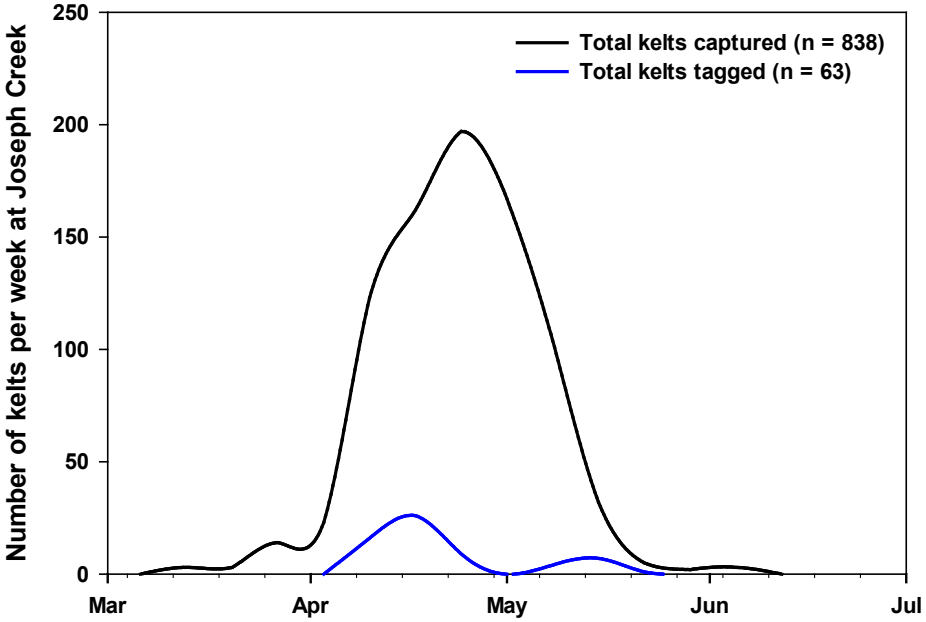

Figure F.3. Number of kelts surgically implanted with acoustic transmitters per week at Joseph Creek compared to the number of kelts captured by the Nez Perce Tribe at the weir in 2013.

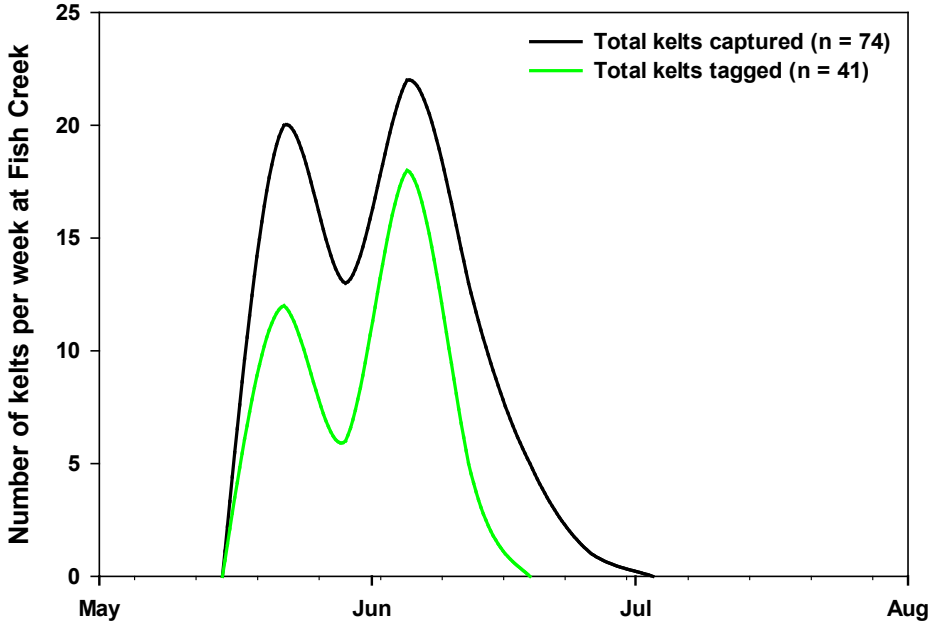

Figure F.4. Number of kelts surgically implanted with acoustic transmitters per week at Fish Creek compared to the number of kelts captured by Idaho Department of Fish and Game at the weir in 2013.

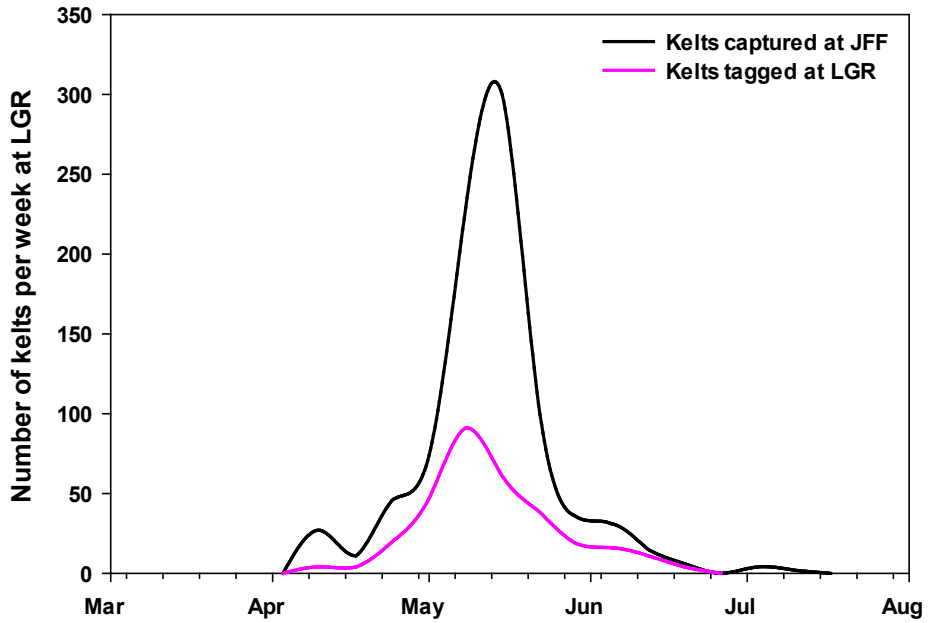

Figure F.5. Number of kelts tagged with acoustic transmitters at Lower Granite Dam (LGR) per week (gray) compared to the total number of steelhead kelts per week captured at the LGR Juvenile Fish Facility (JFF) separator (green) between 1 March and 1 August 2013.

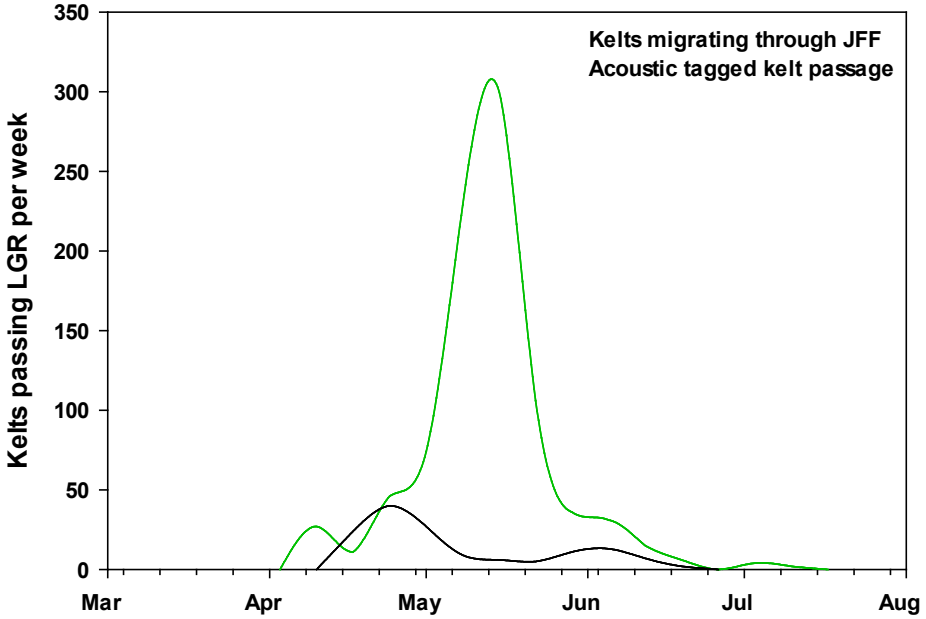

Figure F.6. Number of tagged kelts from tributary sites (gray) that passed Lower Granite Dam (LGR) per week compared to the total number of steelhead kelts captured per week at the LGR Juvenile Fish Facility (JFF) separator (green) between 1 March and 1 August 2013.

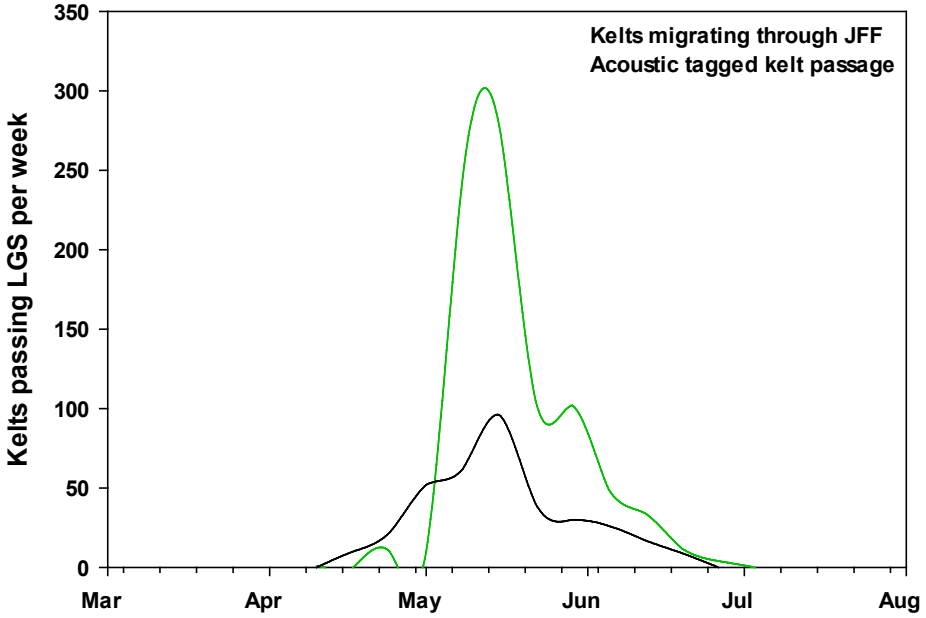

Figure F.7. Number of tagged kelts that passed Little Goose Dam (LGS) per week (gray) compared to the total number of steelhead kelts captured per week at the LGS Juvenile Fish Facility (JFF) separator (green) between 1 March and 1 August 2013.

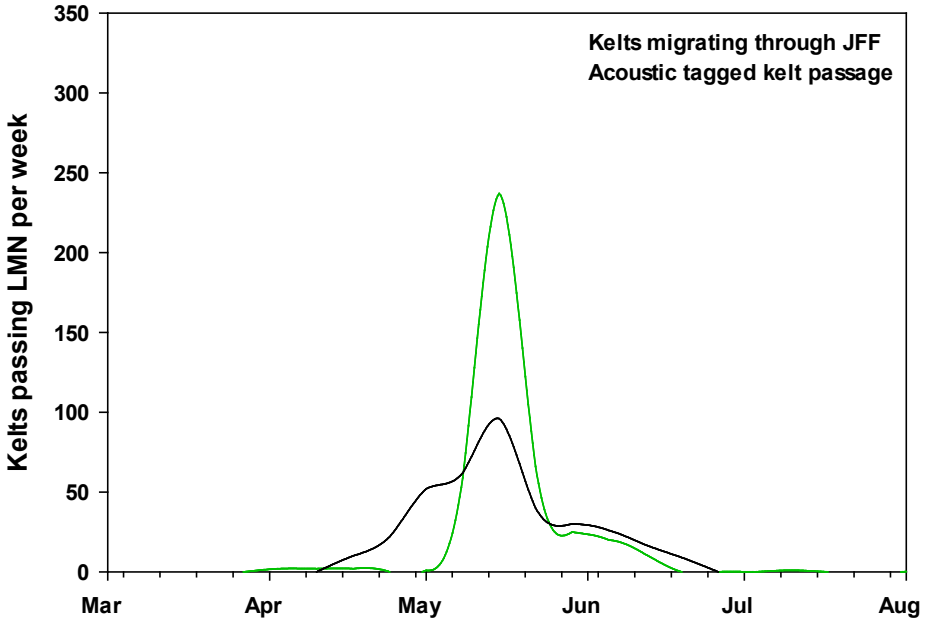

Figure F.8. Number of tagged kelts that passed Lower Monumental Dam (LMN) per week (gray) compared to the total number of steelhead kelts captured per week at the LMN Juvenile Fish Facility (JFF) separator (green) between 1 March and 1 August 2013.

Appendix G

Juvenile Salmon Acoustic Telemetry System Performance

Appendix G

Juvenile Salmon Acoustic Telemetry System Performance

Table G.1. Detection probabilities (± SE) of steelhead kelts implanted with acoustic transmitters on the cabled receiver arrays at Lower Granite, Little Goose and Lower Monumental dams in 2013.

Dam	Array	Detection Probability (SE)
Lower Granite	D1CR695	1.000 (0.000)
Little Goose	D2CR635	0.997 (0.003)
Lower Monumental	D3CR589	1.000 (0.000)

Table G.2. Detection probabilities (± SE) of steelhead kelts implanted with acoustic transmitters on the autonomous receiver arrays throughout the Federal Columbia River Power System in 2013 that were used to estimate survival.

Array	Detection Probability (SE)
A1CR743	1.000 (0.000)
A2CR696	0.992 (0.008)
A4CR636	1.000 (0.000)
A6CR602	0.997 (0.003)
A7CR590	1.000(0.000)
A9CR562	1.000(0.000)
A10CR539	1.000(0.000)
A11CR525	1.000(0.000)
A12CR236	1.000(0.000)

Table G.3. Percentage of steelhead kelts implanted with acoustic transmitters detected on multiple autonomous receivers at each array deployed in the Federal Columbia River Power System in 2013.

Array	Total Number of Receivers	Total Number of Tags Detected	Number of Receivers that Detected Each Fish Within an Array									
			1	2	3	4	5	6	7	8	9	10
CR743	3	160	2.5	23.8	73.8	-	-	-	-	-	-	-
CR696	4	147	6.8	23.8	28.6	40.8	-	-	-	-	-	-
CR693	2	442	7.7	92.3	-	-	-	-	-	-	-	-
CR636	4	382	5.2	11.3	23.8	59.7	-	-	-	-	-	-
CR634	3	360	2.2	26.4	71.4	-	-	-	-	-	-	-
CR602	4	331	0.0	4.2	15.7	80.1	-	-	-	-	-	-
CR590	4	306	0.7	10.5	23.5	65.4	-	-	-	-	-	-
CR587	3	290	2.1	24.1	73.8	-	-	-	-	-	-	-
CR562	4	266	0.0	0.8	10.2	89.1	-	-	-	-	-	-
CR539	4	234	0.9	3.0	18.8	77.4	-	-	-	-	-	-
CR525	4	219	0.5	5.5	33.3	60.7	-	-	-	-	-	-
CR236	4	146	0.0	1.4	8.9	89.7	-	-	-	-	-	-
CR152	8	105	27.6	36.2	23.8	4.8	4.8	1.9	0.0	1.0	-	-
CR126	8	133	6.8	30.8	29.3	17.3	9.0	3.0	3.8	0.0	-	-
CR113	10	26	30.8	42.3	15.4	3.8	0.0	3.8	0.0	3.8	0.0	0.0

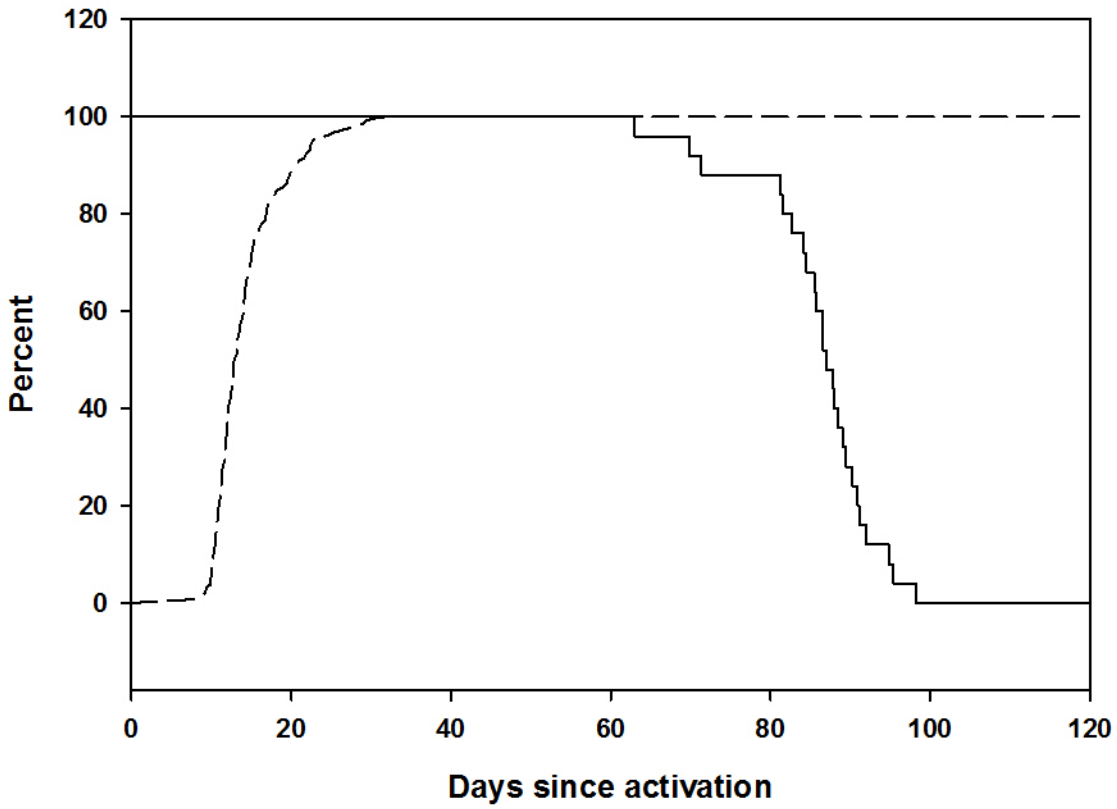

Figure G.1. Proportion of tag-life study tags that were transmitting (solid line) and the cumulative proportion of tagged steelhead kelts (dashed line) that arrived at the rkm 126 survival-detection array as a function of days since tag activation.

Appendix H

Juvenile Salmon Acoustic Telemetry System-Tagged Kelts Dam Passage versus Flow

Appendix H

Juvenile Salmon Acoustic Telemetry System-Tagged Kelts Dam Passage versus Flow

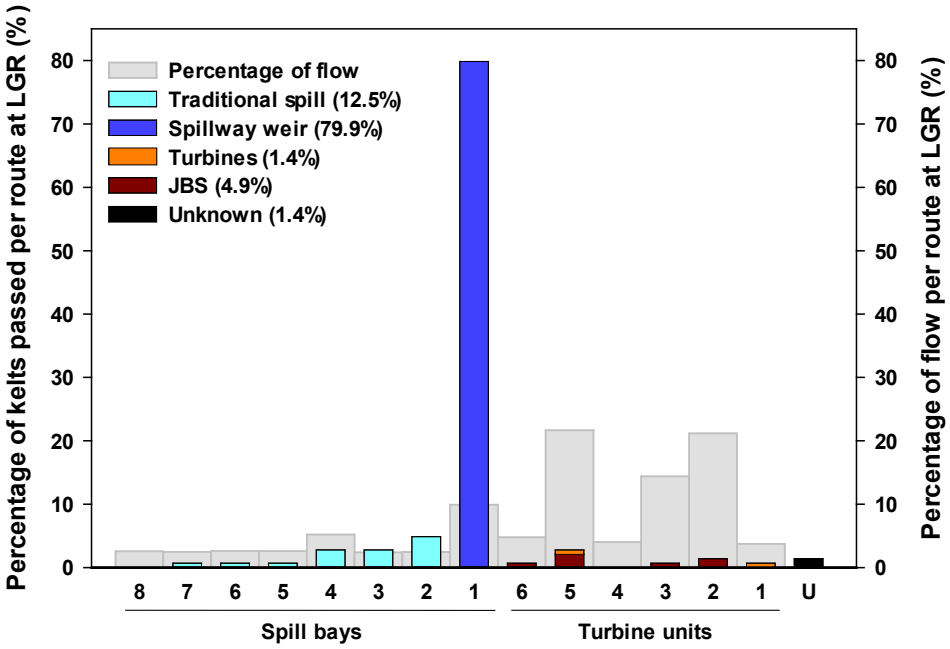

Figure H.1. Percentage of kelts that passed Lower Granite Dam (LGR) via each passage route (colored bars) and percentage of flow through each route (gray bars) during the period of tagged kelt passage at LGR (14 April 2013 to 17 June 2013). Passage routes are ordered from the north side of the river to the south side of the river.

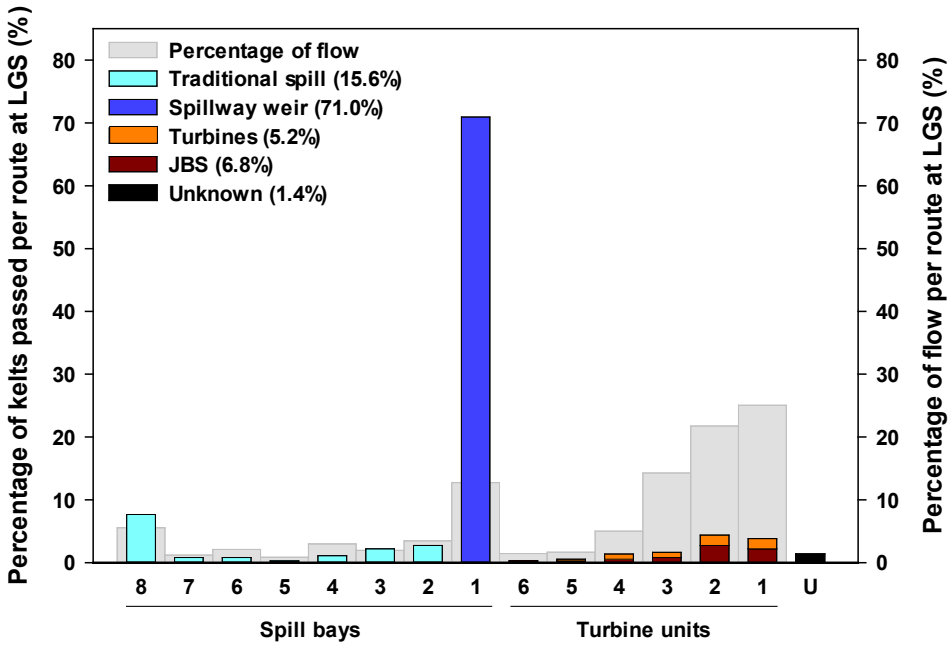

Figure H.2. Percentage of kelts that passed Little Goose Dam (LGS) via each passage route (colored bars) and percentage of flow through each route (gray bars) during the period of tagged kelt passage at LGS (17 April 2013 to 22 June 2013). Passage routes are ordered from the north side of the river to the south side of the river.

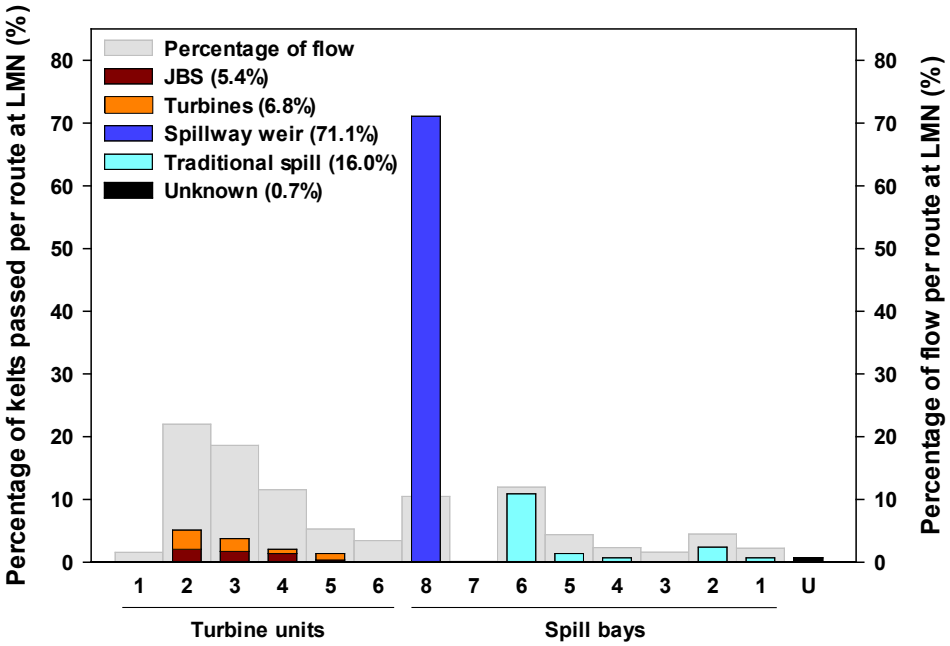

Figure H.3. Percentage of kelts that passed Lower Monumental Dam (LMN) via each passage route (colored bars) and percentage of flow through each route (gray bars) during the period of tagged kelt passage at LMN (19 April 2013 to 24 June 2013). Passage routes are ordered from the north side of the river to the south side of the river.

Appendix I

Diel Distribution and Dam Passage

Appendix I

Diel Distribution and Dam Passage

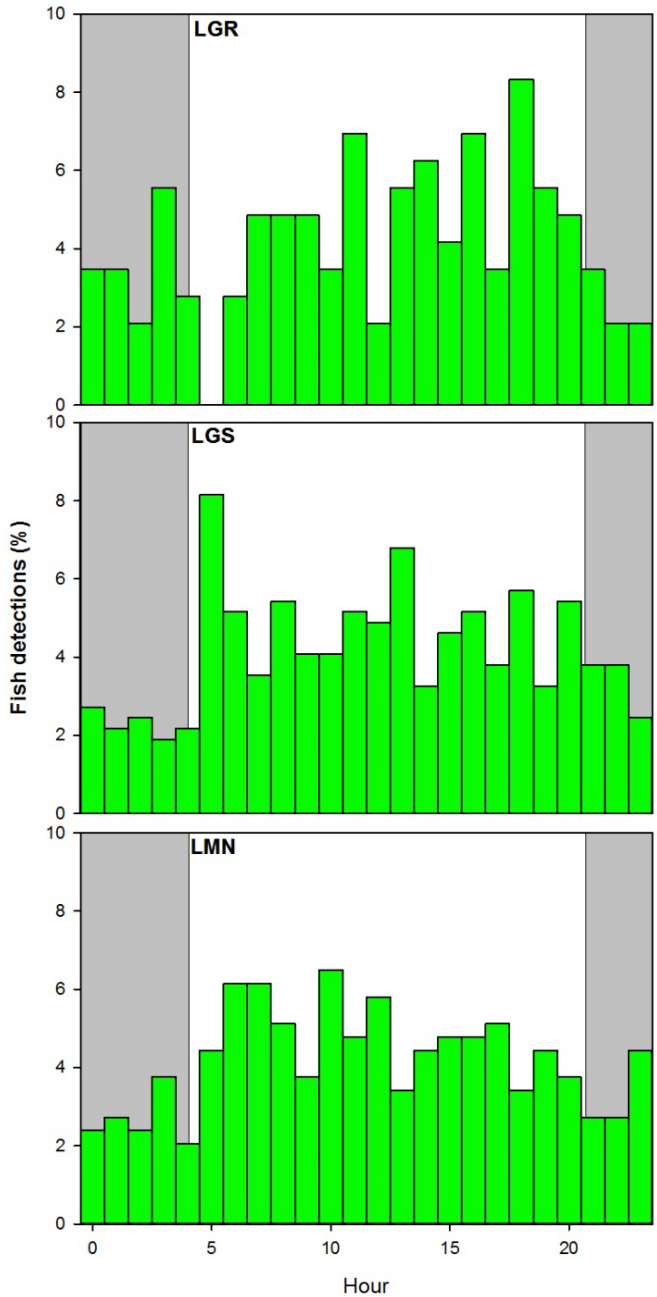

Figure I.1. Hourly distribution of steelhead kelt last detections at the cabled dam-face arrays at Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams. Gray areas represent approximate hours of darkness.

Appendix J

Routes of Passage through Multiple Federal Columbia River Power System Dams

Appendix J

Routes of Passage through Multiple Federal Columbia River Power System Dams

Table J.1. Routes of passage used by tagged kelts through Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams in 2013. The number of individuals from each route combination that were detected below Bonneville Dam (BON) is also presented. JBS = juvenile bypass system.

			Passed through route combination		Detected below BON	
LGR	LGS	LMN	N	%	N	%
Spillway weir	Spillway weir	Spillway weir	28	6.6	12	42.9
Spillway weir	Spillway weir	Traditional spill	9	2.1	6	66.7
Spillway weir	Spillway weir	JBS	2	0.5	0	0.0
Spillway weir	Spillway weir	Turbine	5	1.2	1	20.0
Spillway weir	Spillway weir		10	2.4	0	0.0
Spillway weir	Traditional spill	Spillway weir	5	1.2	3	60.0
Spillway weir	Traditional spill	Traditional spill	2	0.5	0	0.0
Spillway weir	Traditional spill		4	0.9	0	0.0
Spillway weir	Turbine	Spillway weir	2	0.5	1	50.0
Spillway weir	Turbine		2	0.5	0	0.0
Spillway weir			46	10.9	0	0.0
Traditional spill	Spillway weir	Spillway weir	5	1.2	3	60.0
Traditional spill	Spillway weir	Traditional spill	1	0.2	1	100.0
Traditional spill	Spillway weir	Turbine	1	0.2	0	0.0
Traditional spill	Spillway weir		2	0.5	0	0.0
Traditional spill	Traditional spill	Traditional spill	1	0.2	0	0.0
Traditional spill	Traditional spill		1	0.2	0	0.0
Traditional spill			7	1.7	0	0.0
JBS	Spillway weir	Traditional spill	1	0.2	1	100.0
JBS	Spillway weir		1	0.2	0	0.0
JBS			5	1.2	0	0.0
Turbine	Traditional spill		1	0.2	0	0.0
Turbine	Turbine	Spillway weir	1	0.2	0	0.0
	Spillway weir	Spillway weir	127	30.1	67	52.8
	Spillway weir	Traditional spill	21	5.0	8	38.1
	Spillway weir	JBS	9	2.1	7	77.8
	Spillway weir	Turbine	8	1.9	2	25.0
	Spillway weir		29	6.9	0	0.0
	Traditional spill	Spillway weir	24	5.7	9	37.5
	Traditional spill	Traditional spill	3	0.7	1	33.3
	Traditional spill	JBS	3	0.7	1	33.3

Table J.1 (contd)

LGR	LGS	LMN	Passed through route combination N	Passed through route combination %	Detected below BON N	Detected below BON %
	Traditional spill	Turbine	1	0.2	0	0.0
	Traditional spill		13	3.1	0	0.0
	JBS	Spillway weir	12	2.8	5	41.7
	JBS	Traditional spill	3	0.7	1	33.3
	JBS	Turbine	3	0.7	0	0.0
	JBS		7	1.7	0	0.0
	Turbine	Spillway weir	4	0.9	3	75.0
	Turbine	Traditional spill	5	1.2	3	60.0
	Turbine	JBS	2	0.5	0	0.0
	Turbine	Turbine	1	0.2	0	0.0
	Turbine		2	0.5	0	0.0
		Spillway weir	1	0.2	1	100.0
		Traditional spill	1	0.2	0	0.0
		Turbine	1	0.2	0	0.0

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