FINAL TECHNICAL REPORT: ADULT STEELHEAD PASSAGE BEHAVIORS AND SURVIVAL IN THE FEDERAL COLUMBIA RIVER POWER SYSTEM

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Final Technical Report

ADULT STEELHEAD PASSAGE BEHAVIORS AND SURVIVAL IN THE FEDERAL COLUMBIA RIVER POWER SYSTEM

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RATIONALE

This report contains summary information on adult steelhead (*Oncorhynchus mykiss*) migration behaviors and survival through the Federal Columbia River Power System (FCRPS). It provides managers and researchers with a synthesis of previously completed adult steelhead research and newly acquired summaries from passive integrated transponder (PIT) tagged steelhead whose migration histories were archived in the PIT-tag Information System (PTAGIS). Information was included, as available, from all steelhead populations with natal sites upstream from Bonneville Dam in the Columbia and Snake rivers. Several focal populations were identified *a priori* based on known FCRPS passage and survival concerns. Focal groups or populations include steelhead from Fifteenmile Creek, John Day River, Umatilla River, Walla Walla River, and Tucannon River, as well as the Snake River B-group life history type.

Synthesis results are organized as two primary components: (1) a literature review of adult steelhead passage studies in the FCRPS and (2) a summary of newly acquired PIT tag data from adult steelhead in the FCRPS. Adult steelhead research previously funded by the U.S. Army Corps of Engineers during 2005-2015 were reviewed and synthesized, along with select studies conducted prior to or overlapping 2005 and studies funded by other organizations. Newly acquired PIT tag data were also summarized for data collected during 2005-2015. There were six overarching review topics discussed using data from previously funded studies and newly acquired PIT tag summaries: (1) adult steelhead migration timing; (2) overwintering in the FCRPS; (3) natal tributary overshoot; (4) fallback at FCRPS dams; (5) FCRPS reach conversion; and (6) homing and straying. Steelhead behaviors within these six subject areas were highly inter-related and the review was organized to address this complexity.

The combination of using past research summaries and newly acquired PIT tag data should help managers develop effective management strategies for adult steelhead. Ensuring that pre-spawn and post-spawn (kelts) adults can safely and efficiently pass FCRPS dams – both upstream and downstream – should help address concerns identified in the 2008 and 2014 supplemental FCRPS Biological Opinions.

KEY FINDINGS, CRITICAL UNCERTAINTIES, AND TECHNICAL RECOMMENDATIONS

Given the scope of data synthesized as part of this study, in lieu of an Extended Abstract or Executive Summary, we provide a brief summary that includes a list of key findings, critical uncertainties, and technical recommendations at the end of each results sub-section.

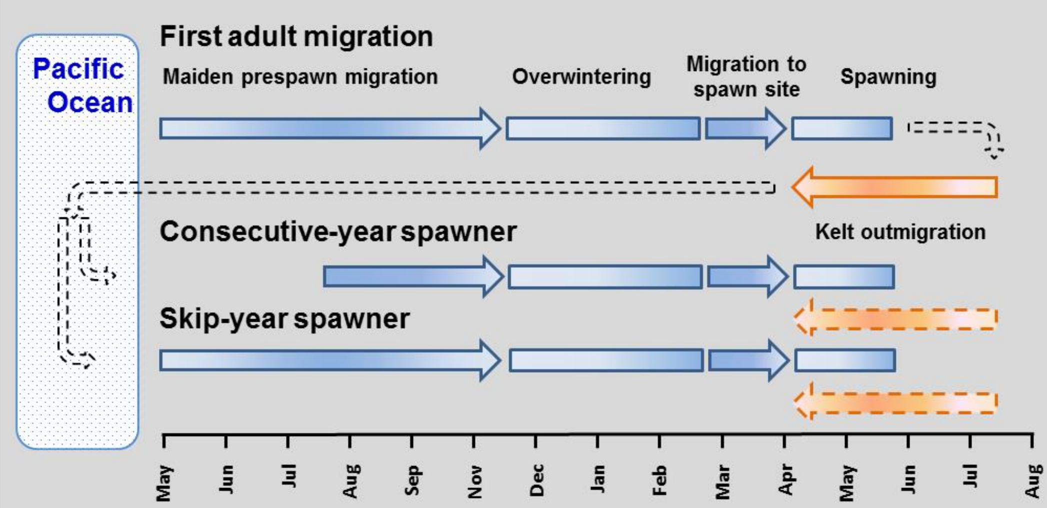
1.0 INTRODUCTION

The Columbia River steelhead run above Bonneville Dam is comprised of a diverse mix of populations and life history types with most adults entering the Columbia River between May and October, some ~6 -11 months before springtime spawning (Busby et al. 1996; Brannon et al. 2004). Some winter-run (ocean-maturing) steelhead pass Bonneville Dam from late fall through early spring. The much more abundant summer-run (stream-maturing) steelhead includes early-timed migrants (May- August) that are mostly 1- and 2-ocean, steelhead that spawn in tributaries throughout the basin. The later-timed summer-run migrants are more commonly 2-ocean and sometimes 3-ocean steelhead from the Clearwater and Salmon rivers in Idaho. The early-run and late-run designations were historically called A-run (A-group) or B-run (B-group), respectively. These terms continue to be used for management and policy decisions, but they are imperfect descriptors of biological traits within and among populations (Nielsen et al. 2009; Campbell et al. 2012). The extended migration period for the aggregate steelhead run means that individuals and populations encounter a diverse range of environmental and dam operational conditions during their pre-spawn migrations through the FCRPS.

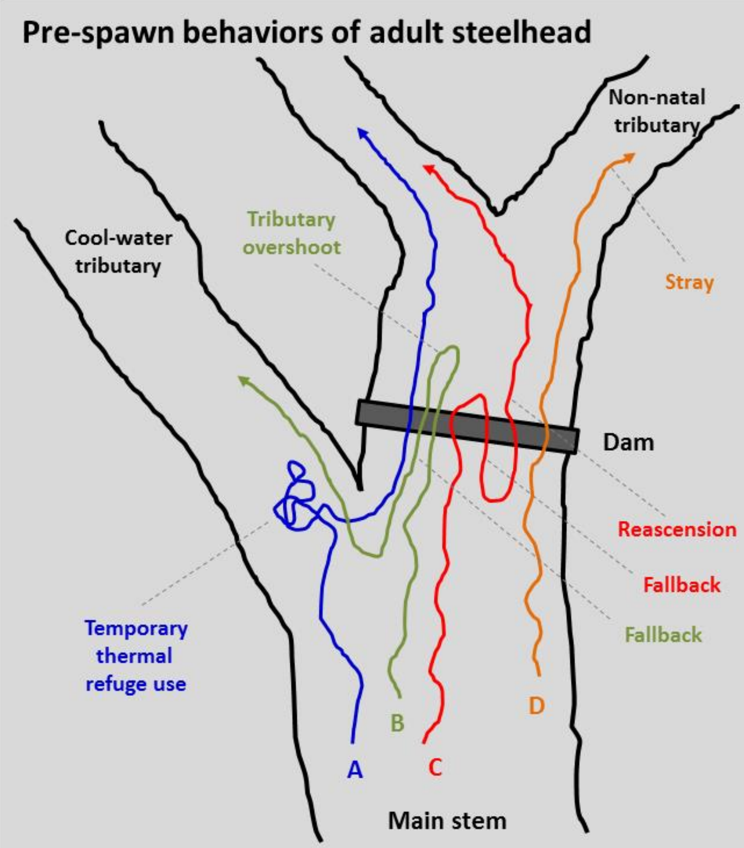
Many Columbia and Snake River summer-run steelhead have complex, multi-stage pre-spawn homing migrations (Busby et al. 1996; Robards and Quinn 2002; Keefer et al. 2008a, 2009) followed by rapid post-spawn 'kelt' migrations (Evans et al. 2004; Wertheimer and Evans 2005; Colotelo et al. 2013) (*Boxes 1 and 2*). Their long freshwater migration and residency periods, as well as use of habitats outside of their direct migration route, create a variety of concerns for management of the FCRPS, including potential need for surface-flow (i.e., non-turbine) downstream passage routes at dams during traditional non-spill periods. This is especially an issue in winter and spring when many adult steelhead are present in the FCRPS and can be overwintering in reservoirs (holding by pre-spawn fish), migrating upstream (post-overwintering pre-spawn fish), or moving downstream (post-spawn kelts and pre-spawn adults that 'overshoot' their natal tributary).

Much of the behavioral and survival data on adult steelhead in the Columbia River basin has been collected in radio telemetry and PIT tag studies, along with targeted hydroacoustic studies to evaluate route-specific passage behavior and survival. The radio and PIT data have dramatically increased awareness of pre- and post-spawn steelhead movements and behaviors including FCRPS overwintering (Keefer et al. 2008a), tributary overshoot and associated fallback at dams (Keefer and Caudill 2014a; Middle Columbia Wild Adult Steelhead Tributary Bypass Workshop 2014), and extensive kelt outmigrations (Evans et al. 2004; Boggs et al. 2008; Narum et al. 2008; Colotelo et al. 2013, 2014). Several of these behaviors have a dam fallback component that presents potential injury and mortality risks to steelhead and there is therefore a need to evaluate seasonal operations of the FCRPS.

Winter fallback by pre-spawn steelhead, tributary overshoot-related fallback in winter and spring, and downstream passage during kelt outmigration were not historically given much consideration in FCRPS management and operations plans. However, due to increased



Box 1. Generalized adult life history stages of summer-run steelhead in the Columbia River basin. Prespawn migration occurs through main stem river reaches and lower sections of major tributaries; overwintering occurs in reservoirs and a variety of tributary sites and is followed by completion of migration to spawning sites in spring. Some fish survive spawning, become kelts, and outmigrate to the ocean. Iteroparous individuals typically return in either the same calendar year as their first spawning event ('consecutive spawners') or in the following year ('skip spawners').



Box 2. Examples of adult steelhead behaviors during their prespawn migration in the main stem Columbia and Snake rivers: (A) fish that used cool-water, non-natal tributary before moving upstream to natal site; (B) fish that overshot its natal tributary and had to fall back at a dam to return to natal site; (C) fish that fell back at a dam and then reascended before returning to its natal site; (D) fish that strayed into a non-natal tributary.

awareness, these behaviors are now considered a significant mortality concern because some downstream passage is via turbines, particularly passage during periods of little or no spill (2012 Kelt Management Plan; 2014 FCRPS Biological Opinion). Results from tagging and hydroacoustic studies (e.g., Wertheimer 2007; Ham et al. 2012a; Khan et al. 2013) and from direct mortality and injury research (e.g., Normandeau Associates 2014) indicate that fallback through surface-flow routes likely provides a survival benefit for adult steelhead relative to fallback through turbines.

Despite the tremendous amount of knowledge gained from these studies, considerable uncertainty remains regarding the most effective locations and times to potentially provide non-turbine passage routes. The literature and data summaries presented herein should provide information needed to develop efficient strategies for increasing pre-spawn and post-spawn steelhead survival during traditional non-spill and non-bypass seasons, and during the full migration season of steelhead. Many of the synthesis topics and steelhead behaviors described here are interrelated (i.e., individual fish may have tributary overshoot, FCRPS overwintering, and FCRPS fallback behaviors); recognizing that these behaviors are related is important for understanding the data summaries and because these behaviors may result from similar underlying mechanisms.

This report contains summary information on adult steelhead migration behaviors and survival in the FCRPS (*Figure 1*). The primary aim is to provide relevant biological information to managers and researchers tasked with increasing adult steelhead survival in the FCRPS and ensuring that adults can successfully home to natal tributaries. The report has two primary sections: (1) a literature review of previously funded adult steelhead research projects in the FCRPS; and (2) data summaries and synthesis from adult steelhead with PIT-tag migration histories in the FCRPS and tributaries. Focal populations include the Snake River ‘B-group’ steelhead and several mid-Columbia and lower Snake River stocks, including but not limited to Fifteenmile Creek, John Day River, Umatilla River, Walla Walla River, and Tucannon River steelhead. Summaries are organized by FCPRS project and by steelhead population insomuch as possible.

Figure 1. Federal Columbia River Power System (FCRPS) dam that are the focus of this report include the four lower Columbia River dams (Bonneville, The Dalles, John Day, McNary) and four lower Snake River dams (Ice Harbor, Lower Monumental, Little Goose, Lower Granite). Some summaries herein also include data collected at the Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams, which are not FCRPS projects.

1.1 OBJECTIVES

The overarching objective of this synthesis is to compile and interpret information related to the behavior and survival of adult steelhead in the FCRPS. The synthesis includes two primary components: (1) summaries derived from previously-conducted adult steelhead research in the FCRPS; and (2) analysis of archived adult steelhead PIT-tag data in the FCRPS. The synthesis focuses on research conducted from 2005-2015 (and directly relevant earlier work) and on PIT-tagged adults detected at FCRPS dams in 2005-2015.

1.1.1 Review and Summary of Findings of Past Studies

The literature-based component draws on the many studies funded by the U.S. Army Corps of Engineers (Corps) and other agencies to examine adult steelhead behavior and survival in the FCRPS. The primary literature sources include studies of: (1) fallback-related direct survival and injury at Bonneville and McNary dams (e.g., Normandeau Associates 2011, 2014); (2) hydroacoustic monitoring to evaluate downstream fallback by pre-spawn steelhead and post-spawn kelts at Bonneville, The Dalles, and McNary dams (Khan et al. 2009, 2010, 2011, 2013; Weiland et al. 2009; Ham et al. 2012a, 2012b, 2015); (3) radiotelemetry studies regarding passage behavior and conversion (Boggs et al. 2004; Keefer et al. 2005, 2008a, 2008b, 2009, 2014b, 2014c, 2015; Caudill et al. 2007, 2013); and (4) several kelt evaluations that used either PIT tags (Evans et al. 2008; Keefer et al. 2008c), radiotelemetry (Wertheimer and Evans 2005; Wertheimer 2007; Keefer et al. 2015b), and/or acoustic telemetry (Colotelo et al. 2013, 2014; Rayamajhi et al. 2013).

1.1.2 PIT-Tag Data Used to Characterize Steelhead Migration Behaviors

The new quantitative summaries for this objective use data from PIT-tagged steelhead that are archived in the PTAGIS database maintained by the Pacific States Marine Fisheries Commission (PSMFC). Many state, federal, and tribal research programs have PIT-tagged juvenile steelhead (and some adults; e.g., Fryer et al. 2013) over the last two decades, providing a largely unreported source of adult migration information. The PIT-tag data are from a mix of population-specific sources (e.g., from the long-running Comparative Survival Study [CSS]; Fish Passage Center 2011, 2013), from population aggregates collected and tagged at dams (e.g., by NOAA-Fisheries at Snake River dams; Marsh et al. 2004, 2011; Faulkner et al. 2009), and from projects conducted by individual agencies within natal tributaries.

While the PIT-tag samples all provide 'known-source' information, we note that the substantial variation in target groups from tagging studies has resulted in variable spatial resolution when assigning population groups. For example, PIT-tagging at hatcheries or collection and tagging of outmigrating smolts in tributaries can provide precise population assignments, whereas other PIT-tag groups represent much larger aggregates of spawning populations (e.g., samples of smolts collected at dams, returning adults PIT-tagged at Bonneville Dam).

Adult migration detection histories from these diverse samples were used to summarize a suite of adult steelhead behaviors in the FCRPS. These behaviors parallel those addressed in the literature review and include: (1) migration timing of pre-spawn adults and post-spawn kelts; (2) overwintering in the FCRPS; (3) natal tributary overshoot; (4) fallback at FCRPS dams by pre-spawn adults and post-spawn kelts; (5) FCRPS reach conversion; and (6) homing and straying. Summaries were for the aggregate steelhead run, for 'A- and B-group' life history aggregates where appropriate, and for individual populations with sufficient available data. Focal populations will include the Snake River 'B-group' from the Clearwater and Salmon rivers and several mid-Columbia and lower Snake River stocks with documented tributary overshoot and FCRPS dam fallback behaviors, including but not limited to Fifteenmile Creek, John Day River, Umatilla River, Walla Walla River, and Tucannon River steelhead. The PIT-tag data summaries should help address information gaps that have not been reported in previous studies. The data summaries are intended to be descriptive; statistical evaluation of potential causal factors (e.g., environmental or FCRPS operational effects on steelhead behaviors) were beyond the scope of this synthesis report.

1.1.3 PIT-Tag Data Used to Assess Passage Timing, Survival, and Homing of Adult Steelhead

The 2005-2015 PIT-tag detection histories were also used to estimate survival or conversion through dam-to-dam and multi-dam FCRPS reaches as well as the rates of homing and straying for populations with sufficient data. Summaries were again compiled for the aggregate steelhead run, for 'A- and B-group' life history aggregates, and for individual populations with sufficient data. Focal populations include the Snake River 'B-group' and several mid-Columbia and lower Snake River stocks, including but not limited to Fifteenmile Creek, John Day River, Umatilla River, Walla Walla River, and Tucannon River steelhead. As with Objective 2, summaries for Objective 3 were descriptive rather than an effort to evaluate causative factors via statistical analysis.

2.0 REVIEW OF PAST STUDIES

2.1 METHODS

We acquired agency reports and peer-reviewed papers for relevant Corps-funded adult summer steelhead studies conducted from 2005-2015, along with relevant earlier and closely-affiliated work. Source material was identified by searching in peer-reviewed databases and by searching for grey literature and agency reports posted by the Corps, Bonneville Power Administration (BPA), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), and tribal websites, and by direct solicitation of USACE biologists for relevant, but difficult to access technical reports. We used citation lists and Google Scholar to identify additional relevant material.

Information from the literature review was summarized by the primary synthesis topics: (1) migration timing of pre-spawn adults and post-spawn kelts; (2) overwintering in the FCRPS; (3) natal tributary overshoot; (4) fallback at FCRPS dams by pre-spawn adults and post-spawn kelts; (5) FCRPS reach conversion; and (6) homing and straying. We note that some previous studies were narrowly focused (i.e., direct survival or injury and hydroacoustic studies) whereas others (i.e., radio telemetry studies) often addressed a broad range of research questions nested within the primary themes (*Table 1*). We note that data from many previous studies are available in existing databases for some topics that were not reported comprehensively or were not reported at all. An annotated bibliography (*Appendix A*) additionally provides brief summaries for key references.

Table 1. Steelhead behavior and survival topics addressed in this report and the suitability of each study type or data source for addressing each topic. Checks denote relative suitability.

	Study Type / Data Source			
Topic	Direct survival	Hydroacoustics	PIT tag	Acoustic or Radiotelemetry
Migration timing			✓✓	✓✓
FCRPS overwintering		✓	✓	✓✓
Tributary overshoot rates			✓	✓
Fallback at FCRPS dams	✓	✓	✓	✓✓
FCRPS reach conversion			✓✓	✓✓
Homing and inter-basin straying			✓✓	✓

2.2 RESULTS

2.2.1 Upstream Migration Timing

Aggregate run timing – The aggregate Columbia River steelhead run at Bonneville Dam has many components: winter- and summer-run life history types, A- and B-group 'types', and many distinct populations nested within the larger life history aggregates. The various groups have different upstream passage timing through the FCRPS and can encounter dramatically different river conditions (e.g., water temperature and discharge) and dam operations (e.g., juvenile fish bypass system operation and the presence/absence of surface spill passage routes). Adult steelhead pass FCRPS dams in all months (*Figure 2*) but are counted year-round only at Bonneville Dam. At other sites, manual and video counts are suspended for several months in most years, with no passage data collected from November-March, on average (*Table 2*). Dewatering of fishways also occurs during winter, but one ladder remains open at all times at the four lower Columbia River dams and at Ice Harbor and Lower Monumental dams; upstream passage through fishways is completely blocked at Little Goose and Lower Granite dams (single fishways), typically for several weeks each winter (*Table 2*). These protocols should be considered when evaluating the migration timing-related metrics in this report.

On average, the peak of the aggregate run at Bonneville Dam has been in mid-August over the last decade (*Figure 2*). Warm Bonneville reservoir water temperatures in summer and early fall prompt many steelhead to seek cool-water tributary refuge sites in the Bonneville-The Dalles reach, and this slows migration (*Figure 3*) and results in later upstream dam passage timing for many fish. Peak steelhead migration dates at The Dalles, John Day, and McNary dams are typically in mid- to late September; passage timing at these dams also tends to be bimodal, with a group of fish that pass in early summer before the warmest reservoir temperatures and a larger group that passes in the fall (*Figure 2*).

Passage timing distributions at the Snake River dams typically show three components: (1) a relatively small group of late-summer migrants; (2) a large majority that passes in September and early October; and (3) a small group of fish that pass in the spring (February-May) after overwintering in FCRPS reservoirs or tributaries to FCRPS reservoirs. Steelhead passage at the upper Columbia River dams (Priest Rapids – Wells) is earlier, on average, than at the Snake River dams. Peak dates in the upper Columbia River are typically from early to mid-September and many fish pass in August. Migration timing differences for the aggregate runs at upper Columbia versus Snake River dams reflect differences in run timing for individual populations (Snake River has late-run, B-group fish, for example) but also cooler summer-fall water temperatures in the upper Columbia River relative to the Snake River and consequently fewer temperature-related migration delays.

Timing of life history types – Early literature on the evolution of steelhead life history types, the A- and B-group management designations, and population-specific migration timing can be found in Howell et al. (1985), Busby et al. (1996), Robards and Quinn (2002), and Brannon et al. (2004). These documents also describe, to varying degrees, the changes in Columbia River basin steelhead population structure, relative abundance, and migration timing that have occurred in parallel with construction and operation of the FCRPS and associated changes in river discharge and water temperature.

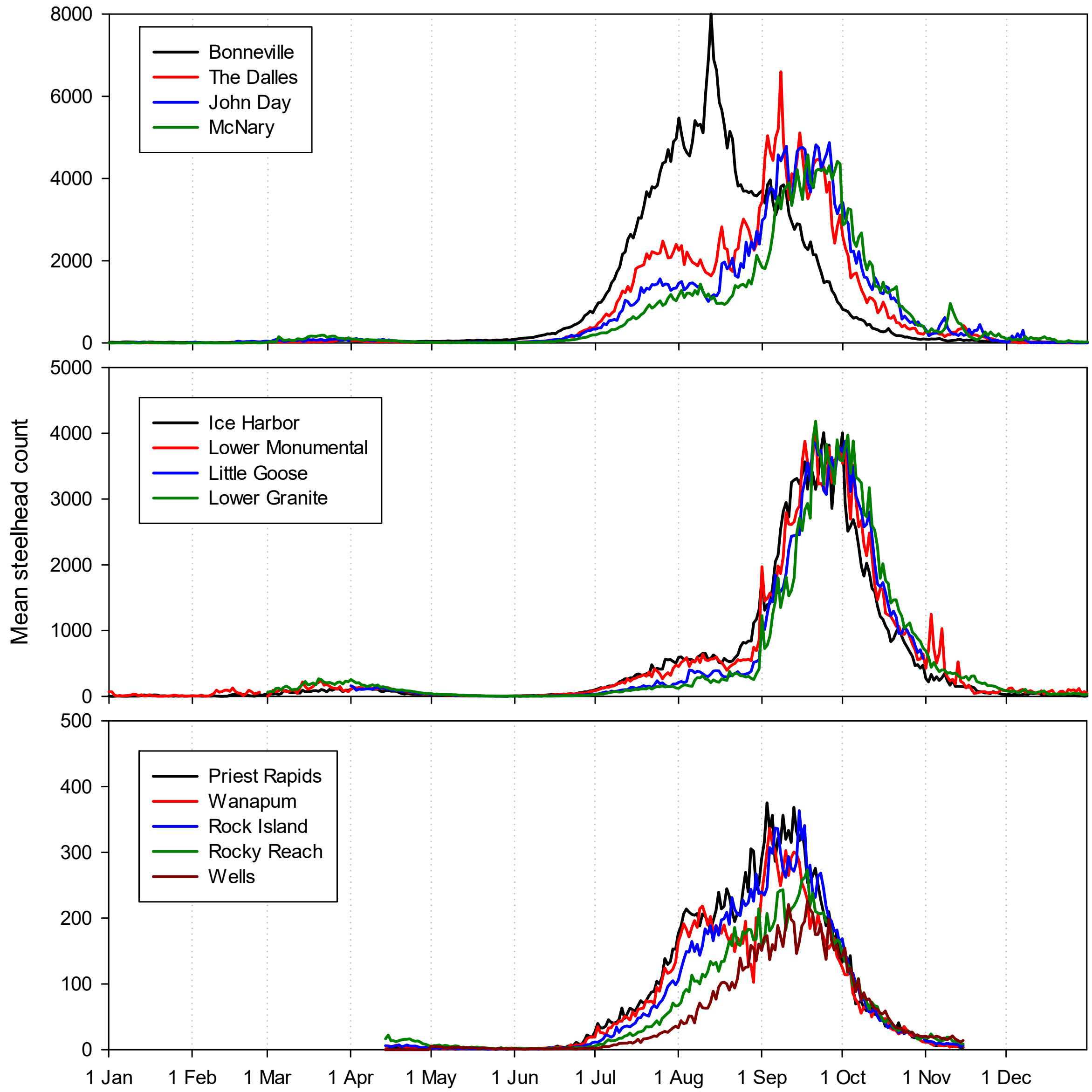


Figure 2. Mean daily adult steelhead counts at Columbia and lower Snake River dams, 2006-2015. Note that fish counting did not occur in late fall and winter at some sites and that hatchery and wild fish are combined. Source: DART (2016).

Within a calendar year, the earliest-timed summer-run steelhead pass Bonneville Dam in early spring after overwintering downstream from the dam (Washington Department of Fish and Wildlife [WDFW], *unpublished*). Excepting overwintering fish, the summer-run is considered to begin in May-June and most individuals passing at this time move rapidly through the FCRPS (Keefer et al. 2004; *Figure 3*). Most early migrants enter tributaries before the onset of potentially stressful warm water temperatures in the main stem Columbia and Snake rivers, but then have extended pre-spawn overwintering and holding behaviors in tributaries. The large group of summer-run steelhead that pass Bonneville Dam in mid- to late summer comprise the peak of the run in most years and include many mid- and upper Columbia River steelhead and most A-group Snake River steelhead. These migrants often have protracted and sometimes multi-modal passage distributions at the FCRPS dams as a result of migration delays and thermoregulatory behaviors during the warm-water period (High et al. 2006; Keefer et al. 2009; Keefer and Caudill *2015*). Nonetheless, most mid- and late summer migrants exit the FCRPS into tributaries before initiating overwintering. Lastly, summer steelhead that pass Bonneville Dam in September and October (i.e., a mix of putative A-group steelhead and almost all Snake River B-group steelhead; Fryer et al. 2012, 2013) have relatively limited exposure to the warmest FCRPS reservoir temperatures. Most therefore pass through the FCRPS quickly (Keefer et al. 2004). However, late-run fish encounter rapidly cooling reservoirs and diminishing photoperiod and are considerably more likely to overwinter in the FCRPS than the earlier-timed groups (Keefer et al. 2008a, 2015b).

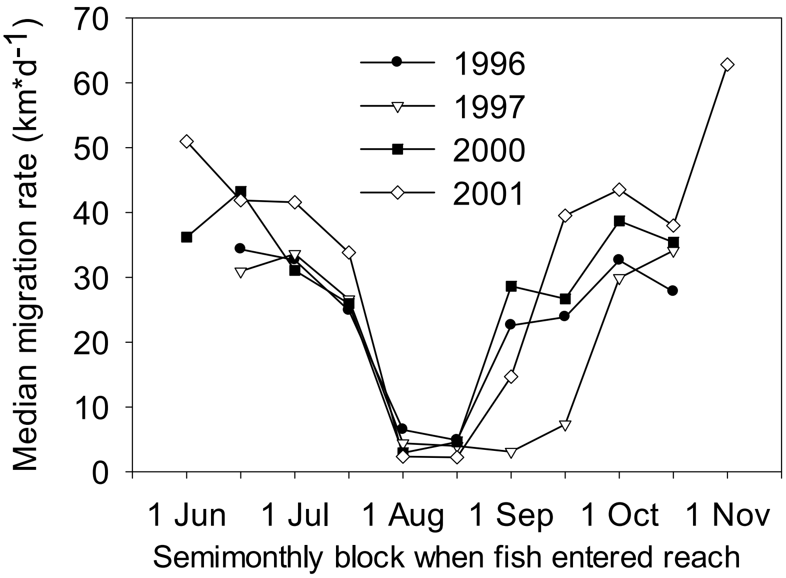


Figure 3. Median migration rates of radio-tagged summer steelhead through the Bonneville reservoir showing dramatically reduced migration speeds during the warmest period. Source: Keefer et al. (2004).

The small group of winter-run steelhead pass Bonneville Dam from late fall (~November) through spring (~May) when Columbia River discharge and water temperature are both generally low and stable. The winter-run fish spawn in tributaries to Bonneville Reservoir and they appear to have limited overwintering or pre-spawn holding behaviors in the reservoir, although data on winter-run steelhead use of the FCRPS is sparse in comparison to that of summer-run fish.

Table 2. Summary of dates when adult salmon and steelhead were not counted ('no counts') either manually or using video at FCRPS dams and dates when fish ladders were dewatered (N = North, S = South) for winter maintenance. At Bonneville Dam, counts were collected year-round and details of dewatering schedules are in the annual reports. Source: USACE Annual Fish Passage reports (2005-2014); available online at USACE digital library.

Year	Data	The Dalles[1]	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
2014	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1-31 March, 1 Nov-31 Dec	1 Jan-31 Mar	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb
	Dewater: N	4-28 Feb	29 Nov-23 Dec	6 Jan-27 Jan	10 Feb-24 Feb	6 Jan-26 Feb	-	-
	Dewater: S	1-31 Jan, 2-31 Dec	4 Jan-26 Feb	27 Jan-28 Feb	6 Jan-3 Feb	6 Feb-27 Feb	6 Jan-26 Feb	4 Jan-28 Feb
2013	No counts	1-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb
	Dewater: N	28 Jan-28 Feb	1 Jan-12 Mar, 2-19 Dec	7-24 Jan	3-10 Jan	2 Jan-11 Feb	-	-
	Dewater: S	1-21 Jan	28 Jan-12 Feb, 2-31 Dec	28 Jan-4 Mar	13 Jan-5 Mar	11-27 Feb	7 Jan-28 Feb	1 Jan-26 Feb
2012	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar2	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb
	Dewater: N	2-23 Feb	1 Jan-31 Mar, 5 Nov-31 Dec	2-16 Feb	28 Jan-22 Feb	3 Jan-7 Feb	-	-
	Dewater: S	1-31 Jan, 2-31 Dec	31 Jan-13 Feb	Not fully dewatered	3-26 Jan	26 Jan-27 Feb	3 Jan-15 Feb	4 Jan-13 Feb, 17-31 Dec
2011	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb
	Dewater: N		1-31 Jan, 7 Nov-31 Dec	15-26 Feb	3-14 Jan	4 Jan-2 Feb	-	-
	Dewater: S	1-31 Jan, 2-31 Dec	12-21 Jan	11 Jan-15 Feb	18 Jan-2 Mar	2 Feb-2 Mar	3 Jan-1 Mar	4 Jan-2 Feb
2010	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb
	Dewater: N		1 Jan-9 Apr, 7-31 Dec		4-13 Jan	5-14 Jan	-	-
	Dewater: S	1-31 Jan, 2-31 Dec	12-21 Jan	12 Jan-26 Feb	1 Jan-25 Feb	20 Jan-24 Feb	5 Jan-24 Feb	4 Jan-2 Feb

[1] South = East ladder at The Dalles

[2] Annual passage report may have error: count data were collected in March 2012

Table 2. Continued.

Year	Data	The Dalles[1]	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
2009	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb
	Dewater: N	14 Jan-4 Feb	5 Jan-17 Feb, 16 Nov-31 Dec	27 Feb	6-21 Jan	6 Jan-6 Feb	-	-
	Dewater: S	1-8 Jan, 3-31 Dec		7 Jan-27 Feb	26 Jan-25 Feb	10 Feb-2 Mar	6 Jan-24 Feb	6 Jan-2 Mar
2008	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	2 Jan-28 Feb
	Dewater: N	11-27 Feb	19-29 Feb	2 Jan-10 Feb	4-13 Feb	9 Jan-9 Feb	-	-
	Dewater: S	1 Jan-6 Feb, 2-31 Dec	1 Jan-20 Feb, 3-31 Dec	4-26 Feb	9-19 Jan	11-28 Feb	3 Jan-28 Feb	6 Jan-21 Feb
2007	No counts	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-4 Mar	1 Jan-28 Feb, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb, 16-31 Dec
	Dewater: N				3-10 Jan	3-25 Jan	-	-
	Dewater: S	4 Jan-22 Feb, 5-31 Dec	3 Jan-28 Feb, 4-31 Dec	1 Jan-4 Mar	16 Jan-14 Feb	30 Jan-26 Feb	3-25 Jan	4 Jan-25 Feb
2006	No counts	1 Jan-19 Feb, 6-31 Dec	1 Jan-19 Feb, 6-31 Dec	1 Jan-28 Feb	1 Jan-28 Feb, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb, 16-31 Dec
	Dewater: N	1-28 Feb, 6-31 Dec	1-16 Jan	13 Jan-31 Mar	31 Jan-14 Feb	3-25 Jan	-	-
	Dewater: S	1-19 Jan	24 Jan-18 Feb	10-12 Jan, 20-31 Dec	3-27 Jan	30 Jan-8 Feb	3-25 Jan	3 Jan-16 Feb
2005	No counts	1 Jan-21 Feb, 6-31 Dec	1 Jan-21 Feb, 6-31 Dec	1 Jan-28 Feb	1 Jan-28 Feb, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-31 Mar, 1 Nov-31 Dec	1 Jan-28 Feb, 16-31 Dec
	Dewater: N	2-18 Feb, 21 Jun	5-31 Dec	3-13 Jan	31 Jan-14 Feb	3 Jan-1 Mar	-	-
	Dewater: S	1-28 Jan, 5-31 Dec	10 Jan-18 Feb	18 Jan-17 Feb	3 Jan-14 Feb	10-25 Jan	3-31 Jan	3 Jan-24Feb

[1] South = East ladder at The Dalles

Upstream migration timing of individual populations – There is surprisingly limited published information on the migration timing of individual steelhead populations in the Columbia River basin. Timing at Bonneville Dam was described for 14 populations of summer steelhead by Keefer et al. (2009), who reported that median migration dates at Bonneville differed by up to two months among populations (*Figure 4*). However, there was considerable overlap among populations and each population had individuals that passed Bonneville Dam over approximately a two-month period. The earliest-timed summer-run populations were last detected at mid-Columbia and lower Snake River sites and included Hanford Reach (including Ringold Hatchery), Tucannon River, Yakima River, and Lyons Ferry Hatchery fish. The latest-timed populations were from the Clearwater and Salmon rivers. The radiotelemetry study included a mix of known-origin steelhead (based on juvenile PIT-tag sites) and unknown-origin fish. The unknown-origin fish were assigned to a population based on their last detection and some strays were likely assigned incorrectly. We think it is unlikely that incorrect assignment substantively affected timing estimates for most groups because the number of strays was typically small relative to the natal population; potential exceptions include the Deschutes and John Day River groups because these rivers are favored by steelhead strays from the Snake River (Carmichael and Hoffnagle 2006; Keefer et al. 2008b; Ruzycki and Carmichael 2010).

Migration timing of Tucannon River steelhead was assessed as part of the tributary overshoot summary by Keefer et al. (2014c). Two passage modes were evident for Tucannon River fish at both McNary and Ice Harbor dams, reflecting differences between wild fish (which tend to be later timed) and outplants from Lyons Ferry Hatchery: the first mode was in late July to early August and the second mode was in September and early October. A few late Tucannon River migrants first passed McNary Dam in late fall and some first passed Ice Harbor Dam from November through March.

There has also been little information on the timing of steelhead exit from FCRPS reservoirs into tributaries. PIT-tag interrogation antennas have been installed in lower reaches of some tributaries, but data from these sites have apparently not been systematically reported. The limited tributary entry information has been from radiotelemetry studies. For example, tributary entry timing was reported for 11 summer-run steelhead populations tagged at Bonneville Dam in 1996 (Keefer et al. 2002). Median entry dates were relatively early (most before 1 September) for fish that entered Bonneville reservoir tributaries and the Deschutes River. Entry timing was considerably later into the John Day, Umatilla, Walla Walla, Yakima and Clearwater rivers (median dates in October-December).

Unpublished tributary entry timing data from other radiotelemetry study years show that tributary entry timing varies by several months among populations, but also that some fish from most tributaries first entered in the winter or spring after likely FCRPS overwintering (*Figure 5*). We note that the data used were mostly from radio-tagged steelhead of unknown natal origin site and that temporary tributary use associated with behavioral thermoregulation (Keefer et al. 2009) was not differentiated from entry into natal sites. Temporary tributary entry was most common into Bonneville Reservoir tributaries and the Deschutes and John Day rivers and therefore tributary entry timing distributions for those sites are likely less representative of behavior by homing fish.

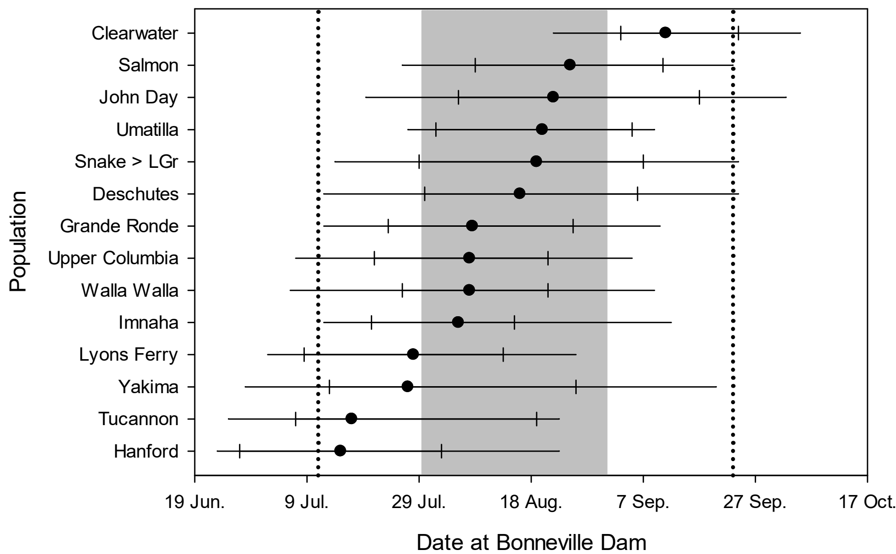


Figure 4. Population-specific summer steelhead migration timing distributions (10th, 25th, 50th, 75th, 90th percentiles) at Bonneville Dam based on radio-tagged fish. Gray-shaded area indicates water temperature ≥21 °C at Bonneville Dam. Source: Keefer et al. (2009).

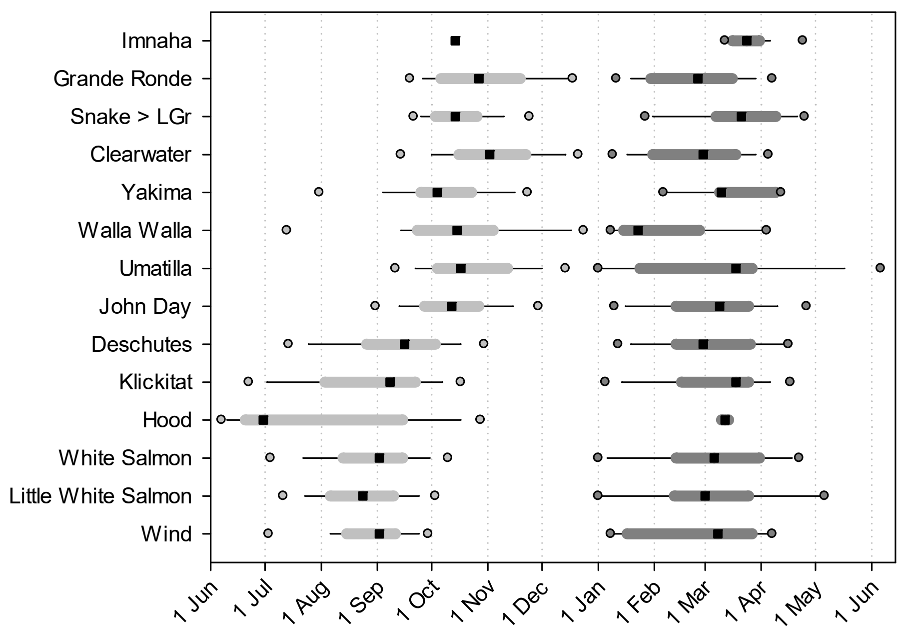


Figure 5. Distributions (5th, 10th, 25th, 50th, 75th, 90th, 95th percentiles) of the dates that radio-tagged steelhead were first detected at monitored tributaries. Summary does not differentiate steelhead that returned to natal sites from those that were temporarily using non-natal sites (most common in tributaries downstream from McNary Dam). Individual steelhead could be detected in multiple tributaries. Light gray box = first detection ≤31 December; dark gray box = first detection >31 December. Source: University of Idaho, unpublished data from steelhead tagged in 1996-1997, 2000-2004, and 2013-2014.

Upstream migration timing of repeat spawners – Although iteroparous steelhead (i.e., repeat spawners) make up a small percentage of adult summer-run steelhead in the Columbia River, there are some data on their upstream migration timing (Boggs et al. 2008; Keefer et al. 2008c). Repeat spawners that made a second migration in the same calendar year as they exited the Columbia River as kelts ('consecutive spawners') passed Bonneville, McNary, and Lower Granite dams mostly in late August and September (*Figure 6*). In contrast, the repeat spawners that made a second migration after spending a winter in the ocean ('skip spawners') migrated much earlier (July and early August), on average. This life history pattern is relatively common in populations closer to the ocean.

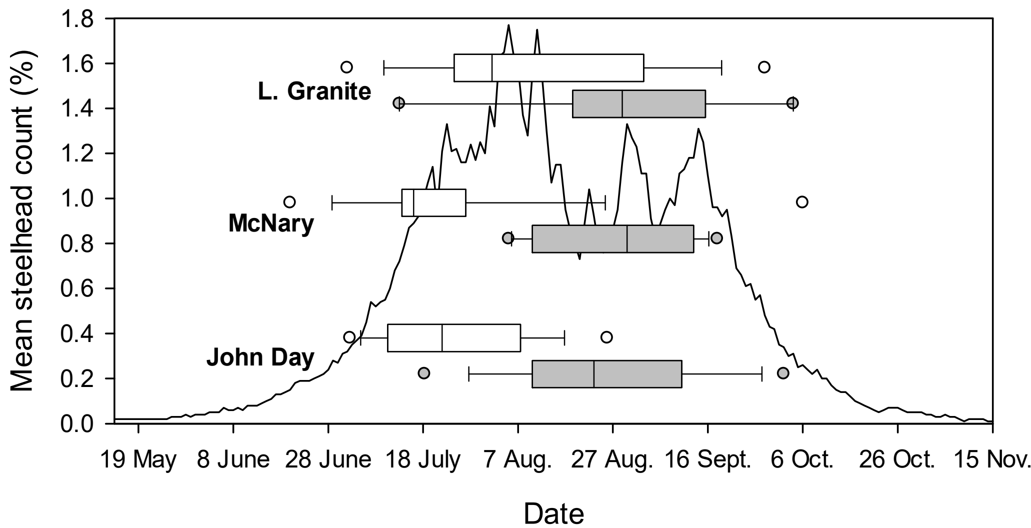


Figure 6. Migration timing distributions (5th, 25th, 50th, 75th, 95th percentiles) of consecutive-year (shaded boxes) or skip-year (open boxes) repeat spawners detected at Bonneville Dam. John Day, McNary and Lower (L) Granite were sites where mixed-populations were tagged. Source: Keefer et al. (2008c).

Upstream Migration Timing – Summary

Key findings

- Winter and early spring fishway operations and counting protocols differ among projects
- Upstream-migrant steelhead pass FCRPS dams in all months
- Small winter-run populations have distinctive timing at Bonneville Dam
- Considerable overlap in the timing of summer-run populations, but median dates vary by weeks to months
- Summer water temperatures strongly influence timing at dams upstream from Bonneville Dam
- Tributary entry timing varies among sites and occurs throughout the year

Critical uncertainties

- Population-specific migration timing summaries limited, especially for wild fish (*but see Section 3.6*)
- Data gaps are greater for wild fish than for hatchery fish in most populations
- Data limited on the timing of movement from FCRPS reservoir into tributaries
- Timing of winter-run passage at Bonneville dam is not well described, especially for wild fish
- Unknown whether there are within-population differences in timing based on age, sex or other demographics

Technical recommendations

- Use of A-run / B-run terminology and the 25 August run separation date at Bonneville should be reconsidered
- Manual or video counting of adult steelhead at main stem dams could be seasonally extended
- Installation of in-stream PIT-detection sites would provide tributary entry timing for PIT-tagged adults

2.2.2 Kelt Outmigration Timing

Steelhead kelts are annually detected passing dams on the lower Snake River and main stem Columbia River from March to July (e.g., *Figures 7 and 8*). Peak passage occurs from late April to mid-May in most but not all years (Evans et al. 2004; Keefer et al. 2008c; Colotelo et al. 2013, 2014). Differences in passage timing by population, rear-type (hatchery, wild), and sex (male, female) have been observed, demonstrating temporal variability in kelt run-timing. Kelt migration timing has also been linked to environmental conditions, with a positive relationship observed between kelt outmigration timing and tributary run-off and discharge at lower Snake River and Columbia River dams (Colotelo et al. 2013). An investigation of diel passage timing at FCRPS dams indicated that kelt passage times were uniformly distributed, with similar proportions of tagged fish passing dams on an hourly basis (Rayamajhi et al. 2013; Colotelo et al. 2013). It should be noted that results from these and other studies were largely based on kelts captured, tagged and released from juvenile bypass systems (JBS). These systems typically are not in operation until late March and therefore data on kelt passage timing may not be representative of all populations, particularly winter-run steelhead that spawn in tributaries below The Dalles Dam. An exception was the radiotelemetry study of Keefer et al. (2015b) where adults radio-tagged as prespawn migrants at Bonneville Dam were monitored as kelts after spawning in the wild. These samples, however, were weighted for late-run steelhead at Bonneville Dam and were therefore not representative of the runs overall, with a majority of identified kelts from the Clearwater River. Notably, the radio-tagged kelts had slightly earlier run timing at the Snake River dams than the samples of kelts collected at JBS facilities, suggesting that a portion of the kelt migration likely occurs prior to the operation of JBSs (*Figures 7 and 8*); annual and population-specific timing likely varies in response to river discharge and water temperatures in spawning areas.

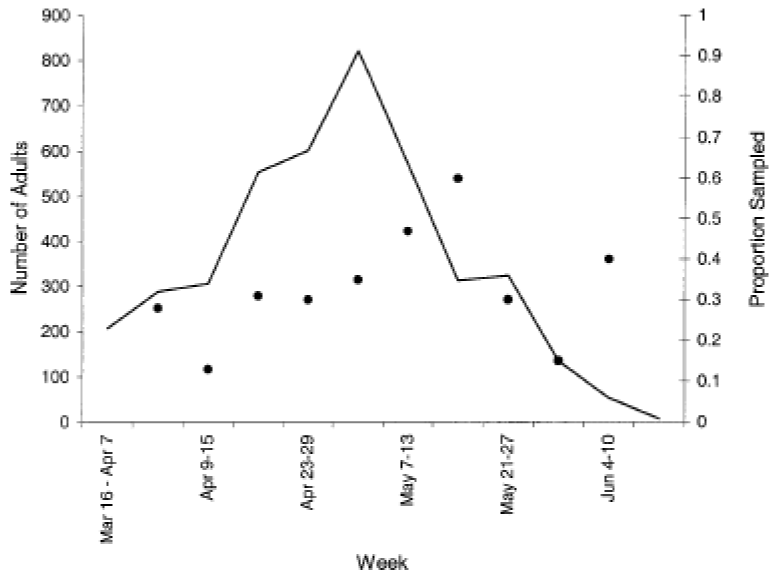


Figure 7. Weekly numbers (line) of adults steelhead encountered at the juvenile bypass facility at Lower Granite dam in 2000 (total n = 3,968). Dots are proportions sampled. Source: Evans et al. (2004). Note that some kelts may have been present before the JBSs are operated at dams and that this is an area of uncertainty.

Studies indicate that kelts are capable of traveling from Lower Granite Dam to below Bonneville Dam in less than 25 days (ranging 7 to 24 days; Colotelo et al. 2014). Within a given project (dam and reservoir combined), travel times are highly variable. For instance, Wertheimer and Evans (2005) documented kelt travel times between McNary Dam and the upper Columbia River estuary of 0.4 to 2.5 km/h in 2002, with rates of travel the fastest in the free-flow section of river below Bonneville Dam. Colotelo et al. (2014) estimated travel times of roughly 1.0 to 1.5 km/h for kelts passing Lower Granite, Little Goose, and Lower Monumental dams in 2013. Rates were considerably faster at 2.5 km/h for kelts passing McNary, John Day and The Dalles dams, and were roughly 4.0 km/h for kelts passing the free-flowing section of river downstream from Bonneville Dam in 2013. A positive relationship between river discharge and kelt travel times were observed in these studies. Finally, numerous studies (Wertheimer et al. 2005; Rayamajhi et al. 2013; Colotelo et al. 2013, 2014; Harnish et al. 2014), have noted that kelt travel times were significantly slower in the forebay regions of dams, a location were kelts maybe searching for passage routes, a milling behavior that presumably delays migration.

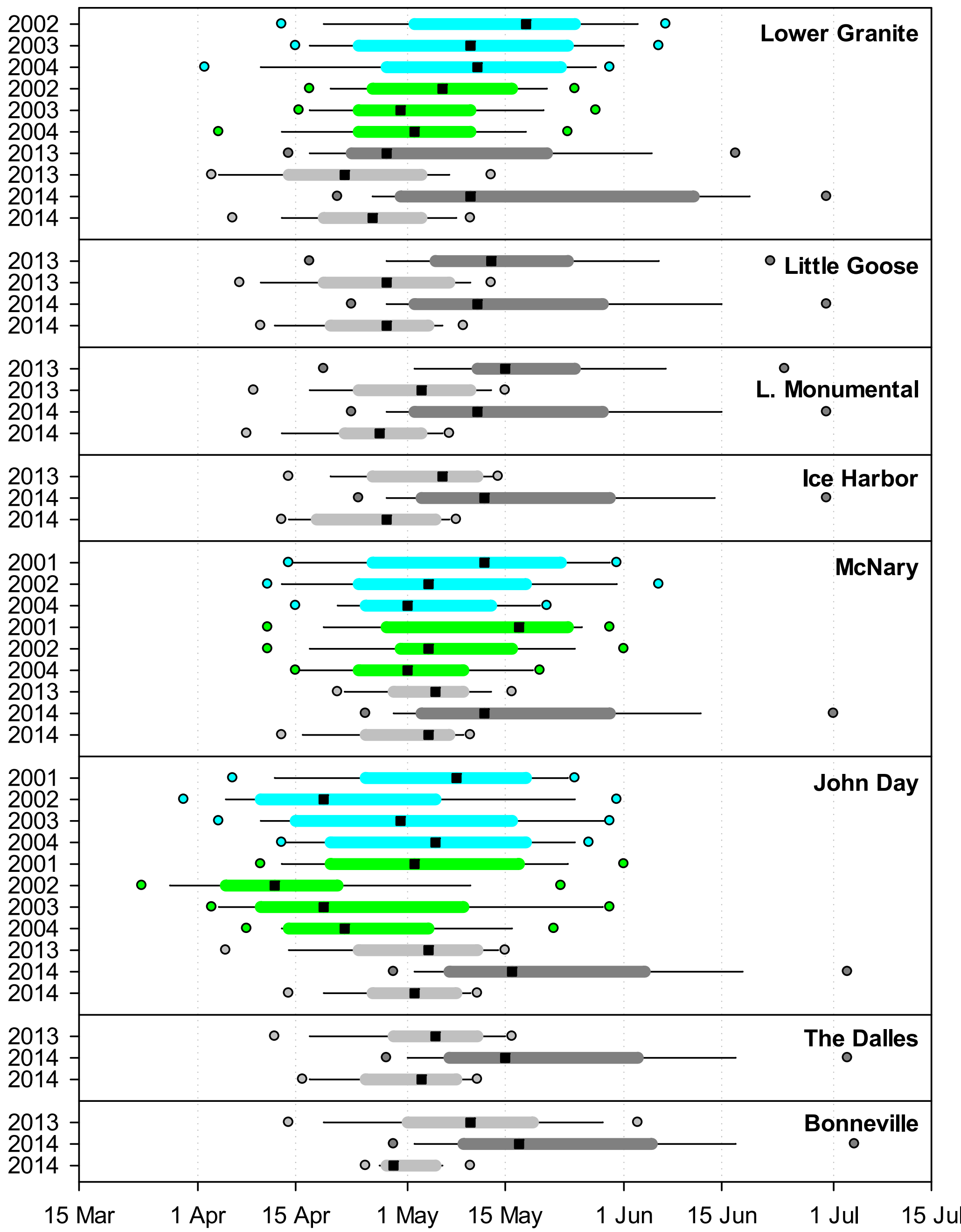


Figure 8. Distributions of dates that steelhead kelts were detected at dams. Light gray, green, and blue plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Dark gray plots have first and last dates in place of 5th and 95th percentiles. Light gray = hatchery and wild adults radio-tagged at Bonneville Dam in 2013 and 2014 that were subsequently identified as kelts; sample weighted for late-run migrants (Source: Keefer et al. 2015b). Dark gray = acoustic-tagged hatchery and wild kelts from sites upstream from Lower Granite Dam and at Lower Granite Dam in 2013 and 2014 (Source: Colotelo et al. 2013, 2014). Green = hatchery kelts examined at JBSs in 2001-2004 (Source: Keefer et al. 2008c). Blue = wild kelts examined at JBSs in 2001-2004 (Source: Keefer et al. 2008c).

Kelt Outmigration Timing – Summary

Key findings

- Kelts are present in the FCRPS from approximately March through July, with peak numbers in April-May
- Kelt outmigration timing data have been collected primarily at JBSs
- Outmigration timing varies among kelt populations, among dams as composition changes, and among years

Critical uncertainties

- Downstream passage timing via non-JBS routes is not well described
- Population-specific timing is largely unknown for all downstream passage routes
- Timing of the onset of kelt migration is poorly understood and likely varies among populations

Technical recommendations

- Earlier operation of JBSs could help identify when kelt outmigration begins in FCRPS
- Methods need to be developed to monitor kelt passage timing and frequency via non-JBS routes
- Population composition of kelts could be addressed by genetic sampling and/or increased tagging

2.2.3 FCRPS Overwintering: Rates

Almost all summer-run steelhead enter freshwater in late spring, summer or fall and consequently 'overwinter' prior to springtime spawning. The behavior presumably evolved so that steelhead could avoid migrating long distances during winter and early spring when water temperatures are low, reducing swim performance, and flow is less predictable (Robards and Quinn 2002). The onset of overwintering behavior in the Columbia River basin is apparently cued by a combination of decreasing water temperature (threshold ~8-10 °C) and reduced photoperiod (Keefer et al. 2008a). Steelhead overwinter in a variety of habitats, but deep, low-velocity areas, including reservoirs, are used preferentially. Overwintering steelhead typically have limited movement and may hold in an area for weeks to months before resuming migration. When steelhead do move in winter, it may be in response to changing environmental conditions or be associated with maturation and subsequent movement towards spawning sites.

Many adult summer-run steelhead at least partially overwinter in mixed-population assemblages in FCRPS reservoirs. Although steelhead movement in winter is limited relative to other seasons, they do exhibit a variety of volitional upstream movements (including past dams) and downstream movements (i.e., fallback) past dams in winter. The upstream movements may be inhibited or blocked when FCPRS dam fishways are dewatered for winter maintenance (see *Table 2*). Dams with fishways adjacent to both shorelines typically dewater one fishway at a time, which likely reduces but does not completely block upstream passage. However, dewatering of the single fishways at Little Goose and Lower Granite dams temporarily blocks all upstream passage. The downstream movements are a management concern because surface-flow options at FCRPS dams are typically limited from fall through early spring and some available routes, especially turbines, present higher injury and direct mortality risks for adult salmonids. Winter-time harvest in FCRPS reservoirs has not been regularly estimated.

Overwintering rate estimation – Most of the reported data on FCRPS overwintering are from radiotelemetry studies conducted in 1996-2003 and 2013-2015 (Keefer et al. 2008a, 2015b). In those studies steelhead were considered to have overwintered in the FCRPS if: (1) they passed upstream over one or more main stem dams after 31 December, or (2) they first exited a reservoir into a likely spawning tributary after 31 December. The tributary entry criterion was used to assign a majority of the radio-tagged fish to the overwintering category; notably, this criterion is only possible with a handful of locations in the PIT summary. The 31 December classification date was somewhat arbitrary, but did coincide with seasonal low water temperatures and the nadir in steelhead movement of any kind (Keefer et al. 2008a). Importantly, some steelhead pass dams and enter tributaries throughout the late fall and winter period and it can be difficult to differentiate overwintering behaviors (i.e., extended holding) from other movements.

A second challenge with estimating the percentage of steelhead that overwinter in the FCRPS is the question of what number(s) to use as the denominator. Many steelhead are harvested in reservoirs in summer and fall and including them in the denominator would result in underestimation of overwintering. The Keefer et al. (2008a) study therefore used only steelhead that successfully reached tributaries in the denominator. This likely resulted in some overestimation of overwintering percentages because fish that were harvested or died naturally during the winter period were excluded. Keefer et al. (2015b) reported two estimates: one for fish that reached tributaries (same as Keefer et al. 2008a) and a second for all fish that were released.

Overwintering rates for early- versus late-run fish – The date that radio-tagged summer steelhead entered the FCRPS was a strong predictor of whether they would overwinter in the system (*Figure 9*). In the Keefer et al. (2015b) report, FCRPS overwintering estimates for early-run steelhead were 6-8% of all tagged fish released below Bonneville Dam; the estimates increased to 9-12% of the early run when the denominators were restricted to those fish that reached tributaries. Estimates were much higher for late-run groups, at 22-27% of all fish released and 30-38% of those that reached tributaries. Note that early- and late-run did not directly correspond to A- and B-group fish in this study. The earlier overwintering study (Keefer et al. 2008a) reported FCRPS overwintering percentages by the month fish were tagged at Bonneville Dam. Estimates were ≤1% for those tagged in May or June, 6-7% for those tagged in July or August, 27% of those tagged in September, and 43% of those tagged in October (denominators were those that reached tributaries).

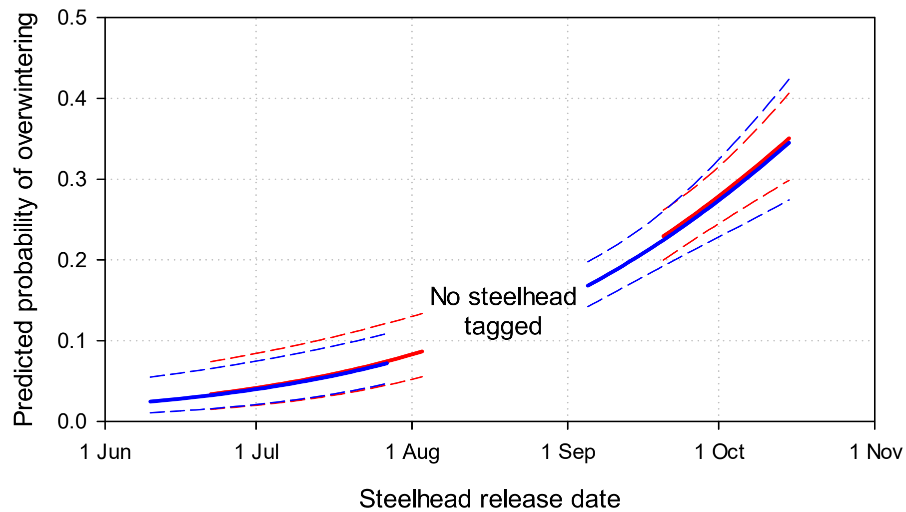


Figure 9. Predicted probability (dotted line is the 95% confidence interval) that radio-tagged steelhead would at least partially overwinter in the FCRPS in relation to release date at Bonneville Dam. Predictions were nearly identical in 2013 (red) and 2014 (blue). Source: Keefer et al. 2014b.

Overwintering rates for specific populations – Radiotelemetry studies have reported FCRPS overwintering for some individual steelhead populations, but at varying levels of geographic specificity. Keefer et al. (2008a) reported estimates for eight aggregate groups and ~20 more specific tributary stocks (*Table 3*). The overwintering estimates were: 1.6% (Lower Columbia River), 4.4% (Deschutes River), 16.0% (John Day River), 8.9% (Snake River – a mix of A-group fish mostly from southeast Washington), 46.2% (Clearwater River), 5.3% (Salmon River – all stocks), 16.1% (Yakima River), and 0.2% (Mid-Columbia River – upstream from Priest Rapids Dam). Population-specific estimates varied within major sub-basin and by month of FCRPS entry (see *Table 3*). The high FCRPS overwintering rates by Clearwater River fish reflect the increasing likelihood of overwintering with later migration timing at Bonneville Dam. This population therefore is numerically predominant in several FCRPS reservoirs, especially in the Lower Granite reservoir (see *Figure 11*); fish overwintering in the Lower Granite reservoir may be less of an FCRPS management concern than groups that overwinter further downstream because they have passed all FCRPS dams and given the proximity to the natal tributary.

Many of the steelhead in the 2013-2015 radiotelemetry study were assigned to specific hatchery populations using a genetic technique called parentage-based tagging (PBT) and both hatchery and wild fish were assigned to broader population aggregates using the regional genetic stock identification (GSI) database (Keefer et al. 2015b). Overwintering estimates for the genetically identified groups generally parallel those described above, with relatively low overwintering rates for early-run migrants and most A-group hatchery populations and relatively high overwintering rates for late-run populations, especially Clearwater River fish (*Tables 4* and *5*).

Table 3. Monthly stock- and metapopulation-specific estimates of the percentage of steelhead that overwintered in the FCRPS before returning to spawning tributaries, 1996-1997 and 2000-2003. Percentages were based on the month that steelhead were collected and radio-tagged at Bonneville Dam and demonstrate the increasing likelihood of overwintering for fish with later migration timing. Total percentages show among-population differences across months. Metapopulations follow Brannon et al. (2004). Known-origin strays were excluded (n = 63) but most fish were unknown origin site and mis-assignment was most likely for fish last detected in lower Columbia River tributaries. Source: Keefer et al. (2008a).

	Numbers of fish radio-tagged at Bonneville Dam and percentages that overwintered in the FCRPS													
	May		June		July		August		September		October		Total[1]	
Metapopulation/Stock	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Lower Columbia metapopulation														
Wind R.			7	*0.0*	5	*0.0*	17	*0.0*	8	*12.5*	1	*0.0*	38	*2.6*
Hood R.	2	*0.0*	23	*0.0*	9	*0.0*	4	*0.0*	5	*0.0*	2	*50.0*	45	*2.2*
White Salmon R.[2]			4	*0.0*	13	*0.0*	21	*0.0*	12	*8.3*			50	*2.0*
Klickitat R.	1	*0.0*	44	*0.0*	27	*0.0*	31	*3.2*	9	*0.0*	8	*0.0*	120	*0.8*
Total	**3**	***0.0***	**78**	***0.0***	**54**	***0.0***	**73**	***1.4***	**34**	***5.9***	**11**	***9.1***	**253**	***1.6***
Deschutes metapopulation			**22**	***0.0***	**71**	***5.6***	**130**	***0.8***	**64**	***4.7***	**34**	***17.6***	**321**	***4.4***
John Day metapopulation			**5**	***0.0***	**31**	***12.9***	**62**	***14.5***	**43**	***23.3***	**15**	***13.3***	**156**	***16.0***
Snake metapopulation														
Umatilla R.			4	*0.0*	17	*29.4*	17	*35.3*	10	*30.0*	1	*0.0*	49	*28.6*
Walla Walla R.			4	*0.0*	15	*26.7*	22	*22.7*	5	*0.0*	1	*0.0*	47	*19.2*
Lyons Ferry H.			6	*0.0*	15	*0.0*	9	*0.0*	2	*0.0*			32	*0.0*
Tucannon R.			7	*0.0*	10	*0.0*	12	*16.7*	2	*0.0*			31	*6.5*
Snake R.			14	*14.3*	88	*9.1*	177	*2.8*	69	*5.8*	12	*16.7*	360	*5.8*
Grande Ronde R.			9	*0.0*	66	*6.1*	109	*13.8*	37	*2.7*	2	*50.0*	223	*9.4*
Imnaha R.					11	*0.0*	17	*5.9*	2	*0.0*	2	*50.0*	32	*6.3*
Total			**44**	***4.6***	**222**	***9.5***	**363**	***9.4***	**127**	***6.3***	**18**	***22.2***	**774**	***8.9***

[1] Includes only fish that reached tributaries

[2] There is limited evidence for recent natural reproduction in the White Salmon River

Table 3. Continued.

	Numbers of fish radio-tagged at Bonneville Dam and percentages that overwintered in the FCRPS													
	May		June		July		August		September		October		Total[1]	
Metapopulation/Stock	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Clearwater metapopulation														
Clearwater R.	1	*0.0*	10	*0.0*	16	*12.5*	85	*22.4*	254	*38.6*	65	*50.8*	431	*35.3*
Dworshak Hatchery							9	*33.3*	97	*69.1*	27	*77.8*	133	*68.4*
SF Clearwater R.					1	*100.0*	18	*55.6*	66	*54.5*	23	*73.9*	108	*59.3*
Lochsa R.			1	*0.0*			11	*72.7*	56	*42.9*	7	*85.7*	75	*50.7*
Total	**1**	***0.0***	**11**	***0.0***	**17**	***17.6***	**123**	***32.5***	**473**	***47.6***	**122**	***63.1***	**747**	***46.2***
Salmon metapopulation														
Salmon R.			5	*0.0*	59	*1.7*	178	*2.2*	123	*5.7*	22	*22.7*	387	*4.4*
Little Salmon R.					10	*0.0*	20	*0.0*	16	*43.8*	5	*80.0*	51	*21.6*
SF Salmon R.					1	*0.0*	6	*0.0*	15	*0.0*	1	*100.0*	23	*4.4*
MF Salmon R.					5	*0.0*	27	*3.7*	12	*0.0*	2	*0.0*	46	*2.2*
Upper Salmon R.			1	*0.0*	12	*8.3*	48	*0.0*	26	*3.8*	7	*28.6*	94	*4.3*
Pahsimeroi Hatchery					6	*0.0*	21	*0.0*	10	*0.0*	2	*0.0*	39	*0.0*
Total			**6**	***0.0***	**93**	***2.2***	**300**	***1.7***	**202**	***7.4***	**39**	***30.8***	**640**	***5.3***
Yakima metapopulation			**6**	***0.0***	**13**	***15.4***	**5**	***0.0***	**6**	***33.3***	**1**	***100.0***	**31**	***16.1***
Mid-Columbia metapopulation[3]														
Priest Rapids-Wells			15	*0.0*	88	*0.0*	164	*0.0*	36	*2.8*	2	*0.0*	305	*0.3*
Above Wells Dam			13	*0.0*	54	*0.0*	85	*0.0*	20	*0.0*			172	*0.0*
Total			**28**	***0.0***	**142**	***0.0***	**249**	***0.0***	**56**	***1.8***	**2**	***0.0***	**477**	***0.2***
All steelhead	**4**	**0.0**	**200**	***1.0***	**643**	***5.6***	**1305**	***6.9***	**1005**	***26.5***	**242**	***42.6***	**3399**	***14.6***

[1] Includes only fish that reached tributaries

[3] 'Mid-Columbia' of Brannon et al. (2004) is synonymous with upper Columbia

Table 4. Numbers of radio-tagged steelhead in the early and late 2013 and 2014 samples that were assigned to specific hatcheries using parentage-based genetic tagging (PBT) and that met the 1 January criteria for at least partial overwintering in the FCRPS. The estimated overwintering percentages (in parentheses) were calculated for all released fish and are likely underestimates. Source: Keefer et al. (2015b).

	2013 Early		2013 Late		2014 Early		2014 Late	
PBT Hatchery	PBT (*n*)	Overwinter *n* (%)	PBT (*n*)	Overwinter *n* (%)	PBT (*n*)	Overwinter *n* (%)	PBT (*n*)	Overwinter *n* (%)
Pahsimeroi	14	-	44	10 (22.7)	12	-	35	3 (8.6)
Oxbow	1	-	8	2 (25.0)	10	-	14	1 (7.1)
Sawtooth (EFSR)			6	2 (33.3)			6	1 (16.7)
Sawtooth (IDFG & SBT)	4	-	41	3 (7.3)	5	-	27	-
Sawtooth (USB/Squaw)			2	-			6	-
Dworshak/C.W.			323	108 (33.4)			310	96 (31.0)
Little Sheep Cr. F.H.			2	-			3	-
Wallowa F.H.	2	-	27	5 (18.5)	1	-	12	-
Lyons Ferry (Cottonwood)	2	1 (50.0)	7	1 (14.3)	3	-	3	-
Lyons Ferry (Touchet)					1	-		
Lyons Ferry	20	-			14	-	7	-
Total assigned	43	1 (2.3)	460	131 (28.5)	46	0 (0.0)	423	101 (23.9)
Total radio-tagged[1]	169	13 (7.7)	620	170 (27.4)	208	12 (5.8)	592	131 (22.1)
Unassigned[1]	*126*	*12 (9.6)*	*160*	*39 (24.4)*	*162*	*12 (7.4)*	*169*	*30 (17.8)*

Table 5. Numbers of radio-tagged steelhead in the early and late 2013 and 2014 samples that were assigned to genetic stock identification (GSI) reporting groups and that met the 1 January criteria for at least partial overwintering in the FCRPS. The estimated overwintering percentages (in parentheses) were calculated for all released fish and are likely underestimates. Source: Keefer et al. (2015b).

	2013 Early		2013 Late		2014 Early		2014 Late	
GSI group	GSI (*n*)	Overwinter *n* (%)	GSI (*n*)	Overwinter *n* (%)	GSI (*n*)	Overwinter *n* (%)	GSI (*n*)	Overwinter *n* (%)
02_LOWCOL							1	-
03_SKAMAN	7	-			13	-	1	-
04_WILLAM			1	-	1	-		
06_KLICKR	1	-			10	-	3	-
07_MGILCS	106	12 (11.3)	92	19 (20.6)	121	11 (9.1)	68	7 (10.3)
08_YAKIMA	3	-	1	-	3	-	1	-
09_UPPCOL	11	-	4	-	8	-	7	-
10_SFCLWR			351	116 (33.0)			352	103 (29.3)
11_UPCLWR			17	7 (41.2)	1	-	30	10 (33.3)
12_SFSALM			4	1 (25.0)	1	-	8	1 (12.5)
13_MFSALM	1	-	1	-			7	-
14_UPSALM	36	1 (2.8)	121	18 (14.9)	45	1 (2.2)	98	5 (5.1)
Total assigned	165	13 (7.9)	592	161 (27.2)	203	12 (5.9)	576	126 (21.9)
Total tagged	169	13 (7.7)	620	170 (27.4)	208	12 (5.8)	592	131 (22.1)
Unassigned	*4*		*28*	*9 (32.1)*	*5*		*16*	*5 (31.2)*

LOWCOL =Lower Columbia; SKAMAN = Skamania; WILLAM =Willamette; KLICKR =Klickitat; MGILCS = Middle Columbia, including Deschutes, John Day, Lower Snake, Grande Ronde, Imnaha, and lower Clearwater/Salmon; YAKIMA = Yakima; SFLCWR = South Fork Clearwater; UPCLWR = Upper Clearwater, including Lochsa and Selway; SFSALM = South Fork Salmon; MFSALM = Middle Fork Salmon; UPSALM = Upper Salmon

FCRPS Overwintering: Rates – Summary

Key findings

- FCRPS overwintering estimates: ~6-12% of early run, ~22-38% of late run
- FCRPS overwintering rates substantially vary among populations
- Individual probability of FCRPS overwintering is positively correlated with migration date at Bonneville

Critical uncertainties

- Rate estimates are sensitive to how overwintering onset is defined
- Rate estimates are sensitive to how harvest and mortality is treated in denominators
- There may be behavioral differences between wild and hatchery fish
- Winter harvest rates in FCRPS reservoirs have not been regularly quantified
- Effects of fishway closures on FCRPS overwintering rates is unknown

Technical recommendations

- Better population-specific estimates would help guide management decisions
- Clear definitions for FCRPS overwintering (e.g., start and end timing, duration, etc.) are needed

2.2.4 FCRPS Overwintering: Locations

Radiotelemetry studies provided information on the spatial distribution of overwintering steelhead among the FCRPS reservoirs. Three broad-scale patterns were evident from these data. First, steelhead tended to overwinter in FCRPS reservoirs that were near their natal river confluences than at more distant sites, though this was not true for all groups (*Figure 10*). Second, the overwintering group in each reservoir included steelhead from a diverse mix of populations (*Figure 10*). Third, steelhead were least likely to move upstream or downstream within the FCRPS or to exit reservoirs into tributaries between December and February, but some fish moved in each direction in all months (*Figure 11*).

Bonneville, The Dalles, John Day, and McNary Reservoirs – Very few radio-tagged steelhead were recorded as overwintering in the Bonneville reservoir in either the 1996-2003 study (*Figure 10*) or the 2013-2015 study (*Figure 11, Tables 6* and *7*). Composition in the Bonneville reservoir primarily included fish from the Deschutes and John Day rivers, plus small numbers from hatcheries in the Salmon and Grande Ronde River basins (Keefer et al. 2008a, 2015b).

In the 1996-2003 radiotelemetry study, approximately 5-10% of FCRPS-overwintering steelhead from the John Day, Clearwater, Snake, and Salmon samples overwintered in The Dalles reservoir. Slightly higher percentages (~10-25%) of the FCRPS-overwintering fish from the Clearwater, Snake and Salmon samples overwintered in the John Day reservoir and ~5-20% overwintered in the McNary reservoir (*Figure 10*). There were several examples of the natal tributary proximity effect: a majority (~70%) of the Deschutes River steelhead that overwintered in the FCRPS were in The Dalles Reservoir; ~20-30% of the John Day River steelhead that overwintered were in the John Day, The Dalles, or McNary reservoirs; and >80% of the Umatilla and Walla Walla steelhead that overwintered were in the John Day or McNary reservoirs. Results from the 2013-2015 study largely corroborated these patterns (*Tables 6* and *7*); however, there were relatively few fish tagged from the early portions of the 2013-2014 runs resulting in small sample sizes for several populations, especially those outside of the Clearwater River basin.

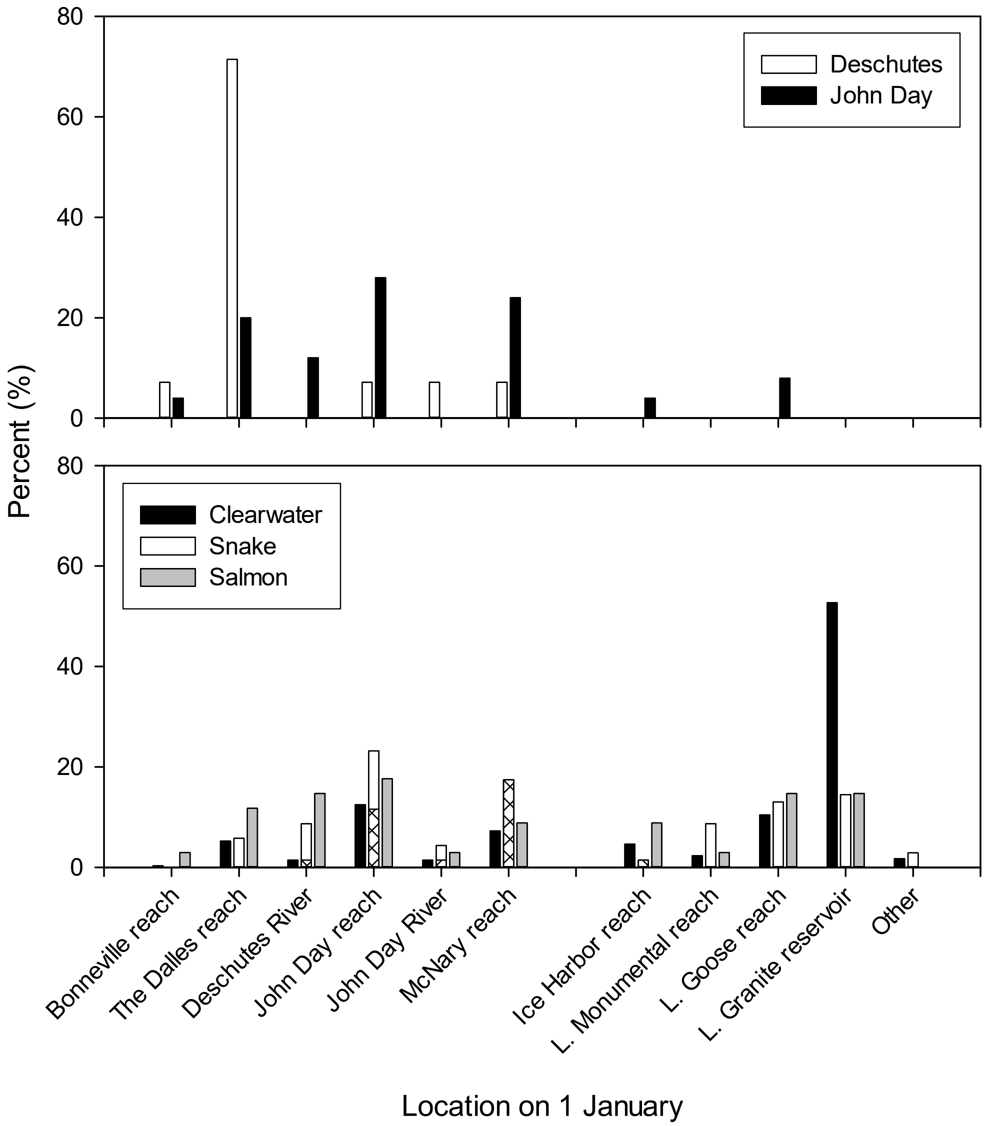


Figure 10. Estimated locations where overwintering steelhead were in the FCRPS on 1 January for two sets of steelhead: Deschutes and John Day rivers (top) and Clearwater, Salmon, and Snake populations (bottom). The Snake population is split into lower (Umatilla, Walla Walla, hashed bars) and upper (Tucannon, Snake, Grande Ronde, Imnaha; open bars) groups. Source: Keefer et al. (2008a).

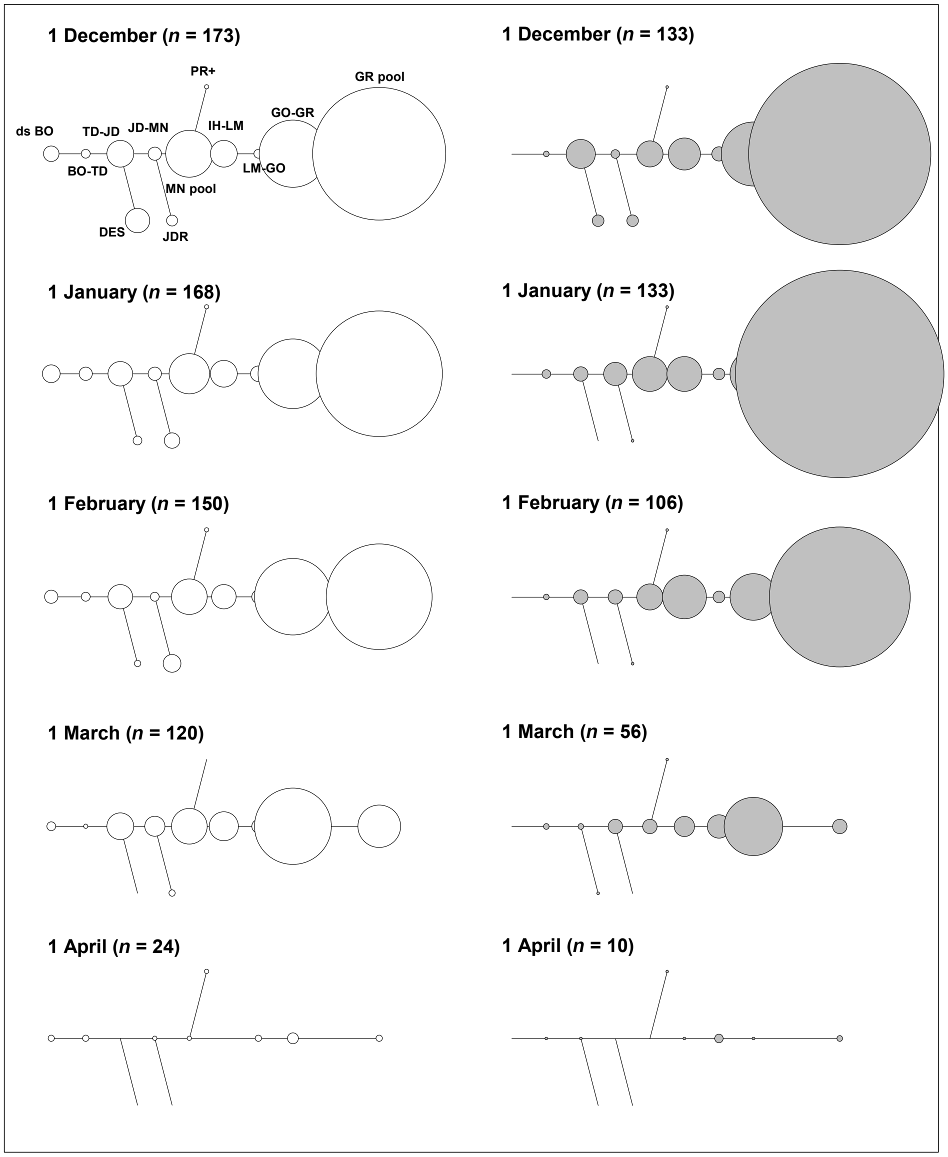


Figure 11. Estimated locations where overwintering steelhead were in the FCRPS on the first of each month from December 2013 to April 2014 (left) and from December 2014 to April 2015 (right). Circle size scaled relative to abundance. Note that samples were weighted for late-run fish and that Clearwater River steelhead were abundant in the Lower Granite reservoir. Source: Keefer et al. (2015b).

Table 6. Number (percent) of overwintering steelhead identified to hatchery stock using parentage-based tagging (PBT) by the river reach where they were located on 1 January 2014 (collected and radio-tagged in 2013) and 1 January 2015 (collected and radio-tagged in 2014). Fish that lost transmitters or had non-functioning transmitters were excluded because their locations were less clear. Source: Keefer et al. (2015b).

	Location on 1 January 2014					Location on 1 January 2015			
Overwintering site	Dworshak	Pahsimeroi	Sawtooth-All sites	Oxbow / Wallowa	Cottonwood	Dworshak	Pahsimeroi	Sawtooth-EFSR	Oxbow
n	100	10	5	6	2	92	2	1	1
Below Bonneville		3 (30.0)	1 (20.0)	2 (33.3)					
Bonneville-The Dalles	4 (4.0)	1 (10.0)	1 (20.0)			2 (2.2)	1 (50.0)		
The Dalles-John Day	9 (9.0)					2 (2.2			
Deschutes River	3 (3.0)	1 (10.0)		1 (16.7)					
John Day-McNary	3 (3.0)		1 (20.0)			4 (4.3)			
John Day River	3 (3.0)								
McNary pool	5 (5.0)	1 (10.0)	1 (20.0)	1 (16.7)	1 (50.0)	6 (6.5)			
>Priest Rapids				1 (16.7)			1 (50.0)		
Ice Harbor-L. Monumental	7 (7.0)	1 (10.0)				7 (7.6)		1 (100)	
L. Monumental-Little Goose	6 (6.0)	1 (10.0)				1 (1.1)			1 (100)
Little-Goose-Lower Granite	18 (18.0)	2 (20.0)	1 (20.0)	1 (16.7)		13 (14.1)			
Lower Granite pool	42 (42.0)				1 (50.0)	57 (62.0)			

Table 7. Number (percent) of overwintering steelhead identified to 'reporting groups' using genetic stock identification (GSI) by the river reach where they were located on 1 January 2014 (collected and radio-tagged in 2013) and 1 January 2015 (collected and radio-tagged in 2014). Fish that lost transmitters or had non-functioning transmitters were excluded because their locations were less clear. Source: Keefer et al. (2015b).

	Location on 1 January 2014					Location on 1 January 2015				
Overwintering site	MGILCS	SFCLWR	UPCLWR	SFSALM	UPSALM	MGILCS	SFCLWR	UPCLWR	SFSALM	UPSALM
n	28	107	6	1	17	17	98	8	-	5
Below Bonneville	2 (7.1)				5 (29.4)					
Bonneville-The Dalles		4 (3.7)			2 (11.8)	1 (5.9)	2 (2.0)			
The Dalles-John Day	1 (3.6)	10 (9.3)				2 (11.8)	2 (2.0)			1 (20.0)
Deschutes River		3 (2.8)			2 (11.8)					
John Day-McNary		4 (3.7)			1 (5.9)	2 (11.8)	4 (4.1)			2 (40.0)
John Day River	2 (7.1)	4 (3.7)			1 (5.9)		1 (1.0)			
McNary pool	11 (39.3)	5 (4.7)	1 (16.7)		1 (5.9)	5 (29.4)	6 (6.1)	1 (12.5)		
>Priest Rapids	2 (7.1)					1 (5.9)				
Ice Harbor-L. Monumental	1 (3.6)	7 (6.5)	1 (16.7)		1 (5.9)	3 (17.6)	7 (7.1)	1 (12.5)		1 (20.0)
L. Monumental-Little Goose		6 (5.6)			1 (5.9)	1 (5.9)	1 (1.0)	1 (12.5)		1 (20.0)
Little-Goose-Lower Granite	4 (14.3)	20 (18.7)	2 (33.3)	1 (100)	3 (17.6)		14 (14.3)			
Lower Granite pool	5 (17.9)	44 (41.1)	2 (33.3)			2 (11.8)	61 (62.2)	5 (62.5)		

MGILCS = Middle Columbia, including Deschutes, John Day, Lower Snake, Grande Ronde, Imnaha, and lower Clearwater/Salmon
SFLCWR = South Fork Clearwater
UPCLWR = Upper Clearwater, including Lochsa and Selway
SFSALM = South Fork Salmon River
UPSALM = Upper Salmon

Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs – Small percentages (~2-8%) of the overwintering radio-tagged steelhead were in the Ice Harbor and Lower Monumental reservoirs (*Figure 10*) in the early study (Keefer et al. 2008a). Notably, however, some fish from the John Day, Umatilla, and Walla Walla rivers did spend part of the winter in the Snake River reservoirs. Proportionately more fish were in the Little Goose reservoir, including ~10-15% of overwintering fish from the Clearwater, Snake, and Salmon samples. The Lower Granite reservoir was also used by many overwintering fish from these tributaries, but especially by Clearwater River steelhead. More than 50% of the Clearwater fish that overwintered in the FCRPS were in the Lower Granite reservoir for several weeks or more, especially in December-February; many of these fish first entered the Clearwater River in February. The 2013-2015 study, when samples were intentionally weighted for late-run fish, further highlighted the use of Lower Granite reservoir by Clearwater River steelhead (*Figure 11, Tables 6 and 7*). Between 46-62% of genetically-assigned Dworshak Hatchery steelhead, and 41-62% of steelhead assigned to the South Fork and Upper Clearwater genetic stock identification (GSI) reporting groups, were in the Lower Granite reservoir on 1 January and remained there for several weeks or more (Keefer et al. 2015b). Many of the Clearwater River fish passed Lower Granite Dam in the fall but were assigned to the FCRPS overwintering category because they were first detected entering the Clearwater River after 1 January.

FCRPS Overwintering: Locations – Summary

Key findings

- Some steelhead overwinter in all FCRPS reservoirs
- Steelhead tend to overwinter in reservoirs closest to natal tributaries, though there are many exceptions
- Largest proportion overwinters in Lower Granite reservoir, especially among late-run populations

Critical uncertainties

- Unknown whether adult fishway closures affect the distribution of overwintering fish
- Steelhead movements among reaches and into tributaries complicates distribution summaries
- Data limited on many populations, especially from early-run and wild groups
- Not clear which FCRPS habitats (e.g., tailraces, forebays, confluence areas, main reservoir) are used

Technical recommendations

- Active telemetry combined with known-origin fish provides best spatial data

2.2.5 FCRPS Overwintering: Timing

Both radio- and PIT-tagged steelhead generate time-stamped data that identify when steelhead pass dams and enter reservoirs, and these dates can potentially be used to estimate the onset of FCRPS overwintering if fish do not pass the next upstream site. However, we did not find onset timing metrics reported for specific river reaches or reservoirs in Corps-funded reports. Rather, Keefer et al. (2008a) reported that many tagged steelhead stopped moving in November, when reservoir temperatures were ~8-12° C, while others continued to migrate at the lowest recorded temperatures. In other words, there was no clear threshold temperature for the onset of overwintering. The nadir in upstream movement occurred in the first half of January (temperatures ~4-5° C), when ~2% of tagged steelhead passed a dam. The nadir of all steelhead movement (upstream, downstream, into tributaries) was in the second half of December (temperatures ~4-6° C).

FCRPS Overwintering: Timing – Summary

Key findings

- Indirect evidence for a temperature (~8-12 °C) or photoperiod threshold for the onset of overwintering
- Nadir in steelhead movements in December-January at temperatures ~4-5 °C

Critical uncertainties

- Overwintering onset and migration resumption timing uncertain
- Causal mechanisms (e.g., environmental cues) for overwintering onset and migration resumption uncertain
- Unknown whether movement thresholds or cues differ among populations

Technical recommendations

- Existing databases could be mined to test overwintering mechanism hypotheses
- FCRPS operational decisions should integrate information on steelhead movement timing

2.2.6 FCRPS Overwintering: Survival

Estimating survival and pre-spawn mortality has been difficult for all types of tagging studies used to monitor adult steelhead in the Columbia Basin. The primary challenge is that only a small proportion of tagged fish are physically recaptured following release, making it difficult to determine a final fate. This is particularly true for wild fish. The most common proxy for survival has been fish detection in a known spawning tributary at an appropriate time (i.e., 'survival to tributaries'), but tributary entry often precedes spawning by several months and the relationship between entry and reproductive success is poorly understood.

Tagged steelhead that are neither recaptured nor detected in spawning tributaries could have a variety of fates. These include pre-spawn mortality in the main stem Columbia or Snake, unreported harvest mortality, undetected entry into monitored tributaries, entry into unmonitored tributaries, and spawning in main stem habitats. Previous radiotelemetry studies have estimated overwintering survival by partitioning apparent fates into at least three categories: (1) successful tributary entry; (2) reported main stem harvest; and (3) unknown fate/unaccounted for. The latter fate is a catchall term for fish last detected at FCRPS dams or in reservoirs with no evidence of tributary spawning. Unknown fate/unaccounted for fate assignments represent mortality, unreported harvest, and undetected tributary entry.

Radiotelemetry studies – The two FCRPS overwintering studies that used radiotelemetry each provided survival-to-tributary estimates. Keefer et al. (2008a) reported that ~82% of the steelhead that met criteria for FCRPS overwintering eventually reached tributaries. Reported harvest was ~4% and the remaining ~14% were last detected at FCRPS dams or in reservoirs and were considered unaccounted for. The harvest estimate was described as a minimum estimate, because additional steelhead were reported harvested by anglers after 1 January, but those fish were excluded from the overwintering analyses because they did not meet FCRPS overwintering criteria (i.e., they neither passed a dam nor entered a tributary after 31

December). The maximum reported winter harvest estimate was ~12%, with most of the fisheries mortality reported from the John Day, Lower Granite, McNary, and Lower Monumental reservoirs. Both fishing mortality and overall steelhead mortality were lower during the overwintering period than during active migration in summer and fall, largely due to a much larger and more dispersed fishery effort in summer and fall relative to during the winter.

The 2013-2015 overwintering study included a disproportionate number of late-run steelhead and therefore survival results were not directly comparable to the earlier study. Overwintering survival was estimated to be 91-92% (Keefer et al. 2015b), and thus just 8-9% of the FCRPS overwintering fish were last detected at dams or in reservoirs, with 2-6% in the lower Columbia River and 3-6% in the lower Snake River. The preponderance of Clearwater River steelhead in the FCRPS overwintering group resulted in concentrations of fish in the Little Goose and Lower Granite reservoirs (*Figure 11*). The close proximity of overwintering fish to the Clearwater River–Snake River confluence required limited movement to enter the natal tributary, and this certainly contributed to the high survival estimates. Furthermore, many of the Clearwater fish did not pass a dam after 31 December, but rather were in the FCRPS overwintering category because they entered the Clearwater River after 31 December. Some fish harvested in the lower Snake River reservoirs during winter were therefore likely excluded from analyses.

FCRPS Overwintering: Survival – Summary

Key findings

- Survival to tributaries by radio-tagged FCRPS-overwintering fish was ~82-92%
- Fish not detected in tributaries (non-survivors) were distributed throughout the FCRPS
- Winter harvest estimates were ~4-12%, much lower than during summer and fall migration

Critical uncertainties

- True fates of fish that did not reach tributaries were unknown except for reported harvest
- Very little population-level survival data because early radiotelemetry studies used unknown-origin fish

Technical recommendations

- Genetic sampling from winter creel surveys could help identify population composition of overwintering fish
- Targeted studies using known-origin steelhead may reduce uncertainty

2.2.7 Tributary Overshoot: Percentages

Data from PIT-and radio-tagged adult steelhead have shown that portions of several populations migrate past their natal tributaries ('overshoot'). Many of these fish pass upstream FCRPS dams and then must fall back downstream past dams to complete homing (Bumgarner and Dedloff 2011; Murdoch et al. 2012; Keefer and Caudill 2014a). The downstream fallback often occurs in winter or spring as maturing fish seek natal spawning sites. Tributary overshoot behavior has also been associated with high rates of permanent straying and is therefore a concern for both the populations that lose fish to straying and populations that gain non-native strays (Keefer and Caudill 2014a). Reported behaviors vary widely among individuals and among populations, presumably because a variety of cues may stimulate overshoot behavior, including the main stem river environment, conditions in the natal tributary, or failures in fish orientation (i.e., missed detection of the natal tributary).

Tributary overshoot has rarely been an explicit objective of Corps-funded research. Instead, most tributary overshoot summaries have been compiled by state agency or hatchery personnel and reports have targeted specific populations such as Lyons Ferry Hatchery steelhead or John Day River wild steelhead.

Radiotelemetry studies – Tributary overshoot was reported for radio-tagged summer steelhead by Boggs et al. (2004, 2005) as part of an evaluation of adult steelhead fallback at FCRPS dams. There were several limitations to these analyses. First, most steelhead were of unknown origin site, so entry into a downstream tributary suggested tributary overshoot and return, but could also have been evidence of permanent straying or harvest of wandering fish. Second, results substantially underestimate total overshoot behavior because steelhead that overshot their natal tributary but did not fall back at a dam could not be identified. The reported radiotelemetry results do, however, provide an estimate of the percentage of all fallback events that were overshoot-related events. This metric is much different than the percentage of a population that overshot their natal site and then fell back, but does provide an indication of how much fallback may be overshoot-related.

Boggs et al. (2004) reported results from 1996-1997 and 2000-2001. The percentages of all pre-spawn fallback events attributed to tributary overshoot were: 16% (fallback events at The Dalles Dam), 17% (John Day Dam), 26% (McNary Dam), 19% (Ice Harbor Dam), 11% (Lower Monumental Dam), 11% (Little Goose Dam), and 9% (Lower Granite Dam). The follow-up report (Boggs et al. 2005) included overshoot data for 1996-1997 and 2000-2003. The annual range of fallback events attributed to tributary overshoot was: 0-11% (fallback events at The Dalles Dam), 3-26% (John Day Dam), 18-54% (McNary Dam), 7-26% (Ice Harbor Dam), 0-29% (Lower Monumental Dam), 4-25% (Little Goose Dam), and 0-22% (Lower Granite Dam). Lastly, a brief evaluation in 2000-2001 estimated that ~57% of radio-tagged steelhead that fell back through juvenile bypass systems had likely overshot natal tributaries; most of the fish were last detected downstream from John Day or McNary dams in the Umatilla, John Day, or Deschutes rivers (Jepson et al. 2004).

PIT-tag studies – The largest summary of overshoot behavior by PIT-tagged steelhead was reported by Murdoch et al. (2012) for the 2009-2011 migration years. The analysis was presented in the context of adult steelhead wandering and straying behaviors and steelhead use of cool water refuge areas. Focal upstream detection sites were Ice Harbor, Lower Granite, and Priest Rapids dams. In one summary, Murdoch et al. (2012) showed the population composition of overshoot steelhead detected at the three dams. The group at Priest Rapids Dam included individuals from 14 populations or population aggregates (*Figure 12*). The largest overshoot contributors were the 'Snake River' (presumably juveniles that were PIT-tagged at Lower Snake River dams), the Imnaha River, the Yakima River, and the Tucannon River. A similar summary for Ice Harbor Dam showed that the majority (64%) of overshoot steelhead there were from the John Day River; 30% were from the Walla Walla River and several other populations were represented by small numbers of fish. Overshoot composition at Lower Granite Dam was 42% John Day River, 37% Tucannon River, and 17% Walla Walla River fish. Note that composition estimates reflect, at least in part, the relative number of available PIT-tagged fish rather than the actual composition of the overshoot group. Murdoch et al. (2012) also calculated the mean percentages of PIT-tagged wild steelhead that overshot their natal tributaries for several populations. Estimates were: 63% (John Day River), 49% (Walla Walla River), 15% (Yakima River), and 67% (Tucannon River).

Steelhead overshoot of the Tucannon River was also addressed by Bumgarner and Dedloff (2011) as part of a Lyons Ferry Hatchery evaluation. In 2004-2008, overshoot by Tucannon River steelhead past Lower Granite Dam averaged 63-66% for the three primary study groups (wild Tucannon, Tucannon Hatchery, and Tucannon outplants from Lyons Ferry Hatchery) (*Table 8*). Approximately a quarter of the Tucannon River steelhead that passed Ice Harbor Dam eventually entered the Tucannon River. The authors noted that PIT monitoring interruptions reduced the precision of some estimates. A very similar result was reported for PIT-tagged Tucannon River steelhead in 2013, when 66% of adults were detected at Lower Granite Dam (Keefer et al. 2014c).

Bumgarner and Dedloff (2011) also reported tributary overshoot by PIT-tagged Walla Walla River steelhead, though using slightly different methods than for the Tucannon River groups. Estimates of Walla Walla steelhead overshoot ranged from 45-83% past Ice Harbor Dam and from 9-30% past Lower Granite Dam (*Table 9*). Few Walla Walla River steelhead eventually returned to the Walla Walla River (~6-30% of the various study groups), although PIT detection systems reportedly had limited or low efficiency in some years. A single-year study of PIT-tagged steelhead from Fifteenmile Creek estimated that 79% overshot the creek and passed The Dalles Dam (Poxon et al. 2014).

Middle Columbia Wild Adult Steelhead Tributary Bypass Workshop – This workshop included a series of presentations directly related to tributary overshoot behavior by adult steelhead. The terms ‘tributary bypass’ and ‘tributary overshoot’ were used synonymously at the workshop. It appears that few of the data presented at the workshop have been reported in agency documents or in peer-reviewed papers, but the presentations provide a variety of useful behavioral information. Targeted steelhead populations included: Hood River, Fifteenmile Creek, Klickitat River, Rock Creek, John Day River, Umatilla River, Walla Walla River, Lyons Ferry Hatchery, and Tucannon River. Presentations from the workshop are available at: www.dfw.state.or.us/fish/crp/mid_columbia_river_plan_WASTB_workshop.asp.

Table 8. Detections of PIT tagged Tucannon endemic stock, Tucannon natural stock, and Lyons Ferry hatchery stock summer steelhead released into the Tucannon River that passed Ice Harbor Dam (IHR) and overshot the Tucannon River past Lower Granite Dam (LGR). Source: Bumgarner and Dedloff (2011).

								Percent of those that passed Ice Harbor Dam		
Migration Year	# Pass IHR	# Pass LGR	#Entered Tucannon	Unknown Location	# Back to Tucannon from LGR [a]	% Back to Tucannon from LGR	Total into Tucannon	% into Tucannon	% above LGR	% Unknown
Tucannon Endemic hatchery stock summer steelhead										
2004	48	30	11	7	5	16.7	16	33.3	52.1	14.6
2005	55	35	17	3	8	22.9	25	45.5	49.1	5.5
2006	105	69	18	18	16	23.2	34	32.4	50.5	17.1
2007	120	77	10	33	4	5.2	14	11.7	60.8	27.5
2008	276	263	68	66	35	13.3	103	26.1	57.7	16.7
Totals	**723**	**474**	**124**	**127**	**68**	**16.2**	**192**	**26.6**	**56.2**	**17.6**
Tucannon natural stock summer steelhead										
2004	17	11	6	2	2	18.2	8	47.1	52.9	11.8
2005	20	12	6	5	3	25.0	10	50.0	45.0	25.0
2006	16	8	3	5	0	0.0	3	18.8	50.0	31.3
2007	5	3	1	1	0	0.0	1	20.0	60.0	20.0
2008	54	37	8	6	3	8.1	11	20.4	63.0	11.1
Totals	**112**	**71**	**24**	**19**	**8**	**11.3**	**33**	**29.5**	**56.3**	**16.9**
Lyons Ferry hatchery stock summer steelhead (released into the lower Tucannon River)										
2006	318	229	54	35	44	19.2	98	30.8	58.2	11.0
2007	176	90	37	49	7	7.8	44	25.0	47.2	27.8
2008	121	898	4	16	10	11.2	16	13.2	65.3	13.2
Totals	**615**	**408**	**95**	**100**	**61**	**12.7**	**158**	**23.0**	**56.9**	**17.4**

[a] The Tucannon River PIT tag array was taken out by high stream flow in January, 2009. Two salt returns from the 2006 migration year, and 1-salt returns from the 2007 migration year, that entered the Tucannon River after the array was destroyed could not be added to the table. Therefore, the percent of fish in the Tucannon, above Granite, or Unknown destination for the 2006 and 2007 migration years are under or over-estimates depending on location. Numbers provided are current through December 22, 2010.

Table 9. Detections of PIT tagged Touchet River endemic stock summer steelhead, and Lyons Ferry stock summer steelhead (Walla Walla and Dayton AP release groups) that crossed McNary Dam, and overshot Ice Harbor Dam (IHR) and Lower Granite Dam (LGR). Source: Bumgarner and Dedloff (2011).

Migration Year	# Passed McNary	# Entered Walla	# Strayed above IHR	# Strayed above LGR	# Entered Tucannon [a]	# Entered Tucannon Mar-Apr [c]	Percent of those that passed McNary Dam [b] % into Walla2	% above IHR	% above LGR	% into Tucannon
Touchet Endemic hatchery stock summer steelhead										
2004	35	3	15	0	11	9	8.6	42.9	0.0	31.4
2005	22	10	7	1	4	3	45.5	31.8	4.5	18.2
2006	32	7	18	4	4	2	21.9	56.3	12.5	12.5
2007	63	18	18	3	2	1	38.1	28.6	4.8	3.2
2008	83	18	47	14	11	8	31.3	56.6	16.9	13.3
Totals	**235**	**70**	**105**	**22**	**32**	**14**	**29.8**	**44.7**	**9.4**	**13.6**
Dayton AP release (LFH stock)										
2007	116	13	93	33	13	0	11.2	80.2	28.4	11.2
2008	155	19	124	47	17	7	12.3	84.3	30.3	11.0
Totals	**271**	**32**	**217**	**80**	**20**	**7**	**11.8**	**80.1**	**29.5**	**11.1**
Walla Walla River release (LFH stock)										
2007	89	2	75	35	3	1	2.2	80.0	39.3	3.4
2008	77	8	62	10	11	3	10.4	80.5	13.0	14.3
Totals	**1066**	**10**	**137**	**45**	**14**	**4**	**6.0**	**82.5**	**27.1**	**8.4**

[a] The Tucannon River PIT tag array was taken out by high stream flow in January, 2009. Two salt returns from the 2006 migration year, and 1-salt returns from the 2007 migration year, that entered the Tucannon River after the array was destroyed could not be added to the table. Therefore, the percent of fish in the Tucannon, above Granite, or Unknown destination for the 2006 and 2007 migration years are under or over-estimates depending on location. Numbers provided are current through January 4, 2011.

[b] Not all fish that crossed McNary Dam are shown in the table, a few were also detected at Priest Rapids Dam, Rock Island Dam, Rocky Reach Dam, and Wells Dam in the upper Columbia River

[c] Numbers included in this column are also included in the previous column

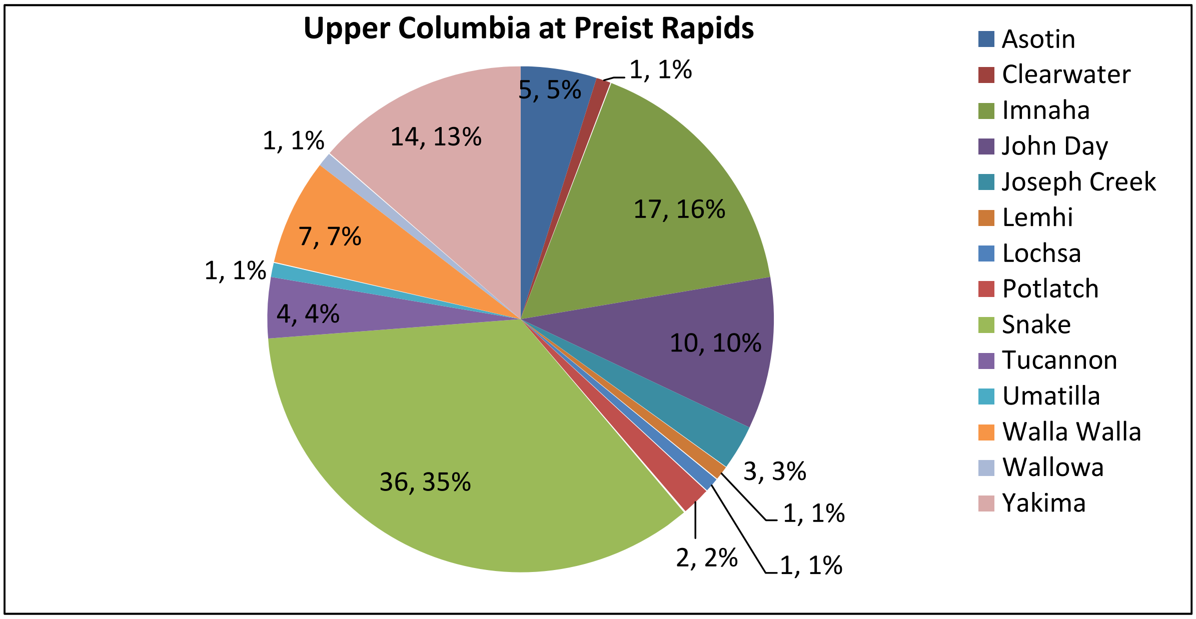


Figure 12. Estimates of the percent composition of PIT-tagged wild adult steelhead that were detected at Priest Rapid Dam after overshooting their natal tributary. Source: Murdoch et al. (2012).

Tributary Overshoot: Percentages – Summary

Key findings

- Steelhead overshoot of natal tributaries and past upstream FCRPS dams is common and may represent the majority of individuals in some populations
- Highest overshoot rates identified for Fifteenmile, John Day, Umatilla, Walla Walla, & Tucannon steelhead

Critical uncertainties

- Previous studies have been ad hoc, with no systematic evaluations (*but see Section 3.8*)
- Radiotelemetry studies used mostly unknown-origin steelhead and therefore underestimated overshoot
- Potential causal mechanisms have not been evaluated and may differ among populations

Technical recommendations

- Increase monitoring of tributary confluence areas to detect steelhead before and after overshoot
- Single populations: mine existing data for causal relationships between overshoot and river environment
- Across populations: test for common mechanisms, synchronous movements

2.2.8 Tributary Overshoot: Timing

Timing statistics for steelhead that overshoot their natal tributary can potentially be calculated at several locations in the Columbia River Basin, but primarily at: (1) dams downstream from the natal tributary confluence, and (2) dams upstream from the natal tributary confluence. In most cases, the two dates would likely be similar, as most actively migrating steelhead pass quickly through FCRPS reservoirs (Keefer et al. 2004; Fryer et al. 2013). However, there may be large timing differences at downstream versus upstream sites for some individuals (i.e., those that spend time thermoregulating in non-natal tributaries and those that overwinter in the natal tributary reach).

There were few specific timing-related details reported in the reviewed PIT-tag and radiotelemetry studies of tributary overshoot. Murdoch et al. (2012) reported that overshoot steelhead were detected at Priest Rapids Dam earlier in the year than at Snake River dams, on average. Median upstream detection dates, with all populations and years combined, were 15 August in the upper Columbia and 15 September in the Snake River. The timing of downstream movements by the overshoot fish also differed with a median of 11 November in the upper Columbia versus 25 April in the Snake River, a timing difference that can be attributed – at least in part – to cooler temperatures in the upper Columbia River relative to the Snake River in late summer and early fall. The authors cautioned that misidentification of strays that spawned before moving downstream as kelts may have inflated estimates in the Snake River.

In the one-year summary of PIT-tagged Tucannon River steelhead (Keefer et al. 2014c), fish that passed Lower Granite Dam did so mainly in the fall (median date = 4 October). A small group of the Tucannon overshoot fish was first detected at both Ice Harbor and Lower Granite dams in the spring, indicating that they overwintered downstream from Ice Harbor Dam before moving into the Snake River. Similar results were reported for Fifteenmile Creek steelhead in the one-year PIT-tag summary reported by Poxon et al. (2014): most overshoot steelhead passed The Dalles Dam in the summer or fall, but a few passed in the following spring.

Tributary Overshoot: Timing – Summary

Key findings

- Overshoot timing has not been systematically studied (*but see Section 3.8.3*)
- There may be timing differences for overshoot fish moving up the Columbia versus into the Snake

Critical uncertainties

- Potential causal mechanisms have not been evaluated and may differ among populations
- Overshoot behavior may be adaptive, but difficult to disentangle from FCRPS and hatchery effects

Technical recommendations

- Mine existing data for causal relationships between overshoot timing and river / tributary environments
- Test for potential hatchery effects within tributaries that have wild and hatchery populations
- Increase monitoring of tributary confluence areas to improve pre- and post-overshoot detection rates

2.2.9 Tributary Overshoot: Homing and Straying

In most populations, a portion of the individuals that overshoot their natal tributary never move downstream to the natal site (Keefer and Caudill 2014a). The fates of these fish may include pre-spawn mortality, harvest, or permanent straying to non-natal sites. Permanent straying by overshoot steelhead has been reported by some agencies, though previous reporting has been uneven across populations. As mentioned above, these data have generally not been reported via Corps-funded research, but they are directly relevant to the synthesis.

Bumgarner and Dedloff (2011) provide some of the more complete estimates of steelhead homing after tributary overshoot. Of the adult fish that overshot the Tucannon River past Lower Granite Dam, 5-23% of Tucannon River Hatchery steelhead, 0-25% of wild Tucannon steelhead, and 8-19% of Lyons Ferry Hatchery steelhead outplanted into the Tucannon River as juveniles eventually homed to the Tucannon River. Many of the fish that did not return to the Tucannon River could not be accounted for, and some were apparently permanent strays to Asotin and Alpowa creeks upstream from Lower Granite Dam.

Though not calculated with the same method, Bumgarner and Dedloff (2011) also reported high straying and low homing for Walla Walla and Touchet River steelhead that overshot and passed Ice Harbor and/or Lower Granite dams. Many of the overshoot fish stayed upstream from Ice Harbor Dam, including movement into the Tucannon River. Some also passed Priest Rapids Dam and did not return downstream to the Walla Walla River.

Tributary Overshoot: Homing and Straying – Summary

Key findings

- There are few previous summaries of homing and straying by overshoot fish (*but see Section 3.8.4*)
- Permanent straying appears to be common among some steelhead that overshoot natal tributaries

Critical uncertainties

- True fates of fish that do not reach natal tributaries are generally unknown
- Substantial monitoring differences among sites and populations means behaviors may be misclassified
- Unknown whether some steelhead attempt to move downstream but fail to pass dams
- Considerable ambiguity regarding movement in and out of natal and non-natal tributaries
- Inter-basin stray rates are likely underestimated

Technical recommendations

- Active-tagging of prespawn adults at JBSs could generate behavioral and homing data for overshoot fish
- Increase monitoring of tributary confluence areas to better estimate both homing and straying

2.2.10 Downstream Passage at Dams: 'Fallback'

Downstream fallback by adult salmon and steelhead at FCRPS dams has been studied for decades. The research indicates that there are several types of fallback events, with different injury and mortality outcomes and different implications for managing the projects. It is clear that some adult steelhead fall back at dams in almost all months of the year and that there are a mix of volitional and non-volitional events. Volitional fallback is associated primarily with: (1) adults that overshoot their natal tributary and must move downstream past a dam to successfully complete homing; and (2) post-spawn kelts that are migrating back to the Pacific Ocean. Non-volitional fallback is thought to occur when adults are entrained in operational flow (spill, turbine or JBS flow) and are carried downstream before exiting the forebay. Distinguishing volitional and non-volitional fallback is impossible without knowledge of the motivational status of individuals and flow conditions encountered. Nonetheless, operational time and route criteria have been used to classify fallback into short-term (i.e., <24 hours after ladder exit) and longer-term events (>24 hours, often after passage of upstream dams) thought to represent non-volitional and volitional fallback, respectively. In some of the literature, kelt movement past dams is not referred to as 'fallback' but rather as 'downstream passage'. Functionally, however, the downstream movements at dams and their potential outcomes are very similar.

During pre-spawn migration, steelhead fallback events are most frequent through spillways. At most dams, surface spill occurs from approximately April through August. In fall, when surface spillway routes are limited, pre-spawn steelhead fall back through the JBS, navigation locks, ice/trash sluiceways, and turbines. Some also move downstream through adult fishways. Downstream dam passage routes are most limited in winter when spillway and JBS routes are typically unavailable; adult fishways are also intermittently dewatered for winter maintenance, leaving turbines and navigation locks as the primary available routes of passage, especially at dams with single fishways (Little Goose, Lower Granite). Post-spawn kelts often have all downstream passage routes available, although some of the earliest emigrants may not encounter surface spill. In recent years, increased awareness of the scale of the steelhead kelt outmigration has prompted FCRPS managers to begin operating surface passage routes at some dams earlier in the spring. Examples include early-season operation of the Bonneville Dam Powerhouse 2 corner collector and the Ice and Trash sluiceway at The Dalles Dam.

FCRPS fallback studies have reported several types of information, including: (1) fallback percentages (i.e., the percent of unique fish that pass a dam that subsequently fall back); (2) fallback rates (i.e., similar to fallback percentage but includes multiple fallback events by individual fish); (3) fallback enumeration, which is an estimate of the number of fish that fall back at a dam, typically using passive methods (e.g., hydroacoustics); (4) fallback timing; (5) fallback route use, which apportions events among available downstream passage routes; and (6) post-fallback survival. Survival has been assessed in short-term studies that used surrogate fish (e.g., resident rainbow trout or hatchery-held adult steelhead) passed through specific routes and in longer-term studies that examined whether fallback fish survived to tributaries.

2.2.11 Fallback: Percentages and Rates

Radiotelemetry and PIT-tag studies have provided most of the recent estimates of fallback percentages and rates for pre-spawn steelhead, where fallback percent is the percentage of adults falling back at least one time at a location and fallback rate is the total number of fallback events divided by the number of passing adults. The radio-based estimates are considered the standard for monitoring fallback, because fish can be detected at a large number of downstream sites, including tailraces, fishway openings, and at sites in reservoirs and downstream tributaries. PIT-tag based estimates require several additional assumptions about behaviors and are usually considered underestimates because fish that fall back and do not attempt to reascend FCRPS dam fishways are less likely to be detected (Burke and Jepson 2006). In a series of annual studies, Fryer et al. (2011-2015) estimated fallback percentages for adult steelhead collected and PIT-tagged at Bonneville Dam. To identify fallback events, the PIT-tagged fish needed to either re-attempt passage at the dam and be detected in a fishway (reascension, with sufficient time gaps between records), be detected in both adult fishways (at dams with two fishways), or be detected passing downstream through a juvenile bypass system. The summaries below provide reported fallback percentages for pre-spawn fish (kelt passage excluded). We note that fallback rates tend to be slightly higher than percentages at most dams because some fish fall back multiple times (Boggs et al. 2004).

Bonneville Dam – Pre-spawn steelhead fallback data were most consistently and completely reported in the radiotelemetry studies of the late 1990s and early to mid-2000s where adult steelhead were collected at Bonneville Dam (*Table 10*). Annual fallback percentages ranged from ~4% to ~9%, with a mean estimate of ~6% (Bjornn et al. 2000a; Boggs et al. 2004, 2005). Radiotelemetry-based fallback estimates were also reported for early- and late-run steelhead tagged in 2013 and 2014 (Keefer et al. 2015a, 2015b). Fallback percentages at Bonneville Dam were 2-4% for early-run steelhead and <1-5% for late-run steelhead (*Table 11*). Annual percent fallback estimates for PIT-tagged steelhead collected at Bonneville Dam in the 2009-2013 migration years ranged from 0.9% to 2.2% (Fryer et al. 2011-2015).

The Dalles Dam – In the radiotelemetry studies of Bjornn et al. (2002b) and Boggs et al. (2004, 2005), annual pre-spawn fallback estimates for steelhead at The Dalles Dam ranged from ~6% to ~11% (mean estimate of 7%). In the 2013-2014 radiotelemetry study, fallback estimates were 2-5% for early-run steelhead and 4-11% for late-run steelhead. There were no PIT-tag interrogation sites at The Dalles Dam in the 2009-2012 migration years, but the estimate was 4.4% in 2013 (Fryer et al. 2015).

Some season-specific fallback percentages have also been reported. For example, Keefer and Peery (2007) reported that 1.4% of radio-tagged steelhead fell back in November at The Dalles Dam, of all fish that passed the dam in the summer or fall. Most of the fish that fell back in November had passed the dam relatively late in the fall (i.e., in October and November).

John Day Dam – In the pre-2005 radiotelemetry studies, annual pre-spawn fallback estimates for steelhead at John Day Dam ranged from ~4% to ~10% (mean estimate was ~7%). In the 2013-2014 study, fallback estimates were 7-8% for early-run steelhead and 3-4% for late-run steelhead. There were no PIT-tag interrogation sites at John Day Dam in any years.

McNary Dam – In the pre-2005 radiotelemetry studies, annual pre-spawn fallback estimates for steelhead at McNary Dam ranged from ~5% to ~11% and mean estimates (from several reports) were 8-9%. In the 2013-2014 study, fallback estimates were 17-22% for early-run steelhead (many events were by fish that overshot downstream tributaries) and 4-5% for late-run steelhead. PIT-tag based estimates ranged from ~1% to ~5% and the mean was ~3%.

Ice Harbor Dam – In the pre-2005 radiotelemetry studies (*Table 10*), annual pre-spawn fallback estimates for steelhead at Ice Harbor Dam ranged from ~4% to ~6% (mean estimate was ~5%). Fallback percentages for early-run steelhead in the 2013-2014 study were ~15-20% (many events were associated with tributary overshoot by Walla Walla River steelhead) versus ~3% for late-run fish (*Table 11*). PIT-tag based estimates ranged from ~0% to ~5% and the mean was ~3%.

Table 10. Pre-spawn adult steelhead fallback percentages and rates at FCRPS dams for run-of-river samples collected and radio-tagged at Bonneville Dam, 1996-1997, 2000-2003, and 2013-2014. ***Fallback*** *% = percentage of unique steelhead that passed a dam that fell back at least once. Fallback rate = number of fallback events divided by number of unique steelhead that passed a dam. Reascension % = percentage of steelhead that fell back at a dam that subsequently re-passed the dam. Potential overshoot % = percentage of steelhead that fell back that were last recorded in a tributary downstream from the dam (includes likely mix of strays and fish homing to natal sites). Sources: Boggs et al. (2005), Keefer et al. (2015b).*

Year	**Bonneville** Fallback %	Fallback rate	Reascension %	Overshoot %	**The Dalles** Fallback %	Fallback rate	Reascension %	Overshoot %
1996	4.9	5.3	85.7	n/a[1]	6.0	6.9	77.1	11.4
1997	9.1	9.9	77.1	n/a	6.6	7.3	75.6	0.0
2000	6.9	7.4	91.1	n/a	6.3	7.2	80.0	7.3
2001	4.3	4.5	78.8	n/a	6.1	8.8	76.3	5.1
2002	3.6	4.4	72.7	n/a	7.1	10.2	76.5	1.2
2003	5.9	8.3	54.5	n/a	10.5	17.5	36.2	2.1
'96-'03 Avg	***5.8***	***6.6***	***76.7***	n/a	***7.1***	***9.7***	***70.3***	***4.5***
2013 early	1.8	1.8	-	-	2.3	2.3	-	-
2014 early	4.0	4.0	-	-	4.9	6.3	-	-
2013 late	4.5	6.0	-	-	10.7	15.0	-	-
2014 late	0.3	0.5	-	-	3.6	5.2	-	-
	John Day				**McNary**			
1996	10.1	11.2	45.7	26.1	7.4	8.6	41.4	24.1
1997	7.9	9.0	75.0	6.8	10.7	12.9	46.2	26.9
2000	4.3	4.5	62.5	18.8	9.8	10.2	47.6	31.7
2001	5.3	5.6	78.3	13.0	7.1	7.6	64.3	17.9
2002	4.6	5.0	59.5	11.9	4.9	5.8	36.6	19.5
2003	9.1	10.4	61.1	2.8	7.2	7.5	29.2	54.2
'96-'03 Avg	***6.9***	***7.3***	***63.7***	***13.2***	***7.9***	***8.8***	***44.2***	***29.1***
2013 early	8.2	10.0	-	-	17.0	17.0	-	-
2014 early	7.2	8.0	-	-	21.8	23.6	-	-
2013 late	3.8	4.2	-	-	5.1	6.0	-	-
2014 late	3.1	3.3	-	-	4.3	4.3	-	-

[1] tributaries downstream from Bonneville Dam not monitored

- indicates not reported

Table 10. Continued.

	Ice Harbor				**Lower Monumental**			
Year	Fallback %	Fallback rate	Reascension %	Overshoot %	Fallback %	Fallback rate	Reascension %	Overshoot %
1996	5.6	6.3	38.9	22.2	-	-	-	-
1997	4.9	5.4	52.6	26.3	4.0	4.8	26.7	20.0
2000	4.7	5.1	52.2	13.0	1.7	1.7	50.0	12.5
2001	3.9	4.7	47.4	21.1	2.8	3.0	92.3	0.0
2002	4.5	5.4	37.9	6.9	4.2	4.6	37.3	14.8
2003	5.1	5.8	71.4	21.4	2.6	2.6	71.4	28.6
'96-'03 Avg	***4.8***	***5.5***	***50.1***	***18.5***	***3.1***	***3.3***	***55.5***	***15.2***
2013 early	20.0	31.1	-	-	27.3	36.4	-	-
2014 early	14.9	17.6	-	-	6.1	9.1	-	-
2013 late	3.2	3.2	-	-	2.1	2.1	-	-
2014 late	3.3	3.6	-	-	1.9	1.9	-	-
	Little Goose				**Lower Granite**			
1996	-	-	-	-	8.4	9.2	36.4	4.5
1997	8.4	9.0	42.9	25.0	5.9	6.9	38.9	22.0
2000	5.3	5.3	43.5	4.3	3.7	3.7	66.7	0.0
2001	5.2	5.2	57.0	4.3	2.7	2.9	50.0	16.7
2002	5.3	5.5	56.3	12.5	4.6	4.8	68.2	8.3
2003	6.0	6.4	68.8	12.5	2.4	2.8	66.7	0.0
'96-'03 Avg	***6.0***	***6.3***	***59.7***	***11.7***	***4.6***	***5.1***	***54.5***	***8.6***
2013 early	15.2	15.2	-	-	9.1	9.1	-	-
2014 early	14.1	14.1	-	-	14.5	16.1	-	-
2013 late	2.4	2.4	-	-	2.5	2.5	-	-
2014 late	2.7	2.7	-	-	1.4	1.4	-	-

- indicates not reported

Lower Monumental Dam – In the pre-2005 radiotelemetry studies, annual pre-spawn fallback estimates for steelhead at Lower Monumental Dam ranged from ~2% to ~4% (mean estimate was ~3%). Fallback percentages for early-run steelhead were 27% (2013) and 6% (2014) versus ~2% for late-run fish. There were no PIT-tag interrogation sites at Lower Monumental Dam prior to 2014 and there were no PIT-based estimates in the CRITFC studies.

Little Goose Dam – In the pre-2005 radiotelemetry studies, annual pre-spawn fallback estimates for steelhead at Little Goose Dam ranged from ~5% to ~8% (mean estimate was ~6%). Fallback percentages for early-run steelhead in the 2013-2014 study were ~14-15% (included overshoot fallback events by Walla Walla and Tucannon River fish) versus ~2-3% for late-run fish. There were no PIT-tag interrogation sites at Little Goose Dam prior to 2014 and there were no PIT-based estimates in the CRITFC studies.

Lower Granite Dam – In the pre-2005 radiotelemetry studies, annual pre-spawn fallback estimates for steelhead at Lower Granite Dam ranged from ~2% to ~8% (mean estimate was ~5%). Fallback percentages for early-run steelhead in the 2013-2014 study were ~9-15% (tributary overshoot contributed to relatively high rates) versus ~1-3% for late-run fish. PIT-tag based estimates ranged from ~1% to ~14% and the mean was ~7%.

Table 11. Pre-spawn fallback percentages (unique fish that fell back / unique fish that passed dam) and fallback rates (total fallback events / unique fish that passed dam) of radio-tagged steelhead collected at Bonneville Dam in 2013 and 2014 either early (before 15 August) or late (after 1 September) in the run. Fallback events that occurred after spawning (i.e., by kelts) were not included. Source: Keefer et al. (2015b).

Run	Dam	Tag year	Passed dam[1]	Unique FB fish	Total FB events	Fallback %	Fallback rate
Early	Bonneville	2013	164	3	3	1.8%	1.8%
		2014	201	8	8	4.0%	4.0%
	The Dalles	2013	131	3	3	2.3%	2.3%
		2014	144	7	9	4.9%	6.3%
	John Day	2013	110	9	11	8.2%	10.0%
		2014	125	9	10	7.2%	8.0%
	McNary	2013	88	15	15	17.0%	17.0%
		2014	110	24	26	21.8%	23.6%
	Ice Harbor	2013	45	9	14	20.0%	31.1%
		2014	74	11	13	14.9%	17.6%
	L. Monumental	2013	44	12	16	27.3%	36.4%
		2014	66	4	6	6.1%	9.1%
	Little Goose	2013	33	5	5	15.2%	15.2%
		2014	64	9	9	14.1%	14.1%
	Lower Granite	2013	33	3	3	9.1%	9.1%
		2014	62	9	10	14.5%	16.1%
Late	Bonneville	2013	579	26	35	4.5%	6.0%
		2014	576	2	3	0.3%	0.5%
	The Dalles	2013	525	56	79	10.7%	15.0%
		2014	502	18	26	3.6%	5.2%
	John Day	2013	474	18	20	3.8%	4.2%
		2014	455	14	15	3.1%	3.3%
	McNary	2013	451	23	27	5.1%	6.0%
		2014	417	18	18	4.3%	4.3%
	Ice Harbor	2013	405	13	13	3.2%	3.2%
		2014	390	13	14	3.3%	3.6%
	L. Monumental	2013	387	8	8	2.1%	2.1%
		2014	378	7	7	1.9%	1.9%
	Little Goose	2013	369	9	9	2.4%	2.4%
		2014	369	10	10	2.7%	2.7%
	Lower Granite	2013	365	9	9	2.5%	2.5%
		2014	365	5	5	1.4%	1.4%

[1] only includes fish that retained radio transmitters

Fallback: Percentages and Rates – Summary

Key findings
- Mean annual pre-spawn fallback: 6-9% at lower Columbia dams and 3-6% at lower Snake River dams
- Fallback is lower, on average, for late-run steelhead than for steelhead migrating during the spill season
- Fallback by early-run fish can be high at McNary and at Snake River dams; associated with overshoot

Critical uncertainties
- Fallback estimates derived from PIT-tag detection data have several potential sources of error
- Population-level estimates have not been routinely reported but are likely to differ
- Volitional (overshoot-related) and non-volitional fallback difficult to separate in most existing datasets

Technical recommendations
- Accuracy and precision of PIT-based fallback estimates could be tested using data from double-tagged fish
- Population-specific fallback estimates could be generated using existing radiotelemetry data
- Increased PIT monitoring at dam fallback routes could improve fallback rate indices

2.2.12 Fallback: Enumeration

A series of hydroacoustic studies of pre-spawn steelhead and post-spawn kelts have been conducted in the forebays of lower Columbia River dams by Batelle/Pacific Northwest National Laboratory (PNNL). These studies have focused on the distribution (vertical and horizontal) of steelhead-sized acoustic targets as they attempt to pass downstream in winter and spring. The primary passage routes evaluated have been turbine units, spillways, ice-and-trash sluiceways, and the Bonneville Dam corner collector (Weiland et al. 2009; Ham et al. 2012a, 2012b 2015; Khan et al. 2009, 2010, 2011, 2013). Full-dam and full-season hydroacoustic coverage did not occur in several studies, resulting in a need to extrapolate for some data categories (e.g., total passage enumeration). In combination, the hydroacoustic studies provided information on relative downstream passage route use and on steelhead behaviors in dam forebays near turbines, sluiceways, and fish guidance structures.

The hydroacoustic studies do not directly estimate fallback percentages or rates because the numbers of 'available' steelhead (i.e., the denominator in calculations) are not available. Rather, these studies enumerate the numbers of fallbacks events, typically using a metric of event frequency or rate (e.g., fallbacks per day) at each FCRPS dam.

Bonneville Dam – Hydroacoustic monitoring was used at Bonneville Dam in 2007-2008 to enumerate downstream passage (fallback) of presumed kelts through the Powerhouse 2 Corner Collector (BCC) (Weiland et al. 2009). Monitoring was conducted in March and April, and peak downstream passage by kelt-sized acoustic targets occurred in early April of both study years. Annual estimates of passage through the BCC were 174 and 223 kelts in 2007 and 2009, respectively.

The Dalles Dam – A series of hydroacoustic studies at The Dalles Dam enumerated downstream passage of pre-spawn steelhead and kelts in 2008-2011 (*Table 12*). The monitored routes in 2008-2009 included powerhouse intakes and sluiceways (Khan et al. 2009). An estimated 1,790 steelhead-sized fish were estimated to have passed in fall 2008 (1 November-15 December). A similar number (n = 1,766) were estimated to have passed during the spring (1 March-9 April) monitoring in 2009. In both periods, a large majority (~95%) of the fish passed through the ice/trash sluiceway, especially via Sluice 1 (Khan et al. 2009).

Passage patterns were broadly similar in the 2009-2010 study: 879 steelhead-sized targets passed in fall 2009 (1 November-15 December) and 1,985 were estimated to have passed in spring 2010 (8 March-10 April) (Khan et al. 2010). Ice/Trash sluiceway entry routes were closed from 16 December to 7 March, and very few (62) adult steelhead-size targets were estimated to have passed the other monitored routes during this operational condition. In the course of the 2009-2010 study, ≥ 92% of passage was via the sluiceway and most fish passed Sluice 1. Passage through turbines was mostly through Unit 18. A third study in this series (Khan et al. 2011) estimated that 215 steelhead passed through turbines on nine days in March and April of 2011; Unit 18 was again the primary downstream passage route. *Figure 13* and *Table 12* shows the distribution of passage events at The Dalles Dam during the three studies.

Table 12. Estimates of adult steelhead downstream passage at The Dalles Dam sluiceway and turbines during five sampling periods in 2008-2010. The sluiceway was closed for sampling period D (16 Dec 2009 to 7 Mar 2010). Source: Khan et al. (2013).

Sampling period	Total steelhead Passage (±95% CI)	Sluiceway (±95% CI)	Turbines (±95% CI)	Turbine passage % of total
(A) 1 Nov-15 Dec 2008	1,790 (250)	1,704 (237)	86 (78)	4.8%
(B) 1 Mar-10 Apr 2009	1,766 (277)	1,673 (264)	93 (84)	5.3%
(C) 1 Nov-15 Dec 2009	879 (165)	804 (156)	75 (55)	8.5%
(D) 16 Dec 2009-7 Mar 2010	62 (40)	Closed	62 (40)	100%
(E) 8 Mar-10 Apr 2010	1,985 (234)	1,958 (229)	27 (48)	1.4%

McNary Dam – Hydroacoustic monitoring was used at McNary Dam in winter 2010-2011, 2011-2012, and 2014-2015 to enumerate downstream passage (fallback) of pre-spawn steelhead and presumed kelts through the turbines (Ham et al. 2012a, 2012b, 2015).

In 2010-2011, monitoring was conducted from mid-December to mid-April at 8 of the 14 turbine intakes (*Table 13*). Steelhead-sized targets passed at higher rates through turbines at the north and south ends of the powerhouse, and total estimated passage was 946 fish (95% confidence interval = 750-1,142 fish). On days when presumed steelhead fell back, passage estimates ranged from ~10 to >75 fish per day, with the highest passage numbers in mid-February. Unfortunately, the study design was somewhat compromised by extended periods of unplanned spill from mid-January through March. The numbers of steelhead-sized turbine passage events appeared to decrease when spill occurred.

In the second study (winter 2011-2012), 12 of the 14 turbines were monitored. Total estimated adult steelhead passage through turbines was higher at 1,786 fish and the confidence interval was narrower (95% ci = 1,670-1,902) due to increased monitoring effort (*Table 13*). As in the first year, passage was highest at turbines near the north and south ends of the McNary powerhouse. On days when presumed steelhead fell back, passage estimates ranged from ~10 to >125 fish per day, with the highest passage numbers in late December, late February, and on a single day at the end of March. There was also a period of unexpected spill in winter 2011-2012 that likely resulted in some adult passage over the spillway. Ham et al. (2012b) concluded that the forced spill operation reduced steelhead passage through turbines.

The hydroacoustic study at McNary Dam in winter 2014-2015 (Ham et al. 2015) was an experimental test of adult steelhead use of the temporary spillway weir (TSW) and an evaluation of whether TSW operation reduced steelhead passage through turbines. The study design included two experimental periods: the first had juvenile fish screens in place ('screens in') and a randomized TSW spill / no spill treatment in November-December 2014; the second period had no juvenile screens ('screens out') and the same randomized spill treatment in February-March 2015. The 'screens in' portion of the study indicated that, when the TSW was operated, proportionately fewer adult steelhead passed turbines and total steelhead passage at McNary Dam increased (*Table 13*). There was also evidence that more adult steelhead passed via the McNary powerhouse as total river flow increased, in spite of either conventional spill or TSW spill. The 'screens out' experimental period was compromised by forced spill, which made it impossible to evaluate the influence of TSW operation (Ham et al. 2015).

Table 13. Estimates of adult steelhead downstream passage at McNary Dam turbines and the temporary spillway weir (TSW) during three winter study periods. Expanded total was estimated for passage through unmonitored turbines. Source: Ham et al. (2012a, 2012b, 2015).

Sampling period	Monitored sites	Total steelhead passage	95% CI	Expanded total
17 Dec 2010 – 13 Apr 2011	8 of 14 turbine units	946	750-1,142	1,419
1 Dec 2011 – 16 Apr 2012	12 of 14 turbine units	1,786	1,670-1,902	1,893

Sampling period	Monitored sites	Steelhead count near TSW	Steelhead count near T14
15 Nov 2014 – 14 Dec 2014[1]	TSW, Turbine 14	900 (TSW spill)	1,596 (TSW spill)
		456 (no spill)	1,392 (no spill)
15 Feb 2015 – 15 Mar 2015[2]	Turbine 14	360 (Total)	816 (Total)

[1] 'screens in' treatment

[2] 'screens out' treatment; experiment compromised by forced spill

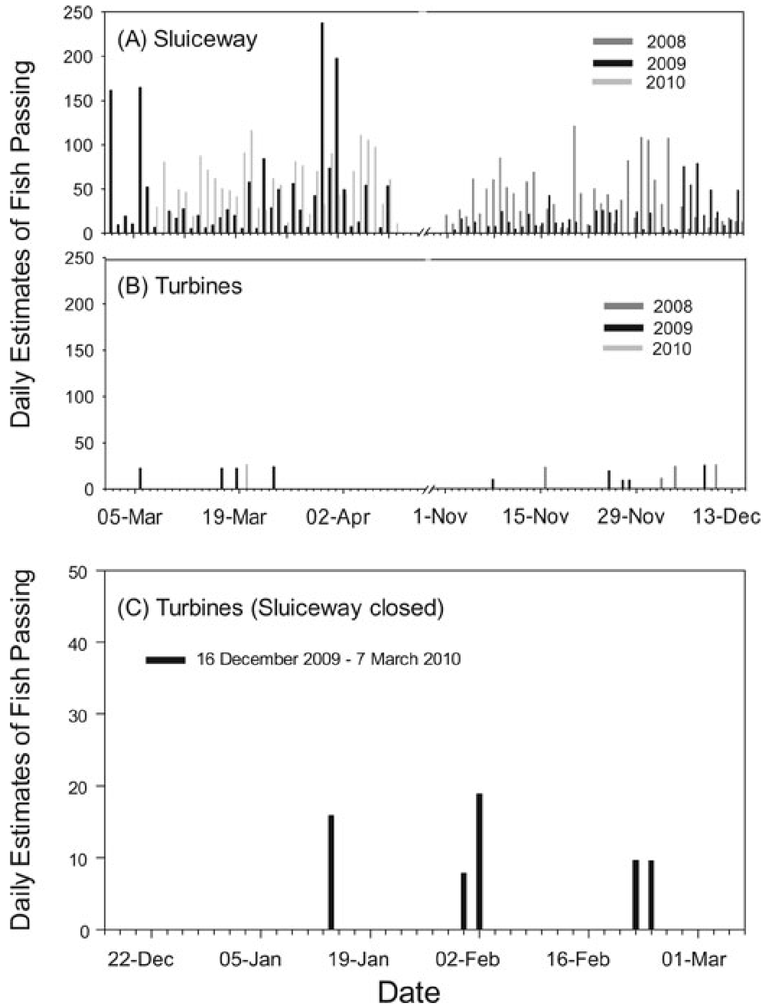


Figure 13. Daily estimates of adult steelhead downstream passage at The Dalles Dam sluiceway (A) and through turbines (B) during four periods when the sluiceway and turbines were sampled concurrently (Nov-Dec 2008 and 2009 and March-April 2009 and 2010) and through turbines when the sluiceway was closed in Dec 2009 to Mar 2010 (C). Source: Khan et al. 2013.

Fallback: Enumeration – Summary

Key findings

- Hydroacoustic studies identified steelhead-sized fish passing downstream in fall, winter, and spring
- Hundreds of likely kelts passed Bonneville corner collector in March-April
- ~900-2000 pre-spawn and/or post-spawn fish passed The Dalles Ice/Trash sluice in fall and spring
- ~950-1800 pre-spawn and/or post-spawn fish passed McNary turbines in winter and spring

Critical uncertainties

- Species identification and population composition not possible with hydroacoustic data
- Not all passage routes were monitored, so estimates were incomplete and/or extrapolations
- Monitoring periods were truncated in most studies and some experiments were compromised by operations

Technical recommendations

- Experiments to evaluate passage route use under different operational criteria could be continued
- Species and population data could be matched to enumeration data by sampling from JBSs in winter, spring
- Seasonally-extended surface bypass operations (e.g., McNary TSW) may benefit kelts and overshoot fish

2.2.13 Fallback: Routes and Timing

Assigning pre-spawn steelhead and post-spawn kelts to specific fallback routes at the FCRPS dam can be challenging, and the degree of route assignment certainty varies among routes and among study types. Assigning routes at the Columbia and Snake River dams is challenging for all monitoring techniques because it is difficult to simultaneously monitor all turbine, spillway, ice and trash sluiceway, fishway, navigation lock, and bypass routes. Route assignment confidence has been highest for tagged fish that fall back through readily-monitored routes: the best examples are PIT-tagged adults detected in juvenile bypass systems (including the Bonneville Corner Collector), radio-tagged fish detected in ice/trash sluiceways and adult fishways, and acoustic-tagged fish at spillway weirs. The passive hydroacoustic studies have identified targets passing into sluiceways and turbines, but there was uncertainty regarding species identification. During spring and summer, many steelhead fallback events are presumably via traditional spillways, but passage over spillways has generally been inferred rather than directly measured. Similarly, turbine passage is difficult to measure and has been inferred, especially during no-spill periods and when other routes (e.g., sluiceways, JBS) were closed.

Some pre-spawn steelhead fall back at FCRPS dams in almost every month, whereas kelt fallback is concentrated in April-May (*Figure 14;* also see *Figure 7* for kelt passage timing). The time stamps for downstream fallback timing are often less precise than for upstream adult passage at dams because it is difficult or impossible to monitor tagged fish through turbine and spillway fallback routes. The timing of fallback events using radiotelemetry could generally be assigned to individual days (i.e., when there were antennas located in forebays, at fishway openings, and in tailraces) but occasionally were assigned to weeks when there was less monitoring effort and fallback was inferred from downstream records. A number of fallback studies have investigated the behaviors during single seasons or at individual routes within season. The summaries below are therefore organized by dam, with details of monitoring methods and seasonal effort where available.

Bonneville Dam – In the 1996-1997 radiotelemetry studies, ~80% of the pre-spawn steelhead fallback events at Bonneville Dam occurred on days with traditional spill, and the spillway was considered the most likely route for most events (Bjornn et al. 2000a). A small number of radio detection histories indicated fallback via the ice/trash sluiceways and the navigation lock. In 2000-2003, additional radio antennas were installed at Bonneville Dam to help with fallback route resolution (Jepson et al. 2004; Boggs et al. 2004, 2005). Even with the extra coverage, ~9-60% of fallback events were assigned to undetermined route (Boggs et al. 2005). Some radio-tagged steelhead fell back through the Bonneville Dam JBS, with estimates as high as 11% of the pre-spawn fallback events (Jepson et al. 2004). The percentage of fallback events estimated for other specific routes were 2-11% through the ice/trash sluiceway and 7-37% through the navigation lock. Most events were estimated to have been over the spillway.

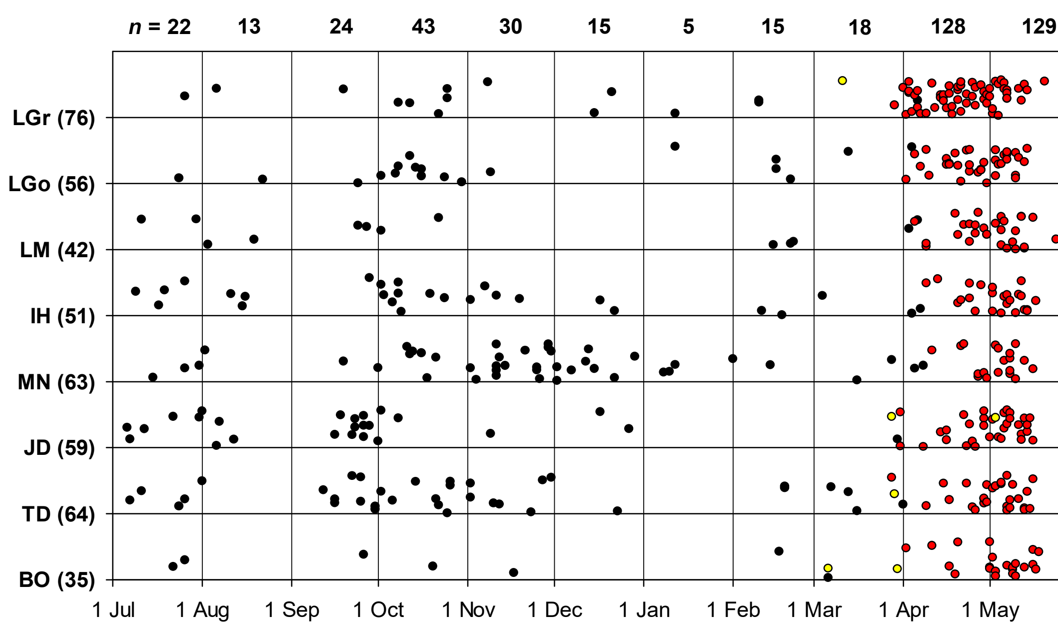


Figure 14. Estimated dates that radio-tagged steelhead tagged at Bonneville Dam in 2014 fell back at FCRPS dams in 2014-2015. Black dots are for presumed pre-spawn steelhead, red dots are for presumed post-spawn kelts, and yellow dots were for events where reproductive status was uncertain. Dams include Bonneville (BO), The Dalles (TD), John Day (JD), McNary (MN), Ice Harbor (IH), Lower Monumental (LM), Little Goose (LGo), and Lower Granite (LGr). Note that the sample was weighted for late-run steelhead. Source: Keefer et al. 2015b.

The Dalles Dam – In the 1996-1997 radiotelemetry studies, about 43% of the pre-pawn steelhead fallback events at The Dalles Dam were on days with spill (*Figure 15*; Bjornn et al. 2000b). Route monitoring was limited, and these authors made few route-specific fallback estimates.

Fallback during winter months was reported for radio-tagged steelhead in 2013-2014 and 2014-2015 (Keefer et al. 2015b). There was uncertainty regarding route-specific events, but the authors estimated that 8-21% of events were via the ice/trash sluiceway, 4-5% were via the adult fishways, and 2% were via the navigation lock (*Table 14*). Fallback over the spillway was considered ‘possible’ (i.e., spill was occurring on the likely fallback date) for 5-33% of events. Fallback via turbines or the navigation lock was considered ‘possible’ (i.e., there was no spill occurring and there were no detections at other routes) for 21-47% of events. The remaining 21-31% of fallback events had insufficient data to assign to a route.

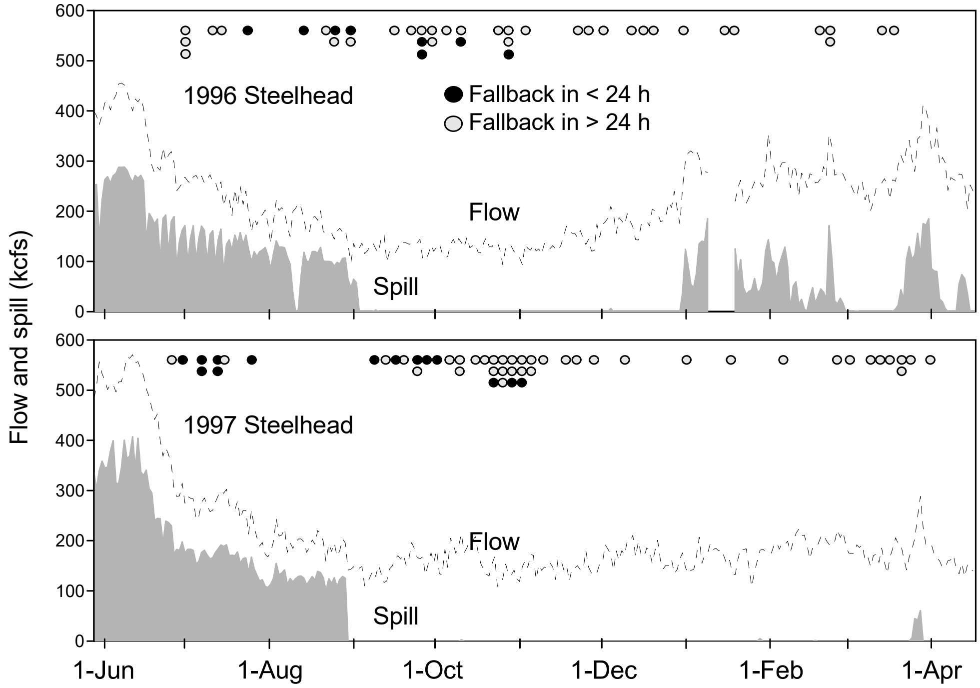


Figure 15. Timing of steelhead fallback events at The Dalles Dam in 1996-1997 and 1997-1998 in relation to river discharge and spill at the dam. Black circles are for fallback events <24 h after exiting a fish ladder and open circles are for fallback events >24 h after fishway exit. Source: Bjornn et al. (2000b).

Table 14. Estimated fallback (FB) routes of overwintering radio-tagged steelhead at The Dalles, John Day, and McNary dams during forebay radiotelemetry monitoring1 in winter 2013-2014 and 2014-2015. Aerial radiotelemetry coverage in the forebay was not definitive for assigning fallback route, particularly via the spillways, powerhouses (PH), and navigation locks (navlock). Underwater or shielded radiotelemetry antennas in the ice and trash sluiceways and adult fish ladders allowed for a higher confidence and "likely" route assignment to these locations. Steelhead that fell back with no forebay radiotelemetry detections did not receive a route assignment. No fish in these groups were detected on juvenile bypass (JBS) PIT tag antennas. FB (n) is the number of fallback events.

			Estimated fallback route (%)						
Dam	Year	FB *n*	Possible spillway	Possible PH / navlock	Likely ice/trash[2]	Likely ladder	Likely navlock	No radio detection	Post-FB % in tributary
The Dalles	2013	19	1 (5.2)	9 (47.4)	4 (21.1)	1 (5.3)	-	4 (21.1)	68%
	2014	48	16 (33.3)	10 (20.8)	4 (8.3)	2 (4.2)	1 (2.1)	15 (31.3)	81%
John Day	2013	10	1 (10.0)	6 (60.0)	-	-	-	3 (30.0)	50%
	2014	35	25 (71.4)	3 (8.6)	-	-	2 (5.7)	5 (14.3)	94%
McNary	2013	21	7 (33.3)	8 (38.1)	1[3] (4.8)	2 (9.5)	-	3 (14.3)	71%
	2014	50	19 (38.0)	6 (12.0)	6 (12.0)	-	2 (4.0)	17 (34.0)	88%

[1] Start dates in 2013 were 11 Dec (The Dalles), 16 Dec (John Day), and 5 Dec (McNary); end dates were 1 April. Start dates in 2014 were 1 Oct (The Dalles), 14 Oct (John Day), and 28 Oct (McNary); end dates were 13 May, 14 May, and 27 May, respectively in 2015.

[2] McNary ice / trash sluiceway was dewatered for part of the winter study period

[3] event recorded on 19 December 2013 was possible false positive; dewatering status uncertain

John Day Dam – In the 1996-1997 radiotelemetry studies, ~76% of the pre-pawn steelhead fallback events at John Day Dam were on days with spill, though spill discharge was ~1 kcfs on many days in the fall (Bjornn et al. 2000c). Fallback route monitoring was limited, and these authors made few route-specific fallback estimates. An exception was that Jepson et al. (2004) estimated that radio-tagged steelhead fallback through the John Day Dam JBS was 9-10% of the pre-spawn fallback events in 2000-2001.

Route-specific fallback estimates for radio-tagged steelhead in the winters of 2013-2014 and 2014-2015 were 10-71% in the ‘possible spillway’ category, 9-60% in the ‘possible turbine or navigation lock’ category, and 6% via the navigation lock (one winter only). The remaining 15-30% of the events had insufficient information to assign to a route (Keefer et al. 2015b).

McNary Dam – An early, but relevant, fallback study at McNary Dam used pre-spawn steelhead counts and a sample of floy-tagged steelhead to estimate fallback through the JBS in the fall (Wagner and Hillson 1993). From 15 September to 30 November 1991, a total of 7,268 adult steelhead were counted in the JBS, with peak counts in October (*Figure 16*). Over a slightly longer study period in 1991 (15 September to 15 December), 11,148 adults were counted in the JBS, with peak passage in November. In both years most fallback events were recorded during daylight. Recaptures of floy-tagged steelhead indicated that some individuals passed through the JBS more than once; approximately one-third of the floy-tagged fish were estimated to have reascended McNary fishways after fallback.

Radio-tagged steelhead fallback through the McNary Dam JBS was estimated to be 26-29% of the pre-spawn fallback events in 2000-2001 (Jepson et al. 2004). Route-specific fallback estimates for radio-tagged steelhead in the winters of 2013-2014 and 2014-2015 were 33-38% in the ‘possible spillway’ category, 12-38% in the ‘possible turbine or navigation lock’ category, 5-12% via the ice/trash sluiceway, 0-10% via adult fishways, and 4% via the navigation lock (one winter only). The remaining 15-30% of the events had insufficient information to assign to a route (Keefer et al. 2015b).

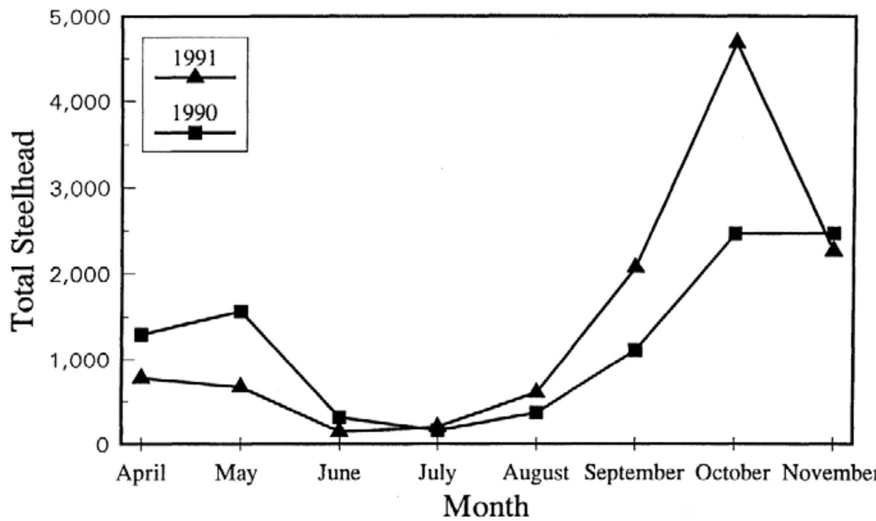


Figure 16. Monthly numbers of pre-spawn steelhead enumerated falling back through the McNary juvenile bypass system (JBS) in fall of 1990 and 1991. Source: Wagner & Hillson (1993).

Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams – Route-specific fallback information and the timing of fallback events by pre-spawn steelhead has been infrequently reported in the radiotelemetry studies at the lower Snake River dams. Radio-tagged steelhead fallback through the Ice Harbor Dam JBS was estimated to be 9-14% of the pre-spawn fallback events in 2000-2001 (Jepson et al. 2004).

Downstream passage routes by kelts – Several radio and acoustic telemetry studies have investigated route-specific passage of steelhead kelts in the FCRPS. Results consistently indicate that the majority of kelts use surface-oriented passage routes (Wertheimer et al. 2007; Rayamajhi et al. 2013; Colotelo et al. 2013, 2014; Harnish et al. 2014). For instance, Colotelo et al. (2013, 2014) estimated that the majority of kelts passing dams on both the lower Snake River and Columbia River used spillways (21-85% of tagged fish, depending on the dam and year) and spillway weirs (17-68%) in 2012-2013. In general, spillway weirs were disproportionately used at dams on the lower Snake River, while traditional spillways were disproportionately used at dams on the Columbia River. Conversely, only a small number and percentage of tagged kelts used the JBS (4-9%) or turbines (2-7%) to pass dams (Colotelo et al. 2013, 2014; Harnish et al. 2014).

Fallback routes of radio-tagged kelts at Bonneville Dam were monitored in spring 2001-2002 and 2004 (Wertheimer and Evans 2005; Wertheimer 2007; Boggs et al. 2008). In 2004 estimated passage routes were: 58% via the B2CC or B1 sluiceway (i.e., surface routes), 28% via the traditional spillway, 9% via turbines, and 4% through the bypass systems (Wertheimer 2007). The results were less clear for 2001 and 2002 as reported in Wertheimer and Evans (2005) and Wertheimer (2007). However, it appears that more details were provided in the companion report by Boggs et al. (2008): route-specific estimates in low-flow 2001 were 29% (JBS), 11% (sluiceway), 23% (spillway), and 37% (turbines); in 2002, estimates were 15% (JBS), 7% (sluiceway), 68% (spillway), and 11% (turbines).

Fallback routes at The Dalles Dam were estimated for the radio-tagged kelts in Wertheimer and Evans (2005) and Boggs et al. (2008). Not all routes were monitored in 2001, and route-specific estimates were: 35% (spillway), 13% (sluiceway), 10% (turbines), and 42% (unknown). In 2002 and 2004, estimates were: 88-93% (spillway), 6-7% (sluiceway), and 1-6% (turbines).

Fallback: Routes and Timing – Summary

Key findings

- Pre-spawn and kelt steelhead fallback primarily via spillways at FCRPS dams when spill is occurring
- Pre- and post-spawn fish also pass JBSs, ice & trash sluiceways, navigation locks, fishways, turbines
- Kelts preferentially pass surface-oriented routes when they are available

Critical uncertainties

- All routes at dams were rarely monitored simultaneously; many route-use estimates were approximate
- Origin populations were rarely considered in fallback route summaries
- Surface-flow volume needed to divert fallback fish from more hazardous routes is not well understood

Technical recommendations

- Genetic sampling of steelhead passing JBSs could provide time-specific index of populations falling back
- Accurate fallback route partitioning will require extensive monitoring effort

2.2.14 Fallback: Survival and Injury Rates

There have been at least two recent direct survival and injury studies of adult steelhead at Bonneville and McNary dams (Normandeau Associates 2011, 2014). These focused studies evaluated survival and injury rates for adult steelhead that were balloon-tagged and released directly into several downstream passage routes. These included: the Bonneville ice/trash sluiceway at Powerhouse 1, the Bonneville corner collector at Powerhouse 2, a temporary spillway weir (TSW) at McNary Dam, and Turbine Unit 12 at McNary Dam. In 2014, a focused direct injury study was also conducted at the Lower Granite Dam JBS on steelhead kelts (O'Connor et al. 2015). For post-spawn kelts, the relationship between fallback (downstream passage) at FCRPS dams and survival has been assessed principally using acoustic telemetry. The relationship between fallback and survival has most frequently been evaluated indirectly. In the radiotelemetry studies of pre-spawn steelhead, for example, the survival effects of fallback has been assessed by comparing final detection locations or fates of fish that either did or did not fall back at a dam. Last detection categories have included main stem harvest, last detection at a FCRPS dam or reservoir, and last detection in a probable spawning tributary. For example, post-fallback survival to tributaries varied widely among dams and among seasons in the 2013-2014 radiotelemetry study, in part because sample sizes were often small.

Direct survival studies – A direct survival study was conducted at Bonneville Dam in March 2011 using radiotelemetry and balloon-tagged hatchery rainbow trout as surrogates for steelhead kelts (Normandeau 2011). Survival (48 hour) and injury rates were assessed for fish that passed through the ice/trash sluiceway at Powerhouse 1 or through the Powerhouse 2 Corner Collector (*Table 15*). Survival was estimated to be ~98% for both routes. Some of the limited mortality was associated with pinniped predation in the Bonneville tailrace. Fallback-related injury rates were reported as 1% for fish that passed both routes.

A similar direct survival study using balloon tags was conducted at McNary Dam in March 2014 (Normandeau 2014). Survival and injury rates were assessed using hatchery steelhead passed through Turbine unit 12 or through the temporary spillway weir (TSW). Survival (1 and 48 h) was estimated to be 91% for fish that passed via the turbine and the malady-free injury rate was 93% (*Table 15*). Estimated survival (1 and 48 hour) and the malady-free estimate were all 98% for the sample that passed the TSW. The authors concluded that the TSW provided steelhead a significant survival benefit relative to the turbine.

A direct injury study was conducted in 2014 using 92 kelts collected and PIT-tagged at the Lower Granite JBS (O'Connor et al. 2015). The test evaluated injury rates for fish passed through a prototype weir in the 5A gatewell and an enlarged orifice (14-inch instead of 10-inch). The modified orifice also included a light ring between the gatewell and juvenile collection channel. The 'control' fish in this study (*n* = 12-16 kelts per injury type) were released directly into the bypass channel downstream from the gatewell. Samples in the experimental treatments were *n* = 6-15 kelts with the orifice light-off, *n* = 7-17 with the light-on treatment, and *n* = 12-23 with the sharp-crested weir. Small sample sizes limited interpretation of these data, but results suggested that minor injuries (body injury, descaling, fin damage) were slightly lower for the control group than for those in the experimental treatments (*Table 16*). Only one kelt had a major injury (O'Connor et al. 2015).

Table 15. Summary of survival and injury estimates (90% ci for Bonneville and 95% ci for McNary) for adult steelhead fallback experiments at Bonneville Dam (2011) and at McNary Dam (2014). Source: Normandeau (2011, 2014).

Dam	*Fallback route*	*n Released*	*1 h Survival*[1]	*48 h Survival*[1]	*Malady-free injury rate*
Bonneville	*PH 1 Ice/Trash Sluiceway*	*100*	*0.980 (±0.023)*	*0.980 (±0.023)*	*0.990 (0.016)*
	PH2 Corner Collector	*100*	*0.950 (0.016)*	*0.979 (0.023)*	*0.990 (0.016)*
	Control	*37*	*1.000*	*1.000*	*1.000*
McNary	*Turbine Unit 12*	*130*	*0.907 (0.050)*	*0.907 (0.050)*	*0.927 (0.046)*
	Temporary Spillway Weir	*88*	*0.977 (0.032)*	*0.977 (0.032)*	*0.977 (0.032)*
	Control	*16*	*0.938*[2]	*0.938*[2]	*1.000*

[1] *includes possible predation by pinnipeds in tailrace*
[2] *no ci reported*

Table 16. Number and percent (%) of steelhead kelts released into gatewell 5A with three experimental treatments (orifice light-off, orifice light-on, sharp-crested weir) or into the bypass channel (control group) observed with a change in fish condition following passage. Source: O'Connor et al. (2015).

		Bypass channel		14" orifice light off		14" orifice light on		Sharp-crested weir	
Injury type	Change	*n*	%	*n*	%	*n*	%	*n*	%
Body injury	None	11	91.7	4	66.7	5	71.4	9	75.0
	Minor	1	8.3	2	33.3	2	28.6	2	16.7
	Major	0	-	0	-	0	-	1	8.3
Descaling	None	19	90.5	13	92.9	17	100	23	100
	Minor	2	9.5	1	7.1	0	-	0	-
	Major	0	-	0	-	0	-	0	-
Fin damage	None	16	100	15	100	15	100	20	100
	Minor	0	-	0	-	0	-	0	-
	Major	0	-	0	-	0	-	0	-

Radiotelemetry studies – In an FCRPS-wide assessment of pre-spawn steelhead fallback on survival, Keefer et al. (2005) estimated that fish that fell back at any dam survived to tributaries at rates of ~67-77%. These survival rates, calculated for fish of unknown origin site, were ~8-20% lower than survival estimates for unknown-origin steelhead that did not fall back at any dam. Survival rates for known-origin Snake River steelhead were 73-81% for fish that fell back versus 90-91% for those that did not. In contrast, the negative fallback effect on survival was not identified for known-origin steelhead from the upper Columba River: estimates were 92% for fallback fish and 91% for non-fallback fish (Keefer et al. 2005).

Post-fallback survival to tributaries was estimated for pre-spawn steelhead that fell back at each FCRPS dam by Boggs et al. (2005). Survival estimates for fallback fish were: 46% (fallback at Bonneville), 58% (The Dalles), 59% (John Day), 73% (McNary), 89% (Ice Harbor), 64% (Lower Monumental), 75% (Little Goose), and 56% (Lower Granite). A caveat in this study was that fish detected at the most upstream FCRPS monitoring sites (Lower Granite and Priest Rapids dams) were considered to have reached tributaries; ≤5% of the fish that fell back at lower Columbia River dams were last at Lower Granite or Priest Rapids, but 18-33% of those that fell back at lower Snake River dams were last at these sites. Post-fallback harvest in the main stem was ~5-14% of the fish that fell back at lower Columbia River dams, but was 0% for those that fell back at lower Snake River dams (Boggs et al. 2005).

In the 2013-2014 radiotelemetry studies, post-fallback survival to tributaries for pre-spawn steelhead was estimated at all FCRPS dams (*Table 17*). Across all dates, mean survival was 60% (fell back at The Dalles), 62% (John Day), 76% (McNary), 69% (Ice Harbor), 58% (Lower Monumental), 71% (Little Goose), and 64% (Lower Granite); survival was estimated at 33% for fish that fell back at Bonneville Dam, but there was no downstream tributary monitoring so this was almost certainly an underestimate. Of the steelhead that fell back in summer (15 June to 31 August), 50% (2013) and 67% (2014) survived to tributaries. Of those that fell back in September or October, 55% (2013) and 67% (2014) survived, and of those that fell back at any dam from November through March, 56% (2013) and 61% (2014) survived to tributaries (*Table*

15). These estimates were based on small sample sizes in some cases, and the samples were weighted for late-run fish (Keefer et al. 2015a). A more narrowly-focused fallback study at The Dalles Dam, reported that 54% of the pre-spawn, radio-tagged steelhead that fell back in November were last recorded in tributaries (Keefer and Peery 2007).

Table 17. Numbers of radio-tagged steelhead that fell back at dams in 2013-2014 and 2014-2015 prior to spawning (i.e., no known or suspected kelt fallback events included) and the percent of events that were eventually followed by tributary entry (% Trib). Source: Keefer et al. (2015b).

		Fallback timing							
	Tag	15 Jun – 31 Aug		1 Sep – 31 Oct		1 Nov – 31 Mar		All dates[1]	
Dam	year	*n*	% Trib	*n*	% Trib	*n*	% Trib	*n*	% Trib
Bonneville[2]	2013	3	33%	9	22%	23	39%	38	39%
	2014	6	33%	2	0%	3	33%	11	27%
The Dalles	2013	1	100%	29	52%	48	50%	82	54%
	2014	5	60%	16	69%	13	62%	35	66%
John Day	2013	9	67%	6	67%	13	46%	31	61%
	2014	9	89%	12	42%	4	75%	27	63%
McNary	2013	1	100%	14	64%	27	70%	42	69%
	2014	4	75%	8	88%	30	80%	44	82%
Ice Harbor	2013	11	55%	5	80%	11	82%	27	70%
	2014	7	43%	9	89%	11	64%	27	67%
L. Monumental	2013	12	33%	5	40%	5	40%	24	38%
	2014	4	75%	4	100%	5	60%	13	77%
Little Goose	2013	1	0%	4	75%	5	40%	13	77%
	2014	2	100%	10	70%	6	33%	20	65%
Lower Granite	2013	1	0%	1	100%	7	71%	13	85%
	2014	1	100%	6	50%	6	17%	14	43%
Any dam	2013	38	50%	73	55%	141	56%	271	58%
	2014	39	67%	67	67%	74	61%	191	66%

[1] includes some presumed pre-spawn events in April and May
[2] very little monitoring downstream from Bonneville Dam

Acoustic telemetry studies: kelts – Route-specific survival results for acoustic-tagged kelts indicate that survival probabilities were often – but not always – the highest for kelts that used spillways and spillway weirs to pass dams (*Table 18*). At Lower Granite, Little Goose, and Lower Monumental dams, Harnish et al. (2014) estimated that kelt survival was 71-94% (traditional spillways) and 67-98% (spillway weirs) in 2012 and 2013. Survival of kelts passing through the JBS and turbines was often lower but more variable with kelt survival of 33-100% (JBS) and 58-100% (turbines). In a 2012 study of route-specific kelt survival at The Dalles and Bonneville dams, Rayamajhi et al. (2013) estimated kelt survival of 91% and 95% at spillways and the Bonneville corner collector (BCC), respectively. Survival of kelts passing through the JBS (Bonneville only), turbines, and sluiceways were lower at 60%, 53-74%, and 80-93%, respectively. Samples sizes, particularly for fish passing via JBS and turbine routes, were often small and passage-specific differences in kelt survival results should be interpreted cautiously.

Table 18. Route-specific fallback survival of acoustic-tagged steelhead kelts at lower Snake River Dams in 2012 and 2013. Routes were not monitored at Ice Harbor Dam. Source: Harnish et al. (2015) and Colotelo et al. (2014).

				Survival (SE)	
Dam	Downstream site[1]	Route	Percent	2012	2013
Lower Granite (rkm 173)	rkm 114	JBS	4.9-5.6%	0.86 (0.13)	0.33 (0.19)
		Turbine	1.4-6.5%	0.88 (0.12)	1.00 (0.00)
		Spillway weir	57.3-79.9%	0.90 (0.04)	0.67 (0.05)
		Traditional spill	12.5-25.8%	0.91 (0.05)	0.71 (0.11)
		All routes	[2]	**0.89 (0.03)**	**0.66 (0.04)**
Little Goose (rkm 113)	rkm 81	JBS	6.7-10.1%	0.97 (0.03)	0.88 (0.07)
		Turbine	4.5-5.3%	0.78 (0.12)	0.84 (0.08)
		Spillway weir	60.8-71.0%	0.97 (0.01)	0.94 (0.02)
		Traditional spill	15.9-24.7%	0.94 (0.03)	0.82 (0.05)
		All routes		**0.94 (0.03)**	**0.82 (0.05)**
L. Monumental (rkm 67)	rkm 40	JBS	5.4-6.9%	1.00 (0.00)	0.94 (0.06)
		Turbine	4.6-6.8%	0.58 (0.14)	0.84 (0.08)
		Spillway weir	68.0-71.1%	0.98 (0.01)	0.93 (0.02)
		Traditional spill	16.0-20.5%	0.93 (0.04)	0.83 (0.06)
		All routes		**0.94 (0.01)**	**0.89 (0.02)**
Ice Harbor (rkm 17)	rkm 3	**All routes**	**n/a**	**0.98 (0.01)**	**0.94 (0.02)**

[1] river kilometer from Snake River mouth
[2] 1.4-4.8% via unknown route at L. Granite Dam

Fallback: Survival and Injury Rates – Summary

Key findings

- Direct survival tests: 48 h survival ≥98% through Bonneville Ice/Trash sluiceway & corner collector
- Direct survival tests: 48 h survival ~98% through McNary TSW and ~91% through McNary turbine
- Radio-tagged, pre-spawn steelhead that fell back had 8-20% lower survival to tributaries than no-fallback fish
- Fallback effects on survival vary among dams and seasonally, likely reflecting route differences
- Acoustic-tagged kelt survival was higher via spillways & spillway weirs and lower via JBSs & turbines

Critical uncertainties

- Experimental data limited to narrow set of conditions and limited routes at Bonneville and McNary dams
- Actual post-fallback fates mostly unknown in acoustic and radiotelemetry studies
- Sample sizes were limiting for route-specific kelt survival estimates
- Cause and effect very difficult to determine in non-experimental fallback-survival analyses
- Very little population-specific information on post-fallback survival

Technical recommendations

- Provision of surface-flow routes may improve post-fallback survival for pre-spawn and kelt steelhead
- Resolving route-specific survival questions may require additional direct release tests
- Active tag studies with mortality sensors may reduce uncertainty associated with post-fallback fates
- It may be possible to assess fallback-related injuries using recaptured PIT-tagged fish

2.2.15 FCRPS Reach Conversion Rates: Pre-spawn Adults

There have been several Corps-funded research projects that addressed FCRPS reach conversion estimates for adult steelhead. There have been three general study types: (1) radiotelemetry studies that used run-of-river (mostly unknown-origin site) samples of adult steelhead collected and tagged at Bonneville Dam; (2) compilation studies using adult PIT-tag data from known-origin steelhead that were tagged as juveniles, primarily by other agencies; and (3) radiotelemetry studies that used genetic data to assign run-of-river fish to genetic reporting groups, typically at the scale of sub-basin or to specific hatchery groups using genetic tagging methods. For all study types, methods for estimating dam-to-dam and multi-dam conversion rates have used established mark-recapture methods (e.g., Cormack-Jolly-Seber models; White and Burnham 1999; Perry et al. 2012). However, the types of estimates have varied, in part because tributary entry can be interpreted differently for fish with known-origin site versus unknown-origin site. For example, a known-origin Snake River steelhead that enters the Deschutes River would be considered an unsuccessful migrant, or stray, whereas a steelhead with unknown-origin site that entered the Deschutes River would be considered successful because it entered a spawning tributary. Various agencies have also differentially accounted for main stem harvest and inter-basin straying in previous reports.

Radiotelemetry – Several of the adult steelhead radio-telemetry studies had reach conversion, reach escapement, or survival to tributaries as a primary study objective (Keefer et al. 2005, 2014b, 2015a; Caudill et al. 2007). The radio-tagged samples from the late 1990s and early-2000s included a mix of mostly unknown-origin, run-of-river steelhead plus some known-origin steelhead (identified from juvenile PIT-tag sites). The 2013-2014 samples were run-of-river, but many were genetically assigned to specific hatcheries and all were assigned to genetic stock identification (GSI) reporting groups (Keefer et al. 2015a).

The 1996-2002 radiotelemetry study of FCRPS reach escapement provided a series of survival estimates that differed in the way that main stem and tributary harvest within a reach were treated (Keefer et al 2005). Most steelhead tagged in this study were of unknown origin site, with small percentages of known Snake River or upper Columbia River origin. The metric most comparable to PIT-tag based estimates of reach conversion was 'Escapement 2', which treated radio-tagged steelhead harvested in main stem fisheries as unsuccessful and all fish last recorded in tributaries as successful (*Table 19*). Annual Escapement 2 estimates for the entire FCPRS (bounded by Bonneville, Priest Rapids and Lower Granite dams) ranged from 60-73% for unknown-origin steelhead, from 79-86% for Snake River steelhead, and from 68-88% for upper Columbia River steelhead. Annual Escapement 2 estimates for individual FCPRS reaches were approximately 82-92% (Bonneville-The Dalles), 93-95% (The Dalles- John Day), 91-95% (John Day-McNary), 89-96% (McNary-Ice Harbor/Priest Rapids), 96-97% (Ice Harbor-Lower Monumental), 91-98% (Lower Monumental-Little Goose), and 95-98% (Little Goose-Lower Granite). Reach survival patterns were similar for unknown- and known-origin site groups, except that known-origin groups tended to have slightly higher reach survival.

A second adult steelhead reach conversion study using radio-tagged fish was conducted in 2013-2014 (Keefer et al. 2015a). Adults were collected and tagged at Bonneville Dam, with samples that were over-weighted for late-run steelhead that were mostly from the Clearwater River. Genetic stock identification was used in this study to provide population-specific estimates for a portion of the fish. As with the earlier radiotelemetry study, Keefer et al. (2015a) provided a series of reach escapement estimates that varied with regards to how harvest and tributary entry were treated. Using the metric (B) that treated main stem harvest as unsuccessful and tributary entry as successful, reach-specific conversion rates for early-run steelhead were: 79-86% (Bonneville-The Dalles), 96-97% (The Dalles-John Day), 91-95% (John Day-McNary), and 74-77% for the combined Bonneville-McNary reach (*Table 20*). Reach conversion estimates were higher, on average, for late-run steelhead: 89-92% (Bonneville-The Dalles), 95-96% (The Dalles-John Day), 95-97% (John Day-McNary), and 82-85% for the combined Bonneville-McNary reach.

PIT-tag compilations – Agency reporting on adult PIT tag data has focused on multi-dam reach conversion estimates (i.e., Bonneville-McNary, Bonneville-Lower Granite, McNary-Lower Granite) with an emphasis on which reaches were associated with 'loss' or 'inter-dam dropout' of ESA-listed Snake River and Upper Columbia River steelhead. Reports have primarily been compiled by NOAA Fisheries (NMFS) and the Fish Passage Center (FPC). Many previous PIT-based results were also summarized in the 2008 and 2014 Supplemental Biological Opinions. Compilation of those estimates was beyond the scope of this report because the studies were not Corps-funded.

The Corps did fund a post-hoc analysis of FCRPS reach conversion by all available PIT-tagged Snake River steelhead from McNary Dam through the lower Snake River (Keefer et al. 2014a).

The dataset included all wild and hatchery steelhead with origins upstream from Lower Granite Dam during the adult migration years 2002-2013. Mean annual reach conversion estimates for the aggregated wild populations were: 93.8% (McNary-Ice Harbor), 96.2% (Ice Harbor-Lower Granite), and 90.1% (McNary-Lower Granite). Means for the aggregated hatchery populations were: 95.0% (McNary-Ice Harbor), 95.7% (Ice Harbor-Lower Granite), and 91.4% (McNary-Lower Granite). Annual estimates for both aggregates are shown in *Figure 17* and estimates for aggregate groups and population-specific groups identified using genetic information are in *Table 21*.

Annual and multi-year conversion estimates for the McNary-Lower Granite reach were also presented for the wild and hatchery populations with the largest sample sizes across years (*Table 21*). In the wild group, the lowest multi-year conversion rates were for steelhead from Asotin Creek (83.7%) and the group barged as juveniles from Lower Granite Dam (84.3%). The highest multi-year estimates were for the group tagged at Lower Granite Dam that migrated downstream in-river (94.4%) and for those tagged at the Imnaha River trap (92.4%). In the hatchery group, the lowest McNary-Lower Granite reach conversion estimates were for the Lower Granite barged group (80.6%) and those tagged at the Little Sheep Facility in the Imnaha River (88.3%). The highest estimates were for the Lower Granite in-river group (95.6%) and those tagged in the main stem Salmon River (92.3%) (Keefer et al. 2014a).

Table 19. FCRPS reach conversion estimates for hatchery and wild adult steelhead radio-tagged at Bonneville Dam in 1996-1997 and 2000-2002. The conversion metric is 'Escapement 2', which treated steelhead harvested in reservoirs as unsuccessful and those last recorded in tributaries as successful (similar to 'Metric B' in Table 20. Snake River and Upper Columbia River groups were identified by juvenile PIT tag locations. ds = released downstream from Bonneville Dam. fbay = released in Bonneville Dam forebay. Source: Keefer et al. (2005).

		Reach conversion estimate – 'Escapement 2'							
	Year	BON-TDD	TDD-JDD	JDD-MCN	MCN-ICH/PRD	ICH-LMA	LMA-GOA	GOA-GRA	BON-GRA/PRD
Unknown-ds	1996	0.870	0.925	0.926	0.897	-	-	-	0.667
Unknown-ds	1997	0.813	0.920	0.937	0.914	0.974	0.907	0.949	0.612
Unknown-ds	2000	0.878	0.951	0.910	0.916	0.970	0.980	0.965	0.693
Unknown-ds	2001	0.893	0.943	0.935	0.966	0.969	0.962	0.983	0.714
Unknown-ds	2002	0.914	0.946	0.933	0.915	0.979	0.970	0.969	0.730
Unknown-fbay	2000	-	-	-	-	-	-	-	0.600
Unknown-fbay	2001	-	-	-	-	-	-	-	0.711
Unknown-fbay	2002	-	-	-	-	-	-	-	0.732
Snake River-ds	2001	0.919	0.957	0.970	0.967	0.977	0.983	0.994	0.812
Snake River-ds	2002	0.933	0.942	0.954	0.986	0.989	0.986	0.993	0.805
Snake River-fbay	2001	-	-	-	-	-	-	-	0.861
Snake River-fbay	2002	-	-	-	-	-	-	-	0.788
Upper Columbia-ds	2001	0.956	0.946	0.935	0.958	-	-	-	0.820
Upper Columbia-ds	2002	0.976	0.917	0.970	0.984	-	-	-	0.877
Upper Columbia-fbay	2001	-	-	-	-	-	-	-	0.681
Upper Columbia-fbay	2002	-	-	-	-	-	-	-	0.714

Table 20. FCRPS reach conversion point estimates for adult steelhead radio-tagged at Bonneville Dam in 2013-2014. 'Early' refers to fish tagged before 15 August and 'Late' refers to those tagged after 1 September. Pahsimeroi, Lyons Ferry, Sawtooth, Dworshak, and Wallowa hatchery fish were genetically identified using parentage-based tagging (PBT). UPPCOL, UPSALM, SFCLWR, and UPCLWR were assigned to genetic stock identification (GSI) reporting groups. Metric B = tributary entry is successful conversion, harvest is unsuccessful. Metric D = tributary entry and harvest are censored. Source: Keefer et al. (2015a).

		BON-TDD		TDD-JDD		JDD-MCN		BON-MCN	
Group	Year	Metric B	Metric D	Metric B	Metric D	Metric B	Metric D	Metric B	Metric D
Early-All	2013	0.861	0.893	0.962	0.974	0.912	0.920	0.771	0.773
Early-All	2014	0.787	0.790	0.973	0.977	0.954	0.975	0.738	0.719
Early-Pahsimeroi	2013	-	-	-	-	-	-	0.714	0.769
Early-Pahsimeroi	2014	-	-	-	-	-	-	0.727	0.700
Early-Lyons Ferry	2013	-	-	-	-	-	-	0.684	0.813
Early-Lyons Ferry	2014	-	-	-	-	-	-	0.714	0.769
Early-UPPCOL	2013	-	-	-	-	-	-	0.909	1.000
Early-UPSALM	2013	-	-	-	-	-	-	0.778	0.824
Early-UPSALM	2014	-	-	-	-	-	-	0.814	0.805
Late-All	2013	0.918	0.947	0.951	0.951	0.973	0.981	0.852	0.879
Late-All	2014	0.891	0.912	0.960	0.969	0.951	0.965	0.817	0.846
Late-Pahsimeroi	2013	-	-	-	-	-	-	0.974	1.000
Late-Pahsimeroi	2014	-	-	-	-	-	-	0.914	0.909
Late-Sawtooth	2013	-	-	-	-	-	-	0.833	0.857
Late-Sawtooth	2014	-	-	-	-	-	-	0.958	0.955
Late-Dworshak	2013	-	-	-	-	-	-	0.859	0.894
Late-Dworshak	2014	-	-	-	-	-	-	0.792	0.827
Late-Wallowa	2013	-	-	-	-	-	-	1.000	1.000
Late-Wallowa	2014	-	-	-	-	-	-	0.583	0.636
Late-SFCLWR	2013	-	-	-	-	-	-	0.852	0.889
Late-SFCLWR	2014	-	-	-	-	-	-	0.805	0.842
Late-UPCLWR	2013	-	-	-	-	-	-	0.765	0.813
Late-UPCLWR	2014	-	-	-	-	-	-	0.900	0.893
Late-UPSALM	2013	-	-	-	-	-	-	0.876	0.899
Late-UPSALM	2014	-	-	-	-	-	-	0.870	0.881

Table 21. FCRPS reach conversion point estimates for adult steelhead that were PIT-tagged as juveniles. Codes are juvenile release site codes from PTAGIS and include the most abundant adult groups in these migration years. Note that columns 1-3 match data in Figure 17. Source: Keefer et al. (2014a).

Year	All MCN-ICH	All ICH-LGR	All MCN-LGR	LGRRBR MCN-LGR	LGRRRR MCN-LGR	WALH MCN-LGR	LSALR MCN-LGR	LSHEEF MCN-LGR	DWORMS MCN-LGR	PAHTRP MCN-LGR	SALR3 MCN-LGR	BCANF MCN-LGR
Hatchery steelhead												
2002	0.917	-	0.917	1.000	0.949	0.800	-	1.000	0.813	-	-	1.000
2003	0.979	0.974	0.953	-	0.981	0.750	1.000	1.000	0.800	0.667	-	1.000
2004	1.000	0.980	0.980	1.000	0.971	1.000	1.000	1.000	1.00	1.000	1.000	1.000
2005	0.988	0.976	0.965	1.000	0.982	1.000	0.857	0.500	1.00	1.000	1.000	-
2006	0.989	0.989	0.934	-	0.951	0.911	1.000	1.000	1.00	-	1.000	-
2007	0.870	0.952	0.828	0.746	0.982	0.919	1.000	1.000	1.00	-	1.000	0.833
2008	0.936	0.955	0.893	0.858	0.953	0.973	0.923	0.337	0.944	-	1.000	0.800
2009	0.922	0.958	0.883	0.800	0.969	0.936	0.937	0.861	0.912	0.914	0.944	0.953
2010	0.949	0.952	0.903	0.801	0.942	0.908	0.929	0.889	0.917	0.945	0.940	0.938
2011	0.965	0.940	0.907	0.778	0.943	0.890	0.935	0.910	0.916	0.946	0.876	0.862
2012	0.938	0.945	0.886	0.736	0.904	0.925	0.836	0.877	0.863	0.863	0.851	0.900
Total	***0.939***	***0.951***	***0.892***	***0.806***	***0.956***	***0.921***	***0.920***	***0.883***	***0.916***	***0.910***	***0.923***	***0.917***

Year	All MCN-ICH	All ICH-LGR	All MCN-LGR	LGRRBR MCN-LGR	LGRRRR MCN-LGR	IMNTRP MCN-LGR	FISTRP MCN-LGR	ASOTIC MCN-LGR	SNKTRP MCN-LGR
Wild Steelhead									
2002	0.932	-	0.932	0.868	0.943	0.944	0.948	-	0.909
2003	0.957	0.960	0.919	0.889	0.933	0.968	0.933	-	1.000
2004	0.991	0.973	0.964	0.952	0.961	0.971	1.000	-	1.000
2005	0.978	0.964	0.942	0.916	0.938	1.000	1.000	-	1.000
2006	0.921	0.969	0.893	0.900	0.867	0.917	0.889	-	-
2007	0.879	0.960	0.843	0.791	0.986	0.833	0.944	0.800	1.000
2008	0.940	0.959	0.901	0.884	0.968	0.945	0.850	0.722	0.875
2009	0.912	0.968	0.883	0.829	0.966	0.968	0.917	0.750	0.926
2010	0.928	0.946	0.877	0.816	0.944	0.918	0.889	0.773	0.842
2011	0.950	0.923	0.878	0.805	0.924	0.866	0.800	0.906	0.833
2012	0.930	0.950	0.883	0.834	0.929	0.887	0.781	0.943	0.900
Total	***0.935***	***0.958***	***0.896***	***0.843***	***0.944***	***0.924***	***0.892***	***0.837***	***0.908***

FCRPS Reach Conversion Rates: Pre-spawn Adults – Summary

Key findings

- Hundreds of dam-to-dam and multi-dam conversion estimates have been reported for pre-spawn steelhead
- Dam-to-dam conversion estimates generally lowest in Bonneville-The Dalles reach
- Dam-to-dam conversion estimates generally highest between pairs of Snake River dams
- Population-specific estimates based on PIT-tagged fish indicate seasonal and among-group differences
- Transportation of juveniles steelhead from the Snake River associated with lower adult reach conversion
- Late-run steelhead appear to have higher FCRPS conversion than some early-run populations

Critical uncertainties

- In radiotelemetry studies, use of unknown-origin site steelhead complicated data interpretation
- Across study types, statistical treatment of tributary turnoff, straying, and harvest differed
- Populations without PIT-tag programs have not been well represented in reach conversion summaries
- Wild-origin groups are under-represented in existing conversion summaries
- PIT-based estimates limited to recent years for reaches including The Dalles, Lower Monumental, and Little Goose dams

Technical recommendations

- Better PIT-tag monitoring in tributaries would identify more strays and improve conversion interpretation
- Better accounting for population-specific harvest would improve conversion rate interpretation
- Installation of PIT antennas at John Day Dam would provide more precise reach conversion estimates
- Strategies to increase adult conversion of transported steelhead need to be further developed

2.2.16 FCRPS Reach Conversion: Kelts

Survival estimates for steelhead kelts passing through the FCRPS have varied by population, origin (hatchery, wild), sex (male, female), migration distance, and year. For those kelts originating upstream from Lower Granite Dam, survival was generally low (e.g., *Figure 18*), with just 4-37% of tagged kelts surviving from Lower Granite Dam to below Bonneville Dam (Wertheimer and Evans 2005; Colotelo et al. 2013, 2014; Keefer et al. 2015b). Of those fish surviving to below Bonneville Dam, survival probabilities were the highest for wild kelts (Colotelo et al. 2013; Keefer et al. 2015b) and for kelts tagged in good external condition (those lacking body injuries or signs of disease; Wertheimer and Evans 2005; Evans et al. 2008; Keefer et al. 2008; Harnish et al. 2014). Several of these studies estimated FCRPS reach survival of kelts (*Table 22*), but we note that methods and monitoring sites differed among study types and years and that good condition fish were preferentially tagged, inflating survival. In general, annual dam-to-dam survival estimates ranged from ~57% (McNary-John Day, Wertheimer and Evans [2005]) to 100% (John Day-The Dalles, Keefer et al. [2015b]). The acoustic telemetry study of Colotelo et al. (2013, 2014) estimated survival through multiple shorter-distance FCRPS reaches, including through dam forebays and from tailraces to mid-reservoir sites (*Table 22*). Most survival estimates over these distances were between 80-95% per reach.

The association between sex and survival has been mixed, though female survival tends to be higher than male survival (Colotelo et al. 2013; Keefer et al. 2008c; 2015b). Survival of mixed-stock kelts (Snake and Middle Columbia River populations combined) tagged at McNary, John Day, and The Dalles Dam – fish that have a relatively shorter migration distance to complete – was significantly higher than that of kelts tagged at Lower Granite Dam: 60-80% of tagged kelts survived from McNary Dam to below Bonneville Dam in 2002 (Wertheimer and Evans 2005). Narum et al. (2008) and Matala et al. (2016) linked kelt survival to body size, with smaller, A-group fish more likely to survive than larger, B-group fish. Harnish et al. (2014) also observed that smaller kelts were more likely to survive passage at lower Snake River dams than larger-sized kelts.

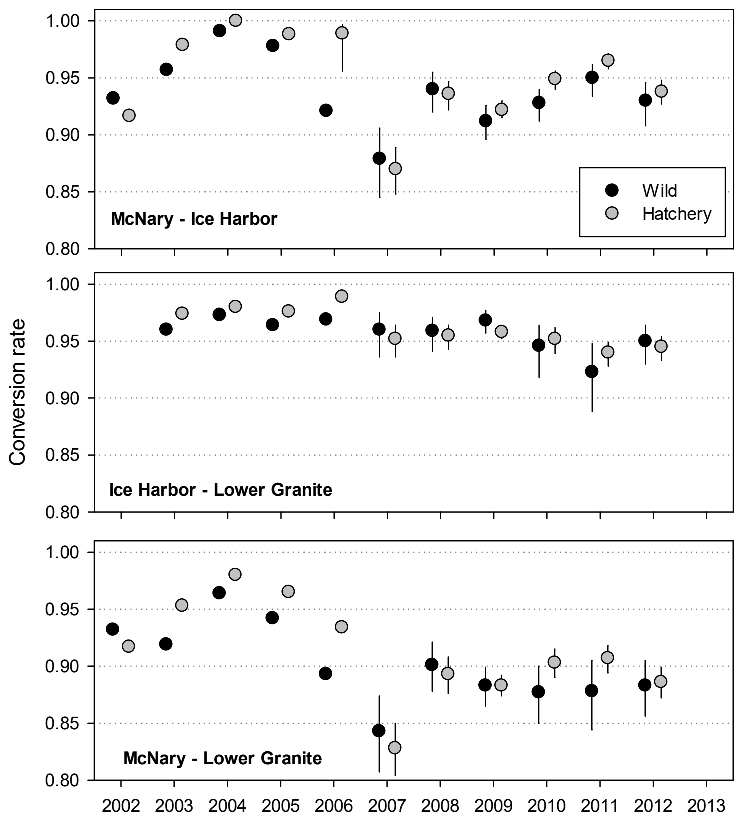


Figure 17. FCRPS reach conversion estimates for wild and hatchery adult PIT-tagged steelhead for the population aggregate detected at McNary Dam (2002-2012). Reaches were: McNary-Ice Harbor, Ice Harbor-Lower Granite, and McNary-Lower Granite. Source: Keefer et al. (2014a).

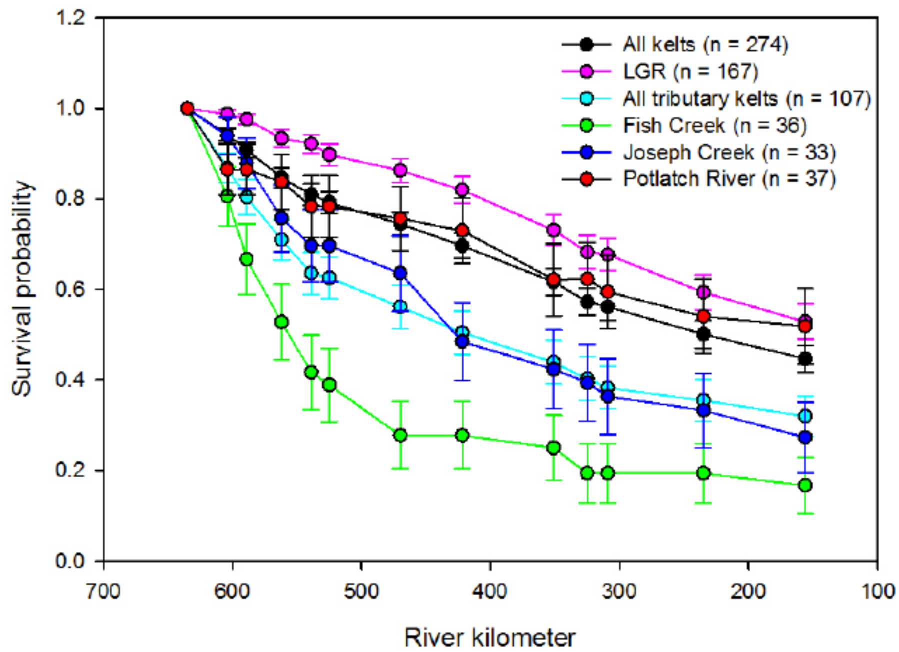


Figure 18. Cumulative survival probabilities of steelhead kelts from the Little Goose forebay to river kilometer 156 downstream from Bonneville Dam, by kelt tagging location. Source: Colotelo et al. (2013).

Table 22. FCRPS reach conversion point estimates (SE) for adult steelhead kelts that were radio- or acoustic-tagged as adults. Note that methods and monitoring sites differed among studies. Source: Wertheimer and Evans (2005), Colotelo et al. (2013, 2014), and Keefer et al. (2015b).

Reach start	Reach end	2001[1]	2002[1]	2013[2]	2014[2]
L. Granite	L. Goose	0.72	0.82	0.75 (0.06)	0.66 (0.06)
L. Goose	L. Monumental	0.65	0.64	0.72 (0.08)	0.82 (0.08)
L. Monumental	Ice Harbor	0.62	0.63	0.85 (0.19)	0.88 (0.09)
Ice Harbor	McNary	-	-	0.69 (0.31)	0.81 (0.10)
McNary	John Day	0.57	0.67	0.67 (0.27)	0.92 (0.11)
John Day	The Dalles	0.67	0.82	1.00	1.00
The Dalles	Bonneville	0.76	0.88	0.99	0.75

Reach start	Reach end	2012[3]	2013[3]
L. Granite hor[4]	L. Granite fbay[5]	0.953 (0.019)	0.919 (0.023)
L. Granite fbay	L. Granite	0.985 (0.011)	0.978 (0.013)
L. Granite	L. Goose fbay	0.895 (0.028)	0.657 (0.042)
L. Granite tr	L. Goose fbay	0.952 (0.013)	0.912 (0.016)
L. Goose fbay	L. Goose	1.000	0.958 (0.010)
L. Goose	L. Mon. mid-res	0.943 (0.014)	0.886 (0.017)
L. Goose	L. Mon. fbay	-	0.818 (0.021)
L. Mon. mid-res	L. Mon. fbay	0.969 (0.011)	0.926 (0.015)
L. Mon. fbay	L. Mon.	0.996 (0.004)	0.960 (0.011)
L. Mon.	Ice Har. mid-res	0.940 (0.015)	0.891 (0.018)
L. Mon.	Ice Har. fbay	-	0.782 (0.024)
Ice Har. mid-res	Ice Har. fbay	0.951 (0.014)	0.878 (0.021)
Ice Har. fbay	Burbank	0.979 (0.010)	0.939 (0.016)
Burbank	McNary fbay	0.996 (0.005)	-
Burbank	Bonneville fbay	-	0.910 (0.024)
McNary fbay	McNary	0.996 (0.005)	-
McNary	John Day mid-res	0.929 (0.018)	-
John Day mid-res	John Day fbay	0.891 (0.022)	-
John Day fbay	John Day	1.002 (0.001)	-
John Day	The Dalles mid-res	0.925 (0.020)	-
The Dalles mid-res	The Dalles	0.982 (0.010)	-
The Dalles	Bonneville fbay	0.902 (0.023)	-
Bonneville fbay	Bonneville	0.997 (0.007)	-
Bonneville	Knapp	0.897 (0.027)	-

[1] Wertheimer and Evans (2005); [2] Keefer et al. (2015b); [3] Colotelo et al. (2013, 2014)
[4] hor = head of reservoir; [5] fbay = forebay; [6] tr = tailrace

FCRPS Reach Conversion: Kelts – Summary

Key findings

- Kelt survival rates vary with several traits, including sex, size and origin population
- Survival of Snake River kelts from Lower Granite to Bonneville is low (~4-37%)
- Mean reach conversion estimates were lower through the Snake River than the lower Columbia River

Critical uncertainties

- FCRPS reach conversion estimates for kelts based on small sample sizes and non-random samples
- Very little previous data for upper and mid-Columbia River populations
- Very difficult to partition kelt mortality among dam passage, reservoir passage, and fish condition effects

Technical recommendations

- Early-season operation of JBSs may improve conversion estimates for PIT-tagged kelts
- Timely provision of surface-flow routes would likely increase kelt conversion rates
- PIT-tag detection capability for additional routes (Ice/Trash sluiceways, spillway weirs) may improve estimates
- Route-specific mortality tests would inform operational decisions
- Better understanding of proportional route use and kelt detection probabilities is needed

3.0 PIT-TAG DATA SUMMARIES

3.1 DATA SOURCE

All PIT-tag data used in the following summaries were acquired from the Columbia Basin PTAGIS, a regional database maintained by the Pacific States Marine Fisheries Commission, available for registered users at http://www.ptagis.org/. The PTAGIS database archives PIT-tag marking details, tag detections at interrogation antennas at dams and other sites, and tag recovery information for tens of thousands of Columbia River basin steelhead. A large majority of the steelhead data was derived from fish that were PIT-tagged as juveniles at hundreds of locations around the basin (*Appendix B*). A smaller portion of the fish were PIT-tagged as adult steelhead, either during pre-spawn migration (mostly collected at Bonneville Dam fishways), at tributary and hatchery traps, or as post-spawn kelts (mostly collected at JBS facilities). Researchers from a diversity of federal, state, tribal, and private organizations contributed PIT-tag data used as part of these PIT-tag Data Summaries (*Appendix C*).

3.2 PTAGIS QUERIES AND QA/QC

The summaries in this section are for steelhead that were detected as adult migrants at Bonneville Dam fishways over 11 study years, from 2005 to 2015. The first set of PTAGIS queries identified all of the unique adult steelhead at Bonneville Dam in each calendar year. A variety of screens and quality-control steps were taken to eliminate juvenile fish from these lists before proceeding with secondary queries.

The annual lists of unique PIT-tagged steelhead codes were then used to query additional information from PTAGIS. These secondary queries obtained information on interrogation histories (i.e., detection histories), reported mortalities (i.e., recovery events), information from the original tagging and release events (i.e., locations, dates, rear-type information, tagging individual or organization, etc.), and final detection locations and dates. Four tables were created for each annual PIT-code list and all data were assembled in a relational database with PIT code as the linkage field (*Table 23*). A fifth set of queries that included more detailed, antenna-group level detection data was added to generate dam fallback summaries.

Table 23. Examples of the types of steelhead PIT-tag data included in the relational database tables for each year, 2005-2015. All tables included PIT-tag code.

Table	
AdultPITs	First BON detection location and date; tag and release site locations and dates; rear-type (H,W); length; Mark Coordinator data; recapture data
DetectionHistory	Abbreviated adult history for each fish, with single records for each detection site×date×PIT-code combination
FinalDetects	The final date, time, and site where each fish was detected; recapture and mortality information
MainStemDetections	Expanded dataset with adult detection details at each FCRPS dam
FallbackDesignations	Antenna details used to flag presumed fallbacks at each FCRPS dam

Data quality control procedures included query logic controls, a variety of data screens, and frequent checking of individual fish histories to evaluate whether screens and controls worked appropriately. For example, to help differentiate juveniles from adults at Bonneville Dam, fish with a juvenile migration year previous to the year of first detection at Bonneville Dam were assigned as adults (e.g., Migration Year = spring 2004 and first detection at Bonneville Dam = summer 2005). Fish that were detected at Bonneville Dam less than one year after their release date were assigned juvenile status but were individually reviewed to determine whether they had upstream migration behavior consistent with precocious adults (e.g., a fish that was tagged and released in April 2005 and then detected in a Bonneville Dam adult fishway in September 2005 and also in adult fishways at McNary and Lower Granite dams in subsequent weeks was assigned adult status; however, a similar fish that was not detected in fishways upstream from Bonneville Dam was assigned juvenile status). Some fish characteristics and conditional comments associated with exports from the PTAGIS database were also queried and reviewed to assure consistency with either adult or juvenile status, and when appropriate, the status of some steelhead was updated in the database. Steelhead that were PIT-tagged as adults were identified using the fish length at tagging (when available), the tagging location (e.g., the adult fish facility at Bonneville Dam, fish ladder traps at other dams), and other information provided in the comments by tag coordinators (e.g., 'fish tagged as kelt' or 'adult fish').

3.3 PIT-TAG MONITORING INFRASTRUCTURE

The spatial distribution of PIT-tag detection arrays at the FCRPS dams (*Figure 19*) and in tributaries (*Figures 20-22*) significantly affected how the adult steelhead data can be summarized for many of the data synthesis topics. The number and distribution of PIT monitoring sites changed in each year, creating some challenges for interpreting and comparing results across years and among populations. At the FCRPS dams, a series of new PIT-tag monitoring arrays were installed in adult fishways over the 2005-2015 study period, including at Rocky Reach (2006), The Dalles (2013), Lower Monumental (2014), and Little Goose (2014) dams. FCRPS adult fishway sites operated in all years included Bonneville, McNary, Ice Harbor, Lower Granite, Priest Rapids, Rock Island, and Wells dams. There was no adult fishway PIT-tag monitoring at John Day or Wanapum dams in any year. A more substantial proliferation of monitoring sites occurred in tributaries over the study period. By 2015, there were several hundred tributary sites described in the PTAGIS interrogation site metadata.

In the main stem Columbia River, identifying steelhead that overshot natal tributaries and estimating FCRPS reach conversion rates was sensitive to which FCRPS sites were monitored. With each new fishway installation, potential detection of overshoot behavior increased and more dam-to-dam (rather than multi-dam) reach conversion estimates were possible.

The installation of new monitoring sites in tributaries influenced evaluations of homing and straying and improved the likelihood that steelhead would be detected in tributaries after a variety of behaviors (e.g., overwintering, tributary overshoot, fallback at dams, etc.). Although detection probabilities increased for many populations, several potential biases stem from the spatial and temporal changes in the PIT monitoring array. First and foremost, not all spawning tributaries had PIT-tag interrogation antennas, and many 'successful' migrants from these tributaries could not be detected outside the FCRPS. Second, hatchery steelhead were more likely than wild steelhead to be detected in many locations because interrogation infrastructure is predominantly at hatchery-operated facilities (i.e., traps, weirs, etc.). Third, detections outside the FCRPS was more likely for populations from river systems with dams located low in the drainage such as the Umatilla (Three Mile Dam), Yakima (Prosser Dam), and Wenatchee (Tumwater Dam) rivers and for rivers with full-channel PIT-tag arrays in lower reaches. The latter included the Tucannon River (starting in 2005), John Day River (2007), Fifteenmile Creek (2011), Hood River (2012), and the Deschutes River (2013). Differences in monitoring effort across populations and through time make it challenging to standardize estimates of tributary overshoot, successful tributary entry, and homing and straying rates across study groups and years.

Figure 19. PIT-tag monitoring arrays were used to monitor adult steelhead at seven FCRPS projects: Bonneville Dam (all years), The Dalles Dam (2013-2105), McNary Dam (all years), Ice Harbor Dam (all years), Lower Monumental Dam (2014-2015), Little Goose Dam (2014-2015), and Lower Granite Dam (all years). Tagged fish were also monitored at four non-FCRPS projects on the Columbia River upstream from the Snake River confluence: Priest Rapids Dam (all years), Rock Island Dam (all years), Rocky Reach Dam (2006-2015), and Wells Dam (all years).

3.4 DATA MANAGEMENT AND ANALYSES

Relational databases described above were the source for most of the data used in the summaries described in the following sections. Most synthesis topics required that subsets of the data be extracted and a combination of spreadsheets and secondary database files were used to manage topic-specific information. In addition, several master datasets were constructed that had specific information on each fish from all study years (2005-2015). These included a set for source data (i.e., PIT-tag and release sites and times, hatchery/wild, first adult detection year, etc.) and a set for fate or final detection data (i.e., last detection or recapture site and date, and tributary 'fate' information if a steelhead had kelt-like downstream movements at the end of its detection history). Fate assignments often required full history reviews for individual fish, especially those that were last detected at JBSs in spring, as many were potentially kelts. We note that fate assignment was challenging for many PIT-tagged steelhead because ambiguous migration histories existed. Large numbers of tagged fish were last detected at FCRPS dams, especially in the earliest study years; it is likely that many of these fish survived to tributaries, but there was no way to verify post-dam fates. Topic-specific analysis details are provided in each of the data synthesis sub-sections described below.

3.5 SAMPLE SUMMARY

3.5.1 Methods

After query controls and a series of data screens, the multi-year dataset had several hundred combinations of PIT-tag mark and release site combinations (*Appendix B*). In total, 93,397 steelhead were included and a majority (*n* = 78,226, 84%) were PIT-tagged as juveniles that were the focus of analyses. The remainder (15,171, 16%) was tagged as adults. We next added several fields to the dataset to simplify subsequent data management and interpretation. Additional fields included: (1) an early- or late-run designation based on the established A- versus B-group run-separation date at Bonneville Dam (25 August); and (2) a site-specific designation based on the natal tributary, hatchery, or dam where juveniles or adults were originally PIT-tagged.

Selecting an appropriate geographic scaling for the 'Site' designations was challenging because there is not consensus on which steelhead population aggregates should be treated separately. There is considerable overlap across steelhead Distinct Population Segments (DPSs), metapopulations (Brannon et al. 2004), and other management units (i.e., Snake River A- versus B-group fish and even summer- versus winter-run in some tributaries) and the management designations do not consistently reflect biological or genetic differences among populations. Given the objectives of this synthesis, we elected to organize study groups primarily at the scale of major tributary basins (*Figures 20-23*). One exception was the separation of some secondary tributary groups in Idaho's Clearwater and Salmon River basins, where B-group steelhead were associated with specific sites. A second exception were juveniles collected and PIT-tagged at FCRPS dams because these fish could be assigned to populations at only broad geographic scales (e.g., lower Columbia, upper Columbia, or Snake River).

The groups of steelhead collected and PIT-tagged as adults at or downstream from Bonneville Dam were excluded from a majority of the synthesis topics because natal sites were unknown, and behavioral data (i.e., overwintering, tributary overshoot, reach conversion, homing and straying) were best addressed with known-origin site fish. We also note that migration summaries for many of the adult steelhead PIT-tagged at Bonneville Dam have been reported previously (e.g., Fryer et al. 2012, 2013; Keefer et al. 2015a, 2015b) and that the adult samples were not very representative of the runs at large (see *Figure 27*).

3.5.2 Sample Composition

Samples PIT-tagged as juveniles – Total sample sizes for adults detected at Bonneville Dam (2005-2015) that were PIT-tagged as juveniles were 19,404 wild, 58,013 hatchery, and 809 unknown-origin (*Tables 24-26*). Annual sample sizes ranged from 409-2,925 wild fish, 3,717-9,142 hatchery fish, and 2-178 unknown fish. Most fish in the unknown group were collected at FCRPS dams.

In total, steelhead PIT-tagged as juveniles were assigned to one of three broad geographic areas: (1) the Columbia River basin downstream from the Columbia River–Snake River confluence, (2) the Columbia River basin upstream from the confluence, and (3) the Snake River (*Figure 20*). Within these broad geographic areas, fish were assigned to 37 'Sites,' which were a mixture of tributaries, main stem dams where juvenile fish were PIT-tagged, and hatcheries adjacent to the main stem rivers (*Tables 24-26*). *Appendix B* has a complete summary of the steelhead PIT-tag groups assigned to each 'Site'.

The area downstream from the Columbia–Snake confluence included Bonneville, John Day, and McNary dams along with eleven tributaries: Wind, White salmon, Klickitat, Hood, Deschutes, John Day, Umatilla, Walla Walla, Mill Creek, Fifteenmile Creek, and Rock Creek (*Figure 21*). The Snake River geographic area included Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams, Lyons Ferry Hatchery, and the Tucannon, Clearwater, Grande Ronde, Salmon and Imnaha rivers and Asotin Creek, plus a catchall Snake River group for fish that were collected and tagged in the main stem Snake River above Lower Granite Dam (*Figure 22*). The sites upstream from the Columbia–Snake confluence include Ringold Hatchery, Wanapum, Rock Island, Rocky Reach, and Wells dams, and the Yakima, Wenatchee, Entiat, Methow, and Okanogan rivers (*Figure 23*).

As noted above, secondary tributaries were also assigned for juveniles tagged in the Clearwater and Salmon rivers. Several of these secondary sites were associated with reported B-group steelhead and others were distinct tributary or hatchery groups. In the Clearwater River the secondary sites included: the Potlatch, Lochsa, Selway, South Fork Clearwater, and Middle Fork Clearwater rivers; an 'other' category was for Clearwater fish not clearly associated with one of these tributaries. Secondary sites in the Salmon basin included: Little Salmon, South Fork Salmon, Middle Fork Salmon, East Fork Salmon, and Lemhi rivers and the Pahsimeroi Hatchery; a similar Salmon River 'other' category was also included.

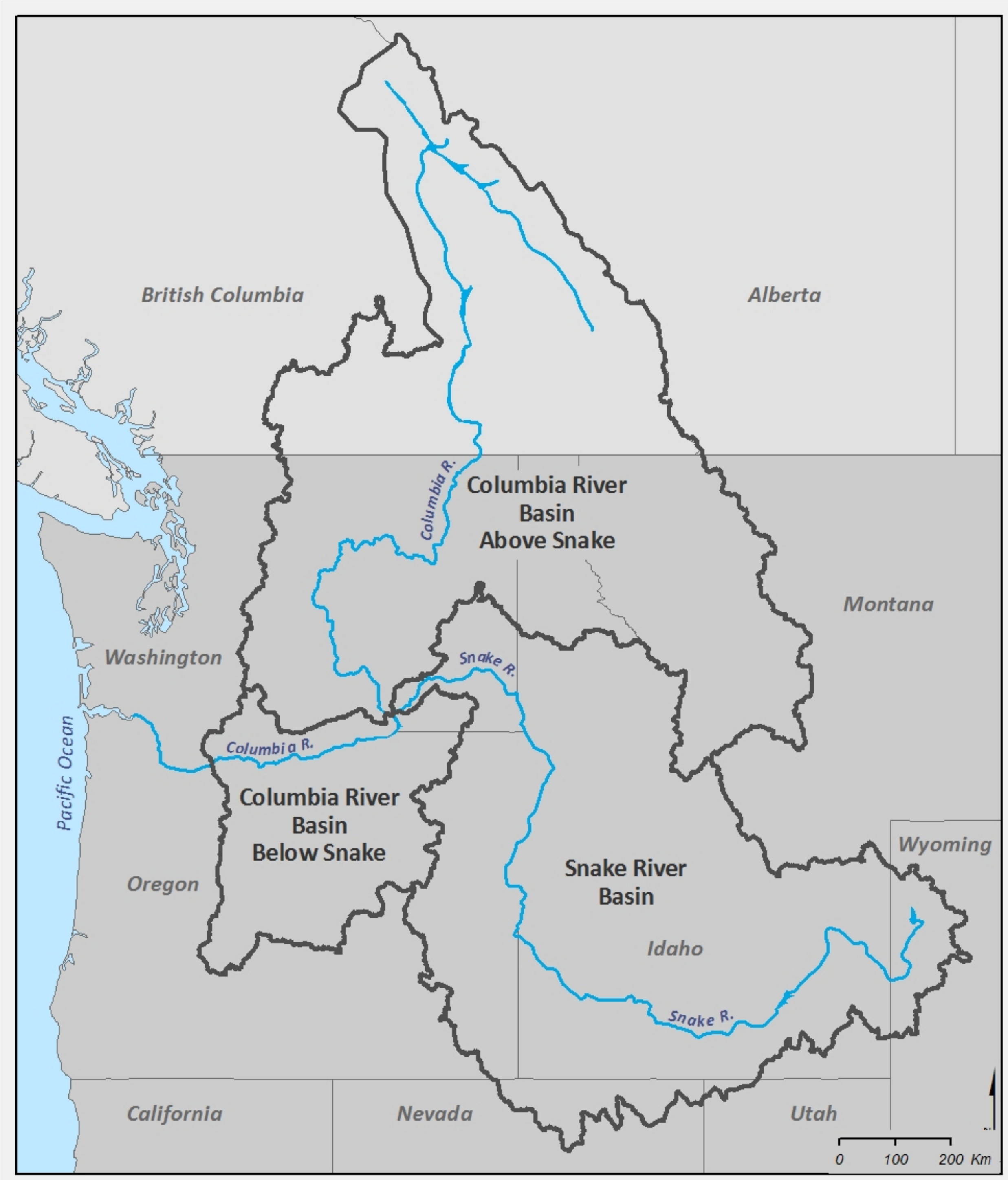


Figure 20. Three broad geographic areas used to organize adult steelhead data summaries for populations that were PIT-tagged as juveniles.

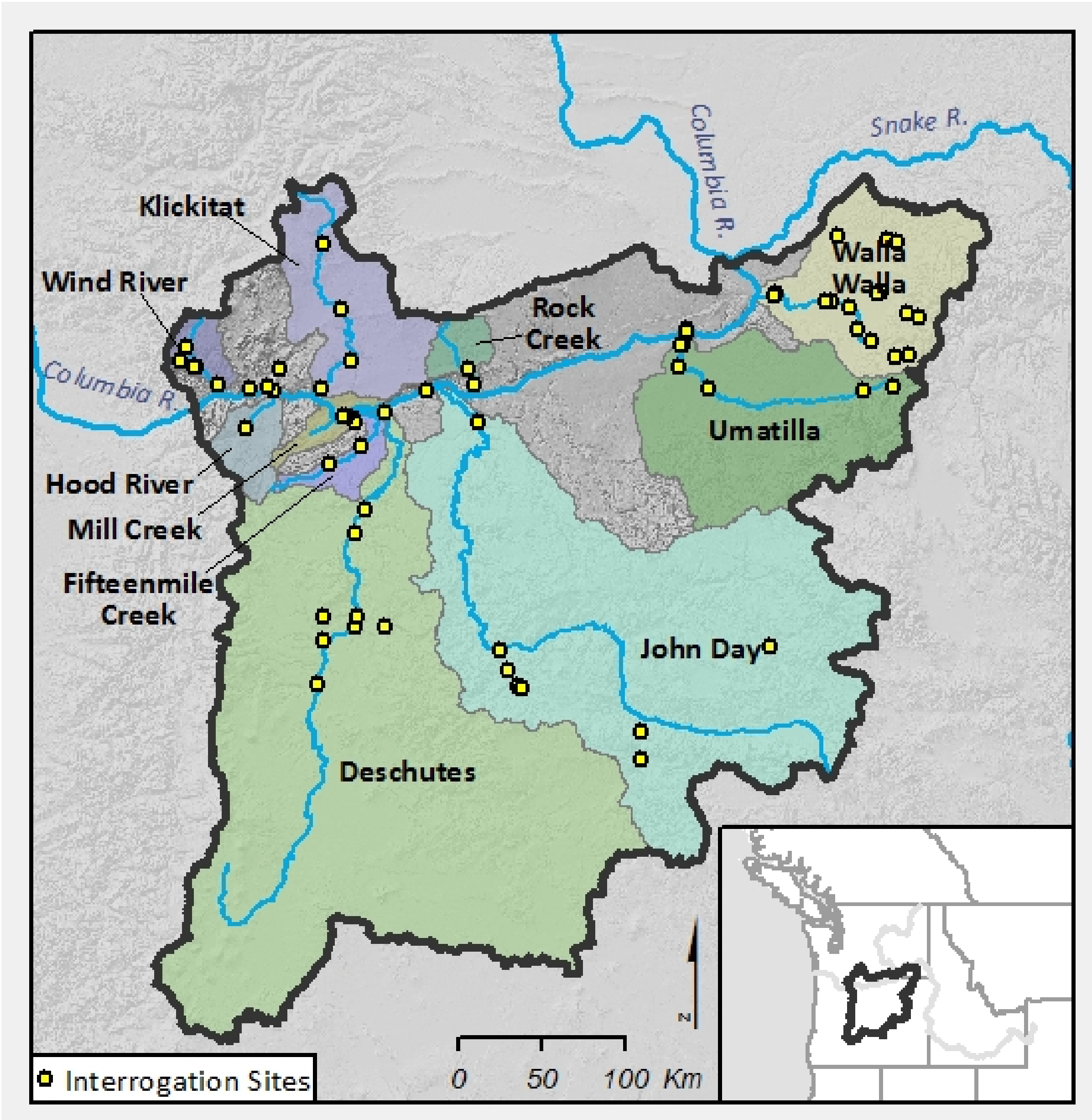


Figure 21. The Columbia River basin downstream from the Columbia River–Snake River confluence, showing the FCRPS dams and tributaries where steelhead were PIT-tagged as juveniles. Yellow circles represent PIT interrogation antenna locations; not all sites were operated in al years.

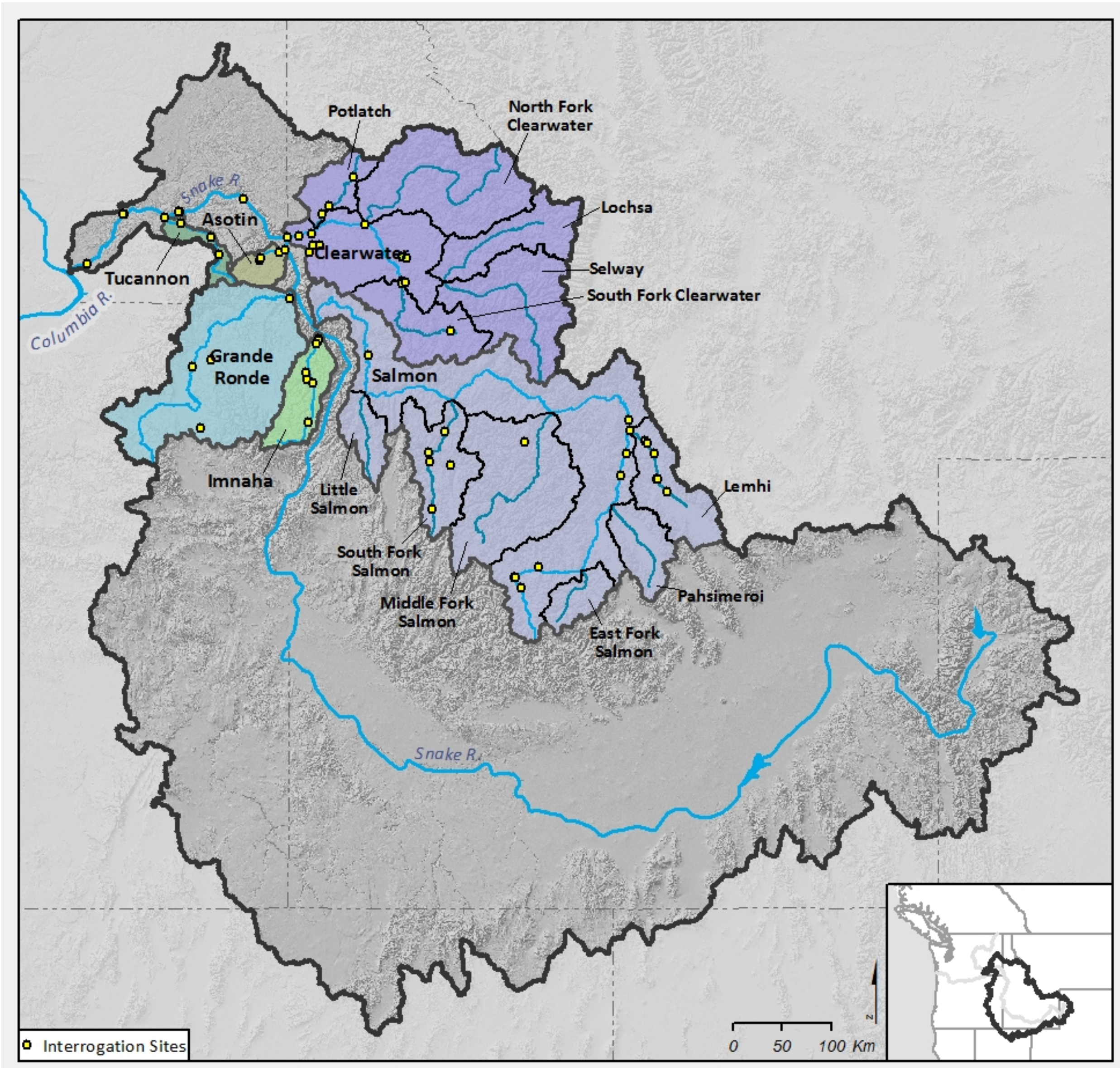


Figure 22. The Snake River basin, showing the FCRPS dams and tributaries where steelhead were PIT-tagged as juveniles. Secondary tributary delineations within the Clearwater and Salmon River drainages were used in analyses related to B-group steelhead. Yellow circles represent PIT interrogation antenna locations; not all sites were operated in al years.

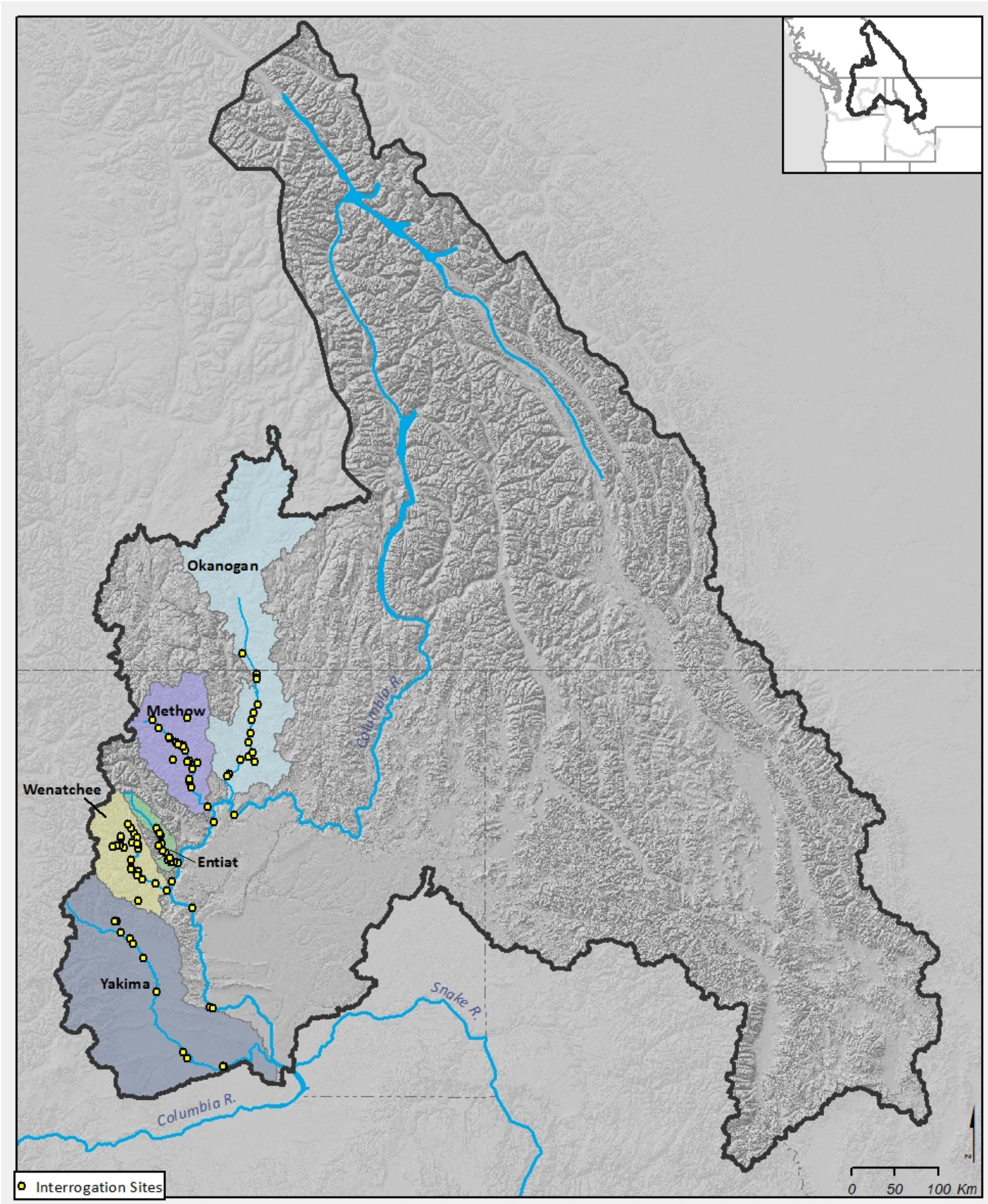


Figure 23. The upper Columbia River basin upstream from the Columbia River–Snake River confluence, showing the main stem dams and tributaries where steelhead were PIT-tagged as juveniles. Yellow circles represent PIT interrogation antenna locations; not all sites were operated in al years.

Table 24. Wild steelhead detected at Bonneville Dam as adults that were PIT-tagged as juveniles, by juvenile origin site.

Site / Dam or Tributary	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**Total**
Columbia River below Snake												
Bonneville Dam[1]			2									**2**
Wind River	46	52	52	64	161	90	97	96	27	42	122	**849**
White Salmon River[2]		1										**1**
Hood River		7	18	7	18	28	24	35	25	44	94	**300**
Klickitat River								3	3	11	9	**26**
Mill Creek									13	23	16	**52**
Fifteenmile Creek				11	45	88	93	31	31	36	31	**366**
Deschutes River			38	67	117	113	108	82	180	95	50	**850**
John Day River	67	119	109	246	343	276	285	148	263	241	218	**2315**
Rock Creek							3		6	17	8	**34**
Umatilla River	3	10	17	21	13	13	81	65	67	171	278	**739**
McNary Dam[1]								8				**8**
Walla Walla River	11	11	10	8	61	95	114	88	56	75	71	**600**
Snake River												
Ice Harbor Dam[1]						1	1					**2**
L. Monumental Dam[1]				3	25	34	10					**72**
Tucannon River	35	25	38	16	49	44	50	53	42	60	59	**471**
Lower Granite Dam[1]	265	84	417	691	1255	1157	612	407	459	689	480	**6516**
Snake River > LGR Dam	4		2	8	37	22	32	12	4	9	22	**152**
Clearwater River	36	30	50	78	136	201	140	111	87	281	177	**1327**
Asotin Creek		1	12	23	30	27	42	45	78	107	56	**421**
Grande Ronde River	35	15	33	36	65	83	86	62	63	62	68	**608**
Salmon River	17	21	19	49	158	103	125	70	113	147	91	**913**
Imnaha River	38	14	35	124	151	124	143	70	92	128	162	**1081**
Columbia River above Snake												
Yakima River	15	12	18	16	31	23	39	23	44	78	91	**390**
Rock Island Dam[1]	2	4	14	11	44	38	26	20	19	25	30	**233**
Wenatchee River			2	8	69	75	51	32	32	42	44	**355**
Entiat River		3	8	7	75	73	55	24	43	65	55	**408**
Methow River			6	13	42	24	32	18	43	46	51	**275**
Okanogan River								2	2	15	19	**38**
Total	**574**	**409**	**900**	**1507**	**2925**	**2732**	**2249**	**1505**	**1792**	**2509**	**2302**	**19404**

[1] Steelhead tagged at FCRPS dams used for some, but not all summaries

[2] Excluded: small *n* across all source categories

Table 25. Hatchery steelhead detected at Bonneville Dam as adults that were PIT-tagged as juveniles, by juvenile origin site.

Site / Dam or Tributary	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**Total**
Columbia River below Snake												
Lewis River[2]				1								**1**
Bonneville Dam[1]		34	16	6								**56**
Hood River		11	81	179	205	420	268	237	118	145	160	**1824**
Klickitat River								282	186	415	312	**1195**
Deschutes River										2	3	**5**
John Day Dam[1]						3	24	14				**41**
Umatilla River	9	12	59	80	115	76	64	24	13	36	42	**530**
McNary Dam[1]	6	9		19	52	34	18	5				**143**
Walla Walla River	33	32	23	298	410	224	262	121	108	167	114	**1792**
Snake River												
Lyons Ferry Hatchery				2	75	53	59	42	79	85	63	**458**
Ice Harbor Dam[1]				5		12	3					**20**
L. Monumental Dam[1]			1	21	132	105	17					**276**
Tucannon River	59	81	544	424	632	266	163	88	119	142	133	**2651**
Little Goose Dam[1]			12	11	2	8	5		1	2		**41**
Lower Granite Dam[1]	60	47	1070	1737	2812	955	311	254	248	438	282	**8214**
Snake River > LGR Dam	17	7	29	26	119	215	358	161	82	189	129	**1332**
Clearwater River	36	34	48	176	95	679	721	650	315	368	317	**3439**
Grande Ronde River	19	102	163	149	1135	618	653	414	382	568	550	**4753**
Salmon River	36	20	67	77	1651	1232	1468	951	962	1129	707	**8300**
Imnaha River	31	36	33	33	734	441	392	161	337	408	407	**3013**
Columbia River above Snake												
Ringold Hatchery	2871	2675	208									**5715**
Rock Island Dam[1]		17	8	19	107	53	43	41	33	29	39	**389**
Wenatchee River	407	401	313	415	731	523	420	381	189	189	173	**4142**
Rocky Reach Dam[1]		69	23									**92**
Wells Dam[1]	635	66	26				12	16	20	28	78	**881**
Methow River	1866	3093	470	22	126	57	319	323	292	286	289	**7143**
Okanogan River	350	463	73	17	9	9	117	134	100	141	115	**1528**
Total	**6435**	**7209**	**3267**	**3717**	**9142**	**5983**	**5697**	**4299**	**3584**	**4767**	**3913**	**58013**

[1] Steelhead tagged at FCRPS dams used for some, but not all summaries
[2] Excluded: downstream population

Table 26. Unknown-origin steelhead detected at Bonneville Dam as adults that were PIT-tagged as juveniles, by juvenile origin site.

Site / Dam or Tributary	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**Total**
Columbia River below Snake												
White Salmon River[2]					3							**3**
John Day Dam[1]					88	83	56	59	67	59	47	**459**
John Day River[1]										18	26	**44**
Umatilla River						1						**1**
Snake River												
Ice Harbor Dam[1]					2	1						**3**
L. Monumental Dam[1]				1	27	12	1		18	27		**86**
Lower Granite Dam[1]						1						**1**
Asotin Creek									3	2	4	**9**
Salmon River									1	7	2	**10**
Columbia River above Snake												
Yakima River								1		1		**2**
Wanapum Dam[1]					39	37	36	25	4		4	**145**
Rock Island Dam[1]					19	18	5			1	1	**44**
Entiat River				1								**1**
Methow River								1				**1**
Total				**2**	**178**	**153**	**98**	**86**	**93**	**115**	**84**	**809**

[1] Steelhead tagged at FCRPS dams used for some, but not all summaries

[2] Excluded: small *n* across all origin categories

Samples PIT-tagged as adults – Small numbers of steelhead PIT-tagged as adults were excluded *a priori*, including kelts collected in tributaries and at FCRPS JBSs and some pre-spawn adults collected at hatchery traps and weirs and then released. The large majority of adults were collected and PIT-tagged at Bonneville Dam as part of monitoring by the Columbia River Inter-Tribal Fish Commission (CRITFC) or for radiotelemetry studies (*Table 27*). A smaller number of adults was collected and PIT-tagged downstream from Bonneville Dam as part of a Washington Department of Fish and Wildlife (WDFW) evaluation. These adult-tagged groups were not included in behavioral summaries.

Table 27. Steelhead tagged as adults at Bonneville Dam or downstream (ds) from Bonneville Dam.

Origin / tag group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**Total**
Wild												
PIT-tagged at Bonneville	41			1	5		134	143	22			**346**
PIT-tagged ds Bonneville							142	241	196			**579**
Hatchery												
PIT-tagged at Bonneville	161				1735	1044	310	272	48			**3570**
PIT-tagged ds Bonneville							377	548	364			**1289**
Unknown-origin												
PIT-tagged at Bonneville	4				652	644	1341	1428	1252	1672	877	**7870**
Radio-tagged at Bonneville									748	769		**1517**
Total	**206**			**1**	**2392**	**1688**	**2304**	**2632**	**2630**	**2441**	**877**	**15171**

Relationships between PIT-tagged samples and steelhead runs-at-large – On average, steelhead PIT-tagged as juveniles and detected at Bonneville Dam as adults were 2.5% (*range* = 1.3-3.6%) of all adults (tagged and untagged) counted each year (*Figure 24*). Ideally, the PIT-tagged samples would be representative of all Columbia and Snake River populations in approximate proportion to their relative abundance. However, this was not the case in most study years (*Figures 25-26*). Some of the largest departures from representative tagging included very large numbers of hatchery steelhead from Ringold Hatchery and the Methow River in 2005 and 2006, large samples of both wild and hatchery steelhead from Lower Granite Dam in 2008-2010, and large samples of hatchery fish from the Grande Ronde and Salmon rivers in some years (*Figures 25-26*).

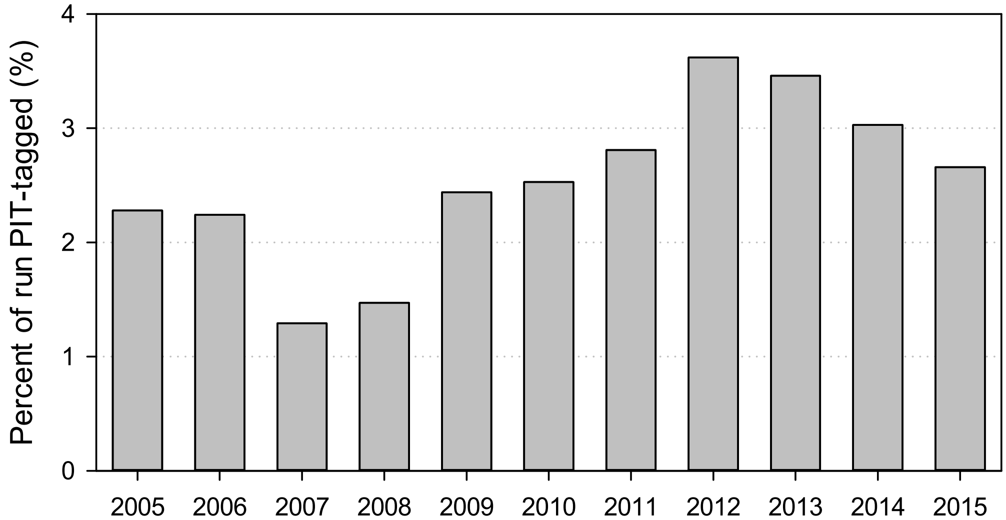


Figure 24. Percent of the adult steelhead count at Bonneville Dam that were PIT-tagged as juveniles (2005-2015).

Figure 26 shows the migration timing of adults at Bonneville Dam for the groups of fish that were PIT-tagged versus the adult runs-at-large. PIT-tagged fish were poorly matched in time to the runs in several years, but especially in 2005-2008 when early-run fish were relatively over-represented. This reflected the large Ringold Hatchery and Methow River samples, but also more PIT-tagging of juveniles from A-group hatchery programs and relatively limited PIT-tagging of wild and B-group populations. Run-timing of the PIT-tagged groups best matched the overall runs in 2010-2014, corresponding with the development of many new juvenile steelhead collection and tagging programs.

Steelhead that were PIT-tagged as adults were less representative in time of the runs at-large (*Figure 27*) than were the juvenile-tagged samples. No adults were PIT-tagged in some years and adults PIT-tagged at or downstream from Bonneville Dam were tagged for at least three different study types: one attempted to tag fish in approximate proportion to the run (CRITFC), but the others (radiotelemetry, WDFW projects) had objectives that precluded PIT-tagging fish throughout the runs. Adult steelhead handling restrictions associated with water temperature further restricted representative collection and tagging of steelhead at the Adult Fish Facility.

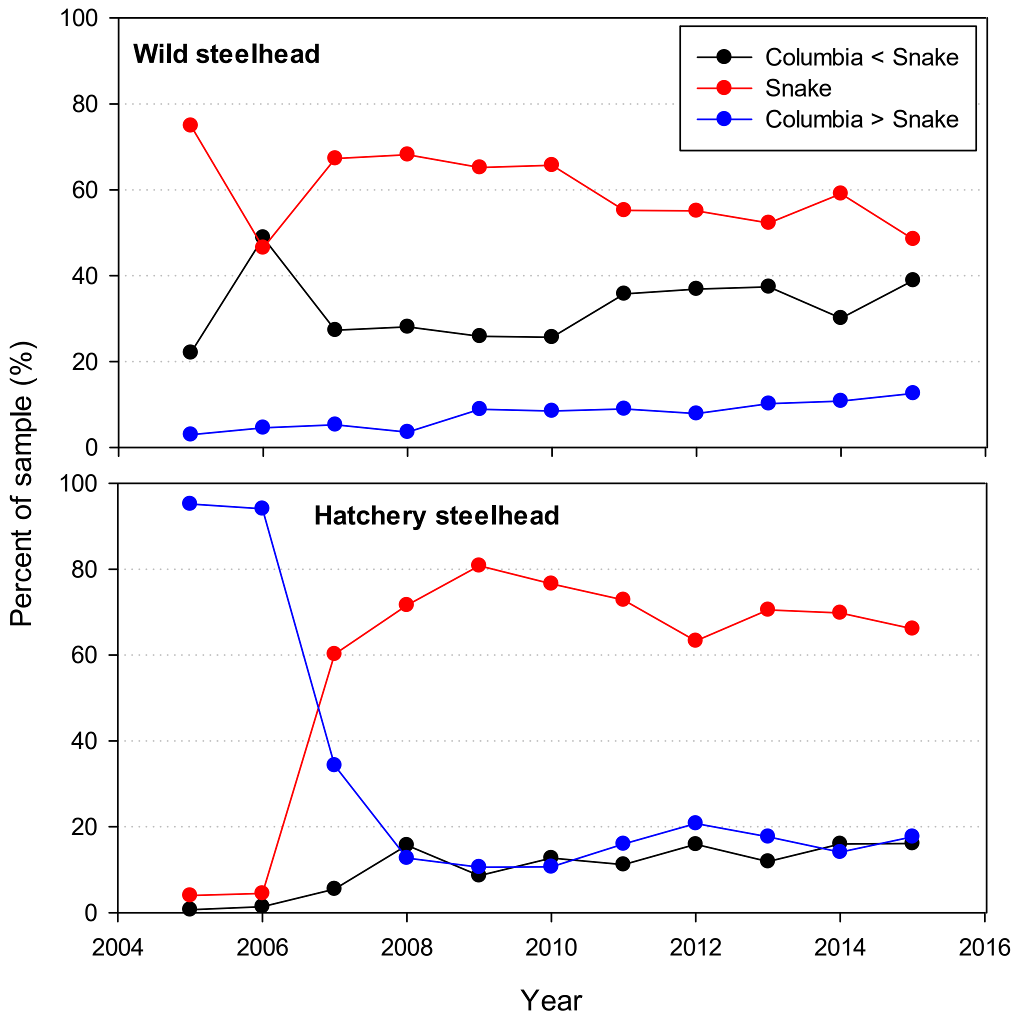


Figure 25. Annual sample composition for wild (top) and hatchery (bottom) steelhead that were PIT-tagged as juveniles. Three groups are the tributaries and dams downstream (black) and upstream (blue) from the Columbia River–Snake River confluence plus the Snake River (Red).

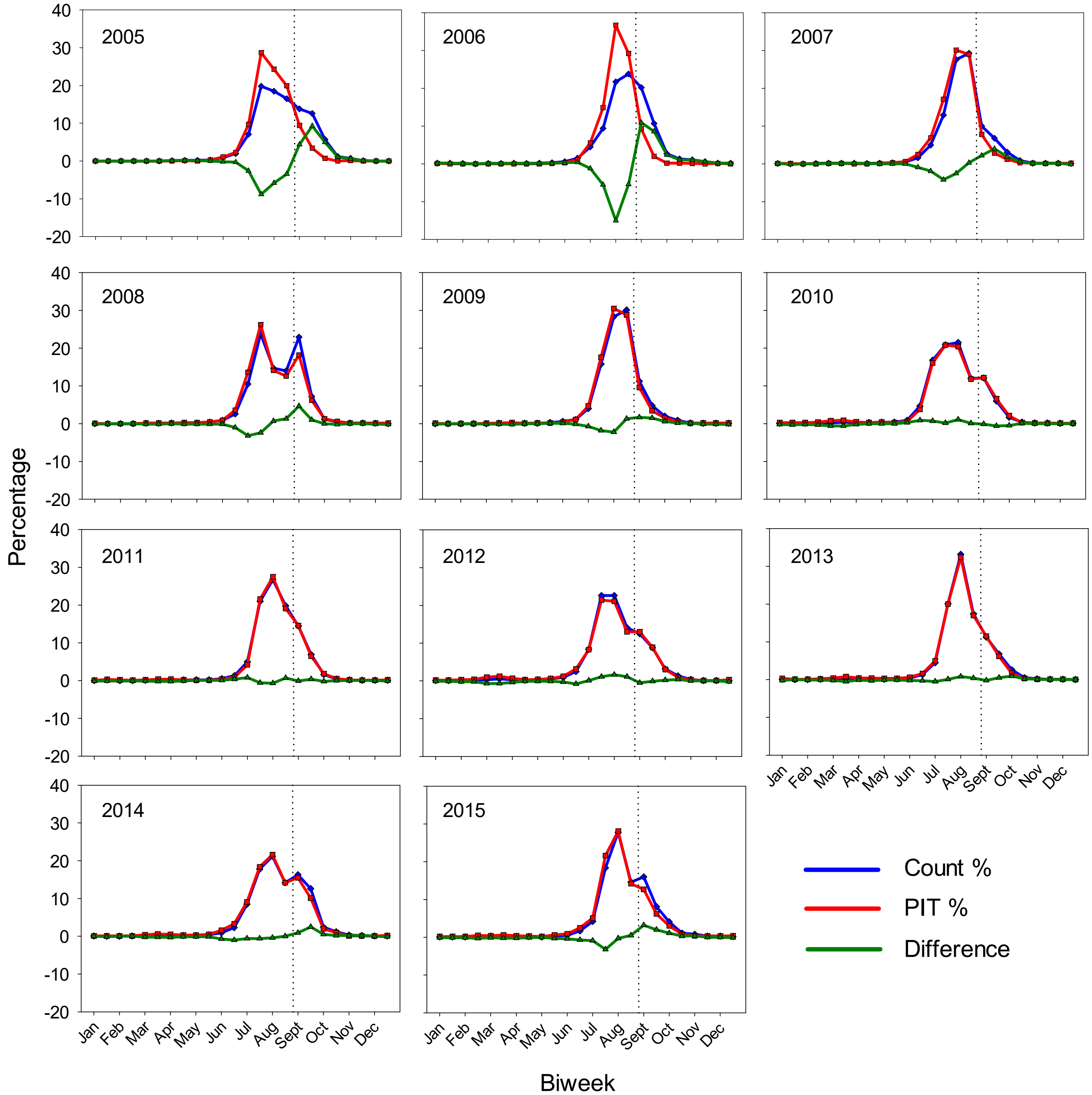


Figure 26. Annual migration timing distributions of adult steelhead at Bonneville Dam (2005-2015). Figures show the bi-weekly percentages of total adult counts (blue) versus percentages of adults that were PIT-tagged as juveniles (red). Green lines show the differences in bi-weekly percentages: numbers <0 indicate PIT-tagged fish were disproportionately abundant and numbers >0 indicate PIT-tagged fish were under-represented. Vertical line = 25 August, the established A-group / B-group separation date.

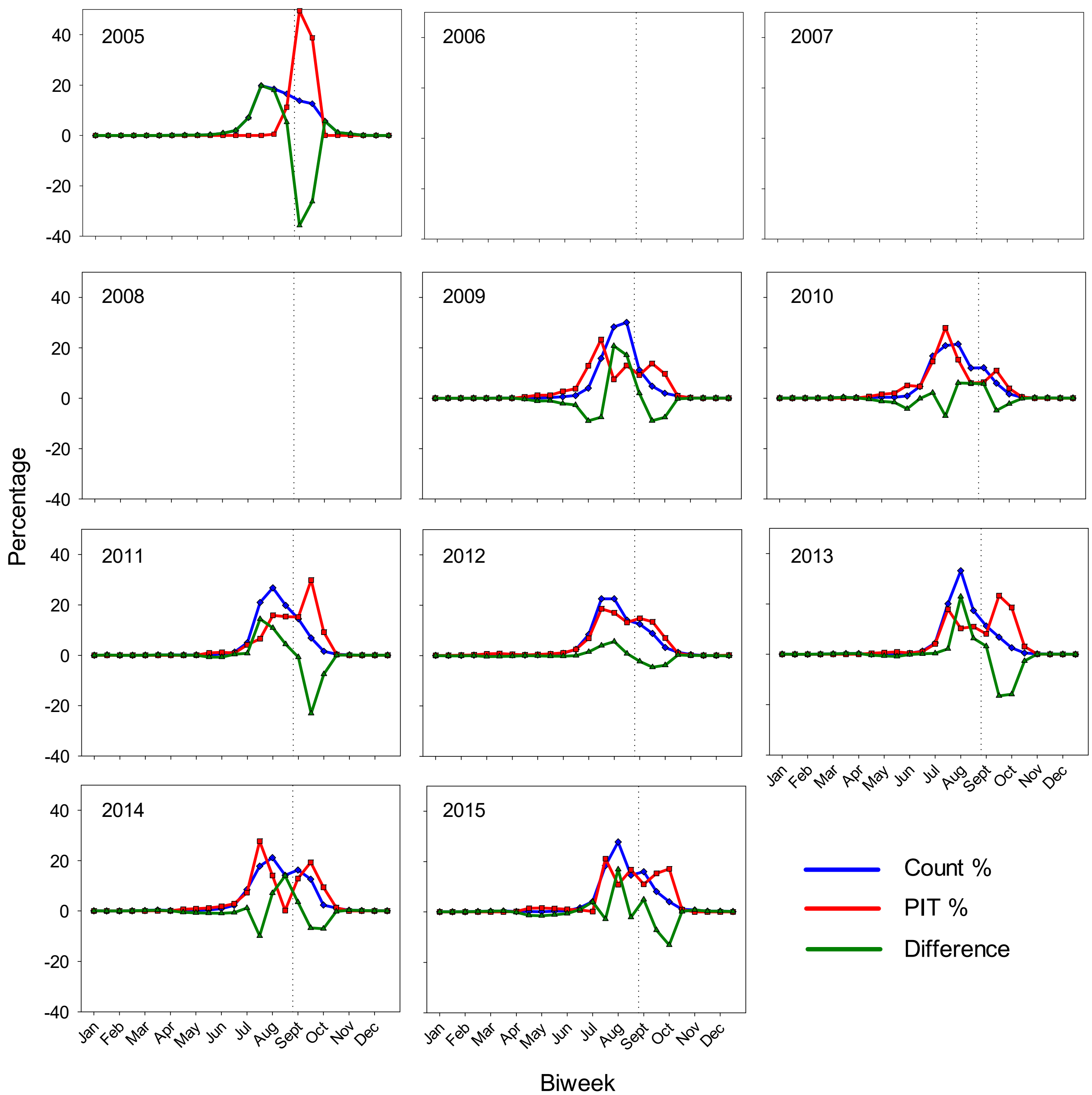


Figure 27. Annual migration timing distributions of adult steelhead at Bonneville Dam (2005-2015). Figures show the bi-weekly percentages of total adult counts (blue) versus percentages of adults that were PIT-tagged as adults at or downstream from Bonneville Dam (red). Green lines show the differences in bi-weekly percentages: numbers <0 indicate PIT-tagged fish were disproportionately abundant and numbers >0 indicate PIT-tagged fish were under-represented. Vertical line = 25 August, the established A-group / B-group separation date.

Sample age estimation – Adult age is one of the criteria used to separate A- from B-group steelhead, with B-group fish more likely to be in older age classes (Busby et al. 1996). However, it can be difficult to extract steelhead age information from PIT tag records alone. Many juvenile steelhead migrate to the ocean in the year that they are PIT-tagged, but others reside in hatcheries, natal tributaries, or larger main stem habitats before emigrating. The combination of juvenile tag year and first adult detection year is therefore an unreliable measure of adult age. Many emigrating juveniles are detected at JBSs or are initially collected and PIT-tagged as smolts at JBSs. The combined year of detection at a FCRPS JBS, plus year of first adult detection, may therefore be a more reliable measure, but many juveniles are never detected following release.

Regardless of the method used to assign age, adult steelhead samples were of mixed age classes for almost all areas and tributary groups (*Table 28*). A very small proportion of adult steelhead had histories consistent with a 'half-pounder' life history, where the first upstream migration year was in the same calendar year as the juvenile emigration year (Age 0 in Table 28). A sequence of upstream detections in the FCRPS was used to confirm the assignments for most of these fish, many of which were tagged in Bonneville reservoir tributaries or FCRPS JBSs; however, there was no way to confirm that fish entered the ocean, and some may have been winter-run jacks, and so the presence of the half-pounder life history remains uncertain. Samples from most sites and from individual tributaries were predominantly a mix of 1- and 2-ocean fish. Three-ocean fish were uncommon, especially when the year of juvenile FCRPS detection was used as the starting year (*Table 28*). Juvenile tagging sites with the highest percentages of older age classes using either method included the Klickitat, Wind, and Hood rivers in the lower Columbia basin, the Clearwater River and Asotin Creek in the Snake River, and Wells Dam and the Wenatchee River in the Upper Columbia basin.

Transported versus in-river juveniles – Transportation of juvenile steelhead from FCRPS dams is a large-scale management action in the Snake River. Previous research has shown that some adult behaviors, like fallback at dams and inter-basin straying are higher for adults that were barged as juveniles versus those that migrated in-river as juveniles (Keefer et al. 2008b; Marsh et al. 2012). Although it is possible to identify in PTAGIS which steelhead were likely transported as juveniles (e.g., those loaded into raceways during the transportation season), transport histories for many fish are unclear and require additional steps and queries to confirm and valid transported versus in-river fish. Furthermore, protocols for transport and the level of detailed information reported to PTAGIS regarding transport change from year-to-year and dam-to-dam. We therefore elected not to try to assign all fish to specific transport histories as this effort was beyond the study scope.

Table 28. Estimated sea-age classes of adult steelhead that were PIT-tagged as juveniles (2005-2015). Ages were estimated by: 1) the difference in calendar years between the year that juvenile fish were PIT-tagged and the first year of adult detection at Bonneville Dam; and 2) the difference in calendar years between the year juveniles were collected and PIT-tagged or detected at FCRPS dams and the first year of adult detection at Bonneville Dam. Note that there was wide variation in the timing/age of juvenile tagging and differences in juvenile freshwater residency that were difficult or impossible to assess and these numbers should be considered approximate.

	Release age – BON adult					FCRPS detection age – BON adult				
Site / Dam or Tributary	n	0	1	2	3+	n	0	1	2	3+
Columbia River < Snake										
Bonneville Dam	67		66	30	4	67		66	30	4
Wind River	838	<1	30	43	27	127		12	85	3
Hood River	2,126	<1	18	70	12	561		22	68	10
Klickitat River	1,221	<1	2	90	8	258		2	89	9
Mill Creek	52	2	63	35		3		100		
Fifteenmile Creek	360	<1	49	50	1	56		54	46	
Deschutes River	853		49	50	1	113		44	56	
John Day Dam	534	<1	65	34	<1	450	<1	65	34	<1
John Day River	2,358		47	42	11	394	<1	60	39	<1
Rock Creek	34			41	59	17		56	44	<1
Umatilla River	1,271		55	45	<1	445		55	45	
McNary Dam	157		73	28		157		73	28	
Walla Walla River	2,391	<1	66	32	2	1,047		68	31	
Snake River										
Lyons Ferry Hatchery	458	<1	78	21		259		78	22	
Ice Harbor Dam	65		82	12		65		82	12	
L. Monumental Dam	421	<1	64	35	<1	421	<1	64	35	<1
Tucannon River	3,122	<1	71	29	<1	1,954		72	28	<1
Little Goose Dam	55		58	42		55		58	42	
Lower Granite Dam	14,731	<1	54	46	<1	14,731	<1	54	46	<1
Snake River > LGR Dam	1,484		63	36	<1	1,150		62	38	<1
Clearwater River	4,757		13	70	17	3,977		17	82	1
Asotin Creek	432		35	56	9	366		42	58	<1
Grande Ronde River	5,360	<1	64	33	3	4,132		66	34	<1
Salmon River	9,223	<1	66	29	5	7,225		69	31	<1
Imnaha River	4,094		73	27	<1	3,321		74	86	<1
Columbia River > Snake										
Yakima River	389		30	43	27	151		56	44	
Ringold Hatchery	5,754		50	50	<1	2,568		52	48	<1
Wanapum Dam	145		53	47		145		53	47	
Rock Island Dam	666		63	37	<1	666		63	37	<1
Wenatchee River	4,653		44	52	4	1,838		47	53	<1
Rocky Reach Dam	92		66	29	5	92		66	29	5
Wells Dam	880		16	79	4	880		16	79	4
Entiat River	409		42	45	13	186		61	39	
Methow River	7,419		51	47	2	3,213		53	47	<1
Okanogan River	1,566		49	51	<1	778		51	49	<1
Total	**78,447**	**0.04**	**51.6**	**44.7**	**3.7**	**51,398**	**0.03**	**55.4**	**44.1**	**0.5**

Sample Composition – Summary

Key findings

- On average, 2.5% of adult steelhead annual counts at Bonneville Dam were PIT-tagged as juveniles (n=78,226)
- Fish were assigned to three broad geographic groups and 37 site-specific groups for summaries
- 15,171 steelhead were PIT-tagged as adults at Bonneville Dam, but without population-specific information
- Samples included multiple age classes (half pounders, 1, 2, and 3-ocean fish), rear-types (hatchery, wild), & life history classes (winter, summer, A- and B-group)

Critical uncertainties

- There is uncertainty regarding how representative PIT-tagged samples were to runs
- Wild-origin populations were under-represented in samples
- Some hatcheries were represented by disproportionate numbers of PIT-tagged fish
- Many sea-age assignments were uncertain due to incomplete emigration timing data
- Smolt transportation history was not included, but would likely affect behavioral summaries

Technical recommendations

- More representative juvenile tagging would improve inferences about adult behavior & survival in the FCRPS
- Relationship between juvenile transport and targeted adult behaviors in the FCRPS should be assessed
- Non-invasive techniques / tools to more accurately age juvenile and adult steelhead are needed

3.6 UPSTREAM MIGRATION TIMING

3.6.1 Methods

PIT-tag detections at the adult fishways at FCRPS dams and in some tributaries provide precise time stamps of upstream passage timing of pre-spawn steelhead. We summarized upstream timing at the FCRPS dams using the first detection dates at adult fishways at each project. For a large majority of individuals, the first dates represent a likely dam passage event, but it was evident that some steelhead took days to weeks to pass, and others passed, fell back downstream, and re-passed the same dam. Multiple events were not included in the summaries for this section.

At Bonneville Dam, 25 August has been used to separate A-group from B-group steelhead. The first migration timing summary, therefore, was to calculate the percentage of each site or population that was nominally A- or B-group based solely on timing. The second summary calculated the timing distributions for each site and tributary population. We combined data from all adult migration years (2005-2015), rear-types (wild, hatchery), age classes, and life history classes (winter, summer, A-group, B-group) for this second summary. Results should be a good indication, however, of the average upstream migration timing for each study population and should demonstrate relative differences among groups. If needed, results for separate life history classes or years can be generated.

3.6.2 A- Versus B-Group Timing at Bonneville Dam

In both the wild and hatchery steelhead categories, almost every site and population had a mix of nominal A-group and B-group fish based on detection date at Bonneville Dam (*Figures 28-29*). In the wild group, populations that were predominantly (>75%) from the early run included the Wind, Klickitat, Deschutes, John Day, Umatilla, and Walla Walla rivers in the lower

Columbia basin, the Tucannon, Potlatch, Grande Ronde, Imnaha, and Lemhi rivers plus Asotin Creek in the Snake River, and all populations from the Upper Columbia basin upstream from the Snake River confluence. Wild populations that were predominantly from the late run were limited to the Lochsa, Selway, Middle Fork Clearwater, South Fork Clearwater, and South Fork Salmon rivers (*Figure 28*).

Geographic patterns were generally similar for the hatchery sample, though some sites had no hatchery fish. Early (A-group) fish predominated from the Klickitat, Umatilla, and Walla Walla rivers in the lower Columbia, in the Tucannon, Grande Ronde, Imnaha, and Lemhi Rivers in the Snake River, and in all upper Columbia River basin sites (*Figure 29*). Late (B-group) hatchery fish predominated in the Middle Fork Clearwater, South Fork Clearwater, and mixed-stock Clearwater groups.

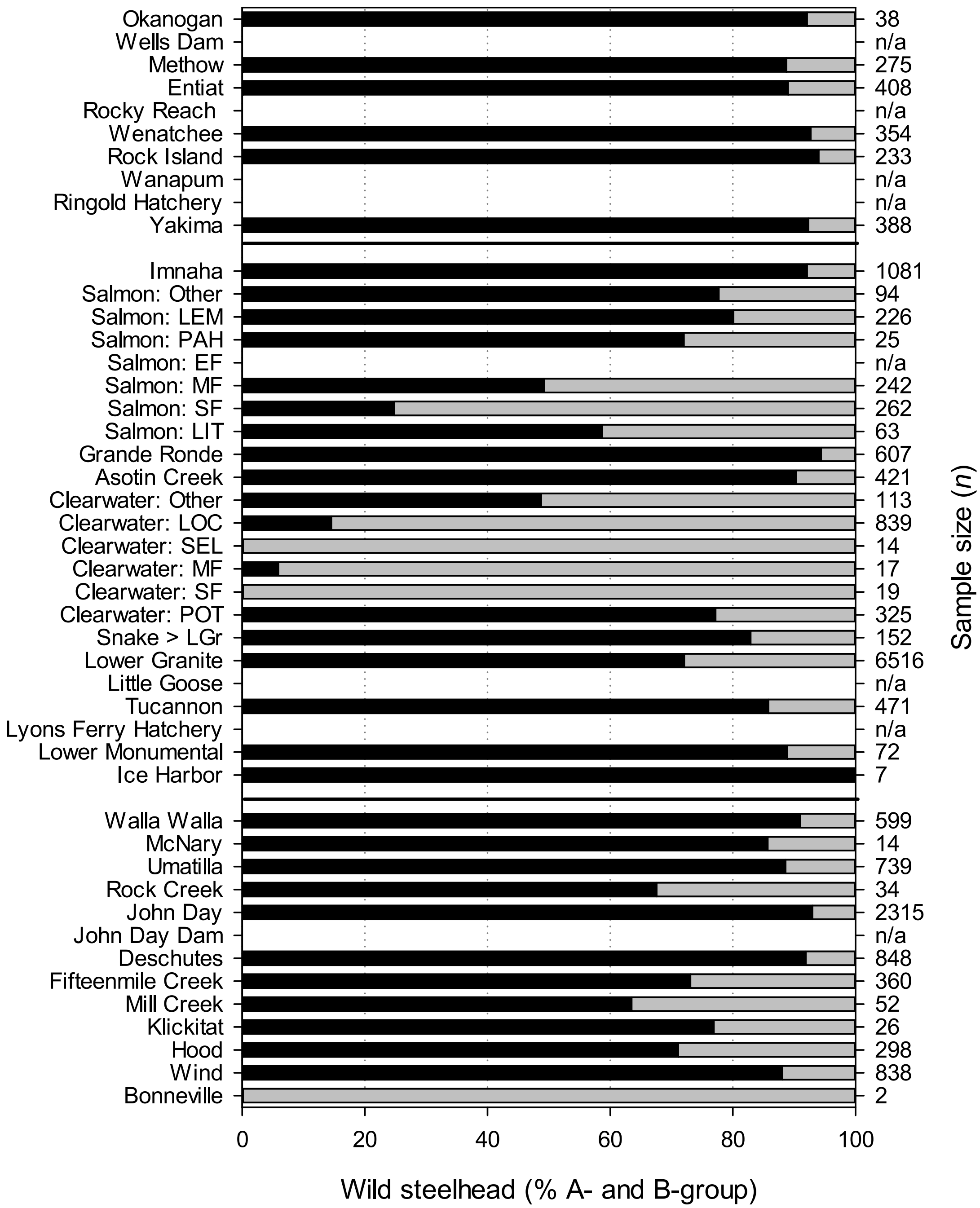


Figure 28. Percent of wild steelhead that was first detected at Bonneville Dam before 26 August (black bars) or after 25 August (gray bars), by study group (2005-2015). Sample = PIT-tagged as juveniles.

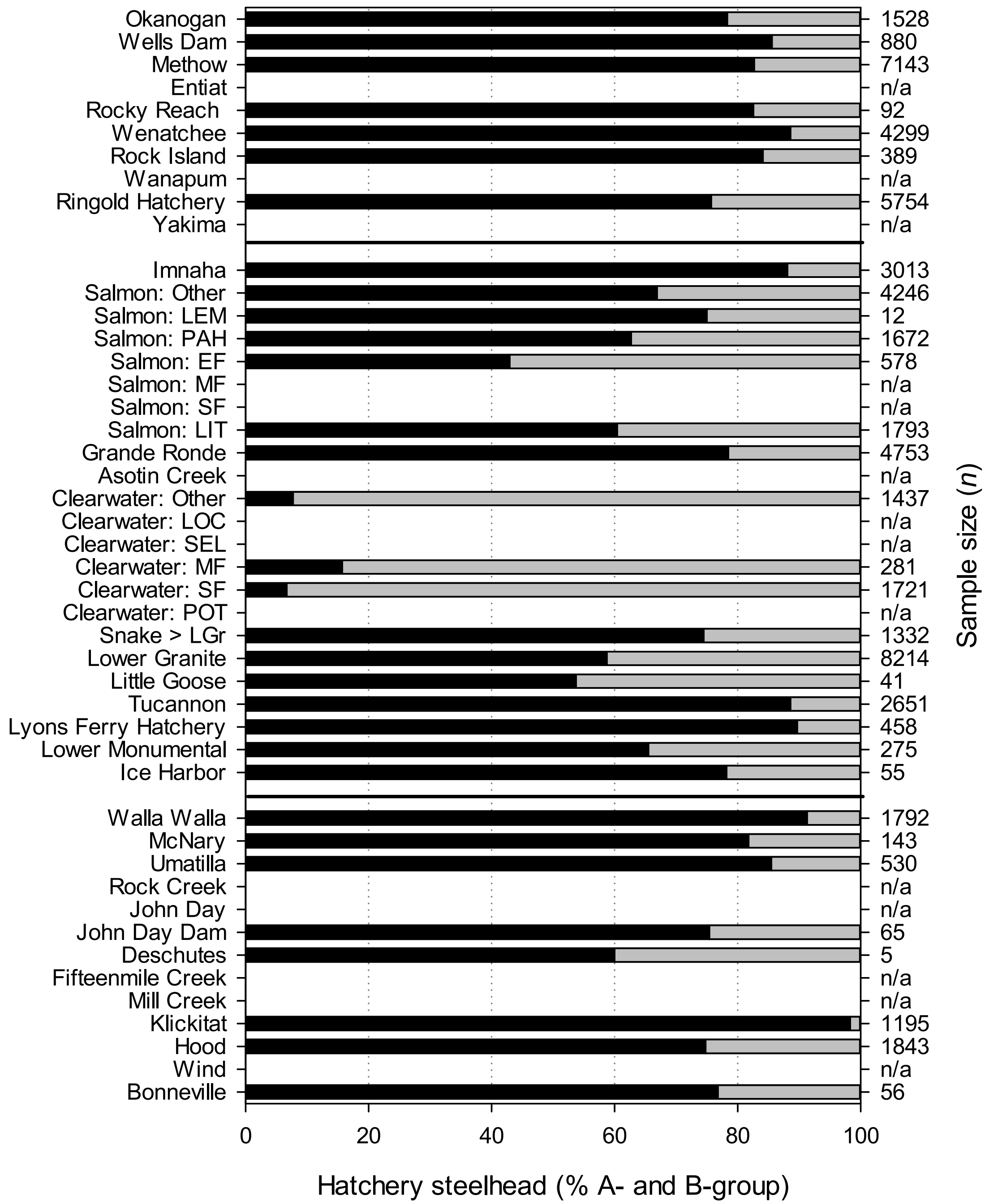


Figure 29. Percent of hatchery steelhead that was first detected at Bonneville Dam before 26 August (black bars) or after 25 August (gray bars), by study group (2005-2015). Sample = PIT-tagged as juveniles.

Upstream Migration: A- Versus B-Group Timing at Bonneville Dam – Summary

Key findings
- Most populations had a mix of nominal A- and B-group fish, based on the 25-Aug run-separation at Bonneville
- Lower, mid-, and upper Columbia tributaries were predominantly A-group (early run) fish
- Several Snake River tributary groups were primarily A-group (early run) fish
- B-group (late run) fish were predominately from the Clearwater and Salmon River basins
- Similar timing patterns were evident for hatchery and wild fish within the A- and B-groups

Critical uncertainties
- The 25 August run separation date at Bonneville Dam does not reflect biological distinction
- All populations, rear-types, age classes, and life history classes were not likely represented

Technical recommendations
- Use of A-run / B-run terminology and the 25 August run separation date at Bonneville should be reconsidered

3.6.3 Population-specific Timing at FCRPS Dams

Adult steelhead migration timing distributions are presented below for Bonneville, The Dalles, McNary, Ice Harbor, Lower Granite, and Priest Rapids dams (*Figures 30-35*). These dams were monitored in all years (2005-2015), except for The Dalles Dam (2013-2015). All populations with adult passage are included at each dam except for groups that were collected as juveniles at dams downstream from the summary site because these were mixed-population samples from an amalgam of upriver sites and distributions were therefore less meaningful.

Bonneville Dam – Adult steelhead passed Bonneville Dam in a well-mixed continuum of populations from late spring through mid-October (*Figure 30*). The population with the earliest migration timing was the Hood River group, which included a mix of winter- and summer-run fish that were not always readily differentiated; the presumed winter-run had a large proportion of hatchery-origin fish, and this group had much earlier timing (*median date* in early March) than the wild-origin fish (*median* in April). The next-earliest groups were from the Klickitat and Wind rivers (median dates in late June and early July), again reflecting a potential mix of life history types. The small (*n* =26) sample of wild Klickitat River steelhead had a median passage date ~30 d later than the much larger sample (*n* = 1,195) of Klickitat hatchery fish.

The earliest-timed summer-run populations, on median across years, were the Yakima River, Lyons Ferry hatchery, John Day River, Walla Walla River, Asotin Creek, Deschutes River, and Tucannon River groups. These fish had median passage dates in July. Many populations had median dates in August, including all populations upstream from Priest Rapids Dam, Ringold Hatchery, the Imnaha and Grande Ronde groups, and several sub-basin groups from the Salmon (Lemhi, Pahsimeroi, Little Salmon) and Clearwater rivers (Potlatch). The latest-timed groups, with median dates after the 25 August separation date, were all from Clearwater and Salmon River sub-basins, with the South Fork and Middle Fork Clearwater fish having the latest timing. Several tributary populations had wild and hatchery fish and in most cases the median passage dates of these groups at Bonneville Dam differed by less than ten days. Exceptions included: hatchery fish from the mixed Clearwater group had a median date 17 d later than the corresponding wild group; Grande Ronde River hatchery fish had a median date 17 d later than wild fish; and Okanogan River hatchery fish had a median date 14 d later than wild fish.

The Dalles Dam – Timing data at The Dalles Dam were available for the 2013-2015 migrations (*Figure 31*). As expected from the fishway count data (see *Figure 2*), median passage dates at The Dalles Dam were later than at Bonneville Dam by 1-2 weeks for most populations. The ordering of the earliest-timed groups at The Dalles Dam was also slightly different than at Bonneville, with the Wenatchee and Entiat River fish joining the Yakima River and Lyons Ferry Hatchery fish in the first tier in early August. More than half the populations had median dates after 1 September. The latest-timed populations were again mainly from the Clearwater River and Salmon River sub-basins, though Rock Creek fish and some overshoot fish from Mill and Fifteenmile creeks also passed The Dalles Dam relatively late in the run.

McNary Dam – A dozen upriver populations had median timing dates before 1 September at McNary Dam and the earliest included steelhead from Lyons Ferry Hatchery, Wenatchee River, Entiat River, and the groups PIT-tagged at Wanapum and Rock Island dams (*Figure 32*). About 20 populations had median dates in early to mid-September. The latest upriver groups had median dates in late September and included five populations from the Clearwater River basin. Also included in the late-run mix were small numbers of Mill Creek, Fifteenmile Creek, and Umatilla River fish that overshot their natal sites.

Within the major population groups, median timing dates for wild and hatchery fish differed by less than 10 d in most cases. An important exception was that hatchery steelhead from the Walla Walla River had a median McNary Dam passage date in mid-August, ~50 d earlier than wild fish (*median date* in early October); this difference was notable given that wild and hatchery Walla Walla River steelhead had similar timing at Bonneville Dam. The Hatchery Okanogan River fish passed McNary Dam ~21 d later, on median, than the small sample (n = 30) of Okanogan wild fish. Hatchery groups from the Grande Ronde River, Pahsimeroi River, and Lemhi River all had median dates ~10-16 d later than corresponding wild fish.

Ice Harbor Dam – On median, the earliest Snake River steelhead to pass Ice Harbor Dam were from Lyons Ferry Hatchery, and the Tucannon River or were tagged at Ice Harbor Dam (*Figure 33*). It was notable as well that small numbers of fish from lower Columbia populations (Klickitat River, Walla Walla River) and from upper Columbia populations (Okanogan River, Methow River) were also in the early mix. A majority of Snake River populations had median Ice Harbor passage dates in September. Clearwater River sub-basin groups were again the latest-timed fish, along with a small mix of strays from lower and upper Columbia River sites. Strays from the Deschutes, John Day, and Umatilla rivers as well as some from Ringold Hatchery were in the late mix, including some that passed in winter and spring.

Lower Granite Dam – At Lower Granite Dam, the earliest median passage dates for Snake River populations were tributary overshoot fish from Lyons Ferry Hatchery and the Tucannon River (*Figure 34*). The earliest-timed populations that originated upstream from the dam were from the Lemhi River, Middle and South Fork Salmon rivers, and the Imnaha River, with median dates in the second half of September. All of the remaining Snake River populations had median dates in late September or early October, with the latest groups from the Selway and Lochsa rivers and from the mixed-stock Clearwater River group. As at Ice Harbor Dam, several groups of strays were also in the late-run mix at Lower Granite Dam.

Priest Rapids Dam – The pattern of early- and late-run strays was repeated at Priest Rapids Dam (*Figure 35*). Several of the populations with the earliest median migration dates were strays from the Umatilla, John Day, Walla Walla, and Yakima rivers and Asotin Creek. Similarly, the latest-timed groups were strays from the Clearwater, Salmon, and Snake rivers, along with fish from Ringold Hatchery. Steelhead that originated upstream from Priest Rapids Dam had median passage dates in a relatively narrow time between late August and mid-September.

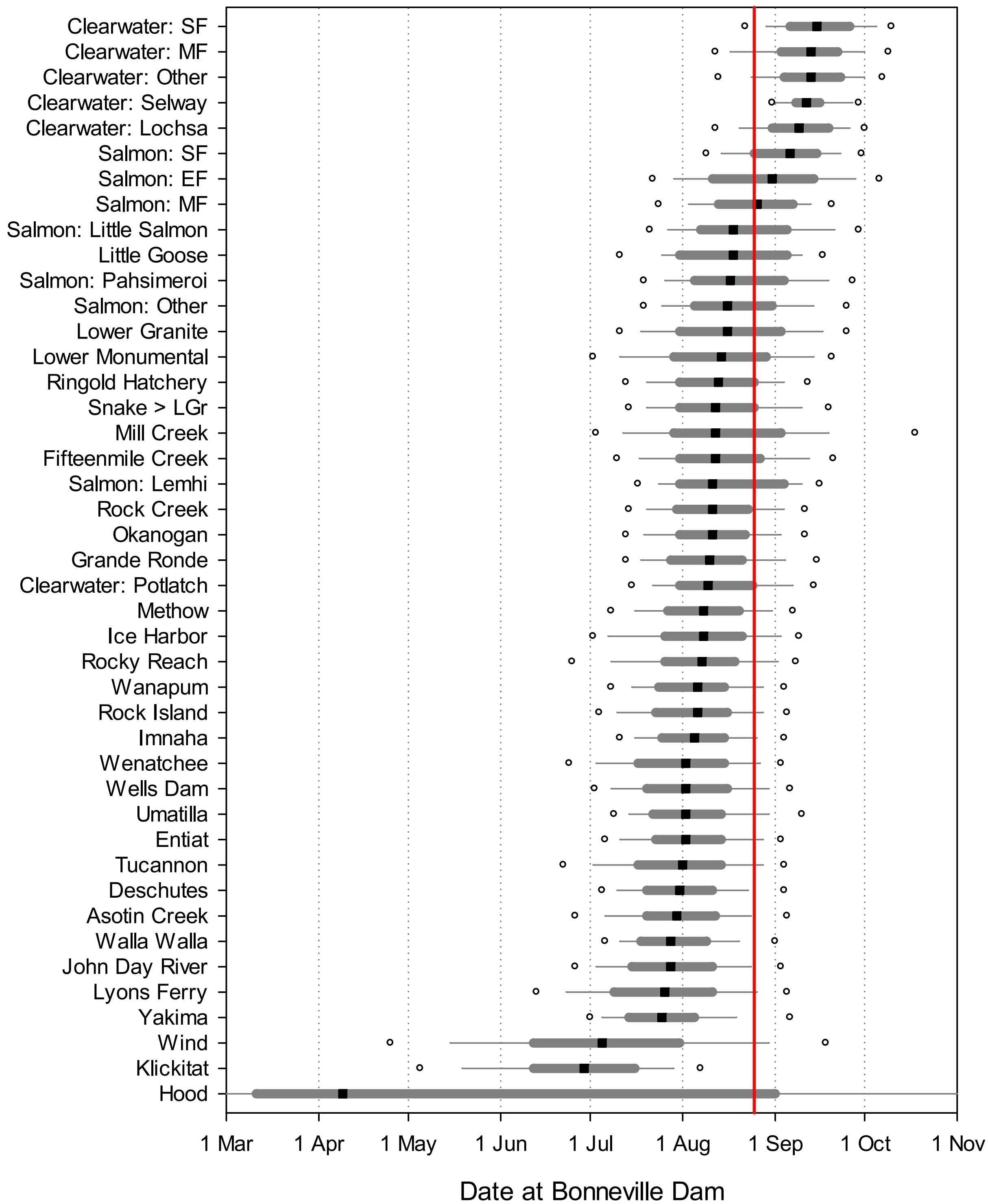


Figure 30. Distributions of dates that adult steelhead (wild and hatchery) were first detected at Bonneville Dam (2005-2015). Plot shows 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Red line denotes A- versus B-group separation date at Bonneville Dam. Sample = PIT-tagged as juveniles.

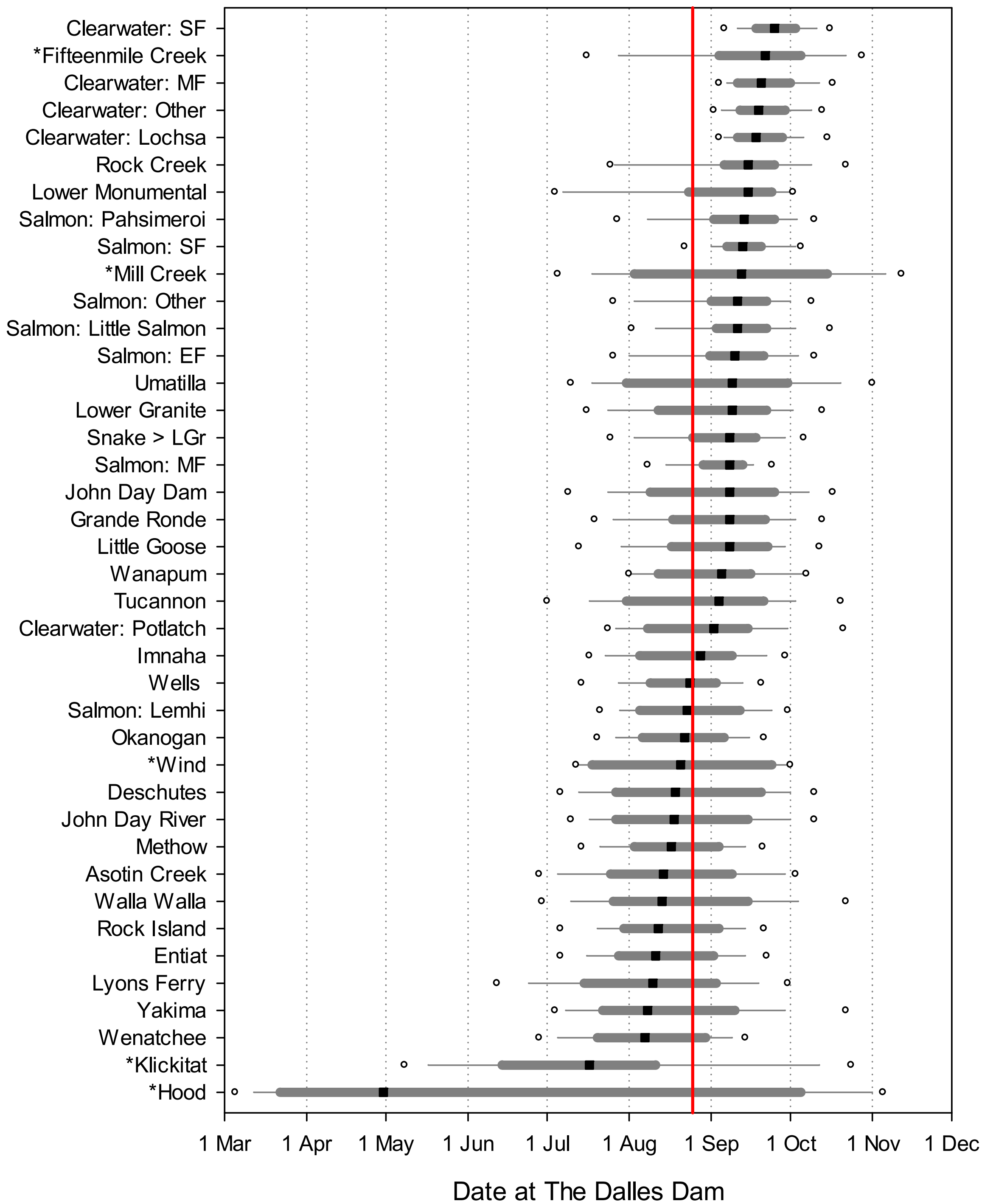


*Figure 31. Distributions of dates that adult steelhead (wild and hatchery) were first detected at The Dalles Dam (2013-2015). Plot shows 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Red line denotes A- versus B-group separation date at Bonneville Dam. Sample = PIT-tagged as juveniles; groups collected at dams downstream from The Dalles Dam excluded. * indicates a site downstream from The Dalles Dam.*

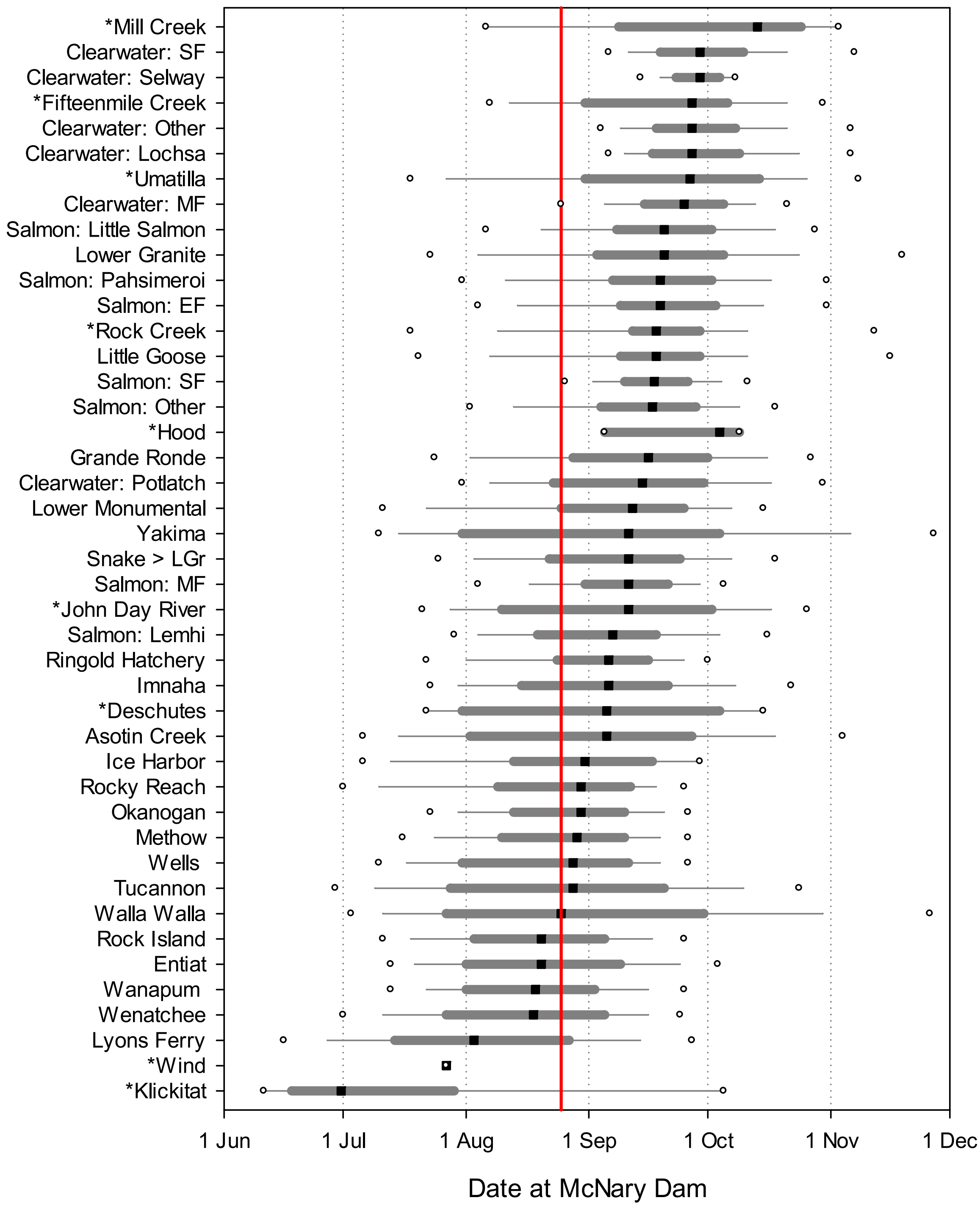


*Figure 32. Distributions of dates that adult steelhead (wild and hatchery) were first detected at McNary Dam (2005-2015). Plot shows 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Red line denotes A- versus B-group separation date at Bonneville Dam. Sample = PIT-tagged as juveniles; groups collected at dams downstream from McNary Dam excluded. * indicates a site downstream from McNary Dam.*

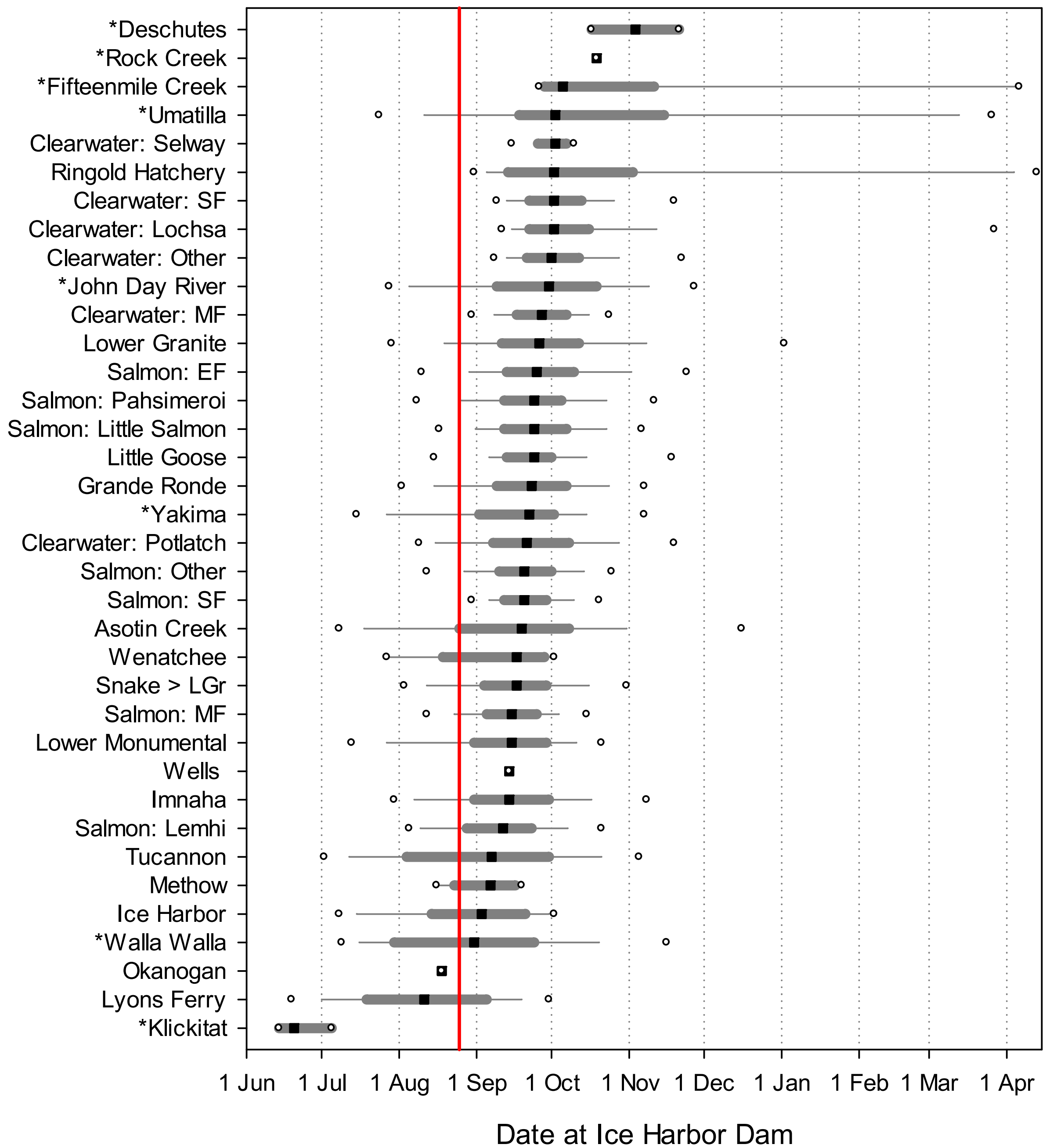


*Figure 33. Distributions of dates that adult steelhead (wild and hatchery) were first detected at Ice Harbor Dam (2005-2015). Plot shows 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Red line denotes A- versus B-group separation date at Bonneville Dam. Sample = PIT-tagged as juveniles; groups collected at dams downstream from Ice Harbor Dam excluded. * indicates a site downstream from Ice Harbor Dam.*

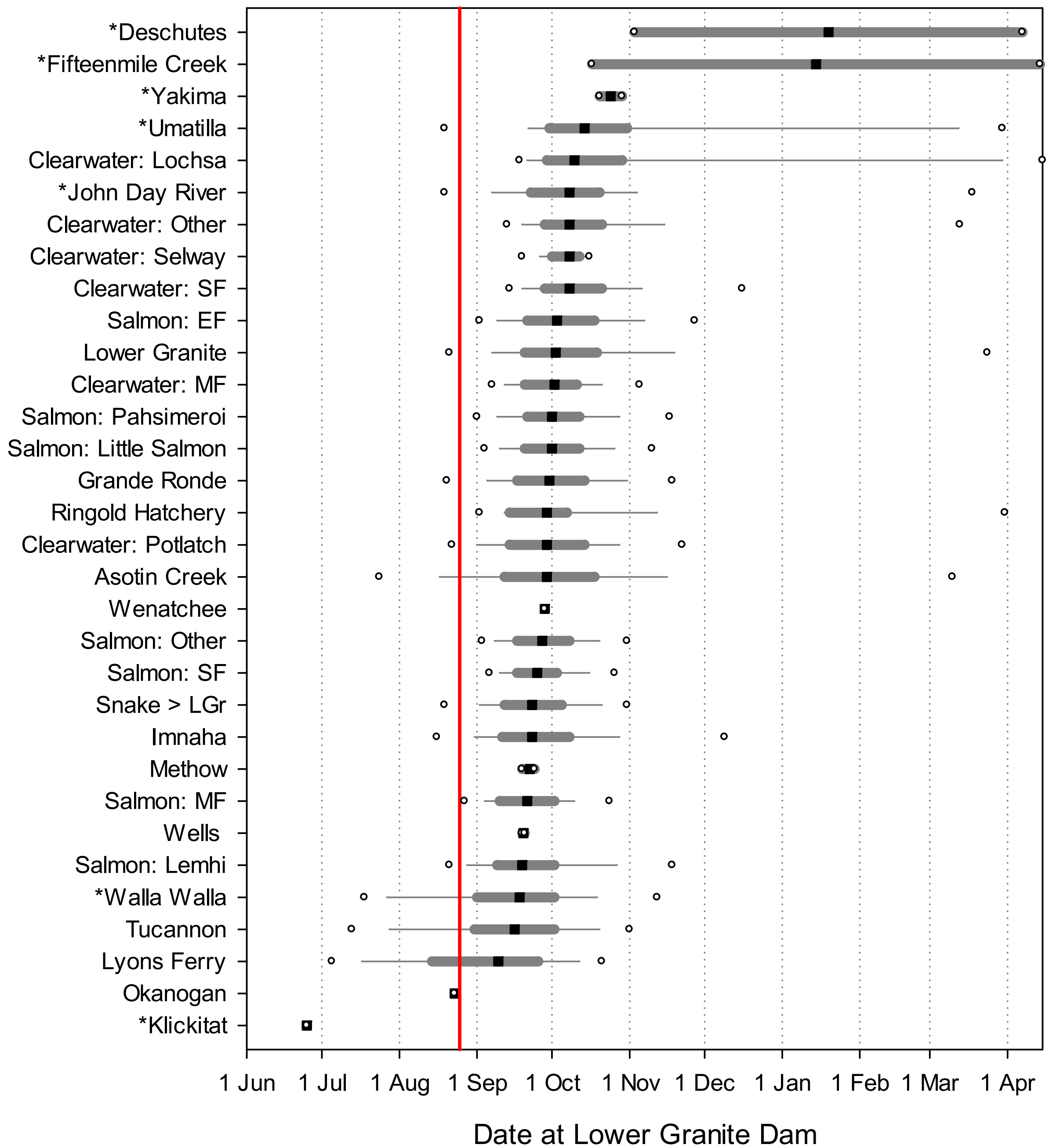


*Figure 34. Distributions of dates that adult steelhead (wild and hatchery) were first detected at Lower Granite Dam (2005-2015). Plot shows 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Red line denotes A- versus B-group separation date at Bonneville Dam. Sample = PIT-tagged as juveniles; groups collected at dams downstream from Lower Granite Dam excluded. * indicates a site downstream from Lower Granite Dam.*

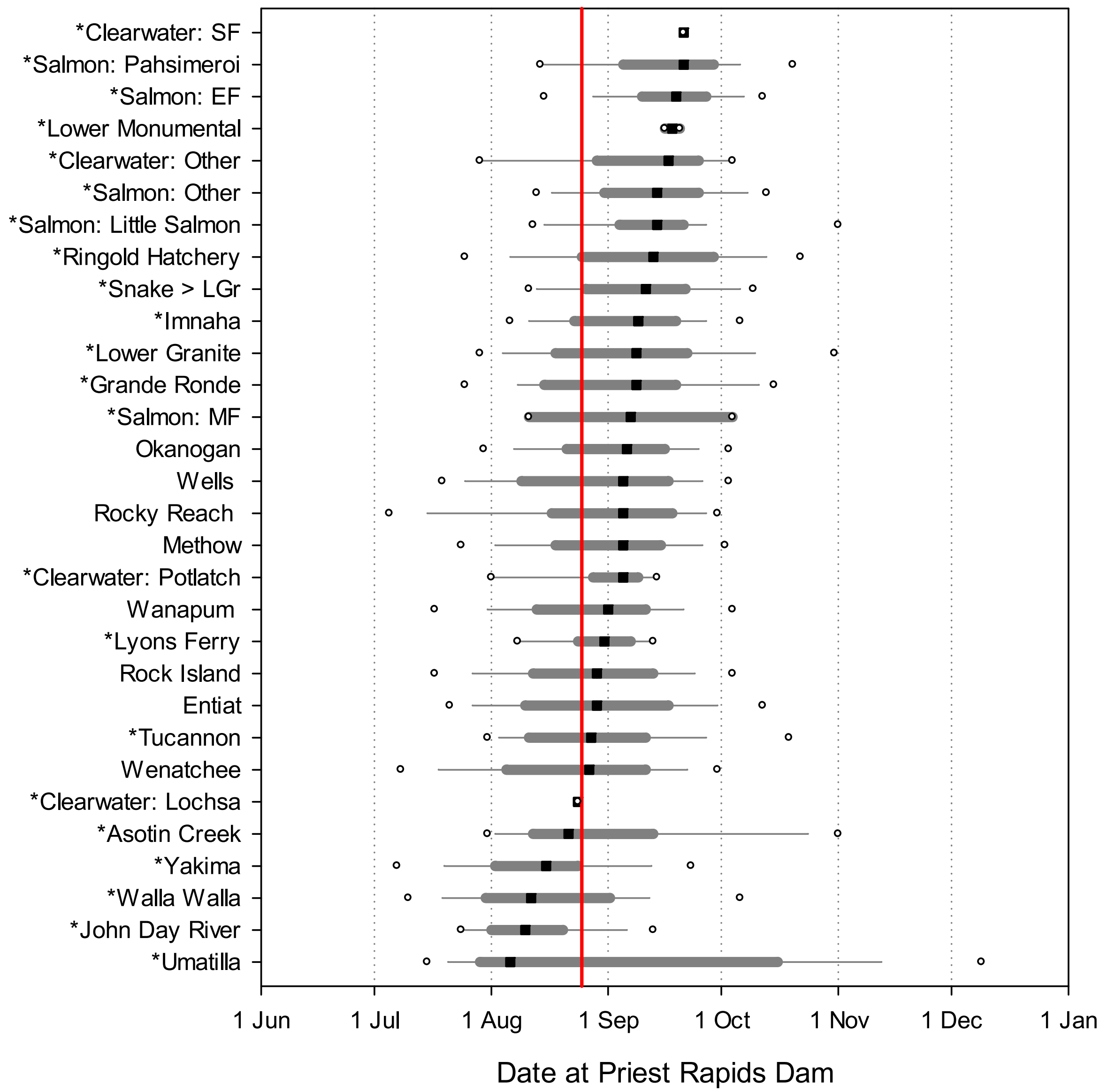


*Figure 35. Distributions of dates that adult steelhead (wild and hatchery) were first detected at Priest Rapids Dam (2005-2015). Plot shows 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Red line denotes A- versus B-group separation date at Bonneville Dam. Sample = PIT-tagged as juveniles; groups collected at dams downstream from Priest Rapid Dam excluded but Snake River dams included. * indicates a site downstream from Priest Rapids Dam.*

Upstream Migration: Population-specific Timing at FCRPS Dams – Summary

Key findings

- Adult steelhead pass lower FCRPS dams in a well-mixed population continuum from late- spring to late-fall
- Adults pass Snake River dams primarily in fall, with extensive overlap among populations
- Many apparent strays from the Clearwater, Salmon and Snake rivers had early or late run timing at dams
- Tributary overshoot fish from lower and mid-Columbia populations often had early or late timing at dams

Critical uncertainties

- All populations, rear-types, age classes, and life history classes were not likely represented

Technical recommendations

- Further separation among populations within tributaries could better differentiate group timing
- Further separation among affiliated hatchery and wild groups may be useful for managers
- Multi-modal distributions are likely for some populations at some sites and may be more useful for managers

3.6.4 Tributary Entry Timing for Selected Populations

Nine tributaries to the lower Columbia or lower Snake rivers had PIT interrogation antennas located relatively close to the tributary–main stem confluence areas (*Figure 36*). The timing of first detections inside tributaries were widely distributed at most sites, with some adults first detected in the summer or fall of the year they were first detected at Bonneville Dam and others first detected in the following winter or spring. Note that detection efficiency information for these sites was unknown at most sites, was likely to vary among seasons, some fish likely entered and/or exited the tributaries before their first recorded detection.

Hood River steelhead had the most distinctive distribution, presumably because there was a mix of winter- and summer-run fish. Most Hood River fish were first detected in March-May of the year they passed Bonneville Dam, though some entered in the fall and a few (~10%) were first detected in the following spring (it is possible that some were repeat spawners). Populations that were primarily detected in tributaries in the summer and fall included the Klickitat (100% summer-fall), Wind (97%), and Deschutes (98%) rivers. In contrast, relatively few (13%) Fifteenmile Creek fish entered in the summer-fall; this may due to low-flow and warm water conditions and because so many steelhead overshot Fifteenmile Creek and passed The Dalles Dam and other upstream dams. Adults from the other tributaries in this category had a mix of summer-fall and winter-spring first detections; the summer-fall component was 71% (John Day River), 42% (Umatilla River), 63% (Walla Walla River), and 48% (Tucannon River) (*Figure 36*).

Upstream Migration: Tributary Entry Timing – Summary

Key findings

- Only nine tributaries had PIT antennas suitable for estimating tributary entry timing, all below the Snake River
- Winter-run steelhead had the most distinct tributary entry timing (March-May)
- Majorities of Fifteenmile Creek and Umatilla River steelhead were first detected in the spring
- Detections at other monitored tributaries were predominately during summer and fall

Critical uncertainties

- A large majority of tributaries did not have PIT antennas near confluence areas
- There was little or no detection efficiency information across sites or within seasons at tributary PIT arrays
- Distributions may be misleading for sites with both winter- and summer-run steelhead

Technical recommendations

- Additional tributary PIT interrogation sites would allow for a more robust and holistic evaluation of timing
- PIT-tag detection efficiency data at tributary arrays would improve timing inferences
- Further separation among populations within tributaries could better differentiate group timing

3.7 FCRPS OVERWINTERING

3.7.1 Methods

PIT-tagged steelhead with apparent overwintering in FCRPS reservoirs (2005-2014 migration years) were identified using three strategies. First, the detection history tables from each annual dataset were queried to find adults that had a first upstream dam passage event at a FCRPS dam after 31 December (i.e., in the calendar year after they were first detected at Bonneville Dam). Second, we identified fish that were first detected at tributary interrogation antennas in their natal tributaries after 31 December. The tributary method was limited to populations that had interrogation sites in lower river reaches close to FCRPS reservoirs. The tributaries included: Wind, Hood, Klickitat, Deschutes, John Day, Umatilla, Walla Walla, and Tucannon Rivers and Fifteenmile and Rock creeks (see *Figure 36*); many of the antenna installations occurred during the study period. Note that additional steelhead first entered tributaries after 31 December at sites upstream from Priest Rapids Dam that are not included in the following summaries. The third method was an effort to identify fish that first passed a FCRPS dam in summer or fall, but then fell back and passed a dam for a second time after 31 December. This method was complicated by emigrating kelts, required review of a large number of individual fish histories, and was thus terminated. (Note that this resulted in some underestimation of FCRPS overwintering.)

The FCRPS overwintering criteria described above were most appropriate for summer-run populations and were less relevant for winter-run fish. We did apply the screens to all fish, and found the likely winter-run steelhead did not meet FCRPS overwintering criteria.

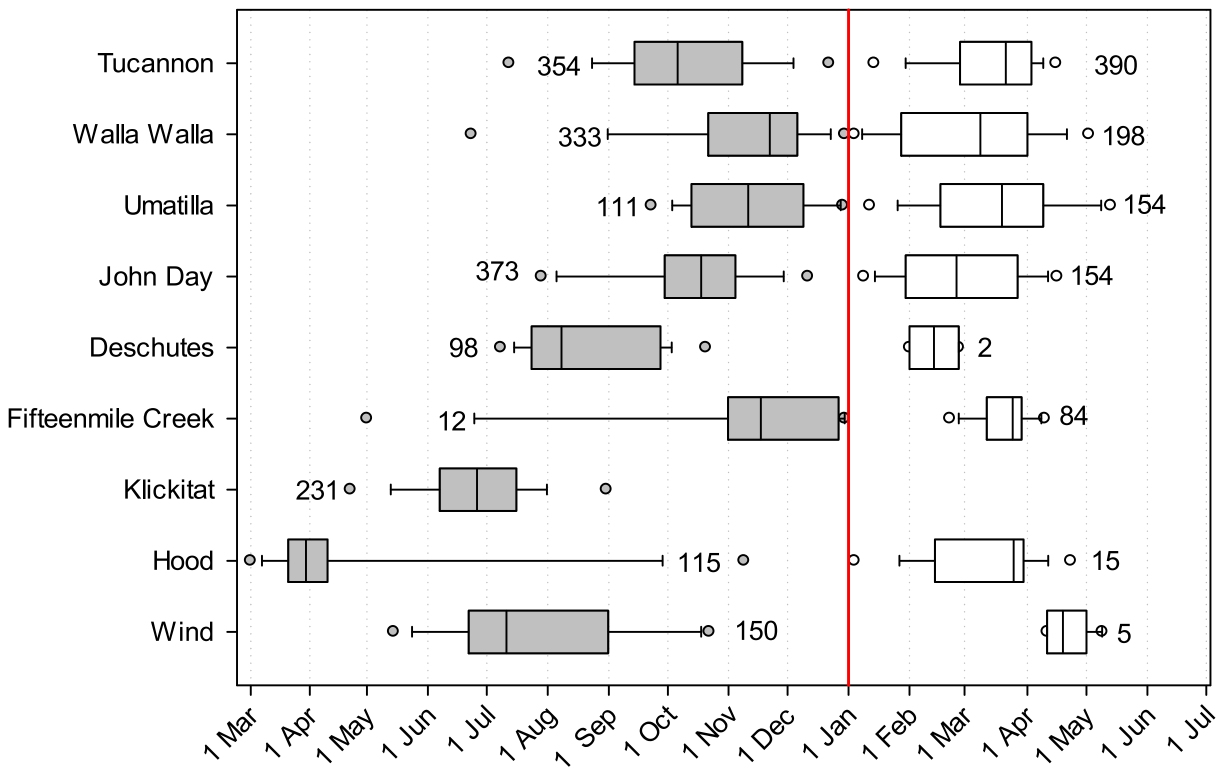


Figure 36 Distributions of dates that adult steelhead (wild and hatchery) were first detected entering tributaries that had PIT-tag antennas located close to FCRPS reservoirs (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the fish that entered in the same calendar year as they were first detected at Bonneville Dam (gray boxes) or in the following year (white boxes). Red line denotes overwintering separation date. Sample = PIT-tagged as juveniles in the respective tributaries (i.e., strays were excluded).

An important constraint for the PIT-tag based overwintering assessment was that many Snake River steelhead overwinter in the Lower Granite reservoir, especially B-group fish from the Clearwater River (Keefer et al. 2008a, 2015a). However, this behavior could not be identified using PIT-tag data because there were no instream PIT interrogation sites in lower reaches of the Clearwater River. This same issue likely resulted in FCRPS underestimates for several other populations for which tributary entry timing could not be reliably assessed. Even for tributaries with instream PIT antennas, detection of reservoir exit was likely underestimated given detection efficiency limitations and antenna operation dates and years.

In addition, assigning overwintering steelhead to specific individual FCRPS reservoir reaches was not possible for much of the 2005-2015 study period. The relatively late installations of The Dalles (2013), Lower Monumental (2014), and Little Goose (2014) adult PIT-tag detection arrays meant that most overwintering fish could only be assigned to Bonneville-McNary, McNary-Ice Harbor/Priest Rapids, or Ice Harbor-Lower Granite reaches.

3.7.2 FCRPS Overwintering: Percentages

In the 2005-2014 dataset, 2,256 adult steelhead first passed at least one FCRPS Dam after 31 December, and therefore met the first FCRPS overwintering criterion. This group included 1,362 steelhead that were nominal A-group fish and 894 that were nominal B-group fish based on first adult detection date of 25 August at Bonneville Dam. FCRPS overwintering estimates for the aggregates were 2.9% for the A-group and 3.6% for the B-group. (Note: winter-run fish were included in the A-group based on early timing at Bonneville Dam. Excluding these fish had minimal impact on results.)

Forty-one of the individual populations had some FCRPS overwintering fish based only on the dam passage criterion (*Figure 37*). Population-specific percentages ranged from near zero for several lower Columbia River tributary groups (including likely winter-run groups) to ~13% for the Lochsa River. Other populations with estimates >5% included the mixed-stock group PIT-tagged at Lower Granite Dam (6.4%), Asotin Creek fish, (5.7%), the group tagged at Rocky Reach Dam (5.4%), and the mixed-stock Clearwater River group (5.1%).

Many additional fish were identified as likely FCRPS overwintering using the tributary entry criterion, though this component was limited to specific populations (*Figure 38*). Less than 1% of steelhead from the Wind, Hood, and Deschutes rivers was first detected in their natal tributaries after 31 December. In contrast, 19.3% of steelhead from Fifteenmile Creek was first detected there after 31 December for a total FCRPS overwintering estimate of 23.1%. Among the John Day reservoir populations, 8.1% of John Day River fish, 50.0% of Rock Creek fish, and 19.4% of Umatilla River fish were first detected on instream antennas after 31 August. Combined (dam passage + tributary entry) FCRPS overwintering estimates for these groups were: 9.0% (John Day River), 50.0% (Rock Creek), and 22.5% (Umatilla River). Further upstream, 13.8% of Walla Walla River steelhead and 19.3% of Tucannon River fish were first detected in tributaries after 31 December; combined estimates for these groups were: 18.6% (Walla Walla River) and 23.0% (Tucannon River). These results suggest that estimates based solely on dam passage timing can result in considerable underestimation of FCRPS overwintering.

FCRPS Overwintering: Percentages – Summary

Key findings

- Estimated minimums of 2.9% (A-group) and 3.6% (B-group) of steelhead overwintered in the FCRPS, based on dam passage
- Population-specific overwintering percentages within the FCRPS ranged from 0 – 13%
- FCRPS overwintering estimates increased considerably when tributary entry date was a criterion (9 sites only)

Critical uncertainties

- Use of dam passage timing as sole criterion resulted in significant underestimation of FCRPS overwintering
- Limited monitoring at The Dalles, John Day, Lower Monumental, & Little Goose limited identification of overwintering
- Limited tributary monitoring also resulted in minimum overwintering estimates
- PIT monitoring configuration limited comparisons across populations and years

Technical recommendations

- PIT-based overwintering estimates should be considered minimums and be interpreted cautiously
- Additional tributary PIT interrogation sites would improve population-specific FCRPS overwintering estimates
- Clear definitions for FCRPS overwintering (e.g., start timing) are needed

3.7.3 FCRPS Overwintering: Timing

The migration timing of the 2,256 FCRPS overwintering fish identified by the dam passage criterion is summarized in *Figure 39*. Median passage dates for the aggregate group were: 17 August (Bonneville), 19 September (The Dalles), 25 October (McNary), 30 January (Ice Harbor), 16 March (Lower Monumental), 25 March (Little Goose), and 27 March (Lower Granite). The timing distributions at each dam are also presented for the passage events that occurred in the first calendar year versus the second calendar year (*Figure 39*). First-year passages were almost all before 1 November at Bonneville and The Dalles Dams. The aggregate distribution was somewhat later at McNary Dam, where about 25% of the first year passage events were after 1 November, and later still at the three lowest Snake River dams. The second-year passage events at most dams were concentrated in March and early April (*Figure 39*). Distributions were wider at McNary and Ice Harbor dams, where about 25% of passage events were in January and February.

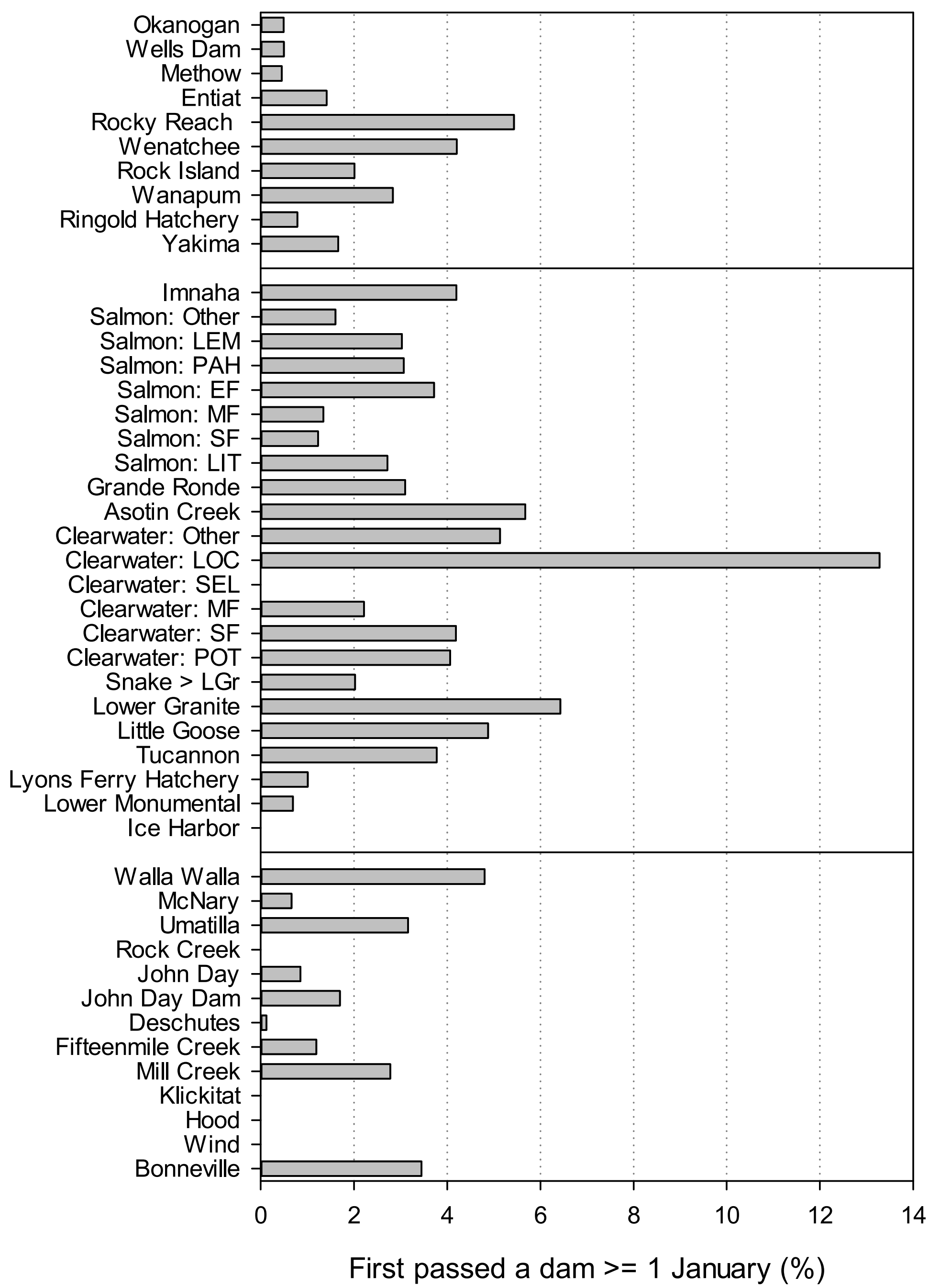


Figure 37. Estimated percent of adult steelhead that at least partially overwintered in the FCRPS (2005-2014). Overwintering defined by a single criterion: at least one first upstream passage of a FCRPS dam after 31 December. This method is known to underestimate FCRPS overwintering behavior because PIT-tagged fish could not be detected entering most tributaries and several dams were not monitored over the PIT-tag time series. Sample = PIT-tagged as juveniles.

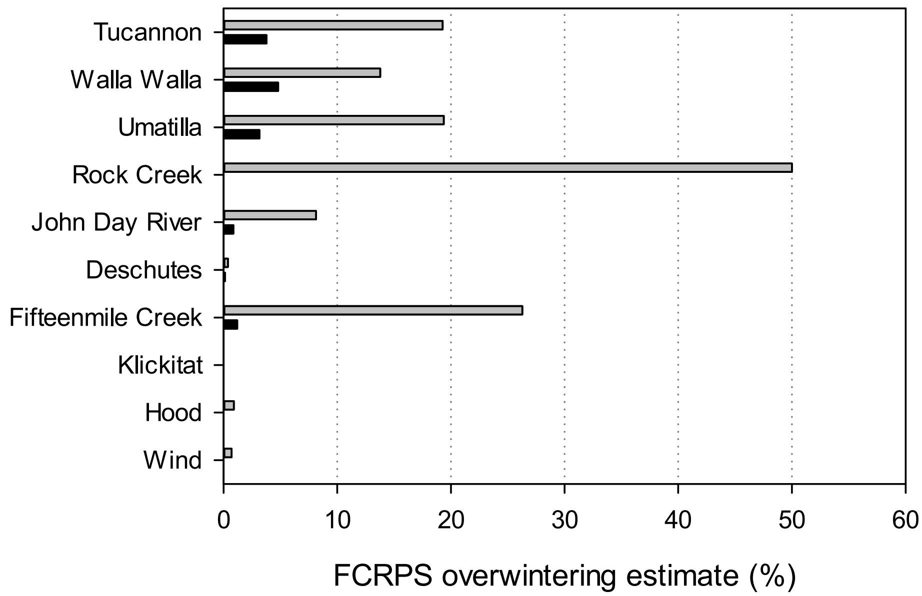


Figure 38. Estimated percent of adult steelhead that at least partially overwintered in the FCRPS (2005-2014). Overwintering identified by two criteria: 1) at least one first upstream passage of a FCRPS dam after 31 December (black bars) or 2) first detection on a tributary PIT antenna after 31 December (gray bars). Sample = PIT-tagged as juveniles, limited to tributaries with PIT antennas near tributary mouths.

Population-specific migration timing sequences for the FCRPS overwintering fish indicated a variety of behaviors, including considerable tributary overshoot during the winter period. The John Day River fish, for example, had upstream dam passage events in winter and spring only at the lower Snake River dams (*Figure 40*). The John Day River steelhead passed the Snake River dams mostly from mid-February through mid-April, suggesting they may have been seeking spawning sites. FCRPS overwintering steelhead from the Umatilla and Walla Walla rivers also had many upstream dam passage events at the Snake River dams, mostly in March and April. Some Umatilla and Walla Walla fish also passed McNary Dam in March and April, but others passed McNary in January and February.

First-year dam passage events by Tucannon River steelhead with FCRPS overwintering were mostly before November, with a few events in November and December at McNary and Ice Harbor dams (*Figure 41*). The second-year events were between mid-February and mid-April at all dams from McNary through Lower Granite, indicating that considerable tributary overshoot occurred in the spring while fish were likely seeking spawning sites. Many steelhead in the large group of FCRPS overwintering steelhead that were PIT-tagged at Lower Granite Dam had first-year passage events at Snake River dams in late fall, especially at Ice Harbor and Lower Monumental dams. Some fish from this tag group continued to pass the Snake River dams in January and February, but a majority of the second year passage events were in March and early April. Patterns were generally similar for the group that was PIT-tagged as juveniles at Snake River sites upstream from Lower Granite Dam (*Figure 41*).

Migration timing distributions for FCRPS-overwintering steelhead from the tributary groups upstream from Lower Granite Dam are shown in *Figure 42*. The most distinctive pattern was for the aggregated Clearwater River group, which passed lower Columbia River dams in a relatively narrow range in September and October relative to the other tributary groups, largely reflecting the A-group versus B-group spilt. Second year dam passage events were broadly similar for these tributary groups: a majority of events was in March and early April, some events were in January and February, and there were relatively few events at The Dalles and McNary dams.

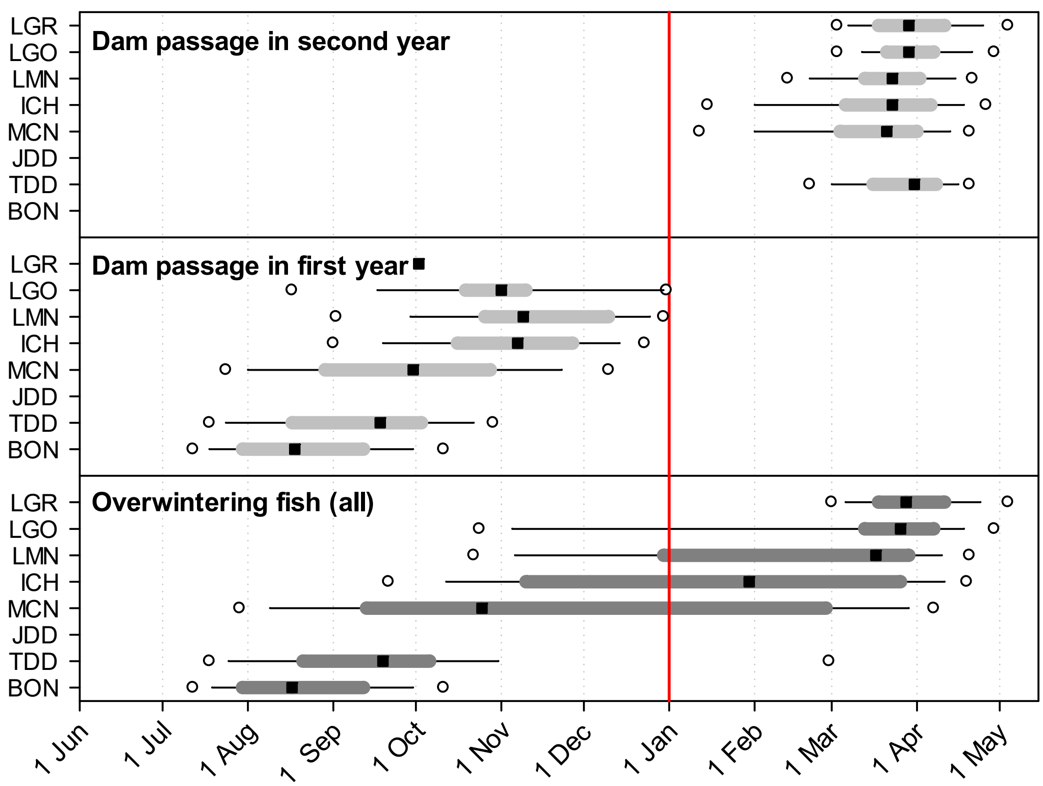


Figure 39. Migration timing for the subset of adult steelhead that potentially overwintered in FCRPS reservoirs as identified by having a first dam passage event after 31 December (red line) during 2005-2014. Panels show all events, and events that occurred in the first and second years. Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Sample = PIT-tagged as juveniles, all populations combined. Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR).

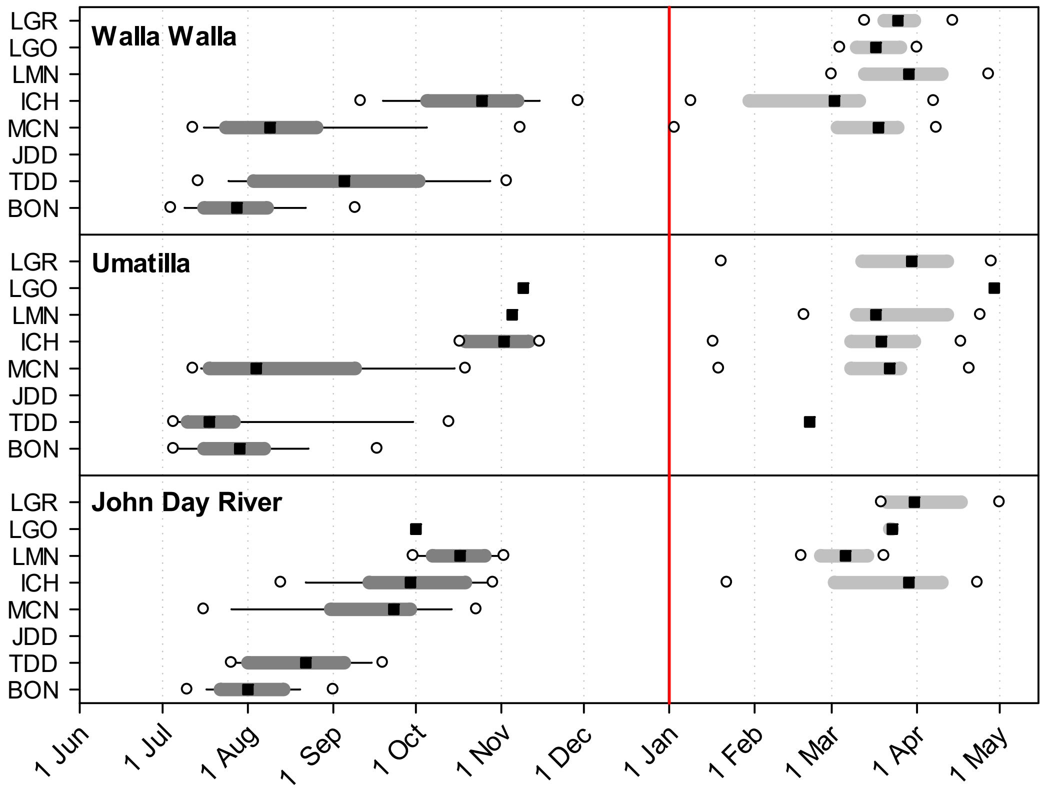


Figure 40. Migration timing for the subset of all FCRPS overwintering adult steelhead identified by a first dam passage >31 December (red line) during 2005-2014. Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the fish that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) or in the following year (light gray boxes). Sample = PIT-tagged as juveniles, John Day River, Umatilla River, and Walla Walla River. Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR).

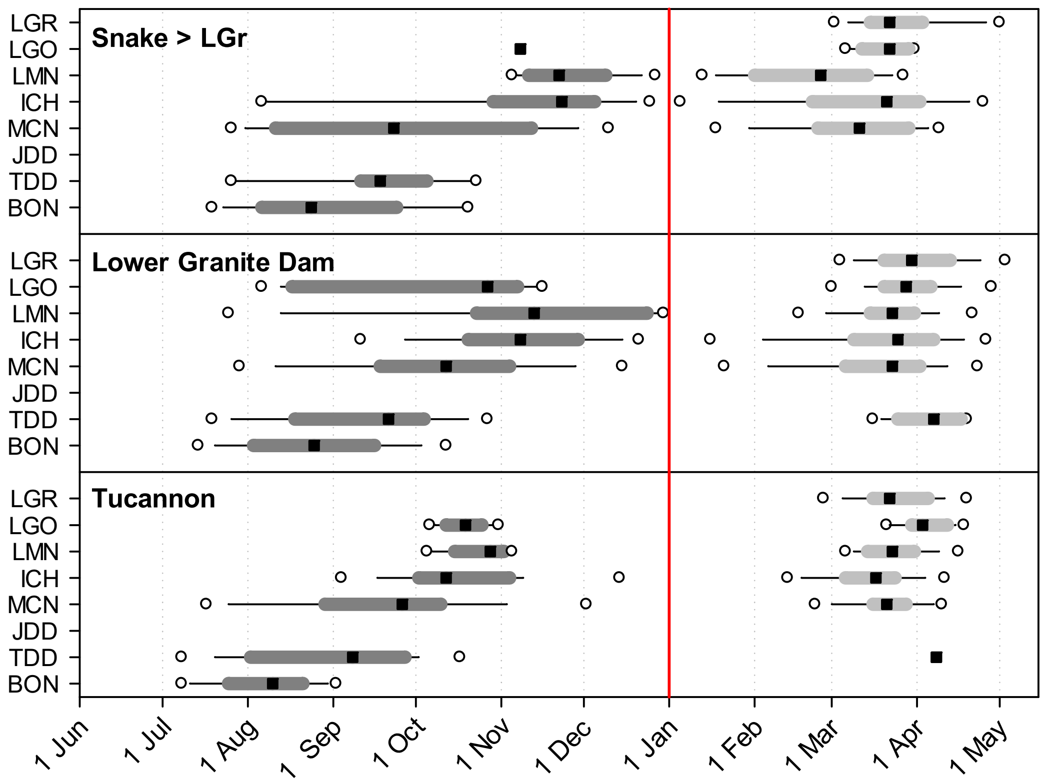


Figure 41. Migration timing for the subset of all FCRPS overwintering adult steelhead identified by a first dam passage >31 December (red line) during 2005-2014. Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the fish that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) or in the following year (light gray boxes). Sample = PIT-tagged as juveniles, Clearwater River, Asotin Creek, Grande Ronde River, Salmon River, and Imnaha River. Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR).

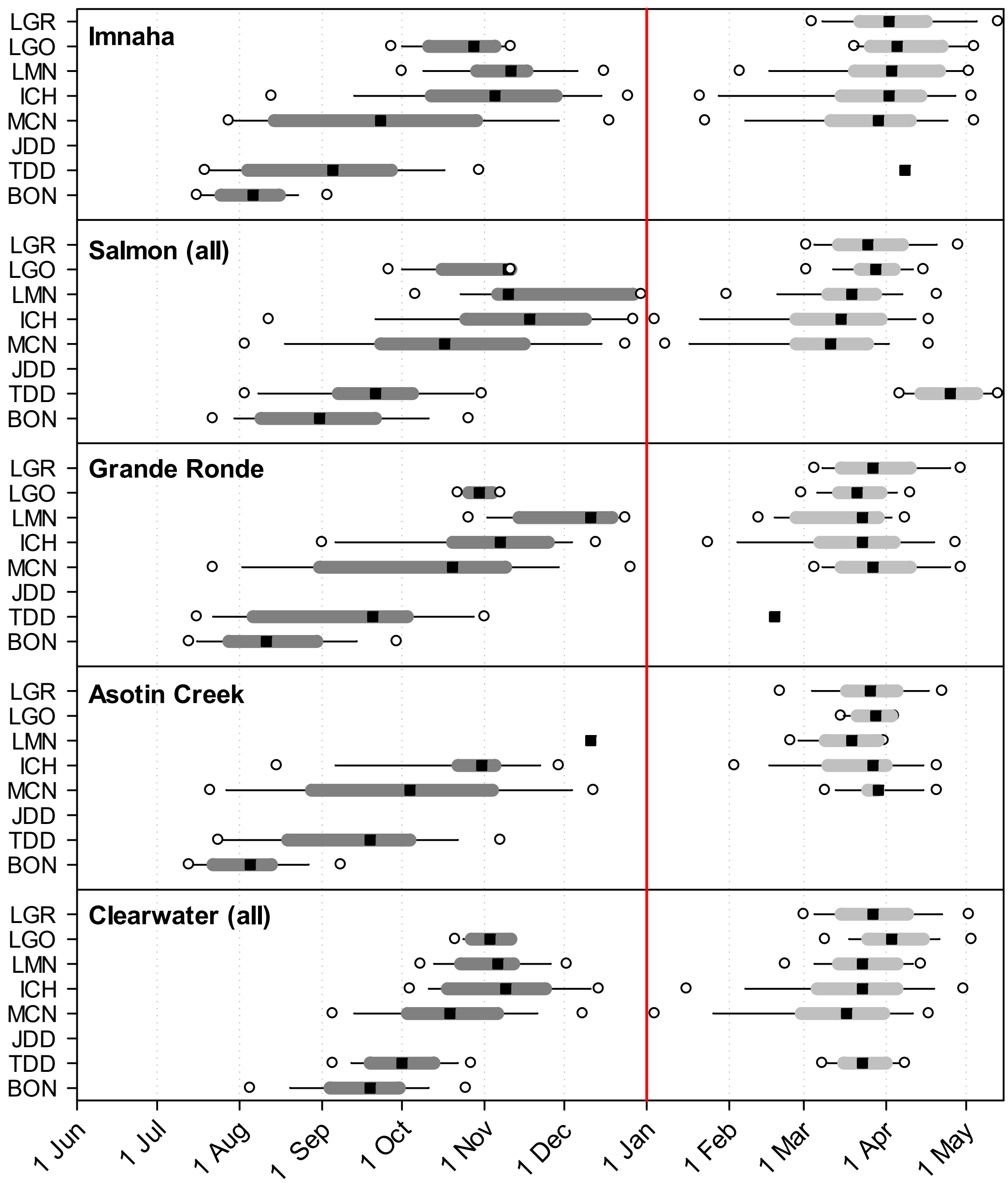


Figure 42. Migration timing for the subset of all FCRPS overwintering adult steelhead identified by a first dam passage >31 December (red line) during 2005-2014). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the fish that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) or in the following year (light gray boxes). Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR). Sample = PIT-tagged as juveniles, Clearwater River, Asotin Creek, Grande Ronde River, Salmon River, and Imnaha River.

FCRPS Overwintering: Timing – Summary

Key findings

- Timing distributions for 2,256 FCRPS overwintering fish showed variety of behaviors
- First-year passages of overwintering fish were before 1 November at Bonneville and The Dalles dams
- First-year passages of overwintering fish at Snake River dams were generally (but not always) after 1 Nov.
- Second-year passage events at most dams were concentrated in March and early-April
- Population-specific dam passage timing was variable and often associated with tributary overshoot

Critical uncertainties

- See list for Section 3.7.2 - FCRPS Overwintering: Percentages

Technical recommendations

- See list for Section 3.7.2 - FCRPS Overwintering: Percentages

3.7.4 FCRPS Overwintering: Locations

A large majority of the FCRPS overwintering by the steelhead identified by dam passage date was in reaches upstream from John Day Dam, and especially in the Snake River reservoirs. A very small number of fish was identified by first passage dates at dams upstream from Wanapum Dam, indicating that limited overwintering occurred in the upper Columbia River reservoirs. The lack of PIT monitoring at The Dalles Dam before 2013 and at John Day Dam in all years significantly limited inferences about overwintering locations in the lower Columbia River. There was a similar lack of geographic specificity in the lower Snake River, where Lower Monumental and Little Goose dams were monitored only in 2014. The available data suggested, however, that some steelhead overwintered in each reservoir and that the Little Goose and Lower Monumental reservoirs were used by relatively large numbers of Snake River fish (including Tucannon River) and fish that overshot natal tributaries downstream (Walla Walla, Umatilla, John Day rivers).

There was some evidence, from repeat passages by individual steelhead at some FCRPS dams, that some fish moved among reaches – including downstream – during the winter period. More generally, however, fish that overwintered in reservoirs tended to move rapidly upstream past multiple dams after initiating movement in the spring.

FCRPS Overwintering: Locations – Summary

Key findings

- A large majority of FCRPS overwintering was upstream from John Day Dam, especially in Snake River reservoirs
- Few steelhead were identified overwintering in reservoirs upstream of Wanapum Dam
- Some fish moved among reservoirs during winter
- Upstream movement through the FCRPS was rapid in spring

Critical uncertainties

- See list for Section 3.7.2 - FCRPS Overwintering: Percentages

Technical recommendations

- See list for Section 3.7.2 - FCRPS Overwintering: Percentages

3.7.5 FCRPS Overwintering: Estimated Fate

The estimated fates / last detections of FCRPS overwintering steelhead varied widely among populations. The most influential factors included the presence/absence of instream PIT monitoring at the respective tributaries, which changed through time, and whether fish had overshot their natal tributary. Groups used for this summary were those identified by dam passage event after 31 December.

Fate summaries for fish from the Hood and Deschutes rivers and from Mill and Fifteenmile creeks were not very meaningful due to small numbers ($n < 5$) identified as FCRPS overwintering (*Table 29*). Of the group of overwintering fish (all wild origin) from the John Day River ($n = 18$), 11% homed and 17% were strays to upriver tributaries; the remaining 72% were last detected at a Snake River dam and could also be considered strays or overshoot fish that failed to move downstream. There were 106 Walla Walla River fish in the overwintering group, and 55% of these homed and 17% were considered strays to other tributaries (note widely distributed locations). The remaining Walla Walla River fish were last detected at dams, including 20% at upstream dams (potential overshoot strays) and 8% at McNary Dam. Wild-origin Walla Walla steelhead were more likely to home (63%) than hatchery-origin steelhead (30%), and wild fish were less likely to stray and less likely to have last detections at upstream dams (*Table 30*).

The largest group of FCRPS overwintering fish was tagged at Lower Granite Dam. Of the 898 fish in this group, 79% had final fates / last detections at Lower Granite Dam or at tributary sites further upstream (*Table 31*). About 5% were considered likely strays that were distributed at sites throughout the study area. The remaining 16% were last detected at FCRPS dams downstream from Lower Granite Dam, with the largest numbers at Ice Harbor or McNary dams. Wild-origin fish tagged at Lower Granite homed at a slightly higher rate (83%) than hatchery-origin fish (76%); 21% of the hatchery group was last detected at a downstream dam versus 12% of the wild fish, suggesting a possible harvest effect (*Table 30*).

Table 29. Final fate / last detection summaries for the subset of FCRPS overwintering adult steelhead that were identified by a first dam passage >31 December (2005-2014). Home = in presumed natal tributary; Stray = detected in non-natal tributary; Dam = at main stem Columbia or Snake River dam. Samples = PIT-tagged as juveniles, lower Columbia River populations.

		Home		Stray		Dam	
Basin	*n*	*n*	%	*n*	%	*n*	%
Walla Walla River	106	58	55%	18	17%	30	28%
Strays: Alpowa Creek (1), Asotin Creek (3), Grande Ronde River (1), Methow River (1), Tucannon River (9), Yakima River (1)							
[1]Upstream dams: L. Goose (1), L. Granite (9), Ice Harbor (7), L. Monumental (4), Rocky Reach (2)							
Downstream dams: McNary (9)							
John Day River	18	2	11%	3	17%	13	72%
Strays: Clearwater River (1), Grande Ronde (1), Umatilla (1)							
[1]Upstream dams: L. Goose (1), L. Granite (6), Ice Harbor (5), L. Monumental (1)							
Deschutes River	1	-	-	1	100%	-	-
Strays: Tucannon River (1)							
Mill Creek						1	100%
[1]Upstream dams: The Dalles (1)							
Fifteenmile Creek	4	1	25%	2	50%	1	25%
Strays: Tucannon River (1), Deschutes (1)							
[1]Upstream dams: The Dalles (1)							

[1] Upstream dams could be considered stray sites, or fish may have been harvested or other mortality

Table 30. Final fate / last detection summaries for the subset of FCRPS overwintering adult steelhead that were identified by a first dam passage >31 December (2005-2014), by natal origin (H = hatchery, W = wild, U = unknown). Home = in presumed natal tributary; Stray = detected in non-natal tributary; Dam = at main stem Columbia or Snake River dam. Samples = PIT-tagged as juveniles, lower Columbia River and Snake River populations other than Clearwater and Salmon rivers.

			Home		Stray		Upstream dam[1]		Downstream dam[2]	
Basin	Origin	n	n	%	n	%	n	%	n	%
Fifteenmile Creek	W	4	1	25%	2	50%	1	25%	-	-
Mill Creek	W	1	-	-	-	-	1	100%	-	-
Deschutes River	W	1	-	-	1	100%	-	-	-	-
John Day River	W	18	2	11%	3	17%	13	72%	-	-
Walla Walla River	H	27	8	30%	6	22%	13	48%	-	-
Walla Walla River	W	79	50	63%	10	13%	14	18%	5	6%
Lyons Ferry Hatchery	H	4	-	-	-	-	1	25%	3	75%
Tucannon	H	82	40	49%	13	16%	12	15%	17	21%
Tucannon	W	13	9	69%	1	8%	1	8%	2	15%
Lower Granite Dam	H	433	327[3]	76%	15	3%	-	-	91	21%
Lower Granite Dam	W	465	385[3]	83%	23	5%	-	-	57	12%
Snake > L. Granite	H	21	1	5%	-	-	-	-	20	95%
Snake > L. Granite	W	6	-	-	1	17%	-	-	5	83%
Asotin Creek	W	20	17	85%	1	5%	-	-	2	10%
Asotin Creek	U	1	1	100%	-	-	-	-	-	-
Grande Ronde	H	106	39	37%	6	6%	-	-	61	58%
Grande Ronde	W	41	9	22%	4	10%	-	-	28	68%
Imnaha	H	90	58	64%	1	1%	-	-	31	34%
Imnaha	W	58	31	53%	1	2%	-	-	26	45%

[1] Upstream dams could be considered stray sites, or fish may have been harvested or other mortality
[2] Includes Lower Granite Dam for populations that originated upstream from Lower Granite Dam (except those tagged at Lower Granite Dam)
[3] At or upstream from Lower Granite Dam

There were 95 fish in the Tucannon River FCRPS overwintering group, of which 52% homed and 16% strayed to other tributaries (*Table 31*). A third of the Tucannon fish were last detected at dams, approximately split between dams upstream and downstream from the Tucannon River. Homing was higher for wild fish (69%) than for hatchery fish (49%, *Table 30*), possibly reflecting harvest. Overwintering fish from the Imnaha and Grande Ronde rivers and Asotin Creek had a mixture of fates that reflected, in part, differences in detection likelihood in tributaries. Fate for the Imnaha group was: 60% homed, 1% strayed, and 39% last at downstream dams (mostly at Lower Granite Dam). Wild-origin Imnaha River steelhead had lower homing (53%) than hatchery-origin fish (64%), likely reflecting difference in detection probability. The Grande Ronde group was 33% (homed), 8% (strays), and 59% (downstream dams), and homing was also lower for wild fish (22%) than for hatchery-origin fish (37%). In contrast, estimates of homing were considerably higher for the well-monitored Asotin Creek population (wild origin), with 81% (homed), 10% (strays), and 10% (downstream dams) (*Table 31*).

There were FCRPS overwintering fish from five Clearwater River groups (*Table 32 and 33*). Homing rates for these groups, defined as detection in the Clearwater basin, ranged from 31% for the mixed-population 'other' group to 52% for the Lochsa River group; differences were likely related to the spatial distribution of PIT antennas. Stray rates were ≤ 2% for all wild- and hatchery-origin Clearwater River groups, and most of the fish last detected at downstream dams were at Lower Granite Dam. Overwintering samples sizes were considerably smaller for most of the Salmon River groups, and a large majority (84-100%) of each wild and hatchery group was last detected at lower Snake River dams, especially Lower Granite Dam (*Table 32 and 33*).

Table 31. Final fate / last detection summaries for the subset of FCRPS overwintering adult steelhead that were identified by a first dam passage >31 December (2005-2014). Home = in presumed natal tributary; Stray = detected in non-natal tributary; Dam = at main stem Columbia or Snake River dam. Samples = PIT-tagged as juveniles, Snake River populations.

		Home		Stray		Dam	
Basin	*n*	*n*	%	*n*	%	*n*	%
Imnaha	148	89	60%	2	1%	57	39%
Strays: Deschutes (1)							
Downstream dams: L. Goose (1), L. Granite (40), Ice Harbor (7), L. Monumental (1), McNary (8)							
Grande Ronde	147	48	33%	12	8%	87	59%
Strays: Asotin Creek (3), Methow River (1) Okanogan River (1), Priest Rapids dam (1), Tucannon River (5), Wells (1)							
Downstream dams: L. Goose (2), L. Granite (72), Ice Harbor (10), McNary (3)							
Asotin Creek	21	17	81%	2	10%	2	10%
Strays: Grande Ronde (1), Okanogan (1)							
Downstream dams: Ice Harbor (2)							
Tucannon River	95	49	52%	15	16%	31	33%
Strays: Alpowa Creek (1), Asotin Creek (2), Grande Ronde River (2), Klickitat River (1), Priest Rapids Dam (1), Umatilla River (2), Walla Walla River (5), Yakima River (1)							
[1]Upstream dams: L. Goose (2), L. Granite (13)							
Downstream dams: Ice Harbor (7), L. Monumental (1), McNary (8)							
Lyons Ferry	4	-	-	-	-	4	100%
[1]Upstream Dams: L. Granite (1)							
Downstream: L. Monumental (3)							
Snake > Lower Granite	27	1	4%	1	4%	25	93%
Strays: Tucannon River (1)							
Downstream dams: L Granite (21), Ice Harbor (2), McNary (2)							
Lower Granite Dam	898	[2]711	79%	43	5%	144	16%
Strays: Hood River (1), Fifteenmile Creek (1), Deschutes River (5), John Day River (9), Rock Creek (2), Tucannon River (13), Umatilla River (1), Walla Walla River (3), Wenatchee River (3)							
[1]Upper Columbia River dams: Priest Rapids (3), Rocky Reach (1)							
Downstream dams: Bonneville (3), McNary (60), Ice Harbor (74), L. Monumental (1), Little Goose (6)							

[1] Upstream dams could be considered stray sites, or fish may have been harvested or other mortality
[2] At or upstream from Lower Granite Dam

Table 32. Final fate / last detection summaries for the subset of FCRPS overwintering adult steelhead that were identified by a first dam passage >31 December (2005-2014). Home = in presumed natal tributary; Stray = detected in non-natal tributary; Dam = at main stem Columbia or Snake River dam. Samples = PIT-tagged as juveniles, Clearwater and Salmon River populations.

		Home		Stray		Dam	
Basin	*n*	*n*	%	*n*	%	*n*	%
CWR: Lochsa	100	52	52%	1	1%	47	47%
Strays: Tucannon River (1)							
Downstream dams: L. Granite (40), Ice Harbor (2), McNary (4), The Dalles (1)							
CWR: Middle Fork	6	2	33%	-	-	4	67%
Downstream dams: L. Granite (4)							
CWR: South Fork	66	31	47%	1	2%	34	52%
Strays: Tucannon River(1)							
Downstream dams: L. Granite (31), Ice Harbor (2),The Dalles (1)							
CWR: Potlatch	10	7	70%	-	-	3	30%
Downstream dams: L. Granite (3)							
CWR: other	72	22	31%	1	1%	49	68%
Strays: Tucannon River (1)							
Downstream dams: L. Granite (45), Ice Harbor (2), McNary (1), The Dalles (1)							
SAL: Lemhi	6	-	-	-	-	6	100%
Downstream dams: L. Granite (5), The Dalles (1)							
SAL: Middle Fork	3	-	-	-	-	3	100%
Downstream dams: L. Granite (3)							
SAL: South Fork	3	-	-	-	-	3	100%
Downstream dams: L. Granite (3)							
SAL: Little Salmon	46	-	-	3	7%	43	93%
Strays: John Day River (1), Tucannon River (1), Walla Walla River (1)							
Downstream dams: L. Granite (37), Ice Harbor (4), McNary (2)							
SAL: other	63	6	10%	3	5%	54	86%
Strays: Methow River (1), Rock Creek (1), Tucannon River (1)							
Downstream dams: L. Granite (44), Ice Harbor (7), L. Monumental (1), McNary (2)							

Table 33. Final fate / last detection summaries for the subset of FCRPS overwintering adult steelhead that were identified by a first dam passage >31 December (2005-2014), by natal origin (H = hatchery, W = wild, U = unknown). Home = in presumed natal tributary; Stray = detected in non-natal tributary; Dam = at main stem Columbia or Snake River dam. Samples = PIT-tagged as juveniles, Clearwater and Salmon River populations.

			Home		Stray		Upstream dam[1]		Downstream dam[2]	
Basin	Origin	n	n	%	n	%	n	%	n	%
CWR: other	H	63	20	32%	1	2%	-	-	42	67%
CWR: other	W	9	2	22%	-	-	-	-	7	78%
CWR: Potlatch	W	10	7	70%	-	-	-	-	3	30%
CWR: South Fork	H	65	30	46%	1	2%	-	-	34	52%
CWR: South Fork	W	1	1	100%	-	-	-	-	-	-
CWR: Lochsa	W	100	52	52%	1	1%	-	-	47	47%
SAL: other	H	62	6	10%	3	5%			53	85%
SAL: other	W	1	-	-	-	-	-	-	1	100%
SAL: Little Salmon	H	44	-	-	3	7%	-	-	41	93%
SAL: Little Salmon	W	2	-	-	-	-	-	-	2	100%
SAL: South Fork	W	3	-	-	-	-	-	-	3	100%
SAL: Middle Fork	W	3	-	-	-	-	-	-	3	100%
SAL: East Fork	H	19	2	11%	1	5%	-	-	16	84%
SAL: Lemhi	W	6	-	-	-	-	-	-	6	100%
SAL: Pahsimeroi	H	46	5	11%	2	4%	-	-	39	85%

[1] Upstream dams does not apply
[2] Includes Lower Granite Dam

The final group of FCRPS overwintering populations was from populations upstream from the Columbia-Snake confluence. The largest number was from the Wenatchee River (*n* = 185), of which just 12% appeared to have homed; a majority (75%) of the Wenatchee fish were last detected upstream at Rocky Reach or Wells dams (*Table 34*). Most Methow River fish were also detected at Rocky Reach or Wells dams, though these sites were downstream from the Methow River confluence. Lastly, most of the FCRPS overwintering group from Ringold Hatchery were last recorded at upper Columbia River dams (67%) or at Snake River dams (24%), indicated a mix of overshoot and straying behaviors. It was not clear whether there was detection capability for PIT-tagged fish returning to Ringold Hatchery and there was no estimate of homing.

Table 34. Final fate / last detection summaries for the subset of FCRPS overwintering adult steelhead that were identified by a first dam passage >31 December (2005-2014). Home = in presumed natal tributary; Stray = detected in non-natal tributary; Dam = at main stem Columbia or Snake River dam. Samples = PIT-tagged as juveniles, populations upstream from the Columbia River – Snake River confluence.

		Home		Stray		Dam	
Basin	*n*	*n*	%	*n*	%	*n*	%
Okanogan River	7	3	43%	-	-	4	57%
Downstream dams: Priest Rapids (1), Rocky Reach (2), Wells (1)							
Methow River	32	6	19%	-	-	26	81%
Downstream dams: Rock Island (2), Rocky Reach (8), Wells (16)							
Entiat River	5	3	60%	1	20%	1	20%
Strays: Methow (1)							
[1]Upstream dams: Wells (1)							
Wenatchee River	180	22	12%	18	10%	140	78%
Strays: Entiat River (11), Methow River (5), Okanogan River (2)							
[1]Upstream dams: Rocky Reach (85), Wells (50)							
Downstream dams: McNary (2), Priest Rapids (1), Rock Island (2)							
Ringold Hatchery	45	-	-	13	29%	32	71%
Strays: L. Granite (1), Ice Harbor (10), Tucannon River (1)							
[1]Upstream dams: Priest Rapids (13), Rock Island (8), Rocky Reach (8), Wells (1)							
Downstream dams: McNary (3)							
Yakima	5	5	100%	-	-	-	-

[1] Upstream dams could be considered stray sites

FCRPS Overwintering: Estimated Fate – Summary

Key findings

- Estimated fates / last known detections of overwintering steelhead varied greatly by population
- In general, wild fish were more likely to home and less like to stray than hatchery fish
- Large numbers and percentages of adults were last detected at a FCRPS dam

Critical uncertainties

- True fates of fish that did not reach natal tributaries were generally unknown
- Substantial monitoring differences among sites and populations means behaviors may be misclassified
- Fish harvest influenced results to an unknown degree
- Also see list associated with Section 3.7.2 - FCRPS Overwintering: Percentages

Technical recommendations

- Population-specific data on the location and rate of harvest events in the FCRPS are needed to generate more complete and accurate fate estimates
- Additional PIT interrogation sites, particularly in tributaries, would improve fate estimation and it would also provide data to more accurately and precisely estimate tributary overshoot, conversion, and staying
- Also see list for Sections 3.8, 3.10, and 3.11 below

3.8 TRIBUTARY OVERSHOOT

3.8.1 Methods

Adult steelhead that overshot their natal tributary confluence were primarily identified using detections at FCRPS dam fishway antennas located upstream from the confluence. A few additional overshoot fish were identified by records at other tributaries that were located upstream from the natal tributary confluence. However, the latter method was considered less reliable given the limited number of monitored tributaries and the results were less relevant to FCRPS operations (e.g., when the upstream tributary entered the same reservoir as the natal tributary). For consistency, we report only the tributary overshoot that was detected at FCRPS dams.

FCRPS fishway monitoring arrays were especially well situated to detect overshoot behaviors by steelhead from Fifteenmile Creek at The Dalles Dam, though The Dalles was only monitored in 2013-2015. Overshoot by John Day and Umatilla River steelhead was readily detected at McNary Dam in all years. Overshoot by Walla Walla River steelhead was detected primarily in the Snake River at Ice Harbor Dam, but also ~130 rkm up the mid-Columbia River at Priest Rapids Dam; both dams were monitored in all years. Tucannon River steelhead that overshot could be detected at Little Goose Dam starting in 2014 but could be detected at Lower Granite Dam (~70 rkm upstream) in all years.

3.8.2 Tributary Overshoot: Percentages

Estimating natal tributary overshoot percentages is sensitive to the locations of both upstream and downstream monitoring sites relative to the tributary. If the downstream monitoring site is distant from the natal tributary, the number of steelhead counted at the downstream site is likely to be an overestimate of the number that eventually reach the tributary and potentially overshoot. For example, many steelhead from the John Day or Walla Walla rivers are likely harvested in lower Columbia River reservoirs before they reach natal tributary confluence areas and using the count of those populations at Bonneville Dam as the denominator in tributary overshoot estimates will produce an underestimate of the behavior. Similarly, the closer the tributary is to the upstream monitoring site the more likely it is that overshoot fish (the numerator) will be detected.

The series of tributary overshoot estimates provided in the following tables use steelhead detection at each of the FCRPS dams located downstream from each tributary, resulting in multiple estimates for several tributary populations. The accuracy of the estimates should increase as the distance between the downstream dam and the tributary confluence decreases. Multiple estimates were also provided because some dams were monitored in all years (Bonneville, McNary, Ice Harbor, Lower Granite) while others were monitored in 2-3 years (The Dalles, Lower Monumental, Little Goose).

The Dalles Dam – Overshoot estimates past The Dalles Dam were calculated for five steelhead populations tagged in tributaries draining into Bonneville reservoir (*Table 35*). Full-year PIT monitoring began at The Dalles Dam in 2013, and all adults from the 2013-2015 migration years were used to estimate overshoot past The Dalles Dam. Aggregate estimates were 2.2% (Wind River), 4.2% (Klickitat River), 5.0% (Hood River), 76.1% (Mill Creek), and 71.7% (Fifteenmile Creek). Annual rates were variable, but mean and median values were similar to the aggregated estimates for all five tributary groups.

Table 35. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from The Dalles Dam (2013-2015). Estimates are the number of steelhead that passed The Dalles Dam (TDD) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary (years)	BON *n*	TDD *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River (11)	179	4	2.2%	27-108	1.2%	0.0%	0.0%	3.7%
Hood River (10)	584	29	5.0%	143-252	4.5%	3.6%	3.5%	6.3%
Klickitat River (4)	936	39	4.2%	189-426	4.1%	3.8%	3.2%	3.8%
Mill Creek (3)	52	38	73.1%	13-23	71.8%	73.9%	53.8%	87.5%
Fifteenmile Creek (8)	92	66	71.7%	25-31	72.0%	72.2%	67.7%	76.0%

McNary Dam – Nine tributaries with steelhead samples enter the Columbia River between Bonneville and McNary dams. Both dams were monitored in all study years and the adult count at Bonneville Dam was used as the denominator in the first set of estimates (*Table 36*). Aggregate overshoot estimates past McNary Dam ranged from 0.1-7.7% for the five populations originating from Bonneville reservoir tributaries. The highest rates were for the Mill Creek (7.7%) and Fifteenmile Creek (6.9%) groups. Overshoot by Deschutes River steelhead past McNary Dam was low (0.7%). Aggregate overshoot estimates for the three populations in the John Day-McNary reach were much higher at 40.6% (Umatilla River), 52.9% (Rock Creek), and 53.9% (John Day River). Mean and median annual overshoot estimates were similar (difference < 3%) to the aggregate rates for all tributary groups (*Table 36*).

Overshoot rates past McNary Dam were also estimated for steelhead from the Deschutes River and the John Day reservoir tributaries and passed McNary Dam using the number of that passed The Dalles Dam as the denominator (*Table 37*). Estimates were 0.7% (Deschutes River), 52.5% (Umatilla River), 56.7% (Rock Creek), and 71% (John Day River).

Table 36. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from McNary Dam (2005-2015). Estimates are the number of steelhead that passed McNary Dam (MCN) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary (years)	BON *n*	MCN *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River (11)	837	1	0.1%	27-161	0.1%	0.0%	0.0%	0.9%
Hood River (10)	2,122	3	0.1%	18-448	0.2%	0.0%	0.0%	1.0%
Klickitat River (4)	1,221	6	0.5%	189-426	0.5%	0.5%	0.0%	1.1%
Mill Creek (3)	52	4	7.7%	13-23	7.1%	8.7%	0.0%	12.5%
Fifteenmile Creek (8)	362	25	6.9%	11-93	8.3%	8.5%	2.8%	18.2%
Deschutes River (9)	853	6	0.7%	38-180	0.7%	0.6%	0.0%	1.7%
John Day River (11)	2,356	1,270	53.9%	67-343	54.5%	54.9%	36.5%	63.8%
Rock Creek (4)	34	18	52.9%	3-17	55.7%	51.0%	33.3%	87.5%
Umatilla River (11)	1,271	516	40.6%	12-321	39.3%	37.7%	30.0%	50.2%

Table 37. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from McNary Dam (2013-2015). Estimates are the number of steelhead that passed McNary Dam (MCN) divided by the number that passed The Dalles Dam (TDD).

	All years			Annual overshoot estimates				
Tributary	TDD *n*	MCN *n*	Overshoot	TDD *n*	Mean	Median	Min	Max
Deschutes River	270	2	0.7%	45-146	1.0%	0.7%	0.0%	2.2%
John Day River	638	453	71.0%	200-221	71.2%	71.0%	65.0%	77.5%
Rock Creek	30	17	56.7%	6-16	63.9%	66.7%	37.5%	87.5%
Umatilla River	510	268	52.5%	64-271	49.8%	45.3%	44.6%	59.4%

Ice Harbor Dam – Ten tributaries with steelhead samples enter the Columbia River between Bonneville and Ice Harbor dams and passage at three dams were used as denominators in overshoot estimates (*Tables 38-40*). Steelhead from three of the five Bonneville reservoir tributary groups passed Ice Harbor Dam: aggregate estimates were 1.5% (Fifteenmile Creek), and 0.2% (Klickitat River) using Bonneville passage as the denominator (*Table 38*).

Aggregate overshoot estimates for the Deschutes River steelhead were 0.2% (*Table 38*) and 0.4% (*Table 39*) using Bonneville and The Dalles passage, respectively, as the denominators (*Table 38*). Estimates for John Day River steelhead were 13.7% (*Table 38*) and 16.1% (*Table 39*), respectively. Estimates for Umatilla River steelhead were 7.7% (*Table 38*) and 12.7%, respectively. No Rock Creek steelhead were detected at Ice Harbor Dam.

Many Walla Walla steelhead passed Ice Harbor Dam. Aggregated estimates were 51.1% (*Table 38*), 60.6% (*Table 39*), and 65.4% (*Table 40*) using Bonneville, The Dalles, and McNary passage as the denominators, respectively. Note that the Walla Walla sample decreased by ~20%

between passage at Bonneville Dam (total *n* = 2,391) and passage at McNary Dam (total *n* = 1,905), demonstrating the importance of which site is used as the downstream starting point.

Table 38. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Ice Harbor Dam (2005-2015). Estimates are the number of steelhead that passed Ice Harbor Dam (ICH) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary (years)	BON *n*	ICH *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River (11)	837	-	-	27-161	-	-	-	-
Klickitat River (4)	1,221	3	0.2%	189-426	0.2%	0.1%	0.0%	0.7%
Mill Creek (3)	52	-	-	13-23	-	-	-	-
Fifteenmile Creek (8)	362	6	1.7%	11-93	1.4%	1.6%	0.0%	3.0%
Deschutes River (9)	853	2	0.2%	38-180	0.2%	0.0%	0.0%	0.9%
John Day River (11)	2,356	323	13.7%	67-343	13.3%	15.2%	2.7%	19.4%
Rock Creek (4)	34	-	-	3-17	-	-	-	-
Umatilla River (11)	1,271	98	7.7%	12-321	6.9%	6.2%	0.0%	16.7%
Walla Walla River (11)	2,391	1,246	52.1%	33-471	48.8%	48.9%	38.6%	59.8%

Table 39. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Ice Harbor Dam (2013-2015). Estimates are the number of steelhead that passed Ice Harbor Dam (ICH) divided by the number that passed The Dalles Dam (TDD).

	All years			Annual overshoot estimates				
Tributary	TDD *n*	ICH *n*	Overshoot	TDD *n*	Mean	Median	Min	Max
Deschutes River	270	1	0.4%	45-146	0.2%	0.0%	0.0%	0.7%
John Day River	638	103	16.1%	200-221	16.3%	18.0%	9.0%	22.0%
Rock Creek	-	-	-	-	-	-	-	-
Umatilla River	510	65	12.7%	64-271	11.5%	13.1%	7.8%	13.7%
Walla Walla River	493	299	60.6%	136-202	65.3%	58.1%	56.6%	65.3%

Table 40. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Ice Harbor Dam (2005-2015). Estimates are the number of steelhead that passed McNary Dam (MCN) divided by the number that passed McNary Dam (MCN).

	All years			Annual overshoot estimates				
Tributary (years)	MCN *n*	ICH *n*	Overshoot	MCN *n*	Mean	Median	Min	Max
Walla Walla River	1,905	1,246	65.4%	22-362	62.0%	64.3%	43.6%	74.7%

Lower Monumental Dam – Ten tributaries with steelhead samples enter the Columbia River between Bonneville and Lower Monumental dams. Overshoot data past Lower Monumental Dam were limited to the 2014 and 2015 migrations. Steelhead from one of the five Bonneville reservoir tributary groups passed Lower Monumental Dam: the estimates was 0.1% (Klickitat River) using Bonneville passage as the denominator (*Table 41*).

No Deschutes River or Rock Creek steelhead were detected at Lower Monumental Dam.

Estimates for John Day River steelhead were 12.8% (*Table 41*) and 15.3% (*Table 42*), respectively, using passage at Bonneville and The Dalles as denominators. Estimates for Umatilla River steelhead were 8.5% (*Table 41*) and 10.1% (*Table 42*), respectively.

Many Walla Walla steelhead passed Lower Monumental Dam. Aggregated estimates were 43.0% (*Table 41*), 51.3% (*Table 42*), and 55.1% (*Table 43*) using Bonneville, The Dalles, and McNary passage as the denominators, respectively.

Table 41. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Monumental Dam (2014-2015). Estimates are the number of steelhead that passed Lower Monumental Dam (LMN) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary (years)	BON *n*	LMN *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River	152	-	-	44-108	-	-	-	-
Klickitat River	747	1	0.1%	321-426	0.1%	0.1%	0.0%	0.2%
Mill Creek	39	-	-	16-23	-	-	-	-
Fifteenmile Creek	61	-	-	25-36	-	-	-	-
Deschutes River	149	-	-	52-97	-	-	-	-
John Day River	500	64	12.8%	243-257	12.9%	12.9%	10.9%	14.8%
Rock Creek	25	-	-	8-17	-	-	-	-
Umatilla River	528	45	8.5%	207-321	8.4%	8.4%	7.7%	9.0%
Walla Walla River	426	183	43.0%	184-242	42.6%	42.6%	39.7%	45.5%

Table 42. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Monumental Dam (2014-2015). Estimates are the number of steelhead that passed Lower Monumental Dam (LMN) divided by the number that passed The Dalles Dam (TDD).

	All years			Annual overshoot estimates				
Tributary	TDD *n*	LMN *n*	Overshoot	TDD *n*	Mean	Median	Min	Max
Deschutes River	124	-	-	45-79	-	-	-	-
John Day River	417	64	15.3%	200-217	15.5%	15.5%	12.9%	18.0%
Rock Creek	24	-	-	8-16	-	-	-	-
Umatilla River	446	45	10.1%	175-271	9.9%	9.9%	9.1%	10.7%
Walla Walla River	357	183	51.3%	155-202	50.8%	50.8%	47.1%	54.5%

Table 43. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Little Goose Dam (2014-2015). Estimates are the number of steelhead that passed Lower Monumental Dam (LMN) divided by the number that passed McNary Dam (MCN).

	All years			Annual overshoot estimates				
Tributary	MCN *n*	LMN *n*	Overshoot	MCN *n*	Mean	Median	Min	Max
Walla Walla River	332	183	55.1%	140-192	54.7%	54.7%	52.1%	57.3%

Little Goose Dam – Eleven tributaries and one hatchery (Lyons Ferry) with steelhead samples enter the Columbia or Snake rivers between Bonneville and Little Goose dams. Overshoot data past Little Goose Dam were limited to the 2014 and 2015 migrations. Overshoot patterns were generally similar to those reported for Lower Monumental Dam. The aggregate estimate for the Bonneville pool tributaries was 0.1% (Klickitat River) (*Table 44*). No Deschutes River or Rock Creek steelhead were detected at Little Goose Dam. Aggregate estimates were 9.4-11.3% (John Day River), 6.3-7.4% (Umatilla River), and 29.1-37.3% (Walla Walla River) (*Tables 44-46*).

The Tucannon River confluence and Lyons Ferry Hatchery are both located between Lower Monumental and Little Goose dams and steelhead from both populations overshot at high rates. Aggregated overshoot estimates for the Tucannon fish ranged from 53.8% using Bonneville passage as the denominator to 80.3% using Lower Monumental passage as the denominator (*Tables 44-48*). Estimates for the Lyons Ferry Hatchery fish past Little Goose Dam were comparable, and ranged from 50.7% to 68.2%.

Table 44. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Little Goose Dam (2014-2015). Estimates are the number of steelhead that passed Little Goose Dam (LGO) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary	BON *n*	LGO *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River (11)	152	-	-	44-108	-	-	-	-
Klickitat River (4)	747	1	0.1%	321-426	0.1%	0.1%	0.0%	0.2%
Mill Creek (3)	39	-	-	16-23	-	-	-	-
Fifteenmile Creek (8)	61	-	-	25-36	-	-	-	-
Deschutes River (9)	149	-	-	52-97	-	-	-	-
John Day River (11)	500	47	9.4%	243-257	9.4%	9.4%	7.8%	11.1%
Rock Creek (4)	25	-	-	8-17	-	-	-	-
Umatilla River (11)	528	33	6.3%	207-321	6.2%	6.2%	5.8%	6.5%
Walla Walla River (11)	426	124	29.1%	184-242	28.9%	28.9%	27.7%	30.2%
Lyons Ferry H. (8)	148	75	50.7%	63-85	50.3%	50.3%	47.6%	52.9%
Tucannon River (11)	394	212	53.8%	192-202	53.8%	53.8%	53.6%	54.0%

Table 45. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Little Goose Dam (2014-2015). Estimates are the number of steelhead that passed Little Goose Dam (LGO) divided by the number that passed The Dalles Dam (TDD).

	All years			Annual overshoot estimates				
Tributary	TDD *n*	LGO *n*	Overshoot	TDD *n*	Mean	Median	Min	Max
Deschutes River	124	-	-	45-79	-	-	-	-
John Day River	417	47	11.3%	200-217	11.4%	11.4%	9.2%	13.5%
Rock Creek	24	-	-	8-16	-	-	-	-
Umatilla River	446	33	7.4%	175-271	7.3%	7.3%	6.9%	7.7%
Walla Walla River	357	124	34.7%	155-202	34.5%	34.5%	32.9%	36.1%
Lyons Ferry Hatchery	126	75	59.5%	54-72	59.0%	59.0%	55.6%	62.5%
Tucannon River	329	212	64.4%	159-170	64.4%	64.4%	64.1%	64.8%

Table 46. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Little Goose Dam (2014-2015). Estimates are the number of steelhead that passed Little Goose Dam (LGO) divided by the number that passed McNary Dam (MCN).

	All years			Annual overshoot estimates				
Tributary	MCN *n*	LGO *n*	Overshoot	MCN *n*	Mean	Median	Min	Max
Walla Walla River	332	124	37.3%	140-192	37.2%	37.2%	36.4%	38.0%
Lyons Ferry Hatchery	118	75	63.6%	49-69	63.2%	63.2%	61.2%	65.2%
Tucannon River	291	212	72.9%	136-155	73.0%	73.0%	70.3%	75.7%

Table 47. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Little Goose Dam (2014-2015). Estimates are the number of steelhead that passed Little Goose Dam (LGO) divided by the number that passed Ice Harbor Dam (ICH).

	All years			Annual overshoot estimates				
Tributary	ICH *n*	LGO *n*	Overshoot	ICH *n*	Mean	Median	Min	Max
Lyons Ferry Hatchery	113	75	66.4%	48-65	65.9%	65.9%	62.5%	69.2%
Tucannon River	272	212	77.9%	127-145	78.2%	78.2%	75.2%	81.1%

Table 48. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Little Goose Dam (2014-2015). Estimates are the number of steelhead that passed Little Goose Dam (LGO) divided by the number that passed Lower Monumental Dam (LMN).

	All years			Annual overshoot estimates				
Tributary	LMN *n*	LGO *n*	Overshoot	LMN *n*	Mean	Median	Min	Max
Lyons Ferry Hatchery	110	75	68.2%	46-64	67.8%	67.8%	65.2%	70.3%
Tucannon River	264	212	80.3%	121-143	80.7%	80.7%	76.2%	85.1%

Lower Granite Dam – Eleven monitored tributaries and one hatchery (Lyons Ferry) with steelhead samples enter the Columbia or Snake rivers between Bonneville and Lower Granite dams. Overshoot rates were generally similar to or lower than those past Lower Monumental and Little Goose dams, but note that sample sizes were much larger for some groups because Lower Granite Dam was monitored in all years. Aggregate estimates for the Bonneville pool tributaries were 0.2% (Klickitat River), and 0.2-0.4% (Deschutes River) (*Tables 49-50*). No Rock Creek steelhead were detected at Lower Granite Dam. Aggregate estimates were 5.6-6.3% (John Day River), 3.1-5.1% (Umatilla River), and 20.3-25.5% (Walla Walla River) (*Tables 49-51*).

Many Tucannon River and Lyons Ferry Hatchery steelhead passed Lower Granite Dam. Aggregated overshoot estimates for the Tucannon fish ranged from 45.4% using Bonneville passage as the denominator to 67.0% using Lower Monumental passage as the denominator (*Tables 49-53*). Estimates for the Lyons Ferry Hatchery fish past Lower Granite Dam ranged from 34.5% to 50.0%.

Table 49. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Granite Dam (2005-2015). Estimates are the number of steelhead that passed Lower Granite Dam (LGR) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary (years)	BON *n*	LGR *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River (11)	837	-	-	27-161	-	-	-	-
Klickitat River (4)	1,221	2	0.2%	189-426	0.1%	0.1%	0.0%	0.4%
Mill Creek (3)	52	-	-	13-23	-	-	-	-
Fifteenmile Creek (8)	362	2	0.6%	11-93	0.5%	0.0%	0.0%	3.0%
Deschutes River (9)	853	2	0.2%	38-180	0.2%	0.0%	0.0%	0.9%
John Day River (11)	2,356	148	6.3%	67-343	6.2%	7.3%	0.0%	13.4%
Rock Creek (4)	34	-	-	3-17	-	-	-	-
Umatilla River (11)	1,271	39	3.1%	12-321	3.5%	2.2%	0.0%	16.7%
Walla Walla River (11)	2,391	486	20.3%	33-471	18.0%	18.3%	11.4%	24.8%
Lyons Ferry H. (8)	458	158	34.5%	2-85	30.8%	33.3%	0.0%	40.0%
Tucannon River (11)	3,122	1,416	45.4%	94-582	44.5%	42.9%	39.7%	51.6%

Table 50. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Granite Dam (2005-2015). Estimates are the number of steelhead that passed Lower Granite Dam (LGR) divided by the number that passed The Dalles Dam (TDD).

	All years			Annual overshoot estimates				
Tributary	TDD *n*	LGR *n*	Overshoot	TDD *n*	Mean	Median	Min	Max
Deschutes River	270	1	0.4%	45-146	0.2%	0.0%	0.0%	0.7%
John Day River	638	36	5.6%	200-221	7.3%	7.3%	2.7%	9.0%
Rock Creek	-	-	-	-	-	-	-	-
Umatilla River	510	26	5.1%	64-271	4.2%	5.1%	1.6%	5.9%
Walla Walla River	493	114	23.1%	136-202	22.8%	22.1%	20.0%	26.2%
Lyons Ferry Hatchery	195	80	41.0%	54-72	43.1%	38.9%	36.2%	47.2%
Tucannon River	462	246	53.2%	133-170	53.9%	51.9%	50.6%	57.2%

Table 51. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Granite Dam (2005-2015). Estimates are the number of steelhead that passed Lower Granite Dam (LGR) divided by the number that passed McNary Dam (MCN).

	All years			Annual overshoot estimates				
Tributary	MCN *n*	LGR *n*	Overshoot	MCN *n*	Mean	Median	Min	Max
Walla Walla River	1,905	486	25.5%	22-362	22.9%	22.9%	12.8%	32.3%
Lyons Ferry Hatchery	368	158	42.9%	2-69	37.6%	43.1%	0.0%	49.3%
Tucannon River	2,407	1,416	58.8%	66-527	58.2%	58.8%	51.2%	66.9%

Table 52. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Granite Dam (2005-2015). Estimates are the number of steelhead that passed Lower Granite Dam (LGR) divided by the number that passed Ice Harbor Dam (ICH).

	All years			Annual overshoot estimates				
Tributary	ICH *n*	LGR *n*	Overshoot	ICH *n*	Mean	Median	Min	Max
Lyons Ferry Hatchery	357	158	44.3%	2-65	38.9%	44.2%	0.0%	52.3%
Tucannon River	2,242	1,416	63.2%	63-499	62.2%	63.5%	50.6%	71.7%

Table 53. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Lower Granite Dam (2014-2015). Estimates are the number of steelhead that passed Lower Granite Dam (LGR) divided by the number that passed Lower Monumental Dam (LMN).

	All years			Annual overshoot estimates				
Tributary	LMN *n*	LGR *n*	Overshoot	LMN *n*	Mean	Median	Min	Max
Lyons Ferry Hatchery	110	55	50.0%	46-64	49.4%	49.4%	45.7%	53.1%
Tucannon River	264	177	67.0%	121-143	67.7%	67.7%	60.1%	75.2%

Priest Rapids Dam – Ten tributaries with steelhead samples enter the Columbia River between Bonneville and Priest Rapids dams. Overshoot percentages using Bonneville passage at the denominator were zero for most populations downstream from McNary Dam except for the aggregates from John Day River (1%) and Umatilla River (0.8%) (*Table 54*). Aggregate estimates were slightly higher (2.2%) for the Walla Walla River fish and considerably higher (12.6%) for Yakima River fish. Some Tucannon River (1.9%) and Lyons Ferry Hatchery (0.9%) steelhead also passed Priest Dam. However, we note that the Snake Rivers groups technically did not overshoot their natal sites, but rather wandered or strayed past Priest Rapids Dam. Using passage at McNary Dam as the denominator resulted in slightly higher estimates for all groups (*Table 55*).

Rock Island, Rocky Reach, and Wells Dams – Overshoot estimates were not calculated for these non-FCRPS projects, but we note that some fish from the target populations did pass these sites.

Table 54. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Priest Rapids Dam (2005-2015). Estimates are the number of steelhead that passed Priest Dam (PRA) divided by the number that passed Bonneville Dam (BON).

	All years			Annual overshoot estimates				
Tributary (years)	BON *n*	PRA *n*	Overshoot	BON *n*	Mean	Median	Min	Max
Wind River (11)	837	-	-	27-161	-	-	-	-
Klickitat River (4)	1,221	-	-	189-426	-	-	-	-
Mill Creek (3)	52	-	-	13-23	-	-	-	-
Fifteenmile Creek (8)	362	-	-	11-93	-	-	-	-
Deschutes River (9)	853	-	-	38-180	-	-	-	-
John Day River (11)	2,356	23	1.0%	67-343	0.9%	0.9%	0.0%	2.5%
Rock Creek (4)	34	-	-	3-17	-	-	-	-
Umatilla River (11)	1,271	10	0.8%	12-321	3.5%	0.6%	0.0%	2.6%
Walla Walla River (11)	2,391	52	2.2%	33-471	2.4%	2.3%	0.0%	4.7%
Yakima River (11)	389	49	12.6%	12-92	12.4%	12.7%	5.6%	18.8%
Lyons Ferry H. (8)	458	4	0.9%	2-85	0.8%	0.0%	0.0%	2.5%
Tucannon River (11)	3,122	58	1.9%	94-681	1.7%	1.7%	0.0%	2.9%

Table 55. Natal tributary overshoot estimates for adult steelhead PIT-tagged as juveniles in tributaries downstream from Priest Rapids Dam (2005-2015). Estimates are the number of steelhead that passed Priest Rapids Dam (PRA) divided by the number that passed McNary Dam (MCN).

	All years			Annual overshoot estimates				
Tributary	MCN *n*	PRA *n*	Overshoot	MCN *n*	Mean	Median	Min	Max
Walla Walla River	1,905	52	2.7%	22-362	3.2%	2.9%	0.0%	5.9%
Yakima River	312	49	15.7%	10-72	15.3%	15.4%	6.3%	23.3%
Lyons Ferry Hatchery	368	4	1.1%	2-69	0.9%	0.0%	0.0%	3.2%
Tucannon River	2,407	58	2.4%	66-527	2.2%	2.0%	0.0%	3.8%

Tributary Overshoot: Percentages – Summary

Key findings

- Estimates of the percentage of steelhead that overshot natal tributaries varied by more than two orders of magnitude among populations and also varies by year
- Overshoot estimates were higher when natal tributary was a short distance downstream from a FCRPS dam
- Overshoot past dams >50% was detected for steelhead from Mill Cr, Fifteenmile Cr, Rock Cr, John Day R, Umatilla R, Walla Walla R, Lyons Ferry H, and Tucannon R

Critical uncertainties

- Overshoot estimates past The Dalles, Lower Monumental, and Little Goose dams were data limited
- There may be important behavioral differences among tributary sub-populations, hatchery/wild groups, and transport/in-river juvenile migration groups
- It is unknown whether natal tributary overshoot is an adaptive behavior or if mechanisms differ among populations and locations
- Fish harvest and monitoring locations influenced overshoot estimates to an unknown degree

Technical recommendations

- Additional PIT interrogation sites, at John Day Dam and in tributaries, could improve overshoot estimates
- Data on location, rate, and timing of harvest could improve overshoot estimates
- Single populations: mine existing data for causal relationships between overshoot and river environment
- Across populations: test for common mechanisms; compare overshoot past Ice Harbor vs. Priest Rapids dams

3.8.3 Tributary Overshoot: Timing

Methods – Environmental cues in either the main stem migration corridor or in natal tributaries may be associated with tributary overshoot behavior by adult steelhead. Migration timing at sites upstream and downstream from the natal tributary can therefore provide evidence for potential seasonal or environmental effects on the behavior. The upstream distributions can also provide an indication of when overshoot fish re-initiate movement in the spring. For each population with overshoot fish, we calculated first passage timing distributions at all FCRPS dams where the overshoot fish were detected. We note that monitoring started in 2013 at The Dalles Dam and in 2014 at Lower Monumental and Little Goose dams, and so timing distributions were less representative at those sites. Sample sizes for the overshoot groups are in the Section 3.8.2 tables.

Bonneville reservoir tributaries – Klickitat River overshoot fish had the earliest upstream passage timing distribution with most passing The Dalles, McNary, and Ice Harbor dams between mid-June and mid-October (*Figure 43*). Most Fifteenmile Creek steelhead that passed The Dalles and McNary dams did so in September or early October, though some also passed in August and November; the small numbers that passed Snake River dams did so mostly in October, though a few passed in winter and spring. Mill Creek and Wind River overshoot fish passed The Dalles Dam from mid-July through mid-October and passed McNary Dam mostly in late September and October (*Figure 43*). The Hood River overshoot group included both winter- and summer-run fish and therefore had a wide passage distribution at Bonneville Dam.

Tributaries between The Dalles and Ice Harbor dams – Overshoot timing for the five populations between The Dalles and Ice Harbor dams were broadly similar (*Figure 44*). Passage at McNary Dam was concentrated in August and September for the Deschutes River and John Day River overshoot groups. Umatilla River fish passed McNary Dam later, on average, with most events in September or early October. The Rock Creek overshoot fish mainly passed McNary Dam in September.

Relatively large numbers of John Day, Umatilla, and Walla Walla River steelhead also overshot Snake River dams (*Figure 44*). These three groups had slightly different timing distributions in the Snake River. Walla Walla River fish (especially hatchery fish) had relatively early timing in the Snake River, with most events in late July through early October. The John Day River group had intermediate timing, with most Snake River dam passage events in September and October. The Umatilla group was latest overall, with most events from mid-September through mid-November. The Umatilla River overshoot group also had the most upstream dam passage events in winter and spring, with some events in March and April.

Lyons Ferry and Tucannon River – Many steelhead from these populations overshot Little Goose and Lower Granite dams, and their passage timing distributions were quite similar (*Figure 45*). Median dates at Little Goose Dam were in mid-September (Lyons Ferry group) and late September (Tucannon Group). The multi-year distributions at Lower Granite Dam had median dates in mid-September for both populations, and some fish passed the dam from mid-July to early November. Differences in distributions at Little Goose and Lower Granite dams reflect, in part, the limited monitoring at Little Goose Dam and possibly differences between hatchery and wild fish.

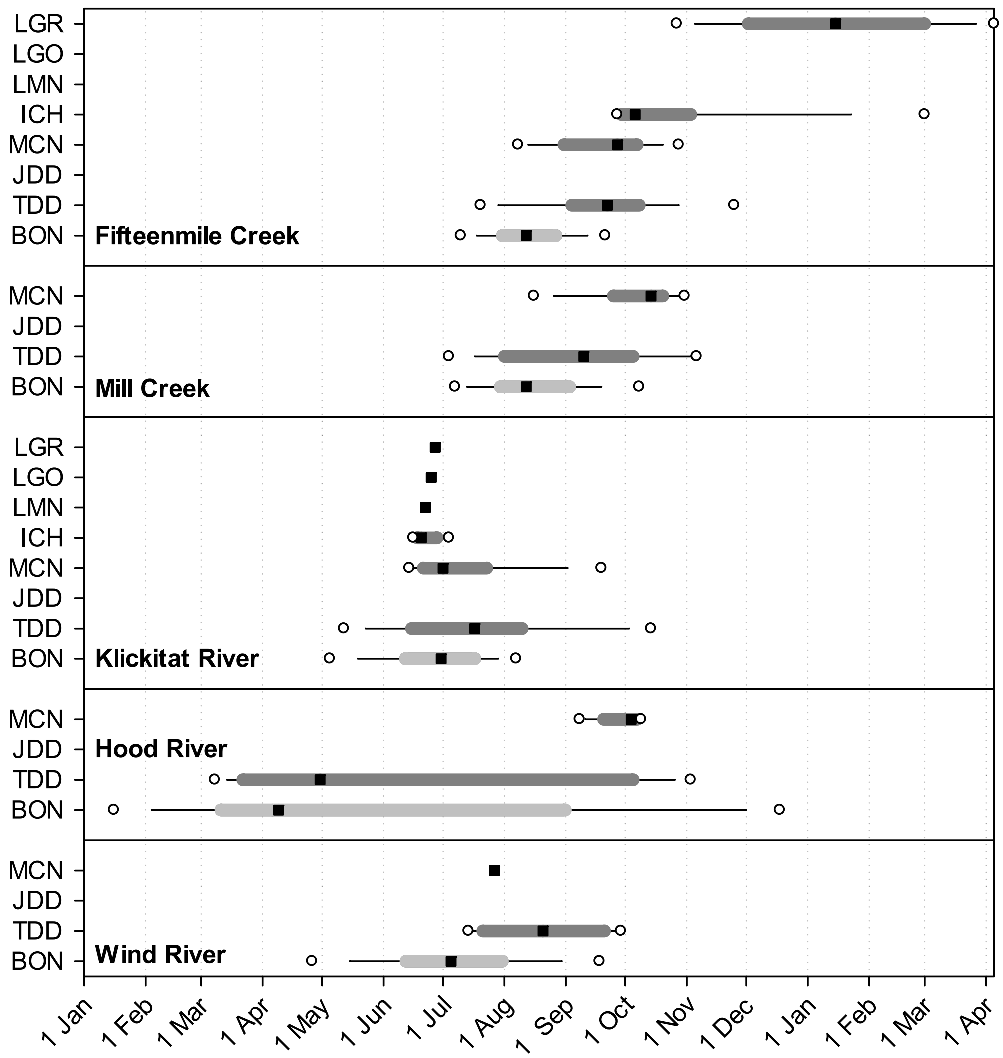


Figure 43. Migration timing for the subset of adult steelhead that overshot their natal tributary and passed upstream FCRPS dams (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR). Sample = PIT-tagged as juveniles, all Bonneville reservoir populations. Light boxes indicated downstream dams and dark boxes indicate upstream dams.

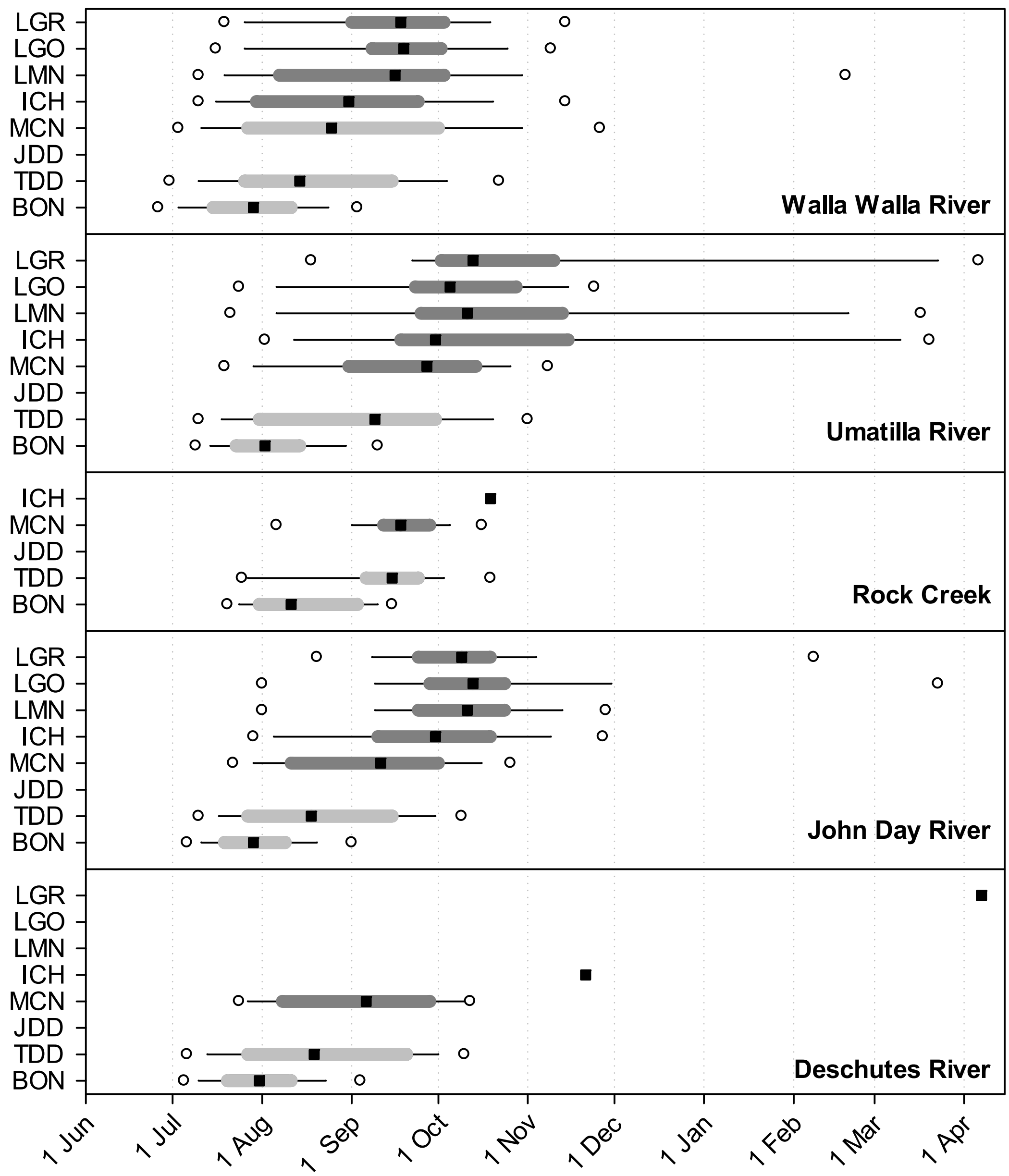


Figure 44. Migration timing for the subset of adult steelhead that overshot their natal tributary and passed upstream FCRPS dams (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR). Sample = PIT-tagged as juveniles, populations between The Dalles and Ice Harbor dams. Light boxes indicated downstream dams and dark boxes indicate upstream dams.

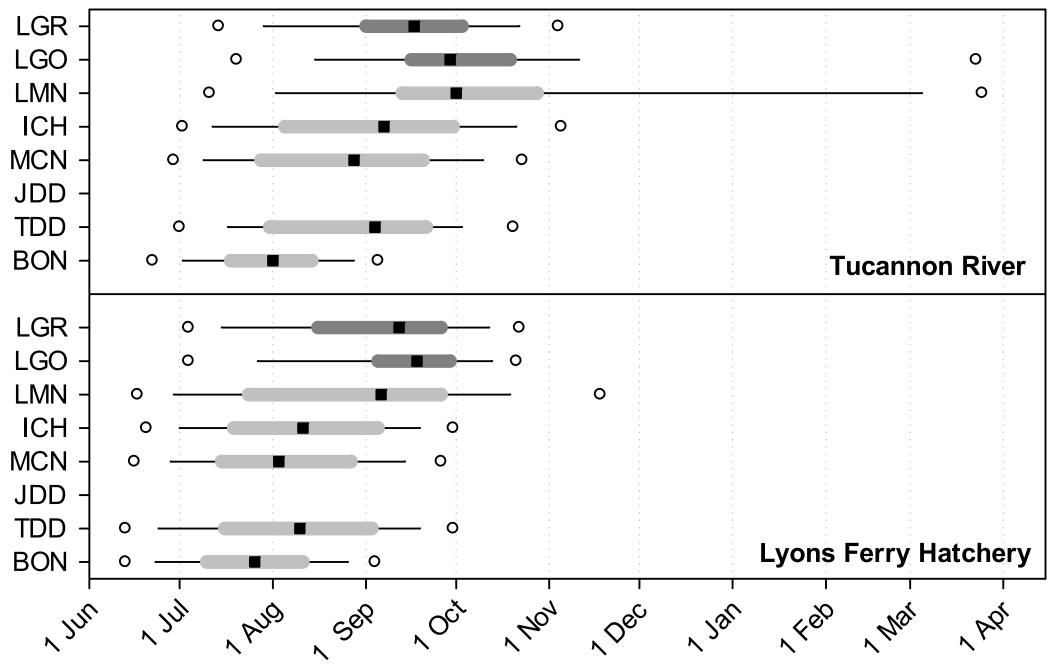


Figure 45. Migration timing for the subset of adult steelhead that overshot their natal tributary and passed upstream FCRPS dams (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Dams include Bonneville (BON), The Dalles (TDD), John Day (JDD), McNary (MCN), Ice Harbor (ICH), Lower Monumental (LMN), Little Goose (LGO) and Lower Granite (LGR). Sample = PIT-tagged as juveniles, populations between Lower Monumental and Little Goose dams. (Note: Little Goose Dam was monitored starting in 2014.) Light boxes indicated downstream dams and dark boxes indicate upstream dams.

Tributary Overshoot: Timing – Summary

Key findings

- Overshoot timing was roughly commensurate with each population's migrating timing
- A small proportion of fish from many populations overshoot in spring (March-April), likely in response to environmental (discharge, water temperature) or maturation cues

Critical uncertainties

- See list for Section 3.8.2 - Tributary Overshoot: Percentages

Technical recommendations

- Mine existing data for environmental cues associated with tributary overshoot events
- Also see list for Section 3.8.2 - Tributary Overshoot: Percentages

3.8.4 Tributary Overshoot: Estimated Fate

Methods – Assigning fates based on PIT-tag detections can be challenging for a variety of reasons, but especially for populations with limited in-stream PIT monitoring infrastructure because identifying successful homing is almost certainly underestimated. We used a combination of final PIT detections and reviews of individual fish histories to assign fates for the tributary overshoot groups. Summaries are for individual years and in aggregate in an effort to present the changes in fate assignments through time associated with increased PIT monitoring effort. Three general fate categories were designated: (1) fish that moved downstream and entered their natal tributary (i.e., they homed); (2) fish that strayed into a non-natal tributary (i.e., last detected at non-natal site); and 3) fish that were last detected at a main stem Columbia or Snake River site. A large majority of the fish in the main stem category were last detected at FCRPS dams upstream from the natal site, and small numbers were recorded at downstream dams or were reported as mortalities (i.e., in fisheries or when tags were recovered from avian colonies). It is likely that some fish last detected at main stem or non-natal sites entered natal tributaries without being detected, and we note that instream detection efficiency differs across antennas due to configuration differences and at each antenna as river conditions change. Similarly, downstream movements (out of tributaries) are likely less likely to be detected than upstream movements, potentially conflating class (2) and (3) above. Within each population, fate estimates were made for the aggregate, for hatchery and wild fish, and for early- versus late-run fish based on migration timing at Bonneville Dam. We included the 2015 dataset in these summaries and note that a small number of fish from the 2015 migration year may have homed after the final PTAGIS query in March 2016.

Bonneville reservoir tributaries – There were 30 Hood River overshoot steelhead in four study years (*Table 56*). A third of these fish were eventually detected in the Hood River, 10% were considered strays, and 57% were last detected at main stem sites. Small numbers of late-run and wild-origin confounded comparisons for these groups.

Of the 42 Klickitat River overshoot fish, equal percentages (26%) homed and strayed and the remaining 48% were last at main stem sites (*Table 57*). The group was predominantly early-run hatchery fish. There were 38 wild fish that overshot Mill Creek and this group had low homing (11%), a stray rate (26%) similar to those of the Hood and Klickitat groups, and a majority (63%) last at main stem sites (*Table 58*). Note that there was no PIT interrogation antenna in Mill Creek.

There were 90 wild overshoot steelhead from Fifteenmile Creek, including ~60% from the early run and ~40% from the late run (*Table 59*). The homing estimate was 40%, with 24% as strays and 36% last detected at main stem sites. Patterns were similar for early- and late-run groups.

Table 56. Last locations where adult Hood River steelhead were detected after passing dams upstream from the Hood River–Columbia River confluence (2005-2015). Home = in Hood River; Stray = tributary other than Hood River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2007	1	-	-	1	-	-	100.0%
2013	5	2	-	3	40.0%	-	60.0%
2014	15	5	3	7	33.3%	20.0%	46.7%
2015	9	3	-	6	33.3%	-	66.7%
Total	**30**	**10**	**3**	**17**	**33.3%**	**10.0%**	**56.7%**
Early-run	26	9	2	16	34.6%	7.7%	61.5%
Late-run	4	1	1	2	25.0%	25.0%	50.0%
Wild	7	5	-	2	71.4%	-	28.6%
Hatchery	23	5	3	15	21.7%	13.0%	65.2%

Tributary monitoring sites: HRM (2012)

Table 57. Last locations where adult Klickitat River steelhead were detected after passing dams upstream from the Klickitat River–Columbia River confluence (2005-2015). Home = in Klickitat River; Stray = tributary other than Klickitat River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2012	3	-	-	3	-	-	100.0%
2013	6	2	2	2	33.3%	33.3%	33.3%
2014	16	3	4	9	18.8%	25.0%	56.3%
2015	17	6	5	6	35.3%	29.4%	35.3%
Total	**42**	**11**	**11**	**20**	**26.2%**	**26.2%**	**47.6%**
Early-run	38	9	9	20	23.7%	23.7%	52.6%
Late-run	4	2	2		50.0%	50.0%	0.0%
Wild	1	-	-	1	-	-	100.0%
Hatchery	41	11	11	19	26.8%	26.8%	46.3%

Tributary monitoring sites: CFF (2011), LFF (2011), SUC (2014), WHC (2010)

Table 58. Last locations where adult Mill Creek steelhead were detected after passing dams upstream from the Mill Creek River–Columbia River confluence (2005-2015). Home = in Mill Creek; Stray = tributary other than Mill Creek; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2013	7	-	4	3	-	57.1%	42.9%
2014	17	-	5	12	-	29.4%	70.6%
2015	14	4	1	9	28.6%	7.1%	64.3%
Total	**38**	**4**	**10**	**24**	**10.5%**	**26.3%**	**63.2%**
Early-run	24	3	7	14	12.5%	29.2%	58.3%
Late-run	14	1	3	10	7.1%	21.4%	71.4%
Wild	38	4	10	24	10.5%	26.3%	63.2%
Hatchery	-	-	-	-	-	-	-

No tributary monitoring sites

Table 59. Last locations where adult Fifteenmile Creek steelhead were detected after passing dams upstream from the Fifteenmile River–Columbia River confluence (2005-2015). Home = in Fifteenmile Creek; Stray = tributary other than Fifteenmile Creek; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2008	2	1	-	1	50.0%	-	50.0%
2009	5	-	2	3	-	40.0%	60.0%
2010	7	2	1	4	28.6%	14.3%	57.1%
2011	3	-	1	2	-	33.3%	66.7%
2012	6	2	1	3	33.3%	16.7%	50.0%
2013	22	14	2	6	63.6%	9.1%	27.3%
2014	26	15	9	2	57.7%	34.6%	7.7%
2015	19	2	6	11	10.5%	31.6%	57.9%
Total	**90**	**36**	**22**	**32**	**40.0%**	**24.4%**	**35.6%**
Early-run	55	19	13	23	34.5%	23.6%	41.8%
Late-run	35	17	9	9	48.6%	25.7%	25.7%
Wild	90	36	22	32	40.0%	24.4%	35.6%
Hatchery	-	-	-	-	-	-	-

Tributary monitoring sites: 158 (2011), 15R (2011), 15D (2012), 85M (2011)

Tributaries between The Dalles and Ice Harbor dams – Just six fish were in the Deschutes overshoot group: 17% homed, 50% strayed, and 33% were last at a main stem site (*Table 60*).

More than 1,200 John Day River steelhead overshot McNary Dam (*Table 61*). This group was entirely of presumed wild, though 27 fish were designated ‘unknown origin’ in PTAGIS; about 77% were from the early-run group. In total, 34% of the John Day River fish homed, with annual estimates that ranged from 1-65%. The aggregate stray rate estimate was 6% (annual range ~3-10%), and the aggregate main stem estimate was 61% (range 32-92%).

There were 18 wild Rock Creek overshoot fish, most of which were late-run (*Table 62*). Two-thirds eventually homed and the remaining one-third was last at a main stem site.

The 516 overshoot fish from the Umatilla River were mostly (76%) early-run and wild (63%) (*Table 63*). In total, 36% (range ~7-79%) of the Umatilla River fish eventually homed, 4% (range 0-33%) strayed, and 60% (14-89%) were last at main stem sites.

Almost 1,300 Walla Walla River steelhead overshot Ice Harbor or Priest Rapids dams (*Table 64*). This group was predominantly hatchery (81%) and from the early-run (83%). In total, just 14% (annual range ~6-26%) of the Walla Walla River fish homed. The aggregate stray rate estimate was 21% (range ~5-53%) and the aggregate main stem estimate was 66% (range 40-82%). Aggregate estimates were very similar for early- versus late-run fish, but hatchery fish homed at lower rates (10%) than wild fish (34%).

Table 60. Last locations where adult Deschutes River steelhead were detected after passing dams upstream from the Deschutes River –Columbia River confluence (2005-2015). Home = in Deschutes River; Stray = tributary other than Deschutes River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2009	2	-	1	1	-	50.0%	50.0%
2010	1	-	1	-	-	100.0%	-
2011	1	1	-	-	100.0%	-	-
2013	1	-	1	-	-	100.0%	-
2015	1	-	-	1	-	-	100.0%
Total	**6**	**1**	**3**	**2**	**16.7%**	**50.0%**	**33.3%**
						-	-
Early-run	6	1	3	2	16.7%	50.0%	33.3%
Late-run	-	-	-	-	-	-	-
Wild	6	1	3	2	16.7%	50.0%	33.3%
Hatchery	-	-	-	-	-	-	-

Tributary monitoring sites: DBH (2012), DBO (2012), DRM (2013), SHK (2014), TR1 (2012), TR2 (2013), WSH (2008), WSR (2014)

Table 61. Last locations where adult John Day River steelhead were detected after passing dams upstream from the John Day River–Columbia River confluence (2005-2015). Home = in John Day River; Stray = tributary other than John Day River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2005	38	1	2	35	2.6%	5.3%	92.1%
2006	65	-	6	59	-	9.2%	90.8%
2007	67	24	-	-	35.8%	-	64.2%
2008	112	33	11	68	29.5%	9.8%	60.7%
2009	210	78	14	118	37.1%	6.7%	56.2%
2010	144	36	8	100	25.0%	5.6%	69.4%
2011	104	1	4	99	1.0%	3.8%	95.2%
2012	78	38	3	37	48.7%	3.8%	47.4%
2013	157	92	12	53	58.6%	7.6%	33.8%
2014	141	92	4	45	65.2%	2.8%	31.9%
2015	155	33	7	115	21.3%	4.5%	74.2%
Total	**1271**	**428**	**71**	**772**	**33.7%**	**5.6%**	**60.7%**
Early-run	986	330	54	602	33.5%	5.5%	61.1%
Late-run	285	98	17	170	34.4%	6.0%	59.6%
Wild	1244	418	71	755	33.6%	5.7%	60.7%
Hatchery	-	-	-	-	-	-	-
Unk	27	10	-	17	37.0%	-	63.0%

Tributary monitoring sites: JD1 (2007), BR0 (2012), BR1 (2012), BR2 (2012), BR3 (2012), MJ1 (2013), JDM (2015), SJ1 (2012), SJ2 (2012)

Table 62. Last locations where adult Rock Creek steelhead were detected after passing dams upstream from the Rock Creek – Columbia River confluence (2005-2015). Home = in Rock Creek; Stray = tributary other than Rock Creek; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2011	1	1	-	-	100.0%	-	0.0%
2013	4	2	-	2	50.0%	-	50.0%
2014	6	5	-	1	83.3%	-	16.7%
2015	7	4	-	3	57.1%	-	42.9%
Total	**18**	**12**	**-**	**6**	**66.7%**	**-**	**33.3%**
Early-run	7	5	-	2	71.4%	-	28.6%
Late-run	11	7	-	4	63.6%	-	36.4%
Wild	18	12	-	6	66.7%	-	33.3%
Hatchery	-	-	-	-	-	-	-

Tributary monitoring sites: RCL (2009), RCS (2009)

Table 63. Last locations where adult Umatilla River steelhead were detected after passing dams upstream from the Umatilla River –Columbia River confluence (2005-2015). Home = in Umatilla River; Stray = tributary other than Umatilla River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2005	6	-	2	4	-	33.3%	66.7%
2006	7	3	-	4	42.9%	-	57.1%
2007	33	7	2	24	21.2%	6.1%	72.7%
2008	42	19	2	21	45.2%	4.8%	50.0%
2009	46	14	1	31	30.4%	2.2%	67.4%
2010	27	2	1	24	7.4%	3.7%	88.9%
2011	51	11	-	40	21.6%	-	78.4%
2012	36	21	-	15	58.3%	-	41.7%
2013	29	23	2	4	79.3%	6.9%	13.8%
2014	78	46	6	26	59.0%	7.7%	33.3%
2015	161	41	6	114	25.5%	3.7%	70.8%
Total	**516**	**187**	**22**	**307**	**36.2%**	**4.3%**	**59.5%**
Early-run	393	137	18	238	34.9%	4.6%	60.6%
Late-run	123	50	4	69	40.7%	3.3%	56.1%
			-				
Wild	324	141	17	166	43.5%	5.2%	51.2%
Hatchery	192	46	5	141	24.0%	2.6%	73.4%

Tributary monitoring sites: FDC (2006), FDD (2008), MWC (2007), TMA (2002), TMF (2006), TMJ (1999), UM1 (2004), UM2 (2007)

Table 64. Last locations where adult Walla Walla River steelhead were detected after passing dams upstream from the Walla Walla River –Columbia River confluence (2005-2015). Home = in Walla Walla River; Stray = tributary other than Walla Walla River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2005	17	-	9	8	-	52.9%	47.1%
2006	17	1	8	8	5.9%	47.1%	47.1%
2007	16	2	5	9	12.5%	31.3%	56.3%
2008	189	14	17	158	7.4%	9.0%	83.6%
2009	266	33	90	143	12.4%	33.8%	53.8%
2010	173	23	14	136	13.3%	8.1%	78.6%
2011	205	32	59	114	15.6%	28.8%	55.6%
2012	86	22	30	34	25.6%	34.9%	39.5%
2013	78	18	6	54	23.1%	7.7%	69.2%
2014	134	22	18	94	16.4%	13.4%	70.1%
2015	94	12	5	77	12.8%	5.3%	81.9%
Total	**1275**	**179**	**261**	**835**	**14.0%**	**20.5%**	**65.5%**
Early-run	1039	141	210	688	13.6%	20.2%	66.2%
Late-run	236	38	51	147	16.1%	21.6%	62.3%
Wild	216	73	47	96	33.8%	21.8%	44.4%
Hatchery	1059	106	214	739	10.0%	20.2%	69.8%

Tributary monitoring sites: BBT (2011), BGM (2007), KCB (2005), LWD (2007), MDR (2012), NFW (2012), ORB (2005), PRV (2012), WW1 (2002), WW2 (2002), YHC (2006), MCD (2005), MCI (2011), MTD (2015)

Lyons Ferry and Tucannon River – There were 179 overshoot steelhead from Lyons Ferry Hatchery, ~72% of which were from the early run (*Table 65*). In total, just 3% of the Lyons Ferry fish homed but collection was limited to broodstock needs and monitoring effort was intermittent at this site (WDFW, *unpublished*). The aggregate stray rate was 10%, with annual estimates that ranged from 4-29%. Most fish were last detected in the main stem, with an aggregate estimate of 87% (range 75-100%).

The Tucannon River had the largest overshoot group (*n* =1,452) and among the better instream monitoring arrays (*Table 66*). The overshoot group was primarily hatchery fish (84%) and from the early run (76%). The aggregate homing estimate was 21% (range = 9-53%). The aggregate stray rate was 11% (range ~0-27%). The majority in almost all years was last detected at main stem sites (aggregate = 68%, range =31-93%). Within the classes, late-run fish strayed at slightly higher rates (16%) than early-run fish (10%), hatchery fish homed at slightly higher rates (22%) than wild fish (17%), and hatchery fish strayed at slightly lower rates (9%) than wild fish (23%).

Table 65. Last locations where adult Lyons Ferry Hatchery steelhead were detected after passing dams upstream from the Lyons Ferry Hatchery–Snake River confluence (2005-2015). Home = Lyons Ferry Hatchery; Stray = tributary other than Lyons Ferry Hatchery; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2009	25	3	3	19	12.0%	12.0%	76.0%
2010	20	-	2	18	-	10.0%	90.0%
2011	17	-	5	12	-	29.4%	70.6%
2012	16	2	2	12	12.5%	12.5%	75.0%
2013	25	-	1	24	-	4.0%	96.0%
2014	46	-	5	41	-	10.9%	89.1%
2015	30	-	-	30	-	-	100.0%
Total	**179**	**5**	**18**	**156**	**2.8%**	**10.1%**	**87.2%**
							-
Early-run	129	5	15	109	3.9%	11.6%	84.5%
Late-run	50	-	3	47	-	6.0%	94.0%
Wild	-	-	-	-	-		-
Hatchery	179	5	18	156	2.8%	10.1%	87.2%

Table 66. Last locations where adult Tucannon River steelhead were detected after passing dams upstream from the Tucannon River–Snake River confluence (2005-2015). Home = in Tucannon River; Stray = tributary other than Tucannon River; Main stem = Columbia or Snake River dam. Sample = PIT-tagged as juveniles.

		Last detection (*n*)			Last detection (%)		
Year	Total n	Home	Stray	Main stem	Home	Stray	Main stem
2005	40	8	-	32	20.0%	-	80.0%
2006	49	5	2	42	10.2%	4.1%	85.7%
2007	264	57	4	203	21.6%	1.5%	76.9%
2008	182	16	13	153	8.8%	7.1%	84.1%
2009	332	68	60	204	20.5%	18.1%	61.4%
2010	160	32	17	111	20.0%	10.6%	69.4%
2011	87	26	14	47	29.9%	16.1%	54.0%
2012	56	19	15	22	33.9%	26.8%	39.3%
2013	70	37	11	22	52.9%	15.7%	31.4%
2014	109	35	25	49	32.1%	22.9%	45.0%
2015	103	6	1	96	5.8%	1.0%	93.2%
Total	**1452**	**309**	**162**	**981**	**21.3%**	**11.2%**	**67.6%**
Early-run	1098	234	104	760	21.3%	9.5%	69.2%
Late-run	354	75	58	221	21.2%	16.4%	62.4%
Wild	237	40	55	142	16.9%	23.2%	59.9%
Hatchery	1215	269	107	839	22.1%	8.8%	69.1%

Tributary monitoring sites: LTR (2005), MTR (2011), TFH (2012), UTR (2011)

Tributary Overshoot: Estimated Fate – Summary

Key Findings
- Overall, a minority of overshoot fish successfully homed to their natal stream
- Average annual homing of overshoot steelhead varied greatly by population and year
- In general, wild fish were more likely than hatchery fish to home and less likely to stray after overshoot
- In most but not all cases, early- and late-run overshoot steelhead were similarly likely to home and stray

Critical uncertainties
- True fates of fish that do not reach natal tributaries are generally unknown
- A lack of PIT interrogation sites in tributaries results in unknown bias(es) in homing estimates
- Apparent straying (i.e., last detection in non-natal tributary) may simply reflect limited PIT monitoring

Technical recommendations
- Terminology associated with tributary overshoot and post-overshoot outcomes should be standardized
- Future evaluations should attempt to adjust for variation in detection efficiencies within and among sites
- Also see list for Section 3.7.5 - FCRPS Overwintering: Estimated Fate

3.9 FALLBACK INDICES USING PIT-TAG DETECTIONS

3.9.1 Methods

The confidence level associated with identifying FCRPS fallback events using PIT-tag detection histories varied widely among fallback event types. The highest confidence was for fish that fell back through JBS and the Powerhouse 2 Corner Collector (BCC) at Bonneville Dam because PIT detection probabilities at these sites were high. JBS and BCC fallback events are also date- and time-stamped, unlike many other fallback event types. Many additional fallback events can be inferred from PIT-tag detections at FCRPS dams or other PIT-tag interrogation sites that were downstream from a dam that a steelhead passed. These ‘downstream detection’ types of events generally have low temporal resolution and potential non-detection issues, and are thus best considered an index of the behavior rather than true estimates. The last type of fallback events inferred from PIT detection histories involve ‘repeat detections’ inside fishways at an individual FCRPS dam. For example, a fish detected at a FCRPS adult fishway PIT-tag antenna and then redetected at either the same location on another day or at another fishway at the same dam (i.e., for dams with two fish ladders) can be flagged as a potential fallback fish. Some detection histories also suggest that fish may have exited a fishway into the forebay and then re-entered the top of a ladder and moved down the fishway. Both types of repeat detections present interpretation challenges and researchers have used a variety of methods (i.e., minimum detection time gaps, specific antenna detection sequences) to infer fallback based on PIT tag detections (Burke and Jepson 2006; Crozier et al. 2016).

In the present study, to identify possible fallback events in the downstream detection and repeat detection categories, we constructed an antenna-group level detection history of each fish based on: (1) interrogation site (fishway, JBS, or arrays located in tributary streams); (2) the specific antenna location or number at each site; and (3) the date/time stamp of each detection. More specifically, antennas in each fishway were ranked by their sequential order and information was used to estimate the directionality of each fish’s movement within the fishway. Fishway ascents were identified by the initial interrogation of a fish at a lower fishway antenna, the reappearance of a fish at one of the lower fishway antennas following a fishway passage exit, or by the subsequent increase in antenna rank immediately following multiple decreases in antenna rank. Descents were identified by the continuous downward trend in antenna rank, whereby antenna rank decreased multiple times without increase and the total decrease in rank was at least 3. In many cases the ascending pattern of detections in a given fishway was enough to presume a fish successfully exited the fishway. Dams with fewer arrays necessitated the use of upstream detections and fallback through the JBS to further confirm a fishway passage exit. Fallbacks via routes other than the JBS were identified by a fish's subsequent re-ascension of the fishway or by subsequent downstream detections following a posited fishway passage exit without detection at the JBS in the interim. The fallback assignments based on these antenna criteria were generated using algorithm scripts in R 3.1.3 (R Core Team 2015). Descriptive statistics of fallbacks events were then calculated to quantify proportions of fallbacks by dam, route and year.

Some fallback fish succumb to harvest, migrate into downstream tributaries lacking PIT arrays, or are otherwise not detected again. As such, the R algorithms likely underestimated the total number of fallback events at each dam in each year. PIT detection efficiency < 1.0 could also result in underestimates of the total number of fallbacks, although detection efficiencies at fishways and JBSs were generally high (> 0.98; Tenney et al. 2010). There were also risks of overestimation when repeat detections merely reflected fish movement within a fishway (i.e., no actual dam passage or fallback). Taken together, the designation of fallback events based on PIT tag detections presented herein is likely less accurate than designations based on radio- or acoustic-tag detections.

3.9.2 Fallback: JBS Rates and Timing

In a first series of summaries, we identified all adult steelhead that were detected at JBS antennas and at the Bonneville Corner Collector (BCC) (*Table 67*) and then linked the events to specific populations. We calculated fallback rates for each site × population combination as the number of fallback events divided by the total number of adult steelhead in the population. This was a very conservative estimate, as many fish never encountered some of the JBS sites, especially those at upstream dams. However, the metric does provide a good relative measure of JBS fallback rates and an indication of which populations fall back at each site. We also calculated timing distributions for fallback events that occurred in Year 1 (presumed pre-spawn fish) and Year 2 (a mix of overwintering pre-spawn adults and post-spawn kelts) because these behaviors have different management implications.

Table 67. Total and annual numbers of adult steelhead detected on JBS antennas (2005-2015). Events were separated by year of detection: Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles.

JBS site	Total events	Annual mean	Years (*n*)	Range	Year 1 events	Year 2 events	Events in Year 1 (%)
Bonneville (B2J)	269	30	9	6–62	184	85	68%
Bonneville (BCC)	1003	100	10	6-211	309	694	30%
John Day (JDJ)	571	57	10	24-126	389	182	68%
McNary (MCJ)	681	68	10	38-167	479	202	70%
Ice Harbor[1]	-	-	-	-	-	-	-
L. Monumental (LMJ)	347	35	10	2-67	161	186	46%
Little Goose (GOJ)	679	70	10	4-132	300	379	44%
Lower Granite (GRJ)	617	62	10	11-115	384	233	62%

[1] Adult fishway and JBS detections were combined at Ice Harbor in PTAGIS

Bonneville Dam – Two bypass sites were monitored at Bonneville Dam: the Powerhouse 2 JBS (B2J) in all years and the BCC starting in 2006. Across years, 269 fallback events were recorded at B2J, and 68% of these events were in Year 1 (i.e., by presumed pre-spawn steelhead) (*Table 67*). Another 1,003 events were at the BCC, and just 30% of these events were in Year 1, suggesting the BCC was used by many kelts.

Individual steelhead from at least 23 study populations were detected at the B2J site across study years (*Table 68*). The estimated fallback rates at B2J were <1% for all but two populations: the Wind River (2.4%) and Umatilla River (2.7%). In almost all populations, more fish fell back through B2J in Year 1 than in Year 2. The only exception was the Wind River group, of which 75% fell back in Year 2, including many likely kelts. Across populations, most of the Year 2 events occurred between mid-February and May, suggesting a mix of pre-spawn adults and kelts (*Figure 46*). The Year 1 events were distributed from May through December, with no distinctive patterns.

Some steelhead from almost all study populations were detected at the BCC site across study years (*Table 69*). The estimated fallback rate at BCC was <3% for most populations. Six groups had >3% rates through the BCC, including three Bonneville reservoir populations: Wind River (9.1%), Hood River (3.3%), and Fifteenmile Creek (3.0%), as did three Snake River populations: Potlatch River (3.1%), Lemhi River (3.3%), and South Fork Salmon River (4.1%). In most populations, more fish fell back through BCC in Year 2 than in Year 1, which was the opposite of results at B2J.

Most of the Year 2 events at BCC were presumably by kelts, and the timing of these events appeared to vary – in part – as a result of the distance between spawning areas and Bonneville Dam (*Table 69*). For example, almost all of the Year 2 events by steelhead from lower Columbia River populations occurred before 1 June and the median dates for these groups were mostly between April and mid-May. In contrast, most of the median Year 2 BCC fallback dates for Snake River and upper Columbia steelhead were in May and June. Fallback timing distributions for the Year 1 events were considerably more variable with median dates in May (Hood River fish), June (Wind, Klickitat, Wenatchee), July (several lower Columbia and lower Snake groups), August (several Snake and upper Columbia groups), and even September (Pahsimeroi River).

John Day Dam (JDJ) – Across years, 571 fallback events were recorded at JDJ, and 68% of these events were in Year 1 (i.e., by presumed pre-spawn steelhead) (*Table 67*). Almost all of the populations upstream from John Day Dam had some steelhead fall back through the JDJ, and fallback rates were <2% for most populations (*Table 70*). Three groups had higher fallback rates: John Day River (2.1%), Middle Fork Salmon River (2.9%), and the group tagged at Ice Harbor Dam (4.0%).

The timing of most Year 2 fallback events at JDJ was concentrated in April and May, with some events in June by fish from several populations (*Figure 48*). Unlike at the BCC, there was not much evidence of a timing × distance relationship at JDJ, except that steelhead from the Okanogan, Methow, and Wenatchee fell back relatively later than fish from most other groups. Year 1 fallback events occurred from July through November and distributions varied considerably among populations. Upper Columbia steelhead (Okanogan, Methow, Wenatchee, Ringold Hatchery) mostly fell back through JDJ in July and August, corresponding with their relatively early upstream migration timing. Year 1 fallback events for most Snake River populations and John Day River steelhead were more widely distributed in time, ranging from late July through late November.

Table 68. Population-specific estimates of minimum fallback rates through the B2J at Bonneville Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58					
Wind R.	849	20	2.4	5	15	25.0
Hood R.	2124	24	1.1	18	6	75.0
Klickitat R.	1221	5	0.4	4	1	80.0
Mill Cr.	52					
Fifteenmile Cr.	366	3	0.8	0	3	-
Deschutes R	855	4	0.5	2	2	50.0
John Day Dam	500					
John Day R.	2889	11	0.4	11	0	100.0
Rock Cr.	34					
Umatilla R.	1270	34	2.7	33	1	97.1
McNary Dam	151					
Walla Walla R.	2392					
Snake River						
Ice Harbor Dam	25					
L. Monumental Dam	434					
Lyons Ferry	458					
Tucannon R.	3122	3	0.1	0	3	-
Little Goose Dam	41					
Lower Granite Dam	14731	82	0.6	59	23	72.0
CWR : Other	1550	5	0.3	2	3	40.0
CWR : Middle Fork	298					
CWR : Lochsa R.	839					
CWR : Potlatch R.	326	1	0.3	0	1	-
CWR : Selway R.	14					
CWR : South Fork	1740	1	0.1	0	1	-
Snake R.>GR	1484	2	0.1	2		100.0
Asotin Cr.	430	1	0.2	0	1	-
Grande Ronde R.	5361	8	0.1	6	2	75.0
Salmon : Other	4340	17	0.4	9	8	52.9
Salmon : East Fork	578					
Salmon : Lemhi R.	239	1	0.4	0	1	-
Salmon : Little Salmon R.	1856	1	0.1	0	1	-
Salmon : Middle Fork	242					
Salmon : Pahsimeroi R.	1697					
Salmon R.: South Fork	271					
Imnaha R.	4094	11	0.3	6	5	54.5
Columbia River above Snake						
Yakima R.	392	2	0.5	0	2	-
Ringold Hatchery	5715	2	0.0	1	1	50.0
Wanapum Dam	145					
Rock Island Dam	433					
Wenatchee R.	4497	4	0.1	4	0	100.0
Rocky Reach Dam	92					
Entiat R.	409					
Wells Dam	881					
Methow R.	7419	19	0.3	17	2	89.5
Okanogan R.	1566					

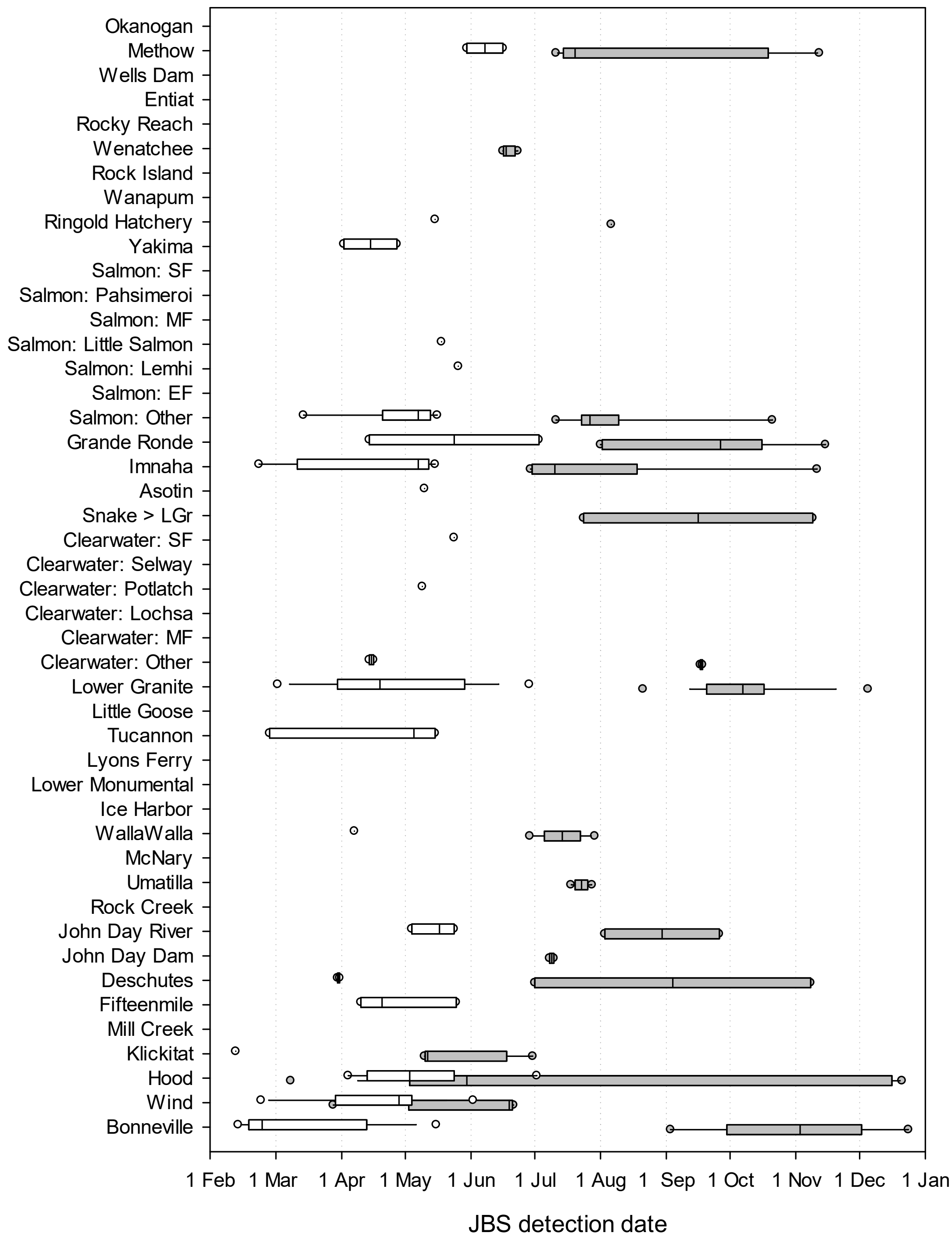


Figure 46. Population-specific timing of adult steelhead fallback detections at B2J at Bonneville Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 68 has sample sizes.

Table 69. Population-specific estimates of minimum fallback rates through the BCC at Bonneville Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58					
Wind R.	849	77	9.1	19	58	24.7
Hood R.	2124	70	3.3	54	16	77.1
Klickitat R.	1221	27	2.2	20	7	74.1
Mill Cr.	52	1	1.9	0	1	-
Fifteenmile Cr.	366	11	3.0	1	10	9.1
Deschutes R	855	12	1.4	4	8	33.3
John Day Dam	500	7	1.4	3	4	42.9
John Day R.	2889	65	2.2	14	51	21.5
Rock Cr.	34	1	2.9	0	1	-
Umatilla R.	1270	13	1.0	2	11	15.4
McNary Dam	151					
Walla Walla R.	2392	42	1.8	9	33	21.4
Snake River						
Ice Harbor Dam	25					
L. Monumental Dam	434	3	0.7	2	1	66.7
Lyons Ferry	458	2	0.4	2	0	100.0
Tucannon R.	3122	29	0.9	10	19	34.5
Little Goose Dam	41					
Lower Granite Dam	14731	220	1.5	51	169	23.2
CWR : Other	1550	4	0.3	3	1	75.0
CWR : Middle Fork	298	4	1.3	1	3	25.0
CWR : Lochsa R.	839	9	1.1	0	9	-
CWR : Potlatch R.	326	10	3.1	0	10	-
CWR : Selway R.	14					
CWR : South Fork	1740	8	0.5	3	5	37.5
Snake R.>GR	1484	11	0.7	6	5	54.5
Asotin Cr.	430	7	1.6	2	5	28.6
Grande Ronde R.	5361	30	0.6	16	14	53.3
Salmon.: Other	4340	68	1.6	18	50	26.5
Salmon : East Fork	578	13	2.2	1	12	7.7
Salmon : Lemhi R.	239	8	3.3	1	7	12.5
Salmon : Little Salmon R.	1856	11	0.6	4	7	36.4
Salmon : Middle Fork	242	10	4.1	0	10	-
Salmon : Pahsimeroi R.	1697	7	0.4	2	5	28.6
Salmon : South Fork	271	11	4.1	0	11	-
Imnaha R.	4094	47	1.1	17	30	36.2
Columbia River above Snake						
Yakima R.	392	3	0.8	1	2	33.3
Ringold Hatchery	5715	11	0.2	5	6	45.5
Wanapum Dam	145					
Rock Island Dam	433	11	2.5	2	9	18.2
Wenatchee R.	4497	54	1.2	24	30	44.4
Rocky Reach Dam	92	2	2.2	1	1	50.0
Entiat R.	409	9	2.2	1	8	11.1
Wells Dam	881	2	0.2	0	2	-
Methow R.	7419	65	0.9	7	58	10.8
Okanogan R.	1566	7	0.4	3	4	42.9

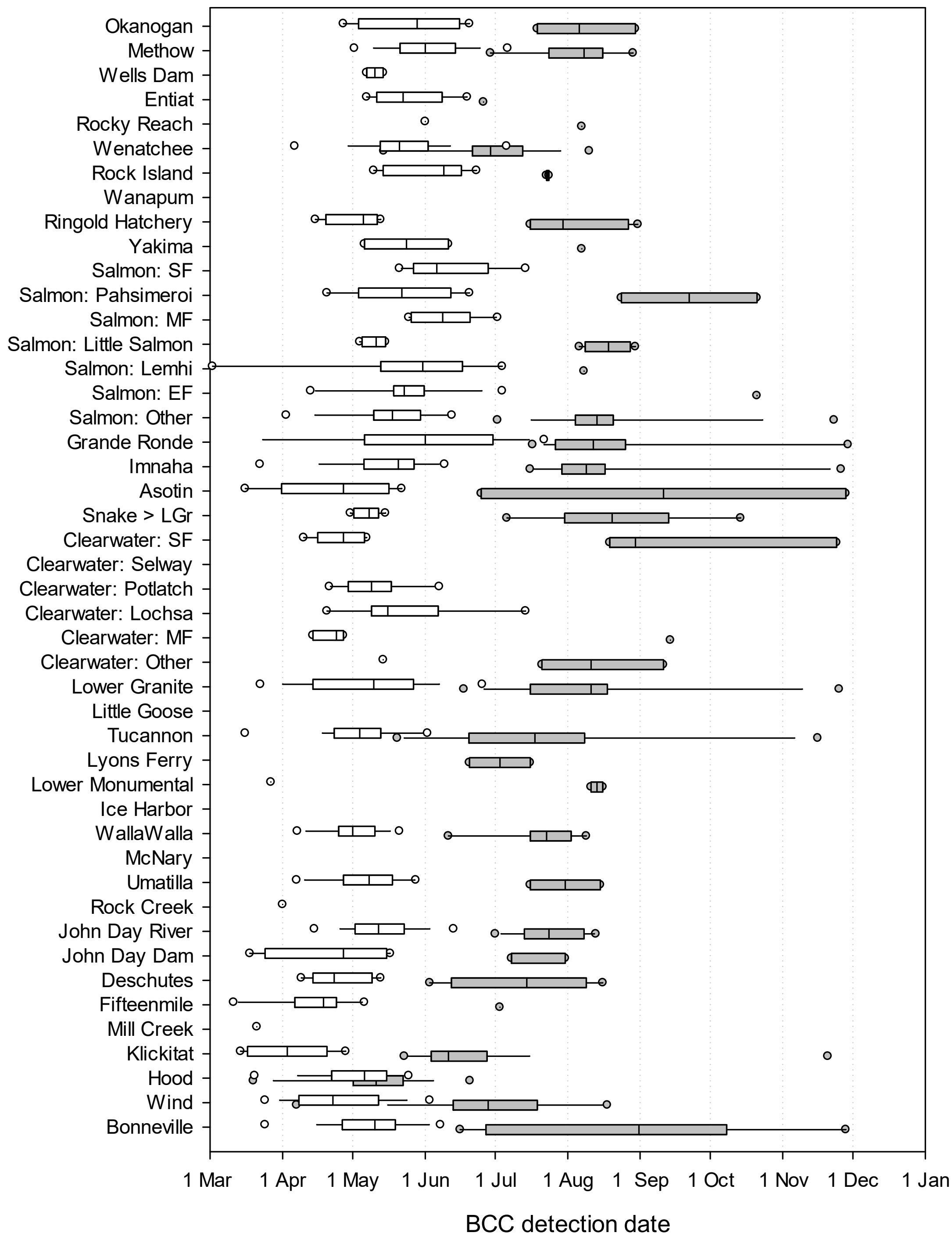


Figure 47. Population-specific timing of adult steelhead fallback detections at BCC at Bonneville Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 69 has sample sizes.

Table 70. Population-specific estimates of minimum fallback rates through the JDJ at John Day Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58	1	1.7	1	0	100.0
Wind R.	849					
Hood R.	2124					
Klickitat R.	1221					
Mill Cr.	52	1	1.9	1	0	100.0
Fifteenmile Cr.	366	6	1.6	5	1	83.3
Deschutes R	855					
John Day Dam	500	6	1.2	3	3	50.0
John Day R.	2889	60	2.1	25	35	41.7
Rock Cr.	34	3	8.8	1	2	33.3
Umatilla R.	1270	12	0.9	4	8	33.3
McNary Dam	151					
Walla Walla R.	2392	18	0.8	8	10	44.4
Snake River						
Ice Harbor Dam	25	1	4.0	1	0	100.0
L. Monumental Dam	434	4	0.9	4	0	100.0
Lyons Ferry	458	3	0.7	2	1	66.7
Tucannon R.	3122	28	0.9	20	8	71.4
Little Goose Dam	41					
Lower Granite Dam	14731	138	0.9	101	37	73.2
CWR : Other	1550	8	0.5	4	4	50.0
CWR : Middle Fork	298	2	0.7	1	1	50.0
CWR : Lochsa R.	839	7	0.8	3	4	42.9
CWR : Potlatch R.	326	2	0.6	1	1	50.0
CWR : Selway R.	14					
CWR : South Fork	1740	4	0.2	4	0	100.0
Snake R.>GR	1484	1	0.1	1	0	100.0
Asotin Cr.	430	2	0.5	1	1	50.0
Grande Ronde R.	5361	19	0.4	16	3	84.2
Salmon : Other	4340	35	0.8	27	8	77.1
Salmon : East Fork	578	7	1.2	6	1	85.7
Salmon : Lemhi R.	239	4	1.7	2	2	50.0
Salmon : Little Salmon R.	1856	12	0.6	9	3	75.0
Salmon : Middle Fork	242	7	2.9	4	3	57.1
Salmon : Pahsimeroi R.	1697	11	0.6	9	2	81.8
Salmon : South Fork	271	2	0.7	1	1	50.0
Imnaha R.	4094	38	0.9	24	14	63.2
Columbia River above Snake						
Yakima R.	392	1	0.3	1	0	100.0
Ringold Hatchery	5715	34	0.6	24	10	70.6
Wanapum Dam	145					
Rock Island Dam	433	5	1.2	4	1	80.0
Wenatchee R.	4497	25	0.6	21	4	84.0
Rocky Reach Dam	92					
Entiat R.	409	1	0.2	1	0	100.0
Wells Dam	881	8	0.9	7	1	87.5
Methow R.	7419	43	0.6	32	11	74.4
Okanogan R.	1566	12	0.8	10	2	83.3

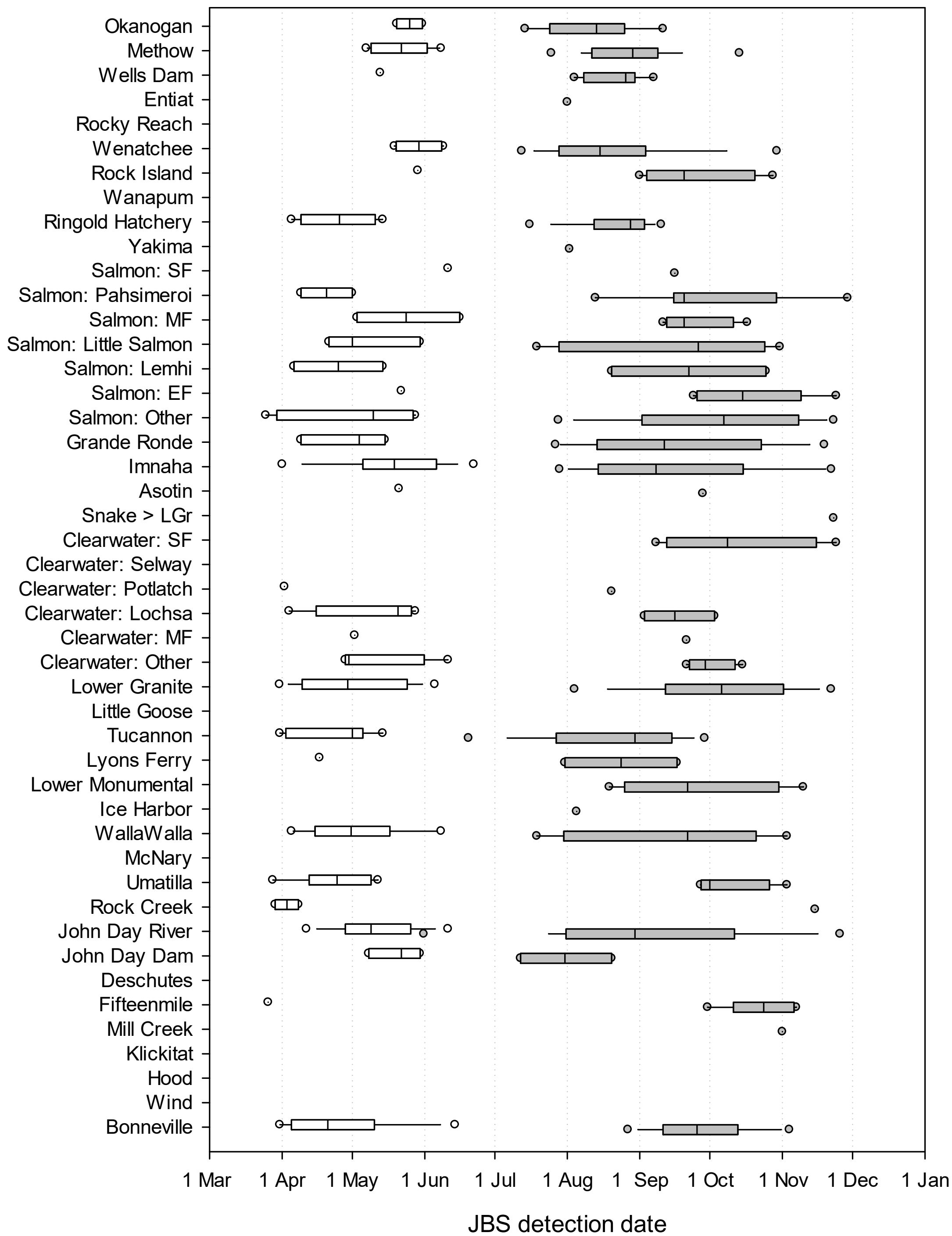


Figure 48. Population-specific timing of adult steelhead fallback detections at JDJ at John Day Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 70 has sample sizes.

McNary Dam (MCJ) – Across years, 680 fallback events were recorded at MCJ, and 70% of these events were in Year 1 (i.e., by presumed pre-spawn steelhead) (*Table 67*). Most of the populations upstream from McNary Dam, as well as many downstream populations, had some steelhead fall back through MCJ (*Table 71*). The estimated fallback rates were ≤1% for most populations. Several groups had higher fallback rates: John Day River (3.8%, located downstream), Mill Creek (1.9%, downstream), Selway River (7.1%, *n* = 1 fallback), Walla Walla River (1.5%), Tucannon River (1.3%), and Lower Granite Dam (1.4%).

As at JDJ, the timing of most Year 2 fallback events at MCJ were concentrated in April and May, with some events in June by fish from several populations (*Figure 49*). Also similar to the pattern at JDJ, steelhead from several upper Columbia River populations fell back relatively later than fish from most other groups. Some of the earliest Year 2 fallback events were by John Day and Umatilla River fish, suggesting that these fish may have been migrating towards natal sites.

Year 1 fallback events occurred from July through November and distributions varied considerably among populations. Upper Columbia steelhead (Methow, Wenatchee) were relatively early-timed, corresponding with their relatively early upstream migration timing. Year 1 fallback events for most Snake River populations and steelhead that overshot lower Columbia River tributaries were mostly in September and October (*Figure 49*).

Ice Harbor Dam (ICH) – The detection history data tables were used for these summaries and we note that PTAGIS combined adult fishway and JBS detection data at Ice Harbor Dam for this query type. Ice Harbor Dam was therefore not included in this JBS metric for consistency. However, the antenna-group level queries did identify JBS fallback events at Ice Harbor (see Section 3.9.3).

Lower Monumental Dam (LMJ) – Across years, 347 fallback events were recorded at LMJ, and there was a relatively even mix of Year 1 (46%) and Year 2 (54%) events (*Table 67*). Steelhead from eight populations downstream from Lower Monumental Dam and from 17 upstream Snake River populations fell back through LMJ (*Table 72*). Fallback rates were <1% for almost all groups, except for steelhead from the Walla Walla River (2.5%, downstream), the Lemhi River (2.1%), and the Tucannon River (1.4%).

On median, fallback timing for Year 2 fallback events was relatively early for overshoot populations and relatively later for upstream populations (*Figure 50*). Fish from the John Day, Umatilla, and Walla Walla rivers fell back mostly in March and April, whereas those from upriver sites were in April, May, and June. Year 1 events occurred from August through November, with few distinctive patterns among groups.

Table 71. Population-specific estimates of minimum fallback rates through the MCJ at McNary Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58					
Wind R.	849					
Hood R.	2124	1	0.1	1	0	100.0
Klickitat R.	1221					
Mill Cr.	52	1	1.9	1	0	100.0
Fifteenmile Cr.	366	2	0.5	2	0	100.0
Deschutes R	855					
John Day Dam	500	5	1.0	4	1	80.0
John Day R.	2889	111	3.8	107	4	96.4
Rock Cr.	34					
Umatilla R.	1270	11	0.9	9	2	81.8
McNary Dam	151					
Walla Walla R.	2392	35	1.5	12	23	34.3
Snake River						
Ice Harbor Dam	25					
L. Monumental Dam	434					
Lyons Ferry	458					
Tucannon R.	3122	40	1.3	19	21	47.5
Little Goose Dam	41					
Lower Granite Dam	14731	207	1.4	166	41	80.2
CWR : Other	1550	6	0.4	5	1	83.3
CWR : Middle Fork	298					
CWR : Lochsa R.	839	6	0.7	4	2	66.7
CWR : Potlatch R.	326	2	0.6	0	2	-
CWR : Selway R.	14	1	7.1	0	1	-
CWR : South Fork	1740	7	0.4	6	1	85.7
Snake R.>GR	1484	13	0.9	13	0	100.0
Asotin Cr.	430	2	0.5	2	0	100.0
Grande Ronde R.	5361	16	0.3	13	3	81.3
Salmon.: Other	4340	45	1.0	35	10	77.8
Salmon : East Fork	578	6	1.0	4	2	66.7
Salmon : Lemhi R.	239	2	0.8	2	0	100.0
Salmon : Little Salmon R.	1856	12	0.6	10	2	83.3
Salmon : Middle Fork	242	1	0.4	0	1	-
Salmon : Pahsimeroi R.	1697	12	0.7	10	2	83.3
Salmon : South Fork	271	1	0.4	1	0	100.0
Imnaha R.	4094	35	0.9	29	6	82.9
Columbia River above Snake						
Yakima R.	392	4	1.0	0	4	-
Ringold Hatchery	5715	42	0.7	8	34	19.0
Wanapum Dam	145					
Rock Island Dam	433	3	0.7	0	3	-
Wenatchee R.	4497	21	0.5	6	15	28.6
Rocky Reach Dam	92					
Entiat R.	409	2	0.5	0	2	-
Wells Dam	881	1	0.1	0	1	-
Methow R.	7419	25	0.3	8	17	32.0
Okanogan R.	1566	2	0.1	1	1	50.0

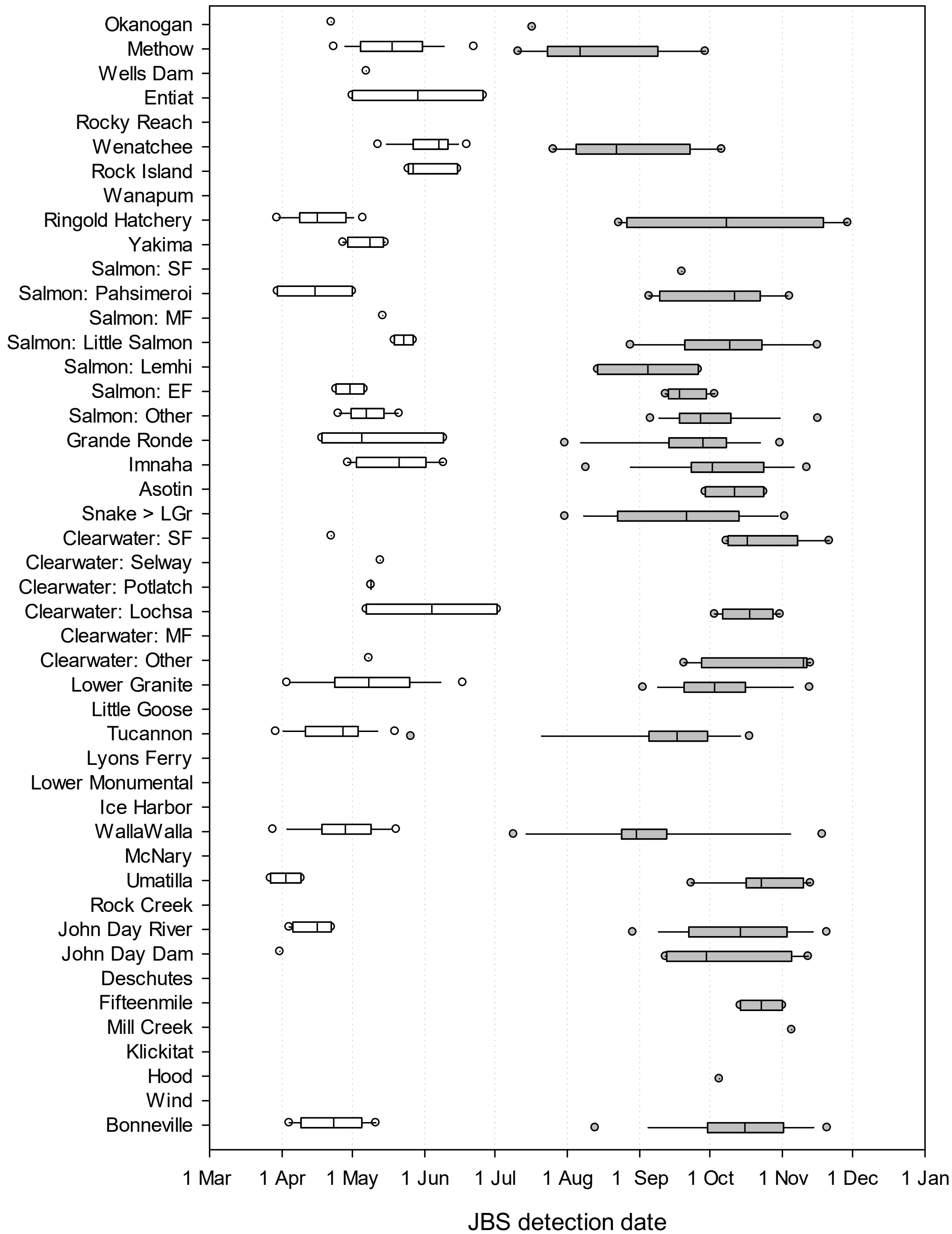


Figure 49. Population-specific timing of adult steelhead fallback detections at MCJ at McNary Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 71 has sample sizes.

Table 72. Population-specific estimates of minimum fallback rates through the LMJ at Lower Monumental Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58					
Wind R.	849					
Hood R.	2124					
Klickitat R.	1221					
Mill Cr.	52					
Fifteenmile Cr.	366	1	0.3	1	0	100.0
Deschutes R	855					
John Day Dam	500	3	0.6	2	1	66.7
John Day R.	2889	21	0.7	11	10	52.4
Rock Cr.	34					
Umatilla R.	1270	2	0.2	0	2	-
McNary Dam	151	1	0.7	1	0	100.0
Walla Walla R.	2392	60	2.5	47	13	78.3
Snake River						
Ice Harbor Dam	25					
L. Monumental Dam	434					
Lyons Ferry	458	4	0.9	3	1	75.0
Tucannon R.	3122	43	1.4	12	31	27.9
Little Goose Dam	41					
Lower Granite Dam	14731	95	0.6	35	60	36.8
CWR:Other	1550	4	0.3	3	1	75.0
CWR:Middle Fork	298					
CWR:Lochsa R.	839	2	0.2	1	1	50.0
CWR:Potlatch R.	326					
CWR:Selway R.	14					
CWR:South Fork	1740	3	0.2	1	2	33.3
Snake R.>GR	1484	6	0.4	4	2	66.7
Asotin Cr.	430	4	0.9	1	3	25.0
Grande Ronde R.	5361	20	0.4	13	7	65.0
Salmon:other	4340	21	0.5	10	11	47.6
Salmon:East Fork	578	4	0.7	0	4	-
Salmon:Lemhi R.	239	5	2.1	0	5	-
Salmon:Little Salmon R.	1856	6	0.3	2	4	33.3
Salmon:Middle Fork	242	1	0.4	0	1	-
Salmon:Pahsimeroi R.	1697	10	0.6	5	5	50.0
Salmon:South Fork	271	2	0.7	0	2	-
Imnaha R.	4094	24	0.6	8	16	33.3
Columbia River above Snake						
Yakima R.	392					
Ringold Hatchery	5715	1	0.0	0	1	-
Wanapum Dam	145					
Rock Island Dam	433					
Wenatchee R.	4497					
Rocky Reach Dam	92					
Entiat R.	409					
Wells Dam	881					
Methow R.	7419					
Okanogan R.	1566					

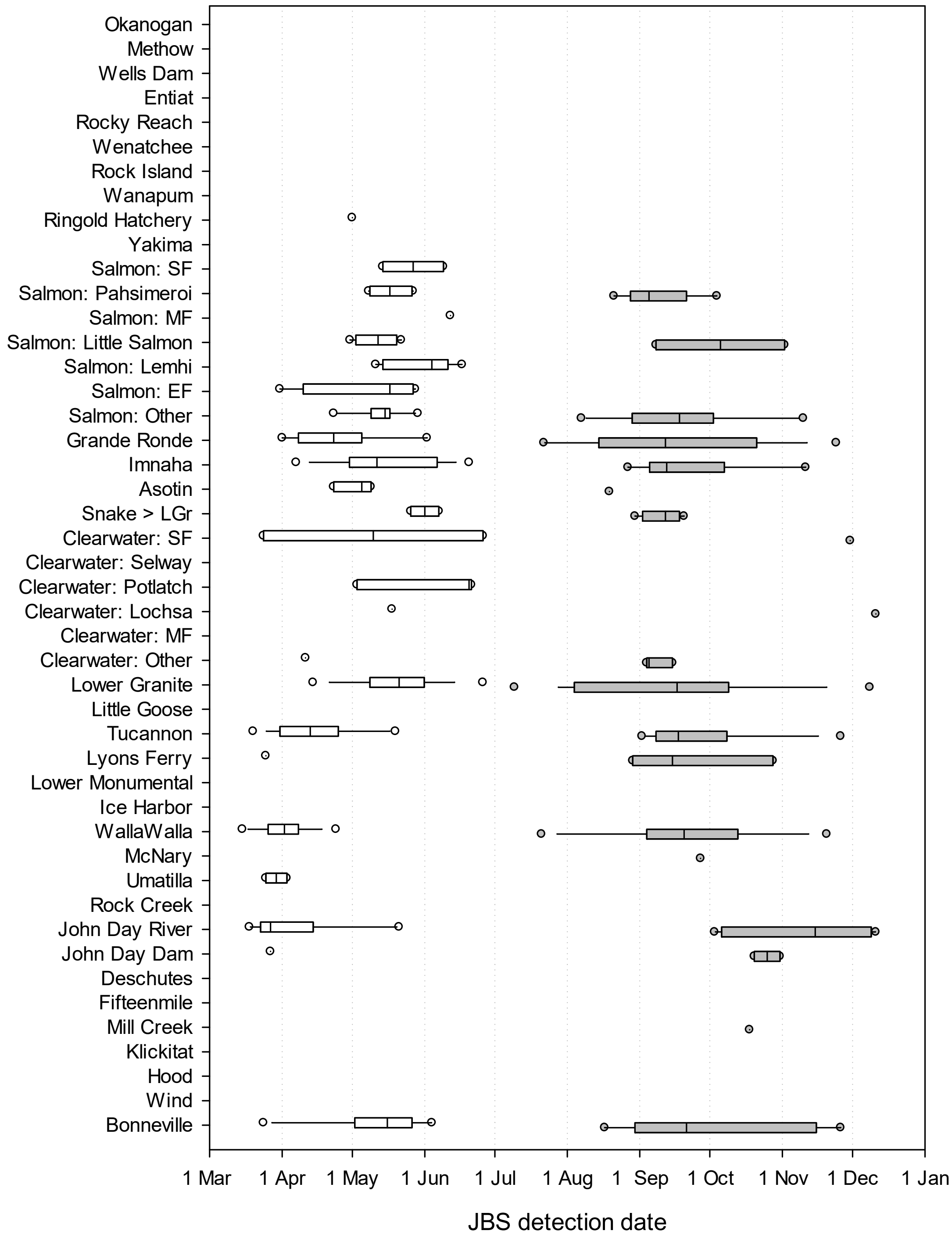


Figure 50. Population-specific timing of adult steelhead fallback detections at LMJ at Lower Monumental Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 72 has sample sizes.

Little Goose Dam (GOJ) – Across years, 679 fallback events were recorded at GOJ, and there was a relatively even mix of Year 1 (44%) and Year 2 (56%) events (*Table 67*). Steelhead from 27 populations fell back through GOJ, including fish from 10 groups located downstream from Little Goose Dam and from 17 groups located upstream (*Table 73*). Fallback rates were higher, on average, through GOJ than at JBS sites further downstream, though estimates were still <2% for most groups. The higher estimates were for steelhead from the Walla Walla River (2.7%, downstream), Tucannon River (2.2%, downstream), 4.1% (Lyons Ferry Hatchery, downstream), Potlatch River (3.7%), Asotin Creek (3.0%), and the East Fork Salmon River (2.9%). The estimate was 8.0% for fish tagged at Ice Harbor Dam, but *n* = 2 fallback events.

Year 2 fallback events at GOJ occurred from April through June (*Figure 51*). The relatively early-timed events were again by steelhead from downstream populations, including those from the John Day, Walla Walla, and Tucannon rivers and Lyons Ferry Hatchery. Median dates of fallbacks by upstream populations were mostly from late April through mid-May. Some of the latest events were by Lochsa River steelhead. The Year 1 events were mostly in August-November, with population-specific medians ranging from early September (Imnaha, Potlatch) to October (East Fork Salmon, Pahsimeroi).

Lower Granite Dam (GRJ) – Across years, 617 fallback events were recorded at GRJ, and 62% of these events were in Year 1 (i.e., by presumed pre-spawn steelhead) (*Table 67*). As at GOJ, steelhead from many downstream populations fell back at GRJ as did fish from almost all upstream populations (*Table 74*). Most population-specific fallback rates were <2%. Those with higher rates included the Walla Walla River (3.0%, downstream), Tucannon River (3.7%, downstream), Lyons Ferry Hatchery (4.8%, downstream), and groups tagged at the Ice Harbor, Lower Monumental, and Little Goose dams (2.4-16%, note small samples). The highest rates for upstream populations were for the Potlatch (2.1%) and Middle Fork Salmon (2.5%) rivers.

Fallback timing distributions were quite variable (*Figure 52*). The Year 1 events were relatively early for the Asotin Creek, Imnaha River, Grande Ronde, and some Salmon River populations. They were relatively later for the mixed-stock Clearwater River group and some of the downstream populations. The Year 2 timing distributions were relatively early, on median, for steelhead from the downstream populations. Year 2 events by fish from upstream populations were in April-June; the latest-timed events were by Lochsa, South Fork Salmon, Middle Fork Salmon, and Lemhi River fish, suggesting a distance × timing relationship or effects of different spawn timing in different tributary populations (*Figure 52*).

Table 73. Population-specific estimates of minimum fallback rates through the GOJ at Little Goose Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58					
Wind R.	849					
Hood R.	2124					
Klickitat R.	1221					
Mill Cr.	52					
Fifteenmile Cr.	366					
Deschutes R	855					
John Day Dam	500	1	0.2	0	1	-
John Day R.	2889	14	0.5	4	10	28.6
Rock Cr.	34					
Umatilla R.	1270	3	0.2	2	1	66.7
McNary Dam	151	2	1.3	1	1	50.0
Walla Walla R.	2392	64	2.7	59	5	92.2
Snake River						
Ice Harbor Dam	25	2	8.0	2		100.0
L. Monumental Dam	434	4	0.9	3	1	75.0
Lyons Ferry	458	19	4.1	15	4	78.9
Tucannon R.	3122	68	2.2	36	32	52.9
Little Goose Dam	41					
Lower Granite Dam	14731	182	1.2	42	140	23.1
CWR:Other	1550	6	0.4	4	2	66.7
CWR:Middle Fork	298					
CWR:Lochsa R.	839	5	0.6	0	5	-
CWR:Potlatch R.	326	12	3.7	5	7	41.7
CWR:Selway R.	14	1	7.1	0	1	-
CWR:South Fork	1740	8	0.5	0	8	-
Snake R.>GR	1484	22	1.5	11	11	50.0
Asotin Cr.	430	13	3.0	6	7	46.2
Grande Ronde R.	5361	50	0.9	28	22	56.0
Salmon:Other	4340	69	1.6	28	41	40.6
Salmon:East Fork	578	17	2.9	4	13	23.5
Salmon:Lemhi R.	239	3	1.3	2	1	66.7
Salmon:Little Salmon R.	1856	23	1.2	8	15	34.8
Salmon:Middle Fork	242	1	0.4	0	1	-
Salmon:Pahsimeroi R.	1697	15	0.9	9	6	60.0
Salmon:South Fork	271	4	1.5	0	4	-
Imnaha R.	4094	69	1.7	29	40	42.0
Columbia River above Snake						
Yakima R.	392					
Ringold Hatchery	5715					
Wanapum Dam	145					
Rock Island Dam	433					
Wenatchee R.	4497					
Rocky Reach Dam	92					
Entiat R.	409					
Wells Dam	881					
Methow R.	7419					
Okanogan R.	1566					

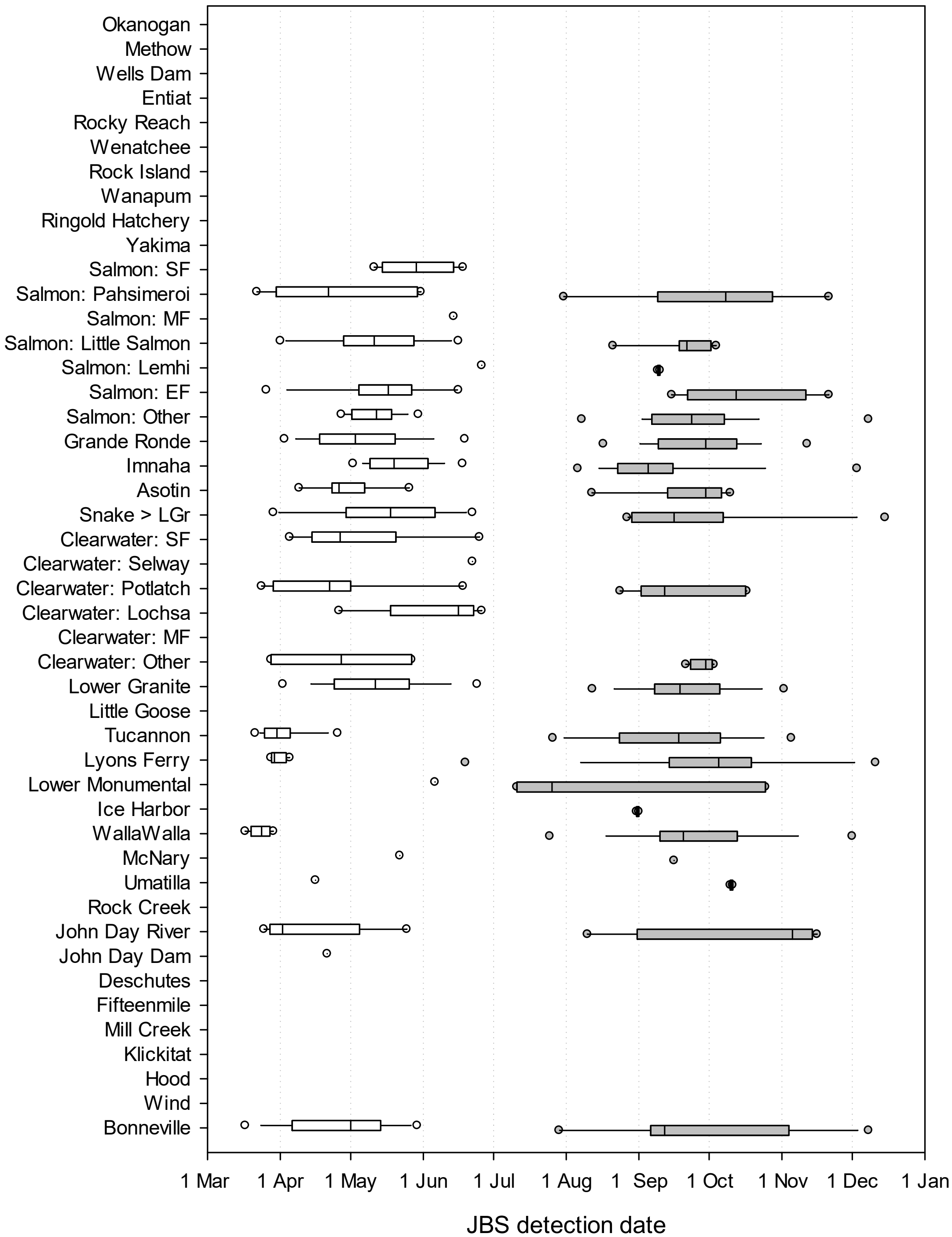


Figure 51. Population-specific timing of adult steelhead fallback detections at GOJ at Little Goose Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 73 has sample sizes.

Table 74. Population-specific estimates of minimum fallback rates through the GRJ at Lower Granite Dam (2005-2015). Rates were calculated at the number of bypass fallback events divided by the total number of adult fish in each population. Year 1 = pre-spawn steelhead detected in the same calendar year as they were first detected at Bonneville Dam; Year 2 = the mix of pre-spawn adults and post-spawn kelts detected after 31 December. Sample = PIT-tagged as juveniles. Sample = PIT-tagged as juveniles.

Population	Total *n*	Total FB *n*	Total FB %	Yr 1 FB *n*	Yr 2 FB *n*	% FB in Yr 1
Columbia River below Snake						
Bonneville Dam	58					
Wind R.	849					
Hood R.	2124					
Klickitat R.	1221					
Mill Cr.	52					
Fifteenmile Cr.	366					
Deschutes R	855					
John Day Dam	500	7	1.4	5	2	71.4
John Day R.	2889	10	0.3	4	6	40.0
Rock Cr.	34					
Umatilla R.	1270	1	0.1	0	1	-
McNary Dam	151	1	0.7	0	1	-
Walla Walla R.	2392	71	3.0	69	2	97.2
Snake River						
Ice Harbor Dam	25	4	16.0	3	1	75.0
L. Monumental Dam	434	12	2.8	11	1	91.7
Lyons Ferry	458	22	4.8	20	2	90.9
Tucannon R.	3122	117	3.7	92	25	78.6
Little Goose Dam	41	1	2.4	1	0	100.0
Lower Granite Dam	14731	151	1.0	56	95	37.1
CWR : Other	1550	10	0.6	5	5	50.0
CWR : Middle Fork	298					
CWR : Lochsa R.	839	3	0.4	1	2	33.3
CWR : Potlatch R.	326	7	2.1	1	6	14.3
CWR : Selway R.	14					
CWR : South Fork	1740	6	0.3	4	2	66.7
Snake R.>GR	1484	15	1.0	10	5	66.7
Asotin Cr.	430	9	2.1	7	2	77.8
Grande Ronde R.	5361	35	0.7	24	11	68.6
Salmon : Other	4340	37	0.9	18	19	48.6
Salmon : East Fork	578	11	1.9	2	9	18.2
Salmon : Lemhi R.	239	4	1.7	2	2	50.0
Salmon : Little Salmon R.	1856	15	0.8	10	5	66.7
Salmon : Middle Fork	242	6	2.5	1	5	16.7
Salmon : Pahsimeroi R.	1697	6	0.4	5	1	83.3
Salmon : South Fork	271	5	1.8	1	4	20.0
Imnaha R.	4094	49	1.2	30	19	61.2
Columbia River above Snake						
Yakima R.	392					
Ringold Hatchery	5715					
Wanapum Dam	145					
Rock Island Dam	433					
Wenatchee R.	4497					
Rocky Reach Dam	92					
Entiat R.	409					
Wells Dam	881					
Methow R.	7419	1	0.0	1	0	100.0
Okanogan R.	1566					

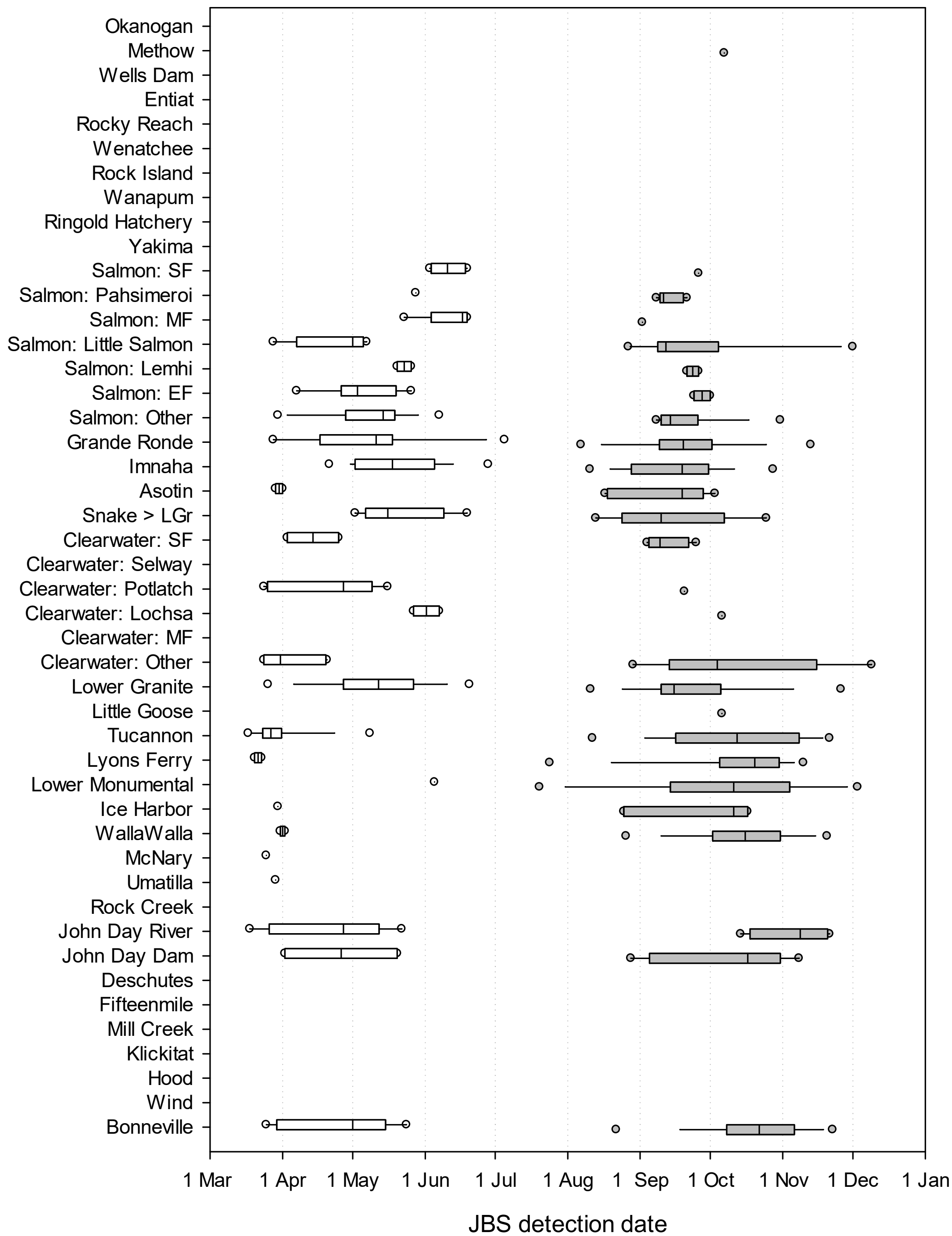


Figure 52. Population-specific timing of adult steelhead fallback detections at GRJ at Lower Granite Dam (2005-2015). Plots show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles for the pre-spawn steelhead that first passed in the same calendar year as they were first detected at Bonneville Dam (dark gray boxes) and for the mix of pre-spawn adults and post-spawn kelts detected in the following year (light gray boxes). Table 74 has sample sizes.

Fallback: JBS Rates and Timing – Summary

Key findings

- Hundreds of PIT-tagged steelhead were detected falling back through JBS routes at FCRPS dams
- JBS fallback was detected for most populations, but timing varied among sites and groups
- More than 1,000 steelhead were detected at the Bonneville Corner Collector (BCC)
- Fallbacks were generally more frequent in Year 1 at lower Columbia dams, and in Year 2 at Snake River dams, indicating a mix of pre-spawn steelhead and kelt fallback events
- Reported rates are minimums and should be considered an index for comparison among sites and groups

Critical uncertainties

- True rates were underestimated to some degree because harvest and other mortality was not accounted for in denominators
- Maturation status was unknown for many steelhead that fell back in Year 2
- It is unknown whether fallback rates via JBSs and the BCC are good indicators of fallback via other routes
- Relationships between JBS and BCC fallback rates and operational or environmental conditions are unknown

Technical recommendations

- Installation of PIT antennas at other FCRPS dam passage routes (e.g., spillway weirs) will allow for a more robust and holistic evaluation of fallback rates and timing
- Mine existing data for causal relationships between JBS and BCC fallback and river environment / operations
- Accounting for harvest, hatchery collection and other adult 'loss' would provide more realistic estimates of population-specific fallback through JBSs and the BCC

3.9.3 Fallback Identified Using Fishway Antenna Algorithms

Methods – Three types of fallback events were identified using algorithms to query the PIT antenna group-level dataset: 1) fallbacks via the JBS; 2) fallbacks identified by detection at antennas downstream from McNary Dam; and 3) fallbacks down the adult fishways or by repeat detection. These types of events were identified at McNary, Ice Harbor, and Lower Granite dams only because antenna arrays at these dams were better suited for data queries that assessed the directionality of fish movements.

The group of JBS fallbacks identified using the algorithms very closely matched the data presented in the previous Section, as would be expected. In *Tables 75-77* the JBS fallback data are presented as the percentage of unique steelhead that had a JBS fallback event divided by the number of unique steelhead that passed McNary, Ice Harbor, or Lower Granite dams (i.e., a fallback percentage). This is a different metric than the JBS fallback rates presented in the previous Section, which was the total number of fallback events divided by the number of fish at Bonneville Dam. As a part of the JBS fallback evaluation, we calculated the elapsed time between adult fishway passage and the JBS fallback event (*Figure 53*). The time gap was highly variable at all three dams, with some fish falling back almost immediately after exiting a fishway into the forebay and others falling back several months later. The mode in *Figure 53* with times >100 d was mostly associated with kelts, whereas the second and third modes appeared to be associated with a mix of pre-spawn adults and kelts.

The downstream fallback category was also calculated as a percentage of the unique fish that passed McNary, Ice Harbor, and Lower Granite dams that were subsequently detected at one or more antennas in downstream tributaries or at downstream FCRPS dams.

Fishway fallback by adult steelhead has been identified in previous radiotelemetry studies. However, confidently identifying fishway fallback events using the PIT detection data was by far the most problematic category. Detection sequences clearly showed that many steelhead moved up and down within fishways, but the time gaps between the end of an apparent fishway ascension and the start of an apparent movement back to the tailrace or a second ascension were highly variable (*Figure 54*). However, large majorities of the potential fishway fallback events had time gaps of <6 h suggesting steelhead never moved into dam forebays but rather held position in the fishways (e.g., over-nighting behavior). Extended fishway residence times by adult steelhead have also been reported at some FCRPS dams in winter, so longer-duration gaps identified using this method may also have incorrectly classified behaviors as fallback. We chose not to report these data given the several sources of uncertainty.

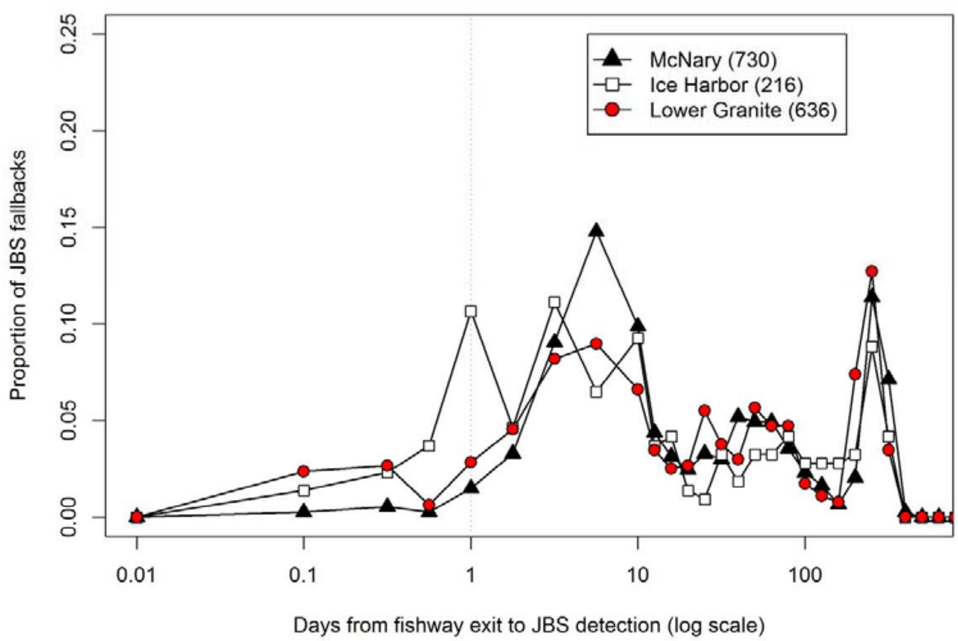


Figure 53. Elapsed time (days, log10 scale) between the last adult fishway detection and subsequent detection at a JBS antenna by PIT-tagged steelhead at McNary, Ice Harbor, and Lower Granite dams (2005-2015). JBS fallback events were by pre-spawn adults and post-spawn kelts.

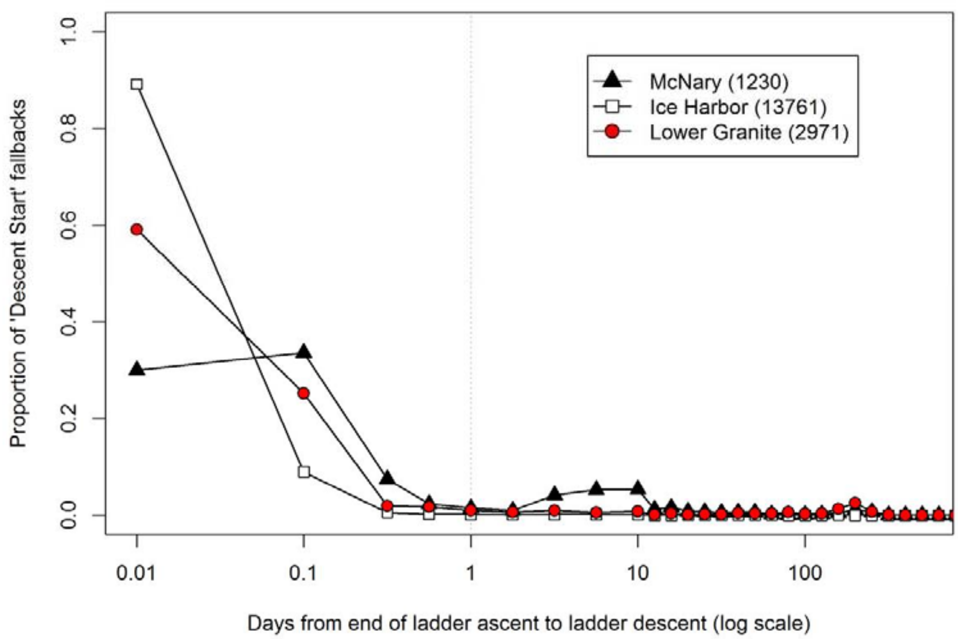


Figure 54. Elapsed time (days, log10 scale) between the last adult fishway detection (moving upstream) and subsequent initiation of downstream movement through a fishway by PIT-tagged steelhead at McNary, Ice Harbor, and Lower Granite dams (2005-2015).

McNary Dam – Estimated McNary JBS (MCJ) fallback percentages were highest for populations downstream from McNary Dam (*Table 75*). These included the John Day River (11.3%), Umatilla River (7.0%) and three Bonneville reservoir tributaries with relatively small sample sizes. JBS fallback percentages for populations upstream from McNary Dam were mostly <1%. The highest estimates were for steelhead from the East Fork Salmon River (2.1%) and those tagged at Lower Granite Dam (1.5%).

Fallback percentages estimated by detection at a downstream antenna were slightly higher, on average, than the JBS fallback estimates for populations downstream from McNary Dam (*Table 75*). Two factors likely explain this pattern: (1) fish from downstream tributaries were more likely to enter those tributaries after falling back than were fish from upstream populations; and (2) the downstream detection category included fish that fell back through the JBS and were subsequently detected somewhere downstream, but not vice versa. Fallback estimates for downstream populations based on downstream detection were 14.5% (John Day River), 15.9% (Umatilla River), 11.8% (Rock Creek), and 13-20% for Klickitat River and Fifteenmile Creek. Estimates for populations located upstream from McNary Dam were <1% for all except the East Fork Salmon River (1.9%) and the group tagged at Lower Granite Dam (1.2%).

Ice Harbor Dam – Ice Harbor JBS fallback events were identified for six downstream populations, eleven Snake River populations, and two populations from the Columbia above the Snake River confluence (*Table 76*). Percentages were 2.9-3.8% for the Walla Walla, Umatilla, and John Day River populations, and were <1% for all Snake River populations except Lyons

Ferry Hatchery (1.3%). Estimates were relatively high for the Yakima River (8.3%, but *n* = 1 fallback) and Ringold Hatchery (5.5%, 3 events).

A total of 97 unique steelhead were identified as falling back at Ice Harbor Dam based on detection at an antenna downstream from Ice Harbor Dam (*Table 76*). A majority (86%) of these were Walla Walla River fish, which had an estimated fallback percentage of 6.9%. Percentages for other downstream populations were 1.1% (Umatilla River) and 0.3% (John Day River). Four groups from the Snake River had estimates ≤0.3%. The highest estimate was for the Yakima River (16.7%, but *n* = 2 fallback fish).

Lower Granite Dam – Lower Granite JBS (GRJ) fallback events were identified for nine downstream populations and for almost all populations upstream from the dam (*Table 77*). Percentages for lower Columbia River groups were 14.6% for Walla Walla steelhead, and 2.5-2.7% for the John Day, and Umatilla River groups. Percentages were also relatively high for lower Snake River populations at 11.9% (Lyons Ferry Hatchery), 6.3% (Tucannon River), and 2.9-6.8% for groups tagged at Ice Harbor, Lower Monumental, and Little Goose dams.

Table 75. Numbers of unique adult steelhead that passed McNary Dam and the numbers and percentages that were identified as falling back via the JBS or by detection at downstream PIT-tag antennas (2005-2015). Sample = PIT-tagged as juveniles.

Population	Passed MCN (*n*)	JBS FB (*n*)	JBS FB (%)	Downstream detect FB (*n*)	Downstream detect FB (%)
Columbia River below Snake					
Bonneville Dam	5	-	-	-	-
Wind R.	1	-	-	-	-
Hood R.	3	-	-	-	-
Klickitat R.	5	-	-	1	20.0
Mill Cr.	4	1	25.0	-	-
Fifteenmile Cr.	23	2	8.7	3	13.0
Deschutes R	6	-	-	-	-
John Day Dam	332	5	1.5	4	1.2
John Day R.	1006	114	11.3	146	14.5
Rock Cr.	17	-	-	2	11.8
Umatilla R.	427	30	7.0	68	15.9
McNary Dam	99	-	-	-	-
Walla Walla R.	1577	10	0.6	6	0.4
Snake River					
Ice Harbor Dam	44	-	-	-	-
L. Monumental Dam	314	-	-	-	-
Lyons Ferry	360	-	-	-	-
Tucannon R.	1503	5	0.3	3	0.2
Little Goose Dam	20	-	-	-	-
Lower Granite Dam	7811	120	1.5	91	1.2
CWR : Other	1110	4	0.4	1	0.1
CWR : Middle Fork	247	-	-	-	-
CWR : Lochsa R.	603	4	0.7	3	0.5
CWR : Potlatch R.	243	-	-	-	-
CWR : Selway R.	7	-	-	-	-
CWR : South Fork	1168	5	0.4	1	0.1
Snake R.>GR	1068	12	1.1	4	0.4
Asotin Cr.	308	2	0.6	1	0.3
Grande Ronde R.	3512	13	0.4	1	<0.1
Salmon : Other	3323	31	0.9	30	0.9
Salmon : East Fork	477	10	2.1	9	1.9
Salmon : Lemhi R.	178	3	1.7	-	-
Salmon : Little Salmon R.	1427	10	0.7	3	0.2
Salmon : Middle Fork	162	-	-	1	0.6
Salmon : Pahsimeroi R.	1326	11	0.8	7	0.5
Salmon : South Fork	191	1	0.5	-	-
Imnaha R.	2902	31	1.1	12	0.4
Columbia River above Snake					
Yakima R.	257	-	-	-	-
Ringold Hatchery	1775	3	0.2	-	-
Wanapum Dam	107	-	-	-	-
Rock Island Dam	431	-	-	-	-
Wenatchee R.	2614	3	0.1	-	-
Rocky Reach Dam	-				
Entiat R.	296	-	-	-	-
Wells Dam	574	-	-	-	-
Methow R.	2767	5	0.2	-	-
Okanogan R.	749	1	0.1	-	-

Table 76. Numbers of unique adult steelhead that passed Ice Harbor Dam and the numbers and percentages that were identified as falling back via the JBS or by detection at downstream PIT-tag antennas (2005-2015). Sample = PIT-tagged as juveniles.

Population	Passed ICH (*n*)	JBS FB (*n*)	JBS FB (%)	Downstream detect FB (*n*)	Downstream detect FB (%)
Columbia River below Snake					
Bonneville Dam	28	-	-	-	-
Wind R.	-				
Hood R.	-	-	-	-	-
Klickitat R.	3	-	-	-	-
Mill Cr.	-				
Fifteenmile Cr.	6	-	-	-	-
Deschutes R	2	-	-	-	-
John Day Dam	229	2	0.9	1	0.4
John Day R.	318	12	3.8	1	0.3
Rock Cr.	1	1	100.0	-	-
Umatilla R.	94	3	3.2	1	1.1
McNary Dam	91	3	3.3	-	-
Walla Walla R.	1207	35	2.9	83	6.9
Snake River					
Ice Harbor Dam	48	-	-	-	-
L. Monumental Dam	326	1	0.3	-	-
Lyons Ferry	339	4	1.2	-	-
Tucannon R.	2186	13	0.6	3	0.1
Little Goose Dam	35	-	-	-	-
Lower Granite Dam	9744	32	0.3	4	<0.1
CWR : Other	1137	2	0.2	-	-
CWR : Middle Fork	245	-	-	-	-
CWR : Lochsa R.	650	-	-	-	-
CWR : Potlatch R.	260	-	-	-	-
CWR : Selway R.	12	-	-	-	-
CWR : South Fork	1301	2	0.2	-	-
Snake R.>GR	1062	1	0.1	-	-
Asotin Cr.	310	2	0.6	1	0.3
Grande Ronde R.	3716	10	0.3	-	-
Salmon : Other	3261	9	0.3	-	-
Salmon : East Fork	435	-	-	-	-
Salmon : Lemhi R.	188	-	-	-	-
Salmon : Little Salmon R.	1401	5	0.4	-	-
Salmon : Middle Fork	177	-	-	-	-
Salmon : Pahsimeroi R.	1286	3	0.2	-	-
Salmon : South Fork	209	1	0.5	-	-
Imnaha R.	2951	10	0.3	1	<0.1
Columbia River above Snake					
Yakima R.	12	1	8.3	2	16.7
Ringold Hatchery	55	3	5.5	-	-
Wanapum Dam	-				
Rock Island Dam	-				
Wenatchee R.	4	-	-	-	-
Rocky Reach Dam	-				
Entiat R.	-				
Wells Dam	2	-	-	-	-
Methow R.	4	-	-	-	-
Okanogan R.	1	-	-	-	-

Table 77. Numbers of unique adult steelhead that passed Lower Granite Dam and the numbers and percentages that were identified as falling back via the JBS or by detection at downstream PIT-tag antennas (2005-2015). Sample = PIT-tagged as juveniles.

Population	Passed LGR (*n*)	JBS FB (*n*)	JBS FB (%)	Downstream detect FB (*n*)	Downstream detect FB (%)
Columbia River below Snake					
Bonneville Dam	27	-	-	-	-
Wind R.	-				
Hood R.	-				
Klickitat R.	2	-	-	-	-
Mill Cr.	-				
Fifteenmile Cr.	2	-	-	1	50.0
Deschutes R	2	-	-	1	50.0
John Day Dam	184	5	2.7	2	1.1
John Day R.	149	4	2.7	-	-
Rock Cr.	-				
Umatilla R.	40	1	2.5	4	10.0
McNary Dam	70	-	-	-	-
Walla Walla R.	485	71	14.6	52	10.7
Snake River					
Ice Harbor Dam	44	3	6.8	2	4.5
L. Monumental Dam	304	10	3.3	4	1.3
Lyons Ferry	159	19	11.9	10	6.3
Tucannon R.	1407	88	6.3	77	5.5
Little Goose Dam	34	1	2.9	-	-
Lower Granite Dam	9292	69	0.7	17	0.2
CWR : Other	1089	5	0.5	-	-
CWR : Middle Fork	236	-	-	-	-
CWR : Lochsa R.	624	1	0.2	2	0.3
CWR : Potlatch R.	249	3	1.2	-	-
CWR : Selway R.	13	-	-	-	-
CWR : South Fork	1234	5	0.4	1	0.1
Snake R.>GR	1025	10	1.0	2	0.2
Asotin Cr.	290	6	2.1	1	0.3
Grande Ronde R.	3611	28	0.8	1	<0.1
Salmon : Other	3159	19	0.6	3	0.1
Salmon : East Fork	416	2	0.5	-	-
Salmon : Lemhi R.	176	1	0.6	-	-
Salmon : Little Salmon R.	1361	10	0.7	-	-
Salmon : Middle Fork	176	2	1.1	-	-
Salmon : Pahsimeroi R.	1233	5	0.4	-	-
Salmon : South Fork	206	1	0.5	1	0.5
Imnaha R.	2824	31	1.1	6	0.2
Columbia River above Snake					
Yakima R.	3	-	-	-	-
Ringold Hatchery	13	-	-	-	-
Wanapum Dam	-				
Rock Island Dam	-				
Wenatchee R.	4	-	-	-	-
Rocky Reach Dam	-				
Entiat R.	-				
Wells Dam	2	-	-	-	-
Methow R.	3	1	33.3	-	-
Okanogan R.	1	-	-	-	-

JBS fallback percentages for the Snake River populations upstream from Lower Granite Dam were highest for the Potlatch River (1.2%), Asotin Creek (2.1%), Middle Fork Salmon River (1.1%), and Imnaha River (1.1%).

Fallback percentages based on downstream detections were again highest for downstream populations (*Figure 55*). The largest numbers of unique fallback fish were from the Tucannon and Walla Walla rivers, and JBS fallback percentages for these groups were 5.5% and 10.7%, respectively. Percentages for other downstream populations with more than a few unique fish were 6.3% (Lyons Ferry Hatchery) and 10.0% (Umatilla River). Few fish from populations upstream from Lower Granite Dam were identified as fallback fish based on downstream detections.

Fallback Identified Using Fishway Antenna Algorithms – Summary

Key findings
- JBS fallback percentages calculated using adults that passed individual dams (different from previous Section)
- Highest fallback percentages were for tributary overshoot populations

Critical uncertainties
- Only McNary, Ice Harbor, and Lower Granite fishways had antenna details sufficient to assess directionality
- Fishway detection data and elapsed times before fallback were highly variable and difficult to interpret
- Also see list for Section 3.9.2 - Fallback: JBS rates and timing

Technical recommendations
- PIT-based fallback estimates for non-JBS routes need to be rigorously evaluated
- PIT-based fallback estimates could be tested using double-tagged (i.e., radio+PIT) steelhead
- Antenna redundancy in adult fishways would improve evaluation of movements and possible fallback
- Also see list for Section 3.9.2 - Fallback: JBS rates and timing

3.10 FCRPS REACH CONVERSION

Methods – The generally high detection efficiency of PIT-tagged fish at the FCRPS dams (Tenney et al. 2010; Fryer et al. 2013) allows calculation of precise estimates of adult reach conversion. We calculated reach conversion estimates for eleven dam-to-dam and multi-dam reaches. Seven of these reaches had PIT data in all years (Bonneville-McNary, Bonneville-Ice Harbor, Bonneville-Lower Granite, Bonneville-Priest Rapids, McNary-Ice Harbor, McNary-Priest Rapids, and Ice Harbor-Lower Granite). The remaining reaches had data available only in recent years: Bonneville-The Dalles (2013-2014), Ice Harbor-Lower Monumental (2014), Lower Monumental-Little Goose (2014), and Little Goose-Lower Granite (2014). We note that data from the 2015 migration were not included in reach escapement estimates because some steelhead were still migrating when the 2016 data were queried.

Given the number of reaches, number of years, number of study groups, and the wild / hatchery and A-group / B-group dichotomies we elected to present only point estimates of reach conversion for this report. The point estimates in *Figures 55-65* are for all available data for each study group, split into hatchery and wild components and also split by early versus late run timing at Bonneville Dam. The timing split uses the 25 August run separation date that is a management-based proxy for A- versus B-group steelhead. We accounted for obvious missed dam passage events (i.e., when a fish was not detected at the FCRPS dam that was at the upstream end of the reach, but was detected at a site further upstream).

Consultation with the Corps POC during the Draft Report planning and preparation indicated that a full statistical analysis of the reach conversion data was beyond the study scope. However, we note that the datasets are now structured so that more formal statistical analyses can be conducted if deemed necessary. For example, the Cormack-Jolly-Seber (CJS) survival models (e.g., Brownie et al. 1985; Perry et al. 2012) described in the study proposal could be used to calculate PIT-tag detection probabilities and survival probabilities that may differ slightly from the point estimates provided below which would use detection probabilities to explicitly account for missed passage events. Annual and population-specific or release-group specific estimates could also be generated as in Keefer et al. (2014a).

Bonneville to The Dalles – Aggregate estimates were calculated for the 2013-2014 migration years (*Figure 55*). Reach conversion point estimates for the population aggregates were 0.857 (all wild fish), 0.844 (all hatchery fish), 0.831 (all early-run fish), and 0.870 (all late-run fish). Point estimates for individual rear-types × population and run-timing × population groups were mostly between 0.800 and 0.910. The few groups with estimates < 0.800 included: Okanogan River (wild), the mixed-stock Clearwater River (wild), Umatilla River (hatchery, late), Grande Ronde River (early), Lemhi River (early), Wells Dam (late), Little Goose Dam (late), and Deschutes River (late).

Bonneville to McNary – Aggregate estimates for this multi-dam reach were calculated for all migration years through 2014 (*Figure 56*). Reach conversion point estimates for the population aggregates were 0.780 (all wild fish), 0.752 (all hatchery fish), 0.751 (all early-run fish), and 0.751 (all late-run fish). Note that the aggregate lines are superimposed for the latter three groups in *Figure 56*. Point estimates for individual rear-type × population and run-timing × population groups were mostly between 0.720 and 0.870. The few groups with estimates < 0.720 included: Ice Harbor Dam (wild), Ringold (hatchery, early, late), Little Goose Dam (hatchery, early, late), Rocky Reach Dam (late), and Ice Harbor Dam (late).

Bonneville to Ice Harbor – Aggregate estimates for this multi-dam reach were calculated for all migration years through 2014 (*Figure 57*). Reach conversion point estimates for the population aggregates were 0.727 (all wild fish), 0.717 (all hatchery fish), 0.710 (all early-run fish), and 0.734 (all late-run fish). Point estimates for individual rear-type × population and run-timing × population groups were mostly between 0.680 and 0.850. The few groups with estimates < 0.680 were all tagged at Lower Snake River dams. Groups with relatively high estimates included: Middle Fork Clearwater (wild), Selway River (late), and Lemhi River (hatchery).

Bonneville to Lower Granite – Aggregate estimates for this multi-dam reach were calculated for all migration years through 2014 (*Figure 58*). Reach conversion point estimates for the population aggregates were 0.689 (all wild fish), 0.678 (all hatchery fish), 0.667 (all early-run fish), and 0.700 (all late-run fish). Point estimates for individual rear-type × population and run-timing × population groups were mostly between 0.670 and 0.800. The aggregate estimates were reduced mainly by the abundant group PIT-tagged at Lower Granite Dam. Point estimates for the Lower Granite groups were: 0.662 (wild), 0.607 (hatchery), 0.615 (early), and 0.654 (late). Groups with relatively high estimates included: Middle Fork Clearwater (wild, late), Selway River (late), and Pahsimeroi River (wild).

Bonneville to Priest Rapids – Aggregate estimates were calculated for all migration years through 2014 (*Figure 59*). Reach conversion point estimates for the population aggregates were 0.780 (all wild fish), 0.743 (all hatchery fish), 0.748 (all early-run fish), and 0.741 (all late-run fish). Point estimates for individual origin × population and run-timing × population were mostly between 0.730 and 0.800. The few groups with estimates < 0.730 included: Wells Dam (hatchery, early, late) and Rocky Reach Dam (late). Groups with relatively high estimates included the Rock Island Dam (wild, late).

McNary to Ice Harbor – Aggregate estimates were calculated for all migration years through 2014 (*Figure 60*). Reach conversion point estimates for the population aggregates were 0.938 (all wild fish), 0.942 (all hatchery fish), 0.937 (all early-run fish), and 0.947 (all late-run fish). Note that the early and wild lines are partially superimposed in *Figure 59*. Point estimates for individual origin × population and run-timing × population groups were mostly higher than 0.940, but the aggregate estimates were pulled downwards by the fish tagged at Lower Granite Dam which had point estimates of ~0.900 (hatchery, early) and ~0.918 (wild, late). Estimates were also relatively low for the South Fork Clearwater River (wild, but $n = 11$) and the East Fork Salmon River (late). Many groups had conversion estimates ≥0.980 (*Figure 60*).

McNary to Priest Rapids – Aggregate estimates were calculated for all migration years through 2014 (*Figure 61*). Reach conversion point estimates for the population aggregates were 0.990 (all wild fish), 0.978 (all hatchery fish), 0.981 (all early-run fish), and 0.975 (all late-run fish). Point estimates for individual origin × population and run-timing × population groups were almost all ≥0.970 and several groups had conversion of 1.000. The two groups with relatively low estimates were those tagged at Wells Dam (late) and Wanapum Dam (early).

Ice Harbor to Lower Monumental – Aggregate estimates were calculated only for the 2014 migration year (*Figure 62*). Reach conversion point estimates for the population aggregates were 0.983 (all wild fish), 0.975 (all hatchery fish), 0.975 (all early-run fish), and 0.980 (all late-run fish). Note that lines for the hatchery and early-run groups are fully superimposed in *Figure 62*. Point estimates for individual origin × population and run-timing × population groups were almost all ≥0.950 and multiple groups (especially late-run groups) had conversion of 1.000. The groups with relatively low estimates were the Lyons Ferry Hatchery (late), Asotin Creek (late), and Lochsa River (early).

Ice Harbor to Lower Granite – Aggregate estimates for this multi-dam reach were calculated for all migration years through 2014 (*Figure 63*). Reach conversion point estimates for the population aggregates were 0.950 (all wild fish), 0.949 (all hatchery fish), 0.944 (all early-run fish), and 0.955 (all late-run fish). Point estimates for individual origin × population and run-timing × population groups were almost all ≥0.920. The Lemhi River (hatchery) group had the lowest estimate, but also a small sample (*n* =11). Several groups had conversion of 1.000, including the wild components from the Pahsimeroi, Middle Fork Clearwater, and South Fork Clearwater as well as the Selway River (late) and Middle Fork Salmon River (early) groups (*Figure 63*). The groups with relatively low estimates were the Lemhi River (hatchery, early), Middle Fork Clearwater River (early), Lochsa River (early), and the mixed-stock wild group collected in the Snake River upstream from Lower Granite Dam.

Lower Monumental to Little Goose – Aggregate estimates were calculated only for the 2014 migration year (*Figure 64*). Reach conversion point estimates for the population aggregates were 0.987 (all wild fish), 0.985 (all hatchery fish), 0.983 (all early-run fish), and 0.989 (all late-run fish). Point estimates for individual origin × population and run-timing × population groups were almost all ≥0.970 and multiple groups (especially late-run groups) had conversion of 1.000. The groups with relatively low estimates were the Middle Fork Clearwater River (hatchery, late), Asotin Creek (late), and Grande Ronde River (wild).

Little Goose to Lower Granite – Aggregate estimates were calculated only for the 2014 migration year (*Figure 65*). Reach conversion point estimates for the population aggregates were 0.987 (all wild fish), 0.985 (all hatchery fish), 0.983 (all early-run fish), and 0.988 (all late-run fish). Point estimates for individual origin × population and run-timing × population groups were almost all ≥0.970 and multiple groups (especially late-run groups) had conversion of 1.000. The groups with relatively low estimates were the Potlatch River (early, wild), Lemhi River (early, wild), and East Fork Salmon River (early, hatchery).

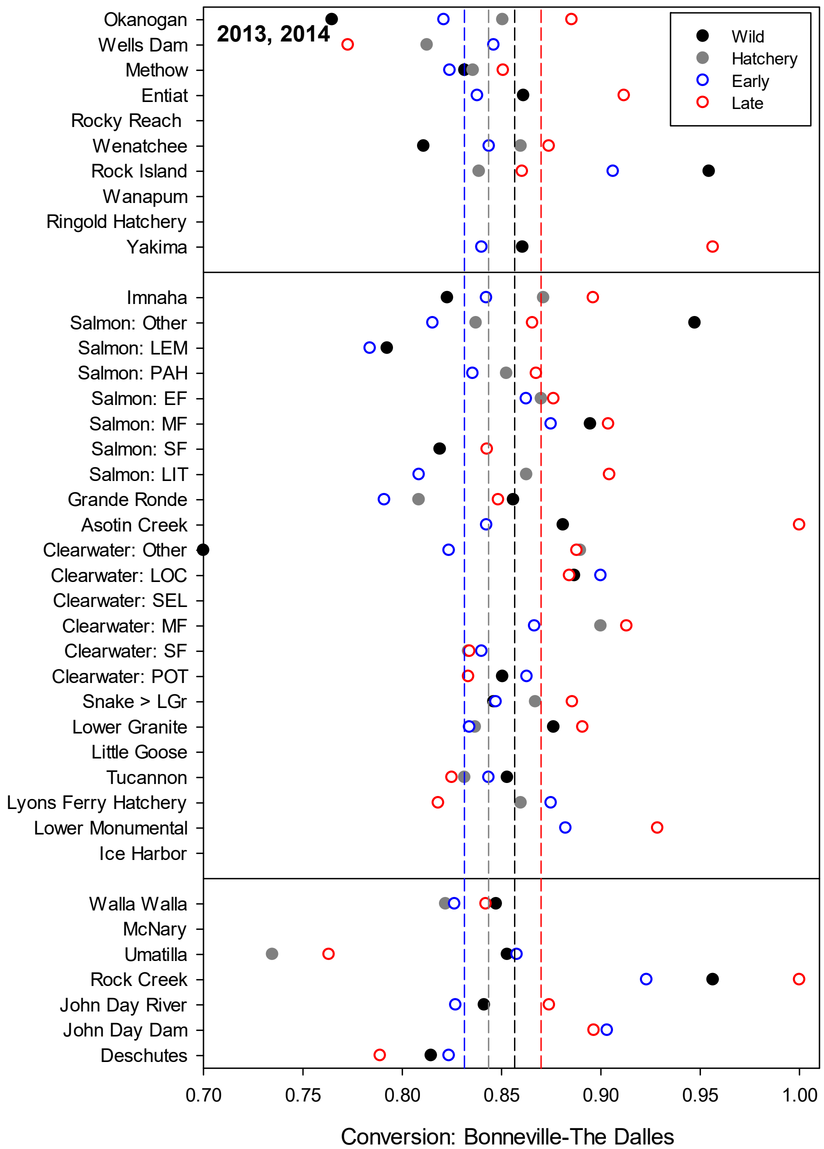


Figure 55. Population-specific reach conversion estimates from Bonneville Dam to The Dalles Dam in 2013-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.857); gray = hatchery fish (0.844); blue = early-run migrants (0.831); red = late-run migrants (0.870). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

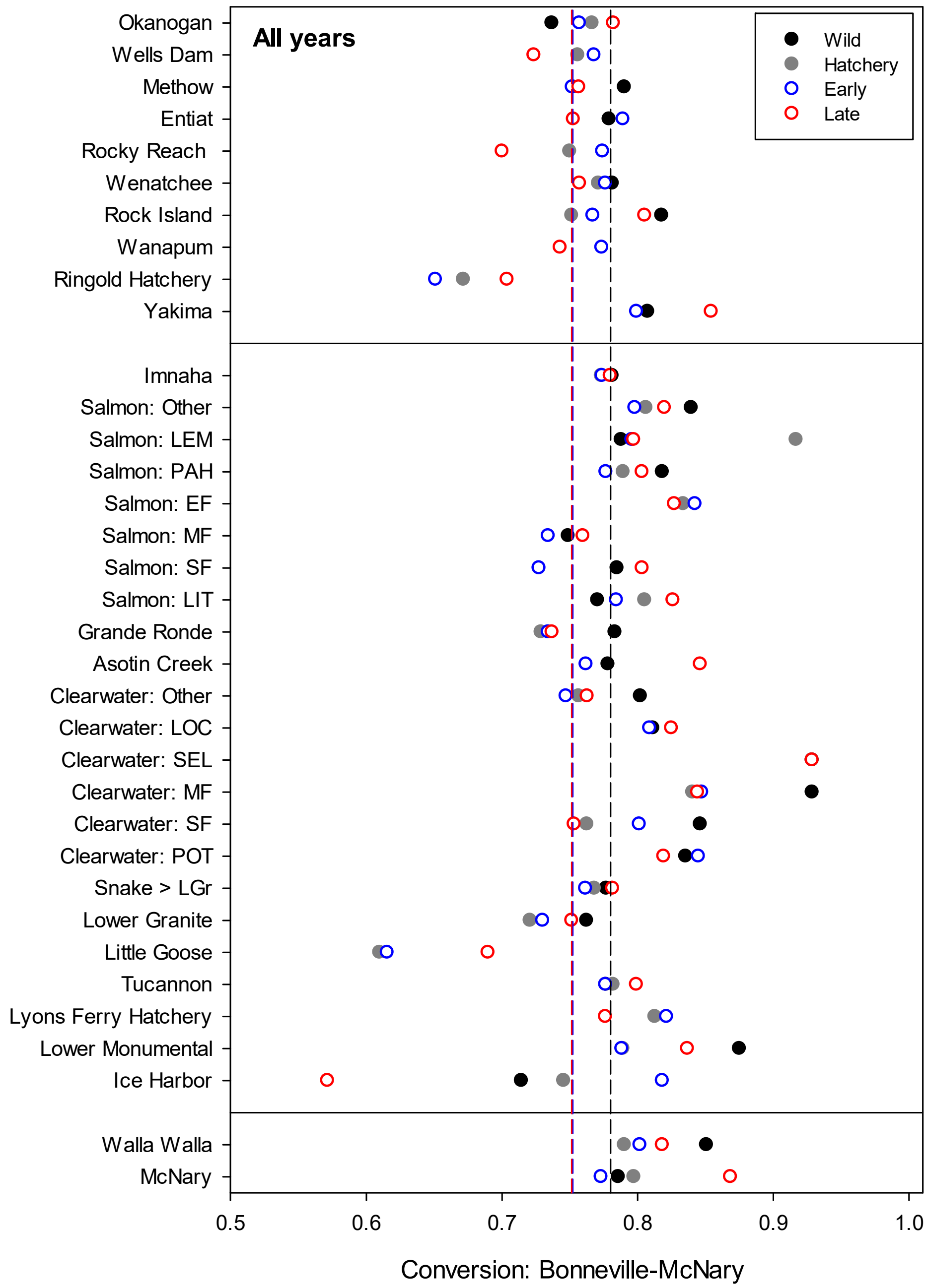


Figure 56. Population-specific reach conversion estimates from Bonneville Dam to McNary Dam in 2005-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.780); gray = hatchery fish (0.752); blue = early-run migrants (0.752); red = late-run migrants (0.767). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

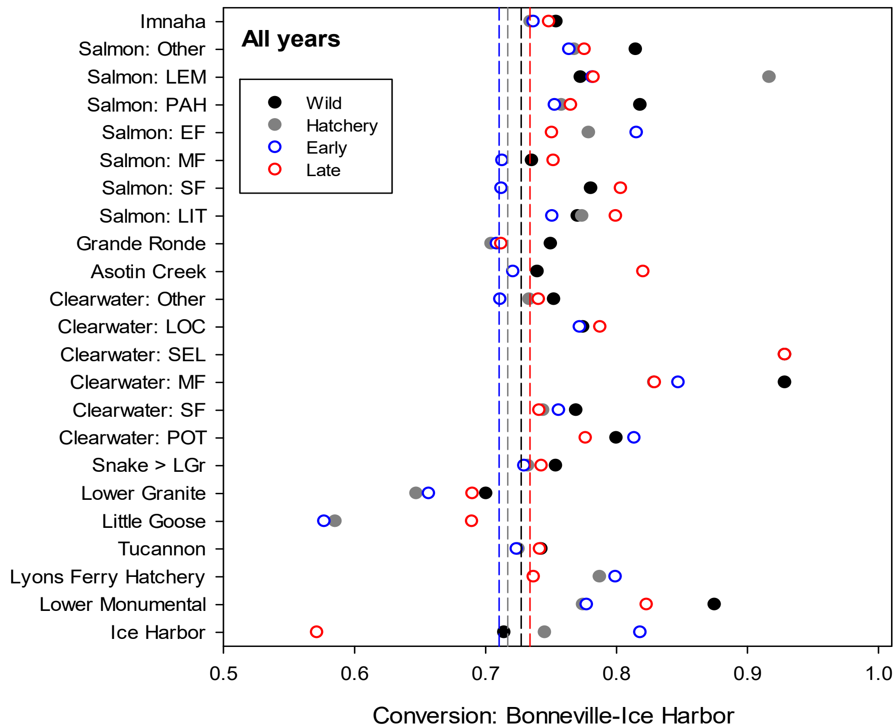


Figure 57. Population-specific reach conversion estimates from Bonneville Dam to Ice Harbor Dam in 2005-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.727); gray = hatchery fish (0.717); blue = early-run migrants (0.710); red = late-run migrants (0.734). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

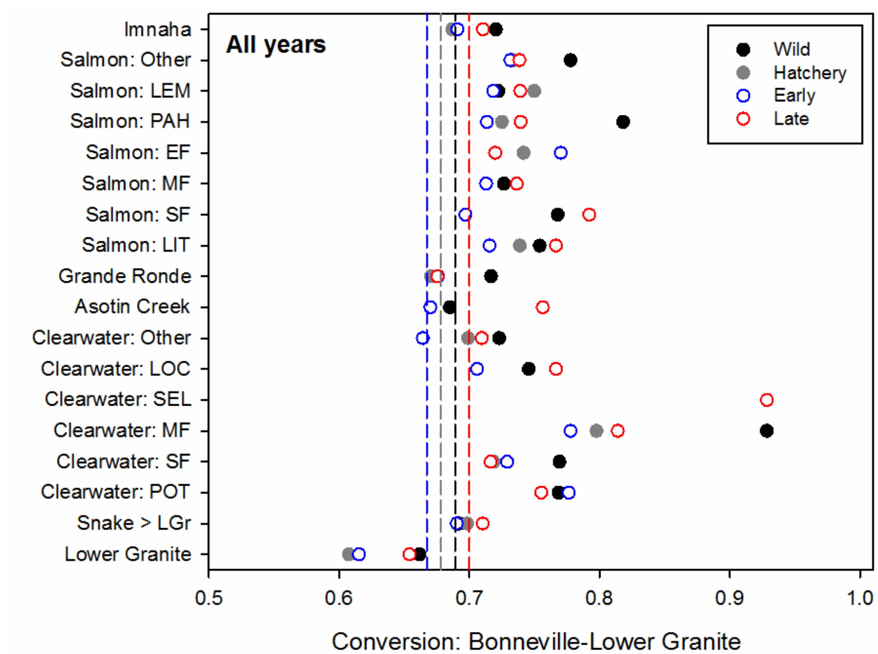


Figure 58. Population-specific reach conversion estimates from Bonneville Dam to Lower Granite Dam in 2005-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.689); gray = hatchery fish (0.678); blue = early-run migrants (0.667); red = late-run migrants (0.700). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

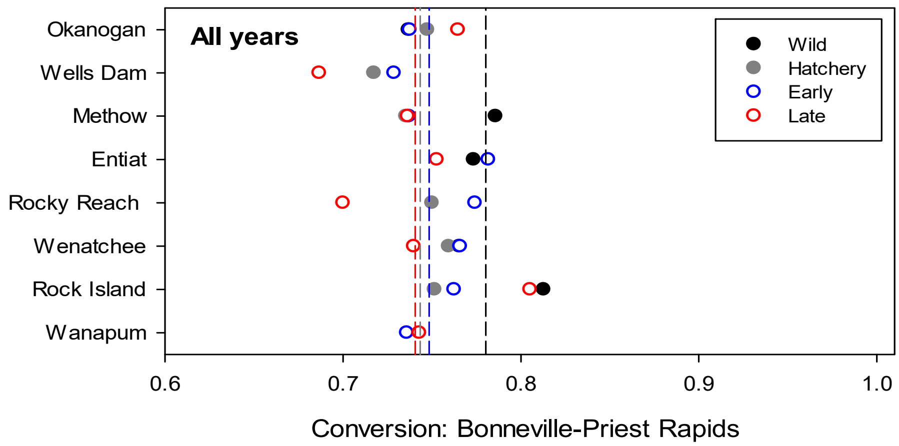


Figure 59. Population-specific reach conversion estimates from Bonneville Dam to Priest Rapids Dam in 2005-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.780); gray = hatchery fish (0.743); blue = early-run migrants (0.748); red = late-run migrants (0.741). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

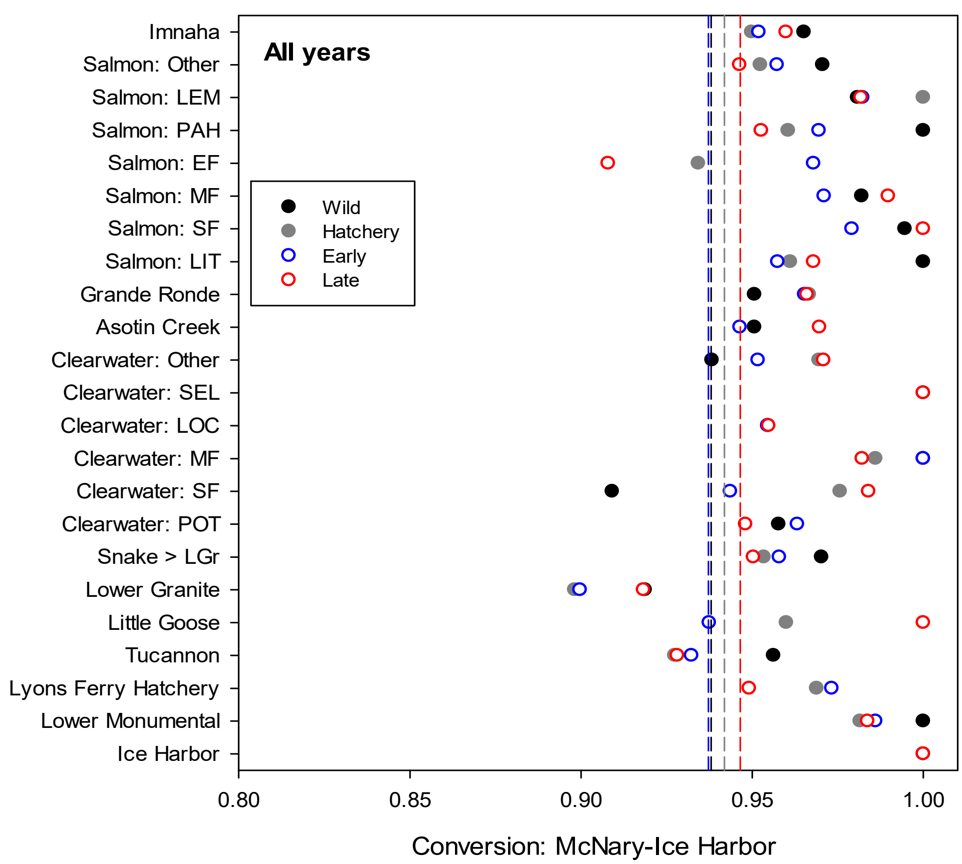


Figure 60. Population-specific reach conversion estimates from McNary Dam to Ice Harbor Dam in 2005-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.938); gray = hatchery fish (0.942); blue = early-run migrants (0.937); red = late-run migrants (0.947). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

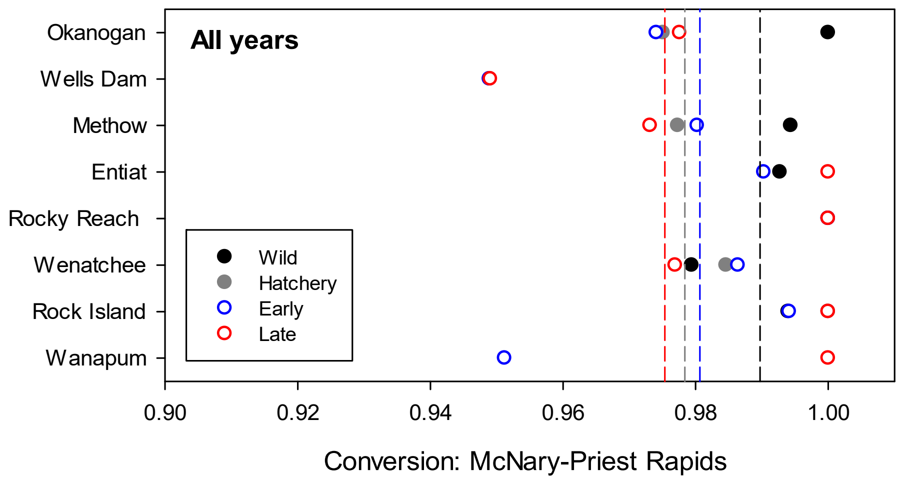


Figure 61. Population-specific reach conversion estimates from McNary Dam to Priest Rapids Dam in 2005-2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.990); gray = hatchery fish (0.978); blue = early-run migrants (0.981); red = late-run migrants (0.975). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

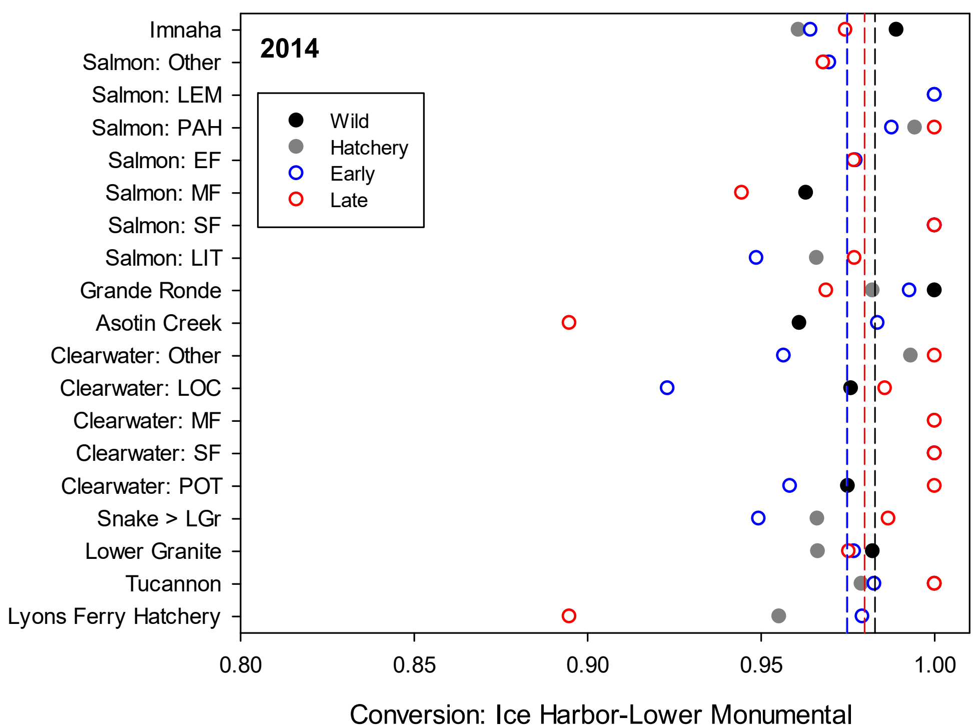


Figure 62. Population-specific reach conversion estimates from Ice Harbor Dam to Lower Monumental Dam in 2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.983); gray = hatchery fish (0.975); blue = early-run migrants (0.975); red = late-run migrants (0.980). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

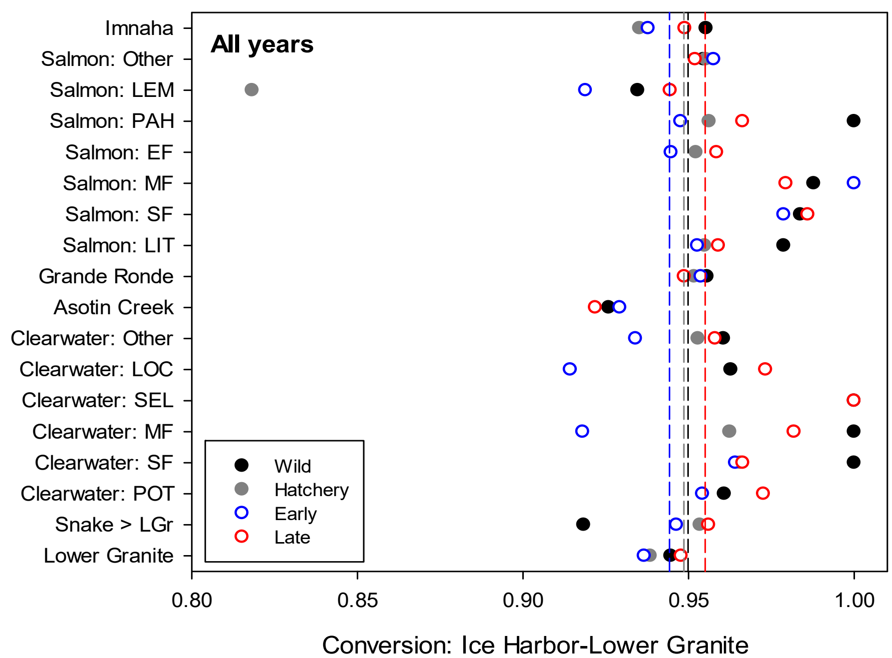


Figure 63. Population-specific reach conversion estimates from Ice Harbor Dam to Lower Granite Dam in 2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.986); gray = hatchery fish (0.985); blue = early-run migrants (0.983); red = late-run migrants (0.988). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

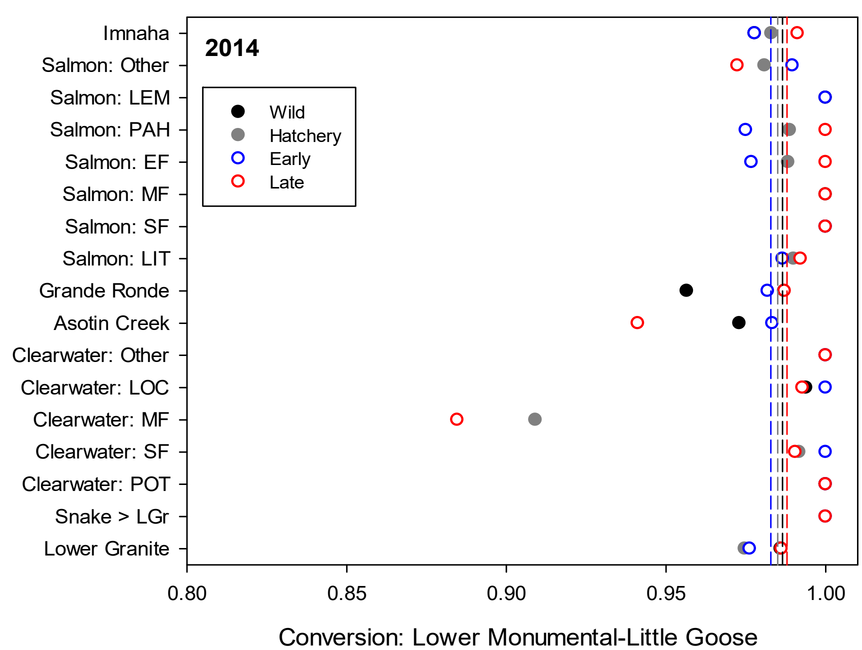


Figure 64. Population-specific reach conversion estimates from Lower Monumental Dam to Little Goose Dam in 2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.950); gray = hatchery fish (0.949); blue = early-run migrants (0.944); red = late-run migrants (0.955). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

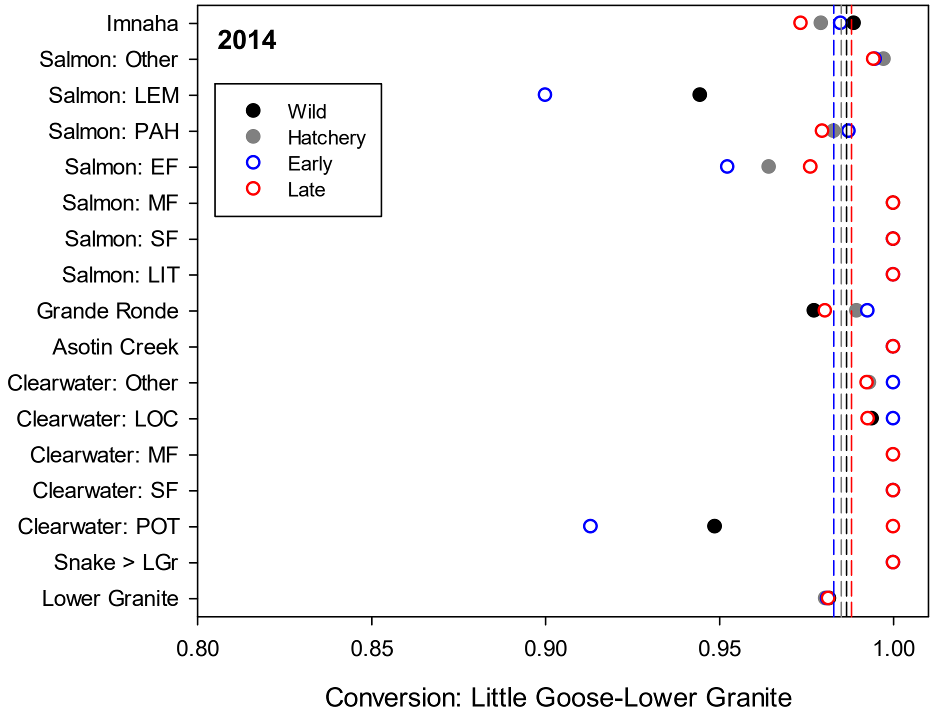


Figure 65. Population-specific reach conversion estimates from Little Goose Dam to Lower Granite Dam in 2014. Dashed vertical lines are estimates for the aggregate groups: black = wild fish (0.984); gray = hatchery fish (0.989); blue = early-run migrants (0.987); red = late-run migrants (0.988). Early- and late-run based on 26 August run separation date at Bonneville Dam. Only populations with ≥10 steelhead included.

FCRPS Reach Conversion – Summary

Key findings

- Reach conversion point estimates varied by year, rear-type, run-timing and population
- Conversion between adjacent FCRPS dams was > 0.95 for most populations, in most years
- The lowest conversion estimates were in the Bonneville–The Dalles reach (~ 0.80 - 0.90 for most groups)
- Bonneville-Lower Granite conversion was ~ 0.70 for aggregate Snake River populations and rear-type groups
- Conversions were often +0.01 to +0.04 higher for wild and late-run fish than for hatchery and early-run fish
- Steelhead PIT-tagged at Snake River dams had lower survival, on average, than many other groups, suggesting a likely negative effect of juvenile transportation on aggregate samples (transport + in-river) summarized herein

Critical uncertainties

- PIT tag arrays were not installed at all FCRPS dams in all years, limiting comparisons across years and reaches
- Some populations, and especially wild groups, were under-represented in conversion estimates
- Fates of 'unsuccessful' fish were unknown but likely included harvest and strays
- Juvenile transportation effects were not assessed but likely contributed to reduced reach conversion

Technical recommendations

- Formal survival analyses that incorporate detection probabilities would improve precision and provide confidence intervals for reach conversion estimates
- Existing data could be mined to assess relationships between reach conversion and environmental covariates, including river environment and FCRPS operations
- Existing data could be mined to assess relationships between reach conversion and biological covariates, including fish traits (e.g., migration timing, age, origin) and behaviors (e.g., fallback, temporary straying)
- Agencies currently use different methods for estimating PIT-based FCRPS reach conversion estimates. We recommend that methods be standardized to reduce confusion and potential misinterpretation

3.11 INTER-BASIN STRAYING

Methods – Inter-basin straying can vary widely among populations and management groups. Consequently, calculating population-specific stray rates is important for assessing how much straying contributes to lowered FCRPS reach conversion rates. Detection of PIT-tagged steelhead strays was largely a function of monitoring effort, and all straying estimates reported below should be considered minimums because not all potential stray locations were monitored for any of the steelhead study populations. Detection of strays was especially limited in the early years of the study period, when far fewer tributary sites were monitored with PIT-tag antennas. The available data should, however, be useful for relative comparisons among groups and for understanding general straying patterns, including important spatial relationships.

PIT-tagged steelhead were identified as 'potential' strays when their final detection was at a site other than the expected terminal location. Within this broad definition, there were several categories. The most clear-cut type of straying was when a fish was last detected in a tributary other than their natal tributary (i.e., a John Day River fish last detected in the Walla Walla River). A second type of potential straying was when a steelhead overshot their natal tributary and was last detected at an upstream main stem dam with no evidence of tributary entry. A third type was when steelhead from the Snake River were last detected at upper Columbia

River dams, or vice versa, with no evidence of tributary entry. The latter two categories were relatively ambiguous with regards to straying because fish may have been mortalities (including harvest), may have entered undetected into either natal or non-natal tributaries, or may have spawned at main stem sites.

Importantly, many final steelhead detections were at JBS antennas as likely post-spawn kelts moved downstream. Detection histories for fish last detected at JBS sites were therefore individually reviewed and fish were assigned as 'homed' if they were detected in natal tributaries at appropriate times or as strays if they apparently spawned in non-natal tributaries before kelt emigration. In the absence of tributary detections, we did not consider fish last detected at dams downstream from natal tributaries as strays. We also did not evaluate local-scale, within-tributary homing and straying (i.e., if a South Fork Clearwater River steelhead strayed into the Middle Fork Clearwater River).

The straying estimates reported below were calculated separately for fish in each straying category (non-natal tributary, overshoot with no return, from the Snake to the upper Columbia, or from the upper Columbia to the Snake). Estimates were calculated by dividing the number of fish in the stray category by the total number in each population. This was a conservative estimation method because fish that were harvested in main stem fisheries or died during main stem migration were included in the denominators.

Lower Columbia River populations – Straying behaviors were detected by some steelhead from all of the populations downstream from the Columbia-Snake confluence (*Table 78*). Straying into non-natal tributaries was highest by steelhead from Mill Creek (19.2%), Walla Walla River (11.5%), Rock Creek (8.8%), and Fifteenmile Creek (6.9%). Straying to non-natal tributaries was lowest for steelhead from the Wind River (0.4%) and Deschutes River (0.8%).

Considerably more 'potential' strays from lower Columbia River populations were tributary overshoot fish last detected at upstream dams (*Table 78*). For example, 46.2% of Mill Creek steelhead were last detected at The Dalles, John Day, or McNary dams. Similarly, 17.6-22.6% of Rock Creek, Umatilla River, and John Day River steelhead were last detected upstream at McNary Dam. Additional fish from these groups were last detected at Snake River dams, including 9.7% of John Day River fish and 5.4% of Umatilla River fish. In the Walla Walla group, 33.8% was last detected at Snake River dams and another 0.7% was at upper Columbia River dams.

Steelhead that were identified as strays in non-natal tributaries were widely dispersed, although fish were more likely to stray into tributaries near natal locations than into more distant sites (*Table 79*). The largest number of Hood River strays was recorded in the Deschutes River, but many were also located in other Bonneville reservoir tributaries. The Deschutes River was also the location where the largest numbers of Klickitat River, Mill Creek, and Umatilla River strays were recorded. Strays from the John Day River were last recorded in several sites both upstream and downstream; the largest numbers were in the Umatilla, Deschutes, and Grande Ronde rivers. Strays from the Walla Walla River were concentrated in Snake River tributaries, and especially in the Tucannon River and at Lyons Ferry Hatchery, which was the rearing location for some Walla Walla River fish (*Table 79*).

Snake River populations – Steelhead from most Snake River populations strayed into non-natal tributaries at rates that were <3% (*Table 78*). However, several groups had higher straying, including the Lyons Ferry Hatchery and Tucannon River fish (7.4-7.5%), Asotin Creek fish (5.6%), and the group tagged as juveniles at Lower Granite Dam (4.0%).

As described in previous sections, many Tucannon River and Lyons Ferry Hatchery fish overshot these sites and were last detected upstream at Little Goose or Lower Granite Dams. Potential overshoot stray rates for these populations were 34.7% (Lyons Ferry) and 31.6% (Tucannon River). Small numbers of steelhead from many Snake River populations were last recorded at upper Columba River dams. Potential stray rates in this category were mostly <1%, with slightly higher estimates for Asotin Creek fish (1.4%) and those tagged at Lower Granite Dam (1.7%).

In general, the geographic distribution of Snake River strays included many fish in lower Columbia River tributaries and relatively limited straying among Snake River tributaries (*Table 80*). A notable exception was that Tucannon River steelhead strayed into many other Snake River tributaries. About a quarter of Tucannon River strays were last detected in the Deschutes, Umatilla, and Walla Walla rivers. The Deschutes River was also where a large majority of strays from the Clearwater, Grande Ronde, Salmon, and Imnaha rivers were last recorded. Fish from these populations also strayed into the John Day River, though at considerably lower rates than into the Deschutes River.

Upper Columbia River populations – Steelhead from most Snake River populations strayed into non-natal tributaries at rates ranging from 0.2% (Ringold Hatchery) to 5.9% (Wenatchee River) (*Table 78*). Small percentages were last detected at Snake River dams; the Yakima River had the highest percentage (2.1%) in this category. Large percentages of the upper Columbia fish were in the potential overshoot stray category: 20.8% (Ringold Hatchery), 34.3% (Wenatchee River), and 12.2% (Entiat River). Most of the strays from upper Columbia River tributaries into other tributaries were last recorded at nearby sites (*Table 80*). Small numbers from each population were also considered strays into the Deschutes River.

Table 78. Estimated potential stray rates based on last PIT-tag detection in non-natal tributaries, at dams upstream from natal tributaries, or at dams outside the migration route. W = wild origin; H = hatchery origin; U = unknown origin; All = all origin groups. Actual fates were unknown for all fish.

			Potential strays							
		Total	Non-natal tributary		Lower Columbia dam		Upper Columbia dam		Snake Dam	
Population	*Origin*	*n*	*n*	%	*n*	%	*n*	%	*N*	%
Columbia River below Snake River										
Wind R.	W	838	3	0.4	4	0.5	-	-	-	-
Hood R.	All	2122	22	1.0	15	0.7	-	-	-	-
	W	298	1	0.3	1	0.3	-	-	-	-
	H	1824	21	1.2	14	0.8				
Klickitat R.	All	1221	32	2.6	17	1.4	-	-	3	0.2
	W	26	-	-	1		-	-	-	-
	H	1195	32	2.7	16	1.3	-	-	3	0.3
Mill Cr.	W	52	10	19.2	24	46.2	-	-	-	-
Fifteenmile Creek	W	360	25	6.9	30	8.3	-	-	3	0.8
Deschutes R.	All	853	7	0.8	3	0.4	-	-	-	-
	W	848	7	0.8	3	0.4	-	-	-	-
	H	5	-	-	-	-	-	-	-	-
John Day R.	W	2359	105	4.5	532	22.6	11	0.5	228	9.7
Rock Cr.	W	34	3	8.8	6	17.6	-	-	-	-
Umatilla R.	All	1270	37	2.9	236	18.6	8	0.6	68	5.4
	W	739	27	3.7	114	15.4	5	0.7	50	6.8
	H	530	10	1.9	122	23.0	3	0.6	18	3.4
	U	1	-	-	-	-	-	-	-	-
Wallla Walla R.	All	2391	276	11.5	-	-	17	0.7	809	33.8
	W	599	54	9.0	-	-	5	0.8	90	15.0
	H	1792	222	12.4	-	-	12	0.7	719	40.1
Snake River										
Ice Harbor	All	65	-	-	-	-	-	-	-	-
	W	7	-	-	-	-	-	-	-	-
	H	55	-	-	-	-	-	-	-	-
	U	3	-	-	-	-	-	-	-	-
Low. Monumental	All	421	-	-	-	-	2	0.5	-	-
	W	72	-	-	-	-	-	-	-	-
	H	275	-	-	-	-	-	-	-	-
	U	72	-	-	-	-	-	-	-	-
Lyons Ferry	H	458	34	7.4	-	-	2	0.4	159	34.7
Tucannon River	All	3122	234	7.5	-	-	21	0.7	985	31.6
	W	471	61	13.0	-	-	3	0.6	142	30.1
	H	2651	173	6.5	-	-	18	0.7	843	31.8

Table 78. Continued.

			Potential strays							
		Total	Non-natal tributary		Lower Columbia dam		Upper Columbia dam		Snake Dam	
Population	*Origin*	*n*	*n*	%	*n*	%	*n*	%	*N*	%
Little Goose	All	55	1	1.8	-	-	-	-	-	-
	H	41	1	2.4	-	-	-	-	-	-
	U	14	-	-	-	-	-	-	-	-
Lower Granite	All	14731	591	4.0	-	-	57	0.4	-	-
	W	6516	273	4.2	-	-	21	0.3	-	-
	H	8214	318	3.9	-	-	36	0.4	-	-
	U	1	-	-	-	-	-	-	-	-
CWR: Other	All	1550	9	0.6	-	-	3	0.2	-	-
	W	113	1	0.9	-	-	1	0.9	-	-
	H	1437	8	0.6	-	-	2	0.1	-	-
CWR : Middle Fork	All	298	-	-	-	-	-	-	-	-
	W	17	-	-	-	-	-	-	-	-
	H	281			-	-			-	-
CWR : Lochsa R.	W	839	6	0.7	-	-	-	-	-	-
CWR : Potlatch R.	W	325	6	1.8	-	-	2	0.6	-	-
CWR : Selway R.	W	14	-	-	-	-	-	-	-	-
CWR : South Fork	All	1740	14	0.8	-	-	-	-	-	-
	W	19	-	-	-	-	-	-	-	-
	H	1721	14	0.8	-	-	-	-	-	-
Snake > LGR	All	1484	23	1.5	-	-	25	1.7	-	-
	W	152	5	3.3	-	-	2	1.3	-	-
	H	1332	18	1.4	-	-	23	1.7	-	-
Asotin Cr.	All	432	24	5.6	-	-	6	1.4	-	-
	W	421	24	5.7	-	-	6	1.4	-	-
	U	11	-	-	-	-	-	-	-	-
Grande Ronde R.	All	5360	186	3.5	-	-	16	0.3	-	-
	W	607	18	3.0	-	-	3	0.5	-	-
	H	4753	168	3.5	-	-	13	0.3		
Salmon : Other	All	4340	71	1.6	-	-	21	0.5	-	-
	W	94	1	1.1	-	-	-	-	-	-
	H	4246	70	1.6	-	-	21	0.5	-	-
Salmon : East Fork	H	578	13	2.2	-	-	5	0.9	-	-
Salmon : Lemhi R.	All	239	-	-	-	-	-	-	-	-
	W	226	-	-	-	-	-	-	-	-
	H	12	-	-	-	-	-	-	-	-
	U	1	-	-	-	-	-	-	-	-

Table 78. Continued.

			Potential strays							
		Total	Non-natal tributary		Lower Columbia dam		Upper Columbia dam		Snake Dam	
Population	*Origin*	*n*	*n*	%	*n*	%	*n*	%	*N*	%
Salmon: Little Sal.	All	1856	46	2.5	-	-	18	1.0	-	-
	W	63	-	-	-	-	-	-	-	-
	H	1793	46	2.6	-	-	18	1.0	-	-
Salmon : Middle Fork	W	242	1	0.4	-	-	1	0.4	-	-
Salmon : Pahsimeroi R.	All	1697	37	2.2	-	-	8	0.5	-	-
	W	25	1		-	-	-	-	-	-
	H	1672	36	2.2	-	-	8	0.5	-	-
Salmon : South Fork	All	271	4	1.5	-	-	-	-	-	-
	W	262	4	1.5	-	-	-	-	-	-
	U	9	-	-	-	-	-	-	-	-
Imnaha R.	All	4094	98	2.4	-	-	24	0.6	-	-
	W	1081	14	1.3	-	-	4	0.4	-	-
	H	3013	84	2.8	-	-	20	1.9	-	-
Columbia River above Snake River										
Yakima R.	All	389	7	1.8	-	-	12	3.1	8	2.1
	W	388	7	1.8	-	-	12	3.1	8	2.1
	U	1	-	-	-	-	-	-	-	-
Ringold Hatchery	H	5754	10	0.2	-	-	1198	20.8	50	0.9
Wenatchee R.	All	4653	273	5.9	-	-	1596	34.3	2	<0.1
	W	354	10	2.8	-	-	10	2.8	1	0.3
	H	4299	263	6.1	-	-	1586	36.9	1	0.2
Entiat R.	W	409	20	4.9	-	-	50	12.2	-	-
Methow R.	All	7419	101	1.4	-	-	-	-	3	<0.1
	W	276	10	3.6	-	-	-	-	2	0.7
	H	7143	91	1.3	-	-	-	-	1	<0.1
Okanogan R.	All	1566	20	1.3	-	-	-	-	4	0.3
	W	38	-	-	-	-	-	-	-	-
	H	1528	20	7.9	-	-	-	-	4	0.3

Table 79. Tributary sites where inter-basin steelhead strays were last detected, by lower Columbia River basin donor (source) population. W = wild origin; H = hatchery origin.

	Donor population									
Stray site	Wind	Hood	Klickitat	Mill	Fifteenmile	Deschutes	John Day	Rock	Umatilla	Walla Walla
Wind		2 H	1 H							
Little White Salmon	1 W	2 H	1 H							
Hood	1 W		14 H	1 W		1 W				
Klickitat		1			1 W	1 W	1 W			
Mill Cr										
Fifteenmile Cr			1 H			2 W				
Deschutes	1 W	1 W, 16 H	14 H	9 W	20 W		28 W	2 W	14 W, 7 H	6 W, 6 H
John Day					1 W	1 W			1 H	
Rock Cr						1 W	1 W		1 H	
Umatilla					1 W		40 W	1 W		
Wallla Walla					1 W		3 W		1 H	
Lyons Ferry										70 H
Tucannon River					1 W	1 W	9 W		6 W, 1 H	40 W, 127 H
Alpowa Cr										2 W, 4 H
Almota Cr										1 H
Clearwater							3 W		1 H	2 W, 6 H
Asotin Cr									1 W	2 W, 3 H
Grande Ronde							17 W			1 W
Salmon			1 H				2 W			
Imnaha									1 W	
Yakima							1 W		2 W	1 H
Wenatchee										
Entiat										1 H
Methow										1 W
Okanogan										
Other									1 W	2 H

Table 80. Tributary sites where inter-basin steelhead strays were last detected, by Snake River basin and upper Columbia River basin donor (source) populations. W = wild origin; H = hatchery origin.

	Donor population											
Stray site	LYFE	Tucannon	Clearwater	Asotin	G. Ronde	Salmon	Imnaha	Yakima	Wenatchee	Entiat	Methow	Okanogan
Wind												
Little White Salmon									1		1 H	
Hood		1 H	1 W			1 H						
Klickitat		1 H		1 W	1 H	5 H	1W, 2H	1 W				
Mill Cr		1 H										
Fifteenmile Cr			1 W, 1 H			5 H	2 H					
Deschutes	4 H	2 W, 20 H	6 W, 13 H	9 W	7 W, 125 H	3W,94H	8W,51H	3 W	1 W, 3 H	2 W	1 W, 7 H	1 H
John Day		5 H	1 H	1 W	5 W, 22 H	1W,24H	3W,20H					
Rock Cr		1 H	1 H			3 H	1W, 1H					
Umatilla		1 W, 14 H	1 H	1 W	1 H	1 H						
Wallla Walla		1 W, 20 H	1 H	1 W	1 W, 2 H	2 H	1 H					
Lyons Ferry												
Tucannon River	25 H		3 W, 2 H	4 W	1 W, 7 H	11 H	1 W	1 W				
Alpowa Cr	2 H	18 W, 19 H										
Almota Cr	2 H	2 H				1 H						
Clearwater		6 W, 41							4 W, 1 H			
Asotin Cr		25 W, 32 H	1 H		1 W, 4 H							
Grande Ronde		3 W, 9 H		5 W								
Salmon		3 H										
Imnaha		3 H			3 H	1 H						
Yakima		2 H			3 H	3 H	2 H					
Wenatchee							1 H	2 W		3 W	1 H	
Entiat		1 H				2 H	1 H		3 W, 77 H			
Methow		2 W, 2 H	1W, 1 H		2 W	5 H	2 H		2 W, 175 H	13W,1U		19 H
Okanogan			1 W	1 W	1 W	3W,5H	1 H		3 H	1 W		
Other	1 H	3 W, 2 H		1 W		2 H			2 H		9 W,82 H	

Inter-basin Straying – Summary

Key findings

- Apparent straying into non-natal tributaries was detected in nearly all populations
- Strays to non-natal tributaries were widely dispersed, although most were in tributaries near natal rivers
- Some of the highest stray rates into non-natal tributaries were by overshoot fish
- Strays from Snake River populations mostly entered lower Columbia River tributaries (e.g., Deschutes)
- Small percentages of Snake River steelhead strayed into the upper Columbia River and vice versa
- 'Potential' strays detected at FCRPS dams upstream from natal tributaries were common in some populations

Critical uncertainties

- Non-natal tributary stray estimates were likely minimums given limited PIT monitoring in many tributaries
- Final fates and reproductive status were unknown and therefore all stray assignments were inferred
- Status was ambiguous for fish last recorded at FCRPS dams upstream from natal tributaries
- Fish last detected in non-natal tributaries may have exited undetected and been misclassified as strays
- Also see lists for Sections 3.8.2 to 3.8.4

Technical recommendations

- Additional tributary PIT interrogation sites are needed to provide more robust straying evaluations
- Terminology associated with homing and straying / non-homing outcomes should be standardized
- Also see lists for Sections 3.8.2 to 3.8.4 (Tributary Overshoot)

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5.0 APPENDICES

APPENDIX A: ANNOTATED BIBLIOGRAPHY

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Study type: Radiotelemetry
Study site: Bonneville Dam
Study years: 1996-1997
Sample size: 1,640

Key findings:

- Fallback percent at Bonneville Dam was 4.8% (1996) and 9.1% (1997)
- Majority of fallbacks likely occurred over spillway with 80% during spill
  Steelhead that fell back within 24 h of dam passage did so 97-100% of time on days during spill
- Few fallback events were through the navlock, powerhouses, and ice/trash sluiceways

Caveats: Fallback routes were inferred: most routes were incompletely monitored

Bjornn et al. 2000b. Adult Chinook and sockeye salmon, and steelhead fallback rates at The Dalles Dam, 1996, 1997, and 1998. Technical Report 2000-2

Study type: Radiotelemetry
Study site: The Dalles Dam
Study years: 1996-1997
Sample size: 1,261

Key findings:

- Pre-spawn steelhead fallback at The Dalles Dam was 6.0% (1996) and 6.7% (1997)
  A smaller percentage of steelhead, 4% in both years, fell back before October 31
- Many (67-70%) steelhead were recorded at upstream sites prior to fallback at The Dalles
- ~29-43% of fallback events at The Dalles were on days with spill; routes were not monitored
  Steelhead that fellback within 24 h of dam passage did so 50-87% of time on days during spill
- Post-fallback survival to tributaries: 54.3% (1996); 40.0% (1997)
  Deschutes, Clearwater, John Day, Salmon, Klickitat rivers most common

Caveats: Navigation lock, ice/trash sluice, and juvenile bypass were not monitored for fallbacks

Bjorn et al. 2000c. Adult Chinook and sockeye salmon, and steelhead fallback rates at John Day Dam, 1996, 1997, and 1998. Technical Report 2000-3
Study type: Radiotelemetry Study years: 1996-1997 Study site: The Dalles Dam Sample size: 1,261 **Key findings:** ● Pre-spawn steelhead fallback at John Day Dam was 10.0% (1996) and 7.9% (1997) A smaller percentage of steelhead, 4% in both years, fell back before October 31 ● Many (67-70%) steelhead were recorded at upstream sites prior to fallback at The Dalles ● ~46-76% of fallback events at John Day were on days with spill; routes were not monitored ● Post-fallback survival to tributaries: 54% (1996); 59% (1997) Deschutes, Clearwater, John Day, rivers most common **Caveats:** Few routes were specifically monitored for fallbacks

Boggs et al. 2004. Fallback, reascension, and adjusted fishway escapement estimates for adult Chinook salmon and steelhead at Columbia and Snake river dams. TAFS 133:932-949
Study type: Radiotelemetry Study years: 1996-1997, 2000-2001 Study site: Lower Columbia and Snake R. Sample size: 4,051 **Key findings:** ● 21% of steelhead fell back at least once at a dam Mean (range) fallback % = 6.3% (4.3-9.1) at Bonneville; 6.3% (6.0-6.6) at The Dalles; 6.9% (5.3-10.1) at John Day; 8.8% (7.1-10.7) at McNary; 4.8% (3.9-5.6) at Ice Harbor; 2.8% (1.7-4.0) at L. Monumental; 6.3% (5.3-10.1) at L. Goose; 5.2% (2.7-8.4) at L. Granite

Boggs et al. 2005. Fallback, reascension, and adjusted fishway escapement estimates for adult Chinook salmon and steelhead at Columbia and Snake river dams, 1996-2003. Technical Report 2005-6

Study type: Radiotelemetry
Study years: 1996-1997, 2000-2003
Study site: Lower Columbia and Snake R.
Sample size: 4,695

Key findings:

- 24% of steelhead fell back at least once at a dam, excluding likely kelts
  Mean (range) fallback % = 5.8% (3.6-9.1) at Bonneville; 7.1% (6.0-10.5) at The Dalles; 6.9% (4.3-10.1) at John Day; 7.9% (4.9-10.7) at McNary; 4.8% (3.9-5.6) at Ice Harbor; 3.1% (1.7-4.2%) at L. Monumental; 6.0% (5.2-8.4) at L. Goose; 4.5% (5.2-8.4) at L. Granite

- Post-fallback reascension percentages varied
  Negatively related to number of fish that entered downstream tributaries

- Tributary overshoot estimates provided, but most fish were of unknown origin site

- Spillway likely route of fallback for 80% of steelhead in 2000; 7-25% in 2001-2003
  Percentages likely through ice/trash sluiceway (2-11%) and the navigation lock (7-37%)

- Fallback produced positive fishway count biases ranging from 1-12% for steelhead

Boggs et al. 2008. A multi-year summary of steelhead kelt studies in the Columbia and Snake rivers. Technical Report 2008-13

Study type: Ultrasound / PIT-tag
Study years: 2000-2004
Study site: Snake and lower Columbia
Sample size: PIT = 6,304; 3,483; 2,395

Key findings:

- Two chapters in this report became peer-reviewed papers
  Evans et al. (2008) Transportation of steelhead kelts to increase iteroparity in the Columbia and Snake rivers. NAJFM 28:1818-1827
  Keefer et al. (2008c) Iteroparity in Columbia River summer-run steelhead (Oncorhynchus mykiss): implications for conservation. CJFAS 65:2592-2605

Brannon et al. 2004. Population structure of Columbia River basin Chinook salmon and steelhead trout. RFS 12: 99-232

Study type: Literature review
Study years: n/a
Study site: Basin-wide
Sample size: n/a

Key findings:

- Steelhead have very diverse life history
  Ocean-maturing winter-run and stream-maturing summer-run are major lineages
  A- and B-run designations based on age, body size, and migration timing differences

- Lag between run timing and spawn timing produces variety of behaviors
  Use of non-natal tributaries for holding
  Overwintering in reservoirs and large tributaries

- Water temperature strongly influences migration timing and behavior

Bumgarner and Dedloff 2011. Lyons Ferry Hatchery Complex evaluation: summer steelhead annual report 2008 and 2009 run year. WDFW Technical Report

Study type: PIT, CWT
Study years: 2004-2008
Study site: Lower Snake River, Tucannon, Walla Walla
Sample size: ~1,450

Key findings:

- Many Tucannon River steelhead overshoot and pass Lower Granite Dam
  63% of natural origin fish overshot L. Granite
  66% of Tucannon endemic hatchery fish overshot L. Granite
  66% of Lyons Ferry Hatchery fish outplanted into the Tucannon overshot L. Granite

- Disposition of all Tucannon fish: 23-27% in Tucannon; 66-57% above L. Granite; 17-18% unknown

- Many Walla Walla steelhead overshoot and pass Ice Harbor and Lower Granite dams
  45-83% overshot Ice Harbor Dm
  9-30% overshot L. Granite

- Strays identified at a variety of locations, including tributaries >L. Granite like Asotin & Alpowa creeks

Burke & Jepson. 2006. Performance of passive integrated transponder tags and radio tags in determining dam passage behavior of Chinook salmon and steelhead. NAJFM 26:742-752

Study type: PIT/Radiotelemetry
Study years: 2002-2003
Study site: Lower Columbia and Snake R.
Sample size: 1,172

Key findings:

- Counts of fish passage between PIT and radiotelemetry were similar (largest difference 5.1%)

- Significant differences were found between PIT and radiotelemetry detections of fallbacks
  Difference at Bonneville -35.4%; McNary -55.0%; Ice Harbor -62.0%; and Lower Granite -62.0%

Caveats: PIT antennas cannot directly detect a fallback; had to infer fallback based on reascensions

Caudill et al. 2007. Slow dam passage in adult Columbia River salmonids associated with unsuccessful migration: delayed negative effects of passage obstacles or condition-dependent mortality? CAFJS 64:979-995

Study type: Radiotelemetry
Study years: 1996-1997, 2000-2002
Study site: Basin-wide
Sample size:

Key findings:

- Upstream migration passage times and survival through the FCRPS were evaluated

- Slow passage speeds at dams associated with reduced survival to tributaries

- Most steelhead rapidly passed individual dams, but many migrated slowly through the L. Columbia
  Attributed to thermoregulatory behaviors during warm water period

Colotelo et al. 2013. Passage distribution and Federal Columbia River Power System survival for steelhead kelts tagged above and at Lower Granite Dam. PNNL-22101

Study type: Acoustic telemetry — Study years: 2012
Study site: Lower Snake and Columbia rivers — Sample size: 324

Key findings:

- 37% kelt survival throughout the FCRPS (Lower Granite Dam to below Bonneville Dam)
  77% survival of wild fish, 23% survival of hatchery fish
  37% survival of females, 37% survival of males
  Kelt survival was generally higher during reservoir passage compared with dam passage
  Kelt survival was generally the highest for fish using spillways (91-94%) and spillway weirs (90-99%), lowest for fish passing the JBS (73-100%) or turbines (50-88%)
  Kelt predominately used the spillway or spillway weir to pass each dam

- Kelt survival varied by stock
  Kelts originating from different tributaries (Potlatch River, Joseph Creek, and Fish Creek) had significantly different survival probabilities through the same river reaches

- Median depth of < 10 meters for kelts first contacted in the forebay region of each dam

Caveats: Only good and fair condition kelts were tagged. Route-specific samples sizes of tagged kelts was small, particularly a downstream dams due to attrition of study fish.

Colotelo et al. 2014. Passage distribution and Federal Columbia River Power System survival for steelhead kelts tagged above and at Lower Granite Dam, year 2. PNNL-23051

Study type: Acoustic telemetry — Study years: 2013
Study site: Lower Snake and Columbia rivers — Sample size: 487

Key findings:

- 27% kelt survival through the FCRPS (Lower Granite Dam to below Bonneville Dam)
  Survival ranged from 66% - 98%, per reach
  Kelts predominately passed dams via spillways and spillway weirs and survival was highest for kelts that passed via spillway and spillway weirs
  Survival was the lowest in the forebay regions of dams

- 7 to 24 day range in travel times through the FCRPS (Lower Granite to below Bonneville Dam)
  Travel rates slowed in forebay regions, was fastest in lower river

- An estimate 18% of the 2012 pre-spawn run counted at LGR were detected as kelts at LGR the following spring

Caveats: Only good and fair condition kelts were tagged. Estimates of the proportion of the run observed as kelts were pooled for hatchery and wild origin fish. Route-specific sample sizes of tagged kelts were small, particularly a downstream dams due to attrition of study fish.

Evans et al. 2004. Identification and enumeration of steelhead kelts at a Snake River hydroelectric dam. TAFS 133:1089-1099

Study type: Ultrasound / PIT and Floy tag
Study years: 2000
Study site: Lower Granite Dam
Sample size: 1,353

Key findings:

- Kelt outmigration timing peaked in April and May
  Wild-origin kelts were more abundance than hatchery-origin kelts; wild kelt outmigration peaked in April, hatchery kelt outmigration peaked in May. Few kelts were observed in June.
  Female kelts were more abundance than males; female kelt outmigration peaked in April, male kelt outmigration peak in May
  A-run kelts more abundant than B-run kelts

- External condition of kelts was generally good (ca. 70%) but lower than that of pre-spawn adults

Evans et al. 2008. Transportation of steelhead kelts to increase iteroparity in the Columbia and Snake rivers. TAFS 28:1818-1827

Study type: PIT tag
Study years: 2002-2004
Study site: Lower Granite Dam, John Day Dam
Sample size: 5,878

Key findings:

- Low survival of Snake River origin kelts compared with mixed-stock kelts (Snake, Upper Columbia, Mid-Columbia)
  Repeat spawning rates of in-river Snake River kelts tagged at Lower Granite Dam were < 1%; Repeat spawning rates of in-river mixed-stock kelts tagged at John Day Dam were 11%.
  Skip spawning more prevalent in Snake River origin kelts (both in-river and transported) compared with mixed-stock kelts
  A second repeat spawning event was documented (i.e., Columbia River Basin steelhead are capable of spawning up to three times during their life time)

- Higher survival of transported Snake River kelts compared with in-river Snake River kelts
  Transported kelts from the Snake River were 2.3 time more likely to return, on average, than in-river migrating kelts from the Snake River.
  Benefits of transportation greatest in wild, female kelts, with transported wild female kelts 5.7 times more likely to return than their in-river counterparts.
  Despite higher return rates of transported kelts, repeat spawning rates were still low in transported kelts (< 3% repeat spawners)

Caveats: Small sample sizes of repeat spawners limited the studies ability to investigate the association between environmental conditions and repeat spawning rates.

Fryer et al. 2011, 2012, 2013, 2014, 2015. Upstream migration timing of Columbia Basin Chinook salmon, sockeye salmon, and steelhead in 2010-2014. Technical Report Series	
Study type: PIT Study site: Basin-wide	Study years: 2010-2014 Sample size: several thousand

Key findings:
- Reports provide dam-to-dam migration rates
- Some distribution and migration timing distributions in relation to age classes
- Adult steehead size and age information summarized for each annual sample
- B-run steelhead identified using adult size and timing data

Ham et al. 2012a. Hydroacoustic evaluation of adult steelhead fallback and kelt passage at McNary Dam, Winter 2010-2011. PNWD-4154	
Study type: Hydroacoustic Study site: McNary Dam	Study years: 2010-2011 Sample size: n/a

Key findings:
- Estimates of downstream passage; 8 of 14 turbines monitored
  946 (±196) steelhead-size targets passed through turbines from 17 December to 13 April
- Passage was higher at north and south ends of the powerhouse
- Passage through turbines appeared to decline during periods of unplanned spill

Caveats: Only 8 of 14 turbine intakes monitored

Ham et al. 2012b. Hydroacoustic evaluation of adult steelhead fallback and kelt passage at McNary Dam, Winter 2011-2012. PNWD-4362	
Study type: Hydroacoustic Study site: McNary Dam	Study years: 2011-2012 Sample size: n/a

Key findings:
- Estimates of downstream passage; 12 of 14 turbines monitored
  1,786 (±116) steelhead-size targets passed through turbines from 1 December to 16 April
- Passage was higher at north and south ends of the powerhouse
- Passage was concentrated near the ceiling of the turbine intake

Ham et al. 2015. Evaluation of adult steelhead passage with TSW spill during the winter of 2014-2015 at McNary Dam. PNNL-24856	
Study type: Hydroacoustic Study site: McNary Dam	Study years: 2014-2015 Sample size: n/a
Key findings: ● Experimental evaluation of temporary spillway weir operation Two study periods: Nov-Dec period had juvenile screens in place; Mar-Apr period had not screens Randomized blocks with TSW spill or no-spill ● In first period, TSW operation had higher total steelhead passage and proportionately lower turbine passage ● In first period, steelhead passage through turbines appeared to increase with river flow ● Second period was compromised by forced spill: no conclusions	

Harnish et al. 2014. Factor affecting route selection and survival of steelhead kelts at Snake River dams in 2012 and 2013. PNNL-23941	
Study type: Acoustic telemetry / PIT tags Study site: Lower Granite, Little Goose, and Lower Monumental dams	Study years: 2012 - 2013 Sample size: 811
Key findings: ● Kelt behavior and distribution in the forebay of dams was the best predictor of route selection Shallow migrating kelts disproportionately used spillway and spillway weirs Deep migrating kelts disproportionately used turbines and the JBS ● Kelts survival was related to fish condition and size Fair condition kelts were less likely to survive than good condition kelts Larger (fork length) kelts were less likely to survive than shorter kelts ● Kelts survival was related to dam operational strategies Kelt survival and travel times were positively related to discharge and % spill ● Kelts survival varied significantly by passage route Kelts survival was generally the highest for fish using spillways (71-94%) and spillway weirs (67-98%), followed by turbines (58-100%) and the JBSs (33-100%) **Caveats:** Only good and fair condition kelts were tagged. Route-specific passage sample sizes were often small. Several different and/or inter-related variables (interactions) were identified in survival models and the author's concluded that additional analysis are needed to identify mechanism that influence kelt survival.	

High et al. 2006. Temporary staging of Columbia River summer steelhead in coolwater areas and its effect on migration rates. TAFS 135:519-528

Study type: Radiotelemetry
Study years: 1996-1997, 2000
Study site: Lower Columbia River
Sample size: 2,900

Key findings:

- 61% of summer steelhead from upriver sites temporarily 'staged' in cool, lower Columbia R. tributaries
  Use of thermal refuges resulted in slower migration speeds, and later upriver migration timing
  Early-run fish (A-run) somewhat more likely to use refuge sites than late-run (B0run) fish
  Early-run fish used refuge sites ~twice as long, on average, as late-run fish

- Deschutes, Little White Salmon and White Salmon rivers were the most-used sites

Jepson et al. 2004. Evaluation of fallback of adult salmon and steelhead via juvenile bypass systems at Bonneville, John Day, McNary, and Ice Harbor dams: 2000-2001. Technical Report 2004-3

Study type: Radiotelemetry
Study years: 2000-2001
Study site: Lower Columbia and Snake R.
Sample size: 2,309

Key findings:

- Majority of steelhead fallbacks through the JBS system occurred at McNary Dam
  In the two years JBS fallback ranges were 0-11.4% at Bonneville; 8.8-10.2% at John Day; 25.9-29.2% at McNary; and 9.1-13.6% at Ice Harbor

- The majority of steelhead in both years and at all four dams re-ascended fishways (55%)

- Tributary overshoot was considered likely for 57% of the steelhead that fell back

Keefer et al. 2002. Migration of adult steelhead past Columbia and Snake River dams, through reservoirs and distribution into tributaries, 1996. Technical Report 2002-2

Study type: Radiotelemetry
Study years: 1996
Study site: Basin-wide
Sample size:

Key findings:

- Median dates that specific populations were collected at Bonneville Dam
  Hood (13 Jul), Klickitat (17 Jul), Tucannon (20 Jul), Lyons Ferry (21 Jul) White Salmon (8 Aug)
  L. White Salmon (11 Aug), Walla Walla (14 Aug), John Day (19 Aug), Deschutes (21 Aug)
  Umatilla (23 Aug), Grande Ronde (22 Aug), Salmon (24 Aug), Wind (29 Aug), Clearwater (10 Sep)

- Median reservoir exit / tributary entry dates for several populations
  Klickitat (2 Aug); Deschutes (31 Aug), John Day (19 Oct), Umatilla (25 Nov), Walla Walla (12 Dec)
  Clearwater (26 Oct), exit Lower Granite reservoir by non-Clearwater fish (13 Oct)

Caveats: All fish of unknown origin site: some population assignments uncertain

Keefer et al. 2005. Escapement, harvest, and unknown loss of radio-tagged adult salmonids in the Columbia River- Snake River hydrosystem. CJFAS 62:930-949

Study type: Radiotelemetry
Study site: Lower Columbia/Snake R.
Study years: 1996-1997, 2000-2002
Sample size: 5,324

Key findings:

- Table 4 summary for steelhead groups: hydrosystem-wide escapement
  Unknown origin: all three Esc estimates: 0.6295, 0.6824, 0.8321
  Known origin: all three Esc estimates: 0.765, 0.717, 0.909

- Figure 5 summary for steelhead: Unknown source
  Approximate range for each reach: all three Esc estimates
  BO-TD (0.74-0.88, 0.83-0.91, 0.92-0.97); TD-JD (0.88-0.94, 0.91-0.96, 0.94-0.97); JD-MN (0.90-0.93, 0.91-0.94,0.94-0.97); MN-IH/PR (0.88-0.93, 0.89-0.96, 0.92-0.96); IH-LM (0.96-0.97, 0.96-0.97, 0.97-0.99); LM-GO (0.90-0.97, 0.90-0.97, 0.95-0.98); GO-GR (0.95-0.97, 0.95-0.97, 0.96-0.98)

- Figure7 summary for steelhead: Known source
  Approximate range for each reach: all three Esc estimates
  BO-TD (0.91-0.93, 0.92-0.97, 0.97-1.00); TD-JD (0.91-0.96, 0.91-0.96, 0.97-0.99); JD-MN (0.93-0.96, 0.93-0.96,0.97-1.00); MN-IH/PR (0.95-0.98, 0.95-0.98, 0.95-0.98); IH-LM (0.97-0.99, 0.97-0.99, 0.98-0.99); LM-GO (0.96-0.98, 0.97-0.98, 0.98-0.98); GO-GR (0.99-0.99, 0.99-0.99, 0.99-0.995)

- Table 5 summary for steelhead: cost of fallback
  Unknown origin escapement (E^3) mean fallback=0.723; no fallback=0.876
  Known origin escapement (E^3) mean fallback=0.822; no fallback=0.904

Keefer et al. 2008a. Overwintering distribution, behavior, and survival of adult summer steelhead: variability among Columbia River populations. NAJFM 28:81-96

Study type: Radiotelemetry
Study years: 1996-1997, 2000-2003
Study site: Basin-wide
Sample size: ~5,900

Key findings:

- FCRPS overwintering estimates for steelhead that reached tributaries
  Overwintering defined by dam passage or first tributary entry from reservoir on or after 1 Jan
  ~12.4% of tagged steelhead overwintered (all years combined)
  ~6.8-19.6% of each annual sample overwintered

- FCRPS overwintering rates varied widely among steelhead populations
  ≤ 2% for many Bonneville reservoir populations and populations above Priest Rapids Dam
  ~4-28% for Deschutes, John Day, Umatilla, Walla Walla, Yakima populations
  ~5-10% for Lyons Ferry, Tucannon, Grande Ronde, Imnaha populations
  ~2-22% for Salmon River populations
  ~35-69% for Clearwater River populations

- FCRPS overwintering was strongly associated with migration timing
  Rates were: 0-1% (May, June), 6% (July), 7% (August), 27% (September), 43% (October)

- Overwintering steelhead moved up- and down-stream among all FCRPS reaches
  No definitive overwintering onset, but many fish reduced movement in November at ~8-10° C
  Movement nadir in early January
  Peak movement into tributaries in March

Caveats: Most fish were unknown origin site; Relatively few winter monitoring sites were operated

Keefer et al. 2008b. Transporting juvenile salmonids around dams impairs adult migration. Ecol. Appl. 18(8):1888-1900

Study type: Radiotelemetry and PIT
Study years: 199-2003
Study site: Basin-wide
Sample size: 518

Key findings:

- Evaluation of barging effects on adult steelhead fallback and survival to Snake River

- Barged steelhead had reduced survival, higher straying and higher fallback rates than in-river migrants

- Barged steelhead fell back at FCRPS dams 1.7 times more often than in0river migrants

Keefer et al. 2008c. Iteroparity in Columbia River summer-run steelhead (**Oncorhynchus mykiss*****): implications for conservation. CJFAS 65:2592-2605***

Study type: PIT tag
Study years: 2001-2004
Study site: Lower Columbia, Snake
Sample size: 2,542

Key findings:

- Upstream migration timing distributions for repeat spawners at Bonneville Dam
  Most consecutive-year spawners return relatively late (mid-Aug through mid-Sep)
  Most skip-year spawners return relatively early (late June through late August)

Caveats: Populations >Priest Rapids Dam likely under-sampled; none from below John Day Dam

Keefer & Peery. 2007. Summary of steelhead fallback during November at The Dalles Dam. UI Letter Report (16 Jan 2007)

Study type: Radiotelemetry
Study site: The Dalles Dam
Study years: 1996-1997, 2000-2003
Sample size: 4,571

Key findings:

- Fallback rates vary seasonally
  Over six study years: 1.4% (0.5-2.3%) of all steelhead that passed The Dalles fell back in November
  Of those that passed The Dalles in October, 4.7% fell back in November
  Of those that passed The Dalles in November, 47.8% fell back in November

- Estimated Nov fallback: *n* = 295 ('96); 1,530 ('97); 449 ('00); 5,160 ('01); 4,436 ('02); 7,005 ('03)

- Fallback may reduce adult steelhead escapement to tributaries
  ~54% of steelhead that fell back in November were last recorded in tributaries (up- and downstream)
  ~11% were reported harvested in main stem reservoirs
  ~35% were unaccounted for (last detection at dams or in reservoirs)

- Potential survival benefits of wintertime surface spill for steelhead that fall back at dams

Caveats: Fallback rates were only calculated for the month of November

Keefer et al. 2009. Behavioral thermoregulation and associated mortality trade-offs in migrating adult steelhead (*Oncorhynchus mykiss*): variability among sympatric populations. CJFAS 66:1734-1747

Study type: Radiotelemetry
Study site: Basin-wide
Study years: 1996-1997, 2000-2003
Sample size: 3,985

Key findings:

- Migration timing assessed for 14 populations at Bonneville Dam
  1st quartile: Hanford Reach, Tucannon River, Yakima River, Lyons Ferry
  2nd quartile: Imnaha, Walla Walla, Upper Columbia, Grande Ronde
  3rd quartile: Deschutes, mixed Snake, Umatilla, mixed Salmon
  4th quartile: mixed Salmon, Clearwater

- Migration timing at upriver dams was much later for steelhead that encountered warm water

Caveats: Most steelhead were of unknown-origin

Keefer & Caudill 2014a. Homing and straying by anadromous salmonids: a review of mechanisms and rates. REV FISH BIOL FISHER 24: 333-368	
Study type: Literature review Study site: n/a	Study years: n/a Sample size: n/a

Key findings:

- Stray rates for winter steelhead ranged from ~4-13%
- Stray rates for summer steelhead were typically 3-10%, but estimates were much higher for some groups
  Tucannon River steelhead had the highest stray rate (55%) among reviewed steelhead populations
- Steelhead straying in the Columbia / Snake associated with hatcheries, juvenile transportation
- Review clarifies definitions of straying-related behaviors and of methods for monitoring

Keefer et al. 2014a. PIT-tagged adult salmon and steelhead conversion from McNary Dam to Lower Granite Dam, 2002-2013. Tech Report 2014-2	
Study type: PIT Study site: Lower Columbia/Snake R.	Study years: 2002-2012 Sample size: 25,549

Key findings:

- Basic summary of text on page 34: the 'all fish' material for three reaches (not individual release sites)
  Wild: MCN-ICH (0.935), ICH-LGR (0.958), MCN-LGR (0.896)
  Hatchery: MCN-ICH (0.939), ICH-LGR (0.951), MCN-LGR (0.892)
- Basic summary of straying on page 36
  Wild: 138 of 8,586 (1.61%)strayed
  Hatchery: 276 of 16,963 (1.63%) strayed

Keefer & Caudill. 2014b. Estimating iteroparity in Columbia River steelhead using records archived in the Columbia River PIT tag information system (PTAGIS) database. Technical Report 2014-1	
Study type: PIT tag Study site: Basin-wide	Study years: 2000-2010 Sample size: 53,282 adults; 139 repeat spawners

Key findings:

- Timing of repeat winter-run fish at Bonneville
  1st migration (5 Apr – 19 Aug, *med* = 4 Jun); 2nd migration (25 Feb – 3 Sep, *med* 20 Jul)
- Timing of repeat summer-run fish at Bonneville
  2nd migration consecutive spawners relatively late (18 Jun – 29 Oct, *med* = 29 Aug)
  2nd migration skip spawners relatively early (20 Jun – 19 Oct, *med* = 2 Aug)

Caveats: many populations were not represented in the PIT tag dataset

Keefer et al. 2014c. Tucannon River steelhead radio- tagged adults at Lower Granite Dam. UI Letter Report (2 Jun 2014)

Study type: Radiotelemetry, PIT-tag
Study site: Tucannon, lower Snake
Study years: 2013-2014
Sample size: 111 (PIT)

Key findings:

- Minimum Tucannon River overshoot estimate: 62%
  Based on detection at Lower Granite Dam; Little Goose Dam did not have PIT antennas in 2013
- 53% of overshoot fish eventually returned to the Tucannon River
- 14% of overshoot fish were last detected in tributaries upstream from L. Granite (likely permanent strays)

Keefer et al. 2015a. Reach conversion rates of radio-tagged Chinook and sockeye salmon and steelhead in the Lower Columbia River, 2013-2014. Tech Report 2015-8

Study type: Radiotelemetry
Study site: Lower Columbia R.
Study years: 2013-2014
Sample size: 1,590

Key findings:

- Early steelhead tributary successful
  BO-TD (0.787-0.861); TD-JD (0.962-0.973); JD-MN (0.912-0.954); BO-MN (.0771-0.738)
- Early steelhead tributary censored
  BO-TD (0.790-0.893); TD-JD (0.974-0.977); JD-MN (0.920-0.975); BO-MN (0.719-0.773)
- Late steelhead tributary successful
  BO-TD (0.891-0.918); TD-JD (0.951-0.960); JD-MN (0.951-0.973); BO-MN (0.817-0.852)
  BO-TD (0.891-0.918); TD-JD (0.951-0.960); JD-MN (0.951-0.973); BO-MN (0.817-0.852)
- Late steelhead tributary censored
  BO-TD (0.912-0.947); TD-JD (0.951-0.969); JD-MN (0.965-0.981); BO-MN (0.846-0.879)
- Mean fallback % for early steelhead
  BO (2.9%); TD (3.6%); JD (7.7%); MN (19.4%)
- Mean fallback % for late steelhead
  BO (2.4%); TD (7.2%); JD (3.5%); MN (4.7%)
- Note that genetic data were reported (no need for population conversion estimates)
  Stray estimates were reported for several groups

Keefer et al. 2015b. Overwintering distribution and fallback behavior by adult radio-tagged steelhead in the Federal Columbia River Power System, migration years 2013-2014 and 2014-2015. Technical Report 2015-15

Study type: Radiotelemetry
Study site: Basin-wide
Study years: 2013-2015
Sample size: 1,588

Key findings:

- FCRPS overwintering estimates
  ~5.8-7.7% of early-run steelhead (of all released); 8.7-12.2% (after censoring harvest, unaccount)
  ~21.8-27.4% of late-run steelhead (of all released); 29.9-37.8% (after censoring harvest, unaccount)
- FCRPS overwintering much more likely for late-run fish

Keefer & Caudill 2015. Estimating thermal exposure of adult summer steelhead and fall Chinook salmon migrating in a warm impounded river. Ecol. Freshwater Fish doi:10.1111/eff.12238

Study type: Radiotelemetry and PIT
Study years: 2004, 2010-2012
Study site: Lower Snake River
Sample size: 50 radio, several thousand PIT

Key findings:

- Summary of temperature exposure in the lower Snake River for temperature-logger tagged fish
  Maximum temperatures (15.8-24.0 °C) were mostly encountered inside FCRPS dam fishways
  Degree day accumulations ranged from 74-973 DD (mean = 130 DD)
- ~50% of steelhead had thermoregulatory behaviors near the Lyons Ferry Hatchery outfall
- Degree days estimated for~10,000 steelhead using PIT tag detections

Khan et al. 2009. Hydroacoustic evaluation of overwintering summer steelhead fallback and kelt passage at The Dalles Dam 2008-2009. PNNL-18590

Study type: Hydroacoustic
Study years: 2008-2009
Study site: The Dalles Dam
Sample size: n/a

Key findings:

- Estimates of downstream passage through powerhouse intakes and operating sluices
  1,790 (±250) steelhead-size targets estimated from 1 November to 15 December (Period 1)
  1,766 (± 277) steelhead-size targets estimated from 1 March to 9 April (Period 2)
- Downstream passage primarily through sluiceway when available
  Period 1 and 2: 95% of events were through sluiceway, especially Sluice 1
- No clear diel passage patterns in Periods 1 & 3; Most activity in morning in Period 2
- Conclusion: operating TDA sluiceway effective for passing prespawn steelhead and kelt

Khan et al. 2010. Hydroacoustic evaluation of overwintering summer steelhead fallback and kelt passage at The Dalles Dam, 2009-2010. PNNL-19615

Study type: Hydroacoustic
Study years: 2009-2010
Study site: The Dalles Dam
Sample size: n/a

Key findings:

- Estimates of downstream passage through powerhouse intakes and operating sluices
  879 (±165) steelhead-size targets estimated from 1 November to 15 December (Period 1)
  62 (± 40) steelhead-size targets estimated from 16 December to 7 March (Period 2: sluice closed)
  1,985 (±243) steelhead-size targets estimated from 8 March to 10 April (Period 3)
- Downstream passage primarily through sluiceway when available
  Period 1: 92% of events were through sluiceway, especially Sluice 1
  Period 2: Turbine Unit 18 passed the majority of fish
  Period 3: 99% of events were through sluiceway, especially Sluice 1
- No clear diel passage patterns except most activity in morning in Period 2
- Conclusion: operating TDA sluiceway effective for passing prespawn steelhead and kelt

Khan et al. 2011. Hydroacoustic evaluation of overwintering summer steelhead fallback and kelt passage at The Dalles Dam, early spring 2011. PNNL-20431

Study type: Hydroacoustic
Study years: 2011
Study site: The Dalles Dam
Sample size: n/a

Key findings:

- Estimates of downstream passage through turbines when sluiceway was open
  215 (±98) steelhead-size targets passed through turbines on 9 days in March and April

- Main Unit 18 passed the majority of fish

Khan et al. 2013. Sluiceway operations for adult steelhead downstream passage at The Dalles Dam, Columbia River, USA. NAJFM 33:1013-1023

Study type: Hydroacoustic
Study years: 2008-2010
Study site: The Dalles Dam
Sample size: n/a

Key findings:

- This paper aggregates results from Khan et al. 2009, 2010, 2011 reports

Narum et al. 2008. Iteroparity in complex mating systems of steelhead trout. J. Fish Biol 72:45-60

Study type: Genetic stock identification
Study years: 2002
Study site: Lower Granite Dam
Sample size: 361

Key findings:

- Kelts from numerous Snake River origin stocks attempt outmigration
  Kelts from numerous stocks (Grande Ronde, Imnaha, Asotin Creek, Clearwater, Salmon and others) were identified via genetic analysis; demonstrating iteroparity was wide spread
- Iteroparity was not uniformly expressed in Snake River origin steelhead stocks
  Smaller body-sized (A-run) stocks were disproportionately detected as kelts relative to larger body-sized (B-run) stocks

Normandeau. 2011. Estimate of direct effects of steelhead kelt passage through the first powerhouse ice-trash-sluice and second powerhouse corner collector at Bonneville Dam Project #21464.008

Study type: Radiotelemetry + Balloon tag
Study years: 2011 (March)
Study site: Bonneville Dam
Sample size: 200

Key findings:

- Adult *O. mykiss* survival assessed: PH1 Ice-Trash sluiceway and PH2 Corner Collector
  48 hour survival was ~98% for both routes and was >99% when seal predation events excluded

- Passage-related injury rates were 1% for both routes

Caveats: Round Butte hatchery fish used as surrogates

Normandeau. 2014. Direct injury and survival of adult steelhead trout passing a turbine and spillway weir at McNary Dam. Project #20517.011	
Study type: Balloon tag Study site: McNary Dam	Study years: 2014 (March) Sample size: 88 and 130

Key findings:

- Survival and injury assessed after passing turbine unit 12 (*n* = 130)
  94.5% recapture rate
  1 hour survival = 90.7% (±5.0%); 48 hour survival = 90.7% (±5.0%)
  Malady-free estimate = 92.7% (±4.6%)

- Survival and injury assessed after passing temporary spillway weir (*n* = 88)
  96.6% recapture rate
  1 hour survival = 97.7% (±3.2%); 48 hour survival = 97.7% (±3.2%)
  Malady-free estimate = 97.7% (±3.2%)

- Some evidence that larger fish had higher mortality and injury rates

- Conclusion: Direct survival was higher and injury rate was lower for fish that passed TSW

Caveats: Round Butte hatchery fish used as surrogates

O'Connor et al. 2014. Lower Granite Dam juvenile fish collection channel prototype overflow weir and enlarged orifice biological evaluation, 2014. USACE Final Report	
Study type: PIT tag Study site: Lower Granite Dam	Study years: 2014 Sample size: 92

Key findings:

- Kelt incurred minor body damage during passage through the Lower Granite Dam juvenile bypass system
  ~ 15 - 25% of kelts traversing a prototype overflow weir or enlarged (14") gatewell orifice incurred minor body damage (subcutaneous scars or wounds) compared with controls (fish that did not pass prototype structures)

- Kelts spent an average of 2 hours in the juvenile bypass system
  Average and median travel times ranged from 1 - 3 hours depending on the route (14" orifice, overflow weir)
  Kelt travel times though the JBS were similar, albeit slightly longer, than those of juvenile steelhead

Caveats: Small (*n* < 25 fish per route) sample sizes of kelts. Study evaluated kelt injury rates and travel times through prototype structures in the LGR JBS and results may not be indicative of kelt passage through the more common 10" orifice.

Rayamajhi et al. 2013. Route-specific passage and survival of steelhead kelts at The Dalles and Bonneville Dams, 2012. PNNL-22461

Study type: Acoustic telemetry | Study years: 2012
Study site: Bonneville, The Dalles | Sample size: 14-177

Key findings:

- At The Dalles, 71-84% passed the spillway, 7% passed the sluiceway, and 9-29% passed the powerhouse
  Two samples, one tagged in Deschutes (n = 14) and one tagged in Snake River (n = 177)

- At The Dalles, passage survival estimates were 75% and 90% for all routes combined (two samples)
  Route-specific survival estimates were: 93% (sluiceway), 91% (spillway), and 53% (turbines

- At Bonneville, 51% passed the spillway, 12% passed the sluiceway, 16% passed the powerhouses, 18% passed the B2 Corner Collector, and 3% passed the PH2 juvenile bypass system (JBS)
  Two samples combined, one tagged in Deschutes (n = 24) and one tagged in Snake River (n = 138)

- At Bonneville, passage survival estimate was 87% for both samples and all routes combined
  Small sample sizes limited route×survival comparisons, but B2CC appeared to have the highest survival

Caveats: No evidence of statistically significant difference in survival or travel times for most comparisons. Route-specific samples size, however, were small and resulted in wide confidence intervals

Robards & Quinn. 2002. The migratory timing of adult summer-run steelhead in the Columbia River over six decades of environmental change. TAFS 131:523-536

Study type: Count data analysis | Study years: 20th Century
Study site: Multiple FCRPS dams | Sample size: n/a

Key findings:

- Bimodal passage at Bonneville Dam has shifted to unimodal over time
  Distinction between early (A-group) and late (B-group) has blurred

- Relative population abundance has changed through time

- Hatchery-origin steelhead now predominate
  1974-1999: 74% of early run and 85% of late run of hatchery origin

- Complex, multi-stage migrations are common across populations
  Function of river environment: river has warmed and peak flows have diminished
  Steelhead have thermoregulatory behaviors in summer, overwintering in winter
  Some shifts in timing for the aggregate early and late populations; shifts vary across dams

Wagner & Hillson. 1993. 1991 – Evaluation of adult fallback through the McNary Dam juvenile bypass system. WDFW Technical Report

Study type: Count data/floy tag
Study years: 1990-1991
Study site: McNary Dam
Sample size: ~2,700 floy-tagged

Key findings:

- Majority of fallbacks through juvenile bypass were steelhead (87% in 1991)
  7,268 fallbacks from 15 Sept to 30 Nov (1990); 11,148 fallbacks from 15 Sept to 15 Dec (1991)
  Peak fallback by steelhead was in Oct (1990) and Nov (1991)
  Some individuals fell back more than once, especially in Nov and Dec; 1/3 reascended after fallback

- Most fallback events were by hatchery steelhead but wild steelhead fell back at higher rates
  Fallback estimates for hatchery steelhead: 7.6% (1990); 6.4% (1991)
  Fallback estimates for wild steelhead: 15.1% (1990); 14.5% (1991)

- Fallback through the bypass had low mortality (<1%) but high injury rates (40-50%)
  Most injuries were bruising and injury rates increased with fish size

- Floy-tagged steelhead recovered (12-23%) in upstream and downstream tributaries
  Hatchery fish mostly (52-74%) in tributaries upstream from McNary (Dworshak H, L. Granite trap)
  Wild fish mostly (70-83%) in tributaries downstream from McNary (John Day R, Umatilla R)

Caveats: Many fallback fish likely passed McNary before the study began, compromising % estimates

Weiland et al. 2009. Evaluation of steelhead kelt passage into the Bonneville Dam second powerhouse corner collector prior to the juvenile migration seasons, 2007 and 2008. PNNL-18323

Study type: Hydroacoustic
Study years: 2007-2008
Study site: Bonneville Dam
Sample size: n/a

Key findings:

- Estimates of downstream passage through the PH2 corner collector (B2CC)
  174 (±8) and 223 (±7) steelhead-size targets identified in March and April of both years
  Peak counts in early April

- Fluid dynamics model described, shows favorable eddy for exposing fish to B2CC

- ~52% of steelhead-sized targets were observed swimming upstream away from B2CC

Wertheimer and Evans. 2005. Downstream passage of steelhead kelts through hydroelectric dams on the lower Snake and Columbia rivers. TAFS 134:853-865

Study type: Radio telemetry
Study site: Lower Snake River and Columbia River dams
Study years: 2000-2001
Sample size: 853

Key findings:

- Kelt passage was predominately via spillways
  During periods of spill, passage efficiencies were at or above 90%
  During periods of non-spill, turbine passage was common, with > 50% of kelts passing through turbines

- Kelt survival and travel times varied substantially by year and reach
  4-16% survival from Lower Granite Dam to below Bonneville Dam
  60-80% survival from McNary Dam or John Day Dam to below Bonneville Dam
  Travel rates were related to average flow (higher flow, higher rates of travel); with rates ranging from 0.43 to 2.47 km/hr; rates were highest in the non-impounded section of the river below Bonneville Dam
  Within a given reach, travel rates were significantly reduced in the forebay region dams

Caveats: Only good and fair condition kelts were tagged. Study was conducted well over decade ago, before corner collectors, removal spillway weirs, and other surface oriented routes were available to kelts

Wertheimer. 2007. Evaluation of a surface flow bypass system for steelhead kelt passage at Bonneville Dam, Washington. NAJFM 27:21-29.

Study type: Radio telemetry
Study site: Bonneville Dam
Study years: 2004 (with a comparison to 2002)
Sample size: 392

Key findings:

- Kelt travel times were related to discharge (greater discharge = faster rates of travel)
  Delay was greatest for kelts in the forebay region of Bonneville Dam, particularly at B1
  Kelts using the spillway generally had the fastest travel times (median = < 1.0 hrs)
  Travel times at B2 were increased following installation of the Corner Collector

- Majority of kelts (ca. 90%) used surface oriented routes of passage
  The proportion of fish using non-turbine routes at B2 increased after the Corner Collector was installed

Caveats: Travel time data were highly variable and relative comparisons across study years (2002, 2004) should be viewed cautiously due small sample sizes and different environmental conditions.

APPENDIX B: COLUMBIA BASIN MAPS AND PIT TAG DATA

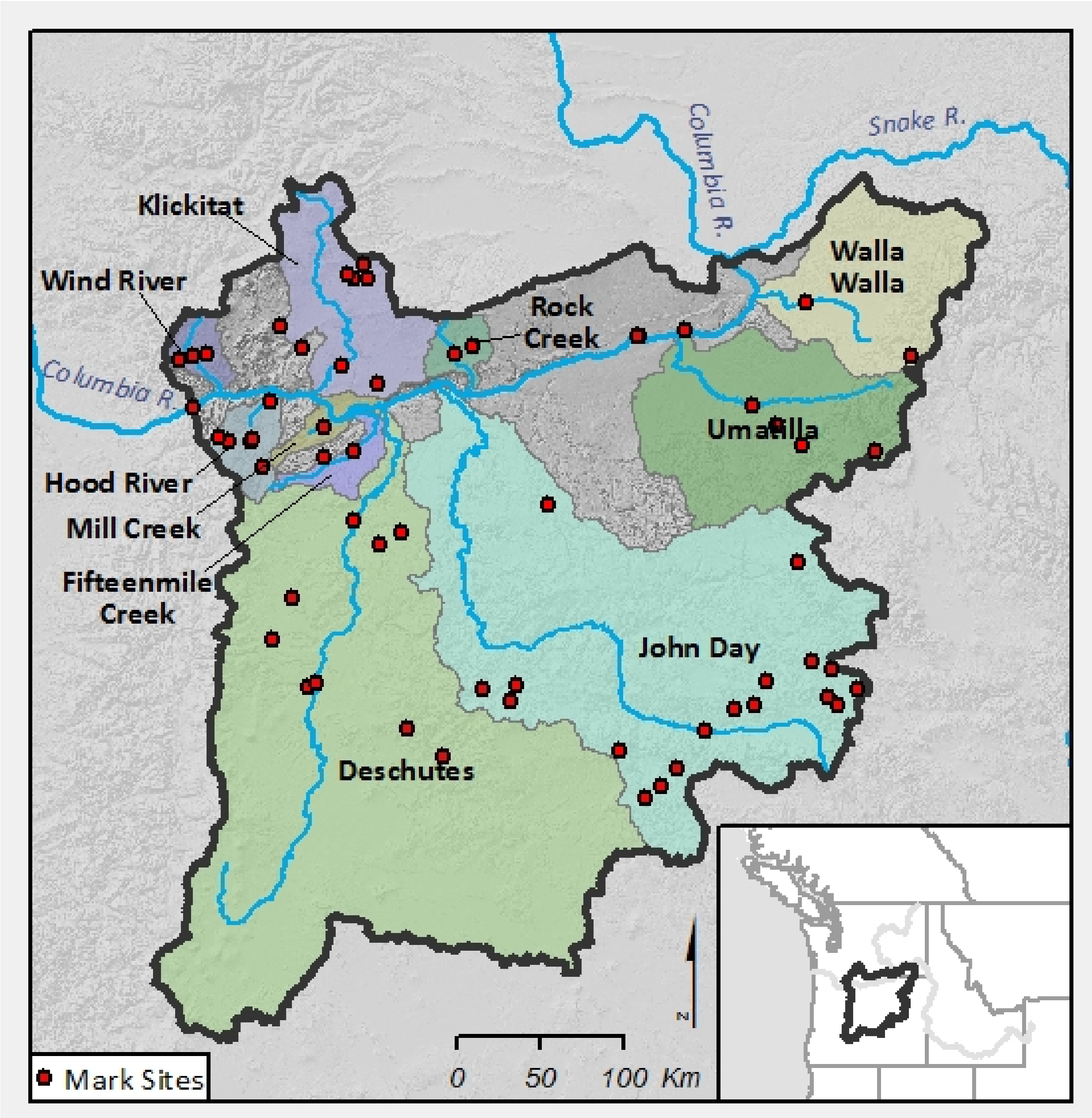

Figure B1. The Columbia River basin downstream from the Columbia River–Snake River confluence, showing the FCRPS dams and tributaries where steelhead were PIT-tagged as juveniles. Red circles represent sites where juvenile steelhead were PIT-tagged (PTAGIS Mark sites); not all sites were used in al years.

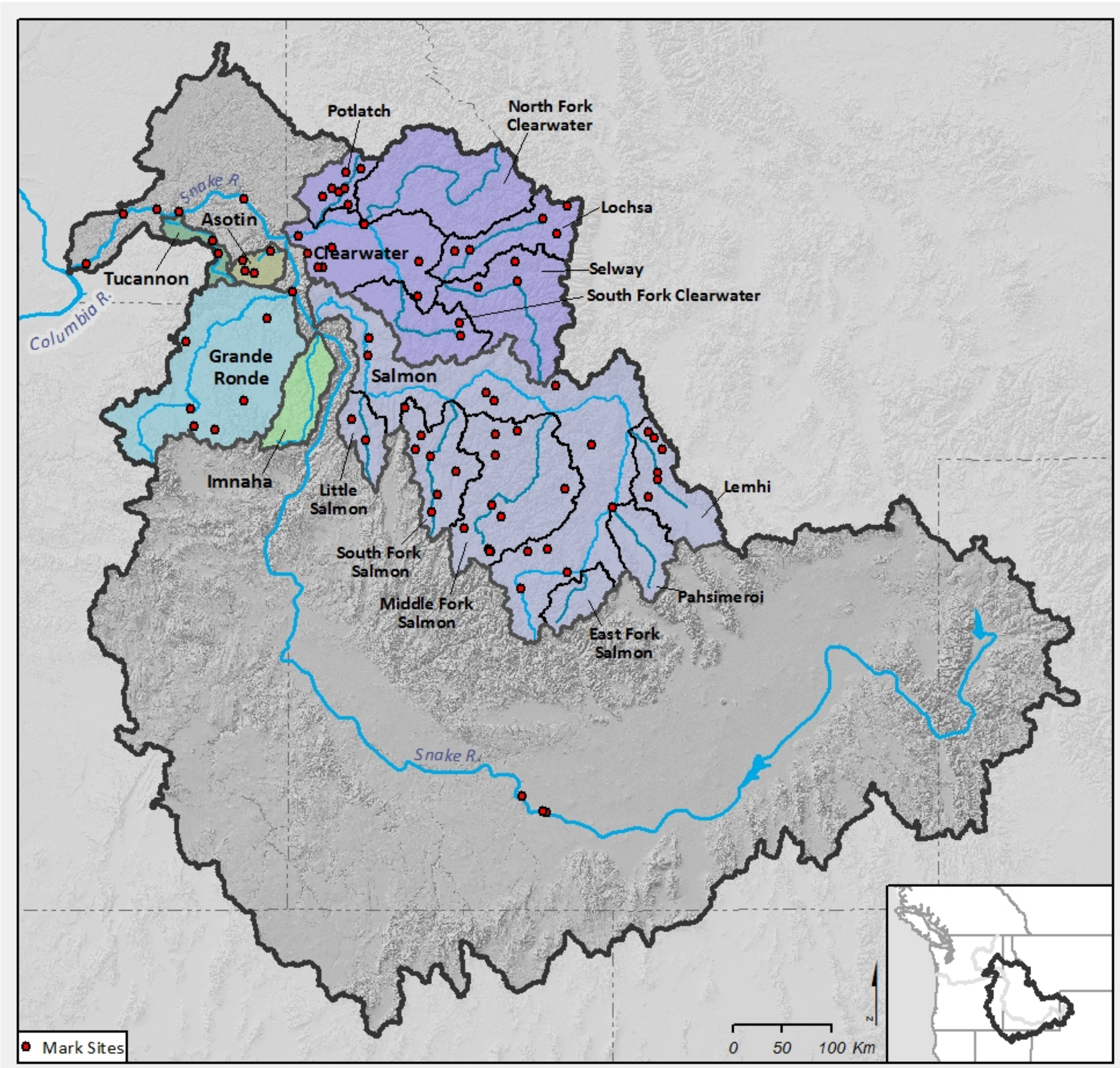

Figure B2. The Snake River basin, showing the FCRPS dams and tributaries where steelhead were PIT-tagged as juveniles. Secondary tributary delineations within the Clearwater and Salmon River drainages were used in analyses related to B-group steelhead. Red circles represent sites where juvenile steelhead were PIT-tagged (PTAGIS Mark sites); not all sites were used in al years.

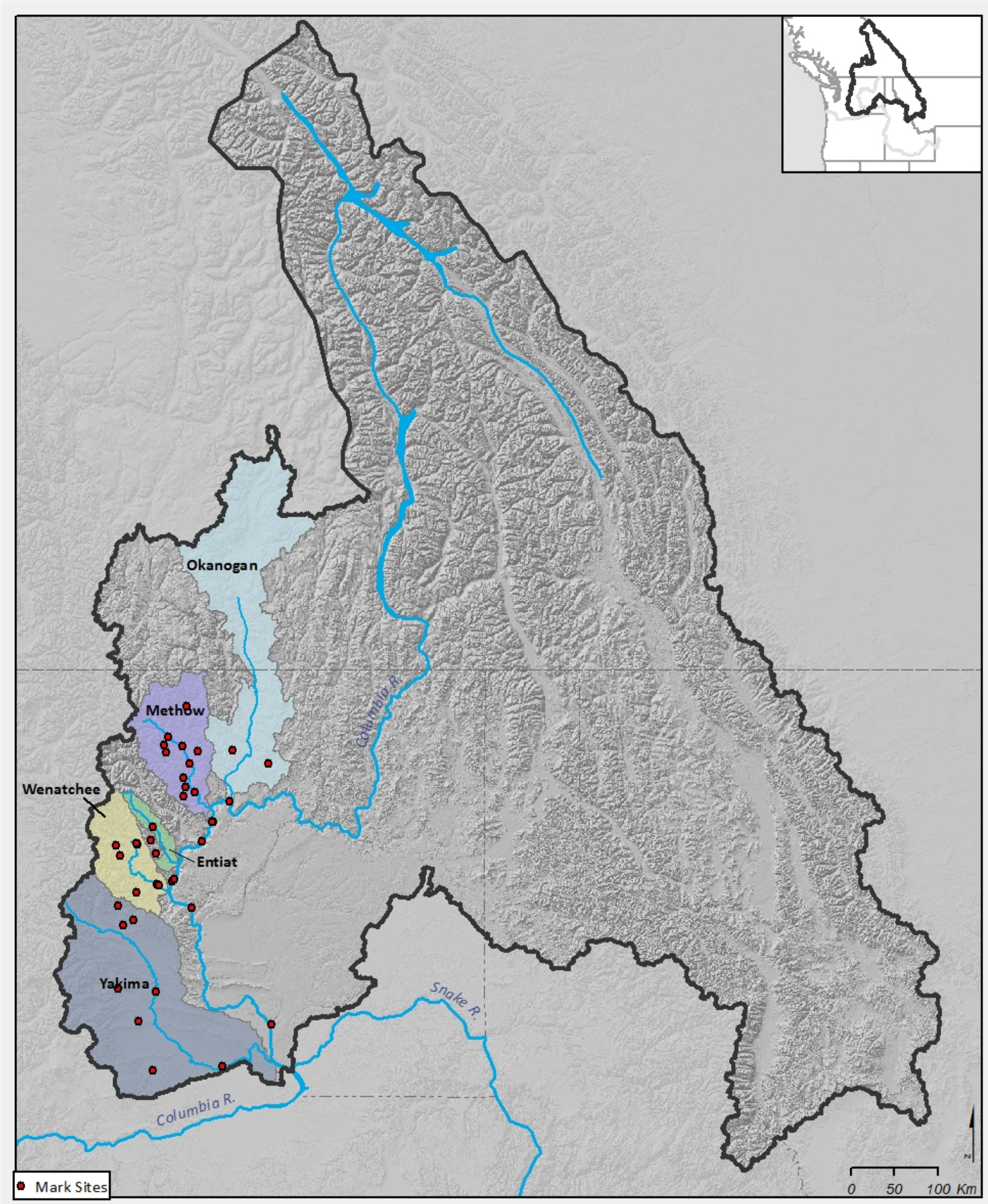

Figure B3. The upper Columbia River basin upstream from the Columbia River–Snake River confluence, showing the main stem dams and tributaries where steelhead were PIT-tagged as juveniles. Red circles represent sites where juvenile steelhead were PIT-tagged (PTAGIS Mark sites); not all sites were used in all years

Table B1. Tributaries and hatcheries where wild (W), hatchery (H) and unknown-origin (U) steelhead detected as adults at Bonneville Dam were PIT-tagged and released. Data was archived in PTAGIS and samples were screened for the data synthesis.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Columbia River below Snake River							
Lewis River	MERH	Merwin Hatch.	LEWISR	Lewis R			
Bonneville Dam[1]	BONAFF	BO adult fish facility	Adult-RT	PIT studies	346	3570	7870
		BO adult fish facility	Adult-RT	Radiotelemetry studies			1517
	COLR3	Lewis R to Bonneville	COLR3	PIT studies	579	1289	
Wind River	PANT2C	Panther Cr	PANT2C	Panther Cr	78		
	TROUTC	Trout Cr	TROUTC	Trout Cr	286		
	WIND2R	Wind R	WIND2R	Wind R	485		
White Salmon River	RATTLC	Rattlesnake Cr	RATTLC	Rattlesnake Cr	1		
	WHITSR	White Salmon R	WHITSR	White Salmon R			3
Hood River	BLKBAS	Blackberry Acc. Site	COLR4	Bon to JD Dam		3	
	HOODEF	EF Hood R	HOODEF	EF Hood R	45	33	
	HOODMF	MF Hood R	HOODMF	MF Hood R	9	18	
			HOODR	Hood R		9	
	HOODR	Hood R	HOODR	Hood R	222	133	
	HOODWF	WF Hood R	HOODR	Hood R	21	7	
	LAKEBR	Lake Branch (WF trib)	LAKEBR	Lake Branch (WF trib)	1		
	OASP	Oak Springs Hatch.	BLKBAS	Blackberry Acc. Site		128	
			COLR4	Bon to JD Dam		4	
			HOODEF	EF Hood R		255	
			HOODMF	MF Hood R		39	
			HOODR	Hood R		306	
			HOODWF	WF Hood R		156	
			PARK	Parkdale Hatchery		295	
			SNDTAP	Sandtrap Acc. Pond		436	
	PARK	Parkdale Hatchery	COLR4	Bon to JD Dam		1	
Klickitat River	BRUS2C	Brush Cr	BRUS2C	Brush Cr	1		
	SKAM	Skamania Hatch.	KLICKR	Klickitat R		1193	
	SWALEC	Swale Cr	SWALEC	Swale Cr	1		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Klickitat River	TEPEEC	Teepee Cr	TEPEEC	Tepee Cr	5		
	WHEELC	Wheeler Canyon	WHEELC	Wheeler Canyon	3		
	WHITEC	White Cr	WHITEC	White Cr	15		
	WHITWF	WF Shite Cr	WHITWF	WF Shite Cr	1		
	-	Unknown	KLICKR			2	
Mill Creek	MILL3C	Mill Cr	MILL3C	Mill Cr	52		
Fifteenmile Creek	15MILC	Fifteenmile Cr	15MILC	Fifteenmile Cr	326		
			EIGH2C	Eightmile Cr	39		
	EIGH2C	Eightmile Cr	EIGH2C	Eightmile Cr	1		
Deschutes River	BAKEOC	Bakeoven Cr	BAKEOC	Bakeoven Cr	37		
	BCHINL	Lake Billy Chinook	BCHINL	Lake Billy Chinook		5	
	BUCKHC	Buckhollow Cr	BUCKHC	Buckhollow Cr	59		
	CROOK1	Crooked R	CROOK1	Crooked R	1		
	MCKA2C	McKay Cr	MCKA2C	McKay Cr	8		
	OCHOCC	Ochoco Cr	OCHOCC	Ochoco Cr	1		
	ROU	Round Butte Dam	PERTAL	Pelton Dam tailrace	6		
	ROUFTF	Round Butte Trans Fac	PERTAL	Pelton Dam tailrace	9		
	ROUFTF	Round Butte Trans Fac	ROUFTF	Round Butte Trans Fac	4		
	SHTIKC	Shitike Cr	SHTIKC	Shitike Cr	8		
	TROU2C	Trout Cr	TROU2C	Trout Cr	707		
	WARMSR	Warm Springs R	WARMSR	Warm Springs River	10		
John Day Dam	JDA	John Day Dam	COLR3	Lewis R to Bon		1	15
			COLR4	Bonneville to JD Dam		27	133
			COLR5	JD Dam to Snake R		7	311
			JDABYP	JD bypass flume		6	
John Day River	BEAR2C	Bear Cr	BEAR2C	Bear Cr	15		1
	BEECHC	Beech Cr	BEECHC	Beech Cr	1		
	BEECEF	EF Beech Cr	BEECEF	EF Beech Cr	3		
	BRDG2C	Bridge Cr (MF)	BRDG2C	Bridge Cr (MF)	2		20
	BRIDGC	Bridge Cr	BRIDGC	Bridge Cr	315		18
	CABLNF	NF Cable Cr	CABLNF	NF Cable Cr.	1		
	CAMP2C	Camp Cr (MF)	CAMP2C	Camp Cr (MF)	46		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
John Day River	CLEA2C	Clear Cr (MF)	CLEA2C	Clear Cr (MF)	1		
	GABLEC	Gable Cr	GABLEC	Gable Cr	8		3
	GRBLDC	Granite Boulder Cr	GRBLDC	Granite Boulder Cr	3		
	JDAR1	Mouth to NF	JDAR1	Mouth to NF	12		
	JDAR2	NF to headwater	JDAR2	NF to headwater	442		
	JDARMF	MF John Day R	JDAR2	NF to headwater	2		
		MF John Day R	JDARMF	MF John Day R	446		
	JDARNF	NF John Day R	JDARNF	NF John Day R	7		
	JDARSF	SF John Day R	JDARSF	SF John Day R	780		
	JSFBC	Black Canyon Cr (SF)	JSFBC	Black Canyon Cr (SF)	57		
			-	Unknown	2		
	JSFDC	Deer Cr	JSFDC	Deer Cr	3		
	JSFMC	Murderer's Cr (SF)	JSFMC	Murderer's Cr (SF)	149		2
	MURDSF	SF Murderer's Cr	MURDSF	SF Murderer's Cr	1		
	ROCK4C	Rock Cr (trib to JD R)	ROCK4C	Rock Cr (trib to JD R)	15		
	SUMI2C	Summit Cr	SUMI2C	Summit Cr	1		
	VNGRC	Vinegar Cr	VNGRC	Vinegar Cr	3		
Rock Creek	ROCK2C	Rock Cr	ROCK2C	Rock Cr	22		
	SQAW3C	Squaw Cr	SQAW3C	Squaw Cr	12		
Umatilla River	BIRCHC	Birch Cr	BIRCHC	Birch Cr	101		
	IRRI	Irrigon Hatchery	BONP	Bonifer Sp Acc Pond		2	
			FEEDCN	Feed Diversion Canal		15	
			MEACHC	Meacham Cr		64	
			MINP	Minthorn Acc Pond		151	
			MXWLCN	Maxwell Div Canal		27	
			PENP	Pendleton Acc Pond		140	
			THOP	Thornhollow Acc Pond		9	
			TMFFBY	Three Mile Falls forebay		1	
			UMAR	Umatilla R		95	
	MCKAYC	McKay Cr	MCKAYC	McKay Cr	1		
	MEACHC	Meacham Cr	MEACHC	Meacham Cr	136		
	TMF	Three Mile Falls Dam	TMFFBY	Three Mile Falls forebay	3		
			TMFTAL	Three Mile Falls tailrace	10		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Umatilla River			UMAR	Umatilla R	436	18	
	UMAH	Umatilla Hatch	BONP	Bonifer Sp Acc Pond		1	
			MINP	Minthorn Acc Pond		3	
			PENP	Pendleton Pond		4	
			IMQP	Imeques Acc Pond	35		
			UMAR	Umatilla R		17	
McNary Dam	MCN	McNary Dam	HATRCK	Hat Rock SP		87	
			MCNGWL	MCN gatewells	8	18	
			MCNTAL	MCN tailrace		38	
Walla Walla River	LYFE	Lyons Ferry	DAYP	Dayton Acc Pond		533	
			TOUCHR	Touchet R		704	
			WALLAR	Walla Walla R		530	
	MILLC	Mill Cr	MILLC	Mill Cr	58		
	TOUCHR	Touchet R	DAYP	Dayton Acc Pond	35		
			TOUCHR	Touchet R	176		
	WALLAR	Walla Walla R	WALLAR	Walla Walla R	321		
	WALLSF	SF Walla Walla R	WALLSF	SF Walla Walla R	1		
	YELHKC	Yellowhawk Cr	YELHKC	Yellowhawk Cr	9		
	-	Unknown	WALLAR	Walla Walla R		1	
Snake River							
Ice Harbor Dam	IHR	Ice Harbor Dam	IHRBYP	IH bypass flume	2	20	3
L. Monumental Dam	LMN	L. Monumental Dam	IHRTAL	Ice Harbor tailrace		1	
			LMNBYP	LM bypass flume	72	259	38
			LMNDTG	Bwtwn coll flume & dewatering fac.		8	
			LMNTAL	LM tailrace		1	1
			SNAKE1	Mouth to Palouse R		6	31
			SNAKE2	Palouse R to Clearwater R		1	16
Lyons Ferry	LYFE	Lyons Ferry Hatch	LYFE	Lyons Ferry Hatch		458	
Tucannon River	LYFE	Lyon's Ferry	TUCR	Tucannon R		1958	
	TUCH	Tucannon Hatch	TUCR	Tucannon R		626	
	TUCR	Tucannon R	TUCR	Tucannon R	471	67	

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Little Goose Dam	LGS	Little Goose Dam	LGSDTG	Collection Flume/Pipe		3	
			LGSTAL	Little Goose tailrace		24	
			SNAKE2	Palouse R to Clearwater R		14	
Lower Granite Dam	LGR	Lower Granite Dam	LGRCOL	Collection Channel		14	
			LGRGWL	Gatewells		114	
			LGRRBR	Diversion gate to barge	4851	6053	
			LGRRRR	Diversion gate to river	1663	2024	
	LGR	Lower Granite Dam	LGRTAL	Tailrace		2	
			SNAKE2	Palouse R to Clearwater R		7	
			-	Unknown	1		
	-	Unknown	LGRRBR	Diversion gate to barge	1		
Snake River > LGR Dam	NISP	Niagara Springs	HCD	Hells Canyon Dam		6	
			SNAKE4	Salmon R to Hells Canyon Dam		971	
	SNKTRP	Snake Trap	SNKTRP	Snake Trap	152	355	
Clearwater River	AMERR	American R	AMERR	American R	5		
	BIGEC	Big Bear Cr	BIGBEC	Big Bear Cr	220		
	BRUSHC	Brushy Fk Cr	BRUSHC	Brushy Fk Cr	2		
	CFCTRP	Crooked Fk Cr Trap	CFCTRP	Crooked Fk Cr Trap	136		
	CLEARC	Clear Cr	CLEARC	Clear Cr	17		
	CLWH	Clearwater H	CLWRSF	SF Clearwater R		763	
			CROOKP	Crooked R Pond		11	
			CROOKR	Crooked R		98	
			KOOS	Kooskia NFH		75	
			LOLOC	Lolo Cr		53	
			MEAD2C	Meadow Cr		220	
			MILL2C	Mill Cr		20	
	`		NEWSOC	Newsome Cr		38	
			REDP	Red R Rearing Pond		227	
			REDR	Red R		70	
	CLWTRP	Clearwater Trap	CLWTRP	Clearwater Trap	82		
	COLTKC	Colt Kill Cr	COLTKC	Colt Kill Cr	36		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Clearwater River	CORRAC	Corral Cr	CORRAC	Corral Cr	1		
	CROTRP	Crooked R Trap	CROTRP	Crooked R Trap	12		
	DWOR	Dworshak NFH	CLEARC	Clear Cr		206	
			CLWRSF	SF Clearwater R		271	
			DWORMS	Dworshak NFH mainstem Clearwater R		1356	
			ELDORC	Eldorado Cr		3	
			LOLOC	Lolo Cr		2	
	FISHC	Fish Cr	FISHC	Fish Cr	11		
	FISHTRP	Fish Cr Trap	FISHTRP	Fish Cr Trap	654		
	GEDNEC	Gedney Cr	GEDNEC	Gedney Cr	3		
	HAGE	Hagerman NFG	AMERR	American R		3	
	LAPC	Lapwai Cr	LAPC	Lapwai Cr	16		
	LBCWF	WF Little Bear Cr	LBCWF	WF Little Bear Cr	15		
	LBEARC	Little Bear Cr	LBEARC	Little Bear Cr	19		
	LOLOC	Lolo Cr	LOLOC	Lolo Cr	4		
	MOOS2C	Moose Cr	MOOS2C	Moose Cr	2		
	MOOS2N	NF Moose Cr	MOOS2N	NF Moose Cr	9		
	PINE2C	Pine Cr	PINE2C	Pine Cr	11		
	POTR	Potlatch R	POTR	Potlatch R	3		
	POTREF	EF Potlatch R	POTREF	EF Potlatch R	47		
	REDTRP	Red R Trap	REDTRP	Red R Trap	2		
	SWEETC	Sweetwater Cr	SWEETC	Sweetwater Cr	5		
	WEBBC	Webb Cr	WEBBC	Webb Cr	6		
Asotin Creek	ASOTIC	Asotin Cr	ASOTIC	Asotin Cr	403		
	ASOTNF	NF Asotin Cr	ASOTNF	NF Asotin Cr	5		4
	ASOTSF	SF Asotin Cr	ASOTSF	SF Asotin Cr	9		3
	CHARLC	Charley Cr	CHARLC	Charley Cr	4		2
Grande Ronde River	CATHEC	Catherine Cr	CATHEC	Catherine Cr	97		
	GRAND2	Wallowa R to headwater	GRAND2	Wallowa to headwater	93		
	GRNTRP	Grande Ronde Trap	GRNTRP	Grande Ronde Trap	121	536	
	IRRI	Irrigon Hatchery	BCANF	Big Canyon Facility		1194	
	IRRI	Irrigon Hatchery	WALH	Wallowa Hatchery		2009	
	JOSEPC	Joseph Cr	JOSEPC	Joseph Cr	1		
	LCATHC	Little Catherine Cr	LCATHC	Little Catherine Cr	1		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Grande Ronde River	LOOKGC	Lookingglass Cr	LOOKGC	Lookingglass Cr	87		
	LOSTIR	Lostine R	LOSTR	Lostine R	108		
	LYFE	Lyon's Ferry Hatchery	COTP	Cottonwood Acc. Pond		1014	
	MINAMR	Minam R	MINAMR	Minam R	100		
Salmon River	BIG2C	Big Cr	BIG2C	Big Cr	191		
	BOHANC	Bohannon Cr	BOHANC	Bohannon Cr	1		1
	CABINC	Cabin Cr	CABINC	Cabin Cr	1		
	CAMASC	Camas Cr	CAMASC	Camas Cr	18		
	CHAMBC	Chamberlain Cr	CHAMBC	Chamberlain Cr	28		
	CHAMWF	WF Chamberlain Cr	CHAMWF	WF Chamberlain Cr	1		
	GOATC	Goat Cr	GOATC	Goat Cr			1
	HAGE	Hagerman NFH	LSALR	Little Salmon R		595	
			SALEFT	EF Salmon R Trap		288	
			SALR4	Pahsimeroi R to headwater		72	
			SALREF	EF Salmon R		177	
			SAWT	Sawtooth Hatch		1180	
			SAWTRP	Sawtooth Trap		696	
			YANKFK	Yankee Fk	13	380	
	HAYDNC	Hayden Cr	HAYDNC	Hayden Cr	45		
	HORSEC	Horse Cr	HORSEC	Horse Cr	1		
	JOHTRP	Johnson Cr Trap	JOHTRP	Johnson Cr Trap	82		
	KENYC	Kenney Cr	KENYC	Kenney Cr	1		
	KNOXB	Knox Bridge	KNOXB	Knox Bridge	75		
	LAKEC	Lake Cr	LAKEC	Lake Cr	10		
	LEMHIR	Lemhi R	LEMHIR	Lemhi R	122		
	LEMHIW	Lemhi R Weir	LEMHIW	Lemhi R Weir	41		
	LICKC	Lick Cr	LICKC	Lick Cr	2		3
	LLSPRC	Lemhi Little Springs Cr	LLSPRC	Lemhi Little Springs Cr	1		
	LOONC	Loon Cr	LOONC	Loon Cr	2		
	LSALR	Little Salmon R	LSALR	Little Salmon R	22		
	LSFTRP	Lower SF Sal R Trap	LSFTRP	Lower SF Sal R Trap	21		
	MARSHC	Marsh Cr	MARSHC	Marsh Cr	1		
	MARTR2	Lower Marsh Cr Trap	MARTR2	Lower Marsh Cr Trap	2		
	MARTRP	Marsh Cr Trap	MARTRP	Marsh Cr Trap	15		
	MAVA	Magic Valley Hatch	LEMHIR	Lemhi R		12	

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Salmon River			LSALR	Little Salmon R		415	
			PAHSIW	Pahsimeroi Weir		7	
			PAHTRP	Pahsimeroi Trap		228	
			SALEFT	EF Salmon R Trap		44	
			SALR1	Mouth to French Cr		4	
			SALR3	MF to Pahsimeroi		975	
			SALR4	Pahsimeroi to headwater		192	
			SALREF	EF Salmon R		89	
			SLAT2C	Slate Cr (Upper)		74	
			SLATEC	Slate Cr (Lower)		7	
			SQAW2C	Squaw Cr		255	
			SQUAWP	Squaw Cr Acc. Pond		6	
			VALEYC	Valley Cr		96	
			YANKFK	Yankee Fk		98	
	MONUMC	Monumental Cr	MONUMC	Monumental Cr	1		
	NISP	Niagara Springs H	LSALR	Little Salmon R		783	
			PAHSIW	Pahsimeroi Weir		15	
			PAHTRP	Pahsimeroi Trap		1422	
	PAHTRP	Pahsimeroi Trap	PAHTRP	Pahsimeroi Trap	25		
	PANTHC	Panther Cr	PANTHC	Panther Cr	1		
	RAPIDR	Rapid R (Lit Sal R)	RAPIDR	Rapid R (Lit Sal R)	7		
	RAPR	Rapid R (MF)	RAPR	Rapid R (MF)	1		
	RPDTRP	Rapid R Smolt Trap	RPDTRP	Rapid R Smolt Trap	34		
	SALMF2	MF Sal – Loon Cr to headwater	SALMF2	MF Sal – Loon Cr to headwater	2		
	SALRMF	MF Salmon R	SALRMF	MF Salmon R	1		
	SALTRP	Salmon Trap	SALTRP	Salmon Trap	41	180	
	SAWTRP	Sawtooth Trap	SAWTRP	Sawtooth Trap	15		
	SESESR	Sesech R	SESESR	Sesech R	16		5
	SECTRP	Sesech R Screw Trap	SECTRP	Sesech R Screw Trap	39		
	SFSTRP	SF Salmon R Trap	SFSTRP	SF Salmon R Trap	17		
	SQUAWP	Squaw Cr Acc Pond	SQUAWP	Squaw Cr Acc Pond		10	
	SULFUC	Sulphur Cr	SULFUC	Sulphur Cr	2		
	WBIRDC	Whitebird Cr	WBIRDC	Whitebird Cr	1		
	WIMPYC	Wimpey Cr	WIMPYC	Whimpey Cr	3		
	YANKFK	Yankee Fk	YANKFK	Yankee Fk	5		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Salmon River	YANKWF	WF Yankee Fk	YANKWF	WF Yankee Fk	1		
	YELLJC	Yellowjacket Cr	YELLJC	Yellowjacket Cr	5		
Imnaha River	IMNTRP	Imnaha R Trap	IMNTRP	Imnaha R Trap	1080	115	
	IRRI	Irrigon Hatchery	BSHEEC	Big Sheep Cr		641	
	IRRI	Irrigon Hatchery	LSHEEF	Little Sheep Facility		2257	
	-		IMNTRP	Imhaha R Trap	1		
Columbia River above Snake River							
Yakima River	AHTANC	Ahtanum Cr	AHTANC	Ahtanum Cr	12		
	CHANDL	Chandler Canal	CHANDL	Chandler Canal	29		1
			COLR3	Lewis R to Bonneville	1		
			YAKIM1	Mouth to Naches R	15		1
	NATCHR	Naches R	NATCHR	Naches R	21		
	NFTEAN	NF Teanaway R	NFTEAN	NF Teanaway R	30		
	ROZ	Roza Dam	ROZ	Roza Dam	3		
	SATUSC	Satus Cr	SATUSC	Satus Cr	30		
	SWAUKC	Swauk Cr	SWAUKC	Swauk Cr	3		
	TANEUC	Taneum Cr	TANEUC	Taneum Cr	13		
	TEANAR	Teanaway R	TEANAR	Teanaway R	60		
	TOPPEC	Toppenish Cr	TOPPEC	Toppenish Cr	143		
	YAKIM2	Naches to headwater	TANEUC	Taneum Cr	3		
			YAKIM2	Naches to headwater	27		
Wanapum Dam	WAN	Wanapum Dam	I-90B	I-90 Bridge			3
			PRDGWL	Priest Rapids gatewell			2
			PRDTAL	Priest Rapids tailrace			59
			RISTAL	Rock Island tailrace			33
			WANGWL	Wanapum gatewell			4
			WANTAL	Wanapum tailrace			44
Rock Island Dam	RIS	Rock Island Dam	RI2BYP	Bypass flume	233	389	44
Wenatchee River	CHEL	Chelan PUD Hatch	CHIWAR	Chiwawa R		60	
			NASONC	Nason Cr		347	
			WENATR	Wenatchee R		157	
	CHIWAC	Chiwaukum Cr	CHIWAC	Chiwaukum Cr	5		

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Wenatchee River	CHIWAR	Chiwawa R	CHIWAR	Chiwawa R	4		
	CHIWAT	Chiwawa R trap	CHIWAR	Chiwawa R	2		
			CHIWAT	Chiwawa R trap	58		
	EBNK	East Bank Hatch	CHIP	Chiwawa Rear Pond		31	
			CHIWAR	Chiwawa R		390	
			NASONC	Nason C		490	
			ROLFIP	Rolfing Acc Pond		45	
			WENATR	Wenatchee R		949	
	MISSC	Mission Cr	MISSC	Mission Cr	4		
	NASONC	Nason Cr	NASONC	Nason Cr	54	1	
	PESHAR	Peshastin R	PESHAR	Peshastin R	5		
	TURO	Turtle Rock Pond	CHIWAR	Chiwawa R		33	
			NASONC	Nason Cr		391	
			WENATR	Wenatchee R		1242	
	WENA2T	Up Wen smolt trap	WENA2T	Up Wen smolt trap	1		
	WENA3T	Up Wen trap above Chiwawa R	WENA3T	Up Wen trap above Chiwawa R	1		
	WENA4T	Lower Wen trap	WENA4T	Lower Wen trap	7		
	WENATR	Wenatchee R	WENATR	Wenatchee R	175		
			-	Unknown	1		
	WENATT	Wen R trap at W Mon Bridge	WENATT	Wen R trap at W Mon Bridge	38		
Rocky Reach Dam	RRE	Rocky Reach Dam	RRETAL	RR tailrace		92	
Entiat River	ENTIAR	Entiat R	ENTIAR	Entiat R	380		1
	ENTIAR	Entiat R	MADRVR	Mad R	11		
	MADRVR	Mad R	MADRVR	Mad R	16		
	TILLIC	Tillicum Cr	TILLIC	Tillicum Cr	1		
Wells Dam	WEL	Wells Dam	WELH	Wells Hatch		9	
			WELTAL	Wells tailrace		89	
			-	Unknown		16	
	WELH	Wells Hatch	WELH	Wells Hatch		705	
			WELTAL	Wells tailrace		4	

Table B1. Continued.

Site / Dam or Tributary	Mark site	Description	Rel. site	Description	W	H	U
Wells Dam			-	Unknown		58	
Methow River	BEAV2C	Beaver Cr	BEAV2C	Beaver Cr	42		
	CHEWUR	Chewuch R	CHEWUR	Chewuch R	50	4	1
	GOLD2C	Gold Cr	GOLD2C	Gold Cr	4		
	HANSPC	Hancock Spr Cr.	-	Unknown	2		
	LBRIC	Little Bridge Cr	LBRIC	Little Bridge Cr	1		
	LIBBYC	Libby Cr	LIBBYC	Libby Cr	6		
	METHR	Methow R	METHR	Methow R	24	7	
	METTRP	Methow smolt trap	METHR	Methow R	15	31	
	METTRP	Methow smolt trap	METTRP	Methow smolt trap	10	11	
	SGOLDC	SF Gold Cr	SGOLDC	SF Gold Cr	2		
	TWISPR	Twisp R	TWISPR	Twisp R	117	73	
	WELH	Wells Hatchery	CHEWUR	Chewuch R		1616	
			METH	Methow Hatchery		148	
			METHR	Methow R		2508	
			TWIS2P	Twisp Acc. Pond (MSRF)		202	
			TWISPP	Twisp Acc. Pond (WDFW)		117	
			TWISPR	Twisp R		1150	
	WELH	Wells Hatchery	TWISPW	Twisp R weir		50	
	WINT	Winthrop NFH	CHEWUR	Chewuch R		2	
			METHR	Methow R		11	
			WINT	Wintrhop NFH		1207	
	WOLFC	Wolf Cr	WOLFC	Wolf Cr	2		
	-	Unknown	CHEWUR	Chewuch R		3	
			METHR	Methow R		2	
			TWISPR	Twisp R		1	
Okanogan River	CASS	Cassimer Bar Hatch	OMAKC	Omak Cr		323	
			STAPAC	Stapaloop Cr		13	
	OKANR	Okanogan R	OKANR	Okanagan R	3		
	OMAKC	Omak Cr	OMAKC	Omak Cr	32		
	SALMOC	Salmon Cr	SALMOC	Salmon Cr	3		
	WELH	Wells Hatchery	OKANR	Okanogan R		195	
			OMAKC	Omak Cr		309	
			SALMOC	Salmon Cr		18	
			SIMILR	Similkameen R		670	

APPENDIX C: PIT-TAG COORDINATOR ACKNOWLEDGEMENT

Results presented in Section 3 relied on data archived on the PIT Tag Information System (PTAGIS: http://www.ptagis.org/). Researchers, referred to as Tag Coordinators, from a variety of state, federal, tribal, and private organizations contributed data to PTAGIS and we sent a letter to these individuals seeking their permission to use their fish in our study. All individuals that responded to our letter granted us permission to use their fish and we would like to take this opportunity to sincerely thank them. The following is a list of Tag Coordinators that provided tag records used in this study:

Tag Coordinator	Org.	Tag Coordinator	Org.	Tag Coordinator	Org.
Alan Byrne	IDFG	Geoff McMichael	CASAQ	Lance Keller	CPUD
Allen Evans	RTR	Gordon Axel	NOAA	Larry Basham	NPT
Andrew Grassell	CPUD	Gus Wathen	ECOR	Lytle Denny	SBT
Benjamin Warren	WDFW	Howard Takata	ODFW	Matt Belnap	IDFG
Bill Bosch	YN	Ian Jezorek	USGS	Matt Cooper	FWS
Brad Ryan	NOAA	James Bartlett	PGN	Megan Hill	PGN
Braden Lott	QC	James Fletcher	WFC	Michael Anderson	ODFW
Brandon Chockley	FPC	Jason Seals	ODFW	Michael Babcock	YN
Brett Bowersox	IDFG	Jason Vogel	NPT	Mike Lambert	NPT
Brian Benjamin	ODFW	Jay Hesse	NPT	Nate Dietrich	WDFW
Brian Jonasson	ODFW	Jeff DiLuccia	IDFG	Nathan Brindza	IDFG
Brian Kennedy	UI	Jeff Fryer	CRITFC	Patrick Uthe	IDFG
Brian Leth	IDFG	Jeff Yanke	ODFW	Paul Kucera	NPT
Carrie Bretz	FWS	Jens Lovtang	CTWSR	R. D. Nelle	FWS
Carrie Crump	CTUIR	Jeremy Stahler	ODFW	Rhonda Dasher	CT
Charles Morrill	WDFW	Jeremy Trump	WDFW	Robert Reagan	ODFW
Charles Snow	WDFW	Jerimiah Bonifer	CTUIR	Robert Wertheimer	USACE
Charlie Cochran	WDFW	Jerry Lockhart	NPT	Ron Roberts	IDFG
Chris Caudill	UI	Jerry McCann	FPC	Russ Kiefer	IDFG
Chris Jordan	NOAA	Jody Brostrom	FWS	Russell Perry	NPT
Chris Peery	FWS	Jody Walters	IDFG	Ryan Gerstenberger	HRECN
Cory Kamphaus	YN	Jody White	QC	Ryan Kinzer	NPT
Craig Rabe	NPT	Joe Bumgarner	WDFW	Ryan Richmond	BIOM
Curt Dotson	GPUD	John Jorgensen	YN	Sandy Downing	NOAA
Cyndi Baker	CTWSR	John Plumb	USGS	Scott Putnam	IDFG
Dave Marvin	PSFMC	Jon Flinders	IDFW	Shane Vatland	NPT
David Lind	YN	Jon Hansen	IDFW	Shannon Jewett	ODFW
David Venditti	IDFG	Joseph Bumgarner	WDFW	Sherman Sprague	NPT
Devin Olsen	NPT	Josh Hanson	ODFW	Stephen Bennett	ECO
Dimitri Vidergar	IDFG	June Johnson	CTUIR	Steve Springston	ODFW
Doug Hatch	CRITFC	Keely Murdoch	YN	Steven Smith	NOAA
Doug Taki	SBT	Keith DeHart	ODFW	Stuart Rosenberger	IDPOW
Eric Hockersmith	USACE	Keith van den Broek	TRRAQUA	Tiffani Marsh	NOAA
Erick Van Dyke	ODFW	Kent Mayer	WDFW	Tom Desgroseillier	FWS
Ethan Crawford	WDFW	Kim Apperson	IDFG	Tom Nelson	ODFW
Gene Ploskey	PNNL	Kyle Martens	WDFW	Wes Stonecypher	ODFW
Gene Shippentower	CTUIR	Lance Clarke	ODFW		