PNNL-22101

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

Final Report

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Richland, Washington 99352

Prepared for
the U.S. Army Corps of Engineers, Walla Walla District
Walla Walla, Washington
under Contract Number W912EF-08-D-0004

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LEGAL NOTICE

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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-11-01: Steelhead kelt passage distributions and Federal Columbia River Power System survival and return rates for fish tagged above and at Lower Granite Dam. The study was led by Battelle for the USACE Walla Walla District. The USACE technical lead was Chris Pinney. The PNNL study project manager was Alison Colotelo (509-371-7248). The data are archived at PNNL offices in Richland, Washington.

Summary

Steelhead (*Oncorhynchus mykiss*) populations throughout the Pacific Northwest have declined in the last century, and many populations are listed under the *Endangered Species Act of 1973* including Snake River steelhead, which are listed as Threatened. The causes of population declines are many and complex but include habitat loss and degradation, overharvest, and dam construction. The 2008 Biological Opinion has an estimated target of a 6% increase in Snake River B-run female steelhead abundance through an increase in iteroparity rates; that target is to be realized by a combination of reconditioning and in-river survival. 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 provide benefits to population abundance and productivity. The U.S. Army Corps of Engineers, Walla Walla District, is evaluating kelt migration and survival through FCRPS dams in order to identify ways to improve kelt passage survival and migration success. 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 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 18 April through 31 August 2012. The objectives were as follows:

- Estimate the annual kelt population abundance arriving at and passing LGR.
- Estimate the route survival and passage probabilities at each FCRPS dam where acoustic transmitter detection capabilities existed.
- Estimate the following passage metrics and timing of acoustic-tagged kelts:
  - **forebay residence time**: travel time between the entrance to the forebay of the dam and passage through the dam.
  - **tailrace egress time**: travel time between passage through the dam and exit from the tailrace of the dam.
  - **project passage time**: travel time between entrance to the forebay and exit from the tailrace of the dam.

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), the Potlatch River (three weirs on tributaries of the Potlatch River at rkm 795, 797, and 836), Joseph Creek (rkm 804), Fish Creek (rkm 944), and the Crooked River (rkm 961).

The objectives of this study were accomplished using the Juvenile Salmon Acoustic Telemetry System (JSATS), which enables managers and researchers to monitor the movement of fish that are tagged with acoustic transmitters using a series of acoustic receivers. In 2012, 22 autonomous and six cabled JSATS receiver arrays were deployed in the FCRPS for juvenile performance studies. An additional cabled array and three autonomous arrays were deployed specifically for this study. 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. Following release, tagged kelts were detected by a series of JSATS autonomous and cabled receiver arrays located between rkm 743 and rkm 86 of the lower Snake and Columbia rivers. Twenty-five autonomous arrays were located in the forebays, tailraces, and reservoirs of FCRPS dams as well as at strategic locations in the lower Columbia River downstream of all FCRPS dams. Cabled hydrophone arrays were also located on the dam faces of LGR, Little Goose Dam (LGS), Lower Monumental Dam (LMN), McNary Dam (MCN), John Day Dam (JDA), The Dalles Dam (TDA), and Bonneville Dam (BON). Detections on cabled receivers allowed for three-dimensional tracking of fish as they approached the dam face and for determining the route of passage.

Virtual single-release survival estimates were calculated for each main route of passage (e.g., 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 using the acoustic telemetry detection data on forebay, dam face, and tailrace arrays, and median times were reported.

Results

Survival Estimates and Passage Proportions

Overall, the estimated survival from all release locations to rkm 156 (most downstream array used to estimate survival) was 0.407 (standard error (SE) = 0.028) for the 324 kelts included in this study. Survival estimates ranged from 0.891 (SE = 0.022) to 1.002 (SE = 0.001) for individual river reaches within the FCRPS studied in 2012. Survival per kilometer was 0.985 for the reach between the forebay and the face of LGR, and was > 0.996 for all other reaches. Acoustic-tagged steelhead kelts most frequently passed through spillway routes (spillway weirs or traditional spill) during this study. Spillway weirs were used by the majority of kelts in the Snake River, whereas most kelts passed through traditional spill in the lower Columbia River. Survival estimates were highest for kelts that passed through spillway weirs at LGS (0.967; SE = 0.014) and JDA (0.986; SE = 0.014) and through traditional spill at LGR where a spillway weir is available for passage (0.906; SE = 0.052) and at TDA where a spillway weir is not available (0.941; SE = 0.020). Kelts that passed through the JBS at LMN, MCN, and BON had the highest survival estimates when compared to all other routes (1.000; SE = 0.000); however, a low percentage of kelts passed through this route (2.2%–6.9%). The percentage of kelts that passed through turbine routes was also low at all dams (1.5%–6.5%), and the survival estimates were generally lower (0.500–0.875) than for all other routes of passage. For the two kelts that passed through the Bonneville Dam powerhouse 2 turbines, survival was 1.000 (SE = 0.000); however, the sample size represented 1.5% of the tagged kelts that passed BON in 2012.

Passage Metrics

Forebay residence, tailrace egress, and project passage times generally decreased as acoustic-tagged kelts moved downstream in the FCRPS in 2012. Median forebay residence times were less than 1.5 hours at all dams included in this study; the lowest median forebay residence time observed at BON (0.48 hour). Median tailrace egress times were less than 0.5 hour, and median project passage times were less than 2.5 hours at all dams. Median tailrace egress and project passage times were lowest at TDA (0.17 and 0.87 hour, respectively); however, these passage metrics were measured for only 19 acoustic-tagged kelts that migrated through TDA between 14 June and 3 July 2012 because forebay and tailrace arrays were not deployed for the entire duration of this study.

Travel times ranged from 7.3 to 18.5 days for the 116 acoustic-tagged kelts that successfully migrated from the LGR tailrace (rkm 693) to Kalama (rkm 113) in 2012. These travel times represented travel rates that ranged from 31.3 to 79.2 km/day. Travel rates through river reaches tended to increase as tagged kelts moved downstream. In the Snake River from rkm 693 to rkm 525, the median travel rate was 35.2 km/day, whereas from rkm 525 to rkm 113, the median travel rate was 88.3 km/day. Median travel rates were noticeably lower as kelts moved through forebays of dams (14.1 to 99.3 km/day), whereas travel rates through tailraces were higher (60.0 to 182.2 km/day).

Conclusions

The results of this study provide information on the route of passage and subsequent survival for steelhead kelts migrating through the Snake and Columbia rivers from LGR to BON. Specifically, this study is the first to document these metrics since the installation of spillway weirs at many of the dams in the FCRPS. Spillway weirs were the primary route of passage for steelhead kelts in the Snake River, whereas the majority of fish passed through traditional spill routes in the lower Columbia River. Spillway routes (spillway weirs and traditional spill) and the JBS provided the highest estimated survival for steelhead kelts. Passage through turbines resulted in the lowest survival estimates; however, the lowest proportion of kelts passed through this route. Average discharge was higher in 2012 when compared to the 10-year average (2002–2011) and likely contributed to the overall high rate of migration success.

Although the results of this study contribute to understanding the impact of hydropower on steelhead kelt migration in the FCRPS, future research is warranted. Future studies should focus on sampling over the full kelt emigration period and on a larger proportion of kelts in fair and poor condition. Such studies also should include additional locations in the Snake River basin to acquire information that is applicable to a larger proportion of the Snake River steelhead population. In addition, the population of upstream migrating steelhead in subsequent years should be monitored for passive integrated transponder (PIT) tags to identify any repeat spawners that may contribute to Snake River steelhead iteroparity rates.

Acknowledgments

Many people made valuable contributions to this study and deserve acknowledgment. Scott Everett (Nez Perce Tribe), Brett Bowersox (Idaho Department of Fish and Game), Paul Kucera (Nez Perce Tribe), Ethan Crawford (Washington Department of Fish and Wildlife), Tim Copeland (Idaho Department of Fish and Game), and Matt Corsi (Idaho Department of Fish and Game) were very helpful in coordinating daily fish sampling at Lower Granite Dam (LGR), Potlatch River sites, Joseph Creek, Asotin Creek, Fish Creek, and Crooked River, respectively. Seasonal staff of the respected agencies also assisted with fish sampling and tagging. Brenda James and Ethan Green of Cascade Aquatics assisted with fish tagging and maintaining cabled receiver systems. Donna Trott (Pacific States Marine Fisheries Commission; PSMFC) assisted with the management of acoustic telemetry data collected during this study. Other PSMFC employees (Darin Etherington and Tyler Mitchell) contributed by maintaining arrays of autonomous acoustic receivers upstream or downstream of lower Columbia River dams or of cabled hydrophones at those dams (Scott Carpenter, Kara Prather, George Batten). Adam Seaburg (Columbia Basin Research) provided statistical support for the mark-recapture population estimate.

Advanced Telemetry Systems (ATS), Inc. manufactured the JSATS acoustic tags and the autonomous and dam-mounted receivers.

Many Battelle staff assisted in the study: deployment and maintenance of acoustic receivers (Scott Titzler, John Stephenson, Bob Mueller, Andy LeBarge, Kyle Larson, Brian Jeide, Ryan Klett, Eric Oldenburg, Evan Arntzen, James Hughes, Caleb Price, Eric Fischer, and Sheri Matzner), fish sampling (Brett Pflugrath, Ricardo Walker), acoustic telemetry data processing (Jayson Martinez, John Ingraham, Huiying Ren, Yong Yuan, Tylor Abel, Craig Swartout, Jinshan Xu, Jina Kim, Christa Woodley, Bishes Rayamajhi), and scientific permitting (Kris Hand). Andrea Currie and Kathy Neiderhiser provided editing and document production support of this report. Gayle Dirkes provided administrative support for this project. Dr. David Geist was the Ecology Group Manager at Battelle, and Steve Schlahta was the Product Line Manager during this study.

Acronyms and Abbreviations

3D	three-dimensional
AFEP	Anadromous Fish Evaluation Program
B1	Bonneville Dam powerhouse 1 (Oregon side)
B2	Bonneville Dam powerhouse 2 (Washington side)
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
IDFG	Idaho Department of Fish and Game
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

MW	megawatt(s)
N	population
n	sample
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)
RSW	removable spillway weir
SE	standard error
TDA	The Dalles Dam
USACE	U.S. Army Corps of Engineers
WDFW	Washington Department of Fish and Wildlife

Contents

Figures

Tables

1.0 Introduction

Steelhead (*Oncorhynchus mykiss*) populations in the Columbia River basin (CRB) have been greatly diminished over the past few decades, and many stocks are listed under the *Endangered Species Act of 1973* (ESA; McClure et al. 2003; NMFS 2004). Causes for population declines are numerous and include overharvest, loss and degradation of habitat, failed hatchery supplementation practices, and various effects of dam passage (Lichatowich 2001; Budy et al. 2002; McClure et al. 2003). However, it is not well understood how these factors have affected repeat spawning rates (termed iteroparity).

Iteroparous fish may have higher population abundance and productivity than semelparous (spawn once and then die) fish because they are afforded multiple spawning opportunities in their lifetime and, as a result, have increased lifetime fitness (Fleming and Reynolds 2004). Furthermore, Seamons and Quinn (2010) also showed that repeat spawners produced more offspring during their second spawning run alone than did one-time spawners. Post-spawn adult steelhead (kelts) from the Snake River basin upstream of Lower Granite Dam (LGR) must 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 not well understood. Reasonable and Prudent Alternative (RPA) 33 of the 2008 Biological Opinion (BiOp; NOAA 2008) identifies actions and requires measures to increase survival of migrating kelts, with particular emphasis on fish that spend multiple years in the ocean. Understanding the sources of mortality and increasing survival of kelt is an important step in improving iteroparity rates. The goal of this study was to quantify migration patterns and estimate dam passage metrics of Snake River steelhead kelt 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 kelt survival during their downstream migration.

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). Since these studies were conducted, several changes to the structure and operations of FCRPS dams have occurred (e.g., installation of spillway weirs at most FCRPS dams, installation of the Bonneville Dam second powerhouse corner collector [B2CC], implementation of the court-order spill program). These modifications, generally implemented to benefit juvenile salmonid survival because the smolts migrate seaward, may have a significant effect on kelt survival because they have been shown to readily pass dams via surface passage routes when available (Wertheimer and Evans 2005; Wertheimer 2007).

This report documents the results of a steelhead kelt migration and FCRPS dam passage study conducted by Battelle–Pacific Northwest Division for the U.S. Army Corps of Engineers (USACE), Walla Walla District, during spring and summer 2012.

1.1 Research 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 18 April through 31 August 2012. The objectives were as follows:

- Estimate the annual kelt population abundance arriving at and passing LGR.
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1.2 Study Area

The CRB spans the majority of Washington, Oregon, Idaho, and southeastern British Columbia, with 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). Extensive hydroelectric development, habitat loss and degradation, overharvest, and various other anthropogenic effects have caused many populations to decline. 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, up to eight FCRPS dams in the lower Snake and Columbia rivers must be passed during the migration of Snake River steelhead.

This research study focused on the lower Columbia and Snake rivers from river kilometer (rkm) 743 (representing the upstream end of the LGR reservoir as measured from the mouth of the Columbia River) to rkm 86 (near Oak Point, Washington; Figure 1.1). Steelhead kelts were collected and tagged at seven weir sites upstream of the detection area within tributaries of the Snake and Clearwater rivers (Figure 1.2), as well as 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 presented in Table 1.1.

1.2.1 FCRPS Dams

LGR is the fourth dam upstream of the mouth of the Snake River, a total of 695 rkm from the Pacific Ocean. It is the most upstream dam in the Snake River 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. There is also an earthen-filled section forming a portion of the dam. LGR is also equipped with a juvenile bypass system (JBS) to route the portion of downstream migrants guided by in-turbine screens to monitoring and collection facilities for study and transportation.

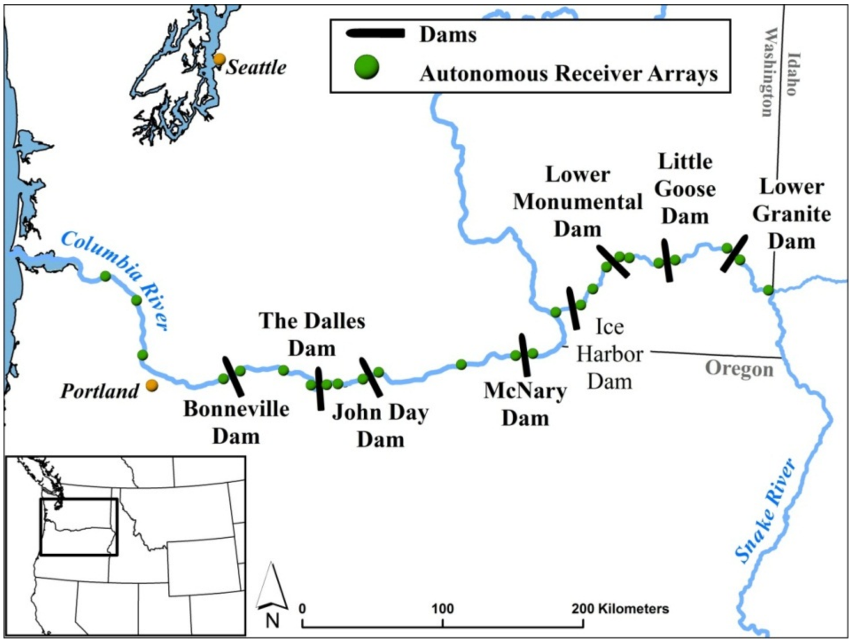

Figure 1.1. Locations of acoustic telemetry receiver arrays used to detect acoustic-tagged steelhead kelt migrating through the Federal Columbia River Power System (FCRPS) in 2012. Cabled receiver arrays were located on the upstream dam-face of Lower Granite, Little Goose, Lower Monumental, McNary, John Day, The Dalles, and Bonneville dams (bolded text). Autonomous receiver arrays (green 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 key locations within the FCRPS to detect fish for survival estimation.

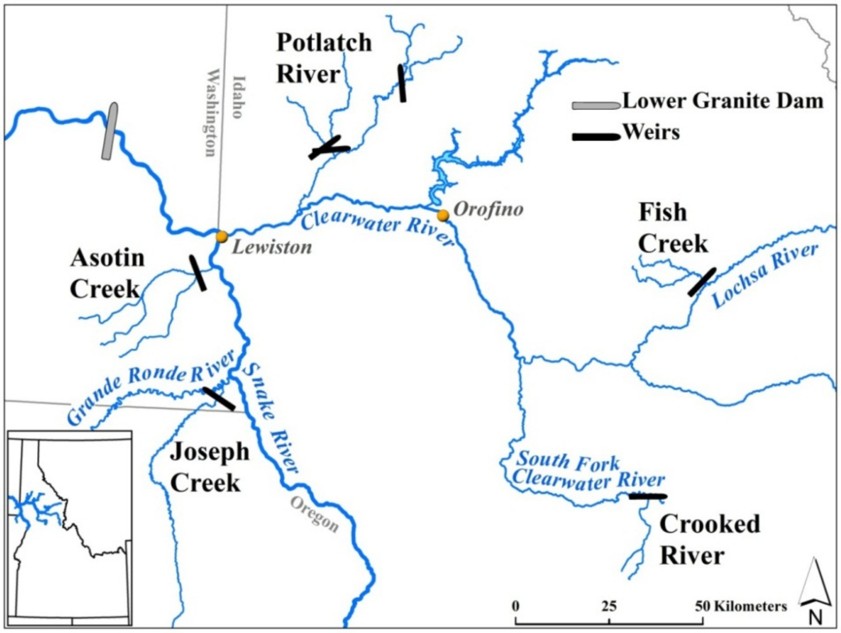

Figure 1.2. Sites where steelhead kelt were captured and tagged with acoustic transmitters in 2012 including Lower Granite Dam, Asotin Creek, Potlatch River, Joseph Creek, Fish Creek, and Crooked River.

Table 1.1. Distances (km) 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
Crooked River	961	266	326	372	423	491	612	652	727
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.

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

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

Ice Harbor Dam (IHR) is the only one of the eight dams in the FCRPS that was not equipped with acoustic receivers in 2012. It is the most downstream dam in the Snake River at rkm 538. It has a single powerhouse with six turbine units on the south side, 10 spillbays on the north side, 1 spillway weir, and a JBS.

MCN is the fourth dam upstream of the mouth of the Columbia River at rkm 470. On the south side, it consists of 14 70-MW turbines and two smaller 3-MW turbines used to provide power for the dam. The spillway, on the north side of the dam, consists of 22 bays, two of which are fitted with spillway weirs. The spillway weirs were removed on 8 June 2012 and left out for the remainder of the study period. MCN is also equipped with a JBS.

John Day Dam (JDA) is located at rkm 349 upstream of the mouth of the Columbia River. It consists of a powerhouse with 16 turbine units and four skeleton bays (bays where turbines were never installed) on the Oregon side and a 20-bay spillway on the Washington side. Two of the spillbays are fitted with spillway weirs. JDA is equipped with a JBS.

The Dalles Dam (TDA) is the second dam upstream of the mouth of the Columbia River at rkm 309. It has one powerhouse running parallel with the Oregon shore with 22 turbine units and a spillway consisting of 23 bays on the Washington side, none of which is currently fitted with a spillway weir. The powerhouse sluiceway is operated to provide an overflow passage route through six 20-ft-wide gates from the forebay to the sluiceway channel. TDA is the only FCRPS dam in the lower Snake and Columbia rivers that is not equipped with a JBS or PIT-tag detection capability for downstream migrants.

BON is the first dam upstream of the Columbia River mouth and is located at rkm 234. It consists of three dam structures and a navigation lock separated by islands. Its spillway, located in the middle section of the dam, consists of 18 bays. It has two powerhouses (powerhouse 1 [B1] on the Oregon side and powerhouse 2 [B2] on the Washington side) with a total of 18 turbine units (10 in B1 and 8 in B2). The second powerhouse is equipped with a surface passage sluiceway known as the B2 corner collector (B2CC) and a JBS. The B2CC has been shown to be used by both salmon smolts and steelhead kelts (Wertheimer 2007).

There also is an ice and trash sluiceway channel above the turbine units at B1; gates over turbine intakes 1B, 3B, 6C, and 10B typically are opened to provide surface outflows from the B1 forebay.

1.2.2 Steelhead Kelt Capture Sites

LGR is the first dam encountered during the downstream migration of Snake River steelhead kelts (which include, but are not limited to, steelhead originating in the Salmon and Clearwater rivers). This makes LGR an opportune sampling location because large numbers of kelts must pass the dam as they begin their migration back to the Pacific Ocean. Steelhead kelts were captured from the separator of the LGR JBS. This sampling was in conjunction with an ongoing Nez Perce Tribe (NPT) study conducted to evaluate the feasibility of reconditioning of Snake River steelhead kelts captured at LGR.

Asotin Creek flows into the Snake River at the town of Asotin, Washington, 61 rkm upstream from LGR. In 1997, the Washington Department of Fish and Wildlife (WDFW) designated Asotin Creek as a wild steelhead refuge, and the last record of hatchery reared steelhead released into Asotin Creek was in 1998. Wild steelhead population monitoring by the WDFW began in 2004 with the use of a floating resistance board weir. Iteroparity rates in Asotin Creek for females have been estimated via scale analyses to be as high as 2.9% (Mayer et al. 2006), but no male repeat spawning steelhead have been documented there (Mayer et al. 2010).

The Potlatch River flows into the Clearwater River 75 rkm from LGR and supports a wild population of steelhead. In 2005, the Idaho Department of Fish and Game (IDFG) began the Potlatch River Steelhead Monitoring and Evaluation Project in an effort to document steelhead population demographics and life history variations within the Potlatch River. The IDFG operated weirs on three tributaries of the Potlatch River during spring 2012. Two picket weirs were located near the town of Kendrick, Idaho, on Big Bear Creek and Little Bear Creek (a tributary of Big Bear Creek), and the third was a floating resistance board weir on the East Fork Potlatch River, a higher-elevation tributary. Several individual repeat spawning male and female fish have been documented since monitoring began on the Potlatch River (BJ Bowersox, Idaho Department of Fish and Game, personal communication, October 2012).

Joseph Creek is a tributary of the Grande Ronde River with its mouth 105 rkm upstream of LGR. Steelhead population monitoring in Joseph Creek began in 1960 when the Oregon Department of Fish and

Wildlife began conducting annual redd counts (McGowan and Winston 2009). The NPT Fisheries Division began an active population monitoring project in 2011 with the use of a floating resistance board weir in an effort to quantify population demographics and escapement within Joseph Creek. There are currently no data on iteroparity rates within Joseph Creek.

Fish Creek is a tributary of the Lochsa River with its mouth 247 rkm from LGR. The IDFG has operated a picket weir since 1992 to monitor the wild steelhead population of Fish Creek. Since the monitoring program began, two individual repeat spawning steelhead have been documented via scale analysis at Fish Creek representing an iteroparity rate of 0.1% (T Copeland, Idaho Department of Fish and Game, personal communication, December 2012).

The Crooked River flows into the South Fork of the Clearwater River 265 rkm from LGR. It supports a reintroduced population of steelhead that was restored following the removal of the Harpster Dam from the South Fork of the Clearwater River in 1962 (Hoss 1970). The Crooked River weir is a permanent concrete structure constructed in 1988 as part of the Lower Snake River Compensation Plan. Trapping of spring Chinook salmon (*Oncorhynchus tshawytscha*) brood stock was the main priority in the design of the weir, but it has since been used by the IDFG for steelhead population monitoring. The Crooked River is the only tributary in the current study into which hatchery reared steelhead are released, but only natural-origin adults are allowed to pass above the weir. No repeat spawning steelhead have been documented in the Crooked River.

1.3 Report Contents

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

2.0 Materials and Methods

2.1 Environmental Conditions

Data on total discharge, spill, and forebay temperature in 2012, as well as the 10-year average (2002–2011), for each FCRPS dam, were downloaded from the Data Access in Real Time (DART) website (http://www.cbr.washington.edu/dart/dart.html). Daily discharge values were calculated by averaging hourly values for each day.

2.2 Definitions

Estimates of single-release reach survival rates are defined by the upstream and downstream boundaries of the reach of interest. The following additional definitions are needed:

- **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 where a significant alteration in the allocation of water flow through dam operational changes affects water velocity or direction of flow. Locations of the forebay entrance arrays of autonomous receivers for LGR, LGS, LMN, and IHR were 1 km upstream of the dam face. Locations of the forebay entrance arrays of autonomous receivers for MCN, JDA, TDA, and BON were 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. Tailrace exit arrays of autonomous receivers for LGS and BON were 1 km downstream of the dam face. Tailrace exit arrays of autonomous receivers for LGR, LMN, MCN, and TDA were 2 km downstream of the dam face. The tailrace exit array for JDA was 3 km downstream of the dam face.
- The **passage-route survival estimate** is the probability of fish surviving when passing through any individual route (e.g., spillway, turbine, bypass) to the second downstream array. In this study, the passage-route survival estimates were calculated for fish passing 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. For TDA and BON, survival rates for sluiceway- and B2CC-passed kelts were also estimated.
- **Survival per kilometer** is the probability of fish surviving through any individual reach of river. It is calculated as (survival probability)$^{1/\mathrm{km}}$. This metric allows for comparison of survival through various reaches of river 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 passage. It is calculated as the difference in time between the last detection on the cabled receiver array and the last detection 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 first detection on the tailrace receiver array and the last detection on the cabled 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.

2.3 Fish Capture, Tagging, and Release

The following sections describe the methods employed for capture, associated record-keeping related to meeting permitting requirements for fish collection and handling, sampling, JSATS acoustic micro-transmitter and PIT-tag implantation, fish recovery and holding, and release.

2.3.1 Capture Sites

Overall, eight capture sites were used during the 2012 study. Wild steelhead kelt were collected from and tagged at seven capture sites on five different tributaries of the Snake and Clearwater rivers (Figure 1.2). In addition, both wild and hatchery-origin steelhead kelts collected from the LGR JFF were tagged during the study.

2.3.2 Federal and State Permitting

Records were kept on all kelts handled and tagged for permit accounting. Sampling 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 to the fish. A federal scientific take permit was authorized for this study by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Hydropower Division's FCRPS Branch and administered by NOAA; permit number 26-12-PNNL86. Scientific collection permits were also obtained from three state fish and wildlife management agencies: the Washington Department of Fish and Wildlife (permit number 12-151a), the Idaho Department of Fish and Game (permit number F-12-03-12), and the Oregon Department of Fish and Wildlife (permit number 17215 M1). All requirements and guidelines of permits 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 Pacific Northwest National Laboratory Institutional Animal Care and Use Committee (protocol number 2012-08).

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 Asotin Creek weir were equipped with downstream migrant trap boxes, which were used with varying levels of success at capturing kelts. Due to the lack of fish voluntarily moving into the downstream migrant trap boxes, most kelt tagged for this study were captured by the use of seine and/or dip nets upstream of tributary weirs.

Demographic information was collected from each fish captured, including sex, maturational status (pre-spawning or kelt), and external physical condition (good, fair, or poor). Each fish was also measured for fork length (cm) at each site, and weighed (kg) at the Potlatch River and LGR capture sites.

Males were identified by their characteristically longer snout and the presence of a kype. Males were also typically thinner 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. Abrasions, especially on the caudal and anal fins served as additional evidence of previous spawning activity. However, one male steelhead tagged at Joseph Creek was captured migrating back upstream with a pre-spawning female, after having been classified as a kelt for this study and released downstream of the weir.

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

2.3.4 Implantation of PIT Tags and JSATS 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 (Potlatch River, Fish Creek, and Crooked River) or the pelvic girdle (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)/liter of water buffered with a solution of 200 mg/L 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/L MS-222 (at LGR) was pumped into the mouth of the kelt for the duration of the surgery (~2–3 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 was implanted into the coelom of each kelt. The acoustic transmitters were (mean ± SD) 11.43 ± 0.08 mm long, 5.93 ± 0.05 mm wide, and 4.31 ± 0.09 mm high. The transmitters weighed 0.50 ± 0.01 g in air. The 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 JSATS transmitters in male and female kelts. For male kelts, the acoustic transmitter was inserted 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 an epoxy. 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 cut, leaving a tail end of approximately 2 mm of suture to help anchor the transmitter to the body wall. The incision was then closed using two stitches in the same manner as done with the males. This method was used to decrease possible transmitter loss in females due to post-spawning swelling of the vent and the small size of the JSATS transmitter.

2.3.5 Recovery, Holding, and Release

Kelts tagged at LGR were held overnight following surgery 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 JSATS arrays, cabled and autonomous, were deployed to detect fish tagged with JSATS acoustic transmitters as they passed downstream through the study reach between the upstream end of the LGR pool (rkm 743) and downstream of BON at rkm 86 (Table 2.1). The cabled dam-face arrays at LGR, LGS, LMN, MCN, JDA, TDA, and BON were used to estimate 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 dam-face arrays to the second-next downstream autonomous receiver array (generally in the reservoir of the next downstream dam). The Global Positioning System (GPS) positions of individual dam-face hydrophones and autonomous receivers are presented in Appendix A.

2.4.1 Cabled Dam-Face Arrays

The cabled dam-face 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, 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.

Table 2.1. River kilometer, description, location, name, and function of acoustic receiver arrays deployed in 2012. Array Name is a concatenation of "A" for autonomous or "D" for dam face, the array sequence number, "CR" for Columbia River, and the distance of the array from the mouth of the Columbia River. For reference, the mouth of the Snake River is located at rkm 522.

rkm	Array Description	Location	Array Name	Array Function
743	LGR Pool Boundary	Red Wolf Bridge	A1CR743	Detect tagged fish entering LGR pool
696	LGR Forebay	1 km upstream LGR	A2CR696	Detect tagged fish entering LGR forebay
695	LGR Dam Face	LGR	D1CR695	Regroup fish for route-specific assignments
693	LGR Tailrace	2 km downstream LGR	A3CR693	Detect tagged fish to estimate egress rate
636	LGS Forebay	1 km upstream LGS	A4CR636	Detect tagged fish entering LGS forebay
635	LGS Dam Face	LGS	D2CR635	Regroup fish for route-specific assignments
634	LGS Tailrace	1 km downstream LGS	A5CR634	Detect tagged fish to estimate egress rate
604	LMN Pool	Ayer's Boat Basin	A6CR604	Detect tagged fish migrating through LMN pool
590	LMN Forebay	1 km upstream LMN	A7CR590	Detect tagged fish entering LMN forebay
589	LMN Dam Face	LMN	D3CR589	Regroup fish for route-specific assignments
587	LMN Tailrace	2 km downstream LMN	A8CR587	Detect tagged fish to estimate egress rate
562	IHR Pool	24 km upstream IHR	A9CR562	Detect tagged fish migrating through IHR pool
539	IHR Forebay	1 km upstream IHR	A10CR539	Detect tagged fish entering IHR forebay
525	MCN Pool	55 km upstream MCN	A11CR525	Detect tagged fish migrating through MCN pool
472	MCN Forebay	2 km upstream MCN	A12CR472	Detect tagged fish entering MCN forebay
470	MCN Dam Face	MCN	D4CR470	Regroup fish for route-specific assignments
468	MCN Tailrace	2 km downstream MCN	A13CR468	Detect tagged fish to estimate egress rate
422	JDA Pool	Crow Butte	A14CR422	Detect tagged fish migrating through JDA pool
351	JDA Forebay	2 km upstream JDA	A15CR351	Detect tagged fish entering JDA forebay
349	JDA Dam Face	JDA	D5CR349	Regroup fish for route-specific assignments
346	JDA Tailrace	3 km downstream JDA	A16CR346	Detect tagged fish to estimate egress rate
325	TDA Pool	Celilo	A17CR325	Detect tagged fish migrating through TDA pool
311	TDA Forebay	2 km upstream TDA	A18CR311	Detect tagged fish entering TDA forebay
308	TDA Dam Face	TDA	D6CR309	Regroup fish for route-specific assignments
307	TDA Tailrace	1 km upstream TDA	A19CR307	Detect tagged fish to estimate egress rate

Table 2.1. (contd)

rkm	Array Description	Location	Array Name	Array Function
275	BON Pool	Hood River	A20CR275	Detect tagged fish migrating through BON pool
236	BON Forebay	2 km upstream BON	A21CR236	Detect tagged fish entering BON forebay
234	BON Dam Face	BON	D7CR234	Regroup fish for route-specific assignments
233	BON Tailrace	1 km downstream BON	A22CR233	Detect tagged fish to estimate egress rate
156	Lower CR	Knapp	A23CR156	Detect tagged fish migrating through Lower CR
113	Lower CR	Kalama	A24CR113	Detect tagged fish migrating through Lower CR
86	Lower CR	Oak Point	A25CR86	Detect tagged fish migrating through Lower CR

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

JSATS cabled arrays were deployed along the upstream-face of LGR, LGS, LMN, MCN, JDA, TDA, and BON to detect JSATS-tagged kelts as they approached and passed the dams. The array at LGR consisted of hydrophones mounted on most main pier noses. Dam-face arrays at the remaining 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. Two hydrophones were deployed at each main pier. One hydrophone was deployed at a shallow elevation and the other was deployed at a deep elevation to provide acceptable geometries for tracking an acoustic-tagged fish in three dimensions and then assigning it a route of passage through the dam. The elevations of each cabled system hydrophone are presented in Appendix A. Two cluster arrays were deployed in the forebay of LGR and LMN approximately 50 m from the spillway weir to assist in 3D tracking of fish as they approached each dam. Each cluster array consisted of a 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 receivers were housed in the gallery of the dam.

2.4.2 Autonomous Receivers and Arrays

Autonomous acoustic telemetry receivers were deployed in arrays at strategic sites throughout the lower Snake and Columbia rivers (Figure 1.1). An array is defined as a group of autonomous receivers deployed across the entire width of a river to detect passing fish that have been surgically implanted with acoustic tags. Most arrays consisted of receivers deployed within 120 m of each other and less than 90 m from the shore.

Twenty-five arrays of autonomous receivers were used in this study. Arrays were named by concatenating “A” (for autonomous array), a sequential array number (counting from upstream to downstream), and “CR” (to represent the distance of the array from the mouth of the Columbia River). For example, array A1CR743 was the most upstream autonomous array, 743 rkm from the mouth of the Columbia River.

Autonomous arrays were located in the forebays of all eight FCRPS dams in the lower Snake and Columbia rivers and in the tailraces of all FCRPS dams except IHR. Additional mid-reservoir arrays were also located in the pools of all FCRPS dams except LGS and LGR. An additional 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.

2.4.2.1 Autonomous Receiver Deployment, Retrieval, Servicing, and Redeployment

Autonomous receivers were rigged with the configuration shown in Figure 2.1. A rope with three 2.7-kg buoyancy floats connected the receiver housing and an InterOcean Systems, Inc. (San Diego, California) Model 111 acoustic release. Another rope connected the acoustic release to a 34.0-kg steel anchor. Longer ropes (up to 2 m) were used in deepwater areas and locations where shifting substrate could potentially bury the acoustic release mechanisms.

Autonomous receivers were retrieved by boat and downloaded at least once per month. To retrieve the receivers, staff entered a release-specific code into a topside transceiver. The code was then transmitted as an acoustic signal via an underwater transducer to the acoustic release mechanism attached to the receiver. Upon receipt of the signal, the acoustic release mechanism would open and free the positively buoyant package from the anchor so that it would surface and could be retrieved by staff in the boat. A pre-activated receiver was immediately deployed in the same location as the recovered receiver (Snake River) or data from the receiver was downloaded and the receiver was redeployed in the same location (Columbia River). The recovered receiver was then dried and opened to retrieve the memory card. The data were downloaded 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.

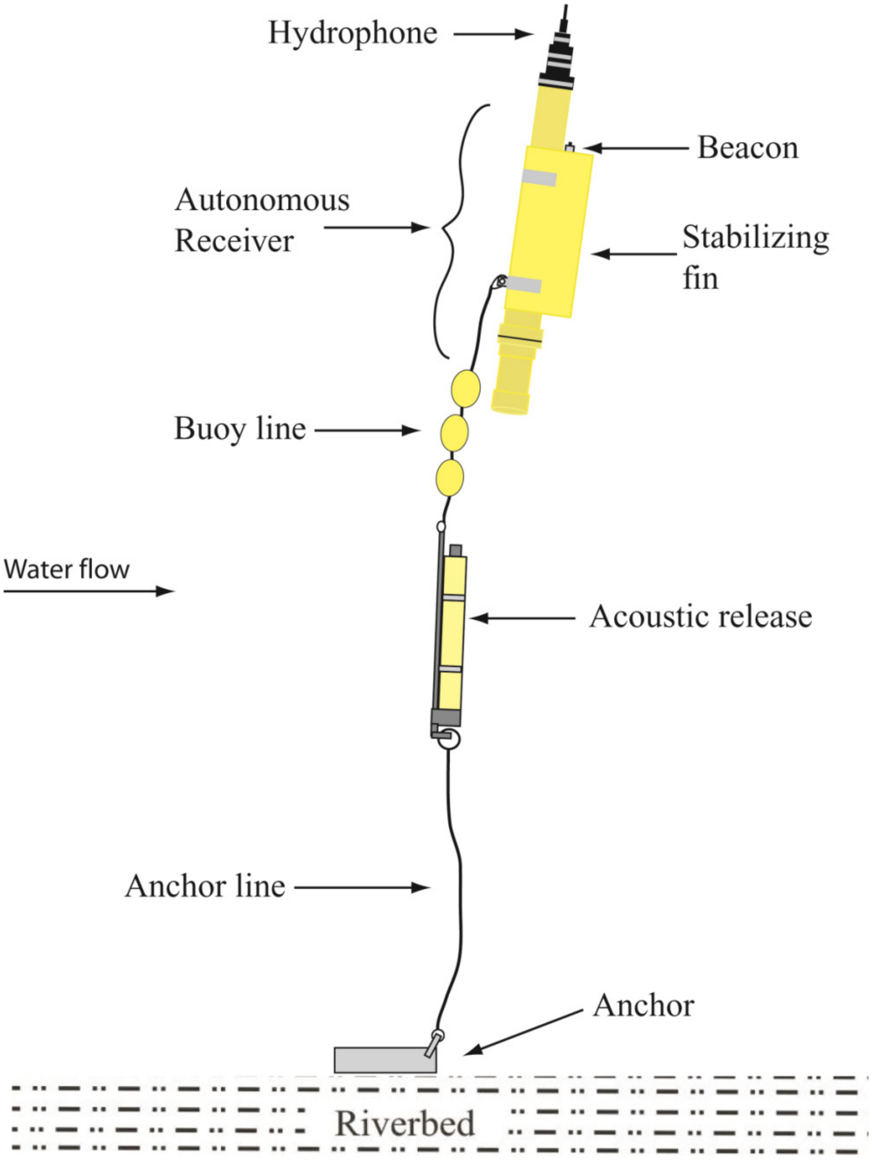

Figure 2.1. The JSATS autonomous acoustic receiver system used in 2012 including the hydrophone, acoustic receiver, acoustic release, and anchor.

2.5 Data Processing and Validation

Signals were decoded and filtered as part of data processing and validation efforts.

Data collected by the JSATS 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 and time of arrival using binary phase shift keying, a digital-modulation technique that transmits messages by altering the phase of the carrier wave. 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 dataset 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 indicate 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 capture specialized information, where available. An example is route of passage, which is assigned a value for that event that immediately precedes dam passage based on the spatial tracking of tagged fish movements to the location of last detection. Multiple receptions of messages within an event were used to triangulate successive tag positions relative to hydrophone locations.

2.6 Statistical Methods

The statistical methods included tests of assumption 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 testing conducted in 2012.

2.6.2 Tag-Life Study

All tags used for this study were delivered prior to the beginning of tagging (18 April 2012), and 25 tags were randomly selected for tag-life assessment. Tag loss or failure would violate Assumption A6 (see Table 2.2). The possibility of acoustic-tag failure depends on travel time relative to battery life. A tag-life curve was constructed for the tags. Tag-life curves and the cumulative percentage of tags passing the most downstream survival-detection array (Knapp, rkm 156) were plotted as a function of time since tag activation.

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 placed 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.

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

- 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.

The detection history of each virtual release group was loaded into SURPH Version 3.4.1[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, since 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, JBS, and sluiceway, where applicable. For fish entering the JBS, the PIT-tag detection system was used to provide a complete tally of that passage abundance, assuming 100% detection efficiency. At BON, passage through the sluiceways and turbine units were separated for the B1 and B2 powerhouses.

2.6.5 Estimation of Passage Metrics and Travel Times

Travel times associated with forebay residence, tailrace egress, and project passage were calculated for each acoustic-tagged kelt that passed LGR, LGS, LMN, MCN, JDA, TDA, and BON in 2012. Travel time requires fish to be detected on both the upstream and downstream arrays for a specific reach (e.g., LGR forebay residence included arrays marking the LGR forebay and the LGR cabled dam-face array. Travel rates were calculated for kelts moving within reservoirs in the FCRPS (i.e., outside the forebay and tailrace of each dam).

2.6.6 Estimation of Population Abundance Arriving at Lower Granite Dam

An estimate of the annual kelt population abundance that arrived at and passed LGR during the study period was calculated using the Lincoln index. Kelts captured and tagged with JSATS transmitters and PIT tags were used as the first sample, and kelts detected through the LGR JFF were used as the second sample.

(2.1)

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

where n_2 = total number of fish caught at the LGR JFF (including recaptures)
n_1 = number of fish caught, marked, and released at tributary weirs
N = population estimate
m_2 = number of recaptures at the LGR JFF (fish marked and released from tributary weirs).

2.7 Dam-Passage Characteristics

In this section, we examined passage characteristics for all kelt passing each dam in the system relative to flow, time of day, and approach depth.

2.7.1 Dam Passage versus Flow

The cross-dam distributions of kelt passage at LGR, LGS, LMN, MCN, JDA, TDA, and BON were analyzed using data collected from the cabled 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, Spillbay 5) 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 study period was also plotted.

2.7.2 Diel Distribution

The diel distributions of kelt passage through each dam were determined for the cabled arrays at LGR, LGS, LMN, MCN, JDA, TDA, and BON. For each cabled array, the number of kelts last detected during each hour was divided by the total number of kelts that passed through that 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 array. Bars indicating approximate hours of darkness were placed beginning one hour after sunset and ending one 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://www.usno.navy.mil/USNO/astronomical-applications/data-services/rs-one-year-us).

2.7.3 Vertical Distribution

The vertical distributions of kelts were determined as they approached LGR, LGS, LMN, MCN, JDA, TDA, and BON in 2012. Kelts were grouped by their route of passage assignment (i.e., powerhouse [turbine and JBS combined], traditional spill, spillway weir, sluiceways) at each dam. Using the 3D positioning information, the median depth in the water column was calculated for each sub-route assignment when kelt were 75 m, 50 m, 25 m, 10 m, 5 m, and less than 5 m (last detection before passage) from the dam face. Depth was calculated relative to the Minimum Operating Pool (MOP) elevation for each dam.

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 at FCRPS dams generally exceeded the 10-year average (2002–2011) in 2012, with the exception of a brief period near the first of June at the lower Columbia River dams (Appendix C). For the entire study period, from the time the first fish was released to the time the last fish was detected (18 April through 6 July 2012), total daily discharge in the Snake River (as measured at LGR) ranged from 48.4 to 186.3 kcfs with a mean of 101.5 kcfs (Table 3.1; Figure C.1). Total daily discharge in the Columbia River (as measured at BON) during the study period ranged from 279.1 to 442.1 kcfs with a mean of 358.3 kcfs (Table 3.1; Figure C.8). Spillways were in use during the entire study period at all eight FCRPS dams, and the average percentage spill during that time ranged from 30.7% at LMN to 60.0% at IHR (Table 3.1). Snake River temperatures fluctuated around or slightly below the 10-year average (2002–2011) during the study period, whereas Columbia River temperatures were generally lower than the 10-year average (Appendix E).

Table 3.1. Mean, maximum, and minimum discharge values (kcfs) and percentage spill at Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), The Dalles (TDA), and Bonneville (BON) dams for the time period between the tagging of the first kelt (18 April 2012) and the detection of the last kelt at any acoustic arrays (6 July 2012). Also shown are the 10-year averages (2002–2011) for the same dates. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

	2012				10-Year Average	
	Mean Discharge (kcfs)	Max. Discharge (kcfs)	Min. Discharge (kcfs)	Mean % Spill	Mean Discharge (kcfs)	Mean % Spill
LGR	101.5	186.3	48.4	33.1	92.8	30.1
LGS	97.4	178.4	49.1	34.9	90.1	28.5
LMN	100.6	192.6	49.8	30.7	92.1	25.2
IHR	102.5	192.2	50.9	60.0	94.5	57.1
MCN	349.2	414.4	279.5	55.0	266.1	45.2
JDA	352.8	432.2	275.7	38.3	265.6	32.6
TDA	335.6	414.5	257.8	39.9	259.7	39.3
BON	358.3	442.1	279.1	39.0	275.6	40.6

3.2 Kelt Migration Timing and Fish Characteristics

3.2.1 Run Timing

Tagging began on 18 April at LGR and continued until 22 June (Table 3.2). Kelt were captured and tagged at Asotin Creek, Potlatch River, Joseph Creek, and the Crooked River between 19 April and 25 May, while tagging at Fish Creek occurred between 27 May and 27 June. Effort was made at all sites to tag kelt for their entire emigration period. However, the onset of tagging was delayed until all necessary federal and state permits were acquired. This delay resulted in the loss of tagging opportunities for the first 12.0% (n = 274 of 2278) of kelts collected at the LGR JFF and the first 45.7% (n = 37 of 81), 10.1% (n = 19 of 189), and 7.3% (n = 27 of 371) of kelts captured at Asotin Creek, Potlatch River, and Joseph Creek weirs, respectively.

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

Location	Kelt Tagged	First Capture	First Tagging	Percentage of Fish Tagged by Date					Last Tagging	Last Capture
				10%	25%	50%	75%	90%		
LGR	182	3 April	18 April	24 April	27 April	7 May	23 May	4 June	22 June	28 June
Asotin Creek	3	10 March	19 April	-	-	19 April	-	-	20 April	14 May
Potlatch River	48	9 April	19 April	20 April	24 April	26 April	1 May	17 May	22 May	23 May
Joseph Creek	37	12 April	23 April	27 April	28 April	1 May	11 May	18 May	25 May	12 June
Fish Creek	52	27 May	27 May	1 June	6 June	12 June	18 June	24 June	27 June	29 June
Crooked River	2	6 May	6 May	-	-	-	-	-	6 May	31 May

Functionality of the weirs at all tributary sites was highly 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 Asotin Creek and the Crooked River precluded sampling at those sites except for brief periods. High water also delayed the onset of tagging at Fish Creek. The timing of kelt capture at each collection site and the timing of tagging for this study over time are presented in Appendix F. There is no graph for the timing of tagging at the Crooked River; only two fish were tagged at this site, and both were tagged on the same day.

Although untagged kelts were first collected from the JFF at LGR on 26 March, the period of passage at FCRPS dams for acoustic tagged kelts was from 21 April through 4 July (Table 3.3). The date by which 50% of kelts had passed each dam ranged from 10 May at LGR to 17 May at BON. The majority (90%) of dam passage had occurred at all FCRPS dams by mid-June, although several kelts were detected passing dams in July.

3.2.2 Length Frequency

Kelts implanted with JSATS transmitters ranged in fork length from 48.9 to 86.5 cm, and the majority of fish (72.5%; n = 235 of 324) were 48.0 to 70.0 cm in length. Males were smaller than females on average at all sites (Table 3.4) except at Fish Creek and the Crooked River (where only two and one males were sampled, respectively). Kelt collected and tagged at Fish Creek and the Crooked River, both of which support what are considered B-run steelhead populations, were larger on average than fish collected and tagged at other sites. Females at those sites were heavier on average than males (Table 3.4). Overall, 35.7% (n = 65 of 182) of the fish tagged at LGR had a clipped adipose fin, indicating they were of hatchery origin and 64.3% (n = 117 of 182) had an unclipped adipose fin. These percentages were very similar to that of all the fish handled at LGR (i.e., 38.7% clipped adipose fin [n = 881 of 2276] and 61.3% unclipped adipose fin [n = 1395 of 2276]).

Table 3.3. Dates that the first and last acoustic-tagged kelt passed at Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), The Dalles (TDA), and Bonneville (BON) 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 10%	25%	50%	75%	90%	Last Kelt Passed
LGR	124	21 April	26 April	30 April	10 May	11 June	19 June	30 June
LGS	291	21 April	27 April	1 May	11 May	30 May	17 June	2 July
LMN	263	23 April	28 April	2 May	11 May	29 May	15 June	30 June
IHR[(a)]	233	24 April	28 April	3 May	12 May	30 May	14 June	30 June
MCN	211	25 April	29 April	3 May	12 May	30 May	12 June	1 July
JDA	173	29 April	2 May	7 May	16 May	4 June	18 June	3 July
TDA	163	28 April	1 May	7 May	15 May	3 June	17 June	3 July
BON	138	29 April	2 May	9 May	17 May	5 June	17 June	4 July

(a) No cabled dam-face arrays were deployed at IHR so forebay array data were used to determine likely passage dates.

Table 3.4. Total number of kelt tagged at Lower Granite Dam (LGR), Asotin Creek, Potlatch River, Joseph Creek, Fish Creek, and Crooked River along with total number tagged, median fork length (cm ± SD), and weight (kg ± SD) of males and females tagged at each site.

Site	M:F Ratio Handled Fish	Total Tagged	M:F Ratio Tagged Fish	Males N	Males Fork Length (cm)	Males Weight (kg)	Females N	Females Fork Length (cm)	Females Weight (kg)
LGR	0.3:1	182	0.3:1	41	57.7 ± 4.7	1.53 ± 0.49	141	60.1 ± 6.4	1.68 ± 0.62
Asotin Creek	0.5:1	3	2:1	2	60.4 ± 4.8	-	1	63.5	-
Potlatch River	0.4:1	48	0.7:1	20	62.5 ± 8.1	2.05 ± 0.96	28	69.3 ± 5.1	2.54 ± 0.61
Joseph Creek	1.1:1	37	0.8:1	17	56.0 ± 7.5	-	20	61.2 ± 7.5	-
Fish Creek	1:10	52	1:25	2	78.0 ± 2.8	-	50	75.8 ± 4.0	-
Crooked River	6:1	2	1:1	1	85	-	1	73.5	-

3.3 Estimates of Survival Rates

3.3.1 Migration Success Through the FCRPS

Overall, 120 of 324 (37.0%) JSATS-tagged steelhead kelts successfully migrated to the Kalama array located in the tidal freshwater portion of the Columbia River estuary at rkm 113, indicating successful migration through the FCRPS. Of the fish that successfully migrated, 23.3% (n = 28) had a clipped adipose fin (denoting hatchery origin) and 76.7% (n = 92) had an intact adipose fin. The migration success rate for kelts of hatchery origin (clipped adipose fin) was 43.1% (n = 28 of 65), and 78.6% (n = 92 of 117) for wild kelts (unclipped adipose fin). Both sexes had migration success rates similar to the overall population, with 36.9% (89 of 241) and 37.3% (31 of 83) of females and males, respectively, detected on the Kalama or Oak Point arrays (rkm 86). Kelts classified as being in good condition at the time of tagging had a similar migration success rate (34.7%; 101 of 291). However, kelts classified as in fair condition had a higher migration success rate with 57.6% (19 of 33) of individuals detected at rkm 113 or rkm 86.

3.3.2 Survival Estimates Through the FCRPS

Overall, kelt survival was generally higher through reservoirs than it was during dam passage (Table 3.5). The highest survival estimate was 1.002 (SE = 0.001) from the JDA forebay array (rkm 351) to the JDA cabled dam-face array (rkm 349). The lowest estimated reach survival was 0.891 (SE = 0.022) from the autonomous array at Crow Butte (rkm 422) to the JDA forebay array (rkm 351). Generally, dam passage survival estimates (cabled array to survival array located 24 to 78 rkm downstream) were lower than survival estimates for the immediate forebay of each dam (forebay array to cabled array). Survival rates ranged from 0.985 (LGR) to 1.002 (JDA) for all river reaches between the forebay array and cabled dam-face array. Comparatively, dam passage survival estimates ranged from 0.895 (LGR) to 0.943 (LGS).

Table 3.5. Reach survival estimates for all acoustic-tagged steelhead kelt detected in 2012 throughout the Federal Columbia River Power System (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).

Location	Upstream Array	Downstream Array	Distance (km)	n	Survival (SE)
LGR reservoir	A1CR743	A2CR696	47	127	0.953 (0.019)
LGR forebay to LGR	A2CR696	D1CR695	1	129	0.985 (0.011)
LGR to LGS forebay	D1CR695	A4CR636	59	124	0.895 (0.028)
LGR tailrace to LGS forebay	A3CR693	A4CR636	57	292	0.952 (0.013)
LGS forebay to LGS	A4CR636	D2CR635	1	274	1.000 (0.000)
LGS to mid-LMN reservoir	D2CR635	A6CR604	31	290	0.943 (0.014)
Mid-LMN reservoir to LMN forebay	A6CR604	A7CR590	14	261	0.969 (0.011)
LMN forebay to LMN	A7CR590	D3CR589	1	260	0.996 (0.004)
LMN to mid-IHR reservoir	D3CR589	A9CR562	27	263	0.940 (0.015)

Table 3.5. (contd)

Location	Upstream Array	Downstream Array	Distance (km)	n	Survival (SE)
Mid-IHR reservoir to IHR forebay	A9CR562	A10CR539	23	244	0.951 (0.014)
IHR forebay to Burbank	A10CR539	A11CR525	14	234	0.979 (0.010)
Burbank to MCN forebay	A11CR525	A12CR472	53	229	0.948 (0.015)
MCN forebay to MCN	A12CR472	D4CR470	2	218	0.996 (0.005)
MCN to mid-JDA reservoir	D4CR470	A14CR422	48	212	0.929 (0.018)
Mid-JDA reservoir to JDA forebay	A14CR422	A15CR351	71	202	0.891 (0.022)
JDA forebay to JDA	A15CR351	D5CR349	2	180	1.002 (0.001)
JDA to mid-TDA reservoir	D5CR349	A17CR325	24	173	0.925 (0.020)
Mid-TDA reservoir to TDA	A17CR325	D6CR309	16	165	0.982 (0.010)
TDA to BON forebay	D6CR309	A21CR236	73	163	0.902 (0.023)
BON forebay to BON	A21CR236	D7CR234	2	148	0.997 (0.007)
BON to Knapp	D7CR234	A23CR156	78	138	0.897 (0.027)

Survival per kilometer rates were ≥0.985 for all river reaches examined in 2012 (Figure 3.1). The lowest survival per kilometer estimate was in the LGR forebay (0.985; rkm 696 to rkm 695). Contrastingly, survival per kilometer rates estimated for the LGS and JDA forebays were 1.000 and 1.002, respectively.

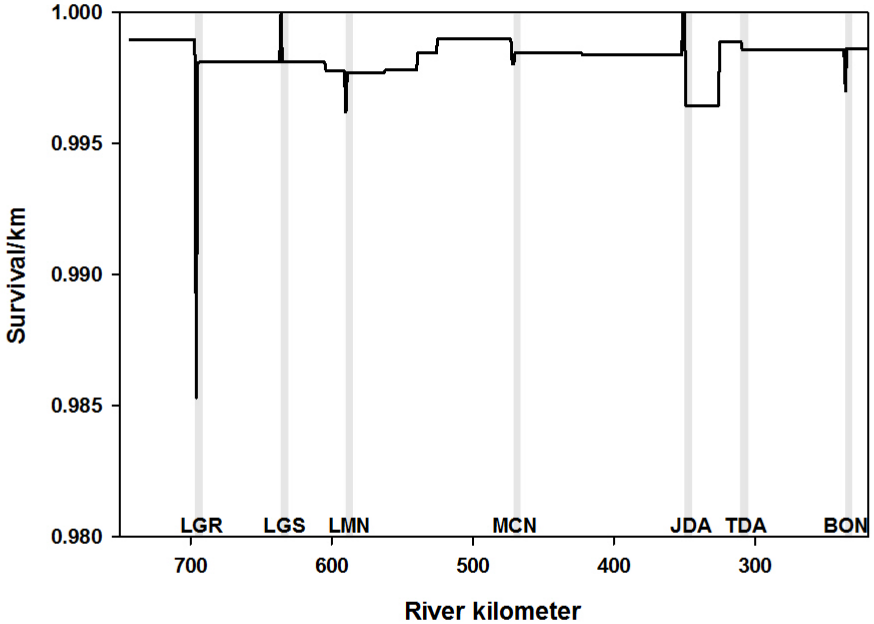

Figure 3.1. Standardized reach survival probability estimates for all tagged steelhead kelt detected in the FCRPS in 2012.

Cumulative survival probability of acoustic-tagged kelts varied among tagging locations from rkm 636 to rkm 156 (Figure 3.2). Overall, the cumulative survival probability from rkm 636 to rkm 156 of kelts tagged at LGR JFF (0.529; SE = 0.039) was higher than for fish tagged in the various tributaries (0.320; SE = 0.045). Of those fish tagged in the various tributaries, the survival probability from rkm 636 to rkm 156 was highest for Potlatch River kelts (0.519; SE = 0.083). The survival probability of Fish Creek kelts declined rapidly in the Snake River, as cumulative survival probability from rkm 636 to rkm 525 was 0.389 (SE = 0.081) between rkm 636 and rkm 525.

3.3.3 Passage Proportions and Survival Estimates Through Each FCRPS Dam

Overall, the largest proportion of steelhead kelts passing through FCRPS dams did so through the spillway (traditional spill and spillway weir combined; Table 3.6 and Table 3.7). The majority of kelts passed through spillway weirs at Snake River dams (LGR, LGS, and LMN), whereas most fish passed through traditional spill at Columbia River dams, including those that have operating spillway surface weirs (MCN, and JDA). At TDA and BON, where spillway weirs do not exist, the highest proportion of kelts passed through traditional spill. The proportion of kelts that passed through traditional spill ranged from 0.205 at LMN to 0.845 at TDA. Comparatively, passage proportions through spillway weirs ranged from 0.171 at MCN to 0.680 at LMN. The least-used route of passage for each dam was through the powerhouse (turbine and JBS combined). The lowest proportion of fish passed through the JBS at LGR and BON, whereas the least-used route of passage was through the turbines at LGS, LMN, MCN, JDA, and TDA. The proportion of kelts passing through turbines was low (<0.07) for all dams except B1 turbines where passage proportions were 0.117. The proportion of fish passing through the JBS ranged from 0.022 at BON to 0.101 at LGS. A total of 10 kelts passed through LGR and TDA (n = 6 and 4, 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 part of the dam not equipped with JSATS cabled receivers. For example, variable water discharge at TDA required spill through some temporarily unmonitored bays southeast of the tailrace wall for a few days in spring 2012. Appendix K outlines the routes of passage through multiple dams in the FCRPS taken by individual kelts.

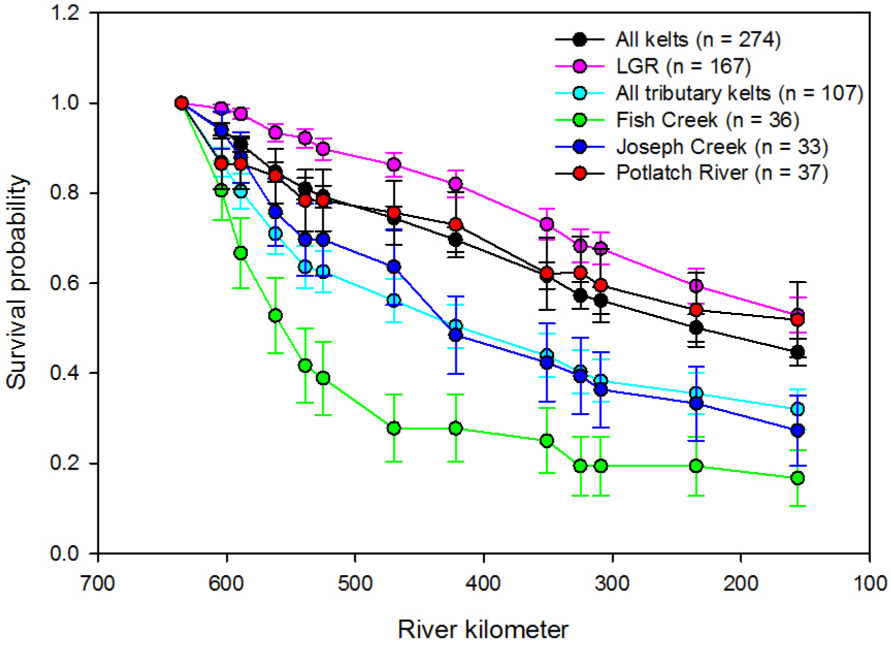

Figure 3.2. Cumulative survival probabilities of steelhead kelts from the Little Goose Dam Forebay array (rkm 636) to Knapp (rkm 156) by tagging location (i.e., Lower Granite Dam Juvenile Fish Facility (LGR), Potlatch River, Joseph Creek, and Fish Creek). Tagging locations with inadequate sample size were not included in this analysis. Survival probabilities were presented for the cabled array at each dam and autonomous arrays located mid-reservoir in the Federal Columbia River Power System.

The spill pattern at LMN in 2012 changed from uniform spill to bulk spill on May 10. However, this did not influence the proportion of kelts that passed through each route (Table 3.8). The highest percentage of kelts passed through the spillway weir during periods of uniform (67.5%; n = 81 of 120) and bulk spill (68.4%; n = 95 of 139), and the lowest percentage of kelts passed through the turbine routes (5.0% [uniform spill]; 4.3% [bulk spill]).

The route of passage that resulted in the highest survival estimate varied for each FCRPS dam investigated in this study (Table 3.6 and Table 3.7). Spillway weir passage resulted in the highest estimates of survival at LGS, and JDA (0.967 [SE = 0.014] and 0.986 [SE = 0.014], respectively), whereas traditional spill passage led to the highest estimates of survival at LGR and TDA (0.906 [SE = 0.0052] and 0.941 [SE = 0.020], respectively). Survival estimates through the JBS were 1.000 at LMN, MCN, and BON and were lowest at LGR and JDA (0.857 [SE = 0.132] and 0.733 [SE = 0.114], respectively).

Table 3.6. Passage proportions and route-specific survival (± SE) estimates of tagged kelts that passed through Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), McNary (MCN), John Day (JDA), and The Dalles (TDA) dams during the 2012 season. 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], adult fish ladder (AFL), sluiceway, unknown) at each dam.

			Route						
Dam	Number of Fish Passed	Measure	Traditional Spill	Spillway Weir	Turbine	JBS	AFL	Sluiceway	Unknown
LGR	124	Passage proportion	0.258	0.573	0.065	0.056	-	-	0.048
		Survival	0.906 (0.052)	0.901 (0.035)	0.875 (0.117)	0.857 (0.132)	-	-	-
LGS	288	Passage proportion	0.247	0.608	0.045	0.101	-	-	0.000
		Survival	0.943 (0.028)	0.967 (0.014)	0.779 (0.119)	0.966 (0.034)	-	-	-
LMN	259	Passage proportion	0.205	0.680	0.046	0.069	-	-	0.000
		Survival	0.926 (0.036)	0.983 (0.010)	0.583 (0.142)	1.000 (0.000)	-	-	-
MCN	210	Passage proportion	0.762	0.171	0.024	0.038	0.005	-	0.000
		Survival	0.931 (0.020)	0.972 (0.027)	0.800 (0.179)	1.000 (0.000)	0.000 (0.000)	-	-
JDA	172	Passage proportion	0.465	0.424	0.023	0.087	-	-	0.000
		Survival	0.925 (0.030)	0.986 (0.014)	0.750 (0.217)	0.733 (0.114)	-	-	-
TDA	161	Passage proportion	0.845	-	0.062	-	-	0.068	0.025
		Survival	0.941 (0.020)	-	0.500 (0.158)	-	-	0.909 (0.087)	-

Table 3.7. Passage proportions and route-specific survival (± SE) estimates of tagged steelhead kelts that passed through Bonneville Dam during the 2012 season. Single-release survival estimates were based on pooled data for each major route of passage (i.e., traditional spill, sluiceway [B1 or B2CC], turbine [B1 or B2], juvenile bypass system [JBS]).

			Route						
Dam	Number of Fish Passed	Measure	Traditional Spill	B1 Sluiceway	B1 Turbine	B2 Sluiceway	B2 Turbine	B2 JBS	Unknown
BON	137	Passage proportion	0.533	0.124	0.117	0.190	0.015	0.022	0.000
		Survival	0.938 (0.030)	0.765 (0.103)	0.825 (0.100)	0.931 (0.053)	1.000 (0.000)	1.000 (0.000)	-

Table 3.8. Percentages of kelts that passed through different routes (i.e., traditional spill, spillway weir, turbines, juvenile bypass systems [JBS]) at Lower Monumental Dam during periods of uniform and bulk spill.

	Traditional Spill		Spillway Weir		Turbine		JBS	
	n	%	n	%	n	%	n	%
Uniform spill	26	21.7	81	67.5	6	5.0	7	5.8
Bulk spill	27	19.4	95	68.4	6	4.3	11	7.9

3.4 Passage and Travel Rates

Passage and travel rates are reported below for the forebays, tailraces, projects, and river reaches.

3.4.1 Forebay Residence

The distance between forebay and cabled dam face arrays ranged from 1 to 2 km for each FCRPS dam investigated in this study. Median forebay residence times ranged from 0.48 hour (BON) to 1.44 hours (LGS; Table 3.9). The shortest recorded forebay residence time was 0.12 hour at LMN, and the longest recorded time for a kelt that passed a dam was 255.42 hours at BON. Four kelts were detected at the forebay array after being detected at the dam face and were not detected again on the dam-face array or on any other downstream arrays, indicating these fish migrated upstream upon encountering the dam. These fish were excluded from the forebay residence calculations (Table 3.10).

Table 3.9. Distance of travel and median forebay residence time (hours) for acoustic-tagged steelhead kelts at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, The Dalles, and Bonneville dams in 2012.

Dam	n	Distance (km)	Forebay Residence Time (Hours) Median (Range)
Lower Granite	124	1	1.25 (0.32–84.69)
Little Goose	271	1	1.44 (0.24–63.88)
Lower Monumental	255	1	1.10 (0.12–28.10)
McNary	209	2	1.38 (0.63–111.40)
John Day	172	2	1.39 (0.31–26.86)
The Dalles(a)	20	2	0.60 (0.41–3.37)
Bonneville	138	2	0.48 (0.16–255.42)

(a) Autonomous receivers in the forebay and tailrace of The Dalles Dam were not deployed for the entire duration of the study (14 June through 31 August 2012).

Table 3.10. Number of kelts last detected on forebay array after detection on dam-face cabled array (i.e., moving upstream) at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, The Dalles, and Bonneville dams.

Dam	Number of Kelts Detected on Cabled Array	Kelts Last Detected Moving Upstream from Dam Face	
		n	%
Lower Granite	124	0	0.0
Little Goose	291	1	0.3
Lower Monumental	263	2	0.8
McNary	212	0	0.0
John Day	173	1	0.6
The Dalles	163	0	0.0
Bonneville	138	0	0.0

3.4.2 Tailrace Egress

The distance between the cabled dam face arrays and tailrace arrays ranged from 1 to 3 km for each FCRPS dam investigated in this study. Median tailrace egress times ranged from 0.17 hour (TDA) to 0.40 hour (LGR, LGS, and JDA; Table 3.11). The shortest recorded tailrace egress time was 0.11 hour (TDA), and the longest was 199.10 hours (BON).

Table 3.11. Distance of travel and median tailrace egress time (hours) for acoustic-tagged steelhead kelts at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, The Dalles, and Bonneville dams in 2012.

Dam	n	Distance (km)	Tailrace Egress Time (Hours) Median (Range)
Lower Granite	119	2	0.40 (0.18–22.70)
Little Goose	268	1	0.40 (0.15–37.19)
Lower Monumental	245	2	0.29 (0.19–55.75)
McNary	206	2	0.29 (0.17–12.68)
John Day	151	3	0.40 (0.24–23.35)
The Dalles[(a)]	19	2	0.17 (0.11–1.06)
Bonneville	96	1	0.32 (0.20–199.10)

(a) Autonomous receivers in the forebay and tailrace of The Dalles Dam were not deployed for the entire duration of the study (14 June through 31 August 2012).

3.4.3 Project Passage Times

The distance between the forebay and tailrace arrays ranged from 2 to 5 km for each FCRPS dam investigated in this study. Median project passage times ranged from 0.87 hour (TDA) to 2.31 hours (LGS; Table 3.12). The shortest recorded project passage time was 0.41 hour (LMN) and the longest was 199.59 hours (BON).

Table 3.12. Distance of travel and median project passage time (hours) for acoustic-tagged steelhead kelts at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, The Dalles, and Bonneville dams in 2012.

Dam	n	Distance (km)	Project Passage Time (Hours) Median (Range)
Lower Granite	122	3	1.73 (0.55–85.47)
Little Goose	268	2	2.31 (0.46–64.89)
Lower Monumental	244	3	1.60 (0.41–60.53)
McNary	211	4	1.71 (0.81–111.69)
John Day	156	5	1.93 (0.61–27.34)
The Dalles[a]	19	4	0.87 (0.59–4.14)
Bonneville	103	3	1.03 (0.43–199.59)

(a) Autonomous receivers in the forebay and tailrace of The Dalles Dam were not deployed for the entire duration of the study (14 June through 31 August 2012).

3.4.4 Travel Rate

Travel rates were calculated for river reaches located between the dams. Generally, travel rates increased as fish migrated downstream, with the lowest median travel rates occurring in the Snake River (26.0 km/day from rkm 604 to 590; Figure 3.3) and the highest median travel rates occurring in the Columbia River (132.3 km/day from rkm 346 to rkm 325). Median travel rates were largely higher for the reach of river immediately downstream of each dam when compared to the reach of river directly upstream from the dams.

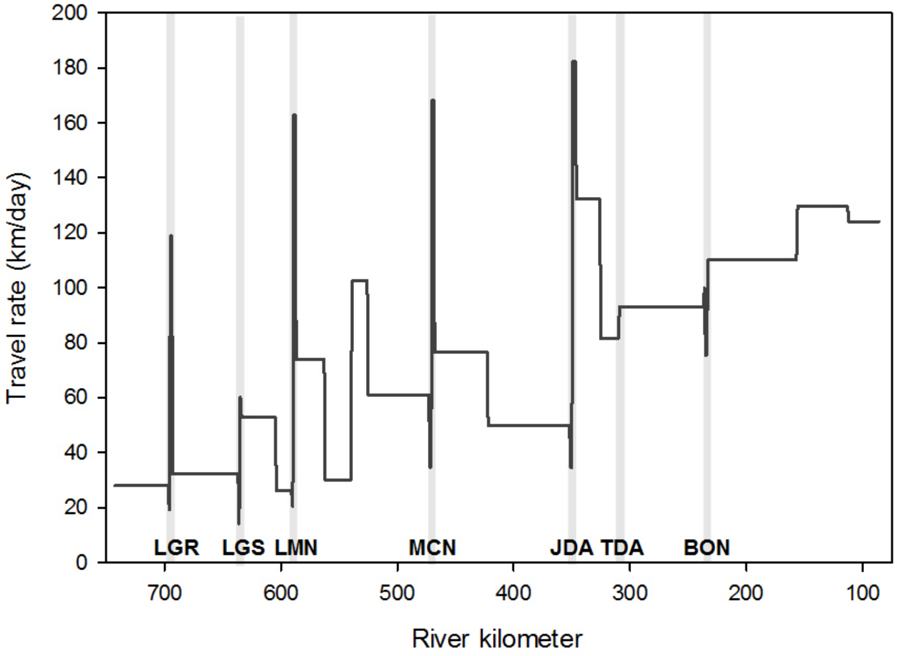

Figure 3.3. Median travel rates (km/day) of steelhead kelts through various reaches of the Snake and Columbia rivers from rkm 743 to 86 in 2012.

3.5 Estimation of Population Abundance Arriving at Lower Granite Dam

A total of 324 steelhead kelts were acoustic-tagged during the 2012 season. Of those, 142 were tagged at tributary sites throughout the Snake River, upstream of LGR and had the potential to be recaptured at the LGR JFF. Based on the number of JSATS-tagged kelts detected at the LGR JFF (n = 7) and the number of kelts sampled at LGR JFF during the study period (n = 2235), it was estimated that 45,338 (± 12,921; SE) steelhead kelts were available for tagging at the tributary sites during the study period in 2012. Using the survival estimate for JSATS-tagged kelts from tributary release to LGR (0.895), it can be estimated that 40,578 steelhead kelts from the population groups sampled in this study arrived at LGR in 2012.

3.6 Iteroparity Rates

PTAGIS (www.ptagis.org) was monitored throughout fall 2012 for PIT-tag codes of steelhead kelts tagged during the 2012 season. Upstream movements of steelhead during fall 2012 may be a sign that steelhead were preparing to spawn again in spring 2013. At the time of this report (29 March 2013), no kelts that were acoustic-tagged in 2012 had been detected moving upstream based on PIT-tag detections.

In addition, PTAGIS was queried to recover the detection histories of steelhead that were PIT-tagged prior to being implanted with a JSATS transmitter in 2012. This information could be used to identify that kelts captured in 2012 successfully spawned in previous years. At the time of this report, no kelts implanted with JSATS transmitters as part of this study were identified as previous upstream migrants.

3.7 JSATS Performance

JSATS performance was evaluated in terms of detection probabilities for autonomous and cabled arrays, fish distribution at autonomous arrays, and probabilities of implanted tags still working by the time they passed the survival-detection arrays.

3.7.1 Detection Probabilities at Cabled and Autonomous Arrays

Overall, cabled array detection probabilities were greater than 0.94 for the 2012 season (Appendix G, Table G.1). Detection probabilities of the autonomous arrays used for survival estimates were greater than 0.91 for 2012 (Appendix G, 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 downstream migration (Appendix G, Table G.3). The median percentage of fish detected on two or more receivers within an autonomous array was 92.7% (range: 44.8%–100.0%). Overall, the percentage of fish detected on two or more receivers within an autonomous array was lower at the tailrace array when compared with the forebay array of the same dam, despite nodes being similar distances apart. This coincides with the lower detection probability to tailrace arrays when compared to forebay arrays (Appendix G, Table G.1 and Table G.2).

3.7.3 Tag Life

All steelhead kelts studied in 2012 passed the survival-detection arrays well before the time at which any appreciable tag failure was observed during the tag life study (Appendix G). The time since tag activation required for 100% of implanted kelts to pass the final survival detection array at Kalama (rkm 113) was 24.2 days and the minimum lifespan observed during the tag life study was 45.3 days. Therefore, no tag life correction was applied to survival estimates.

3.8 Dam-Passage Characteristics

3.8.1 Dam Passage versus Flow

The largest percentage of flow passed through the powerhouses at LGR, LGS, LMN, JDA, TDA, and BON (58.8% [TDA]–68.6% [LMN]). 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 (57.3%–68.0%) did so through the spillway weir, whereas less than 10% of flow passed through this route. In the Columbia River, a lower percentage of flow passed through the spillway weirs (5.4% at both MCN and JDA), and the majority of kelts (46.5%–76.2%) passed through the traditional spill routes.

3.8.2 Diel Distribution

The hourly distributions of kelt passage at LGR, LGS, LMN, MCN, JDA, TDA, and BON were fairly consistent during the study period (Appendix I). There was a trend of a higher proportion of kelts first detected on the cabled dam-face array at LGR during daylight hours, but this difference was slight. Nearly 13.1% of kelts that passed LMN were first detected during the period of 2300 hours and 0000 hours, which is contrasted to the less-than 8% of kelts being first detected during each of the other hourly bins. The hourly distributions of first detections on the cabled arrays in the Columbia River (MCN, JDA, TDA, and BON) were more variable than those in the Snake River (LGR, LGS, and LMN). Generally, there were greater differences in the proportion of fish that were first detected during sequential hours of the day.

3.8.3 Vertical Distribution

The median depth of kelts 75 m from the dam-face was generally less than 10 m, irrespective of ultimate route of passage (Appendix J). Migration toward the powerhouse (turbines and JBS) was concluded with a sudden increase in depth as calculated from the last detection prior to passage (<5 m from the dam face). For example, kelts that eventually passed through the powerhouse at LGS and LMN migrated through the forebay at median depths of less than 5 m and, at the last detection prior to passage, were estimated to have median depths of approximately 25 m. Migration toward the TDA and BON sluiceways occurred at a shallow depth (<4 m).

4.0 Discussion and Conclusions

4.1 Discussion

Overall, a high proportion of JSATS-tagged steelhead kelts successfully migrated through the FCRPS in 2012. Of the 324 kelts in this study, 120 (37.0%) were detected at rkm 113 or rkm 86 (the most downstream arrays). Migration success rate was higher for fish tagged and released at LGR (47.8%; n = 87 of 182), when compared to those tagged in the tributaries (23.2%; n = 33 of 142). System-wide migration success was substantially higher than that reported for 2001 and 2002, when it was measured to rkm 181 (4.1% and 15.6%, respectively; Wertheimer and Evans 2005). However, these results are comparable to those from 2003 when 34.4% of externally radio-tagged kelts released into the LGR tailrace were detected in the BON tailrace (rkm 232.3; Boggs and Peery 2004). It is important to note that in all of these studies, including the current one, only fair and good condition kelts were selected for tagging and therefore all measures of survival and migration success cannot be applied to poor condition kelts.

Previous studies showed lower migration success rates for kelts classified as in fair condition (15.5%) at the time of tagging when compared to good-condition kelts (44.0 %; Boggs and Peery 2004). However, during this research, a higher percentage of fair-condition kelts (57.6%; n = 19 of 33) were detected at the most downstream arrays (rkm 113 and 86) than good-condition kelts (34.7%; n = 101 of 291). The lower proportion of fair-condition fish sampled in this study (9.9%) compared to those sampled by Boggs and Peery (26.4%; 2004) may explain the difference in migration success between years and condition categories, as Boggs and Peery (2004) sampled a larger number of fish in fair condition. Although the method used to grade steelhead kelts is employed throughout the CRB, it is subjective, and differences in grading may contribute to the differences observed in 2002 and 2012.

The location of capture and tagging of kelts resulted in differences in system-wide survival and migration success. Overall, kelts that were captured and tagged at the LGR JFF survived at a higher rate from rkm 636 to 156 (52.9%) than those captured and tagged in the tributaries (32.0%). This may be due to the inherent biases in the study design, as fish were graded for condition on the same scale at all locations, although they may not have been in the same condition when they reached LGR (i.e., fish tagged in good condition in the tributaries may have degraded to a poorer condition by the time arrived at LGR [rkm 636]). Additionally, differences may be due to the tributary source of the fish captured and tagged at LGR. With the exception of a few fish that had tributary specific markings (e.g., previously PIT-tagged, opercular punches), the source of fish captured and tagged at LGR was largely unknown. Genetic samples collected by the NPT at the time of tagging may glean some information regarding this issue.

Kelts captured and tagged at the tributary sites furthest upstream, specifically Fish Creek (rkm 944) and the Crooked River (rkm 961), had the lowest migration success rates of all tagging groups. For the kelts from Fish Creek, migration success rate was 11.5% (n = 6 of 52), whereas none of the fish tagged at the Crooked River (n = 2) were ever detected on a receiver after release. The migration success rate for Fish Creek kelts is comparable to previous studies, where 10.0% (n = 3 of 30) of kelts tagged at the Fish Creek weir were detected below BON in 2011 (Jones 2013). One potential reason for this low migration success rate is the timing of outmigration by these kelts. All kelts tagged at Fish Creek in 2012 were sampled between May 27 and June 27, whereas, sampling at all other tributary weirs occurred between

April 18 and May 25. Due to this later outmigration, Fish Creek kelts were exposed to higher water temperatures, particularly in the Snake River. These higher water temperatures can lead to increased metabolic activity and physiological stress, which may affect the behavior and ultimately the survival of downstream migrants. Tiffan et al. (2009) have noted changes in the behavior of juvenile fall Chinook salmon as they migrate from the Clearwater to the Snake River, and further research is necessary to understand how late migrating kelts are influenced by these changes in temperature.

In 2012, survival was found to be lower through reaches that included a dam than through river reaches between dams. In contrast, Wertheimer and Evans (2005) found that in 2001 and 2002, radio-tagged kelts had higher migration success rates through JDA (95%), TDA (94%), and BON (93%) when compared to the river reaches between dams (e.g., 2001: JDA to TDA = 67%; TDA to BON = 76%; BON to rkm 156 = 89%). One possible reason for the differences in survival between this study and Wertheimer and Evans (2005) was the location of the survival arrays. Wertheimer and Evans (2005) assumed dam-passage survival when kelts were detected on the tailrace arrays, whereas in this study a detection array 24 to 78 km downstream of the dam was used to calculate the virtual single-release survival estimates. This was done to reduce the likelihood that kelts that died as a direct result of dam passage would be detected and assumed to be alive on the survival arrays. An important assumption of the survival model is that fish that die while passing the dam will not be detected on downstream survival detection arrays, and violation of that assumption could upwardly bias survival estimates.

The majority of acoustic-tagged kelts that passed through FCRPS dams in 2012 did so through spillways. This result is similar to those of previous studies that examined the route of passage of kelts (Boggs and Peery 2004; Wertheimer and Evans 2005; Wertheimer 2007). However, this study was the first to examine the route of passage for kelts since the installation of spillway weirs at most dams in the Snake and Columbia rivers (i.e., LGR, LGS, LMN, MCN, and JDA). The percentage of fish that passed through spillway weirs was 31.5%–47.5% greater than through traditional spill at LGR, LGS, and LMN. Conversely, passage through traditional spill was 59.1% and 4.1% greater than the percentage that passed through spillway weirs at MCN and JDA, respectively. Although a larger proportion of kelts passed through the traditional spillbays at MCN and JDA, upon closer examination it was determined that the majority of kelts that passed through traditional spill routes utilized the spillbays adjacent to the spillway weirs. The results of this study suggest that spillway weirs, where available, are effective at influencing the route of passage for steelhead kelts. It should also be noted that the higher proportions of kelts that passed through the spillway weirs and adjacent spillbays is not due to higher flow through those routes of passage. For example, less than 10% of the flow through LGR, LGS, and LMN dams passed through the spillway weirs; however, ≥ 57.3% of kelts passed through these routes. The proportions of kelts that passed through turbines, JBS, and sluiceways in 2012 were relatively low at all dams, as has been observed in other studies (Boggs and Peery 2004; Wertheimer and Evans 2007).

This study was the first to identify route-specific survival estimates for steelhead kelts that passed FCRPS dams. Overall, survival estimates were high (≥90.1%) for spillway weir-passed fish at all dams, regardless of the type of weir installed (i.e., removable spillway weir or temporary/top spillway weir). Survival estimates were highest for steelhead kelts that passed through spillway weirs compared to all other passage routes at LGS, LMN, and JDA. Survival of kelts that passed through the spillway weir at LGR was also high (90.1%), and only 0.5% lower than survival estimates for kelts that passed through traditional spill (90.6%). At JDA, survival of kelts that passed through the spillway weir was 98.6%. Survival estimates were variable, ranging from 73.3% (JDA) to 100.0% (LMN, MCN, and BON) for steelhead kelts that passed through the JBS in 2012. The low percentage of kelts that passed through the

JBS at all dams (2.2%–10.1%) likely contributed to this variability. Survival estimates for turbine-passed kelts were lower than for kelts that passed through all other routes, which is consistent with survival estimates observed in many juvenile salmonid survival studies (Weiland et al. 2009; Ploskey et al. 2012). The exception to this trend in 2012 was at BON where survival was estimated to be 100% for the two steelhead kelts that happened to pass through B2 turbines. Overall, JBS and turbine survival estimates for all dams investigated in this study should be considered with caution because the percentage (and therefore, sample size) is based on a small number of kelts that passed through the JBS and turbines at all dams (1.5%–11.7%).

Overall, travel rates observed in this study were higher than have been observed in previous studies that investigated the downstream migration of steelhead kelts in the FCRPS. Wertheimer and Evans (2005) reported that travel from LGR (rkm 694) to downstream of BON (rkm 181) took a median time of 27 and 19 days in 2001 and 2002, respectively. These travel times represented median travel rates of 19.0 and 27.0 km/day. Fish moved faster in 2012, as travel from the LGR tailrace (rkm 693) to BON tailrace (rkm 233) took a median time of 9.0 days, representing a median travel rate of 51.3 km/day. In addition, travel rates of steelhead kelts through the forebays and tailraces of FCRPS dams were faster in 2012 than those observed in 2001. Median forebay residence times were 1.3 and 3.0 hours at TDA and BON in 2001, respectively, whereas they were 50% lower at TDA (0.60 hour) and reduced by over 80% at BON (0.48 hour) in 2012. Mean river discharge was higher in 2012 compared to 2001 and 2002, and spill rates were very low in 2001, likely explaining some of the differences in travel rates. For example, at LGR mean river discharge was approximately 47 kcfs in 2001 and 85 kcfs in 2002, whereas mean discharge was 101.5 kcfs in 2012. Higher flows and lower travel rates have been associated with higher migration success for downstream migrating salmonids because delayed migration can expose fish to high water temperatures and increased risk of predation. Kelts are in a particularly vulnerable position during their seaward migration because their energy stores have been depleted due to recent spawning.

Travel rates observed in this study are comparable to travel rates observed for steelhead kelts as they moved downstream through unimpounded rivers in British Columbia. English et al. (2006) found that Skeena River steelhead kelt travel rates were 42.3 and 54.3 km/day in 1994 and 1995, respectively. The results of this study suggest that water velocity is an important factor in the travel rate of steelhead kelts, as travel rates were faster in the tailraces of dams when compared with other river reaches, particularly forebays of dams.

An estimated 40,578; Lincoln mark-recapture estimate with survival estimate from tributary release to LGR applied) steelhead kelts passed LGR in 2012 using the Lincoln index. This estimate represents 22.4% of the number of pre-spawn steelhead that moved upstream through the adult fish ladder at LGR between 1 June 2011 and 30 May 2012 (181,284). These estimates should be interpreted with caution as not all steelhead kelts that passed LGR had the same chance of being marked in this study, which violates an assumption of this population estimation method. Efforts were focused on five main tributaries of the Snake River where downstream weirs were operated in 2012, whereas many of the kelts that passed LGR likely spawned in tributaries that were not sampled (e.g., Salmon River, Snake River subbasins in Oregon). Sampling was also limited for periods of time due to high spring run-off flows, further violating the assumptions of the population estimate. Another way of approximating how many kelts have passed LGR is based on the assumption that the steelhead kelts captured on the separator at LGR JFF in 2012 (n = 2235) represented 5.6% of the total kelt population that passed LGR (as determined using acoustic telemetry passage data in this study). From this assumption, it could be estimated that 39,910 (2235/0.056) kelts passed through all routes.

4.2 Conclusions

The results of this study provide information on the route of passage and subsequent survival for steelhead kelts migrating through the Snake and Columbia rivers from LGR to BON. Specifically, this study is the first to document these metrics since the installation of spillway weirs at many of the dams in the FCRPS. Spillway weirs were the primary route of passage for steelhead kelts in the Snake River, whereas the majority of fish passed through traditional spill routes in the lower Columbia River. Spillway routes (spillway weirs and traditional spill) and the JBS provided the highest estimated survival for steelhead kelts. Passage through turbines resulted in the lowest survival estimates. JBS- and turbine-specific survival estimates should be interpreted with cautionbecause the lowest proportion of kelts passed through these routes. In addition, only kelts in fair and good condition were tagged in this study, so the results may not be applicable for poorer condition kelts. Average discharge was higher in 2012 when compared to the 10-year average (2002–2011) and likely contributed to the overall high rate of migration success.

Although the results of this study contribute to understanding the impact of hydropower on steelhead kelt migration in the FCRPS, future research is warranted. Future studies should focus on sampling over the full kelt emigration period and on a larger proportion of kelts in fair and poor condition. Future studies also should include additional locations in the Snake River basin to acquire information that is applicable to a larger proportion of the Snake River steelhead population. In addition, the population of upstream migrating steelhead in subsequent years should be monitored for PIT tags to identify any repeat spawners that may contribute to Snake River steelhead iteroparity rates.

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Appendix A

Hydrophone and Autonomous Node Deployment Tables

Appendix A

Hydrophone and Autonomous Node Deployment Tables

Table A.1. Cabled hydrophone locations at Lower Granite Dam in 2012. Hydrophones were deployed on 29 March 2012.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
P00_01D	46.65744698	-117.4310272	638.8	Powerhouse
P00_01S	46.65746826	-117.4310724	723.0	
P01_02D	46.65764453	-117.4308245	638.8	
P01_02S	46.65766582	-117.4308698	723.0	
P02_03D	46.65784912	-117.4306226	638.9	
P02_03S	46.65787038	-117.4306679	723.0	
P04_05D	46.6582565	-117.4302212	639.3	
P04_05S	46.65827777	-117.4302664	723.5	
P05_06D	46.65846149	-117.4300189	639.3	
P05_06S	46.65848275	-117.4300642	723.4	
P06_D	46.65866026	-117.4298219	639.2	
P06_S	46.65868153	-117.4298671	723.5	
S02_03D	46.65911295	-117.4295452	695.4	Spillway
S02_03S	46.65911295	-117.4295452	722.8	
S03_04D	46.65926287	-117.4293973	695.8	
S03_04S	46.65926287	-117.4293973	722.8	
S04_05D	46.65940622	-117.4292555	695.9	
S04_05S	46.65940622	-117.4292555	722.9	
S05_06D	46.65955209	-117.4291111	695.9	
S05_06S	46.65955209	-117.4291111	722.9	

Table A.2. Cabled hydrophone locations at Little Goose Dam in 2012. Hydrophones were deployed on 29 April 2012.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
FLS	46.58292046	-118.0263206	626.4	South Ladder
P00_01D	46.58322677	-118.0264129	540.4	Powerhouse
P00_01S	46.5832194	-118.0264623	623.5	
P01_02D	46.58346927	-118.0264836	540.2	
P01_02S	46.5834619	-118.026533	623.2	
P02_03D	46.58371146	-118.0265517	540.1	
P02_03S	46.58370407	-118.0266013	623.4	
P03_04D	46.58395382	-118.02662	540.4	
P03_04S	46.58394645	-118.0266694	623.4	
P04_05D	46.58419775	-118.026688	540.2	
P04_05S	46.58419037	-118.0267375	623.4	
P05_06D	46.58443904	-118.0267558	540.3	
P05_06S	46.58443167	-118.0268053	623.4	
P06D	46.58468107	-118.0268228	539.7	
P06S	46.5846737	-118.0268722	622.8	
S01_02D	46.58495583	-118.0270391	595.6	Spillway
S01_02S	46.58495583	-118.0270391	622.6	
S01D	46.58478223	-118.0269909	597.5	
S01S	46.58478223	-118.0269909	624.3	
S02_03D	46.58512962	-118.0270884	597.1	
S02_03S	46.58512962	-118.0270884	624.1	
S03_04D	46.5853015	-118.0271363	597.3	
S03_04S	46.5853015	-118.0271363	624.2	
S04_05D	46.58547392	-118.0271846	596.9	
S04_05S	46.58547392	-118.0271846	624.0	
S05_06D	46.5856469	-118.0272337	597.2	
S05_06S	46.5856469	-118.0272337	624.2	
S06_07D	46.58581759	-118.027281	597.1	
S06_07S	46.58581759	-118.027281	624.1	
S07_08D	46.5859912	-118.0273299	597.1	
S07_08S	46.58599116	-118.02733	624.1	
S08D	46.58616544	-118.0273788	597.0	
S08S	46.58616544	-118.0273788	624.1	

Table A.3. Cabled hydrophone locations at Lower Monumental Dam in 2012. Hydrophones were deployed from 30 April through 1 May 2012.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
FLN	46.56455186	-118.5401841	530.9	North Ladder
FLS	46.56159715	-118.5369512	531.3	South Ladder
P00_01D	46.56420981	-118.5396079	443.1	Powerhouse
P00_01S	46.56418889	-118.5396474	527.3	
P01_02D	46.56402349	-118.5394061	443.1	
P01_02S	46.56400256	-118.5394456	527.3	
P02_03D	46.56382662	-118.5391931	442.9	
P02_03S	46.56380561	-118.5392327	527.4	
P03_04D	46.563628	-118.5389782	443.2	
P03_04S	46.56360717	-118.5390175	527.2	
P04_05D	46.56343076	-118.5387648	443.2	
P04_05S	46.56340984	-118.5388042	527.3	
P05_06D	46.5632326	-118.53855	443.1	
P05_06S	46.56321168	-118.5385895	527.3	
P06D	46.56303591	-118.5383368	443.4	
P06S	46.56301499	-118.5383762	527.5	
RSW_N_01	46.56322148	-118.537817	424.1	Spillway weir Approach
RSW_N_02	46.56320324	-118.5378237	424.1	
RSW_N_03	46.56320941	-118.5377983	424.3	
RSW_N_04	46.56321158	-118.5378139	429.2	
RSW_S_01	46.56303552	-118.537614	427.4	
RSW_S_02	46.56302939	-118.5375982	432.9	
RSW_S_03	46.56304589	-118.5376005	432.7	
RSW_S_04	46.56303196	-118.5375818	435.6	
S00_01D	46.56176912	-118.5371344	498.0	Spillway
S00_01S	46.56176912	-118.5371344	526.9	
S01_02D	46.56191116	-118.5372882	497.7	
S01_02S	46.56191116	-118.5372882	526.7	
S02_03D	46.56205257	-118.5374415	497.9	
S02_03S	46.56205257	-118.5374415	526.9	
S03_04D	46.56219314	-118.5375935	498.0	
S03_04S	46.56219314	-118.5375935	526.9	
S04_05D	46.56233307	-118.5377448	497.9	
S04_05S	46.56233307	-118.5377448	526.8	
S05_06D	46.56247364	-118.5378969	498.0	
S05_06S	46.56247364	-118.5378969	526.8	
S06_07D	46.56261439	-118.538049	497.9	
S06_07S	46.56261439	-118.538049	526.8	

Table A.4. Cabled hydrophone locations at McNary Dam in 2012. Hydrophones were deployed between 25 April through 1 May 2012.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
FLN_S	45.94070833	-119.2976139	329.0	North Ladder
FLS_OR_1	45.92865905	-119.2943001	331.2	South Ladder
FLS_OR_2	45.92865531	-119.2943122	323.7	
FLS_OR_3	45.92865146	-119.2943241	331.2	
FLS_OR_4	45.92864186	-119.2943035	329.2	
FLS_WA_1	45.92855143	-119.2942663	331.3	
FLS_WA_2	45.92855518	-119.2942543	323.9	
FLS_WA_3	45.92855902	-119.2942423	331.3	
FLS_WA_4	45.92856862	-119.294263	329.4	
F00_F01S	45.93214206	-119.2965986	330.2	Powerhouse
F01_F02S	45.93227445	-119.2966798	327.7	
F02_P01D	45.93251406	-119.2966875	269.1	
F02_P01S	45.93250787	-119.2967323	327.4	
P01_02D	45.93274617	-119.2967442	269.2	
P01_02S	45.93273998	-119.2967889	327.4	
P02_03D	45.93297873	-119.296801	269.2	
P02_03S	45.93297254	-119.2968458	327.5	
P03_04D	45.93321184	-119.2968587	269.4	
P03_04S	45.93320565	-119.2969037	327.7	
P04_05D	45.93344412	-119.296915	269.2	
P04_05S	45.93343793	-119.2969598	327.5	
P05_06D	45.93367596	-119.2969718	269.3	
P05_06S	45.93366977	-119.2970167	327.5	
P06_07D	45.93390942	-119.2970289	269.2	
P06_07S	45.93390323	-119.2970738	327.5	
P07_08D	45.93414162	-119.2970859	269.3	
P07_08S	45.93413543	-119.2971306	327.5	
P08_09D	45.93437426	-119.2971421	269.1	
P08_09S	45.93436807	-119.2971869	327.4	
P09_10D	45.93460565	-119.2971989	269.3	
P09_10S	45.93459946	-119.2972436	327.5	
P10_11D	45.93483811	-119.2972552	269.1	
P10_11S	45.93483192	-119.2973001	327.4	
P11_12D	45.93507095	-119.2973128	269.5	
P11_12S	45.93506475	-119.2973575	327.5	
P12_13D	45.93530324	-119.2973693	269.2	
P12_13S	45.93529704	-119.2974141	327.3	
P13_14D	45.93553625	-119.2974264	269.3	
P13_14S	45.93553005	-119.2974713	327.5	
P14D	45.9357641	-119.2974826	269.4	
P14S	45.93575794	-119.2975274	327.6	
PUD_1	45.93968117	-119.2985745	332.3	Spillway
PUD_2	45.93967208	-119.2985724	324.8	
PUD_3	45.93966301	-119.2985701	332.3	

Table A.4. (contd)

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
PUD_4	45.93967456	-119.2985515	330.3	
S01_02D	45.93942991	-119.2985117	302.2	
S01_02S	45.93942991	-119.2985117	329.0	
S02_03D	45.9392686	-119.2984723	302.2	
S02_03S	45.9392686	-119.2984723	329.0	
S03_04D	45.93910569	-119.2984324	302.1	
S03_04S	45.93910569	-119.2984324	329.2	
S04_05D	45.93894472	-119.2983935	301.9	
S04_05S	45.93894472	-119.2983935	329.0	
S05_06D	45.93878159	-119.2983529	302.0	
S05_06S	45.93878159	-119.2983529	329.0	
S06_07D	45.93861954	-119.2983132	301.9	
S06_07S	45.93861954	-119.2983132	328.8	
S07_08D	45.93845757	-119.298274	301.9	
S07_08S	45.93845757	-119.298274	328.9	
S08_09D	45.93829581	-119.2982358	302.0	
S08_09S	45.93829581	-119.2982358	328.9	
S09_10D	45.93813376	-119.2981962	301.8	
S09_10S	45.93813376	-119.2981962	328.9	
S10_11D	45.93797086	-119.2981562	302.0	
S10_11S	45.93797086	-119.2981562	329.0	
S11_12D	45.93780924	-119.298117	301.8	
S11_12S	45.93780924	-119.298117	328.8	
S12_13D	45.93764625	-119.2980764	301.9	
S12_13S	45.93764625	-119.2980764	329.0	
S13_14D	45.93748453	-119.298037	301.4	
S13_14S	45.93748453	-119.298037	328.5	
S14_15D	45.93732212	-119.2979974	301.8	
S14_15S	45.93732212	-119.2979974	328.9	
S15_16D	45.93715953	-119.2979576	301.9	
S15_16S	45.93715953	-119.2979576	328.9	
S16_17D	45.93699661	-119.2979182	301.8	
S16_17S	45.93699661	-119.2979182	328.9	
S17_18D	45.93683559	-119.297879	301.9	
S17_18S	45.93683559	-119.297879	328.9	
S18_19D	45.93667306	-119.2978395	301.7	
S18_19S	45.93667306	-119.2978395	328.8	
S19_20D	45.93651123	-119.2978004	301.8	
S19_20S	45.93651123	-119.2978004	328.8	
S20_21D	45.93634825	-119.2977605	301.7	
S20_21S	45.93634825	-119.2977605	328.7	
S21_22D	45.93618295	-119.2977203	302.1	
S21_22S	45.93618295	-119.2977203	329.2	
S22S	45.9359851	-119.2976721	330.5	
S23P	45.93585996	-119.2976266	330.5	

Table A.5. Cabled hydrophone locations at John Day Dam in 2012. Hydrophones were deployed between 30 April and 3 May 2012.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
1_NORTH	45.71922393	-120.6964239	256.5	
1_SOUTH	45.71902332	-120.6962929	256.7	
P00_01D	45.71222526	-120.6891244	166.2	Powerhouse
P00_01S	45.71220439	-120.6891758	252.5	
P00N	45.71206031	-120.6890279	256.3	
P00S	45.71192871	-120.6888921	255.9	
P01_02D	45.7124209	-120.6893268	166.3	
P01_02S	45.71240003	-120.6893783	252.4	
P02_03D	45.71262094	-120.6895345	166.1	
P02_03S	45.71259998	-120.689586	252.4	
P03_04D	45.71282026	-120.6897405	166.3	
P03_04S	45.7127993	-120.6897919	252.6	
P04_05D	45.71301976	-120.6899474	166.0	
P04_05S	45.7129988	-120.6899988	252.4	
P05_06D	45.71321944	-120.6901543	166.2	
P05_06S	45.71319857	-120.6902056	252.3	
P06_07D	45.71341921	-120.6903614	166.4	
P06_07S	45.71339834	-120.6904128	252.6	
P07_08D	45.71361916	-120.690568	166.2	
P07_08S	45.7135982	-120.6906194	252.5	
P08_09D	45.71381857	-120.6907736	165.1	
P08_09S	45.7137977	-120.6908251	251.2	
P09_10D	45.7140186	-120.6909826	166.1	
P09_10S	45.71399773	-120.691034	252.3	
P10_11D	45.71421855	-120.6911901	166.5	
P10_11S	45.71419759	-120.6912414	252.7	
P11_12D	45.71441859	-120.6913967	165.9	
P11_12S	45.71439762	-120.6914482	252.4	
P12_13D	45.71461826	-120.6916034	166.1	
P12_13S	45.7145973	-120.6916548	252.5	
P13_14D	45.71481785	-120.6918109	166.2	
P13_14S	45.71479698	-120.6918622	252.5	
P14_15D	45.71501717	-120.6920165	166.1	
P14_15S	45.7149962	-120.692068	252.4	
P15_16D	45.7152172	-120.6922249	166.3	
P15_16S	45.71519624	-120.6922763	252.5	
P16_17D	45.71541687	-120.6924311	166.0	
P16_17S	45.71539591	-120.6924825	252.3	
P17_18D	45.71561673	-120.6926383	166.2	
P17_18S	45.71559577	-120.6926899	252.6	
P18_19D	45.71581586	-120.692845	166.2	
P18_19S	45.7157949	-120.6928964	252.5	

Table A.5. (contd)

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
P19_20D	45.71601617	-120.6930522	166.0	
P19_20S	45.7159953	-120.6931038	252.3	
P20D	45.71621817	-120.6932618	165.6	
P20S	45.71619721	-120.6933133	252.0	
S01_02D	45.71887243	-120.6961348	229.3	Spillway
S01_02S	45.71887243	-120.6961348	256.9	
S02_03D	45.71873447	-120.6959918	229.4	
S02_03S	45.71873447	-120.6959918	257.0	
S03_04D	45.71859668	-120.6958493	229.4	
S03_04S	45.71859668	-120.6958493	257.0	
S04_05D	45.71845998	-120.6957073	229.3	
S04_05S	45.71845998	-120.6957073	257.0	
S05_06D	45.71832256	-120.6955648	229.2	
S05_06S	45.71832256	-120.6955648	256.9	
S06_07D	45.71818549	-120.6954224	229.1	
S06_07S	45.71818549	-120.6954224	256.9	
S07_08D	45.71804654	-120.6952788	229.3	
S07_08S	45.71804654	-120.6952788	256.9	
S08_09D	45.71790939	-120.6951366	229.2	
S08_09S	45.71790939	-120.6951366	256.9	
S09_10D	45.71777169	-120.6949936	229.1	
S09_10S	45.71777169	-120.6949936	256.8	
S10_11D	45.71763427	-120.6948514	229.4	
S10_11S	45.71763427	-120.6948514	257.0	
S11_12D	45.7174963	-120.6947091	229.0	
S11_12S	45.7174963	-120.6947091	256.8	
S12_13D	45.71735887	-120.694567	229.2	
S12_13S	45.71735887	-120.694567	256.8	
S13_14D	45.71722127	-120.6944246	229.3	
S13_14S	45.71722127	-120.6944246	256.9	
S14_15D	45.71708367	-120.694282	227.7	
S14_15S	45.71708367	-120.694282	256.9	
S15_16D	45.71694606	-120.6941392	229.1	
S15_16S	45.71694606	-120.6941392	256.7	
S16_17D	45.71680818	-120.6939966	229.0	
S16_17S	45.71680818	-120.6939966	256.7	
S17_18D	45.71667004	-120.6938539	229.3	
S17_18S	45.71667004	-120.6938539	256.6	
S18_19D	45.7165327	-120.6937114	229.2	
S18_19S	45.7165327	-120.6937114	256.7	
S19_20D	45.71639456	-120.6935686	229.2	
S19_20S	45.71639456	-120.6935686	256.9	
S20D	45.7162592	-120.6934257	228.6	
S20S	45.7162592	-120.6934257	256.2	

Table A.6. Cabled hydrophone locations at The Dalles Dam in 2012. The majority of the hydrophones were deployed on 10 April 2012. On 26 June 2012, 17 additional hydrophones were installed.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
F00_01S	45.6158095	-121.1273519	146.17	Powerhouse
F01_02D	45.61590233	-121.1272625	104.997	
F02_P01S	45.61596606	-121.1271231	146.272	
P01_02D	45.61615339	-121.1268949	106.473	
F00_01D	45.61582576	-121.1273746	105.407	
F01_02S	45.61588607	-121.1272397	145.76	
F02_P01D	45.61598228	-121.1271457	105.607	
P01_02S	45.61613715	-121.1268722	147.187	
P02_03S	45.61630036	-121.1266332	147.046	
P03_04D	45.61648141	-121.1264148	106.706	
P04_05S	45.61662984	-121.1261505	147.97	
P05_06D	45.61680728	-121.1259383	106.299	
P02_03D	45.61631656	-121.1266558	106.43	
P03_04S	45.61646518	-121.1263921	147.42	
P04_05D	45.61664607	-121.1261732	107.256	
P05_06S	45.61679103	-121.1259156	147.062	
P06_07S	45.61695584	-121.1256752	147.177	
P07_08D	45.61713692	-121.1254573	106.182	
P08_SS1S	45.61728489	-121.1251942	149.243	
SS2_P09D	45.61744926	-121.1249537	108.46	
P06_07D	45.6169721	-121.125698	106.414	
P07_08S	45.61712066	-121.1254346	146.945	
P08_SS1D	45.61730112	-121.1252169	108.529	
SS2_P09S	45.61746545	-121.1249763	149.076	
P09_10S	45.61761484	-121.1247127	146.476	
P10_11D	45.61779564	-121.1244936	106.322	
P11_12S	45.61794353	-121.1242319	147.125	
P12_13D	45.61812496	-121.1240132	106.427	
P09_10D	45.61763105	-121.1247353	105.811	
P10_11S	45.61777945	-121.124471	146.938	
P11_12D	45.61795977	-121.1242546	106.411	
P12_13S	45.61810872	-121.1239905	147.141	
P13_14S	45.61827345	-121.1237499	147.226	
P14_15D	45.6184538	-121.1235314	106.315	
P15_16S	45.61860242	-121.1232675	147.02	
P16_17D	45.61878393	-121.1230495	106.28	
P13_14D	45.61828971	-121.1237726	106.463	
P14_15S	45.61843756	-121.1235087	147.029	
P15_16D	45.61861866	-121.1232902	106.306	
P16_17S	45.61876767	-121.1230268	147.043	
P17_18S	45.61893162	-121.1227866	147.135	
P18_19D	45.61911289	-121.1225691	106.46	

Table A.6. (contd)

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
P19_20S	45.61926117	-121.1223063	147.43	
P20_21D	45.61944257	-121.1220876	106.532	
P17_18D	45.61894788	-121.1228094	106.372	
P18_19S	45.61909665	-121.1225464	147.174	
P19_20D	45.61927743	-121.122329	106.667	
P20_21S	45.61942633	-121.1220649	147.246	
P21_22S	45.61959048	-121.1218254	147.295	
P21_22D	45.61960674	-121.1218482	106.532	
P22S	45.61974967	-121.1215909	146.876	
P22D	45.61976593	-121.1216137	106.112	
N01S	45.61534985	-121.1365284	143.435	Spillway
N02S	45.61526884	-121.1363534	143.369	
N03S	45.61502601	-121.1359567	142.779	
N04S	45.61491483	-121.1357384	142.811	
S00_01S	45.61480058	-121.1355114	152.636	
S00_01D	45.61480058	-121.1355114	124.986	
S01_02S	45.61470704	-121.1353254	152.529	
S02_03D	45.61461117	-121.1351377	124.972	
S03_04S	45.61451305	-121.1349457	152.575	
S04_05D	45.61441666	-121.1347575	125.028	
S01_02D	45.61470704	-121.1353254	124.929	
S02_03S	45.61461117	-121.1351377	152.572	
S03_04D	45.61451305	-121.1349457	125.025	
S04_05S	45.61441666	-121.1347575	152.628	
S05_06S	45.61431976	-121.1345678	152.688	
S06_07D	45.61422273	-121.1343777	124.955	
S07_08S	45.61412558	-121.1341886	152.734	
S05_06D	45.61431976	-121.1345678	125.038	
S06_07S	45.61422273	-121.1343777	152.605	
S07_08D	45.61412558	-121.1341886	125.084	
S09_10S	45.6139324	-121.1338147	150.227	
S10_11D	45.61383576	-121.1336205	125.09	
S11_12S	45.61373929	-121.1334314	152.592	
S10_11S	45.61383576	-121.1336205	152.69	
S11_12D	45.61373929	-121.1334314	124.992	
S12_13S	45.61364211	-121.1332473	150.08	

Table A.7. Cabled hydrophone locations at Bonneville Dam in 2012. Hydrophones were deployed on 10 April 2012.

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
P01_02D	45.63935952	-121.946666	10.3	Powerhouse 1
P01_02S	45.63937043	-121.9467004	62.1	
P01_F01D	45.63915244	-121.9467884	10.9	
P01_F01S	45.63916334	-121.9468228	62.7	
P02_03D	45.63956829	-121.9465452	11.3	
P02_03S	45.6395792	-121.9465796	63.1	
P03_04D	45.63977646	-121.9464225	10.0	
P03_04S	45.63978728	-121.9464568	61.7	
P04_05D	45.63998283	-121.9462997	9.9	
P04_05S	45.63999374	-121.9463341	61.7	
P05_06D	45.64019349	-121.9461789	10.6	
P05_06S	45.64020431	-121.9462133	62.3	
P06_07ND	45.64039534	-121.9459932	39.9	
P06_07NS	45.64039534	-121.9459932	62.9	
P06_07SD	45.64037249	-121.9460066	39.6	
P06_07SS	45.64037249	-121.9460066	62.7	
P07_08D	45.64060971	-121.9459355	10.9	
P07_08S	45.64062062	-121.9459697	62.6	
P08_09D	45.64081761	-121.945813	11.1	
P08_09S	45.64082851	-121.9458473	62.7	
P09_10D	45.64102644	-121.9456944	14.8	
P09_10S	45.64103648	-121.9457261	62.6	
P10D_NW	45.64121817	-121.9455262	43.8	
P10S_NW	45.64121819	-121.9455248	66.3	
PNW	45.64123862	-121.9450731	71.0	
PSS_F01S	45.63908965	-121.9468648	62.3	
PSW	45.63865099	-121.9461725	64.6	
P11_12D	45.64743369	-121.9380924	23.3	Powerhouse 2
P11_12S	45.64744666	-121.9381129	64.7	
P12_13D	45.64762538	-121.937847	22.7	
P12_13S	45.64763853	-121.9378677	64.3	
P13_14D	45.64782373	-121.937594	23.1	
P13_14S	45.6478368	-121.9376145	64.7	
P14_15D	45.64801569	-121.9373491	23.1	
P14_15S	45.64802884	-121.9373696	64.7	
P15_16D	45.64820243	-121.9371109	23.2	
P15_16S	45.64821558	-121.9371314	64.8	
P16_17D	45.64839429	-121.9368656	22.9	
P16_17S	45.64840744	-121.9368862	64.5	
P17_18D	45.64858652	-121.9366204	23.1	
P17_18S	45.64859958	-121.936641	64.7	
P18_19D	45.6487782	-121.936375	23.2	

Table A.7. (contd)

Hydrophone Name	Latitude (Degrees North)	Longitude (Degrees West)	Elevation (ft) (NGVD29)	Array Location
P18_19S	45.64879136	-121.9363956	64.9	
P19	45.64897884	-121.9361485	53.8	
PCC	45.64712879	-121.9384236	70.7	B2CC
PCC_11D	45.64724991	-121.9383528	52.7	
PCC_11S	45.64725459	-121.9383602	67.7	
S01_02D	45.64563148	-121.9406194	39.4	Spillway
S01_02S	45.64563148	-121.9406194	67.0	
S01D	45.64577567	-121.9406254	39.1	
S01S	45.64577567	-121.9406254	65.9	
S02_03D	45.64530379	-121.9406284	67.0	
S02_03S	45.64546745	-121.9406241	66.9	
S03_04D	45.64530379	-121.9406284	39.5	
S03_04S	45.64546745	-121.9406241	39.5	
S04_05D	45.6451385	-121.9406339	39.5	
S04_05S	45.6451385	-121.9406339	67.0	
S05_06D	45.6449732	-121.9406389	39.1	
S05_06S	45.6449732	-121.9406389	67.0	
S06_07D	45.64480936	-121.9406433	39.1	
S06_07S	45.64480936	-121.9406433	66.9	
S07_08D	45.64464434	-121.9406486	38.7	
S07_08S	45.64464434	-121.9406486	66.7	
S08_09D	45.64448031	-121.9406534	40.3	
S08_09S	45.64448031	-121.9406534	67.9	
S09_10D	45.64431601	-121.9406581	40.7	
S09_10S	45.64431601	-121.9406581	68.1	
S10_11D	45.6441518	-121.9406627	39.6	
S10_11S	45.6441518	-121.9406627	67.2	
S11_12D	45.64398642	-121.9406683	39.4	
S11_12S	45.64398642	-121.9406683	67.3	
S12_13D	45.64382185	-121.9406729	39.4	
S12_13S	45.64382185	-121.9406729	67.1	
S13_14D	45.64365926	-121.9406773	39.8	
S13_14S	45.64365926	-121.9406773	67.4	
S14_15D	45.64349324	-121.940683	40.1	
S14_15S	45.64349324	-121.940683	67.7	
S15_16D	45.64332984	-121.9406879	40.1	
S15_16S	45.64332984	-121.9406879	67.6	
S16_17D	45.64316456	-121.9406925	38.9	
S16_17S	45.64316456	-121.9406925	66.7	
S17_18D	45.6429998	-121.9406978	38.4	
S17_18S	45.6429998	-121.9406978	65.9	
S18D	45.64286054	-121.9407015	39.8	
S18S	45.64286054	-121.9407015	67.7	

Table A.8. Approximate global positioning system coordinates of autonomous hydrophone nodes deployed in the Snake, Clearwater, and Columbia rivers in 2012. Array_Node is a concatenation of array name and autonomous node number. Array name is a concatenation of river name (SR for Snake River and 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.

Array_Node	Array Function	Latitude (Degrees North)	Longitude (Degrees West)	rkm	Deployment Date
SR743.0_01	Clearwater Mouth	46.4260817	-117.0712233	743	04/20/12
SR743.0_02		46.4254917	-117.0708383	743	04/20/12
SR743.0_03		46.4249333	-117.0700500	743	04/20/12
SR696.0_01	LGR Forebay	46.6587200	-117.4153867	696	04/19/12
SR696.0_02		46.6572533	-117.4166717	696	04/19/12
SR696.0_03		46.6557967	-117.4176833	696	04/19/12
SR696.0_04		46.6543650	-117.4182283	696	04/19/12
SR693.0_01	LGR Tailrace	46.6729267	-117.4465917	693	04/19/12
SR693.0_02		46.6729150	-117.4483300	693	04/19/12
SR636.0_01	LGS Forebay	46.5892917	-118.0172300	636	04/25/12
SR636.0_02		46.5883650	-118.0155117	636	04/25/12
SR636.0_03		46.5872056	-118.0152194	636	04/25/12
SR636.0_04		46.5859650	-118.0159367	636	04/25/12
SR634.0_01	LGS Tailrace	46.5810733	-118.0467017	634	04/25/12
SR634.0_02		46.5804533	-118.0454817	634	04/25/12
SR634.0_03		46.5798950	-118.0448117	634	04/25/12
SR604.0_01	LMN Mid Res.	46.5912217	-118.3752717	604	04/25/12
SR604.0_02		46.5908250	-118.3746350	604	04/25/12
SR604.0_03		46.5902867	-118.3735717	604	04/25/12
SR604.0_04		46.5897778	-118.3726333	604	04/25/12
SR590.0_01	LMN Forebay	46.5674517	-118.5315100	590	04/24/12
SR590.0_02		46.5666933	-118.5296717	590	04/24/12
SR590.0_03		46.5657867	-118.5289133	590	04/24/12
SR590.0_04		46.5647200	-118.5282000	590	04/24/12
SR587.0_01	LMN Tailrace	46.5473817	-118.5554317	587	04/24/12
SR587.0_02		46.5466533	-118.5558883	587	04/24/12
SR587.0_03		46.5469767	-118.5532850	587	04/24/12
SR562.0_01	IHR Mid Res.	46.3788778	-118.6953694	562	04/24/12
SR562.0_02		46.3786150	-118.6945333	562	04/24/12
SR562.0_03		46.3784600	-118.6932450	562	04/24/12
SR562.0_04		46.3783050	-118.6922283	562	04/24/12
SR539.0_01	IHR Forebay	46.2527333	-118.8701650	539	04/24/12
SR539.0_02		46.2520017	-118.8689350	539	04/24/12
SR539.0_03		46.2511267	-118.8684200	539	04/24/12
SR539.0_04		46.2499183	-118.8675983	539	04/24/12
SR525.0_01	Snake Mouth	46.2161833	-119.0243600	525	04/24/12
SR525.0_02		46.2152550	-119.0232617	525	04/24/12
SR525.0_03		46.2148850	-119.0226200	525	04/24/12

Table A.8. (contd)

Array_Node	Array Function	Latitude (Degrees North)	Longitude (Degrees West)	rkm	Deployment Date
SR525.0_04		46.2144333	-119.0217417	525	04/24/12
CR472.0_01	MCN Forebay	45.9458680	-119.2754788	472	04/24/12
CR472.0_02		45.9441585	-119.2749115	472	04/24/12
CR472.0_03		45.9424310	-119.2743442	472	04/24/12
CR472.0_04		45.9404336	-119.2735706	472	04/24/12
CR472.0_05		45.9383282	-119.2729002	472	04/24/12
CR472.0_06		45.9363308	-119.2721782	472	04/24/12
CR472.0_07		45.9345493	-119.2715593	472	04/24/12
CR472.0_08		45.9327858	-119.2708630	472	04/24/12
CR468.0_01	MCN Tailrace	45.9335131	-119.3250311	468	04/24/12
CR468.0_02		45.9321274	-119.3244124	468	04/24/12
CR468.0_03		45.9307058	-119.3237679	468	04/24/12
CR422.0_01	JDA Mid Res.	45.8414759	-119.8569511	422	04/24/12
CR422.0_02		45.8405815	-119.8565531	422	04/24/12
CR422.0_03		45.8396049	-119.8560968	422	04/24/12
CR422.0_04		45.8382934	-119.8555380	422	04/24/12
CR422.0_05		45.8373816	-119.8551334	422	04/24/12
CR422.0_06		45.8363181	-119.8546435	422	04/24/12
CR422.0_07		45.8354667	-119.8540333	422	04/24/12
CR351.0_01	JDA Forebay	45.7263480	-120.6850310	351	04/26/12
CR351.0_02		45.7252350	-120.6839480	351	04/26/12
CR351.0_03		45.7241920	-120.6829290	351	04/26/12
CR351.0_04		45.7230820	-120.6816760	351	04/26/12
CR351.0_05		45.7219190	-120.6805270	351	04/26/12
CR351.0_06		45.7208840	-120.6793880	351	04/26/12
CR351.0_07		45.7197450	-120.6781820	351	04/26/12
CR351.0_08		45.7186490	-120.6769790	351	04/26/12
CR346.0_01	JDA Tailrace	45.7085740	-120.7246590	346	04/25/12
CR346.0_02		45.7074530	-120.7238100	346	04/25/12
CR346.0_03		45.7062870	-120.7228740	346	04/25/12
CR346.0_04		45.7051500	-120.7219640	346	04/25/12
CR325.0_01	TDA Mid Res.	45.6554574	-120.9670791	325	04/26/12
CR325.0_02		45.6544704	-120.9663697	325	04/26/12
CR325.0_03		45.6535996	-120.9656131	325	04/26/12
CR325.0_04		45.6527011	-120.9649274	325	04/26/12
CR325.0_05		45.6520335	-120.9644344	325	04/26/12
CR325.0_06		45.6511814	-120.9638134	325	04/26/12
CR311.0_01	TDA Forebay	45.6288000	-121.1157960	311	06/14/12
CR311.0_02		45.6278630	-121.1142710	311	06/14/12
CR311.0_03		45.6269450	-121.1126290	311	06/14/12
CR311.0_04		45.6261530	-121.1111270	311	06/14/12
CR311.0_05		45.6253450	-121.1096530	311	06/14/12
CR307.0_01	TDA Tailrace	45.6083160	-121.1510940	307	06/14/12
CR307.0_02		45.6072850	-121.1500350	307	06/14/12

Table A.8. (contd)

Array_Node	Array Function	Latitude (Degrees North)	Longitude (Degrees West)	rkm	Deployment Date
CR307.0_03		45.6063758	-121.1488433	307	06/14/12
CR275.0_01	BON Mid Res.	45.7091259	-121.4712970	275	06/15/12
CR275.0_02		45.7086224	-121.4717591	275	06/15/12
CR275.0_03		45.7078330	-121.4724400	275	06/15/12
CR275.0_04		45.7072915	-121.4729401	275	06/15/12
CR275.0_05		45.7066440	-121.4735049	275	06/15/12
CR275.0_06		45.7057667	-121.4734667	275	06/15/12
CR236.0_01	BON Forebay	45.6509740	-121.9203458	236	03/30/12
CR236.0_02		45.6504350	-121.9198845	236	03/30/12
CR236.0_03		45.6498599	-121.9193207	236	03/30/12
CR236.0_04		45.6493209	-121.9188595	236	03/30/12
CR233.0_01	Bon Tailrace	45.6350167	-121.9624833	233	03/30/12
CR233.0_02		45.6350270	-121.9613769	233	03/30/12
CR233.0_03		45.6346314	-121.9606050	233	03/30/12
CR156.0_01	CR at km 156	45.7145222	-122.7615090	156	03/29/12
CR156.0_02		45.7146662	-122.7627333	156	03/29/12
CR156.0_03		45.7147742	-122.7634608	156	03/29/12
CR156.0_04		45.7149182	-122.7643340	156	03/29/12
CR156.0_05		45.7150981	-122.7647500	156	03/29/12
CR156.0_06		45.7152422	-122.7665426	156	03/29/12
CR156.0_07		45.7153861	-122.7668500	156	03/29/12
CR156.0_08		45.7155301	-122.7680333	156	03/29/12
CR113.0_01	CR at km 113	46.0561370	-122.8727154	113	03/29/12
CR113.0_02		46.0593333	-122.8806833	113	03/29/12
CR113.0_03		46.0602333	-122.8813500	113	03/29/12
CR113.0_04		46.0593333	-122.8820167	113	03/29/12
CR113.0_05		46.0601000	-122.8830333	113	03/29/12
CR113.0_06		46.0591167	-122.8841000	113	03/29/12
CR113.0_07		46.0600333	-122.8847834	113	03/29/12
CR113.0_08		46.0590333	-122.8851500	113	03/29/12
CR113.0_09		46.0589000	-122.8860833	113	03/29/12
CR113.0_10		46.0587833	-122.8871167	113	03/29/12
CR113.0_11		46.0586500	-122.8881333	113	03/29/12
CR113.0_12		46.0585167	-122.8891000	113	03/29/12
CR086.0_01	CR at km 86	46.1866151	-123.1807629	86	06/19/12
CR086.0_02		46.1861112	-123.1804002	86	06/19/12
CR086.0_03		46.1855354	-123.1799856	86	06/19/12
CR086.0_04		46.1850315	-123.1796747	86	06/19/12
CR086.0_05		46.1845276	-123.1793120	86	06/19/12
CR086.0_06		46.1840597	-123.1788974	86	06/19/12
CR086.0_07		46.1835918	-123.1785865	86	06/19/12
CR086.0_08		46.1831239	-123.1783274	86	06/19/12

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, BBW = Big Bear Weir [Potlatch River], LBW = Little Bear Weir [Potlatch River], JOS = Joseph Creek, EFP = East Fork of the Potlatch River, FC = Fish Creek, and CR = Crooked River), 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	3D9.1BF27D2A75	G7250EDC3	Good	Female	Intact	80.0	3.73	4/19/2012	695
LGR	3D9.1BF27F5F7A	G724F371E	Good	Female	Intact	72.0	2.66	4/19/2012	695
LGR	3D9.1BF27F2B37	G724FB52E	Good	Male	Intact	62.5	1.94	4/19/2012	695
LGR	3D9.1BF27F1FDF	G72515C6B	Good	Female	Intact	63.0	2.07	4/20/2012	695
LGR	3D9.1BF27F3C3A	G7250094B	Good	Female	Intact	60.0	1.73	4/20/2012	695
LGR	3D9.1BF27F513B	G72528956	Good	Female	Intact	68.0	2.36	4/20/2012	695
LGR	3D9.1BF27F32ED	G7251953D	Good	Female	Clipped	65.0	1.91	4/21/2012	695
LGR	3D9.1C2D58BE1A	G726FCC8B	Good	Male	Clipped	57.0	1.40	4/21/2012	695
LGR	3D9.1BF253097E	G72517309	Good	Female	Clipped	55.0	1.14	4/23/2012	695
LGR	3D9.1BF2533652	G72511E91	Good	Female	Intact	64.0	1.98	4/23/2012	695
LGR	3D9.1BF253A981	G724F7606	Good	Female	Intact	64.0	1.91	4/23/2012	695
LGR	3D9.1BF253BF32	G72501575	Good	Female	Intact	82.0	4.11	4/23/2012	695
LGR	3D9.1BF253555B	G72519F43	Good	Male	Intact	64.0	2.29	4/23/2012	695
LGR	3D9.1BF253838E	G724F3C3E	Good	Female	Intact	67.0	2.14	4/23/2012	695
LGR	3D9.1C2DA0E7CD	G724EF710	Good	Male	Intact	55.0	1.27	4/23/2012	695
LGR	3D9.1BF25E3AF9	G7250995A	Good	Male	Intact	60.0	1.61	4/25/2012	695
LGR	3D9.1BF2603825	G72503408	Good	Female	Intact	64.0	1.76	4/25/2012	695
LGR	3D9.1BF26048AA	G724F11E0	Good	Female	Clipped	60.0	1.55	4/25/2012	695
LGR	3D9.1BF25EC080	G72510013	Good	Female	Intact	57.0	1.46	4/25/2012	695
LGR	3D9.1BF2604686	G72515D35	Good	Female	Clipped	56.0	1.27	4/25/2012	695
LGR	3D9.1BF2606AA5	G724F7AA5	Good	Female	Intact	64.0	1.73	4/25/2012	695
LGR	3D9.1BF25EA1B6	G7250C3FF	Good	Female	Intact	60.0	1.65	4/25/2012	695
LGR	3D9.1BF2606063	G724FC0E9	Good	Male	Intact	55.0	1.30	4/25/2012	695
LGR	3D9.1BF25EA11A	G72511912	Good	Female	Intact	53.0	1.17	4/25/2012	695
LGR	3D9.1BF25E89E8	G724FBDEC	Good	Female	Intact	61.0	1.66	4/25/2012	695
LGR	3D9.1C2D5509DF	G7250A2C4	Good	Female	Intact	65.0	2.15	4/25/2012	695
LGR	3D9.1BF25EB89F	G724F5244	Good	Female	Clipped	64.0	1.90	4/26/2012	695

Table B.1. (contd)

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	3D9.1BF25EDA27	G7250E282	Good	Male	Intact	60.0	1.51	4/26/2012	695
LGR	3D9.1BF25EDE92	G72506EAD	Good	Female	Clipped	57.0	1.31	4/26/2012	695
LGR	3D9.1BF25EECF8	G724F49F9	Good	Male	Intact	65.0	2.46	4/26/2012	695
LGR	3D9.1BF25E7384	G72527EA1	Good	Female	Clipped	52.0	1.12	4/26/2012	695
LGR	3D9.1BF25E7311	G72507A51	Good	Male	Intact	58.0	1.67	4/26/2012	695
LGR	3D9.1BF26036B7	G724FA4ED	Good	Female	Clipped	57.0	1.36	4/26/2012	695
LGR	3D9.1BF22C68D0	G7251DDB9	Good	Female	Intact	63.0	1.80	4/26/2012	695
LGR	3D9.1C2D554941	G7250E8FC	Good	Female	Intact	68.0	2.10	4/26/2012	695
LGR	3D9.1BF25ECCC5	G72511FCF	Good	Female	Clipped	53.0	1.08	4/26/2012	695
LGR	3D9.1C2D58C2E2	G72506C11	Good	Female	Intact	67.0	2.13	4/26/2012	695
LGR	3D9.1BF25EB479	G7251915C	Good	Female	Intact	74.0	3.44	4/26/2012	695
LGR	3D9.1BF22C9E30	G7250D362	Good	Female	Clipped	55.0	1.01	4/26/2012	695
LGR	3D9.1BF22C9029	G725041CF	Good	Female	Intact	69.0	2.30	4/27/2012	695
LGR	3D9.1BF22C94E7	G7250C47C	Good	Female	Intact	53.0	0.95	4/27/2012	695
LGR	3D9.1C2D54CC20	G726FCDD5	Good	Female	Intact	65.0	2.18	4/27/2012	695
LGR	3D9.1BF22C9BFB	G72523625	Good	Female	Intact	65.0	2.03	4/27/2012	695
LGR	3D9.1BF22CAB1D	G7251A87E	Good	Female	Intact	65.0	2.01	4/27/2012	695
LGR	3D9.1BF22CA101	G724FE4AB	Good	Female	Clipped	56.0	1.52	4/27/2012	695
LGR	3D9.1BF22C69B4	G72517A95	Good	Female	Intact	72.0	3.15	4/28/2012	695
LGR	3D9.1BF22C95E7	G7251F385	Good	Female	Clipped	57.0	1.20	4/28/2012	695
LGR	3D9.1BF22CA4A4	G72508DA6	Good	Female	Clipped	57.0	1.35	4/28/2012	695
LGR	3D9.1BF22C9CF1	G724F7EC4	Fair	Male	Intact	77.0	3.55	4/28/2012	695
LGR	3D9.1BF22C928B	G724F31C3	Good	Female	Intact	59.0	1.54	4/29/2012	695
LGR	3D9.1BF22CAC66	G724F029F	Good	Female	Intact	68.0	2.16	4/29/2012	695
LGR	3D9.1BF22C9DB1	G724FB011	Good	Female	Intact	65.0	2.09	4/29/2012	695
LGR	3D9.1BF22C908B	G72518FDE	Good	Female	Clipped	72.0	2.62	4/29/2012	695
LGR	3D9.1BF22CAAA8	G7250F861	Good	Female	Intact	63.0	1.68	4/29/2012	695
LGR	3D9.1BF22C90F0	G724FDB54	Good	Female	Clipped	59.0	1.58	4/30/2012	695
LGR	3D9.1BF22C9AC0	G725130AD	Good	Female	Clipped	58.0	1.52	4/30/2012	695
LGR	3D9.1C2D584B28	G724FCFA8	Good	Female	Intact	54.0	1.18	4/30/2012	695

Table B.1. (contd)

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	3D9.1BF22C9B09	G72515615	Good	Female	Clipped	58.0	1.36	5/1/2012	695
LGR	3D9.1BF22C948C	G7252585F	Good	Female	Clipped	57.0	1.36	5/1/2012	695
LGR	3D9.1BF22C9141	G7251837D	Good	Female	Intact	75.0	3.15	5/1/2012	695
LGR	3D9.1BF22C4C55	G725285F5	Good	Female	Clipped	58.0	1.43	5/1/2012	695
LGR	3D9.1BF22B1E60	G72523BD8	Good	Female	Clipped	58.0	1.29	5/2/2012	695
LGR	3D9.1BF22C7D71	G72514DA8	Good	Female	Clipped	57.0	1.37	5/2/2012	695
LGR	3D9.1BF22C9BD3	G72511C2D	Good	Female	Intact	57.0	1.30	5/2/2012	695
LGR	3D9.1BF25EE698	G724F4B45	Good	Female	Clipped	60.0	1.63	5/2/2012	695
LGR	3D9.1BF25EBD35	G724F74BA	Good	Male	Clipped	58.0	1.52	5/2/2012	695
LGR	3D9.1BF25E5E7A	G724F916C	Good	Male	Intact	59.0	1.84	5/2/2012	695
LGR	3D9.1BF22CAFC0	G72504C32	Good	Female	Clipped	53.0	1.12	5/3/2012	695
LGR	3D9.1BF22C9A1E	G72502777	Good	Male	Intact	58.0	1.63	5/3/2012	695
LGR	3D9.1BF22CA920	G725226B8	Good	Female	Clipped	56.0	1.33	5/3/2012	695
LGR	3D9.1BF22CAD97	G72526C80	Good	Female	Clipped	71.0	2.71	5/4/2012	695
LGR	3D9.1BF22C4931	G72511653	Good	Female	Clipped	58.0	1.24	5/4/2012	695
LGR	3D9.1BF22CAB79	G725243E2	Good	Female	Intact	58.0	1.38	5/4/2012	695
LGR	3D9.1BF22CAF06	G724F6E59	Good	Female	Clipped	59.0	1.69	5/4/2012	695
LGR	3D9.1BF22CB276	G7252571E	Good	Female	Clipped	55.0	1.22	5/4/2012	695
LGR	3D9.1BF22C8E11	G7251DF05	Good	Female	Clipped	65.0	1.91	5/4/2012	695
LGR	3D9.1BF22C962A	G725254FC	Good	Female	Intact	59.0	1.58	5/4/2012	695
LGR	3D9.1BF22CB22A	G72518642	Good	Female	Intact	59.0	1.51	5/4/2012	695
LGR	3D9.1BF22C8B56	G72707252	Good	Female	Clipped	58.0	1.36	5/5/2012	695
LGR	3D9.1BF25E7A18	G724F886D	Good	Male	Clipped	55.0	1.15	5/6/2012	695
LGR	3D9.1BF25EA580	G72503137	Good	Female	Intact	68.0	1.96	5/6/2012	695
LGR	3D9.1BF25E9C7A	G7252213B	Good	Female	Intact	60.0	1.61	5/6/2012	695
LGR	3D9.1BF25ED70A	G7251B3C3	Good	Female	Clipped	60.0	1.61	5/6/2012	695
LGR	3D9.1BF25EE24E	G72522065	Good	Female	Clipped	54.0	1.48	5/6/2012	695
LGR	3D9.1BF25EC6AD	G7251C4B8	Good	Male	Intact	55.0	1.29	5/6/2012	695
LGR	3D9.1BF25E3B35	G7250CDE0	Good	Female	Clipped	57.0	1.31	5/6/2012	695
LGR	3D9.1BF2607444	G725207C5	Good	Female	Intact	53.0	1.30	5/6/2012	695

Table B.1. (contd)

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	3D9.1BF26071B0	G725193E0	Good	Female	Clipped	58.0	1.56	5/7/2012	695
LGR	3D9.1BF25EEFD0	G7250A126	Good	Male	Clipped	56.0	1.28	5/7/2012	695
LGR	3D9.1BF25E44E0	G725270BE	Good	Female	Clipped	56.0	1.19	5/7/2012	695
LGR	3D9.1BF22CAFB6	G725090C6	Good	Female	Intact	62.0	1.61	5/8/2012	695
LGR	3D9.1BF22C571B	G724F9C91	Good	Female	Clipped	57.0	1.33	5/8/2012	695
LGR	3D9.1BF22C57C3	G72523499	Good	Female	Clipped	57.0	1.29	5/8/2012	695
LGR	3D9.1BF22B1491	G7251BA5F	Good	Male	Intact	55.0	1.41	5/9/2012	695
LGR	3D9.1C2D581377	G7250C6C0	Good	Male	Intact	55.0	1.31	5/9/2012	695
LGR	3D9.1BF22CAD2D	G7250F93F	Good	Female	Intact	66.0	2.31	5/9/2012	695
LGR	3D9.1BF25309D8	G7250A078	Good	Female	Intact	74.0	2.69	5/10/2012	695
LGR	3D9.1BF2531DD5	G72527581	Good	Female	Intact	60.0	1.69	5/10/2012	695
LGR	3D9.1BF22CA40A	G725203A4	Fair	Male	Clipped	57.0	1.38	5/11/2012	695
LGR	3D9.1BF22CAF50	G724F48A7	Fair	Female	Intact	83.0	4.63	5/11/2012	695
LGR	3D9.1BF2537A82	G7250F21F	Good	Female	Clipped	56.0	1.25	5/12/2012	695
LGR	3D9.1BF253A8D3	G725082E7	Good	Female	Clipped	59.0	1.51	5/12/2012	695
LGR	3D9.1C2D4520B5	G72504FD0	Good	Female	Intact	57.0	1.45	5/12/2012	695
LGR	3D9.1BF2530AA3	G724FE194	Good	Female	Clipped	59.0	1.46	5/12/2012	695
LGR	3D9.1BF25309A1	G7251F406	Good	Male	Intact	54.0	1.35	5/12/2012	695
LGR	3D9.1BF253141A	G72527D43	Good	Female	Clipped	52.0	1.04	5/12/2012	695
LGR	3D9.1BF253949F	G72520427	Good	Male	Intact	56.0	1.34	5/12/2012	695
LGR	3D9.1BF2536F8D	G72516394	Good	Female	Clipped	57.0	1.59	5/13/2012	695
LGR	3D9.1BF25311BE	G72501A34	Good	Female	Clipped	56.0	1.30	5/14/2012	695
LGR	3D9.1BF253510B	G724FCA97	Good	Female	Clipped	51.0	1.12	5/14/2012	695
LGR	3D9.1BF25335A9	G7251F2DB	Fair	Female	Clipped	57.0	1.27	5/14/2012	695
LGR	3D9.1BF2530AA2	G725013A8	Good	Female	Clipped	56.0	1.16	5/15/2012	695
LGR	3D9.1BF253C067	G7251748A	Fair	Female	Clipped	56.0	2.06	5/15/2012	695
LGR	3D9.1BF2539439	G7252735C	Good	Female	Clipped	52.0	1.02	5/15/2012	695
LGR	3D9.1BF25326D2	G7252377B	Fair	Female	Intact	56.0	1.19	5/15/2012	695
LGR	3D9.1BF22C6694	G7252383A	Fair	Female	Intact	58.0	1.34	5/15/2012	695
LGR	3D9.1BF22C2AE2	G7251AEA3	Fair	Female	Intact	57.0	1.43	5/16/2012	695

Table B.1. (contd)

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	3D9.1BF22C98AA	G725215E4	Fair	Female	Intact	56.0	1.43	5/16/2012	695
LGR	3D9.1BF22CADC7	G72522CC6	Fair	Female	Clipped	58.0	1.48	5/16/2012	695
LGR	3D9.1BF22C7A40	G724F7185	Good	Female	Intact	53.0	1.14	5/17/2012	695
LGR	3D9.1BF22C934F	G724FE808	Fair	Male	Intact	59.0	1.62	5/17/2012	695
LGR	3D9.1BF22CACE1	G72501697	Fair	Female	Clipped	60.0	1.65	5/17/2012	695
LGR	3D9.1BF22CA33F	G724FBE0E	Good	Female	Intact	59.0	1.55	5/17/2012	695
LGR	3D9.1BF22CB2E6	G7250CCBE	Good	Female	Clipped	55.0	1.26	5/20/2012	695
LGR	3D9.1C2CF467A8	G72508F1A	Good	Male	Intact	51.0	1.06	5/20/2012	695
LGR	3D9.1BF22B1F5C	G724F928E	Good	Female	Intact	54.0	1.11	5/20/2012	695
LGR	3D9.1C2D983638	G725128F2	Good	Male	Intact	57.0	1.36	5/21/2012	695
LGR	3D9.1C2D994691	G7251A73F	Good	Female	Intact	65.0	1.96	5/21/2012	695
LGR	3D9.1C2DA143BC	G725089C7	Good	Female	Intact	58.0	1.53	5/22/2012	695
LGR	3D9.1C2D996BC1	G724FEF8B	Good	Female	Intact	54.0	1.07	5/22/2012	695
LGR	3D9.1C2D998A60	G72502629	Fair	Female	Intact	71.0	2.48	5/22/2012	695
LGR	3D9.1C2D988371	G724F8C0C	Good	Female	Intact	58.0	1.53	5/23/2012	695
LGR	3D9.1C2D944008	G72521819	Good	Female	Intact	58.0	1.64	5/23/2012	695
LGR	3D9.1C2D988D92	G7250A547	Good	Female	Intact	58.0	1.51	5/23/2012	695
LGR	3D9.1C2D959FAD	G7251B51E	Good	Male	Intact	50.0	0.93	5/24/2012	695
LGR	3D9.1C2D930AA4	G72507F6E	Good	Female	Clipped	57.0	1.56	5/24/2012	695
LGR	3D9.1C2DA12091	G724F4F24	Good	Female	Intact	56.0	1.40	5/24/2012	695
LGR	3D9.1C2D97F750	G7250490D	Good	Female	Intact	56.0	1.44	5/25/2012	695
LGR	3D9.1C2D936C3C	G7250B0E5	Good	Female	Clipped	56.0	1.42	5/25/2012	695
LGR	3D9.1C2D985BCD	G725280CA	Fair	Male	Intact	55.0	1.34	5/25/2012	695
LGR	3D9.1C2D98153B	G725184FE	Good	Female	Intact	59.0	1.53	5/25/2012	695
LGR	3D9.1C2D937BFE	G72515ED7	Good	Female	Intact	56.0	1.27	5/25/2012	695
LGR	3D9.1C2D943B8A	G725171B5	Fair	Female	Intact	59.0	1.57	5/25/2012	695
LGR	3D9.1C2D9507E2	G725168B4	Good	Female	Intact	72.0	2.60	5/26/2012	695
LGR	3D9.1C2D988061	G725167F5	Good	Female	Intact	82.0	3.99	5/26/2012	695
LGR	3D9.1C2D9988F7	G724FA230	Good	Female	Intact	62.0	1.70	5/26/2012	695
LGR	3D9.1C2D95D809	G725209DA	Fair	Male	Intact	56.0	1.48	5/26/2012	695

Table B.1. (contd)

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	3D9.1C2D998882	G724FFE48	Good	Female	Intact	58.0	1.44	5/28/2012	695
LGR	3D9.1C2D946534	G7251C187	Good	Male	Intact	60.0	1.43	5/28/2012	695
LGR	3D9.1C2D980BB2	G7251F7E4	Good	Female	Intact	54.0	1.19	5/29/2012	695
LGR	3D9.1C2D999299	G724F75E4	Good	Male	Clipped	56.0	1.37	5/30/2012	695
LGR	3D9.1C2D94E22E	G72526DDE	Good	Female	Intact	59.0	1.42	5/30/2012	695
LGR	3D9.1C2D959D34	G72502495	Good	Male	Intact	52.0	1.12	5/30/2012	695
LGR	3D9.1C2D94D91B	G72516549	Good	Female	Intact	57.0	1.36	5/31/2012	695
LGR	3D9.1C2D584561	G725077AC	Fair	Female	Intact	57.0	1.52	5/31/2012	695
LGR	3D9.1C2D9553BC	G725274DF	Fair	Male	Intact	55.0	1.08	5/31/2012	695
LGR	3D9.1C2D945561	G726FA572	Good	Female	Intact	61.0	1.66	6/1/2012	695
LGR	3D9.1C2D9836FA	G724F4A1B	Fair	Female	Intact	60.0	1.70	6/1/2012	695
LGR	3D9.1C2D99970E	G72526A5D	Fair	Female	Clipped	58.0	1.52	6/3/2012	695
LGR	3D9.1C2D956244	G724F3BBD	Good	Female	Clipped	54.0	1.19	6/4/2012	695
LGR	3D9.1C2D555BA6	G7250026B	Fair	Female	Intact	57.0	1.38	6/4/2012	695
LGR	3D9.1C2D94E27E	G725210DB	Fair	Female	Intact	59.0	1.51	6/4/2012	695
LGR	3D9.1C2D99987E	G724F9032	Fair	Female	Clipped	56.0	1.38	6/5/2012	695
LGR	3D9.1C2D995E72	G724F4065	Good	Female	Intact	58.0	1.58	6/5/2012	695
LGR	3D9.1C2D551F0E	G724F8590	Fair	Female	Intact	60.0	1.62	6/5/2012	695
LGR	3D9.1C2D981726	G724EF371	Fair	Female	Intact	58.0	1.50	6/7/2012	695
LGR	3D9.1C2D9445A4	G72702E2A	Fair	Female	Intact	54.0	1.16	6/7/2012	695
LGR	3D9.1C2D94353E	G7251B021	Good	Female	Intact	58.0	1.50	6/8/2012	695
LGR	3D9.1C2D571FE9	G724F2DFD	Fair	Female	Intact	54.0	1.26	6/9/2012	695
LGR	3D9.1C2D9356A9	G724F215E	Fair	Male	Intact	61.0	1.87	6/9/2012	695
LGR	3D9.1C2D99BCAE	G724F0B03	Good	Male	Clipped	54.0	1.30	6/10/2012	695
LGR	3D9.1C2D9943E4	G7250AD85	Fair	Male	Clipped	55.0	1.21	6/12/2012	695
LGR	3D9.1C2D993691	G7251DB64	Good	Male	Intact	59.0	1.51	6/12/2012	695
LGR	3D9.1C2D986558	G72510B33	Good	Male	Clipped	65.0	2.59	6/14/2012	695
LGR	3D9.1C2D980E55	G725129AC	Good	Male	Intact	52.0	1.15	6/17/2012	695
LGR	3D9.1C2D95C3FF	G72503CCA	Fair	Female	Intact	51.0	0.97	6/17/2012	695
LGR	3D9.1C2D98364B	G724FC488	Good	Male	Intact	61.0	1.34	6/21/2012	695

Table B.1. (contd)

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	3D9.1C2D944B38	G7251EEE5	Good	Male	Intact	59.0	1.32	6/22/2012	695
LGR	3D9.1C2D952226	G72500D2A	Good	Male	Intact	54.0	1.08	6/22/2012	695
LGR	3D9.1C2DAFE395	G724F9DCF	Fair	Female	Intact	68.0	2.42	6/23/2012	695
LGR	3D9.1C2D984EB8	G724F67C5	Good	Female	Intact	55.0	1.13	6/23/2012	695
LGR	3D9.1C2D990EE2	G72500BF7	Fair	Male	Intact	62.0	2.16	6/23/2012	695
ASO	3D9.1C2CFC8C6B	G72517FAA	Good	Male	Intact	57.0	-	4/19/12	760
ASO	3D9.1C2DCE3593	G7251B8E3	Good	Female	Intact	63.5	-	4/19/12	760
ASO	3D9.1C2DC81652	G724FDCD7	Good	Male	Intact	63.8	-	4/20/12	760
BBW	3D9.1C2D9DC2E2	G725134CC	Good	Female	Intact	73.0	2.44	4/24/12	793
BBW	3D9.1C2D5471D8	G72522404	Good	Male	Intact	64.6	1.84	4/27/12	793
LBW	3D9.1C2D9B5FB4	G7251ED07	Good	Female	Intact	70.8	3.09	4/19/12	795
LBW	3D9.1C2D9F45DD	G72519DFF	Good	Female	Intact	68.3	2.93	4/19/12	795
LBW	3D9.1C2D551BC7	G7250FFE2	Good	Female	Intact	68.7	2.78	4/19/12	795
LBW	3D9.1C2D9A3E0B	G724FEAB4	Good	Female	Intact	68.2	2.61	4/19/12	795
LBW	3D9.1C2D9E76C0	G724F5964	Good	Male	Intact	58.4	2.05	4/20/12	795
LBW	3D9.1C2D996EA1	G72523C5B	Good	Female	Intact	73.6	3.48	4/20/12	795
LBW	3D9.1C2D9EF611	G724F0F62	Good	Female	Intact	57.5	1.13	4/20/12	795
LBW	3D9.1C2D5CE90F	G7250DE9F	Good	Male	Intact	58.7	1.59	4/22/12	795
LBW	3D9.1C2D9B47DB	G7250AE67	Good	Female	Intact	74.0	2.60	4/24/12	795
LBW	3D9.1C2D9B89E3	G72513C0E	Good	Male	Intact	86.5	5.32	4/24/12	795
LBW	3D9.1C2D9F673E	G724F6427	Good	Male	Intact	73.1	3.47	4/24/12	795
LBW	3D9.1C2D9E9A45	G72510CB0	Good	Female	Intact	70.5	2.59	4/24/12	795
LBW	3D9.1C2D94643E	G72507DD2	Good	Male	Intact	62.0	2.10	4/24/12	795
LBW	3D9.1C2D9CD44F	G725052B0	Good	Female	Intact	59.1	1.54	4/25/12	795
LBW	3D9.1C2D9E98F8	G7251871C	Good	Male	Intact	59.4	1.64	4/25/12	795
LBW	3D9.1C2D5CBA37	G72509F87	Good	Male	Intact	63.9	1.97	4/25/12	795
LBW	3D9.1C2D9C7D70	G726FFAE8	Good	Male	Intact	59.1	1.84	4/25/12	795
LBW	3D9.1C2D9C1297	G7251E5C5	Good	Male	Intact	60.1	1.71	4/25/12	795
LBW	3D9.1C2D9E7F6C	G7251250F	Good	Female	Intact	71.0	2.62	4/25/12	795
LBW	3D9.1C2D9BEF14	G724FD2C8	Good	Male	Intact	60.2	1.70	4/26/12	795

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Clipped/Intact)	Length (cm)	Weight (kg)	Release Date	Release rkm
LBW	3D9.1C2D9E61FA	G7251999E	Good	Female	Intact	69.8	2.58	4/26/12	795
LBW	3D9.1C2D9CBA0C	G725147D6	Good	Female	Intact	71.4	2.80	4/26/12	795
LBW	3D9.1C2D9EB4A2	G7250EA40	Good	Female	Intact	73.2	3.06	4/26/12	795
LBW	3D9.1C2D9F65FD	G725056D1	Good	Female	Intact	70.6	2.54	4/26/12	795
LBW	3D9.1C2D9E1A31	G72513FEC	Good	Female	Intact	74.6	3.10	4/26/12	795
LBW	3D9.1C2D9C9984	G724EF1CD	Good	Female	Intact	64.6	1.99	4/26/12	795
LBW	3D9.1C2DB01B9E	G72502C57	Good	Female	Intact	68.3	2.34	4/26/12	795
LBW	3D9.1C2D9C89F3	G725271E0	Good	Male	Intact	56.5	1.71	4/27/12	795
LBW	3D9.1C2D9ECE47	G726F9FB2	Good	Male	Intact	62.8	2.16	4/27/12	795
LBW	3D9.1C2D9F5204	G7250E7BD	Good	Male	Intact	50.2	0.97	4/27/12	795
LBW	3D9.1C2D995170	G72516417	Good	Female	Intact	76.5	3.70	4/27/12	795
LBW	3D9.1C2D9E6CFA	G725004B6	Good	Female	Intact	72.8	2.79	4/29/12	795
LBW	3D9.1C2D9A314A	G724F5499	Good	Male	Intact	77.1	3.14	5/1/12	795
LBW	3D9.1C2D9BDC99	G7250104A	Good	Male	Intact	61.5	1.69	5/1/12	795
LBW	3D9.1C2D9E8BCB	G72502BD4	Good	Female	Intact	73.9	3.20	5/1/12	795
LBW	3D9.1C2D584C4D	G7251FB47	Good	Female	Intact	75.8	3.05	5/3/12	795
LBW	3D9.1C2D9EAFD8	G72514897	Good	Female	Intact	68.9	2.20	5/22/12	795
JOS	3D9.1C2D47D238	G724F413B	Good	Male	Intact	57.8	-	4/23/12	800
JOS	3D9.1C2DB4DBFC	G72500F96	Good	Male	Intact	59.7	-	4/23/12	800
JOS	3D9.1C2D4760AE	G724F834D	Good	Female	Intact	65.6	-	4/27/12	800
JOS	3D9.1C2D474DF9	G724FB470	Fair	Female	Intact	65.2	-	4/27/12	800
JOS	3D9.1C2D55192D	G724FDA0A	Good	Female	Intact	51.2	-	4/27/12	800
JOS	3D9.1C2D482CE9	G724F5C5B	Good	Female	Intact	73.3	-	4/27/12	800
JOS	3D9.1C2D47606C	G725106CE	Good	Female	Intact	73.6	-	4/27/12	800
JOS	3D9.1C2D48435D	G724FF7D4	Good	Male	Intact	52.4	-	4/27/12	800
JOS	3D9.1C2D5850CC	G724F309D	Good	Female	Intact	56.0	-	4/28/12	800
JOS	3D9.1C2D478D1E	G724F253F	Good	Male	Intact	61.2	-	4/28/12	800
JOS	3D9.1C2D47352E	G72521EC4	Good	Male	Intact	59.3	-	4/28/12	800
JOS	3D9.1C2D474FAB	G72512030	Good	Female	Intact	60.1	-	4/28/12	800
JOS	3D9.1C2D4809EC	G72527922	Good	Male	Intact	63.0	-	4/29/12	800

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Clipped/Intact)	Length (cm)	Weight (kg)	Release Date	Release rkm
JOS	3D9.1C2D54F295	G7251DCE7	Good	Female	Intact	67.0	-	4/30/12	800
JOS	3D9.1C2D47761E	G72521758	Good	Female	Intact	54.0	-	4/30/12	800
JOS	3D9.1C2D47F28C	G72508CF8	Good	Female	Intact	58.5	-	4/30/12	800
JOS	3D9.1C2D450261	G72503A17	Good	Male	Intact	57.0	-	5/1/12	800
JOS	3D9.1C2D482E7F	G7251AC1F	Good	Female	Intact	69.5	-	5/1/12	800
JOS	3D9.1C2D48165B	G724F3640	Good	Female	Intact	57.8	-	5/1/12	800
JOS	3D9.1C2D476089	G724FC634	Good	Female	Intact	70.2	-	5/3/2012	800
JOS	3D9.1C2D4536FD	G724F3901	Good	Female	Intact	58.2	-	5/3/2012	800
JOS	3D9.1C2DAC5B0E	G724FA1D2	Good	Female	Intact	52.8	-	5/3/2012	800
JOS	3D9.1C2DA11AF7	G725103F1	Good	Male	Intact	55.7	-	5/6/2012	800
JOS	3D9.1C2D484BBB	G72508E44	Good	Male	Intact	52.3	-	5/7/2012	800
JOS	3D9.1C2D489BEC	G7251A200	Good	Male	Intact	54.8	-	5/7/2012	800
JOS	3D9.1C2D4760C0	G725266FE	Good	Female	Intact	71.6	-	5/7/2012	800
JOS	3D9.1C2D452907	G72520118	Good	Male	Intact	56.9	-	5/7/2012	800
JOS	3D9.1C2D7098E6	G7250DAFE	Good	Male	Intact	58.3	-	5/11/2012	800
JOS	3D9.1C2D4746D0	G7250EF7F	Good	Female	Intact	54.4	-	5/11/2012	800
JOS	3D9.1C2D47F2F3	G724FF68A	Good	Female	Intact	54.7	-	5/11/2012	800
JOS	3D9.1C2D453626	G7252617D	Good	Female	Intact	56.7	-	5/14/2012	800
JOS	3D9.1C2D48434B	G72504853	Good	Male	Intact	51.7	-	5/18/2012	800
JOS	3D9.1C2D47DCAE	G724FED37	Good	Male	Intact	55.8	-	5/18/2012	800
JOS	3D9.1C2D454164	G725076F2	Good	Male	Intact	54.3	-	5/19/2012	800
JOS	3D9.1C2D4853EF	G72515BE8	Good	Male	Intact	48.9	-	5/20/2012	800
JOS	3D9.1C2D476EE4	G72518223	Good	Female	Intact	53.6	-	5/22/2012	800
JOS	3D9.1C2D5479A6	G72520579	Good	Male	Intact	53.5	-	5/25/2012	800
EFP	3D9.1C2D872129	G724FFCF4	Good	Female	Intact	67.2	2.53	5/4/12	835
EFP	3D9.1C2D8A6AF2	G726F701A	Good	Male	Intact	55.0	1.44	5/5/12	835
EFP	3D9.1C2D84CDFA	G7250D5BF	Good	Female	Intact	64.0	2.22	5/15/12	835
EFP	3D9.1BF279B137	G724F6F07	Good	Male	Intact	60.7	1.64	5/17/12	835
EFP	3D9.1C2D7E78FA	G724FA70F	Good	Male	Intact	62.7	1.94	5/17/12	835
EFP	3D9.1C2D88BEE9	G72523D05	Good	Male	Intact	56.9	1.13	5/17/12	835

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Clipped/Intact)	Length (cm)	Weight (kg)	Release Date	Release rkm
EFP	3D9.1C2D84B830	G724F8AD1	Good	Female	Intact	70.2	2.33	5/17/12	835
EFP	3D9.1C2D84DD92	G72505533	Good	Female	Intact	57.0	1.32	5/22/12	835
EFP	3D9.1C2D87807F	G724EF64E	Good	Female	Intact	65.5	1.69	5/22/12	835
FC	3D9.1C2E01EF8F	G724F03C1	Good	Female	Intact	76.0	-	5/27/2012	944
FC	3D9.1C2E08D3B9	G72507B0F	Good	Female	Intact	73.0	-	5/28/2012	944
FC	3D9.1BF242F49B	G72513592	Good	Female	Intact	71.0	-	6/1/2012	944
FC	3D9.1C2E01D7A4	G72527202	Good	Female	Intact	70.0	-	6/1/2012	944
FC	3D9.1BF244A8E3	G724F051C	Good	Female	Intact	77.0	-	6/1/2012	944
FC	3D9.1C2E07F1D6	G7270468D	Good	Female	Intact	78.0	-	6/1/2012	944
FC	3D9.1C2E0901B1	G724F1EA1	Good	Female	Intact	70.0	-	6/1/2012	944
FC	3D9.1C2E091117	G724F4E7A	Good	Female	Intact	83.0	-	6/5/2012	944
FC	3D9.1C2E01E5A8	G724F1663	Good	Female	Intact	80.0	-	6/5/2012	944
FC	3D9.1C2E016A96	G72514055	Good	Female	Intact	77.0	-	6/5/2012	944
FC	3D9.1C2E0963F7	G7251FD9A	Good	Female	Intact	72.0	-	6/5/2012	944
FC	3D9.1C2E01CF6E	G72517829	Good	Female	Intact	76.0	-	6/6/2012	944
FC	3D9.1C2E01D87F	G725045AE	Good	Female	Intact	76.0	-	6/7/2012	944
FC	3D9.1C2E018B06	G72521185	Good	Female	Intact	80.0	-	6/7/2012	944
FC	3D9.1C2E016A04	G72517257	Good	Female	Intact	80.0	-	6/9/2012	944
FC	3D9.1C2E01CA7E	G725214BA	Good	Female	Intact	78.0	-	6/9/2012	944
FC	3D9.1C2DB00FA5	G7251334F	Good	Female	Intact	76.0	-	6/10/2012	944
FC	3D9.1BF242AF87	G72509C65	Good	Female	Intact	80.0	-	6/10/2012	944
FC	3D9.1C2E091E3F	G724F6579	Good	Female	Intact	79.0	-	6/10/2012	944
FC	3D9.1BF242BB33	G72520DBB	Good	Male	Intact	76.0	-	6/11/2012	944
FC	3D9.1C2E080D17	G724F7758	Good	Female	Intact	75.0	-	6/12/2012	944
FC	3D9.1C2E01BD77	G724F6DBB	Good	Female	Intact	78.0	-	6/12/2012	944
FC	3D9.1C2E091E6E	G72517977	Good	Female	Intact	84.0	-	6/12/2012	944
FC	3D9.1C2E01A11B	G72516D8B	Good	Female	Intact	76.0	-	6/12/2012	944
FC	3D9.1BF23E679A	G724F6B66	Good	Female	Intact	72.0	-	6/12/2012	944
FC	3D9.1C2E08D328	G724F93D0	Good	Female	Intact	82.0	-	6/12/2012	944
FC	3D9.1C2E0888BD	G7251BE3E	Good	Female	Intact	76.0	-	6/12/2012	944

Table B.1. (contd)

Tagging Site	PIT Tag #	JSATS Tag #	Condition (Good/Fair)	Sex (Male/Female)	Adipose Fin (Clipped/Intact)	Length (cm)	Weight (kg)	Release Date	Release rkm
FC	3D9.1C2E01DD08	G72503D94	Good	Female	Intact	79.0	-	6/14/2012	944
FC	3D9.1C2E07E4B2	G7250B827	Good	Female	Intact	78.0	-	6/14/2012	944
FC	3D9.1C2E018729	G72500754	Good	Female	Intact	81.0	-	6/14/2012	944
FC	3D9.1C2E01BC72	G725251C3	Good	Female	Intact	72.0	-	6/15/2012	944
FC	3D9.1C2E016609	G72513EB2	Good	Female	Intact	72.0	-	6/15/2012	944
FC	3D9.1C2E093990	G7250C2A1	Good	Female	Intact	74.0	-	6/15/2012	944
FC	3D9.1C2E087937	G72513AD3	Good	Female	Intact	74.0	-	6/16/2012	944
FC	3D9.1C2E093992	G724EFFD2	Good	Female	Intact	77.0	-	6/16/2012	944
FC	3D9.1C2E09595A	G724F9B12	Good	Female	Intact	72.0	-	6/16/2012	944
FC	3D9.1BF231E2D7	G724F1202	Good	Female	Intact	74.0	-	6/17/2012	944
FC	3D9.1C2E08B019	G724FD074	Good	Male	Intact	80.0	-	6/18/2012	944
FC	3D9.1C2E089FFE	G7250BBC5	Good	Female	Intact	74.0	-	6/18/2012	944
FC	3D9.1C2E01F12E	G724F3221	Good	Female	Intact	70.0	-	6/18/2012	944
FC	3D9.1C2E017299	G724FE956	Good	Female	Intact	75.0	-	6/19/2012	944
FC	3D9.1C2E08AE0E	G72516F37	Good	Female	Intact	65.0	-	6/20/2012	944
FC	3D9.1C2E018728	G72523A86	Good	Female	Intact	86.0	-	6/20/2012	944
FC	3D9.1C2E08CA08	G72516CD5	Good	Female	Intact	72.0	-	6/20/2012	944
FC	3D9.1BF244B0B5	G72507171	Good	Female	Intact	74.0	-	6/23/2012	944
FC	3D9.1C2E097F16	G724F42D9	Good	Female	Intact	77.0	-	6/24/2012	944
FC	3D9.1C2E01A24B	G7252651C	Good	Female	Intact	74.0	-	6/24/2012	944
FC	3D9.1C2E096DAB	G725037EA	Good	Female	Intact	72.0	-	6/26/2012	944
FC	3D9.1C2DA128B4	G7250C981	Good	Female	Intact	74.0	-	6/26/2012	944
FC	3D9.1C2E017075	G724F1C1D	Good	Female	Intact	79.0	-	6/26/2012	944
FC	3D9.1BF24350D4	G724FD7F7	Good	Female	Intact	76.0	-	6/27/2012	944
FC	3D9.1BF23E6101	G72515196	Good	Female	Intact	73.0	-	5/29/102	944
CR	3D9.1C2E080C8B	G724FEC69	Good	Male	Intact	85.0	-	5/6/2012	961
CR	3D9.1C2E09463B	G724FE749	Good	Female	Intact	73.5	-	5/12/2012	961

Appendix C

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

Appendix C

Timing of Juvenile Salmon Acoutic Telemetry System-Tagged Kelt Passage versus Dam Discharge

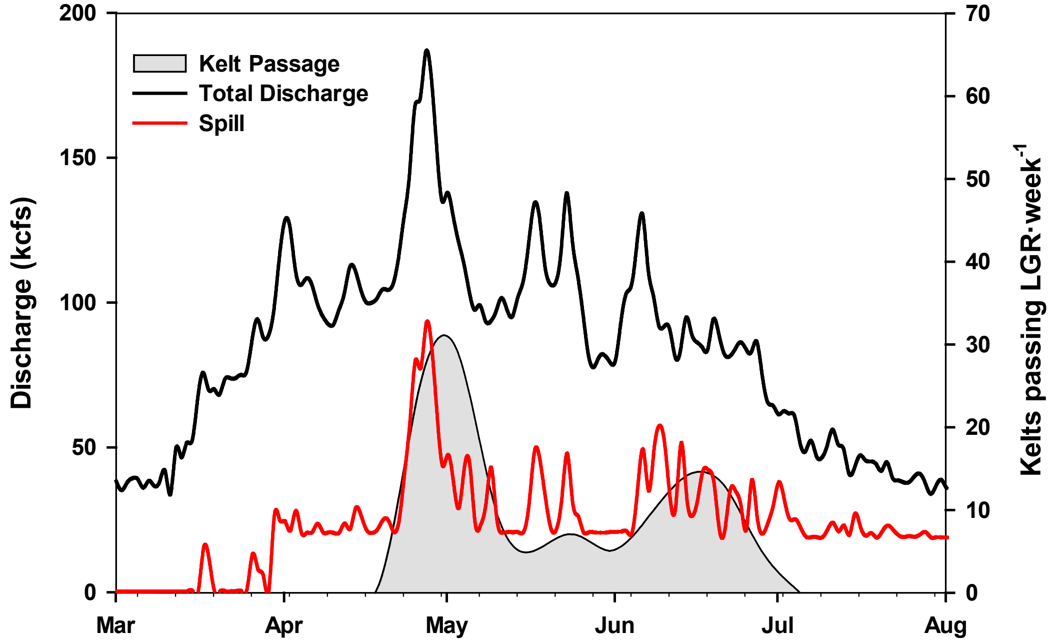

Figure C.1. Average daily discharge and spill (kcfs) at Lower Granite Dam (LGR) from 1 March to 1 August 2012. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing LGR during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

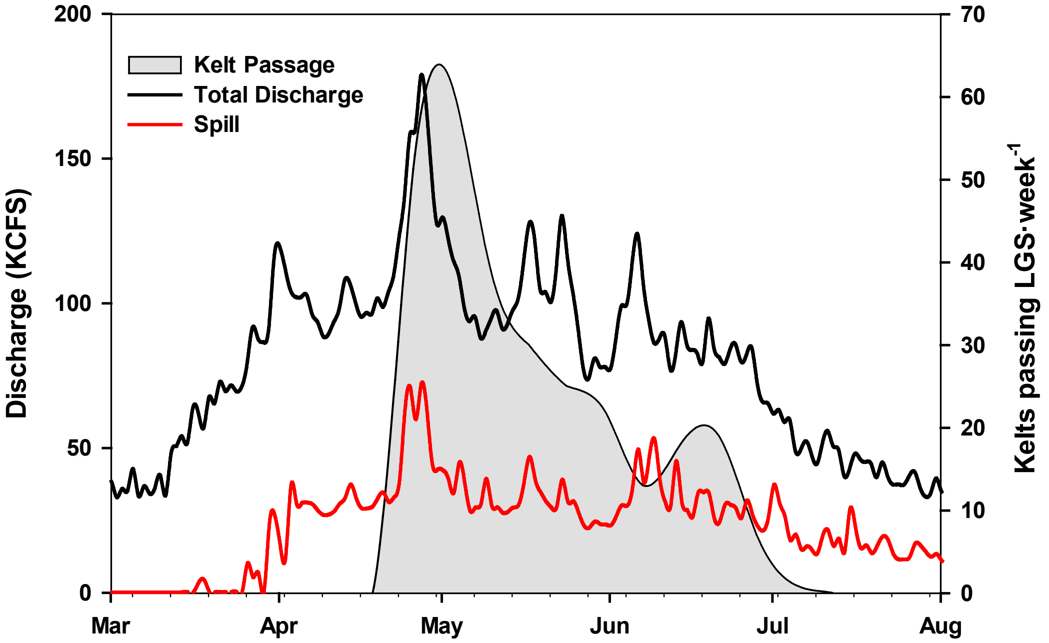

Figure C.2. Average daily discharge and spill (kcfs) at Little Goose Dam (LGS) from 1 March to 1 August 2012. Also shown are the number of kelt per week (Monday–Sunday) detected passing LGS during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

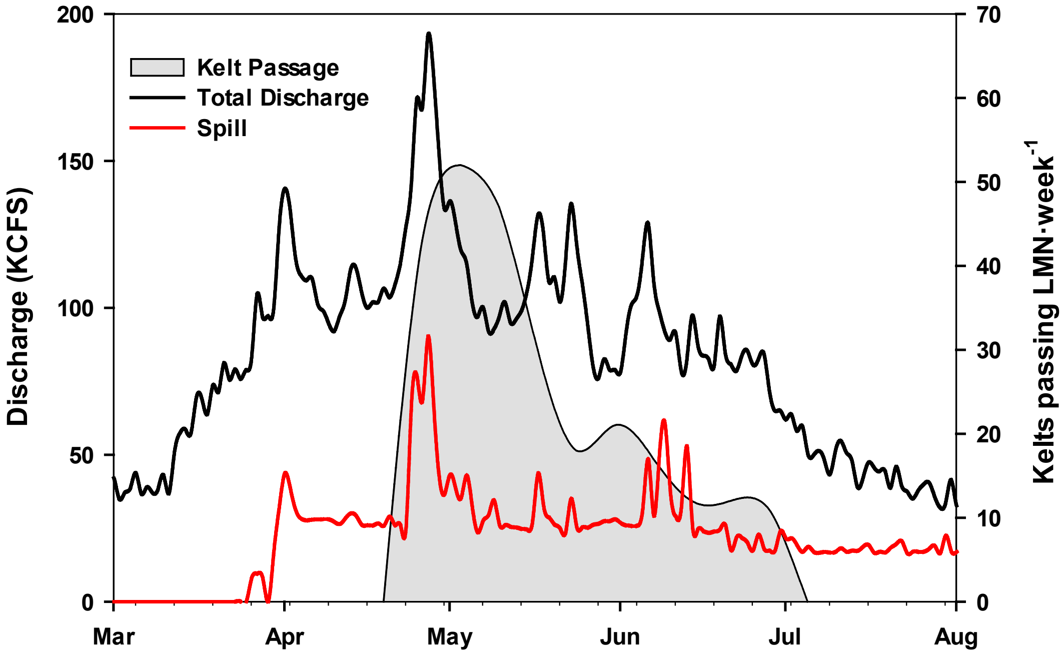

Figure C.3. Average daily discharge and spill (kcfs) at Lower Monumental Dam (LMN) from 1 March to 1 August 2012. Also shown are the number of kelt per week (Monday–Sunday) detected passing LMN during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

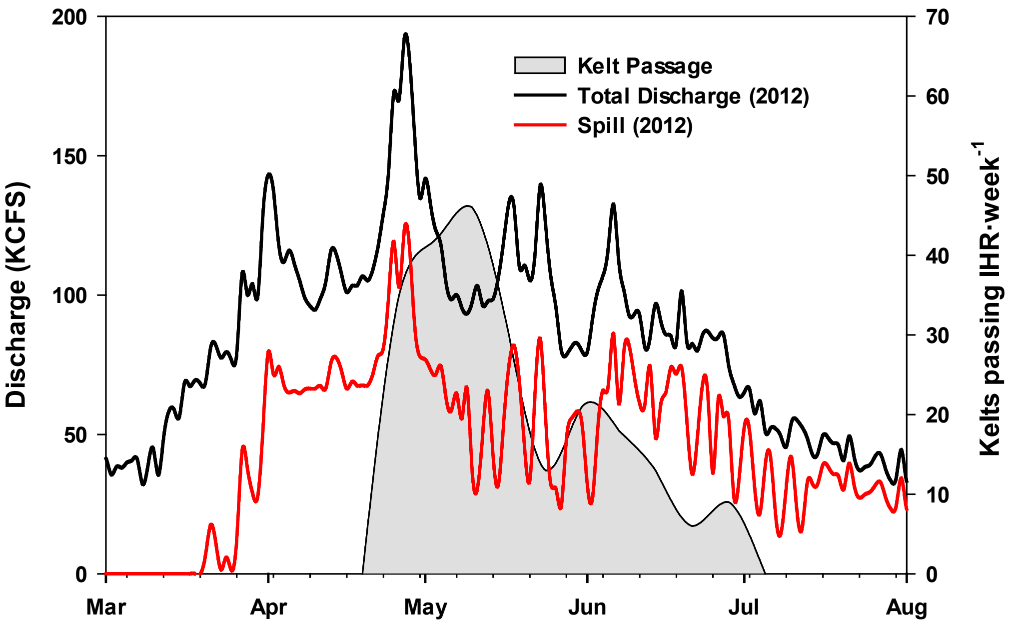

Figure C.4. Average daily discharge and spill (kcfs) at Ice Harbor Dam (IHR) from 1 March to 1 August 2012. Also shown are the number of kelt per week (Monday–Sunday) detected passing IHR during the same period. There were no cabled dam-face acoustic receiver arrays at IHR in 2012, so kelt passage dates shown here represent the last detection of each kelt at the autonomous forebay array. 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/).

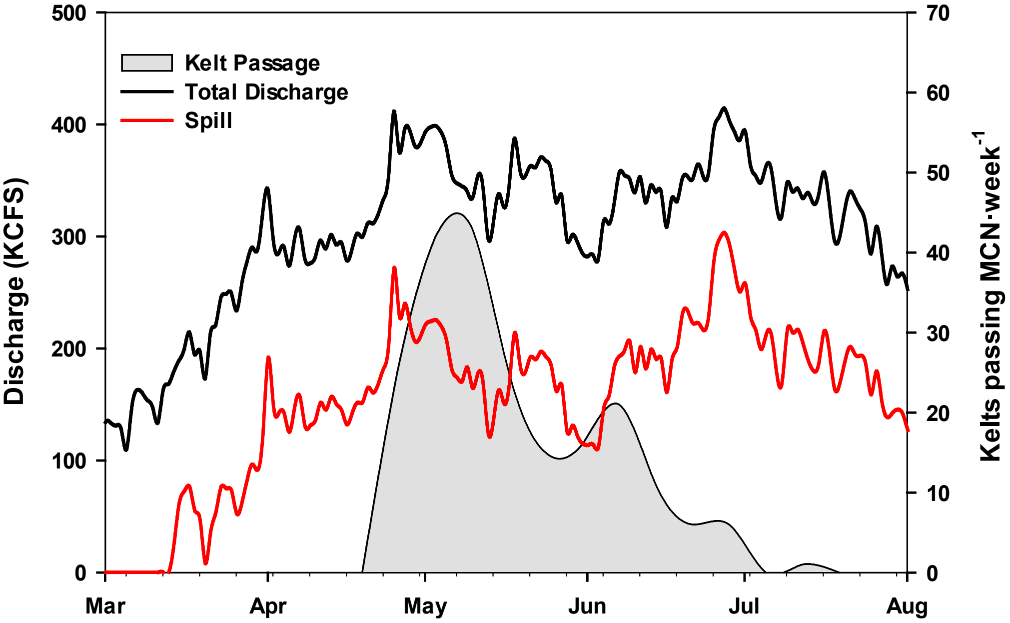

Figure C.5. Average daily discharge and spill (kcfs) at McNary Dam (MCN) from 1 March to 1 August 2012. Also shown are the number of kelt per week (Monday–Sunday) detected passing MCN during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

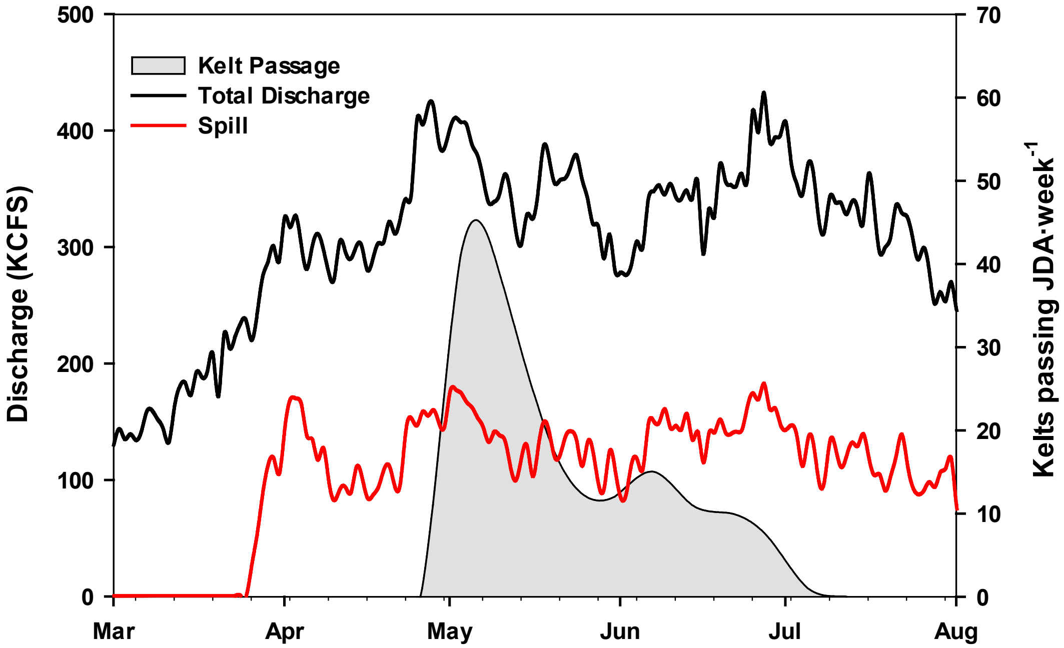

Figure C.6. Average daily discharge and spill (kcfs) at John Day Dam (JDA) from 1 March to 1 August. Also shown are the number of kelt per week (Monday–Sunday) detected passing JDA during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

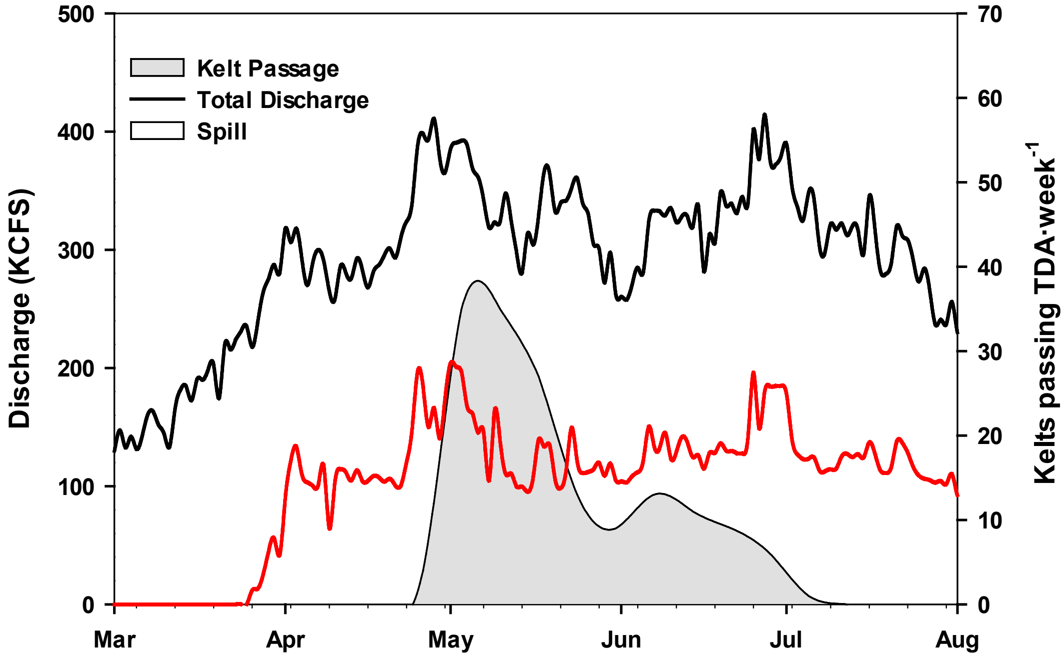

Figure C.7. Average daily discharge and spill (kcfs) at The Dalles Dam (TDA) from 1 March to 1 August 2012. Also shown are the number of kelt per week (Monday–Sunday) detected passing TDA during the same period. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

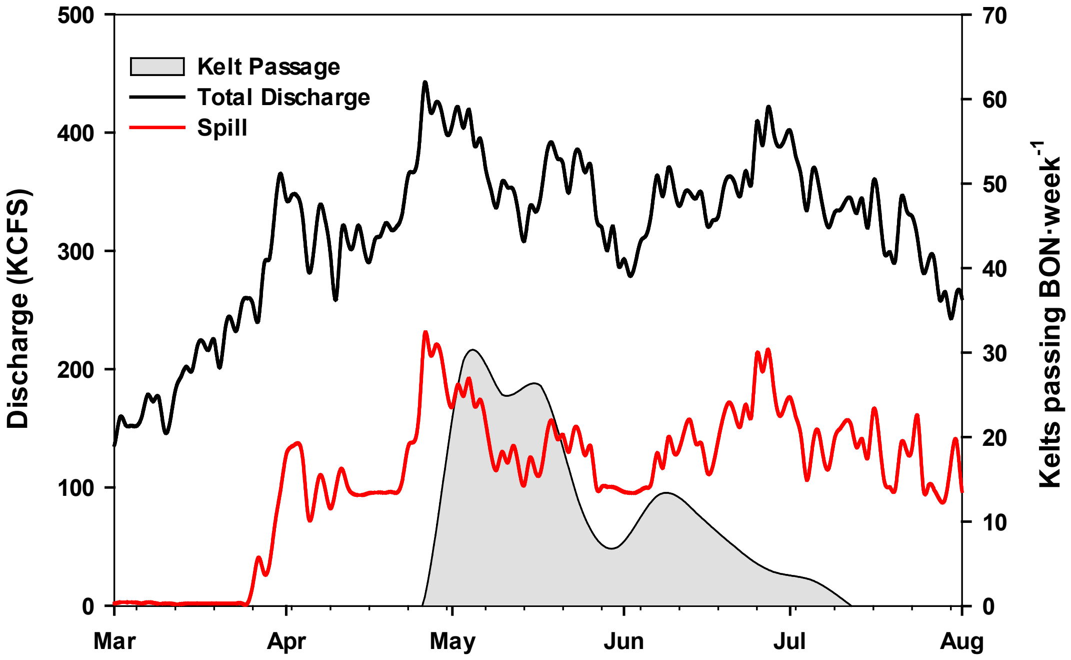

Figure C.8. Average daily discharge and spill (kcfs) at Bonneville Dam (BON) from 1 March to 1 August 2012. Also shown are the number of kelt per week (Monday–Sunday) detected passing BON during the same time period. Average daily discharge values represent averages of hourly measurements for each day. 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

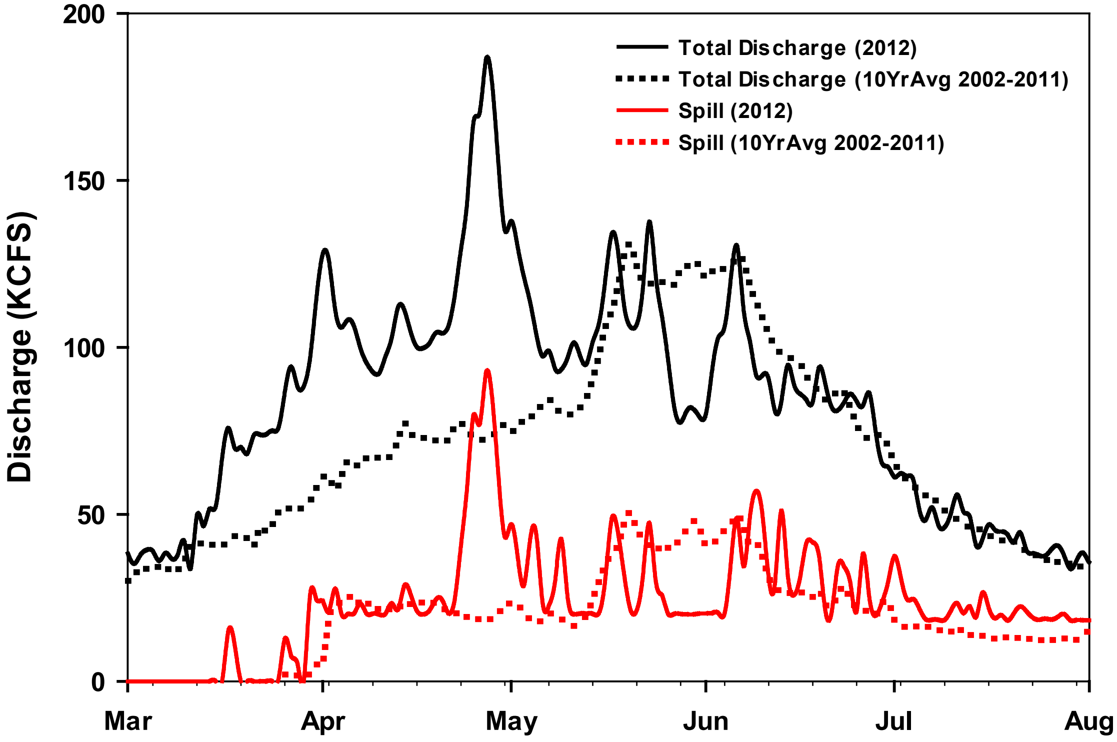

Figure D.1. Average daily discharge and spill (kcfs) at Lower Granite Dam (LGR) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

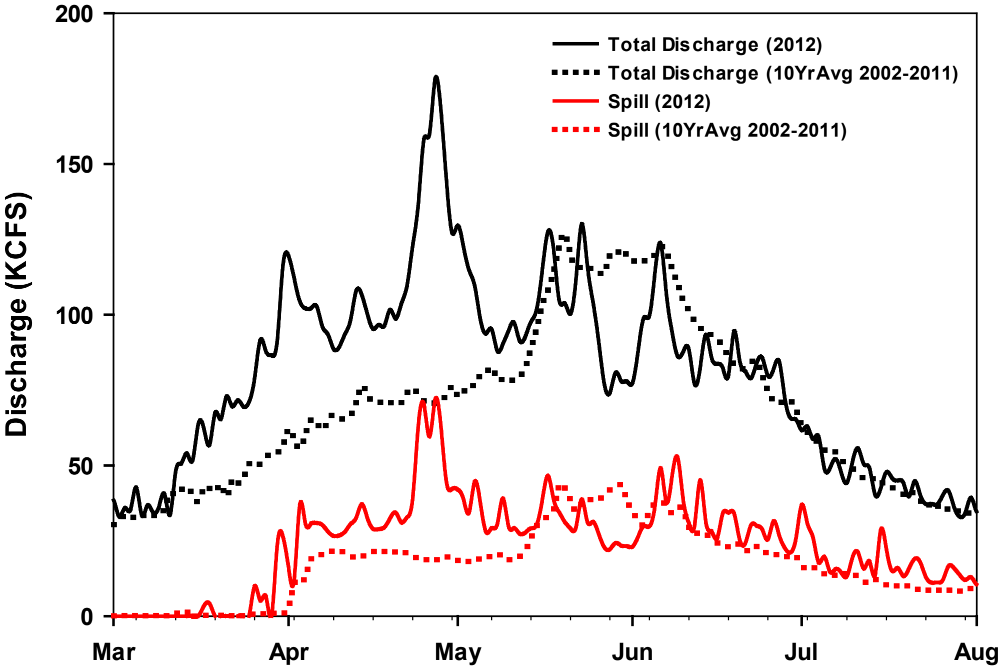

Figure D.2. Average daily discharge and spill (KCFS) at Little Goose Dam (LGS) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

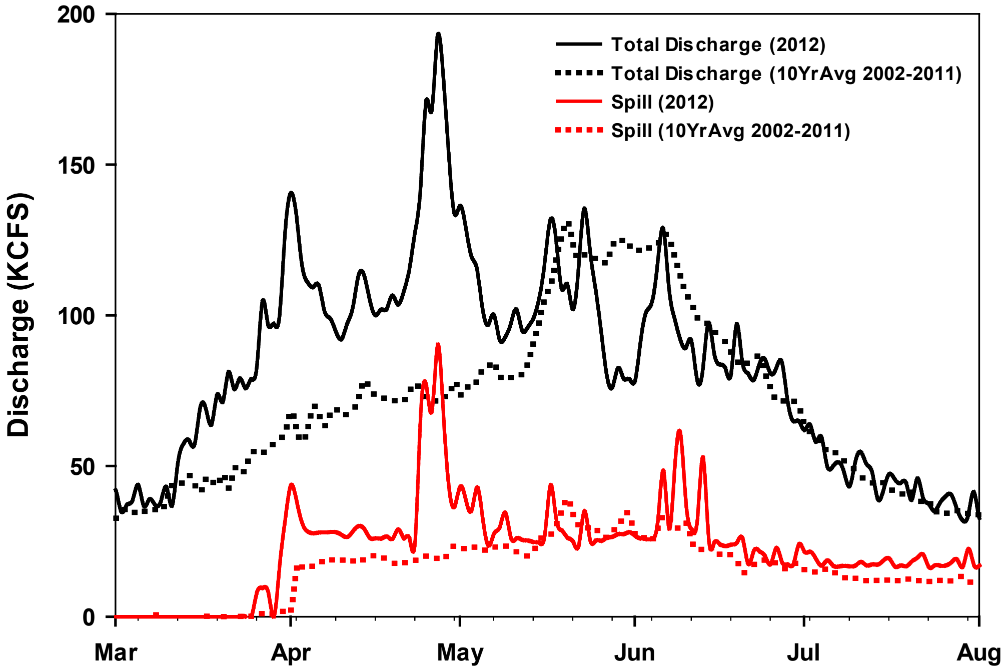

Figure D.3. Average daily discharge and spill (kcfs) at Lower Monumental Dam (LMN) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

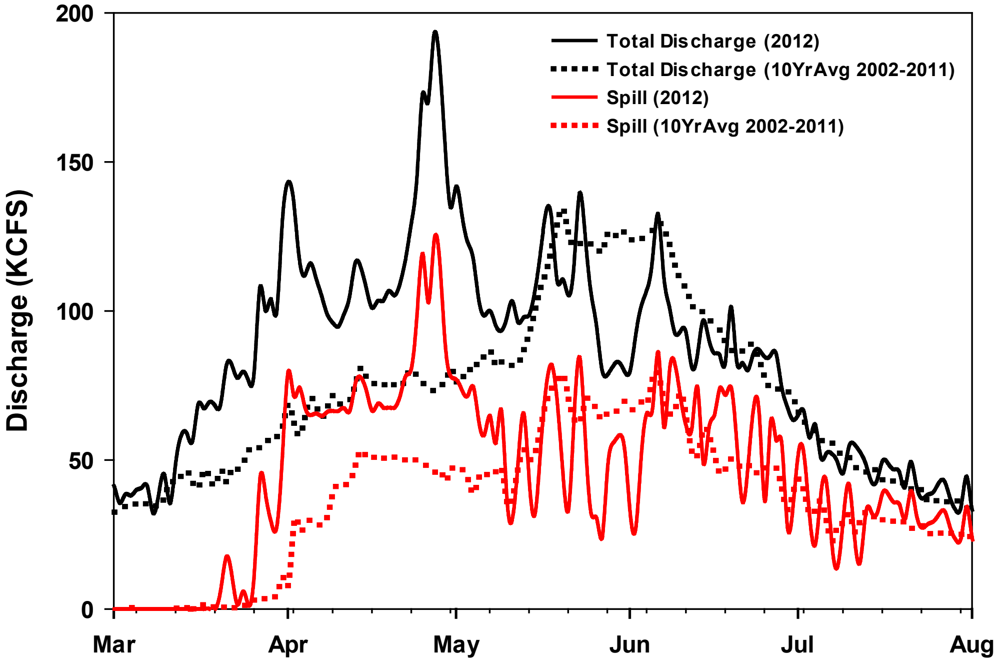

Figure D.4. Average daily discharge and spill (kcfs) at Ice Harbor Dam (IHR) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

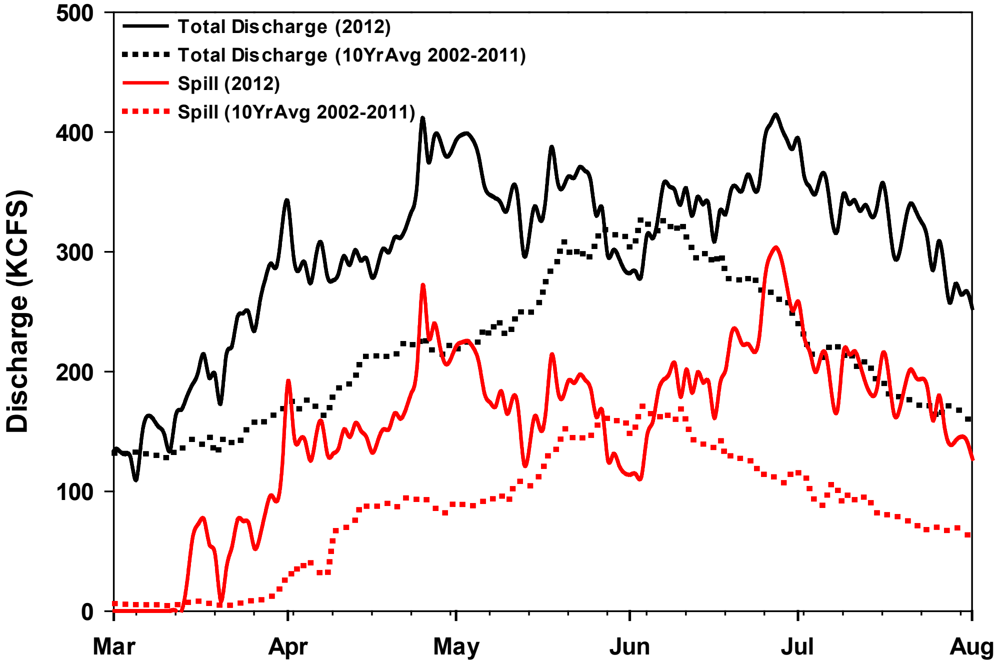

Figure D.5. Average daily discharge and spill (kcfs) at McNary Dam (MCN) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

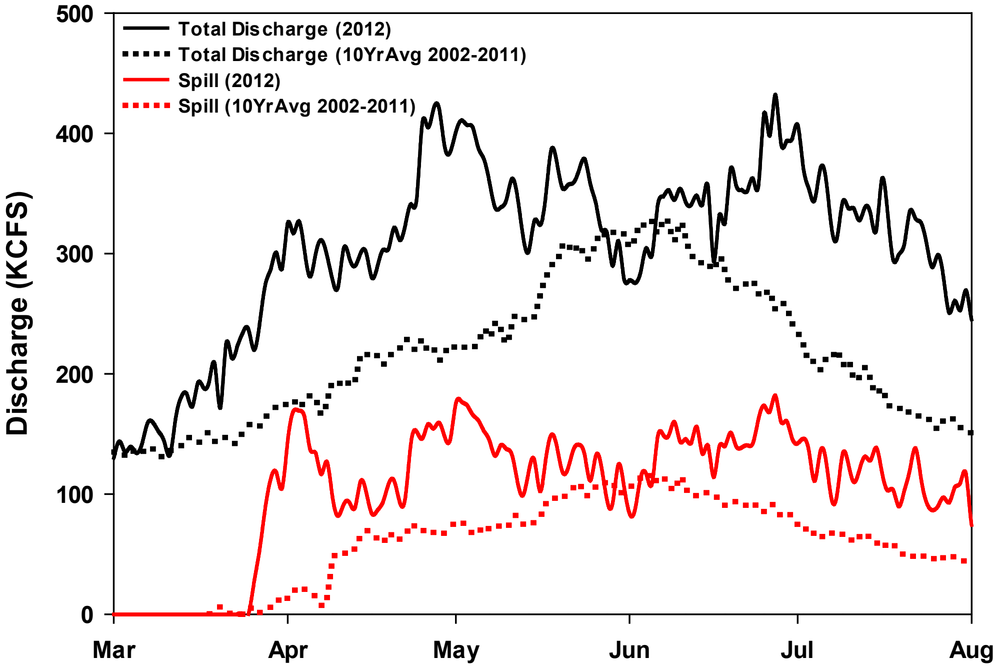

Figure D.6. Average daily discharge and spill (kcfs) at John Day Dam (JDA) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

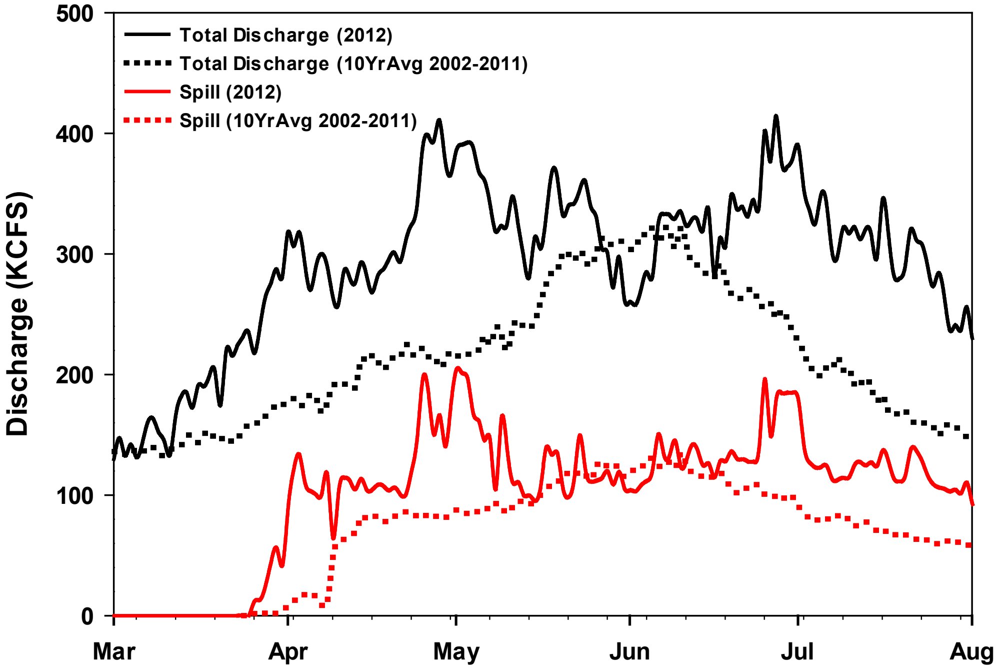

Figure D.7. Average daily discharge and spill (kcfs) at The Dalles Dam (TDA) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

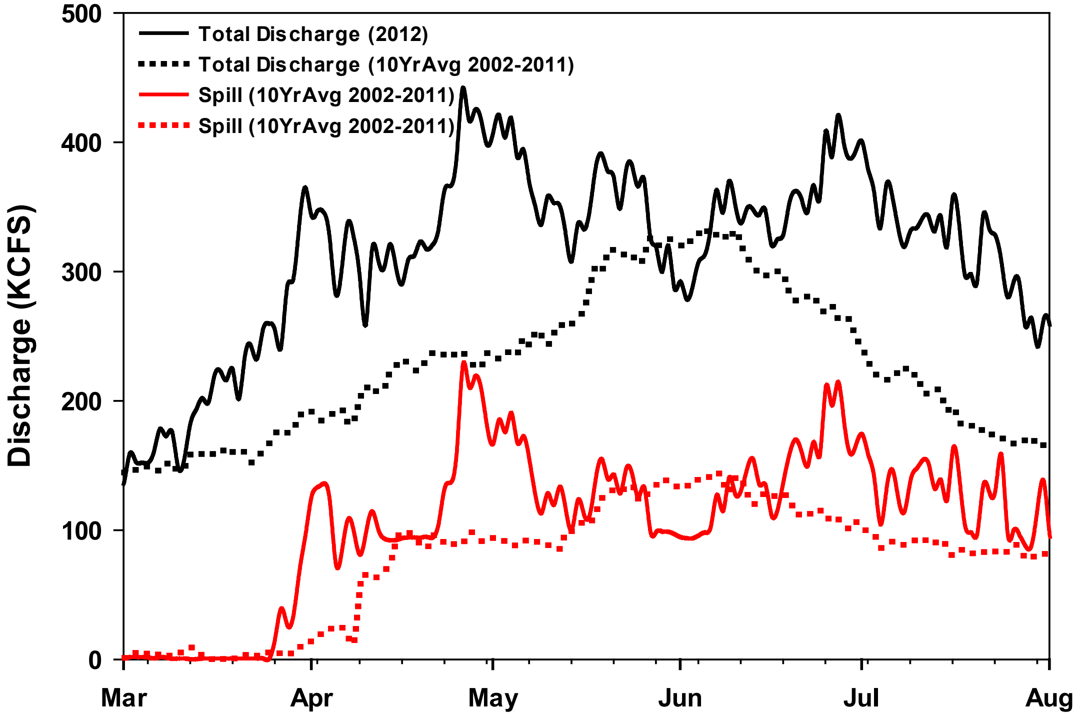

Figure D.8. Average daily discharge and spill (kcfs) at Bonneville Dam (BON) from 1 March to 1 August 2012 with 10-year averages. Average daily discharge values represent averages of hourly measurements for each day. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

Appendix E

Timing of Kelt Passage versus Temperature

Appendix E

Timing of Kelt Passage versus Temperature

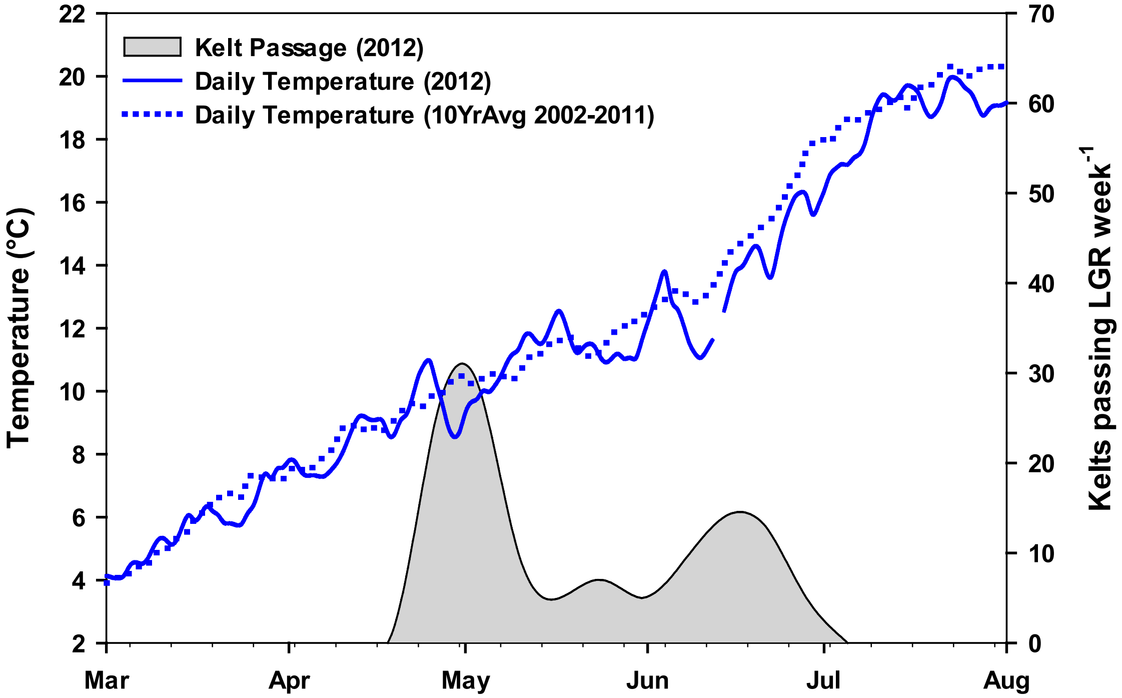

Figure E.1. Average daily forebay temperature (°C) at Lower Granite Dam (LGR) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing LGR during the same period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. All temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

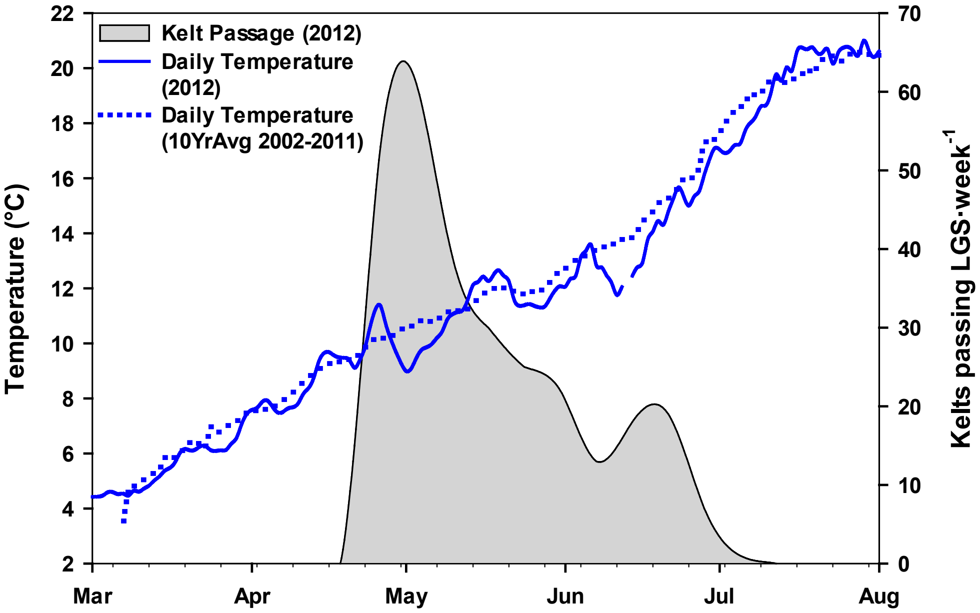

Figure E.2. Average daily forebay temperature (°C) at Little Goose Dam (LGS) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing LGS during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. All temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

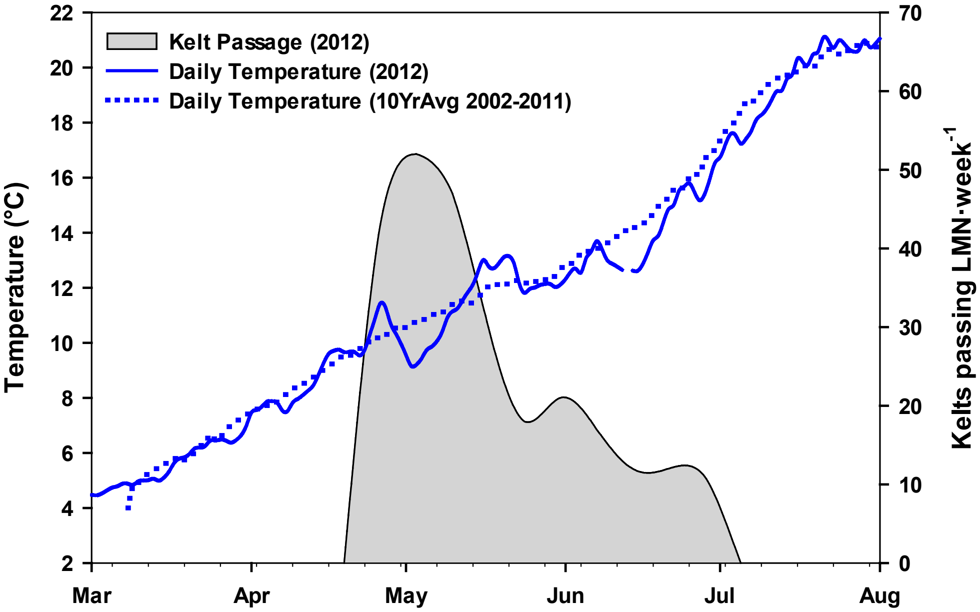

Figure E.3. Average daily forebay temperature (°C) at Lower Monumental Dam (LMN) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing LMN during the same time period. Reported temperatures are daily averages as recorded at 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/).

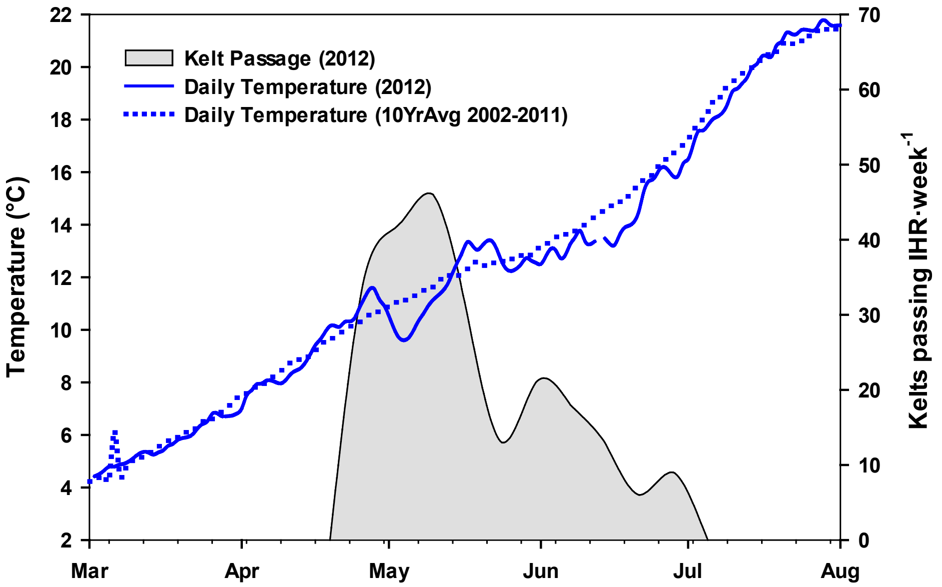

Figure E.4. Average daily forebay temperature (°C) at Ice Harbor Dam (IHR) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing IHR during the same time period. There were no cabled dam-face acoustic receiver arrays at IHR in 2012 so kelt passage dates shown in this figure represent the last detection of each kelt at the autonomous forebay arrays. 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/).

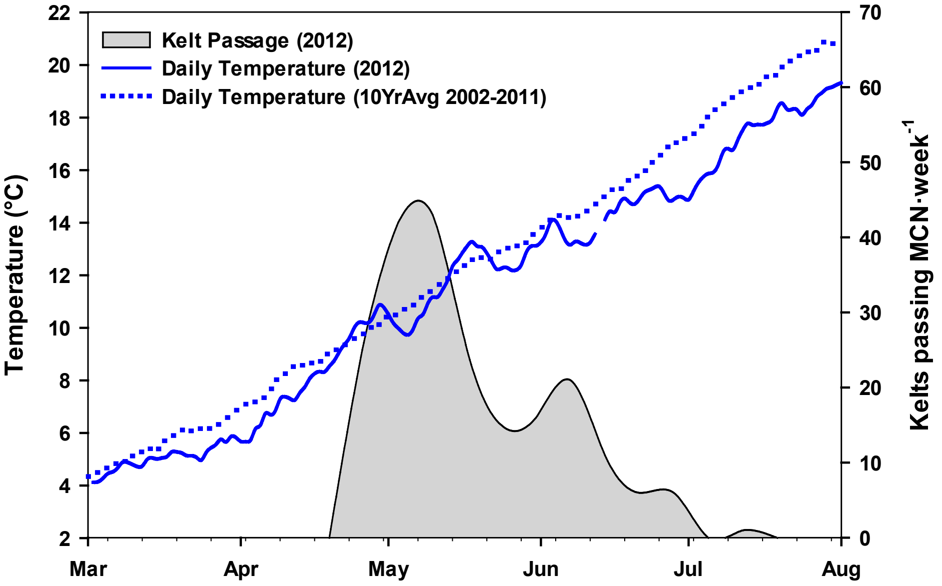

Figure E.5. Average daily forebay temperature (°C) at McNary Dam (MCN) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing MCN during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. All temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

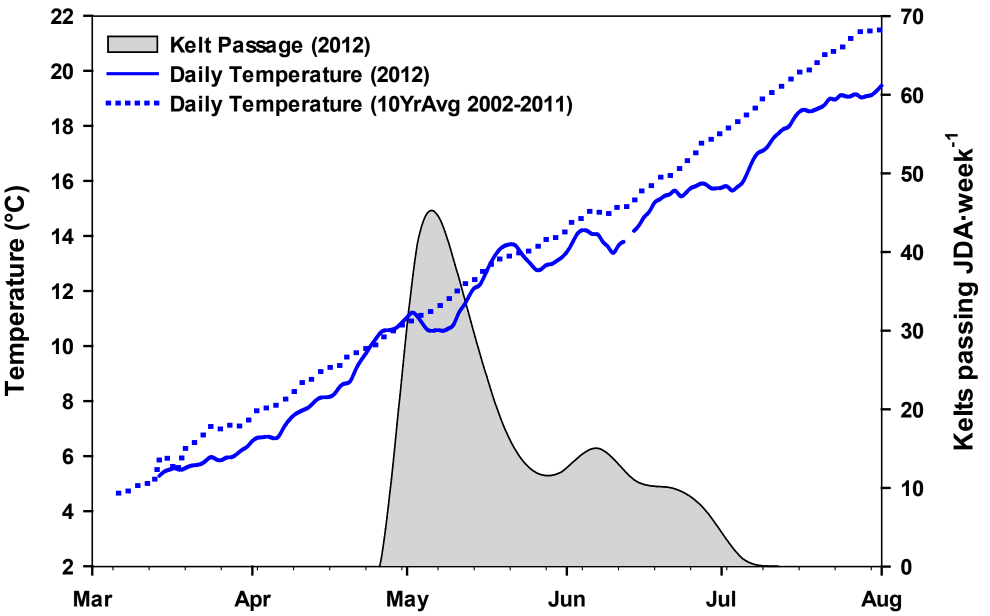

Figure E.6. Average daily forebay temperature (°C) at John Day Dam (JDA) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing JDA during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. All temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

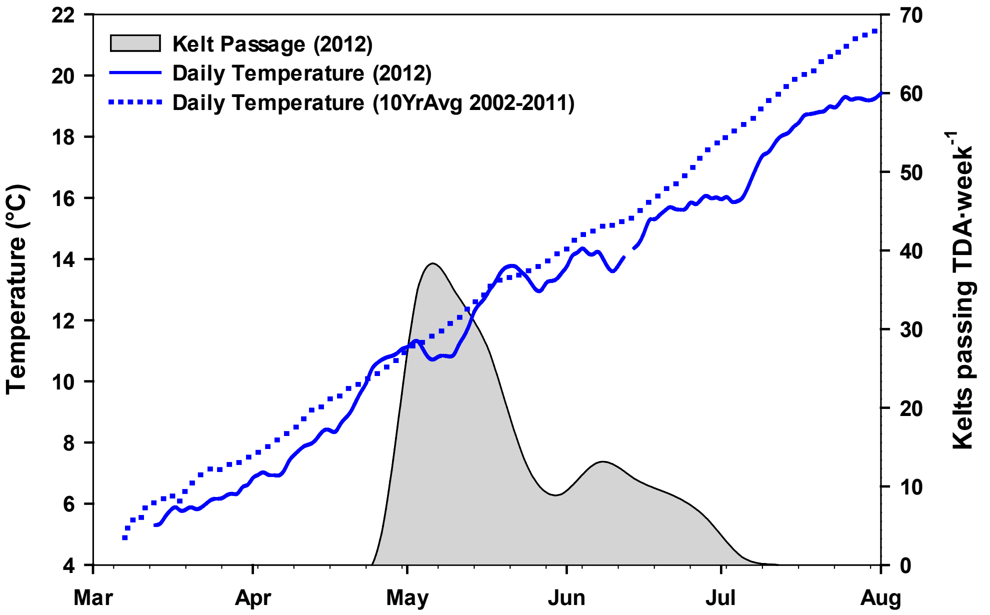

Figure E.7. Average daily forebay temperature (°C) at The Dalles Dam (TDA) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing TDA during the same time period. Reported temperatures are daily averages as recorded at forebay water quality monitoring stations. All temperature data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

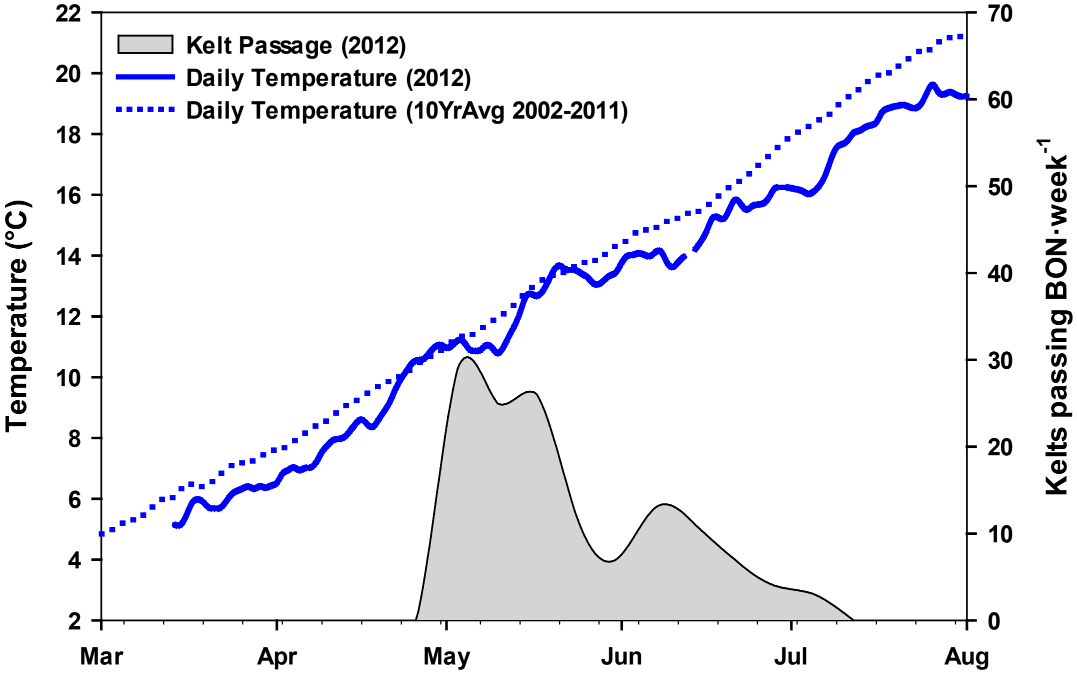

Figure E.8. Average daily forebay temperature (°C) at Bonneville Dam (BON) from 1 March to 1 August 2012 with the 10-year average. Also shown are the numbers of kelt per week (Monday–Sunday) detected passing BON during the same time period. Reported temperatures are daily averages as recorded at forebay 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

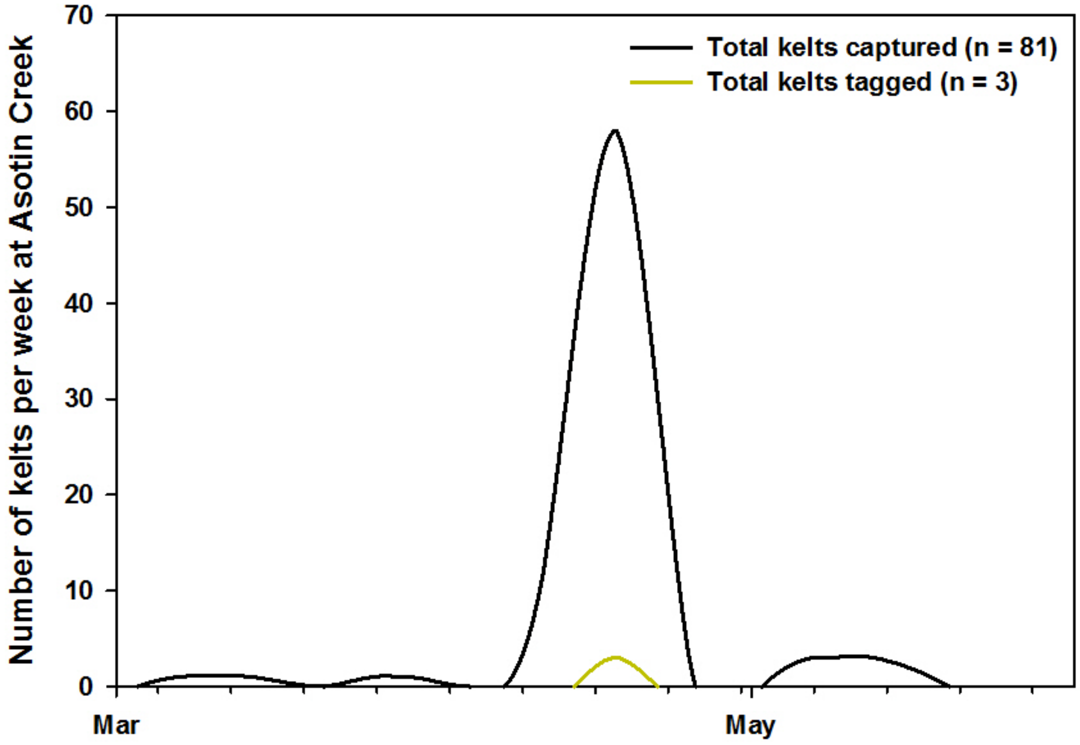

Figure F.1. Number of kelts per week surgically implanted with acoustic transmitters at Asotin Creek compared to the number of kelts captured by Washington Department of Fish and Wildlife crews at the weir.

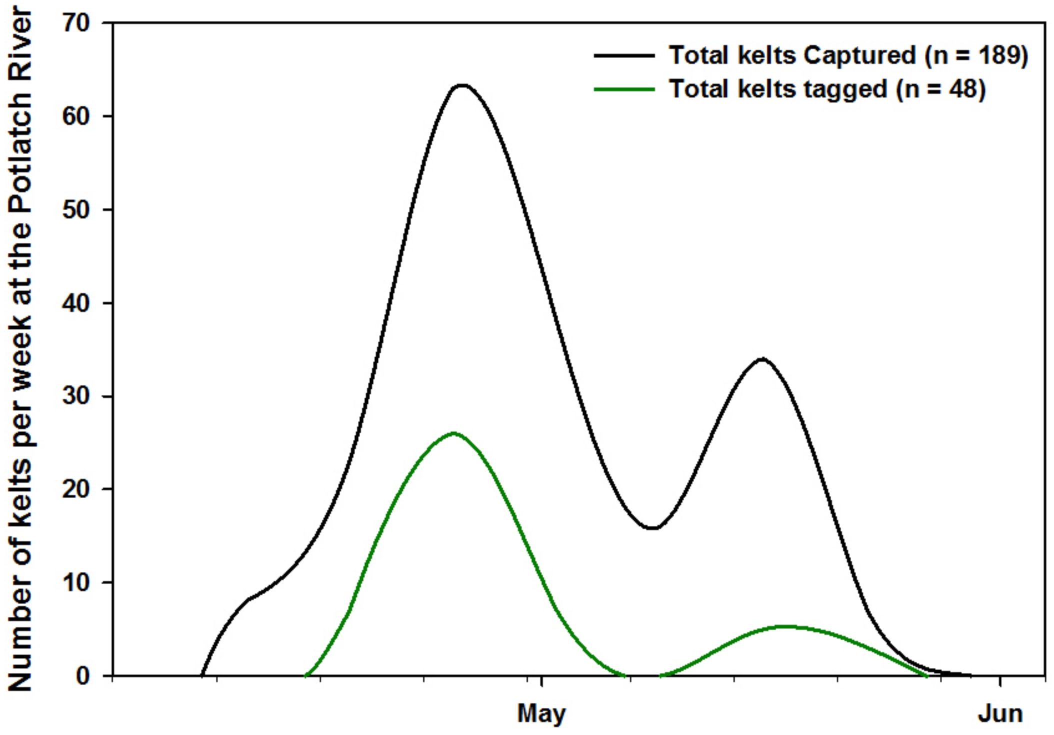

Figure F.2. Number of kelts per week surgically implanted with acoustic transmitters at the Potlatch River compared to the number of kelts captured by Idaho Department of Fish and Games crews at the weirs.

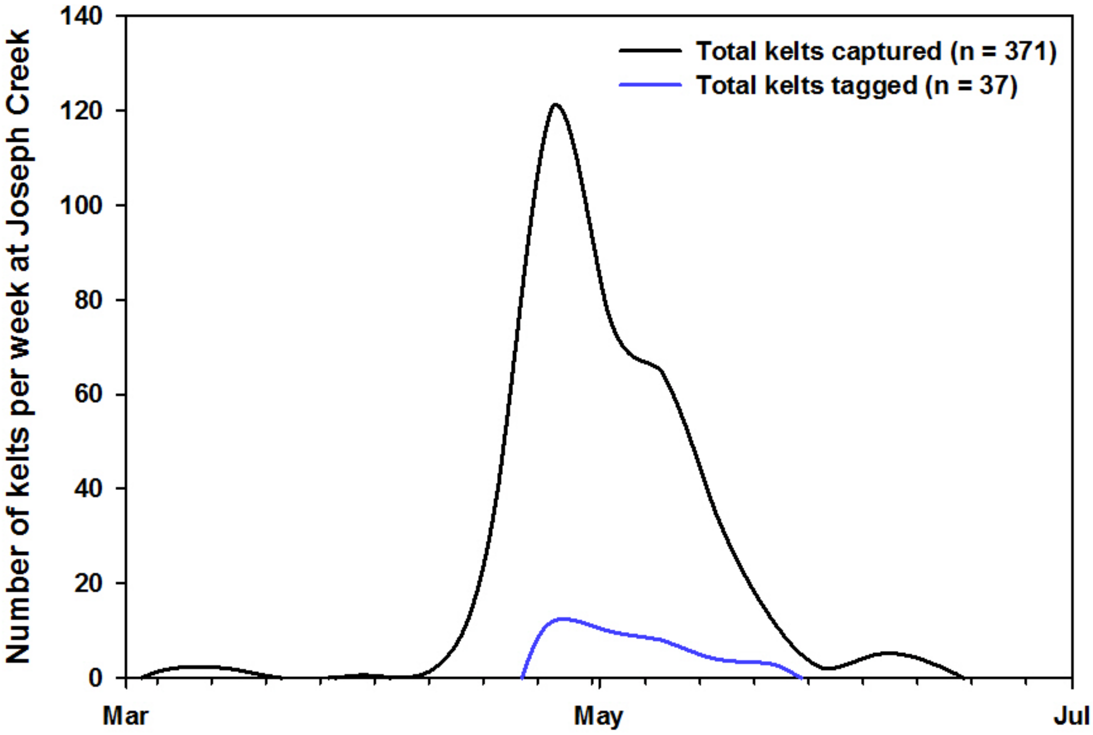

Figure F.3. Number of kelts per week surgically implanted with acoustic transmitters at Joseph Creek compared to the number of kelts captured by Nez Perce Tribe crews at the weir.

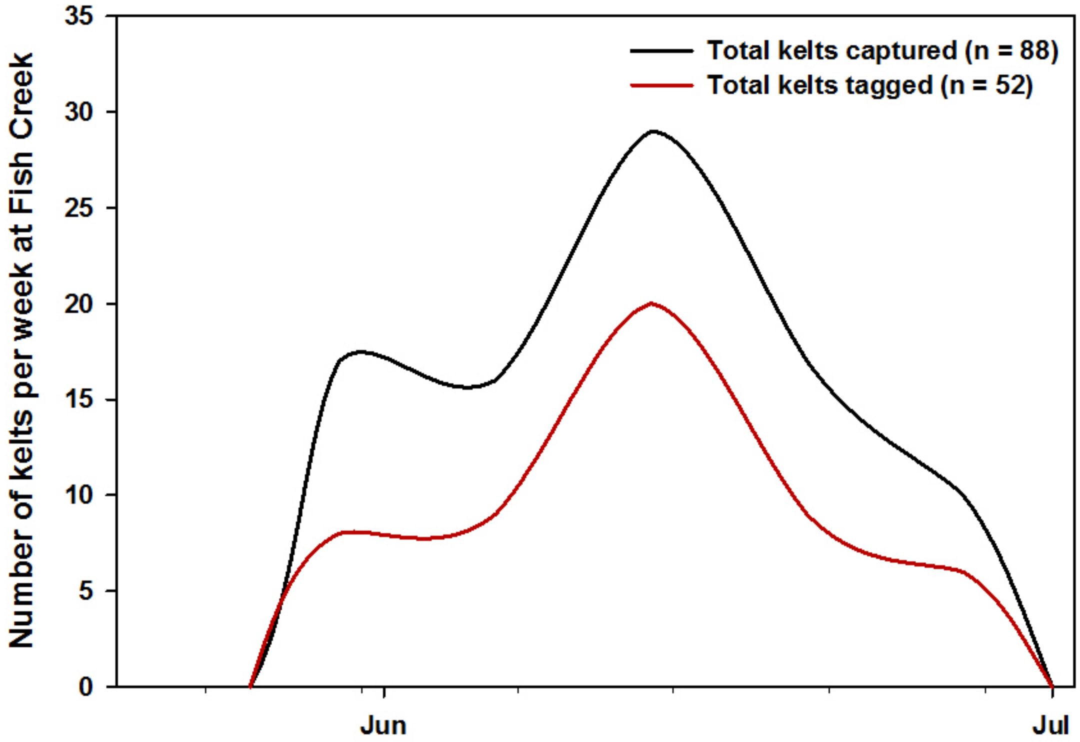

Figure F.4. Number of kelts per week surgically implanted with acoustic transmitters at Fish Creek compared to the number of kelts captured by Idaho Department of Fish and Game crews at the weir.

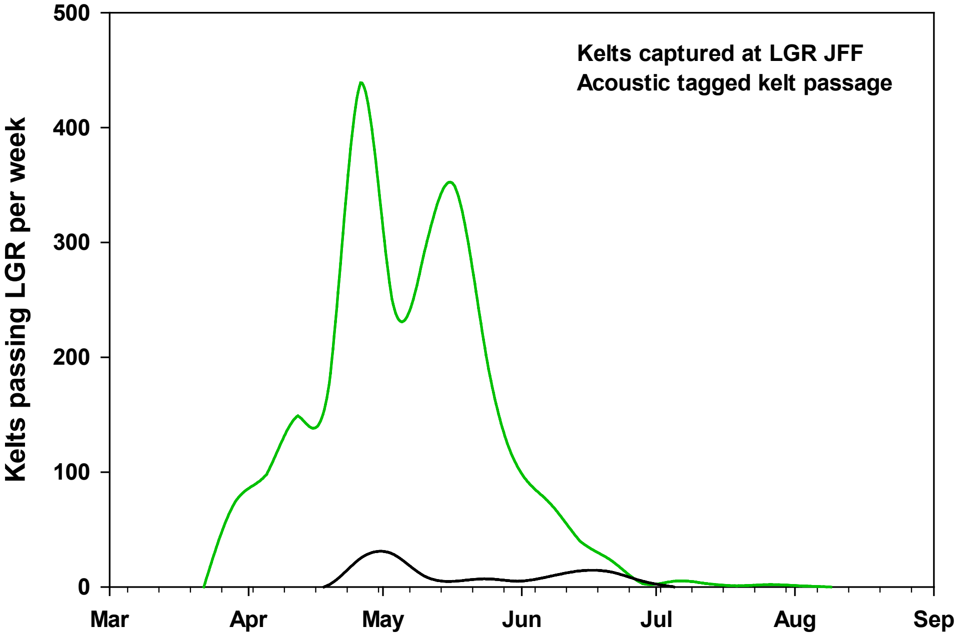

Figure F.5. Number of kelts tagged with acoustic transmitters at tributary sites (grey) detected passing Lower Granite Dam (LGR) per week compared to the total number of steelhead kelts per week captured at the LGR Juvenile Fish Facility (JFF) separator (green).

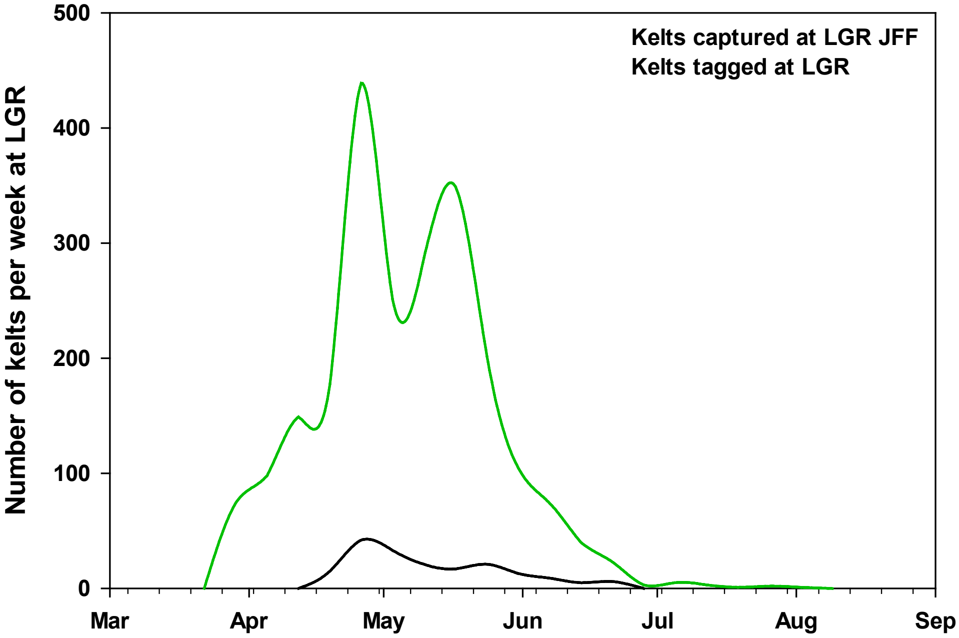

Figure F.6. Number of kelts tagged with acoustic transmitters at Lower Granite Dam (LGR) per week (grey) compared to the total number of steelhead kelts per week captured at the LGR Juvenile Fish Facility (JFF) separator (green).

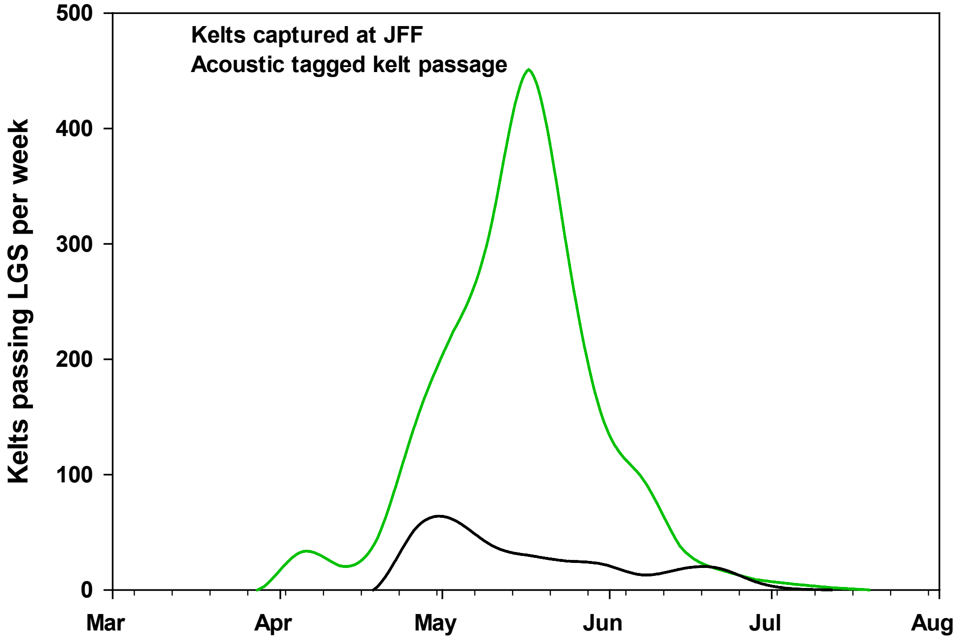

Figure F.7. Number of kelts tagged with acoustic transmitters detected passing Little Goose Dam (LGS) per week (grey) compared to the total number of steelhead kelts per week captured at the LGS Juvenile Fish Facility (JFF) separator (green).

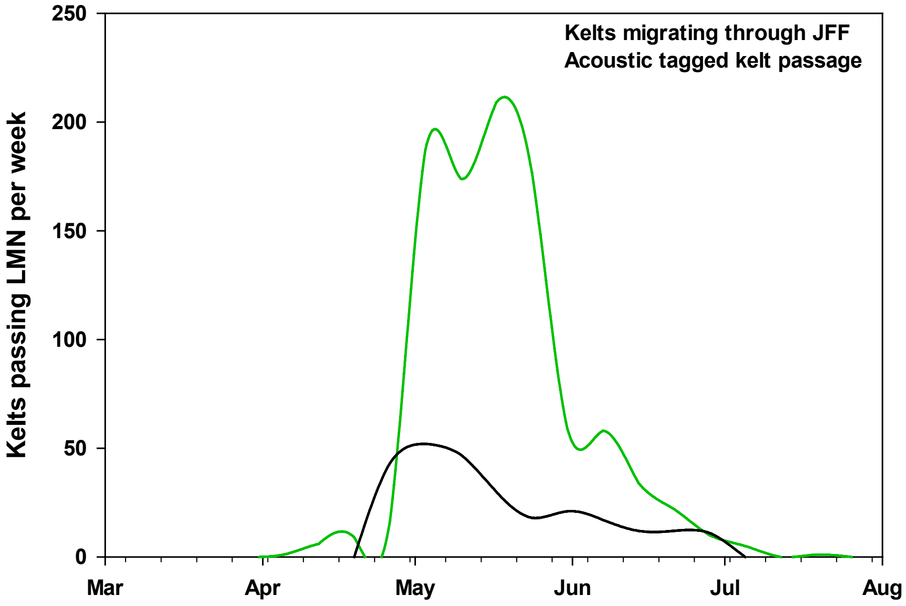

Figure F.8. Number of kelts tagged with acoustic transmitters detected passing Lower Monumental Dam (LMN) per week (grey) compared to the total number of steelhead kelts per week captured at the LMN Juvenile Fish Facility (JFF) separator (green).

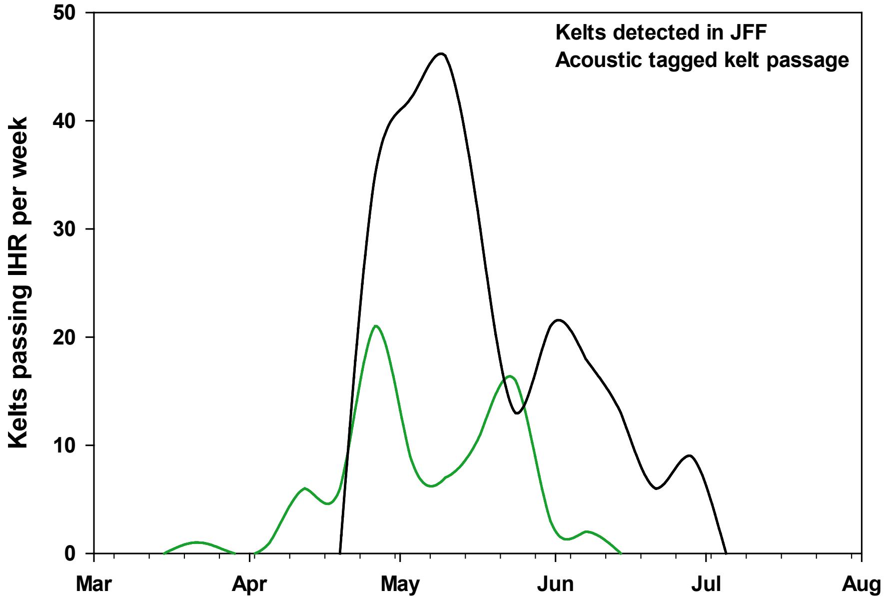

Figure F.9. Number of kelts tagged with acoustic transmitters detected passing Ice Harbor Dam (IHR) per week (grey) compared to the number of all passive integrated transponder (PIT)-tagged kelts detected migrating through the IHR Juvenile Fish Facility (JFF; green). Data from the autonomous receiver array in the IHR forebay were used to determine approximate dates of passage of acoustic-tagged kelts at that site because no cabled dam-face receiver array was deployed at IHR in 2012. In addition, few kelts were netted off the separator at the IHR JFF because of sampling design at that site, so a query of the PIT Tag Information System database (PTAGIS; www.ptagis.org) was performed to identify PIT-tagged steelhead kelts from the Snake River basin passing through the IHR JFF and determine their dates of passage.

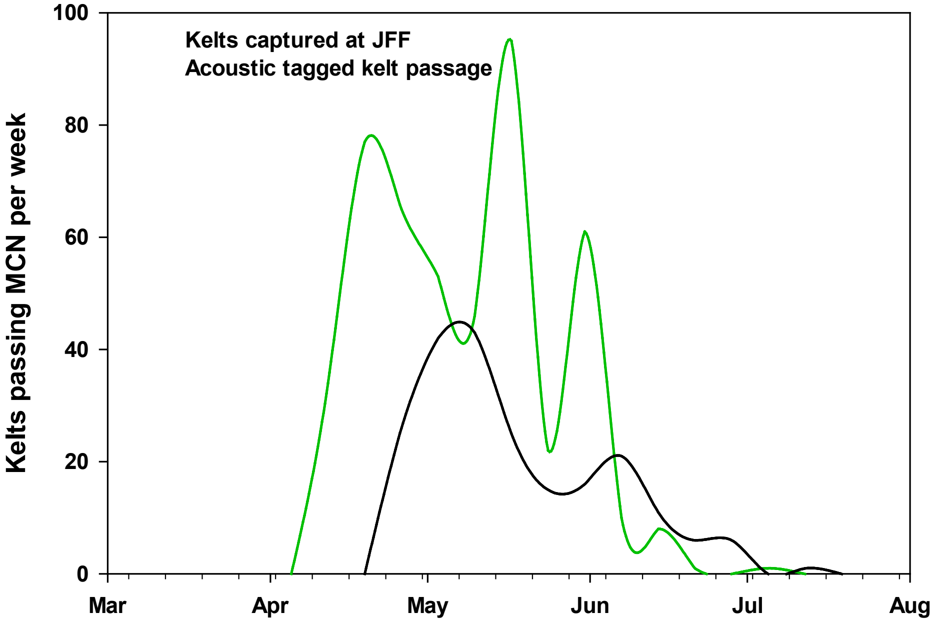

Figure F.10. Number of kelts tagged with acoustic transmitters detected passing McNary Dam (MCN) per week (grey) compared to the total number of steelhead kelts per week captured at the MCN Juvenile Fish Facility (JFF) separator (green).

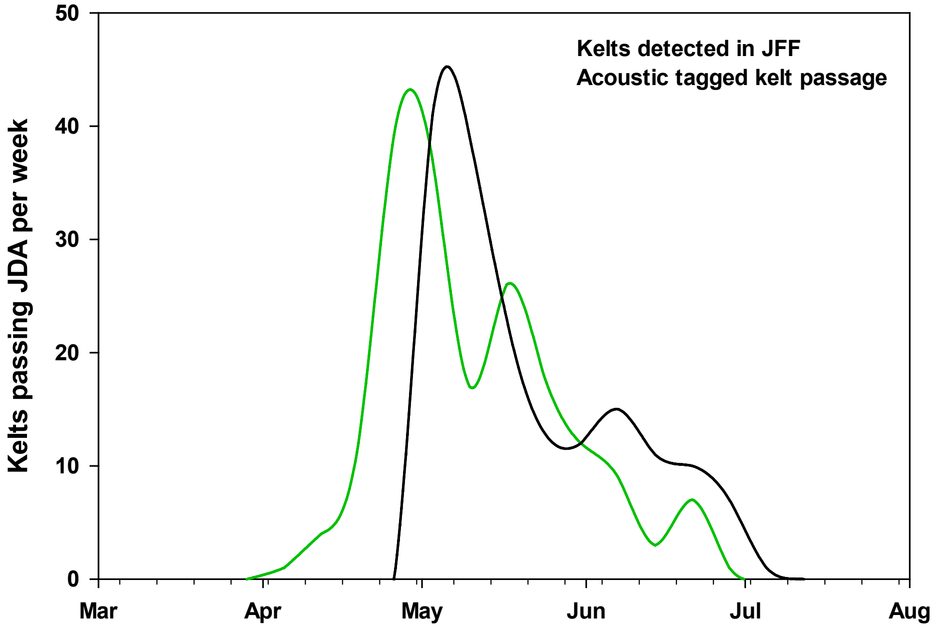

Figure F.11. Number of kelts tagged with acoustic transmitters detected passing John Day Dam (JDA) per week (grey) compared to the number of all passive integrated transponder (PIT)-tagged kelts detected migrating through the JDA Juvenile Fish Facility (JFF; green). The configuration of the JFF separator at JDA allows kelts to be diverted directly back into the river without being netted. Because of this configuration, data on the total number of kelts passing through the JFF at that site were unavailable, so a query of the PIT Tag Information System database (PTAGIS; www.ptagis.org) was performed to identify all

PIT-tagged steelhead kelts passing through the JDA JFF and determine their dates of passage.

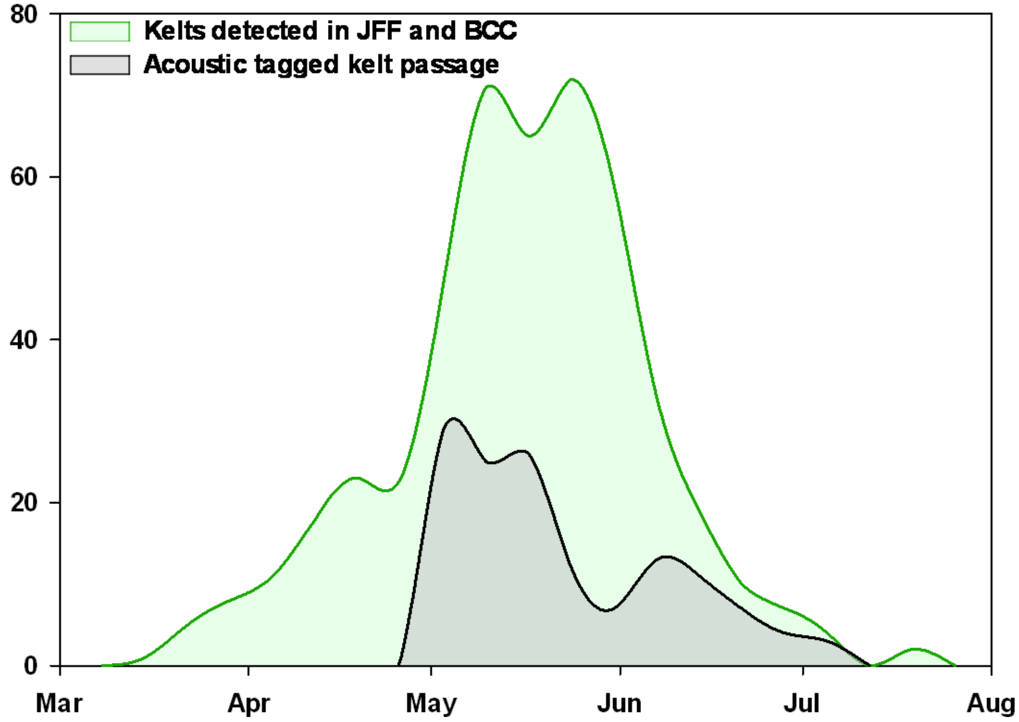

Figure F.12. Number of kelts tagged with acoustic transmitters detected passing Bonneville Dam (BON) per week (grey) compared to the number of all passive integrated transponder (PIT)-tagged kelts detected migrating at BON (Juvenile Fish Facility (JFF) and Powerhouse 2 Corner Collector (B2CC) PIT-tag detections combined; green). The configuration of the JFF separator at BON allows kelts to be diverted directly back into the river without being netted and enumerated. Because of this configuration, data on the total number of kelts passing through the JFF at that site were unavailable so a query of the PIT Tag Information System database (PTAGIS; www.ptagis.org) was performed to identify all PIT-tagged steelhead kelts passing through the BON JFF and the B2CC and determine their dates of passage.

Appendix G

Juvenile Salmon Acoustic Telemetry System Performance

Appendix G

Juvenile Salmon Acoustic Telemery System Performance

Table G.1. Detection probabilities (± SE) of acoustic-tagged steelhead kelts on the Juvenile Salmon Acoustic Telemetry System dam-face cabled arrays at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, The Dalles, and Bonneville dams in 2012.

Dam	Array	Detection Probability (SE)
Lower Granite	D1CR695	0.98 (0.01)
Little Goose	D2CR635	1.00 (0.00)
Lower Monumental	D3CR589	1.00 (0.00)
McNary	D4CR470	0.98 (0.01)
John Day	D5CR349	0.96 (0.02)
The Dalles	D6CR309	0.99 (0.01)
Bonneville	D7CR234	0.94 (0.02)

Table G.2. Detection probabilities (± SE) of acoustic-tagged steelhead kelts on the autonomous Juvenile Salmon Acoustic Telemetry System arrays located throughout out the Federal Columbia River Power System in 2012 that were used to estimate survival.

Array	Detection Probability (SE)
A1CR743	0.94 (0.02)
A2CR696	1.00 (0.00)
A4CR636	0.94 (0.01)
A6CR604	0.95 (0.01)
A7CR590	0.98 (0.01)
A9CR562	0.99 (0.01)
A10CR539	1.00 (0.00)
A11CR525	1.00 (0.00)
A12CR472	1.00 (0.00)
A14CR422	1.00 (0.00)
A15CR351	1.00 (0.00)
A17CR325	0.99 (0.01)
A21CR236	1.00 (0.00)
A23CR156	0.93 (0.02)

Table G.3. Percentage of acoustic-tagged steelhead kelts detected on multiple autonomous receivers at each array deployed in the Federal Columbia River Power System in 2012.

Array	Total Number of Receivers	Total Number of Tags Detected	Percentage of Tags Detected on Multiple Autonomous Nodes											
			1	2	3	4	5	6	7	8	9	10	11	12
A1CR743	3	127	40.9	31.5	27.6	-	-	-	-	-	-	-	-	-
A2CR696	4	129	10.9	27.1	38.8	23.3	-	-	-	-	-	-	-	-
A3CR693	2	289	17.8	82.2	-	-	-	-	-	-	-	-	-	-
A4CR636	4	274	3.6	17.2	31.8	47.4	-	-	-	-	-	-	-	-
A5CR634	3	268	4.1	29.9	66.0	-	-	-	-	-	-	-	-	-
A6CR604	4	261	0.0	4.2	30.3	65.5	-	-	-	-	-	-	-	-
A7CR590	4	260	0.8	11.5	35.8	51.9	-	-	-	-	-	-	-	-
A8CR587	3	246	6.5	32.5	61.0	-	-	-	-	-	-	-	-	-
A9CR562	4	244	0.0	3.3	20.1	76.6	-	-	-	-	-	-	-	-
A10CR539	4	234	1.3	10.6	25.1	63.0	-	-	-	-	-	-	-	-
A11CR525	4	229	1.7	9.2	43.7	45.4	-	-	-	-	-	-	-	-
A12CR472	8	218	9.6	44.5	41.7	3.2	0.5	0.0	0.0	0.5	-	-	-	-
A13CR468	3	211	33.2	51.2	15.6	-	-	-	-	-	-	-	-	-
A14CR422	7	202	0.0	2.0	19.8	52.0	23.8	2.5	0.0	-	-	-	-	-
A15CR351	8	180	0.6	6.7	28.3	50.6	7.8	3.3	1.1	1.7	-	-	-	-
A16CR346	4	156	22.4	65.4	9.0	3.2	-	-	-	-	-	-	-	-
A17CR325	6	165	7.3	33.3	50.9	6.1	2.4	0.0	-	-	-	-	-	-
A18CR311	5	20	0.0	5.0	75.0	20.0	0.0	-	-	-	-	-	-	-
A19CR307	3	19	52.6	36.8	10.5	-	-	-	-	-	-	-	-	-
A20CR275	6	19	10.5	47.4	10.5	26.3	5.3	0.0	-	-	-	-	-	-
A21CR236	4	148	0.7	10.8	61.5	27.0	-	-	-	-	-	-	-	-
A22CR233	3	103	42.7	56.3	1.0	-	-	-	-	-	-	-	-	-
A23CR156	8	123	55.3	40.7	3.3	0.0	0.8	0.0	0.0	0.0	-	-	-	-
A24CR113	12	119	40.3	26.9	20.2	10.9	0.8	0.0	0.8	0.0	0.0	0.0	0.0	0.0
A25CR86	8	14	35.7	42.9	7.1	7.1	7.1	0.0	0.0	0.0	-	-	-	-

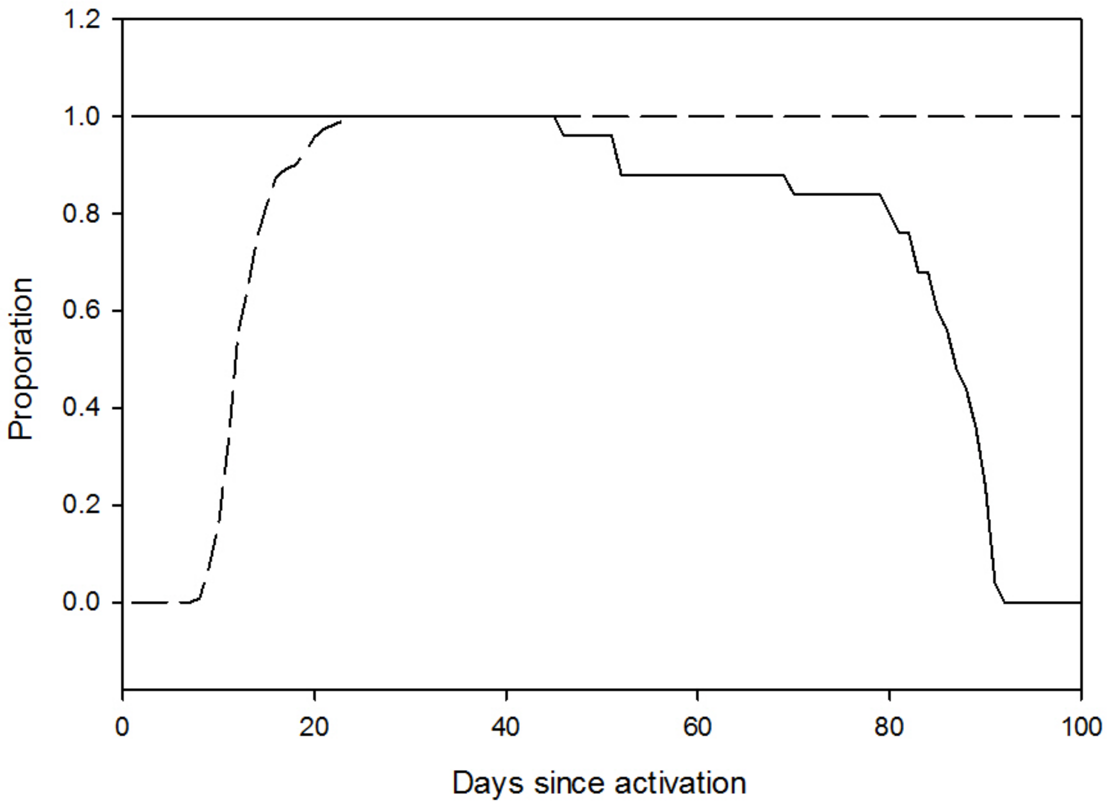

Figure G.1. Proportion of tag-life study stags transmitting (solid lines) and the cumulative proportion of tagged steelhead kelts arriving at the Knapp survival-detection array (dashed lines; rkm 156) as a function of days since tag activation.

Appendix H

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

Appendix H

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

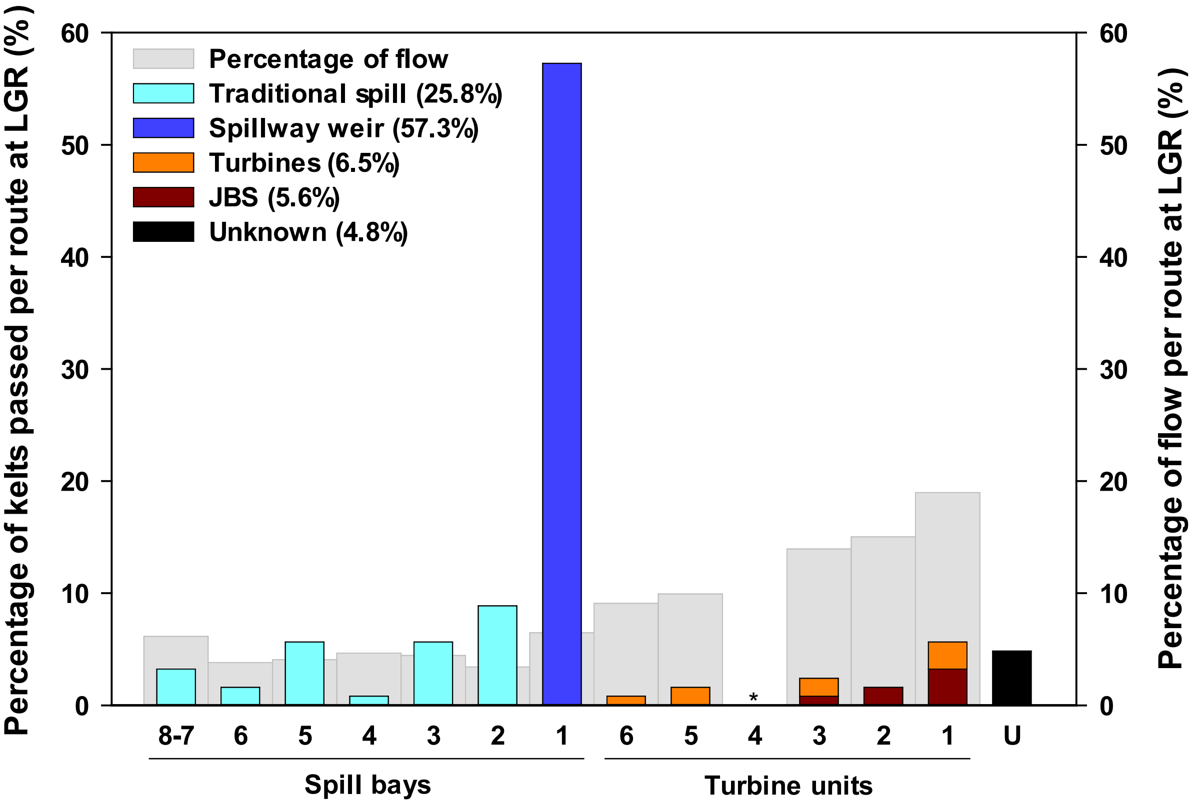

Figure H.1. Percentage of kelt passing Lower Granite Dam (LGR; rkm 695) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at LGR (21 April 2012 to 30 June 2012). Passage routes are ordered from the north side of the river to the south side of the river. Passage through spillbays 7 and 8 was combined because hydrophones were not equipped on these spillbays to determine the opening through which kelt passed. *Turbine unit 4 was not operating during the kelt migration period.

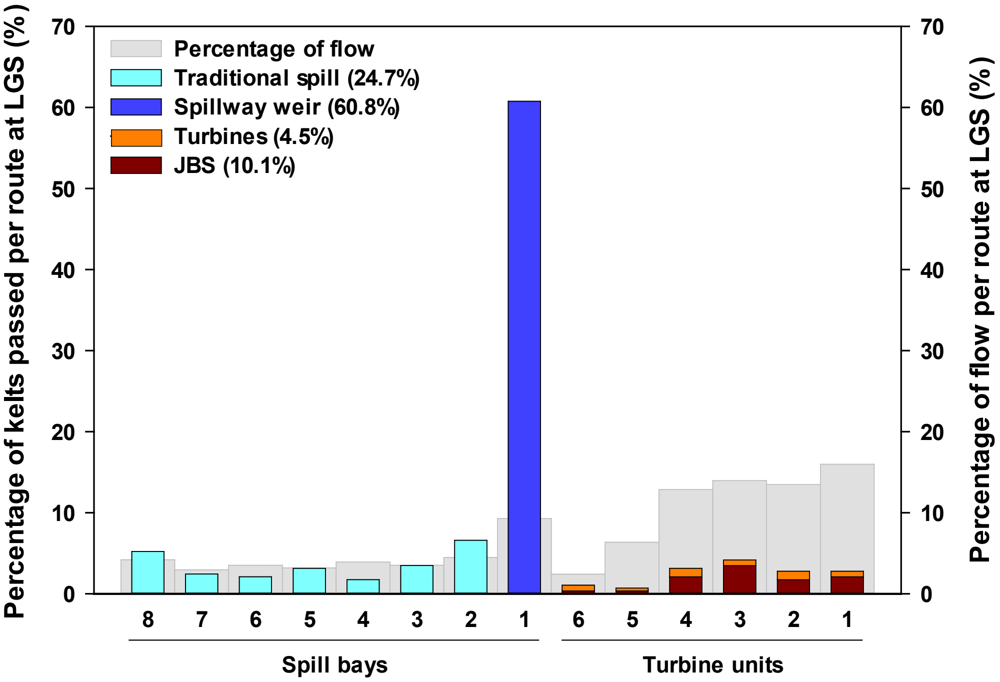

Figure H.2. Percentage of kelt passing Little Goose Dam (LGS; rkm 635) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at LGS (21 April 2012 to 2 July 2012). Passage routes are ordered from the north side of the river to the south side of the river.

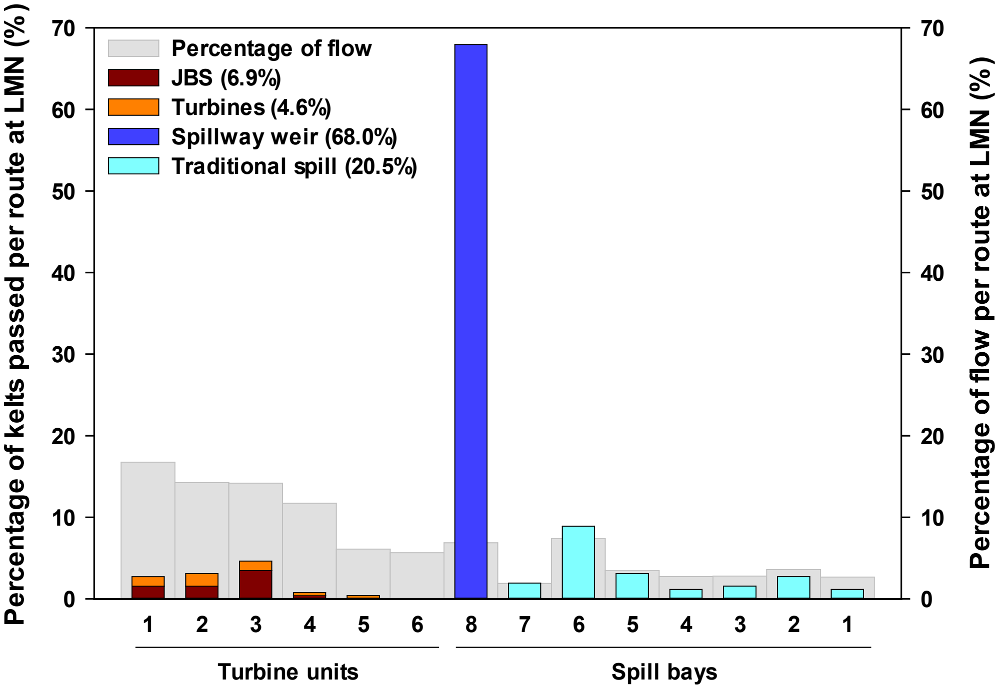

Figure H.3. Percentage of kelt passing Lower Monumental Dam (LMN; rkm 589) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at LMN (23 April 2012 to 30 June 2012). Passage routes are ordered from the north side of the river to the south side of the river.

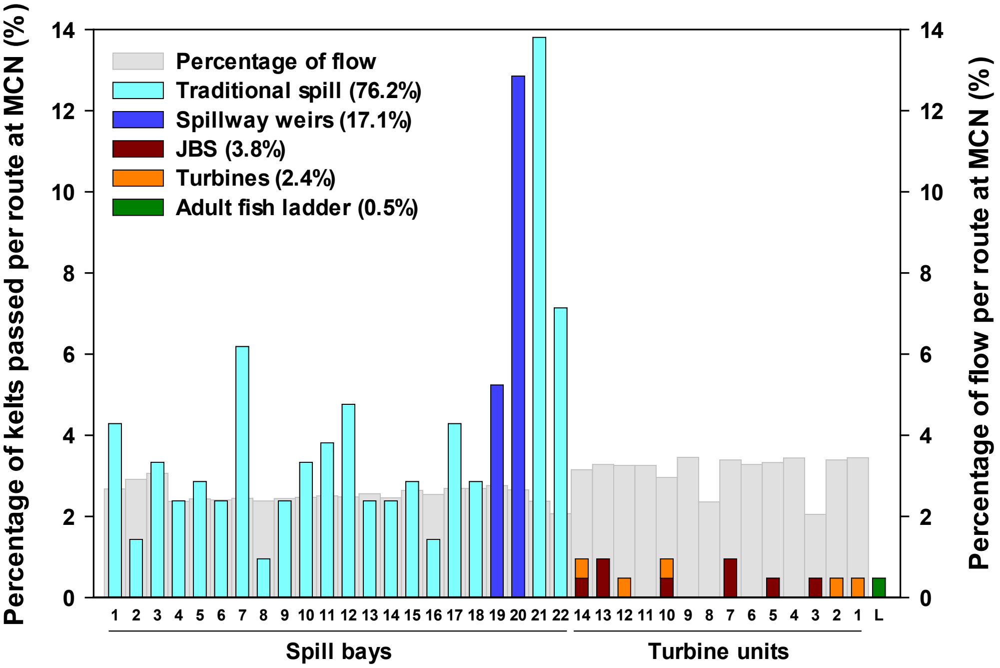

Figure H.4. Percentage of kelt passing McNary Dam (MCN; rkm 470) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at MCN (25 April 2012 to 1 July 2012). Passage routes are ordered from the north side of the river to the south side of the river.

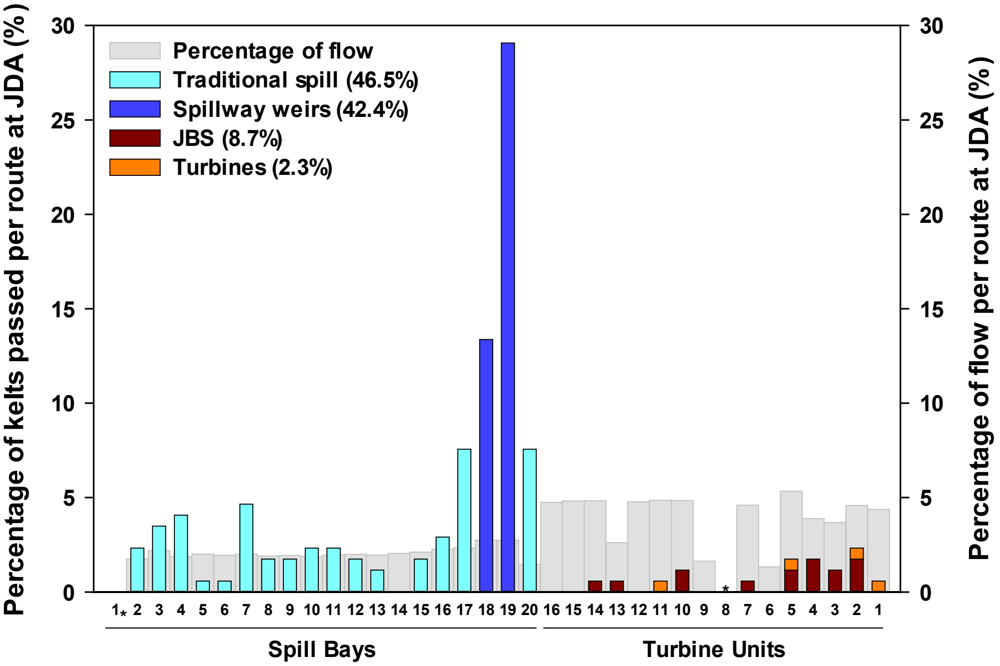

Figure H.5. Percentage of kelt passing John Day Dam (JDA; rkm 349) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at JDA (29 April 2012 to 3 July 2012). Passage routes are ordered from the north side of the river to the south side of the river. *Turbine unit 8 was not operated during the kelt migration period.

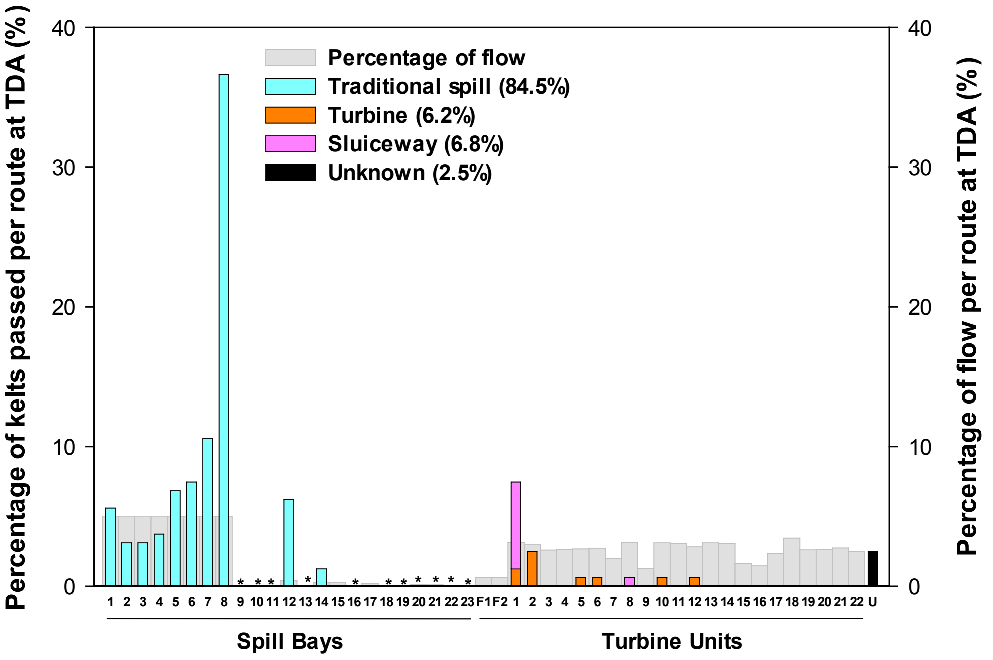

Figure H.6. Percentage of kelt passing The Dalles Dam (TDA; rkm 349) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at TDA (28 April 2012 to 3 July 2012). Passage routes are ordered from the north side of the river to the south side of the river. *Spillbays 9, 10. 11, 16, 18, 19, and 23 were not used during the kelt migration period, and flow through spillbays 13, 20, 21, and 22 was negligible (<0.1% total dam flow).

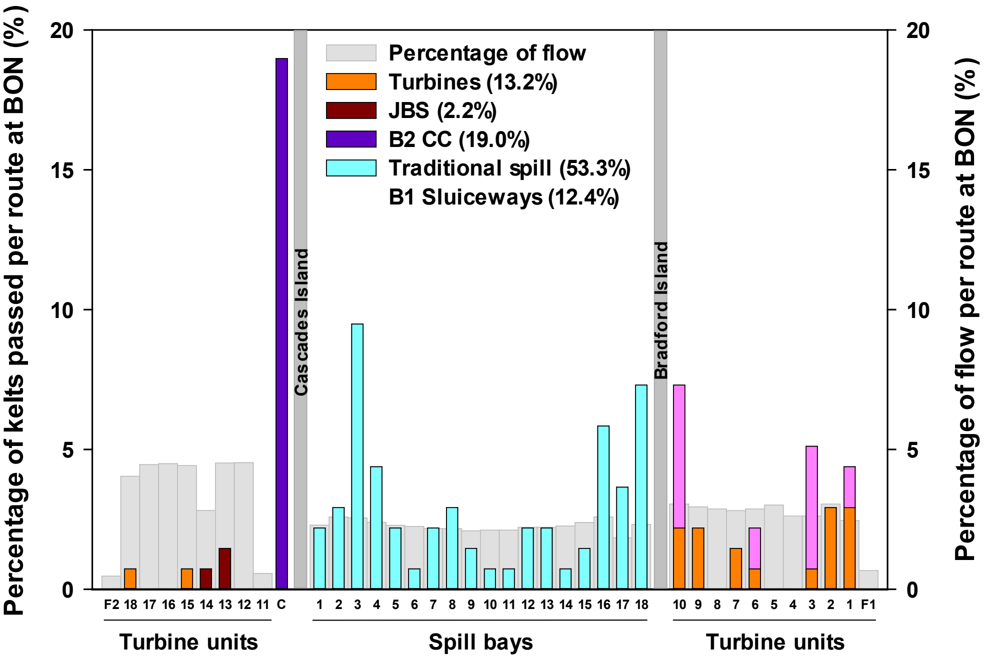

Figure H.7. Percentage of kelt passing Bonneville Dam (BON; rkm 234) via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at BON (29 April 12 to 4 July 2012). Passage routes are ordered from the north side of the river to the south side of the river.

Appendix I

Diel Distribution at Dam Passage

Appendix I

Diel Distribution at Dam Passage

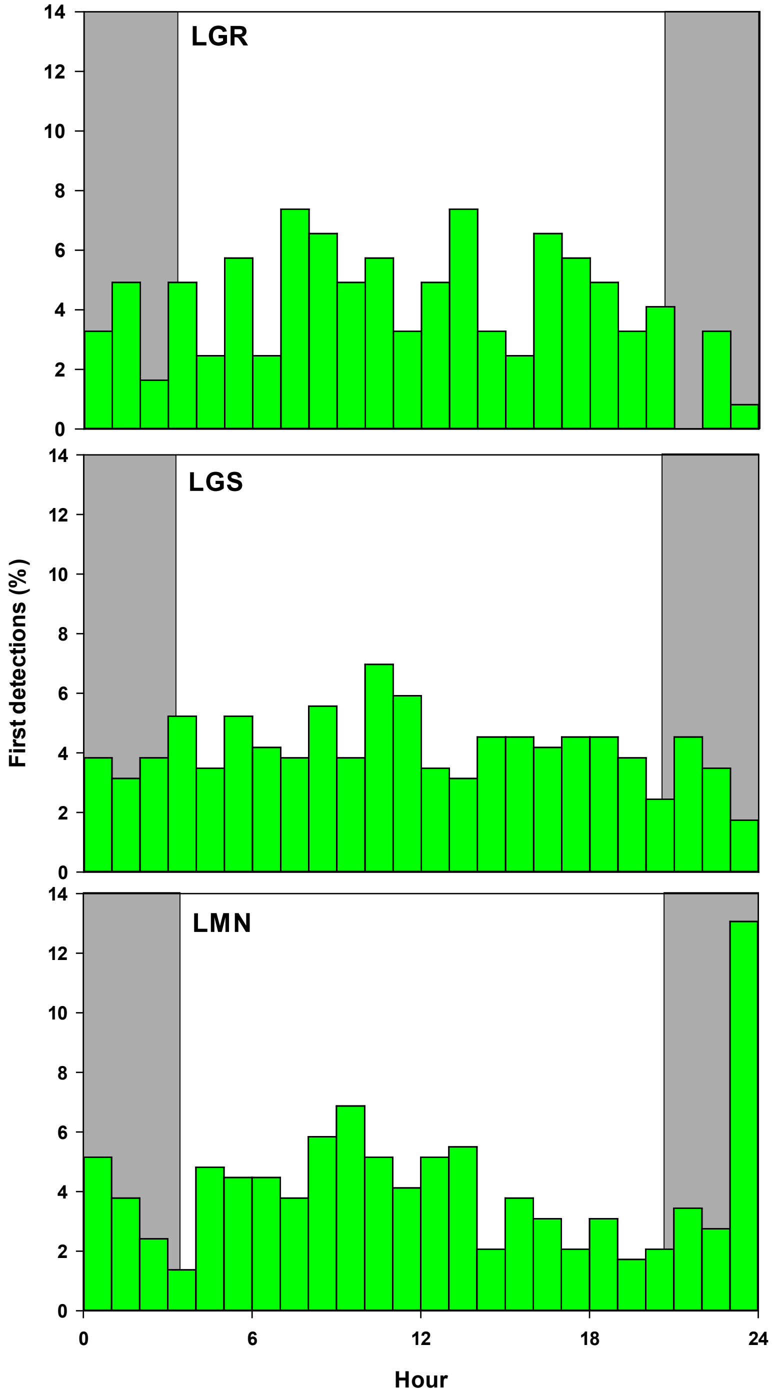

Figure I.1. Hourly distributions of steelhead kelt first detections at the cabled dam-face arrays at Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams. Grey bars represent approximate hours of darkness.

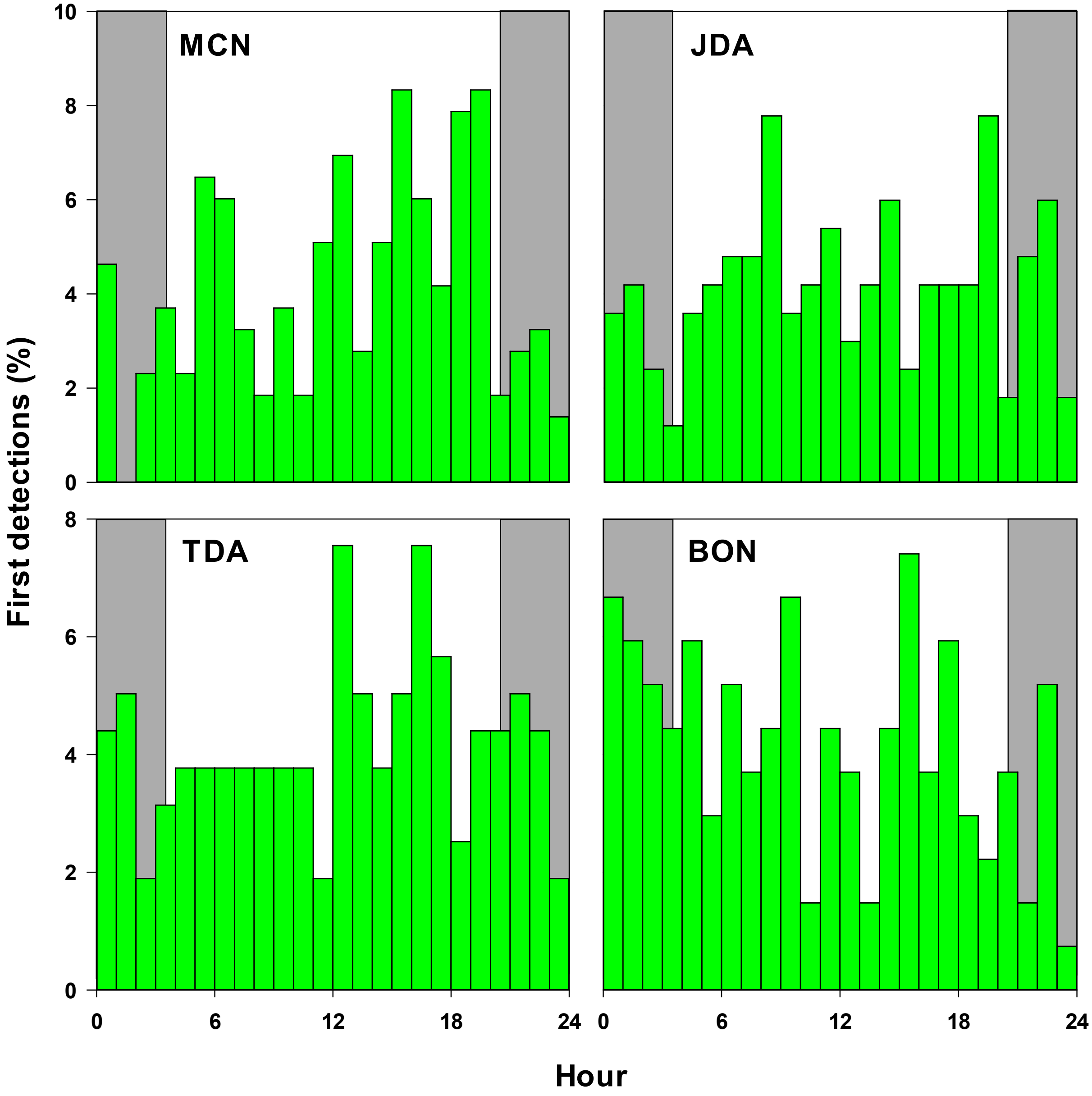

Figure I.2. Hourly distributions of steelhead kelt first detections at the cabled dam-face arrays at McNary (MCN), John Day (JDA), The Dalles (TDA), and Bonneville (BON) dams. Grey bars represent approximate hours of darkness.

Appendix J

Vertical Distribution of Kelts

Appendix J

Vertical Distribution of Kelts

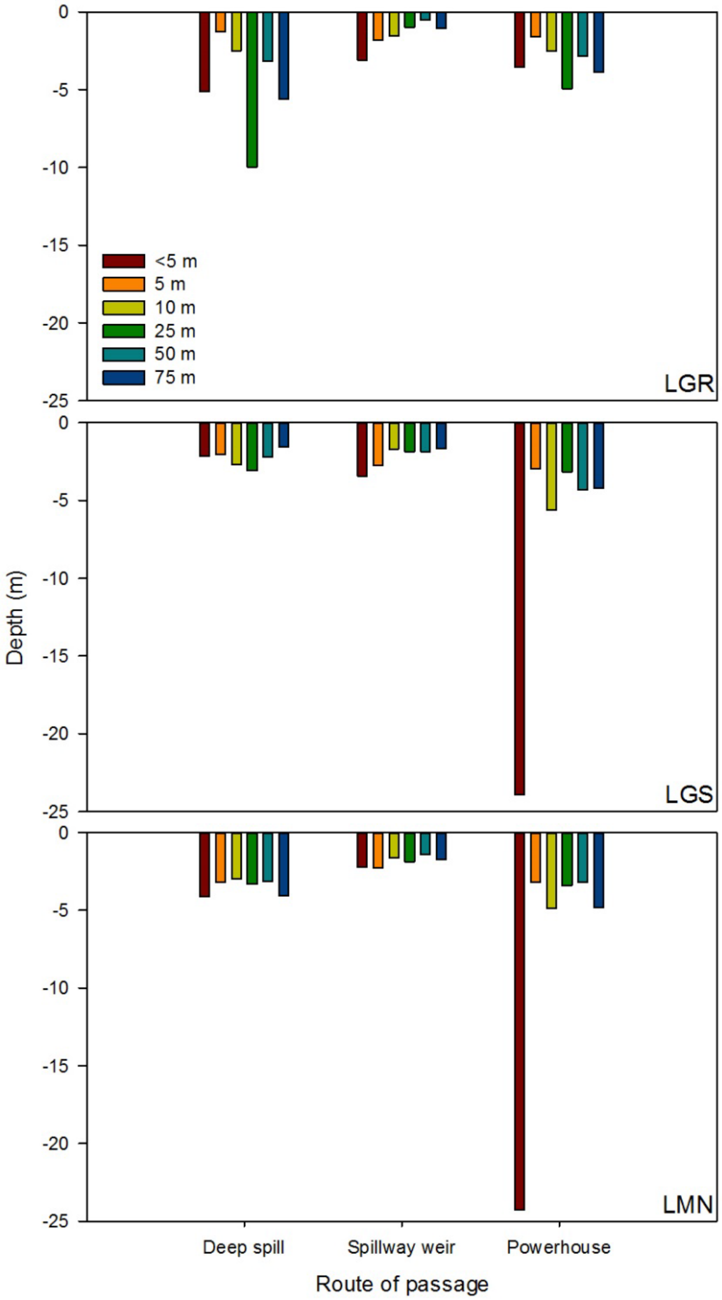

Figure J.1. Median depths (m) of acoustic-tagged steelhead kelt 75, 50, 25, 10, 5 m from the dam face and at the last detection prior to passage (<5 m) through Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams during 2012. Zero depth was referenced to the elevation of the minimum operating pool at 223.4, 192.9, and 163.7 m above sea level. Fish were pooled based on their ultimate route of passage through the dam (i.e., traditional spill, spillway weir, or powerhouse [turbine and juvenile bypass system]).

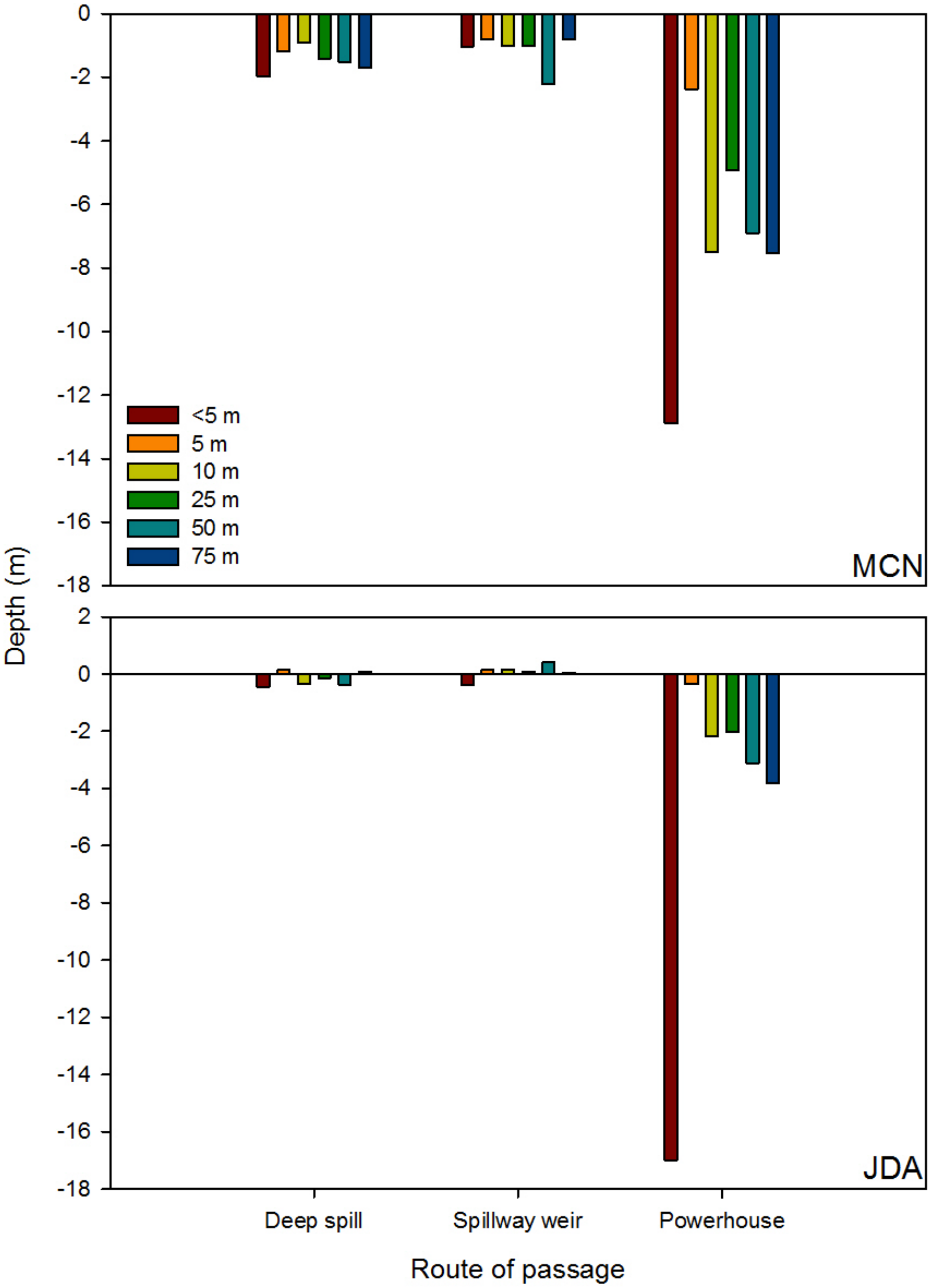

Figure J.2. Median depths (m) of acoustic-tagged steelhead kelt 75, 50, 25, 10, 5 m from the dam face and at the last detection prior to passage (<5 m) through McNary (MCN) and John Day (JDA) dams during 2012. Zero depth was referenced to the elevation of the minimum operating pool at 102.1 and 78.3 m above sea level, respectively. Fish were pooled based on their ultimate route of passage through the dam (i.e., traditional spill, spillway weir, or powerhouse [turbine and juvenile bypass system]).

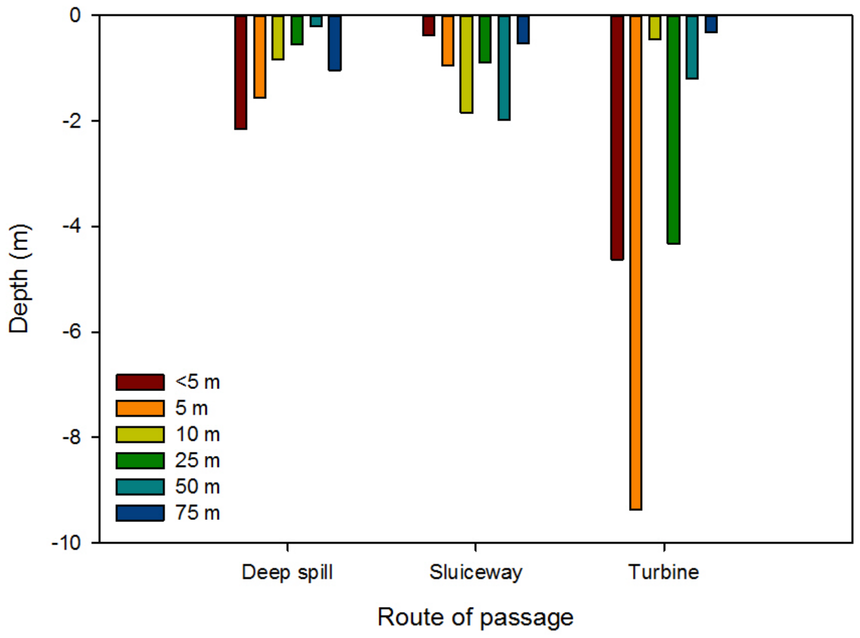

Figure J.3. Median depths (m) of acoustic-tagged steelhead kelt 75, 50, 25, 10, 5 m from the dam face and at the last detection prior to passage (<5 m) through The Dalles Dam during 2012. Zero depth was referenced to the elevation of the minimum operating pool at 47.2 m above sea level. Fish were pooled based on their ultimate route of passage through the dam (i.e., traditional spill, sluiceway, or turbine).

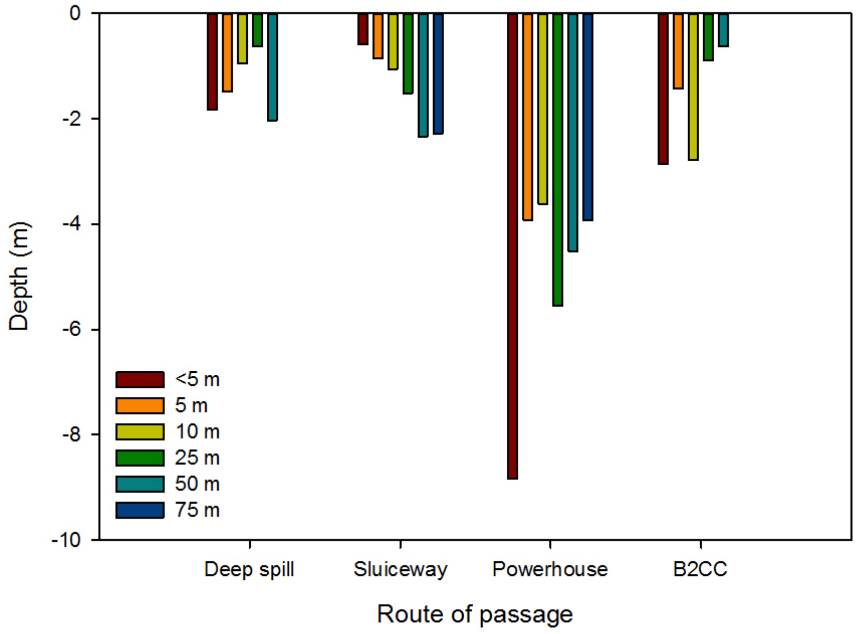

Figure J.4. Median depths (m) of acoustic-tagged steelhead kelt 75, 50, 25, 10, 5 m from the dam face and at the last detection prior to passage (<5 m) through Bonneville Dam during 2012. Zero depth was referenced to the elevation of the minimum operating pool at 21.3 m above sea level. Fish were pooled based on their ultimate route of passage through the dam (i.e., traditional spill, B1 sluiceway, powerhouse [turbine and juvenile bypass system combined], and the B2 corner collector [B2CC]).

Appendix K

Routes of Passage through Multiple Federal Columbia River Power System Dams

Table K.1. Routes of passage used by kelts tagged with Juvenile Salmon Acoustic Telemetry System transmitters through Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), McNary (MCN), John Day (JDA), The Dalles (TDA), and Bonneville (BON) dams in 2012. JBS = juvenile bypass system.

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
	JBS	JBS	Traditional spill	JBS			1	0.3
	JBS	Spillway weir	JBS	JBS	Traditional spill		1	0.3
	JBS	Spillway weir	JBS	Traditional spill	Traditional spill		1	0.3
	JBS	Spillway weir	Traditional spill	JBS	Traditional spill	Turbine	1	0.3
	JBS	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	4	1.3
	JBS	Spillway weir	Traditional spill	Traditional spill	Turbine	Traditional spill	1	0.3
	JBS	Spillway weir	Traditional spill	Traditional spill			1	0.3
	JBS	Spillway weir	Traditional spill	Turbine	Traditional spill	Traditional spill	2	0.7
	JBS	Spillway weir	Traditional spill	Turbine			1	0.3
Spillway weir	JBS	Spillway weir	Traditional spill				1	0.3
Traditional spill	JBS	Spillway weir	Traditional spill				1	0.3
	JBS	Spillway weir	Traditional spill				1	0.3
	JBS	Spillway weir	Turbine	Spillway weir	Traditional spill	Traditional spill	1	0.3
Spillway weir	JBS	Spillway weir					1	0.3
	JBS	Traditional spill	Traditional spill	JBS			1	0.3
	JBS	Traditional spill	Traditional spill	Spillway weir	Traditional spill	Traditional spill	1	0.3
	JBS	Traditional spill	Traditional spill	Spillway weir	Traditional spill	Turbine	1	0.3
	JBS	Traditional spill	Traditional spill	Spillway weir			1	0.3
	JBS	Traditional spill	Traditional spill				1	0.3
	JBS	Traditional spill					2	0.7
	JBS	Turbine	Traditional spill	Spillway weir	Traditional spill	Turbine	1	0.3
Spillway weir	JBS	Turbine	Turbine				1	0.3
Spillway weir	JBS						1	0.3
	JBS						1	0.3
	Spillway weir	JBS	Spillway weir	Traditional spill	Traditional spill	Sluiceway	1	0.3
JBS	Spillway weir	JBS	Spillway weir				1	0.3
	Spillway weir	JBS	Traditional spill	Spillway weir	Traditional spill	Traditional spill	1	0.3

Table K.1. (contd)

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
Spillway weir	Spillway weir	JBS	Traditional spill	Traditional spill	Traditional spill	JBS	1	0.3
	Spillway weir	JBS	Traditional spill	Traditional spill	Traditional spill	Traditional spill	1	0.3
	Spillway weir	JBS	Traditional spill	Turbine	Turbine		1	0.3
	Spillway weir	JBS	Traditional spill				3	1.0
	Spillway weir	JBS		JBS			1	0.3
Spillway weir	Spillway weir	JBS					2	0.7
JBS	Spillway weir	JBS					1	0.3
	Spillway weir	Spillway weir	JBS	Spillway weir	Sluiceway		1	0.3
	Spillway weir	Spillway weir	JBS	Traditional spill	Traditional spill	Sluiceway	1	0.3
	Spillway weir	Spillway weir	JBS	Traditional spill	Traditional spill	Traditional spill	1	0.3
	Spillway weir	Spillway weir	JBS	Traditional spill	Traditional spill		1	0.3
	Spillway weir	Spillway weir	Adult fish ladder				1	0.3
	Spillway weir	Spillway weir	Spillway weir	JBS			1	0.3
	Spillway weir	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	3	1.0
Spillway weir	Spillway weir	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	2	0.7
	Spillway weir	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Turbine	2	0.7
Spillway weir	Spillway weir	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Turbine	1	0.3
	Spillway weir	Spillway weir	Spillway weir	Spillway weir	Traditional spill		1	0.3
	Spillway weir	Spillway weir	Spillway weir	Spillway weir	Turbine	Sluiceway	1	0.3
	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Sluiceway	2	0.7
Traditional spill	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Sluiceway	1	0.3
	Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	5	1.7
	Spillway weir	Spillway weir	Spillway weir				1	0.3
Spillway weir	Spillway weir	Spillway weir	Traditional spill	JBS	Traditional spill	Sluiceway	1	0.3
	Spillway weir	Spillway weir	Traditional spill	JBS	Traditional spill	Traditional spill	1	0.3
Spillway weir	Spillway weir	Spillway weir	Traditional spill	JBS			1	0.3
	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Sluiceway	Sluiceway	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Sluiceway	Traditional spill	2	0.7
	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Sluiceway	3	1.0
Traditional spill	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Sluiceway	2	0.7
	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	10	3.3

Table K.1. (contd)

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
Spillway weir	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	3	1.0
JBS	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	1	0.3
Traditional spill	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Turbine	2	0.7
Traditional spill	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Turbine	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Spillway weir	Traditional spill		2	0.7
	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Sluiceway	Turbine	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway	4	1.3
Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway	2	0.7
Traditional spill	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	5	1.7
Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	3	1.0
Traditional spill	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	1	0.3
Spillway weir	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Turbine	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Turbine	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill		2	0.7
JBS	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Turbine	Turbine	1	0.3
	Spillway weir	Spillway weir	Traditional spill	Traditional spill	Turbine		1	0.3
Traditional spill	Spillway weir	Spillway weir	Traditional spill	Traditional spill			1	0.3
	Spillway weir	Spillway weir	Traditional spill	Traditional spill			1	0.3
	Spillway weir	Spillway weir	Traditional spill		Sluiceway	Sluiceway	1	0.3
	Spillway weir	Spillway weir	Traditional spill		Traditional spill		1	0.3
Spillway weir	Spillway weir	Spillway weir	Traditional spill				4	1.3
	Spillway weir	Spillway weir	Traditional spill				4	1.3
Traditional spill	Spillway weir	Spillway weir	Traditional spill				2	0.7
Turbine	Spillway weir	Spillway weir	Traditional spill				1	0.3
	Spillway weir	Spillway weir	Turbine	Traditional spill	Turbine		1	0.3
	Spillway weir	Spillway weir		Traditional spill	Traditional spill	Sluiceway	1	0.3
	Spillway weir	Spillway weir					10	3.3
Spillway weir	Spillway weir	Spillway weir					4	1.3

Table K.1. (contd)

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
Traditional spill	Spillway weir	Spillway weir					1	0.3
	Spillway weir	Traditional spill	Spillway weir	JBS	Traditional spill	Traditional spill	1	0.3
	Spillway weir	Traditional spill	Spillway weir	Spillway weir	Traditional spill	Traditional spill	2	0.7
	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	JBS	1	0.3
	Spillway weir	Traditional spill	Spillway weir		Traditional spill	Sluiceway	1	0.3
	Spillway weir	Traditional spill	Spillway weir				1	0.3
	Spillway weir	Traditional spill	Traditional spill	JBS	Traditional spill	Traditional spill	1	0.3
	Spillway weir	Traditional spill	Traditional spill	Spillway weir	Traditional spill	Traditional spill	2	0.7
	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway		1	0.3
Turbine	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill		1	0.3
	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Turbine		1	0.3
	Spillway weir	Traditional spill	Traditional spill	Traditional spill		Sluiceway	1	0.3
Spillway weir	Spillway weir	Traditional spill	Traditional spill	Traditional spill			1	0.3
	Spillway weir	Traditional spill	Traditional spill				3	1.0
Traditional spill	Spillway weir	Traditional spill	Turbine	Traditional spill			1	0.3
	Spillway weir	Traditional spill	Turbine				1	0.3
	Spillway weir	Traditional spill					3	1.0
Spillway weir	Spillway weir	Traditional spill					1	0.3
	Spillway weir	Turbine	JBS				1	0.3
	Spillway weir	Turbine	Traditional spill	Spillway weir	Traditional spill	Turbine	1	0.3
Spillway weir	Spillway weir	Turbine	Traditional spill	Spillway weir	Turbine	Traditional spill	1	0.3
Spillway weir	Spillway weir	Turbine					2	0.7
	Spillway weir	Turbine					2	0.7
Turbine	Spillway weir	Turbine					1	0.3
Spillway weir	Spillway weir						7	2.3
Traditional spill	Spillway weir						7	2.3
	Spillway weir						3	1.0

Table K.1. (contd)

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
Turbine	Spillway weir						1	0.3
	Traditional spill	JBS	Spillway weir	JBS	Traditional spill	Sluiceway	1	0.3
	Traditional spill	JBS	Traditional spill	JBS	Turbine		1	0.3
Turbine	Traditional spill	JBS					1	0.3
	Traditional spill	Spillway weir	JBS	JBS	Traditional spill		1	0.3
	Traditional spill	Spillway weir	Spillway weir	Spillway weir		Turbine	1	0.3
Traditional spill	Traditional spill	Spillway weir	Spillway weir		Traditional spill	Traditional spill	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Spillway weir	Sluiceway	Turbine	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Sluiceway	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	4	1.3
Spillway weir	Traditional spill	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	2	0.7
	Traditional spill	Spillway weir	Traditional spill	Spillway weir	Traditional spill	Turbine	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Spillway weir	Traditional spill		1	0.3
	Traditional spill	Spillway weir	Traditional spill	Spillway weir		Sluiceway	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Sluiceway	Sluiceway	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	JBS	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway	5	1.7
Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
Traditional spill	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
Spillway weir	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	2	0.7
	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill	Traditional spill	1	0.3
	Traditional spill	Spillway weir	Traditional spill	Traditional spill	Traditional spill		2	0.7
JBS	Traditional spill	Spillway weir	Traditional spill	Traditional spill			1	0.3
	Traditional spill	Spillway weir	Traditional spill	Traditional spill			1	0.3
	Traditional spill	Spillway weir	Traditional spill		Traditional spill	Traditional spill	1	0.3
Spillway weir	Traditional spill	Spillway weir	Traditional spill		Traditional spill		1	0.3
	Traditional spill	Spillway weir	Traditional spill				2	0.7
Turbine	Traditional spill	Spillway weir	Traditional spill				1	0.3
	Traditional spill	Spillway weir		Spillway weir	Traditional spill	Sluiceway	1	0.3

Table K.1. (contd)

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
Spillway weir	Traditional spill	Spillway weir		Spillway weir			1	0.3
	Traditional spill	Spillway weir					3	1.0
Spillway weir	Traditional spill	Spillway weir					2	0.7
Traditional spill	Traditional spill	Spillway weir					1	0.3
Spillway weir	Traditional spill	Traditional spill	Spillway weir	Spillway weir	Sluiceway	Traditional spill	1	0.3
	Traditional spill	Traditional spill	Spillway weir	Spillway weir	Traditional spill	Traditional spill	1	0.3
	Traditional spill	Traditional spill	Spillway weir	Traditional spill			1	0.3
JBS	Traditional spill	Traditional spill	Spillway weir				1	0.3
	Traditional spill	Traditional spill	Traditional spill	JBS	Turbine	Sluiceway	1	0.3
Spillway weir	Traditional spill	Traditional spill	Traditional spill	Spillway weir	Sluiceway	Traditional spill	1	0.3
Spillway weir	Traditional spill	Traditional spill	Traditional spill	Spillway weir	Traditional spill	Traditional spill	1	0.3
	Traditional spill	Traditional spill	Traditional spill	Spillway weir	Traditional spill	Traditional spill	1	0.3
	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Traditional spill	1	0.3
	Traditional spill	Traditional spill	Traditional spill	Traditional spill	Traditional spill		1	0.3
	Traditional spill	Traditional spill	Traditional spill	Traditional spill		Turbine	1	0.3
	Traditional spill	Traditional spill	Traditional spill				2	0.7
Spillway weir	Traditional spill	Traditional spill					2	0.7
Traditional spill	Traditional spill	Traditional spill					1	0.3
	Traditional spill	Traditional spill					1	0.3
Spillway weir	Traditional spill	Turbine	Traditional spill		Traditional spill	Sluiceway	1	0.3
	Traditional spill	Turbine					1	0.3
Spillway weir	Traditional spill						2	0.7
	Traditional spill						2	0.7
Traditional spill	Traditional spill						1	0.3
Traditional spill	Turbine	JBS	Traditional spill	Traditional spill	Traditional spill	Sluiceway	1	0.3
Spillway weir	Turbine	Spillway weir	Spillway weir	Spillway weir		Sluiceway	1	0.3
	Turbine	Spillway weir	Traditional spill	Spillway weir	Traditional spill		1	0.3
	Turbine	Spillway weir	Traditional spill	Traditional spill	Traditional spill		1	0.3
	Turbine	Spillway weir	Traditional spill				1	0.3
	Turbine	Spillway weir					1	0.3

Table K.1. (contd)

LGR	LGS	LMN	MCN	JDA	TDA	BON	N	%
Traditional spill	Turbine	Traditional spill	Traditional spill	Spillway weir			1	0.3
Spillway weir	Turbine	Traditional spill					2	0.7
	Turbine						2	0.7
Traditional spill	Turbine						1	0.3
Turbine	Turbine						1	0.3
Spillway weir							10	3.3
Traditional spill							3	1.0
JBS							1	0.3
Turbine							1	0.3