Technical Report 2015-8

REACH CONVERSION RATES OF RADIO-TAGGED CHINOOK AND SOCKEYE SALMON AND STEELHEAD IN THE LOWER COLUMBIA RIVER, 2013-2014

A Report for Study Code ADS-P-13-2

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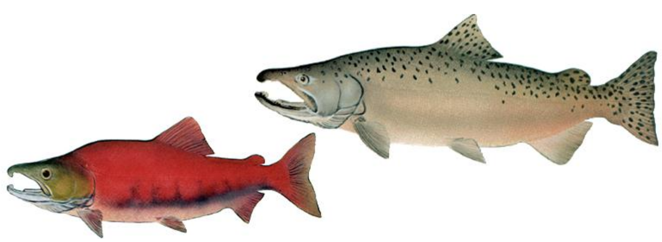

For

U.S. Army Corps of Engineers
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Table of Contents

Executive Summary

Our primary objective in this two-year study was to estimate upstream migration survival (i.e., 'conversion rates') of adult salmon and steelhead from release downstream from Bonneville Dam, through dam-to-dam reaches, and past McNary Dam. Radiotelemetry was used to help estimate final fates of tagged fish and to monitor fish behaviors at dams, in reservoirs, and as they entered lower Columbia River tributaries. Radiotelemetry was selected to provide more explicit spatial and temporal accounting of adults that did not successfully pass through the lower Columbia River Hydrosystem. PIT tags were used as a secondary marker that provided additional detection information at Bonneville, The Dalles and McNary dams, at upstream dams, and at many tributary sites and collection facilities.

In 2013-2014, we collected and double-tagged (radio + PIT) 1,200 adult spring–summer Chinook salmon, 600 jack spring–summer Chinook salmon, 799 adult sockeye salmon, and 1,590 adult summer steelhead at Bonneville Dam in approximate proportion to the runs and released them downstream. The steelhead sample was separated into 'early' and 'late' groups, with oversampling of late-run fish to address overwintering objectives (reported separately). Genetic samples were collected for all adult and jack Chinook salmon and all steelhead.

Fish fates – Fish were assigned to one of four fate categories using telemetry records and recapture information: 1) upstream from McNary Dam; 2) entered a tributary downstream from McNary Dam; 3) fisher-reported harvest downstream from McNary Dam; and 4) unaccounted for downstream from McNary Dam. Final detections indicated that 65-69% of adult Chinook salmon, 76-83% of jack Chinook salmon, 81-83% of sockeye salmon, 45-46% of early steelhead, and 72-73% of late steelhead passed McNary Dam; majorities of these fish were ultimately detected in tributaries or at dams in the Snake or upper Columbia River basins. Entry into lower Columbia River tributaries varied considerably among groups: 8-15% (adult Chinook salmon), 10-11% (jack Chinook salmon), 0% (sockeye salmon), 30% (early steelhead), and 8% (late steelhead). Fisher-reported main stem harvest rates from release to McNary Dam were 5% (adult Chinook), <1-2% (jack Chinook), 2-3% (sockeye), 5-7% (early steelhead), and 4-5% (late steelhead); these were minimum indicators of harvest rates given evidence for low transmitter return rates from fisheries and discordance between adult and jack conversion rates. The unaccounted-for percentages downstream from McNary Dam were: 16-18% (adult Chinook), 5-11% (jack Chinook), 13-18% (sockeye), 18-23% (early steelhead), and 15-16% (late steelhead). A portion of the unaccounted-for fish in each group was almost certainly harvested but was not reported to us.

Reach-specific conversion rates – Conversion rates were estimated for five reaches: (1) release downstream from Bonneville Dam past Bonneville Dam; (2) from the top of Bonneville Dam past The Dalles Dam; (3) from the top of The Dalles Dam past John Day Dam; (4) from the top of John Day Dam past McNary Dam; and (5) the cumulative conversion from the top of Bonneville Dam past McNary Dam. We calculated a suite of four conversion rates that differentially accounted for tributary turnoff and fisher-reported harvest of radio-tagged fish.

Conversion rate estimates for the aggregate samples from release past Bonneville Dam averaged 0.967 and ranged from 0.932 (2014 sockeye) to 0.982 (2014 early steelhead). Rates in

dam-to-dam reaches were lowest between Bonneville and The Dalles dams, the reach with the most fisheries effort. Rates were generally highest between John Day and McNary dams. When tributary entry was treated as successful migration, conversion estimates through the multi-dam Bonneville-McNary reach were: 0.806-0.815 (adult Chinook), 0.907-0.966 (jack Chinook), 0.858-0.863 (sockeye), 0.738-0.771 (early steelhead), and 0.817-0.852 (late steelhead). Bonneville-McNary reach conversion estimates that accounted for known tributary turnoff and main stem harvest were slightly higher for all groups: 0.830-0.841 (adult Chinook), 0.911-0.966 (jack Chinook), 0.879-0.886 (sockeye), 0.719-0.773 (early steelhead), and 0.846-0.879 (late steelhead). By excluding tributary turnoff and main stem harvest, the latter estimates measured unknown loss in the main stem.

Conversion rates were statistically associated with a variety of covariates including fish traits (origin, size, sex), fish behaviors (fallback at dams), and seasonal environmental conditions. In general, lower reach conversion rates for adult Chinook salmon were associated with warm water temperature, fallback at downstream dams, and large size. The size effect may indicate some size-selective harvest. Hatchery adult Chinook salmon also had lower conversion than wild adults, but only through the Bonneville-The Dalles reach. There was little evidence for covariate effects on jack Chinook salmon, largely because jack conversion rates were consistently among the highest in this study. The only statistically significant covariate for jack Chinook salmon was year, as conversion rates were higher in 2013 than in 2014 through the Bonneville-The Dalles and the multi-dam Bonneville-McNary reaches.

Sockeye salmon conversion rates were lower for larger fish (possible harvest effect), for late-timed migrants that encountered relatively warm water, and for those that fell back at Bonneville Dam. There was also a year effect, with higher conversion in 2013 than in 2014 through the release-Bonneville and John Day-McNary reaches. There were few statistically significant covariate effects for early-run steelhead, except that larger steelhead were less likely to survive the Bonneville-The Dalles reach and fallback was surprisingly associated with higher survival in the Bonneville-McNary reach. A variety of covariates were associated with late-run steelhead conversion rates. Wild late-run steelhead and males had lower conversion rates than hatchery fish and females, respectively. Head injuries, marine mammal injuries, gillnet marks, and downstream fallback events were all associated with lower late-run steelhead survival.

Genetic assignments – We used parentage-based tagging (PBT) and genetic stock identification (GSI) to assign Chinook salmon and steelhead to specific hatcheries (PBT) or reporting groups (GSI). There were 16 Chinook salmon and 11 steelhead source hatcheries identified in the PBT analysis and 14 Chinook salmon and 12 steelhead GSI reporting groups. PBT assignments were possible for varying percentages of the tagged fish approximately in proportion to the abundance of Snake River hatchery fish in each sample: adult spring Chinook salmon (26-31% PBT assigned), adult summer Chinook salmon (2-5%), jack spring Chinook salmon (30-50%), jack summer Chinook salmon (21-38%), early-run steelhead (22-25%), and late-run steelhead (71-74%). Large majorities of each Chinook salmon and steelhead sample were assigned to GSI reporting groups.

The genetic assignments were used to calculate population-specific reach conversion rates for groups with adequate sample sizes and to estimate the origin of fish that were harvested or were unaccounted for downstream from McNary Dam. The genetic information was also used to identify fish that likely strayed from populations upstream from McNary Dam into tributaries between Bonneville and McNary dams.

Bonneville-McNary reach conversion estimates varied considerably among species and populations. Using the metric that treated main stem harvest, strays, and unaccounted for fish as unsuccessful, conversion estimates for PBT-assigned adult spring Chinook salmon were: 0.773-0.882 (Dworshak), 0.793-0.852 (Rapid River), 0.538-0.950 (McCall), and 0.857 (South Fork Clearwater). Estimates for PBT-assigned jack spring Chinook salmon were: 1.000 (Dworshak) 0.946-1.000 (Rapid river), and 0.778 (McCall). Estimates for PBT-assigned early-run steelhead were: 0.636-0.714 (Pahsimeroi) and 0.684-0.714 (Lyons Ferry). Estimates for late-run steelhead were: 0.857-0.897 (Pahsimeroi), 0.833-0.875 (Sawtooth), 0.762-0.818 (Dworshak), 0.583-1.000 (Wallowa), and 0.714 (Oxbow). Radio-tagged sample sizes varied widely among PBT groups.

The GSI assignments were less geographically precise than the PBT assignments, and some GSI reporting groups including a mixture of fish that potentially originated either upstream or downstream from McNary Dam. We used the GSI data to calculate reach conversion estimates only for those populations that primarily or exclusively originated upstream from McNary Dam. Using the Bonneville-McNary conversion metric described above, estimates for GSI-assigned adult spring Chinook salmon were: 0.864-0.870 (Yakima), 0.750-0.785 (Hells Canyon), 0.705-0.909 (South Fork Salmon), and 0.667-0.880 (upper Salmon). Estimates for adult summer Chinook salmon were: 0.692-0.738 (upper Columbia summer/fall) and 0.818 (South Fork Salmon). GSI-based estimates for jack Chinook salmon were consistently higher than for adults within the respective reporting groups. Bonneville-McNary conversion estimates for PBT-assigned early-run steelhead were: 0.818 (upper Columbia) and 0.639-0.737 (upper Salmon). Estimates for late-run steelhead were: 0.777-0.814 (South Fork Clearwater), 0.765-0.833 (upper Clearwater), and 0.804-0.848 (upper Salmon).

Using the PBT data from hatchery origin adults we estimated that stray rates from the Snake River into lower Columbia River tributaries were 3.0-3.3% (adult spring Chinook), 0.0% (adult summer Chinook), 0.0-1.0% (jack spring Chinook), 0.2-3.2% (jack summer Chinook), 3.6% (early steelhead), and 4.5-7.1% (late steelhead). These estimates were calculated across hatchery groups to increase sample size; estimates for individual hatchery samples were higher and lower than the aggregate estimates. Straying estimates based on GSI assignments were generally aligned with the PBT-based results. We note that some fish designated as strays were likely harvested and may not have been permanent, breeding strays in the absence of fisheries.

Conclusions – The combination of radiotelemetry and PIT-tag detection histories with genetically-based stock assignments allowed us to generate precise estimates of dam-to-dam and multi-dam reach conversion estimates for upstream-migrating salmonids in the lower Columbia River hydrosystem. The self-reported harvest, tributary turnoff, and straying rates reported in this study, along with the analysis of covariate effects, provide information needed for understanding why some groups do not survive at the performance standards mandated by the FCRPS Biological Opinion. A critical remaining uncertainty regards the fates of upstream migrants that were unaccounted for. We presume that many of these fish were harvested but not reported to us. Others were presumably prespawn mortalities and smaller numbers may have entered tributaries undetected or spawned at main stem sites.

Introduction

The overarching objective of this study was to estimate upstream passage success (i.e., 'conversion rates') by salmon and summer steelhead through the lower Columbia River. Recent conversion rate estimates between Bonneville Dam and McNary have been below performance standards established by the Federal Columbia River Power System (FCRPS) Biological Opinion ('BiOp') for three Evolutionarily Significant Units (ESUs). These include Snake River and Upper Columbia River spring–summer Chinook salmon (*Oncorhynchus tshawytscha*) and Snake River steelhead (*O. mykiss*). Standards are currently being developed for the endangered Snake River sockeye salmon (*O. nerka*).

Understanding where and why migrants from the listed ESUs fail to pass through the lower FCRPS is critically important for managers responsible for maintaining the native fish runs and for achieving the recovery goals outlined by NOAA Fisheries (NOAA) and the Northwest Power Planning Council (NWPPC). Adequate upstream passage and high survival through the FCRPS for adult salmonids are requirements of the 2008 BiOp, the 2010 Supplemental BiOp, and the recently-released 2014 BiOp.

Conversion estimates lower than the Bonneville-McNary performance standards have primarily been calculated using PIT-tag detections of adults that were tagged as juveniles at sites upstream from McNary Dam (e.g., Tuomikoski et al. 2013). While the PIT-tagged samples provide good estimates of Bonneville-to-McNary conversion rates, they do not provide much information on the behaviors or fates of the fish that fail to pass or on potential causative factors. The pre-2013 PIT-based estimates also could not partition loss rates among dam-to-dam reaches because The Dalles and John Day dams had no PIT detection antennas (antennas were installed at The Dalles Dam in 2013).

There are several potential sources of mortality and unaccounted-for loss in the lower FCRPS study area. These include legal and illegal harvest (Dauble and Mueller 2000), natural mortality (e.g., from sea lion *Zalophus californianus* and *Eumetopias jubatus* predation; Stansell et al. 2010; Keefer et al. 2012), mortality associated with fallback at dams (Boggs et al. 2004; Keefer et al. 2005), failure to pass dams (Caudill et al. 2007), straying into non-natal tributaries associated with natural processes or as a result of juvenile transportation (e.g., Keefer et al. 2008b; Marsh et al. 2012; Keefer and Caudill 2014), and environmental effects such as exposure to high water temperature (Naughton et al. 2005; Goniea et al. 2006; Keefer et al. 2009; Crozier et al. 2014).

Efforts to partition adult loss in the lower FCRPS have included harvest monitoring, estimation of stray rates using tagged fish, and radiotelemetry studies with transmitter reward programs (e.g., Keefer et al. 2005; Naughton et al. 2005; Caudill et al. 2007). In 2013 and 2014, we collected and radio-tagged upstream-migrating salmon and steelhead at Bonneville Dam to address the conversion rate objectives described above as well as several dam-specific behavioral objectives and FCRPS overwintering objectives for adult steelhead (see companion reports: Burke et al. 2014, Johnson et al. 2014, Keefer et al. 2014a). The radiotelemetry study groups included adult sockeye salmon, adult and jack spring–summer Chinook salmon, and adult summer steelhead.

This report addresses the following specific objectives for samples of adult and jack salmon and adult steelhead radio-tagged at Bonneville Dam in 2013-2014:

1) *estimate conversion rates of spring-summer Chinook salmon, sockeye salmon, and steelhead between Bonneville and McNary dams to identify reaches where loss is occurring*;

2) *estimate tributary turnoff rates of spring-summer Chinook salmon and steelhead*;

3) *evaluate fallback, re-ascension, and Bonneville to McNary conversion rates of spring Chinook salmon in relation to sea lion presence in the Bonneville tailrace*;

4) *evaluate fallback, re-ascension, and Bonneville to McNary conversion rates of spring-summer Chinook, sockeye salmon, and steelhead passing FCRPS dams*;

5) *evaluate the influence of fish traits, fallback behavior, and environmental variables on Objectives 1-4*; and

6) *use genetic assignment data to estimate population-specific Bonneville-McNary reach conversion rates and straying rates of Chinook salmon and steelhead*.

Methods

Adult fish collection and tagging at Bonneville Dam

We collected and intragastrically radio-tagged jack and adult spring–summer Chinook salmon, adult sockeye salmon, and adult summer steelhead at the Adult Fish Facility (AFF), located adjacent to the Washington-shore ladder. In 2013, Chinook salmon were collected and tagged starting 2 May 2013 (i.e., none were tagged in April) due to a contractual delay between USACE and the transmitter vendor. Samples were tagged in approximate proportion to the run thereafter. In 2014, Chinook salmon were tagged throughout the spring–summer run. Sockeye salmon were collected throughout the run in each year. In contrast to the salmon, summer steelhead were not sampled in proportion to the runs. Instead, samples were split each year into early (June-August) and late (September-October) components, with an overweighting of late-run fish that were targeted for overwintering evaluations reported separately (e.g., Keefer et al. 2014a).

Fish were selected in the order that they entered the trap each day (i.e., random with respect to passage sequence). However, we excluded all fish that had PIT tags from juvenile tagging projects due to concerns about handling effects on research outcomes (i.e., all known-origin fish were excluded from radio tagging). Selection against previously PIT-tagged fish meant that the samples were not representative of the runs at large. It also made it impossible to identify fish that strayed into lower Columbia River tributaries, a behavior that can reduce reach conversion for upriver populations (Keefer et al. 2008a; Marsh et al. 2012; Keefer and Caudill 2014). (Note, however, that genetic data were used to evaluate straying: see below.)

Protocols for collecting and outfitting salmon with transmitters at Bonneville Dam, coding of the data, and data analysis were similar to those used in prior years (e.g., Keefer et al. 2004a; 2005; Jepson et al. 2011). Fish receiving a radio transmitter were anesthetized in a ~18 mL/L solution of AQUI-S-20E (Aquatactics, Kirkland, WA) using protocols described by Caudill et al. (2014). We used six types of digitally-encoded radio transmitters manufactured by Lotek Wireless Inc. (Newmarket, Ontario). The transmitter models used to tag adult Chinook salmon were 7-volt MCFT-7F (16mm × 88mm; 31g in air) and MCFT-7A (16mm × 83mm; 29 g in air). Jack Chinook salmon were tagged with either a nano transmitter (NTC-6-2; 9mm × 30mm; 4.3 g in air) or a 3-volt MCFT2-3BM transmitter (11mm × 43mm; 7.7 g in air) or a MST-930 transmitter (9.5 mm x 26 mm; 4 g in air). Adult sockeye salmon were tagged with a 3-volt MCFT2-3BM transmitter (11mm × 43mm; 7.7 g in air), or a MST-930 transmitter (9.5 mm x 26 mm; 4 g in air) and steelhead were tagged with a 3-volt MCFT2-3A transmitter (16mm x 46mm; 16 g in air). Taggers distinguished between jack and adult male Chinook salmon using a combination of length, jaw and head morphology, and body shape rather than using a strict size criterion in an effort to minimize the potential to bias either sample when operating the collection flume, with the greatest uncertainty for individuals 60-65 cm. For example, when selecting for a jack, there was potential for taggers to unintentionally select against larger jacks. Most individuals classified as jacks were < ~ 64 cm, had longer jaws and snouts, and were generally thinner in overall body shape than individuals classified as adults. All fish were also tagged with a full duplex PIT-tag inserted to the abdominal cavity as a secondary tag that allowed identification of transmitter loss, radio detection efficiencies and conversion rates using both radio- and PIT-detections.

Fish that were radio-tagged were weighed (nearest 10 g), measured for fork length (nearest 0.5 cm), and were assessed for lipid content using a Distell Fatmeter (Distell Industries Ltd., West Lothian, Scotland). All fish were inspected for fin clips, a variety of injuries, and other marks. We also collected scale samples from each fish to determine fish age and caudal fin punches for genetic analyses (see methods below). After recovery from anesthesia, radio-tagged fish were transported by truck in oxygenated river water and released ~ 8 km downstream from Bonneville Dam from sites on both sides of the Columbia River.

Radiotelemetry and PIT monitoring

We used an array of fixed-site radio receivers with digital spectrum processors (DSPs) at dams, in reservoirs, and in major tributaries to monitor tagged salmon (Table 1, Figure 1). Radio receivers with Yagi aerial antennas were used to monitor dam tailraces, reservoirs, and major tributaries. At dams, most antennas were underwater coaxial cable antennas, though a few sites also had aerial Yagis. Underwater antennas at dams were used to monitor fishway openings, collection channels, transition areas, ladders, and top-of-ladder exit areas. Fish detection efficiencies on these arrays have historically been >95% at most sites, and antenna redundancy in most fishways increased dam-wide detection efficiency to near 100%. We used top-of-ladder sites and upstream detections to determine whether fish passed dams and to estimate dam-to-dam reach conversion rates (see methods below). Missed radio detections at top-of-ladder antennas mostly occurred during receiver power outages.

Table 1. Radiotelemetry monitoring sites in the Columbia and Snake rivers in 2013-2015[1].

Site	Antenna type	# Receivers
Bonneville Dam Tailrace	Aerial	2
Bonneville Dam Fishways	Aerial	6
Bonneville Dam Fishways	Underwater	11
Bonneville Reservoir – Bridge of the Gods	Aerial	1
Bonneville Tributary – Wind River Mouth	Aerial	1
Bonneville Reservoir – Viento State Park	Aerial	1
Bonneville Reservoir – Cook-Underwood Rd	Aerial	1
Bonneville Tributary – Little White Salmon River Mouth	Aerial	1
Bonneville Tributary – White Salmon River	Aerial	2
Bonneville Tributary – Hood River Mouth	Aerial	1
Bonneville Reservoir – Chamberlain Lake Rest Area	Aerial	1
Bonneville Reservoir – Memaloose Rest Area State Park	Aerial	1
Bonneville Reservoir – Chamberlain Lake Rest Area	Aerial	1
Bonneville Tributary – Klickitat River Mouth	Aerial	1
The Dalles Dam Tailrace	Aerial	2
The Dalles Dam Fishways	Underwater	8
The Dalles Reservoir – Celilo Park	Aerial	1
The Dalles Reservoir – Wishram-Celilo	Aerial	1
The Dalles Tributary – Deschutes River Mouth	Aerial	1
The Dalles Tributary – Deschutes River Sherars Falls	Aerial	1
John Day Dam Tailrace	Aerial	2
John Day Dam Fishways	Underwater	6
John Day Tributary – John Day River Mouth	Aerial	1
McNary Dam Tailrace	Aerial	2
McNary Dam Fishways	Underwater	6
Priest Rapids Dam Fishways	Underwater	2
Ice Harbor Dam Tailrace	Aerial	1
Ice Harbor Dam Fishways	Underwater	6
Lower Monumental Dam Tailrace	Aerial	1
Lower Monumental Dam Fishways	Underwater	6
Lower Monumental Reservoir – Lyons Ferry Hatchery	Aerial	1
Lower Monumental Reservoir – Downstream of Tucannon River	Aerial	1
Lower Monumental Tributary – Tucannon River	Aerial	1
Little Goose Dam Tailrace	Aerial	2
Little Goose Dam Fishways	Underwater	6
Lower Granite Dam Tailrace	Aerial	2
Lower Granite Dam Fishways	Underwater	5
Lower Granite Tributary – Clearwater River near Potlatch Mill	Aerial	1
Lower Granite Tributary – Snake River upstream of 3 Mile Island	Aerial	1

[1] Does not include some temporary antennas used to monitor overwintering steelhead in dam forebays

The raw radiotelemetry data were screened for likely ‘noise’ records using filters that identified signal collisions (i.e., two or more codes at the same receiver at the same time). A detection history for each radio-tagged fish was generated using an automated coding program that assigned activity codes (e.g., tailrace entry and exit, fishway entry and exit, ladder passage, tributary entry, etc.) to the time-stamped detections at each antenna using a set of coding rules followed by review by experienced technicians who identified records that did not have corroborating support from detections at nearby antennas.

Each fish received a full-duplex PIT tag as a secondary marker, and we supplemented the radiotelemetry histories using PIT detections inside dam fishways (Bonneville, The Dalles, McNary, Ice Harbor, Little Goose, Lower Granite, and upper Columbia River dams), inside tributaries, and at fish collection facilities. The PIT detection data were downloaded from the Pacific States Marine Fisheries Commission PIT Tag Information System database (PTAGIS). PIT detections were also used to identify dam passage by salmon that lost radio transmitters or that had transmitters that were not working. The combination of radio and PIT data were used to assign dam passage events and to assign final detection locations.

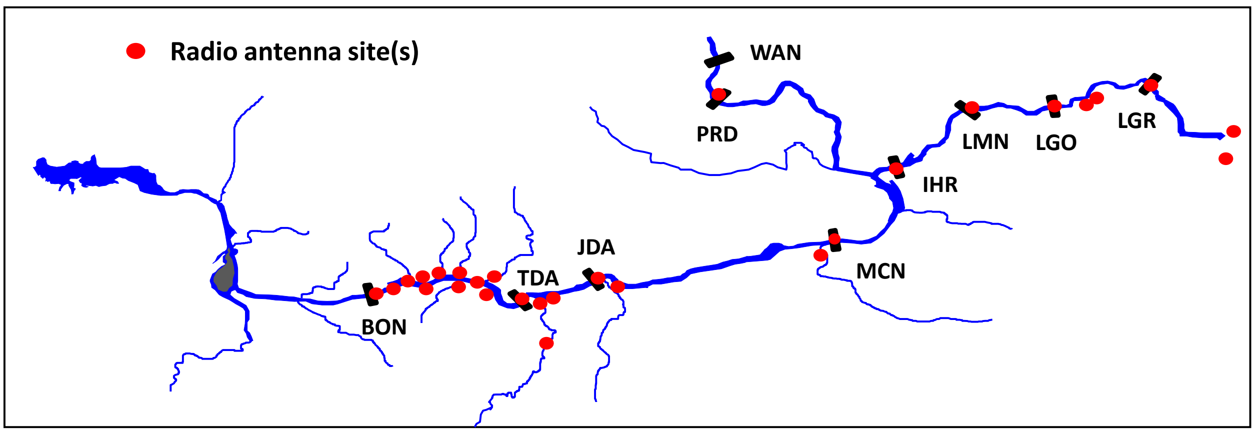

Figure 1. Map of the study area showing locations of one or more radiotelemetry receivers in 2013-2014. The reaches where conversion rates were estimated for radio-tagged adult Chinook and sockeye salmon and steelhead included: release below Bonneville Dam (BON) to pass Bonneville Dam; Bonneville Dam to The Dalles Dam (TDA); The Dalles Dam to John Day Dam (JDA), John Day Dam to McNary Dam (MCN), and Bonneville Dam to McNary Dam. Note that no tributaries were monitored with radiotelemetry downstream from Bonneville Dam.

Genetic assignment

Genetic samples were processed by the Hagerman Genetics Laboratory (Hagerman, ID) and were analyzed using two methods: parentage-based tagging (PBT) and genetic stock identification (GSI). The PBT assignments rely on genetic data from adult broodstock collected at Snake River hatcheries starting in ~2008. The method used single nucleotide polymorphisms (SNPs) to identify the parents of many hatchery-origin radio-tagged fish collected in this study; for a full description of genetic procedures see Steele et al. (2013), Matala et al. (2014), and Hess et al. (2015).. The accuracy level for these assignments approaches 100% and is geographically precise. PBT assignments were for jack and adult Chinook salmon and steelhead tagged in both study years; no genetic analyses are planned for sockeye salmon. A total of 16 hatchery Chinook salmon populations (Table 2) and 11 hatchery steelhead populations (Table 3) were represented in the radio-tagged samples.

The GSI method used an extensive baseline of genetic data to assign individual fish to stock-based reporting groups (e.g., Seeb et al. 2007; Anderson et al. 2008; Hess et al. 2011). In contrast to PBT, GSI was used for both hatchery- and wild-origin fish but differentiation among genetically-similar stocks is somewhat limited and geographic precision is therefore reduced relative to PBT. GSI assignments are often probability-based (i.e., a fish could have a 67% probability of belonging to reporting group A and a 33% probability of belonging to reporting group B); we summarized the GSI data using the highest probability for each fish. GSI assignments were for jack and adult Chinook salmon and steelhead tagged in both years. A total of 14 Chinook salmon GSI reporting groups (Table 2) and 12 steelhead reporting groups (Table 3) were represented in the radio-tagged samples.

Conversion rate estimation

In study year 1 (2013), we estimated reach-specific conversion rates using Cormack-Jolly-Seber (CJS) survival models (Lebreton et al. 1992; Perry et al. 2012) in program MARK (White and Burnham 1999). This method has frequently been used to estimate reach survival for juvenile salmonids in the Columbia River system (e.g., Muir et al. 2001; Sandford and Smith 2002) and to estimate adult salmon reach survival and escapement to tributaries (e.g., Keefer et al. 2005, 2010). CJS models allow simultaneous estimation of detection probabilities (ρ, accounting for undetected fish) and survival probabilities (φ). In the report summarizing the salmon data collected in 2013 (Keefer et al. 2014c), we used radiotelemetry detections at dams to calculate detection efficiency estimates (ρ) at the top-of-fishway sites at dams.

We did not use program MARK to estimate reach conversion estimates for the current report but instead report Wilson binomial confidence intervals (Agresti and Coull 1998; Brown et al. 2001). In a sensitivity analysis using a subset of the ~320 possible reach-specific estimates, we compared reach conversion estimates and associated 95% profile likelihood confidence intervals generated using MARK with point estimates and 95% Wilson binomial confidence intervals. The results were essentially equivalent (see Appendix Figure A1) and the latter were much easier to implement across the many reaches and study groups. The similarity in confidence intervals was due to the generally high detection efficiency of combined radio- and PIT-tagged fish in the adult fishways at Columbia River dams, particularly with the added detections at upstream dams and tributaries. We calculated the binomial confidence intervals using the ‘binom’ package in R (R Development Core Team).

We estimated conversion rates for the full samples through five lower Columbia River reaches: (1) from release to the top of Bonneville Dam; (2) from the top of Bonneville Dam to the top of the Dalles Dam; (3) from the top of The Dalles Dam to the top of John Day Dam; (4) from the top of John Day Dam to the top of McNary Dam; and (5) from the top of Bonneville Dam to the top of McNary Dam (Figure 1).

Table 2. Genetic stock identification (GSI) reporting groups (top) and parentage-based tagging (PBT) hatcheries that were identified in genetic analyses of radio-tagged Chinook salmon in 2013-2014. The PBT assignments were for hatchery salmon only (primarily from the Snake River basin) whereas hatchery and wild fish had GSI assignments. See Appendix B for map of reporting groups.

GSI Reporting Group	Reporting Group Description
02_WCASSP	West Cascade spring-run; *rivers downstream from Bonneville*
06_KLICKR	Klickitat River spring-run
07_DESCSP	Deschutes River spring-run
08_JOHNDR	John Day River spring-run
09_YAKIMA	Yakima River spring-run
10_UCOLSP	Upper Columbia River spring-run, Carson Hatchery spring-run; *mix of Winthrop, Wenatchee, Entiat, Little White Salmon*
11_TUCANO	Tucannon River spring-run
12_HELLSC	Hells Canyon spring-run; *mix of Grande Ronde, Imnaha, Clearwater*
13_SFSALM	South Fork Salmon River spring/summer-run
14_CHAMBLN	Chamberlain Creek spring/summer-run
15_MFSALM	Middle Fork Salmon River spring/summer-run
16_UPSALM	Upper Salmon River spring/summer-run; *mix of North Fork, Lemhi, Pahsimeroi, East Fork, West Fork Yankee Fork, Valley Cr, Sawtooth*
18_UCOLSF	Upper Columbia River summer/fall-run; *mix of Lower Yakima, Hanford Reach, Wenatchee, Entiat, Methow*
19_SRFALL	Snake River fall-run; *mix of Lyons Ferry, Clearwater*

PBT Source Hatchery	River Basin	GSI Reporting Group
Klickitat	Klickitat	06_KLICKR
Tucannon	Tucannon	11_TUCANO
Dworshak / Clearwater	Clearwater	12_HELLSC
Nez Perce Tribal Hatchery	Clearwater	12_HELLSC
South Fork Clearwater	Clearwater	12_HELLSC
Powell	Clearwater	12_HELLSC
Grande Ronde	Grande Ronde	12_HELLSC
Catherine Creek	Grande Ronde	12_HELLSC
Lookingglass Creek	Grande Ronde	12_HELLSC
Lostine	Grande Ronde	12_HELLSC
Imnaha	Imnaha	12_HELLSC
Pahsimeroi	Salmon	16_UPSALM
Rapid River	Salmon	12_HELLSC
Johnson Creek	Salmon	13_SFSALM
McCall	Salmon	13_SFSALM
Sawtooth	Salmon	16_UPSALM

Table 3. Genetic stock identification (GSI) reporting groups (top) and parentage-based tagging (PBT) hatcheries that were identified in genetic analyses of radio-tagged steelhead in 2013-2014. The PBT assignments were for hatchery steelhead only (primarily from the Snake River basin) whereas hatchery and wild fish had GSI assignments. See Appendix B for map of reporting groups.

GSI Reporting Group	Reporting Group Description
02_LOWCOL	Lower Columbia
03_SKAMAN	Skamania
04_WILLAM	Willamette River
06_KLICKR	Klickitat River
07_MGILCS	*Mixed: Deschutes, mid-Columbia, lower Snake, lower Clearwater, Grande Ronde, Imnaha, lower Salmon*
08_YAKIMA	Yakima River
09_UPPCOL	Upper Columbia River: *mix of Wenatchee, Methow, Entiat, Okanogan*
10_SFCLWR	South Fork Clearwater River
11_UPCLWR	Upper Clearwater River
12_SFSALM	South Fork Salmon River
13_MFSALM	Middle Fork Salmon River
14_UPSALM	Upper Salmon River

PBT Source Hatchery	River Basin	GSI Reporting Group
Idaho Power/IDFG, Pahsimeroi F.H.	Upper Salmon River	14_UPSALM
Idaho Power/IDFG, Oxbow F.H.	Upper Snake River	14_UPSALM
LSRCP/IDFG Sawtooth (EFSR)	Upper Salmon River	14_UPSALM
LSRCP/IDFG Sawtooth (IDFG & SBT)	Upper Salmon River	14_UPSALM
LSRCP/IDFG Sawtooth (USB/Squaw)	Salmon River[1]	10_SFCLWR
LSRCP/IDFG/USFWS Dworshak/C.W.	Clearwater River	10_SFCLWR
LSRCP/ODFT - Little Sheep Cr. F.H.	Imnaha River	07_MGILCS
LSRCP/ODFW-Wallowa F.H.	Grand Ronde River	07_MGILCS
LSRCP/WDFW-L.F. (G.R. Cottonwood)	Grand Ronde River	07_MGILCS
LSRCP/WDFW-L.F. (Touchet)	Walla Walla River	07_MGILCS
LSRCP/WDFW-Lyons Ferry	Snake River	07_MGILCS

[1] Original source: Clearwater River

We calculated several reach conversion estimates to differentially account for fish that were fisher-reported as harvested (known to be minimum estimates) and those that entered tributaries between release below Bonneville Dam and passage of McNary Dam (Table 4). The first estimate (Metric A, Table 4) was a raw minimum survival estimate, unadjusted for fisher-reported harvest or tributary turnoff and is similar in principle to estimates based solely on adult counts at dams (adjusted for fallback). The second estimate (Metric B) treated fish last recorded in a reach tributary as successful if the tributary had a population of the species (in particular, sockeye salmon last recorded in Bonneville reservoir tributaries were treated as unsuccessful because there are no sockeye salmon populations in those rivers). The third estimate (Metric C) treated tributary fish as successful and those fisher-reported as harvested in the reach were censored (i.e., removed from the sample because their reach survival was largely independent of FCRPS operations). The final estimate (Metric D) censored both fisher-reported harvest and tributary fish, leaving only the 'unaccounted for' group in the failed category. This metric was closest to management-based methods that use counts at dams, harvest estimates, and estimates of tributary turnoff and straying to 'adjust' reach conversion estimates (e.g., Dauble and Mueller 2000; the 2008 and 2014 Biological Opinions).

The above estimates were calculated separately for adult Chinook salmon, jack Chinook salmon, sockeye salmon, and steelhead. Point estimates for spring-only and summer-only Chinook salmon were reported separately and in combination at the request of stakeholders. We used 16 June as the start date for the summer Chinook salmon run at Bonneville Dam (date based on the U.S. v Oregon agreement). Point estimates were also reported separately for 'early' and 'late' tagging groups in steelhead due to the split sampling effort before and after high summer temperatures.

Table 4. Four metrics used to evaluate reach-specific upstream conversion rates in the lower FCRPS. Metrics differ in how reported harvest and tributary turnoff are treated.

Conversion estimate	Passed upstream dam	Entered tributary	Reported harvested	Unaccounted for
A	Success	Fail	Fail	Fail
B	Success	Success[1]	Fail	Fail
C	Success	Success[1]	Censor	Fail
D	Success	Censor	Censor	Fail

[1] sockeye salmon in BON-TDD and JDD-MCN tributaries considered unsuccessful

Effects of covariates on reach conversion

For each sample group, we used Pearson's χ^2 tests for categorical variables or generalized linear models for continuous variables (PROC GLM in SAS) to evaluate relationships between reach conversion rate and a suite of covariates. These included basic fish traits such as fork length (cm), estimated sex (M, F), and hatchery versus wild origin (based on fin clips). Fork length was selected as the measure of fish size; models with fish weight produced similar results, but more fish were missing weight than fork length data. We also evaluated several types of injuries, including: gill net marks (Y, N), head injuries (Y, N), descaling ($\leq$ 10%, > 10%), and marine mammal injuries (none, old scrapes or bites, new scrapes or bites). The injury scoring followed the protocols described by Naughton et al. (2011). Several environmental terms were considered, including year, migration date, and Columbia River water temperature and flow on the date each fish entered a reach. We note that date and water temperature were positively correlated through the spring and summer in each year so date was not modeled for the salmon groups in multivariate analyses; date was used as a surrogate for water temperature for the steelhead analyses because temperature data were not available at most dams in the fall.

A single behavioral variable, fallback, was evaluated. The fallback covariate was binary (yes, no) and indicated whether a fish fell back at any downstream dam prior to passing through a dam-to-dam reach (Bonneville-The Dalles, The Dalles-John Day, John Day-McNary) or at any dam before passing the Bonneville-McNary reach. For example, a fish that passed Bonneville Dam and fell back at Bonneville Dam prior to passing The Dalles Dam was in the fallback = Yes group for the Bonneville-The Dalles reach. A fish that passed Bonneville and then passed The Dalles before falling back at both dams was in the Fallback = No group for the Bonneville-The

Dalles reach but the Fallback = Yes group for The Dalles-John Day reach. In the latter example, the fallback event at Bonneville Dam occurred after the fish had successfully passed through the Bonneville-The Dalles reach and the event was therefore unrelated to conversion through this reach. Lastly, an example fish that fell back at The Dalles Dam, reascended and then passed John Day Dam was included in the Fallback = Yes group for the John Day-McNary reach. In this case, the fallback event at The Dalles Dam may have had a delayed effect on conversion through the upstream reach. Fallback events at McNary Dam, the Snake River dams, and upper Columbia River dams were not considered as all fish had to have passed McNary Dam (the upstream end of the study area) before fallback at these sites. Similarly, post-spawn fallback events by steelhead kelts were excluded from all analyses.

We compared a series of multivariate models in SAS (PROC GENMOD in SAS; Agresti 2012) to evaluate the effects of each covariate independently and in several *a priori* combinations. The GENMOD procedure is similar to logistic regression, where the response variable is binary (reach conversion = Y/N); we used the binomial probability distribution and a logit link function in all models. For Chinook and sockeye salmon groups, the covariate combinations included: 1) fish traits plus fallback; 2) all injuries; 3) the environmental variables year, temperature, and flow (date excluded); 4) fish traits + injuries; 5) fish traits + environmental variables; 6) injuries + environmental variables; and 7) a full model with all terms (except date). No interactions were considered and some categories were excluded due to small sample size (i.e., there were very few jack ('jill') Chinook salmon identified as female and few fin-clipped sockeye salmon) or missing data (i.e., date replaced water temperature in most steelhead models due to data availability). In all model comparisons, fish that entered reach tributaries were considered successful and those reported harvested in the main stem Columbia were treated as unsuccessful (conversion rate Metric B in Table 4). The models were ranked using Akaike's corrected information criteria (AIC_c) and evaluated with respect to ΔAIC_c, the change in AIC_c relative to the most parsimonious model (Burnham and Anderson 2002).

Results

Radio-tagged sample summary

In each study year, we collected and radio-tagged 600 adult Chinook salmon, 300 jack Chinook salmon, 399-400 adult sockeye salmon, 169-208 early summer steelhead, and 593-620 late summer steelhead (Table 5, Figure 2). Radio-tagged adult Chinook salmon represented 0.21-0.45% of the adult Chinook salmon counted at the dam during the tagging periods; percentages were 0.54-0.66% of jack Chinook salmon, 0.07-0.23% of adult sockeye salmon, 0.24-0.27% of early steelhead, and 0.64-3.42% of late steelhead. Note that relative oversampling of late steelhead was to address overwintering objectives reported separately.

Estimated sex composition of the radio-tagged samples were 49-50% male for adult Chinook salmon, 97-100% male for jack Chinook salmon, 55-56% male for sockeye salmon, and 37-54% male for the steelhead samples (Tables 6 and 7). A genetic marker for sex determination (OmyY1_2SEXY and Ots_SEXY3-1) was tested for subsamples of the adult Chinook salmon and steelhead. The results indicated that in-hand sex assignments were correct for only ~60% of

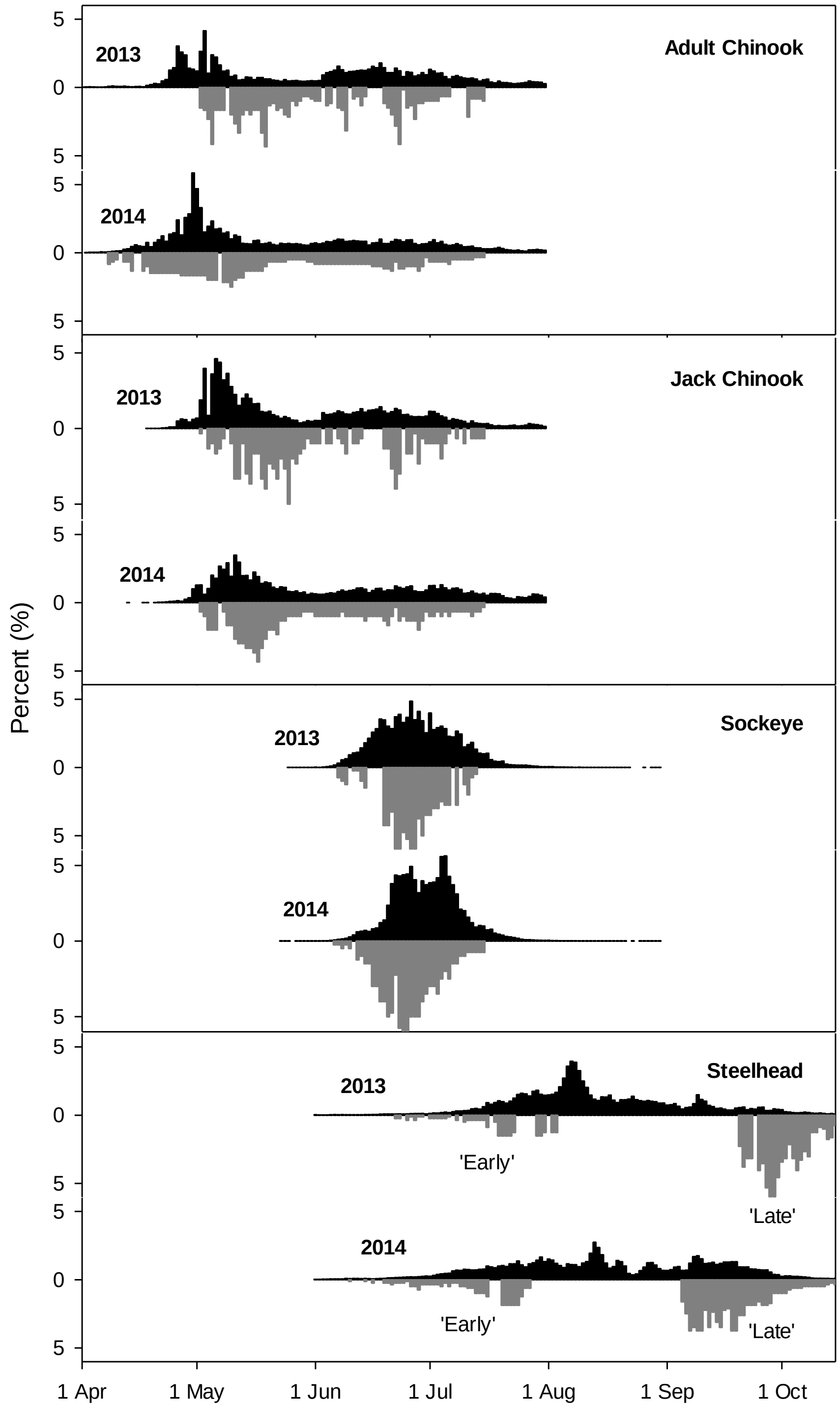

Figure 2. Timing distributions of adult and jack Chinook salmon, adult sockeye salmon, and adult summer steelhead at Bonneville Dam in 2013-2014, expressed as a percent of the run totals. Black bars represent fish count data and gray bars represent fish that were radio-tagged and released downstream from Bonneville Dam. The tagged steelhead samples were split into 'early' and 'late' groups in each year; the primary objective for steelhead was to assess overwintering. Note: 16 June was the nominal start of the summer Chinook salmon run at Bonneville Dam.

Table 5. Summary of the numbers of fish counted at Bonneville Dam, the numbers that were collected and radio-tagged with their collection date ranges, and the samples as a percentage of counts over the full season and over the sampling date range.

Run	Year	Run season BON count	Radio-tagged fish *n*	Radio-tagged fish Start	Radio-tagged fish End	% of total run season	% of sample date range
Chinook - Adult	2013	176,442[1]	600[5]	2 May	15 Jul	0.34%	0.45%
	2014	297,817[1]	600[6]	8 Apr	15 Jul	0.20%	0.21%
Chinook - Jack	2013	60,006[1]	300[7]	2 May	15 Jul	0.50%	0.54%
	2014	51,436[1]	300[8]	2 May	15 Jul	0.58%	0.66%
Sockeye	2013	185,505[2]	400	7 Jun	13 Jul	0.22%	0.23%
	2014	614,179[2]	399	6 Jun	15 Jul	0.06%	0.07%
Steelhead – Early	2013	140,994[3]	169	22 Jun	3 Aug	0.12%	0.24%
	2014	168,420[3]	208	10 Jun	27 Jul	0.12%	0.27%
Steelhead – Late	2013	91,387[4]	620	20 Sep	15 Oct	0.68%	3.42%
	2014	154,998[4]	593	5 Sep	15 Oct	0.38%	0.64%

[1] 1 January – 31 July; [2] 1 April – 30 September; [3] 1 April – 15 August; [4] 16 August – 31 December
[5] *n* = 414 sp, 186 su; [6] *n* = 459 sp, 141 su; [7] *n* = 208 sp, 92 su; [8] *n* = 213 sp, 87 su

the salmon and ~67% of the steelhead; note that all summaries use the in-hand age assignments due to delayed availability of genetic data.

Presumed wild origin (i.e., no fin clips) was 52% for adult Chinook salmon, 34-48% for jack Chinook salmon, 98-99% for sockeye salmon, 61-65% for early steelhead, and 32-34% for late steelhead. The incidence of head injuries ranged from ~2% of sockeye salmon to ~4-14% of adult Chinook salmon and steelhead. Most fish had some descaling, and majorities of all sample groups had descaling > 10%. The incidence of gillnet marks was low (≤ 9%) for all groups, but was relatively high for steelhead and relatively low for jack Chinook salmon and sockeye salmon. Marine mammal injury rates varied among groups: the percent with no mammal injuries were 77-79% for adult Chinook salmon, 91-94% for jack Chinook salmon, 87-93% for sockeye salmon, 81-86% for early steelhead, and 62-67% for late steelhead. For fish with mammal injuries, ‘old’ (i.e., healed) injuries were more frequent for sockeye salmon and steelhead while ‘new’ injuries were more frequent for adult and jack Chinook salmon (Tables 6 and 7).

Mean fork lengths for the tag groups were: 75.3-76.4 cm for adult Chinook salmon, 52.8-52.9 cm for jack Chinook salmon, 49.0-50.8 cm for sockeye salmon, 59.4-66.2 cm for early steelhead, and 71.0-75.5 cm for late steelhead (Figure 3). Based on tagger assessment of phenotypic traits, there was some limited size overlap between adult and jack Chinook salmon. The PBT genetic data allowed us to assess the in-hand age assignment accuracy for a subset of the hatchery-origin Chinook salmon. In the combined 2013-2014 samples, 263 Chinook salmon were designated as adults when trapped but the PBT data indicated that 8 (3.0%) were jacks. Fork lengths for the incorrectly assigned fish ranged from 55.5-68.5 cm (*mean* = 61.6 cm). A total of 241 Chinook salmon were designated as jacks when trapped, of which 2 (0.8%) were adults based on PBT age data; their fork lengths were 52 and 61 cm. Note that all reported analyses (except the kelts summary) used the in-hand age assignments due to delayed availability of genetic data.

Last detection sites: Adult Chinook salmon

Three radio-tagged adult Chinook salmon were censored from all analyses (Table 6). One adult Chinook salmon died (0.08% of 1,200 tagged) during transport and two regurgitated transmitters in the transport tank prior to release. These two fish were last detected at PIT antennas at Lower Granite Dam and Leavenworth fish hatchery. The telemetry data suggested that additional fish likely lost transmitters upon release, but transmitters were not recovered and these fish were conservatively treated as unaccounted for in all analyses.

At least 70.0% (2013) and 66.8% (2014) of adult spring–summer Chinook salmon passed McNary Dam at least once and 64.8-69.2% was last detected upstream from the dam (Table 6). Fisher-reported main stem harvest downstream from McNary Dam was 4.7-5.3% in the two years. Relatively more harvest was fisher-reported in the Bonneville-The Dalles reach (2.5-2.7%) than in other reaches, including below Bonneville Dam. Tributary turnoff by adults in the Bonneville-McNary reach was 8.2% (2013) and 14.2% (2014), with some fish in each year last detected in seven different tributaries (Wind, Little White Salmon, Hood, Klickitat, Deschutes, John Day, and Umatilla rivers) (Table 6). Estimates of unaccounted for fish were 17.5% (2013), and 15.7% (2014), and a third to half of those was last detected in the Bonneville pool.

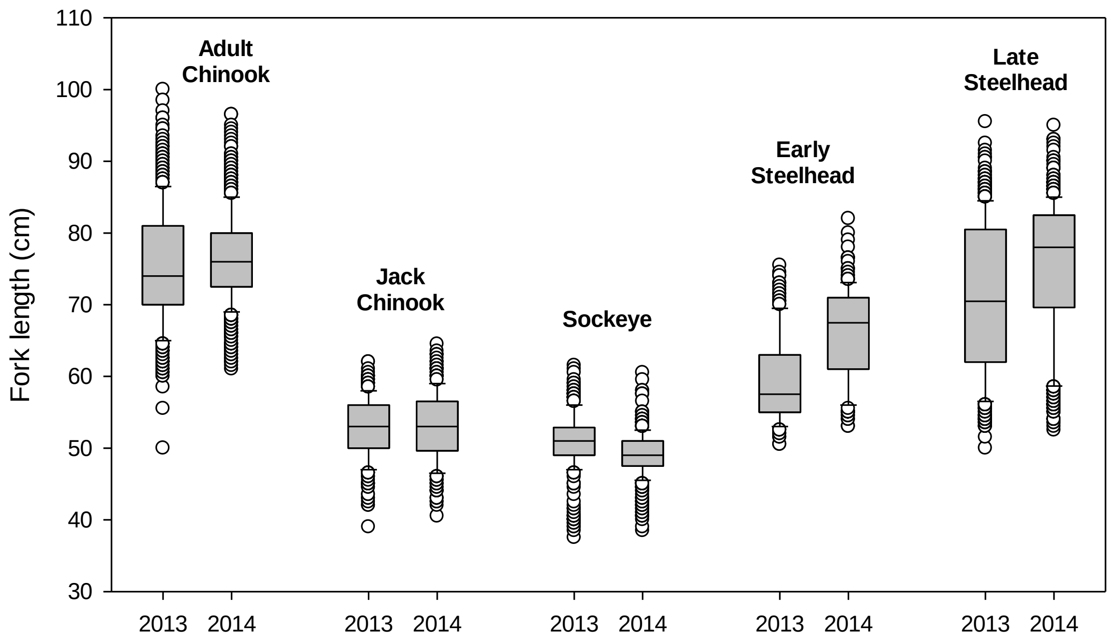

Figure 3. Fork length distributions for fish that were radio-tagged in 2013-2014. Plots show medians and quartiles (boxes), 10^{th} and 90^{th} percentiles (whiskers), and all individuals in the distribution tails (○). Adult versus jack Chinook salmon designations were assigned by tagging crews at Bonneville Dam. Sample sizes in Table 5.

Table 6. Traits of radio-tagged spring–summer Chinook and sockeye salmon in 2013-2014.

	'13 Adult Chinook	%	'14 Adult Chinook	%	'13 Jack Chinook		'14 Jack Chinook	%	'13 Adult sockeye	%	'14 Adult sockeye	%
Tagged	600		600		300		300		400		399	
Male	299	*49.8*	*292*	*48.7*	292	*97.3*	300	*100*	218	*54.5*	222	*55.6*
Female	300	*50.0*	306	*51.0*	7	*2.3*	-	-	173	*43.3*	169	*42.4*
Unknown	1	*0.2*	2	*0.3*	1	*0.3*	-	-	9	*2.3*	8	*2.0*
Wild	310	*51.7*	313	*52.3*	144	*48.0*	101	*33.7*	392	*98.0*	396	*99.3*
Hatchery	289	*48.2*	286	*47.8*	156	*52.0*	199	*66.3*	8	*2.0*	3	*0.8*
Unknown	1	*0.2*	1	*0.2*	-	-	-	-	-	-	-	-
Head injury (No)	569	*94.8*	523	*87.2*	290	*96.7*	281	*93.7*	394	*98.5*	391	*98.0*
Head injury (Yes)	31	*5.2*	77	*12.8*	10	*3.3*	19	*6.3*	6	*1.5*	8	*2.0*
Descaling (≤ 10%)	81	*13.5*	92	*15.3*	62	*20.7*	68	*22.7*	22	*5.5*	15	*3.8*
Descaling (> 10%)	519	*86.5*	508	*84.7*	238	*79.3*	232	*77.3*	378	*94.5*	384	*96.2*
Gillnet (No)	582	*97.0*	590	*98.3*	297	*99.0*	295	*98.3*	396	*99.0*	392	*98.3*
Gillnet (Yes)	18	*3.0*	10	*1.7*	3	*1.0*	5	*1.7*	4	*1.0*	7	*1.8*
Marine mammal (None)	475	*79.2*	463	*77.3*	273	*91.0*	281	*93.7*	349	*87.3*	370	*92.7*
Marine mammal (Old)	51	*8.3*	35	*5.8*	9	*3.0*	9	*3.0*	29	*7.3*	23	*5.8*
Marine mammal (New)	73	*12.2*	101	*16.9*	18	*6.0*	10	*3.3*	22	*5.5*	6	*1.5*

Table 7. Traits of radio-tagged steelhead in 2013-2014.

	‘13 early steelhead	%	‘14 early steelhead	%	‘13 late steelhead		‘14 late steelhead	%
Tagged	169		208		620		592	
Male	85	*50.3*	*77*	*37.0*	271	*43.7*	321	*54.2*
Female	84	*49.7*	130	*62.5*	347	*56.0*	259	*43.8*
Unknown	-	-	1	*0.5*	2	*0.3*	12	*2.0*
Wild	103	*60.9*	136	*65.4*	212	*34.2*	191	*32.3*
Hatchery	66	*39.1*	72	*34.6*	407	*65.7*	401	*67.7*
Unknown	-	-	-	-	1	*0.2*	-	-
Head injury (No)	147	*87.0*	196	*94.2*	532	*85.8*	569	*96.1*
Head injury (Yes)	22	*13.0*	12	*5.8*	85	*13.7*	23	*3.9*
Head injury (Unknown)	-	-	-	-	3	*0.5*	-	-
Descaling (≤ 10%)	17	*10.1*	29	*13.9*	74	*11.9*	95	*16.0*
Descaling (> 10%)	152	*89.9*	179	*86.1*	546	*88.1*	497	*83.8*
Gillnet (No)	162	*95.9*	207	*99.5*	583	*94.0*	536	*90.4*
Gillnet (Yes)	7	*4.1*	1	*0.5*	37	*6.0*	56	*9.4*
Marine mammal (None)	144	*85.7*	168	*80.8*	388	*62.6*	397	*67.1*
Marine mammal (Old)	15	*8.9*	22	*10.6*	127	*20.5*	104	*17.6*
Marine mammal (New)	9	*5.4*	18	*8.7*	104	*16.8*	90	*15.2*

Last detection sites: Jack Chinook salmon

Four radio-tagged jack Chinook salmon were censored from all analyses (Table 8). Two jacks died (0.33% of 600 tagged), including one during transport and one that was found dead in the AFF trap after recapture. Two jacks regurgitated transmitters in the transport tank prior to release or near the release site (transmitters recovered). These jacks were last detected at PIT antennas at The Dalles Dam. The telemetry data suggested that additional jacks likely lost transmitters upon release, but tags were not recovered and these fish were conservatively treated as unaccounted for in all analyses.

At least 86.0% (2013) and 78.3% (2014) of jack spring–summer Chinook salmon passed McNary Dam at least once and 76.3-83.3% was last detected upstream from the dam (Table 8). Fisher-reported main stem harvest downstream from McNary Dam was very low at 0.3-2.0% per year distributed throughout the study area. Tributary turnoff by jacks in the Bonneville-McNary reach was 10.3-10.7%, with the largest numbers last detected in the Umatilla, Klickitat, and Deschutes rivers. Unaccounted for estimates were 5.0% (2013) and 10.7% (2014), with most last detected in the Bonneville pool or downstream from Bonneville Dam (Table 8).

Last detection sites: Sockeye salmon

Two sockeye salmon (0.25% of 799 tagged) were censored, one after its transmitter was found in the transport tank and one with uncertainty regarding tagging status (Table 8).

Sockeye salmon were presumed to originate almost exclusively from sites upstream from McNary Dam. A total of 83.7% (2013) and 80.5% (2014) passed McNary Dam and was last detected upstream from the dam (Table 8). Fisher-reported main stem harvest downstream from McNary Dam was low at 1.8-3.0% per year, mostly in the Bonneville pool. A few sockeye salmon were last detected in the Little White Salmon and Klickitat rivers (potentially representing harvested fish with ‘in-air’ transmitters); these fish were treated as unaccounted for because harvest was unconfirmed. Total unaccounted for estimates were 13.3% (2013) and 17.5% (2014), with last detection sites throughout the study area but especially in the Bonneville pool (Table 8).

Last detection sites: Early steelhead

No early steelhead were censored in 2013 or 2014, though some likely spit transmitters at the release site. These were conservatively included in all analyses.

In total, 54.4% (2013) and 55.3% (2014) passed McNary Dam (45.2-46.2% last detected upstream), 5.3-6.5% was reported harvested downstream from McNary Dam, 26.4-29.6% entered tributaries below McNary Dam, and 17.8% (2013) and 23.1% (2014) was unaccounted for (Table 9). The fisher-reported main stem harvest was primarily in the Bonneville pool, but some was reported from each reservoir. The most-entered tributaries below McNary Dam were the John Day and Deschutes rivers in both years, though fish were last recorded in several other tributaries. Unaccounted for fish were last detected in each reservoir, with a majority in the Bonneville pool in both years (Table 9).

Last detection sites: Late steelhead

No late steelhead were censored in 2013 and one was censored in 2014 (pre-release mortality). In total, 74.7% (2013) and 74.4% (2014) passed McNary Dam (72.1-72.7% last detected upstream), 3.5-5.4% was reported harvested downstream from McNary Dam, 6.1-8.2% entered tributaries downstream from McNary Dam, and 14.7-16.1% was unaccounted for in the study reach (Table 9). As with the early group, the fisher-reported main stem harvest was primarily in the Bonneville pool. The most-entered tributaries below McNary Dam were the John Day and Deschutes rivers. A large majority of unaccounted for late steelhead was last detected in the Bonneville pool or downstream from Bonneville Dam in both years (Table 9).

Radio detection efficiency at top-of-ladder sites

Estimates of radio detection efficiency at the top-of-ladder antennas were calculated by dividing the number of fish known to have passed a dam based on upstream radio or PIT-tag detections by the number detected at top-of-ladder radiotelemetry antennas. Estimates ranged from 0.860 (adult Chinook salmon at McNary Dam in 2014) to 0.985 (jack Chinook salmon at Bonneville Dam in 2014) (Figure 4). At individual dams, mean detection efficiencies across run-years were: 0.949 (Bonneville), 0.970 (The Dalles), 0.954 (John Day), and 0.915 (McNary). Mean detection efficiencies for each run across dams were: 0.945 (adult Chinook salmon), 0.926 (jack Chinook salmon), 0.961 (sockeye salmon), and 0.955 (early and late steelhead combined).

All detection efficiency estimates were considered unbiased at the dam scale and were conservative for individual sites because all types of 'missed' detections were included. For example, some fish likely passed dams via navigation locks (in previous studies when navigation locks were monitored, 1-4% of radio-tagged Chinook salmon and steelhead and slightly more sockeye salmon passed via locks). Low detection efficiency at McNary Dam in 2013 was associated with a receiver power outage at the south fishway. Other missed detections were associated with presumed spit or non-functioning transmitters. The relatively low detection efficiency for jack Chinook salmon in 2013 across dams was presumably associated with lost transmitters or perhaps a group of under-performing transmitters (Figure 4).

Table 8. Last recorded locations of radio-tagged spring–summer Chinook and sockeye salmon in 2013-2014 derived from the combination of radiotelemetry and PIT detection histories. Note that some fish were recorded passing dams upstream from their final location (i.e., they fell back downstream) and harvest estimates are likely minima.

	'13 Adult Chinook	%	'14 Adult Chinook	%	'13 Jack Chinook	%	'14 Jack Chinook	%	'13 Adult sockeye	%	'14 Adult sockeye	%
Tagged	600		600		300		300		400		399	
Censored	*3*	*0.5*	-	-	*3*	*1.0*	*1*	*0.3*	*2*	*0.5*	-	-
Below BON (harvest)	2	*0.3*	*1*	*0.2*	-	-	1	*0.3*	-	-	*1*	*0.3*
Below BON (unacct)	25	*4.2*	20	*3.3*	6	*2.0*	8	*2.7*	12	*3.0*	*26*	*6.5*
BON reservoir (harvest)	15	*2.5*	16	*2.7*	1	*0.3*	1	*0.3*	11	*2.8*	*5*	*1.0*
BON reservoir (unacct)	40	*6.7*	45	*7.5*	5	*1.7*	17	*5.7*	22	*5.5*	*22*	*5.8*
Wind River	8	*1.3*	15	*2.5*	-	-	4	*1.3*	-	-	-	-
Little White Salmon R.	3	*0.5*	14	*2.3*	1	*0.3*	2	*0.7*	[1]4	*1.0*	-	-
Hood River	6	*1.0*	3	*0.5*	2	*0.3*	4	*1.3*	-	-	-	-
Klickitat River	5	*0.8*	8	*1.3*	9	*3.0*	6	*2.0*	[1]1	*0.3*	-	-
TDD reservoir (harvest)	7	*1.2*	5	*0.8*	-	-	2	*0.7*	-	-	*1*	*0.3*
TDD reservoir (unacct)	25	*4.2*	19	*3.2*	-	-	4	*1.3*	11	*2.8*	*11*	*2.8*
Deschutes River	16	*2.7*	14	*2.3*	6	*2.0*	9	*3.0*	-	-	-	-
JDD reservoir (harvest)	4	*0.7*	10	*1.7*	-	-	2	*0.7*	1	*0.3*	*1*	*0.3*
JDD reservoir (unacct)	15	*2.5*	10	*1.7*	4	*1.3*	3	*1.0*	3	*0.8*	*11*	*2.8*
John Day River	9	*1.5*	18	*3.0*	4	*1.3*	3	*1.0*	-	-	-	-
Umatilla River	2	*0.3*	13	*2.2*	9	*3.0*	4	*1.3*	-	-	-	-
Top of McNary Dam	11	*1.8*	10	*1.7*	4	*1.3*	4	*1.3*	25	*6.3*	*29*	*7.3*
Snake River dams	20	*3.3*	11	*1.8*	37	*12.3*	22	*7.3*	2	*0.5*	*1*	*0.3*
Snake River tributaries	148	*24.7*	184	*30.7*	117	*39.0*	113	*37.7*	1	*0.3*	*2*	*0.6*
Walla Walla River	1	*0.2*	-	-	-	-	-	-	-	-	-	-
Yakima River	28	*4.7*	18	*3.0*	19	*6.3*	22	*7.3*	1	*0.3*	-	-
Hanford Reach	-	-	-	-	-	-	-	-	1	*0.3*	-	-
Upper COL River dams	132	*22.0*	55	*9.2*	50	*16.7*	29	*9.7*	173	*43.3*	*73*	*18.3*
Upper COL River tribs	75	*12.5*	111	*18.5*	23	*7.7*	39	*13.0*	130	*32.5*	*216*	*54.1*
Release-MCN Harvest	28	*4.7*	32	*5.3*	1	*0.3*	6	*2.0*	12	*3.0*	8	*1.8*
Release-MCN Tributary	49	*8.2*	85	*14.2*	31	*10.3*	32	*10.7*	-	-	-	-
Release-MCN Unacct	105	*17.5*	94	*15.7*	15	*5.0*	32	*10.7*	53	*13.3*	70	*17.5*
Passed MCN[2]	420	*70.0*	401	*66.8*	258	*86.0*	235	*78.3*	333	*83.7*	321	*80.5*
Last detection >MCN	415	*69.2*	389	*64.8*	250	*83.3*	229	*76.3*	333	*83.7*	321	*80.5*

[1]Treated as unaccounted for; potentially harvested but not reported to us

[2] Most Chinook salmon that passed MCN but were last detected downstream entered the Umatilla River

Table 9. Last recorded locations of radio-tagged steelhead in 2013-2014 derived from the combination of radiotelemetry and PIT detection histories. Samples were split into 'early' and 'late' components due to unequal sampling effort (see Methods). Note that some fish were recorded passing dams upstream from their final location (i.e., they fell back downstream or were kelts) and harvest estimates are likely minima given low fisher-reported harvest rates.

	'13 early steelhead	%	'14 early steelhead	%	'13 late steelhead		'14 late steelhead	%
Tagged	169		208		620		593	
Censored	-	-	-	-	-	-	1	*0.2*
Below BON (harvest)	-	-	3	*1.4*	1	*0.2*	-	
Below BON (unacct)	3	*1.8*	5	*2.4*	37	*6.0*	16	*2.7*
Willamette River	-	-	-	-	1	*0.2*	-	-
BON reservoir (harvest)	7	*4.1*	4	*1.9*	18	*3.0*	14	*2.4*
BON reservoir (unacct)	16	*9.5*	39	*18.8*	48	*8.0*	50	*8.4*
Wind River	-	-	1	*0.5*	-	-	4	*0.7*
Lit. White / White Salm	3	*1.8*	4	*1.9*	3	*0.5*	-	
Hood River / 15 Mile Ck	-	-	-	-	1	*0.2*	2	*0.3*
Klickitat River	5	*3.0*	7	*3.4*	4	*0.6*	5	*0.8*
TDD reservoir (harvest)	2	*1.2*	1	*0.5*	1	*0.2*	11	*1.9*
TDD reservoir (unacct)	4	*2.4*	3	*1.4*	10	*1.6*	7	*1.2*
Deschutes River	14	*8.3*	12	*5.8*	20	*3.2*	16	*2.7*
JDD reservoir (harvest)	2	*1.2*	3	*1.4*	2	*0.3*	9	*1.5*
JDD reservoir (unacct)	7	*4.1*	1	*0.5*	5	*0.8*	17	*2.9*
John Day River	23	*13.6*	28	*13.5*	18	*2.9*	8	*1.3*
Umatilla R / Rock Cr	5	*3.0*	3	*1.4*	4	*0.6*	1	*0.2*
Top of McNary Dam[1]	4	*2.4*	6	*2.9*	17	*2.7*	10	*1.7*
Snake River dams/res	17	*10.1*	17	*8.2*	62	*10.0*	62	*10.5*
Snake River tributaries	34	*20.1*	55	*26.4*	356	*57.4*	347	*58.5*
Walla Walla River	2	*1.2*	1	*0.5*	4	*0.6*	1	*0.2*
Yakima River	3	*1.8*	2	*1.0*	1	*0.2*	2	*0.3*
Hanford / PR hatchery	1	*0.6*	-	-	-	-	-	-
Upper COL River dams	5	*3.0*	7	*3.4*	3	*0.5*	3	*0.5*
Upper COL River tribs	12	*7.1*	6	*2.9*	4	*0.6*	6	*1.0*
Release-MCN Harvest	11	*6.5*	11	*5.3*	22	*3.5*	32	*5.4*
Release-MCN Tributary	50	*29.6*	55	*26.4*	51	*8.2*	36	*6.1*
Release-MCN Unacct	30	*17.8*	48	*23.1*	100	*16.1*	87	*14.7*
Passed MCN[2]	92	*54.4*	115	*55.3*	463	*74.7*	441	*74.4*
Last detection >MCN	78	*46.2*	94	*45.2*	447	*72.1*	431	*72.7*

[1] includes a few fish that passed McNary Dam and subsequently fell back

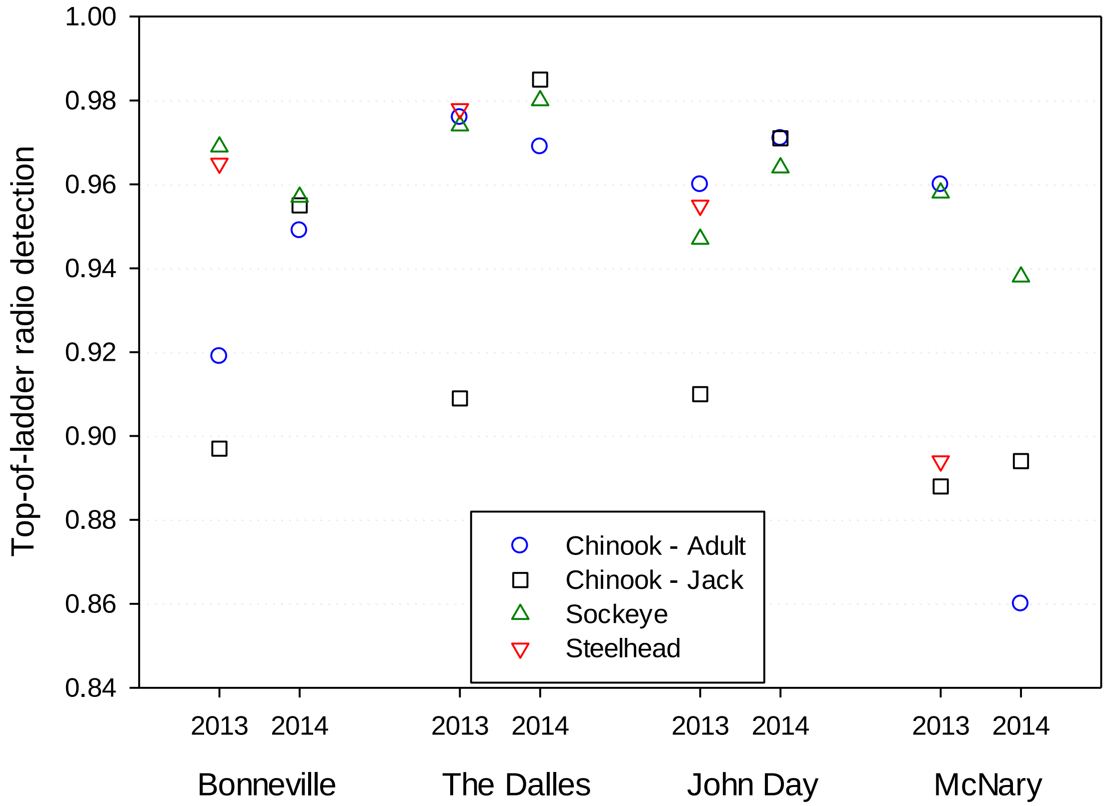

Figure 4. Detection efficiency of radio-tagged samples that had radiotelemetry records at the top-of-ladder antennas at the four study dams, 2013-2014. Denominators were based on upstream detections (radiotelemetry or PIT) at any radiotelemetry or PIT antenna site. Fish passing without radiotelemetry records primarily fell into four categories: 1) spit transmitter; 2) non-functioning transmitter; 3) passage during radio receiver power outage; or 4) fish passage through navigation lock.

Reach conversion estimates: Overview

The complete detection data used to estimate the four reach conversion metrics (A, B, C, D) are presented in appendix tables A1 (Release to pass Bonneville), A2 (top of Bonneville to top of The Dalles), A3 (top of The Dalles to top of John Day), A4 (top of John Day to top of McNary), and A5 (top of Bonneville to top of McNary). In the following report sections we present summaries for Metric B, where fish that entered tributaries were treated as successful migrants, and metric D, where fish harvested in the main stem and those that entered tributaries were censored. We selected these two metrics because they highlight the harvest and unaccounted for components of reach conversion (i.e., the terms with the most direct management applications). For each reach, we report the numbers that were voluntarily reported as harvested, that were unaccounted for in the main stem, and that entered tributaries. Note that these numbers may differ slightly from those reported in Table 8, which shows final detection locations and includes post-fallback movements.

At the request of interested stakeholders, we present conversion estimates for spring- and summer-run adult and jack Chinook salmon separately and in combination. Chinook salmon were assigned to the spring or summer groups based on their collection date at Bonneville Dam, with 16 June as the start date for the summer Chinook salmon run based on the U.S. v Oregon agreement. We also present separate estimates for early- and late-run steelhead because the radio-tagged samples were designed to overweight late migrants to better evaluate FCRPS overwintering.

Separate Bonneville-McNary conversion estimates were calculated for the Chinook salmon and steelhead with PBT and GSI genetic assignments. Our focus was on populations that originated upstream from McNary Dam with at least 10 fish in a year. We identified potential strays based on mismatches between origin – as identified in the genetic analyses – and final tributary detection location. Fish that were harvested in non-natal tributaries were considered strays for this summary.

Reach conversion estimates: Adult Chinook salmon

Release-top of Bonneville. With spring- and summer-run salmon combined, estimates were 0.966-0.970 for Metric B and 0.970-0.972 for Metric D (Figure 5). A total of 2 adult salmon were reported harvested downstream from the dam in each year and 16-18 were unaccounted for (Appendix Table A1). Note that no tributaries were monitored downstream from Bonneville Dam.

Conversion estimates differed for spring- and summer-run adults, with some estimates higher for spring fish and others higher for summer fish (Figure 5). Metric B estimates were 0.959 (spring) and 0.984 (summer) in 2013 and were 0.972 (spring) and 0.963 (summer) in 2014. Metric D estimates were 0.959 (spring) and 0.995 (summer) in 2013 and 0.974 (spring) and 0.972 (summer) in 2014.

Bonneville-The Dalles. With spring- and summer-run salmon combined, Metric B estimates were 0.910 (2013) and 0.890 (2014) and Metric D estimates were 0.934 (2013) and 0.910 (2014). Sixteen salmon were reported harvested in the reach in each year, 38 (2013) and 48 (2014) were unaccounted for, and 15 (2013) and 34 (2014) entered tributaries (Appendix Table A2).

Conversion estimates were mixed for spring- versus summer-run adults. Metric B estimates were 0.914 (spring) and 0.901 (summer) in 2013 and were 0.874 (spring) and 0.947 (summer) in 2014. Metric D estimates were 0.933 (spring) and 0.937 (summer) in 2013 and were 0.894 (spring) and 0.961 (summer) in 2014.

The Dalles-John Day. With spring- and summer-run salmon combined, Metric B estimates were 0.922 (2013) and 0.948 (2014) and Metric D estimates were 0.932 (2013) and 0.959 (2014). Six to seven salmon were reported harvested in the reach in each year, 33 (2013) and 19 (2014) were unaccounted for, and 20 (2013) and 19 (2014) entered the Deschutes River (Appendix Table A3).

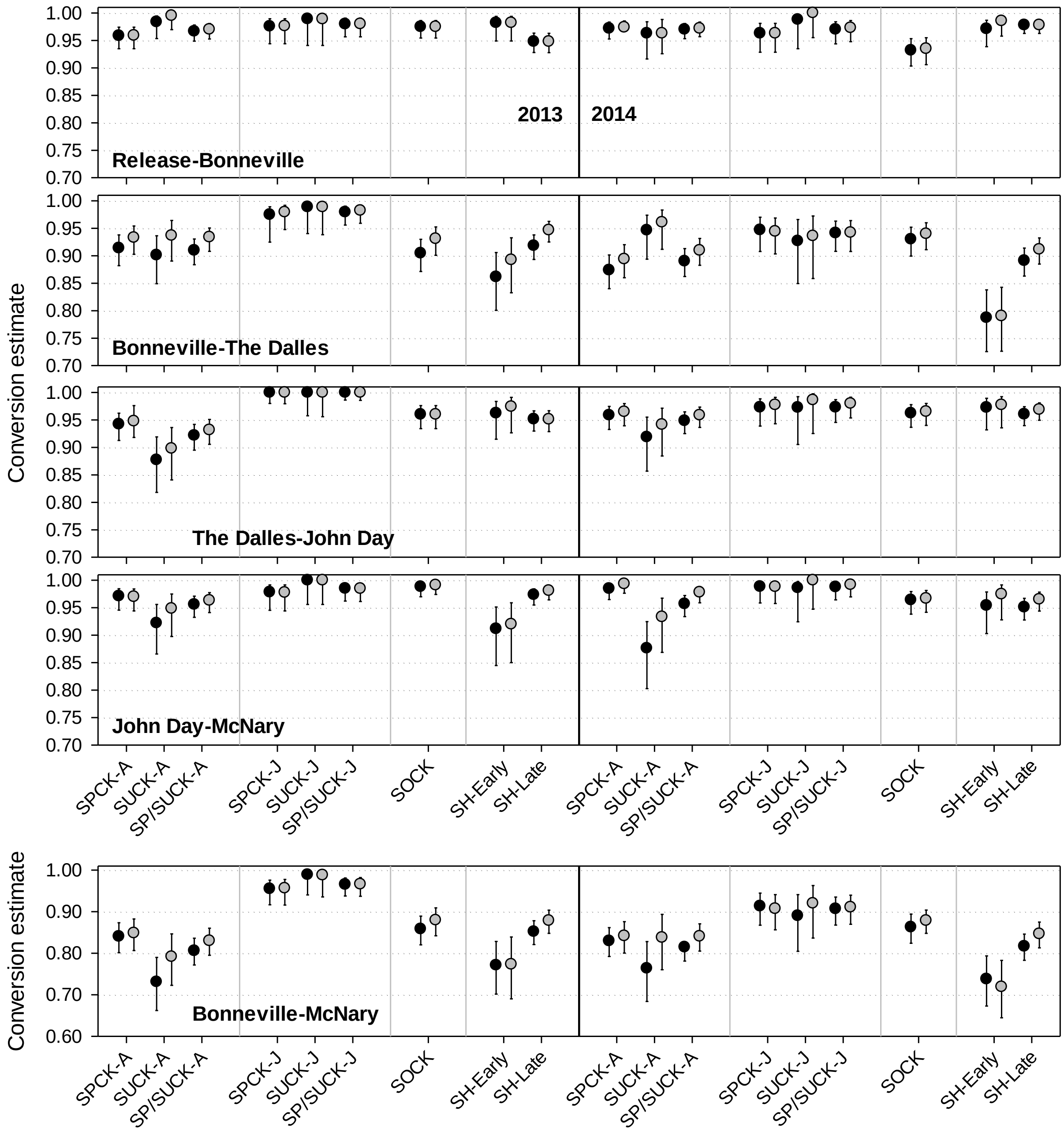

Figure 5. Annual reach conversion point estimates with 95% Wilson binomial confidence intervals for the five study reaches and all study groups. Data are for Metric B (●; tributary = successful) and Metric D (●; tributary and main stem harvest = censored). SPCK = spring Chinook salmon; SUCK = summer Chinook salmon; SOCK = sockeye salmon; SH = steelhead; A = adult; J = jack. Solid vertical line separates data from 2013 (left) and 2014 (right). Note different y-axis scale for the bottom panel (Bonneville-McNary reach).

Conversion estimates were higher for spring- versus summer-run adults in all comparisons. Metric B estimates were 0.942 (spring) and 0.877 (summer) in 2013 and were 0.959 (spring) and 0.919 (summer) in 2014. Metric D estimates were 0.948 (spring) and 0.898 (summer) in 2013 and were 0.965 (spring) and 0.942 (summer) in 2014. Very few summer-run adults were last detected in the Deschutes River.

John Day-McNary. With spring- and summer-run salmon combined, Metric B estimates were 0.956 (2013) and 0.957 (2014) and Metric D estimates were 0.963 (2013) and 0.978 (2014). Four to ten salmon were reported harvested in the reach in each year, 16 (2013) and 9 (2014) were unaccounted for, and 10 (2013) and 21 (2014) entered tributaries (Appendix Table A4).

Conversion estimates were higher for spring- versus summer-run adults in all comparisons. Metric B estimates were 0.971 (spring) and 0.922 (summer) in 2013 and were 0.985 (spring) and 0.876 (summer) in 2014. Metric D estimates were 0.970 (spring) and 0.919 (summer) in 2013 and were 0.993 (spring) and 0.933 (summer) in 2014. Very few summer-run adults were last detected in the John Day or Umatilla rivers.

Bonneville-McNary. With spring- and summer-run salmon combined, Metric B estimates were 0.806 (2013) and 0.815 (2014) and Metric D estimates were 0.830 (2013) and 0.841 (2014). Twenty-six to 32 salmon were reported harvested in the multi-dam reach in each year, 86 (2013) and 76 (2014) were unaccounted for, and 45 (2013) and 74 (2014) entered tributaries (Appendix Table A5).

Conversion estimates were higher for spring- versus summer-run adults in all comparisons. Metric B estimates were 0.841 (spring) and 0.731 (summer) in 2013 and were 0.830 (spring) and 0.763 (summer) in 2014. Metric D estimates were 0.848 (spring) and 0.791 (summer) in 2013 and were 0.842 (spring) and 0.838 (summer) in 2014.

Reach conversion estimates: Jack Chinook salmon

Release-top of Bonneville. With spring- and summer-run salmon combined, estimates were 0.970-0.980 for Metric B and 0.973-0.980 for Metric D (Figure 5). One jack salmon was reported harvested downstream from the dam and 6-8 were unaccounted for in each year (Appendix Table A1).

Conversion estimates were lower for spring-run jacks than for summer-run jacks in all comparisons (Figure 5). Metric B estimates were 0.976 (spring) and 0.989 (summer) in 2013 and were 0.963 (spring) and 0.988 (summer) in 2014. Metric D estimates were 0.976 (spring) and 0.989 (summer) in 2013 and 0.963 (spring) and 1.000 (summer) in 2014.

Bonneville-The Dalles. With spring- and summer-run salmon combined, Metric B estimates were 0.979 (2013) and 0.941 (2014) and Metric D estimates were 0.982 (2013) and 0.942 (2014). One salmon was reported harvested in the reach in each year, 5 (2013) and 16 (2014) were unaccounted for, and 9 (2013) and 13 (2014) entered tributaries (Appendix Table A2).

Conversion estimates were mixed for spring- versus summer-run jacks. Metric B estimates were 0.975 (spring) and 0.989 (summer) in 2013 and were 0.947 (spring) and 0.927 (summer) in 2014. Metric D estimates were 0.979 (spring) and 0.989 (summer) in 2013 and were 0.944 (spring) and 0.936 (summer) in 2014.

The Dalles-John Day. With spring- and summer-run salmon combined, Metric B estimates were 1.000 (2013) and 0.973 (2014) and Metric D estimates were 1.000 (2013) and 0.980 (2014). Zero to two jacks were reported harvested in the reach in each year, 0 (2013) and 5 (2014) were unaccounted for, and 9 (2013) and 10 (2014) entered the Deschutes River (Appendix Table A3).

Metrics B and D were 1.000 for both spring- and summer-run jacks in 2013. In 2014, Metric B estimates were 0.973 for both spring and summer fish and Metric D estimates were 0.977 (spring) and 0.986 (summer) in 2014.

John Day-McNary. With spring- and summer-run salmon combined, Metric B and Metric D estimates were ≥ 0.982 in both years. Zero to one salmon were reported harvested in the reach in each year, 4 (2013) and 2 (2014) were unaccounted for, and 5 entered tributaries in each year (Appendix Table A4).

All Metric B and D estimates were ≥ 0.978 for both spring- and summer-run jacks.

Bonneville-McNary. With spring- and summer-run salmon combined, Metric B estimates were 0.966 (2013) and 0.907 (2014) and Metric D estimates were 0.966 (2013) and 0.911 (2014). One to four salmon were reported harvested in the multi-dam reach in each year, 9 (2013) and 23 (2014) were unaccounted for, and 23 (2013) and 28 (2014) entered tributaries (Appendix Table A5).

Conversion estimates were mixed for spring- versus summer-run jacks. Metric B estimates were 0.955 (spring) and 0.989 (summer) in 2013 and were 0.913 (spring) and 0.890 (summer) in 2014. Metric D estimates were 0.956 (spring) and 0.988 (summer) in 2013 and were 0.907 (spring) and 0.920 (summer) in 2014.

Genetic assignments: Chinook salmon

Adults (PBT). In 2013, PBT assignments were possible for 26% of adult spring Chinook salmon and 2% of adult summer Chinook salmon (Table 10). The most abundant spring groups identified were from Rapid River (n = 33, 31% of 108 assigned), McCall (21, 19%), and Dworshak (15, 14%) hatcheries. PBT assignments for adults radio-tagged in 2014 were possible for 31% of spring-run fish and 5% of summer-run fish. The most abundant 2014 spring groups identified were from Rapid River (54, 38%), Dworshak (17, 12%), and the South Fork Clearwater (14, 10%) hatcheries.

In 2013, PBT assignments were possible for 5 of 11 (45%) spring Chinook salmon adults voluntarily reported as harvested and 22 of 69 (32%) of those that were unaccounted for downstream from McNary Dam (Table 10). The five harvested fish originated from five different hatcheries, while the unaccounted for group was from eight sites, and particularly from Rapid River and Klickitat hatcheries. In 2014, PBT assignments were possible for 6 of 20 (30%) harvested fish and 20 of 70 (29%) unaccounted for fish (Table 11). The harvested fish were from three hatcheries (Rapid River, McCall, Sawtooth) and the unaccounted for group assigned to 12 different sites (1-4 fish per hatchery).

Only one harvested adult summer Chinook salmon had a PBT assignment (Pahsimeroi hatchery in 2014). Similarly, only one unaccounted for summer adult was assigned (Imnaha hatchery in 2014).

Adults (GSI). In 2013, genetic stock identification assignments were possible for 89% of adult spring Chinook salmon and 84% of adult summer Chinook salmon (Table 11). Thirteen GSI groups were identified in the spring sample and 8 were identified for the summer sample. The most abundant spring fish with assignments were the Hells Canyon (n = 112, 31% of 367 assigned), the upper Columbia summer-fall (62, 17%), and the upper Columbia spring/Carson Hatchery spring group (58, 16%) groups. GSI assignments for adults radio-tagged in 2014 were possible for 98% of spring-run fish and 91% of summer-run fish. The most abundant spring groups were the Hells Canyon (n = 163, 36% of assigned fish), the upper Columbia summer-fall (63, 14%), and the South Fork Salmon (45, 10%) groups. The summer-run sample was predominantly assigned to the upper Columbia summer-fall group (Table 11).

In 2013, GSI assignments were possible for 11 of 11 (100%) spring Chinook salmon adults voluntarily reported as harvested and 63 of 69 (91%) of those that were unaccounted for downstream from McNary Dam (Table 11). The 11 harvested fish originated from six different groups, with 6 of the 11 from the Hells Canyon group. The unaccounted for fish assigned to ten reporting groups and the largest numbers were from the Hells Canyon and upper Columbia River spring/Carson hatchery groups. In 2014, GSI assignments were possible for 19 of 20 (30%) harvested spring adults and 67 of 70 (96%) unaccounted for fish (Table 11). The harvested fish were from five groups and the unaccounted for group assigned to eight different groups; the largest numbers were from Hells Canyon, upper Columbia spring/Carson hatchery, and upper Columbia summer-fall groups.

Most of the self-reported harvest (89-94%) and unaccounted for (82-93%) summer-run adults assigned to the upper Columbia summer/fall group in both years (Table 11).

Jacks (PBT). In 2013, PBT assignments were possible for 30% of jack spring Chinook salmon and 21% of jack summer Chinook salmon (Table 12). The most abundant spring groups were from Rapid River (n = 17, 28% of 61 assigned), Dworshak (12, 20%), and Lookingglass (9, 15%) hatcheries. PBT assignments for adults radio-tagged in 2014 were possible for 50% of spring-run fish and 38% of summer-run fish. The most abundant spring groups were from Rapid River (37, 34%), McCall (20, 18%), Dworshak (10, 9%), and Powell (10, 9%) hatcheries.

Only three jacks (2013 and 2014 combined) were voluntarily reported as harvested and all were assigned to McCall hatchery (Table 12).

PBT assignments were possible for 3 of 13 (23%) spring jacks that were unaccounted for downstream from McNary Dam in 2013 and 12 of 25 (48%) that were unaccounted for in 2014. These fish originated from eight different hatcheries, with the largest number of individuals from McCall hatchery. Three unaccounted for summer jacks were assigned: one to the Lostine hatchery and two to McCall hatchery.

Jacks (GSI). In 2013, genetic stock identification assignments were possible for 82% of jack spring Chinook salmon and 82% of jack summer Chinook salmon (Table 13). Ten GSI groups were identified in the spring sample and nine were identified for the summer sample. The most abundant spring fish were the Hells Canyon (*n* = 58, 35% of 168 assigned) and the upper Columbia spring/Carson Hatchery spring group (21, 13%) groups. GSI assignments for jacks in 2014 were possible for 97% of spring-run fish and 92% of summer-run fish. The most abundant spring groups were the Hells Canyon (*n* = 86, 41% of assigned fish), the upper Columbia spring/Carson Hatchery spring group (41, 20%), and the South Fork Salmon (22, 11%) groups. The summer-run sample was mostly assigned to the upper Columbia summer-fall group (*n* = 33, 43% of 77 assigned) and the South Fork Salmon (21, 27%) (Table 13).

In 2013-2014, GSI assignments were possible for 5 of 5 (100%) spring and summer Chinook salmon jacks that were voluntarily reported as harvested; three of the five were from the South Fork Salmon group and two were from the upper Columbia spring/Carson hatchery and upper Columbia summer/fall groups (Table 13). Assignments were possible for 13 of 15 (87%) unaccounted for spring and summer jacks in 2013 and for 25 of 31 (81%) unaccounted for in 2014. The spring jacks assigned to nine different GSI groups (largest numbers to Hells Canyon and South Fork Salmon) and the summer jacks assigned to two groups (Hells Canyon and South Fork Salmon) (Table 13).

Population-specific Bonneville-McNary reach conversion: Chinook salmon

Spring Adults (PBT). In the two years, 3-4 hatchery populations had ≥10 PBT-assigned spring adults: Dworshak (*n* = 15-17), Rapid River (*n* = 29-54), McCall (*n* = 13-20), and the South Fork Clearwater (*n* = 14, 2014 only) (Figure 6). (Note that conversion estimates in this section are for fish that passed Bonneville Dam, in contrast to the previous section which included fish that did not pass Bonneville Dam.)

Conversion estimates for the Dworshak fish were 0.733-0.882 (Metric A), 0.800-0.882 (Metric B), and 0.846-0.882 (Metric D). In 2013, one Dworshak fish entered a tributary in the Bonneville-McNary reach and was considered an unsuccessful stray (6.7% of the total that passed Bonneville Dam) and one (6.7%) was reported in main stem harvest. In each year, 1-2 were unaccounted for, or 10.0-13.3% of those that passed Bonneville Dam.

Estimates for the Rapid River fish were 0.793-0.852 (Metric A), 0.828-0.889 (Metric B), and 0.852-0.920 (Metric D). One to two fish were considered strays (3.4-3.7%), one to two were reported harvested (3.4-3.7%), and four (7.4-13.8%) were unaccounted for in each year.

Estimates for the McCall fish were 0.538-0.950 (Metric A), 0.692-0.950 (Metric B), and 0.778-0.950 (Metric D). In 2013, one of 20 fish (5.0%) did not pass through the reach; it was unaccounted for. In 2014, two fish were considered strays (15.4%), two were reported harvested (15.4%), and two (15.4%) were unaccounted for.

Estimates for the SF Clearwater group in 2014 were 0.857 for all three metrics. Two of the 12 fish were unaccounted for (14.3%).

Spring Jacks (PBT). Three PBT hatchery groups had ≥10 assigned spring jacks: Dworshak (*n* = 10-11 fish), Rapid River (*n* = 17-37), and McCall (*n* = 18, 2014 only).

In 2013, all Dworshak and Rapid River jacks successfully passed through the Bonneville-McNary reach (all Metrics = 1.000). In 2014, the Dworshak estimates were 0.900 (all Metrics), with a single fish unaccounted for. Estimates for the 2014 Rapid River group were 0.946 (all Metrics), with two fish unaccounted for (5.4%). Estimates for the McCall group were 0.778 (Metric A), 0.833 (Metric B), and 0.824 (Metric D); one fish (5.6%) was considered a stray and three (16.7%) were unaccounted for (Figure 6).

Summer Adults and Jacks (PBT). No PBT hatcheries had ≥10 assigned summer adults. In 2014, there were 11 jacks assigned to the Imnaha hatchery (all Metrics = 1.000) and 14 jacks assigned to the McCall hatchery. Reach conversion estimates for the McCall fish were 0.786 (Metric A and B) and 0.917 (Metric D); 2 of 14 fish were reported harvested (14.3%) and 1 was unaccounted for (7.1%).

Spring Adults (GSI). Six GSI reporting groups had ≥10 adult spring Chinook salmon in both years with origins primarily upstream from McNary Dam (Figure 7). These included the Yakima (*n* = 22-23 fish), upper Columbia/Carson hatchery (*n* = 57-88), Hells Canyon (*n* = 104-158), South Fork Salmon (*n* = 25-44), upper Salmon (*n* = 24-62), and upper Columbia summer/fall (*n* = 60-62) groups.

Conversion estimates for the Yakima group were 0.864-0.870 (Metrics A and B) and 0.864-0.909 (Metric D). No fish were considered strays in either year, one (4.3%) was reported harvested in 2013, and 2-3 were unaccounted for (8.7-13.6%).

The upper Columbia/Carson group was presumably a mixture of fish with origins upstream from Priest Rapids Dam, from the Little White Salmon River in the Bonneville-The Dalles reach, and potentially from other lower Columbia River sites. No Metric A estimates were therefore calculated for this group and we did not estimate straying. Conversion estimates for the group were 0.789-0.795 (Metric B), and 0.750-0.764 (Metric D) in the two years. One and five fish were reported harvested (1.8-5.7%) and 11-13 were unaccounted for (14.8-19.3%).

Estimates for the Hells Canyon group were 0.750-0.785 (Metric A), 0.856-0.867 (Metric B), and 0.879-0.897 (Metric D). In the two years, 11-13 (8.2-10.6%) fish were considered strays, 4-6 (2.5-5.8%) were reported harvested, and 9-17 (8.7-10.8%) were unaccounted for.

Estimates for the South Fork Salmon group were 0.705-0.909 (Metric A), 0.773-0.977 (Metric B), and 0.838-0.976 (Metric D); all three Metrics were higher in 2013 than 2014. In both year, three (6.8%) salmon were considered strays, four (9.1%) were reported harvested in 2014, and one to six (2.3-13.6%) were unaccounted for.

Estimates for the upper Salmon group were 0.667-0.880 (Metric A), 0.750-0.920 (Metric B), and 0.800-0.957 (Metric D); all three Metrics were higher in 2013 than 2014. One to two (4.0-8.3%) fish were considered strays, one to two were reported harvested (4.0-8.3%), and one to four (4.0-16.7%) were unaccounted for.

A surprising number of spring-run adults were assigned to the upper Columbia summer/fall GSI group. Conversion estimates for this group were 0.800-0.839 (Metric A), 0.817-0.855 (Metric B), and 0.828-0.867 (Metric D); all three Metrics were higher in 2013 than 2014. In both years, one (1.6-1.7%) fish was considered a stray, one was reported harvested (1.6-1.7%), and eight to ten (12.9-16.7%) were unaccounted for.

Summer Adults (GSI). Two GSI reporting groups had ≥10 adult summer Chinook salmon with origins primarily upstream from McNary Dam (Figure 7). These were the upper Columbia summer/fall group (n = 106-143) and South Fork Salmon (n = 11, 2014 only) group.

Estimates for the upper Columbia summer/fall group were 0.692-0.738 (Metric A), 0.692-0.777 (Metric B), and 0.780-0.835 (Metric D); all estimates were higher in 2014 than in 2013. No strays were identified in 2013, but four (3.9%) were likely strays in 2014. In the two years, 8-16 (7.8-11.2%) were reported harvested and 15-28 (14.6-19.6%) were unaccounted for.

Estimates for the South Fork Salmon group in 2014 were 0.818 (Metric A), 0.909 (Metric B), and 0.900 (Metric D). One (9.1%) fish was considered a stray and one (9.1%) was unaccounted for.

Spring Jacks (GSI). Five to six GSI groups had ≥10 jack spring Chinook salmon assigned in each year, with groups that largely overlapped those reported above for adults (Figure 8). Bonneville-McNary Metric B and D estimates for spring jacks were almost all > 0.900, with the exception of the mixed stock upper Columbia/Carson group in 2013 (Metric B = 0.833, Metric D = 0.818) and the South Fork Salmon group in 2014 (Metric B = 0.889, Metric D = 0.882).

No spring jack from the above groups was reported harvested. Stray rate estimates were 2.4-3.0% (Hells Canyon group), 5.6% (South Fork Salmon group, 2014), and 6.7% (upper Salmon group, 2014). Unaccounted-for fish made up 0.0-7.3% of the spring jack groups (Figure 8).

Summer Jacks (GSI). Two to three GSI groups had ≥10 jack summer Chinook salmon assigned in each year (Figure 8). As with the spring-run jacks, most conversion rate estimates for the summer jacks were > 0.900. The only exceptions were Metric A for: the Hells Canyon group in 2013 (0.857), the South Fork Salmon group in 2013 (0.833), and Metric A (0.800) and B (0.850) for the upper Columbia summer/fall group in 2014 (Figure 8).

Table 10. Parentage-based tagging (PBT) population assignments for adult Chinook salmon that were radio-tagged at Bonneville dam in 2013-2014. Harvested and unaccounted for (Unacct) groups include all fish in those categories that did not pass McNary Dam. 'Total tagged' refers to all fish released downstream from Bonneville Dam. Percentages in parentheses are for the total in each assignment group. Spring and summer run designations based on the U.S. v Oregon agreement (summer run begins 16 June).

	2013 Adult (spring)			**2013 Adult (summer)**			**2014 Adult (spring)**			**2014 Adult (summer)**		
PBT Hatchery	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)
Klickitat	9	1 (11.1)	5 (55.6)				9		1 (11.1)			
Tucannon	2		1 (50.0)									
Dworshak	15	1 (6.7)	2 (13.3)				17		2 (11.8)			
NPT Hatchery	2		1 (50.0)				2		2 (100)			
SF Clearwater	1						14		2 (14.3)			
Powell	5	1 (20.0)	2 (40.0)				6		1 (16.7)			
Grande Ronde							3					
Catherine Cr							2					
Lookingglass	1						5		1 (20.0)			
Lostine							2		1 (50.0)			
Imnaha	7			2			2		1 (50.0)	1		1 (100)
Pahsimeroi	4		1 (25.0)				4		1 (25.0)	2	1 (50.0)	
Rapid River	33	1 (3.0)	8 (24.2)				54	2 (3.7)	4 (7.4)			
Johnson Creek							2					
McCall	21		2 (9.5)	2			13	2 (15.4)	2 (15.4)	3		
Sawtooth	8	1 (12.5)					8	2 (25.0)	2 (25.0)	1		
Total assigned	108	5 (4.6)	22 (20.3)	4	-	-	143	6 (4.2)	20 (14.0)	7	1 (14.3)	1 (14.3)
Total tagged[1]	412	11 (2.7)	69 (16.7)	185	17 (9.2)	35 (18.9)	465	20 (4.3)	70 (15.1)	135	9 (6.7)	23 (17.0)
Unassigned[1]	*304*	*6 (2.0)*	*47 (15.5)*	*181*	*17 (9.4)*	*35 (19.3)*	*322*	*14 (4.3)*	*50 (15.5)*	*128*	*8 (6.3)*	*22 (17.2)*

[1] includes all wild-origin fish

Table 11. Genetic stock identification (GSI) population assignments for jack (or jill) Chinook salmon that were radio-tagged at Bonneville dam in 2013-2014. Harvested and unaccounted for (Unacct) groups include all fish in those categories that did not pass McNary Dam. 'Total tagged' refers to all fish released downstream from Bonneville Dam. Percentages in parentheses are for the total in each assignment group. Spring and summer run designations based on the U.S. v Oregon agreement (summer run begins 16 June).

	2013 Adult (spring)			**2013 Adult (summer)**			**2014 Adult (spring)**			**2014 Adult (summer)**		
GSI group	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)
02_WCASSP	1		1 (100)									
06_KLICKR	13	1 (7.7)	7 (53.8)				10		1 (10.0)			
07_DESCSP	16		7 (43.8)				13					
08_JOHNDR	1						8		1 (12.5)			
09_YAKIMA	25	1 (4.0)	4 (16.0)	1			23		4 (17.4)			
10_UCOLSP	58	1 (1.7)	12 (20.7)	1		1 (100)	93	5 (5.4)	18 (19.4)			
11_TUCANO	2		1 (50.0)				1					
12_HELLSC	112	6 (5.4)	17 (15.2)	2			163	5 (3.1)	21 (12.9)	1		1 (100)
13_SFSALM	46		3 (6.5)	3			45	4 (8.9)	7 (15.6)	11		1 (9.1)
14_CHAMBLN	2						2					
15_MFSALM	2						9					
16_UPSALM	27	1 (3.7)	3 (11.1)	3			24	2 (8.3)	4 (16.7)	4	1 (25.0)	1 (25.0)
18_UCOLSF	62	1 (1.6)	8 (12.9)	143	16 (11.2)	28 (19.6)	63	3 (4.8)	11 (17.5)	106	8 (7.5)	18 (17.0)
19_SRFALL				2	1 (50.0)	1 (50.0)				1		1 (100)
Total assigned	367	11 (3.0)	63 (17.2)	155	17 (11.0)	30 (19.4)	454	19 (4.2)	67 (14.8)	123	9 (7.3)	22 (17.9)
Total tagged	412	11 (2.7)	69 (16.7)	185	17 (9.2)	35 (18.9)	465	20 (4.3)	70 (15.1)	135	9 (6.7)	23 (17.0)
Unassigned	45	-	6 (13.3)	30	-	5 (16.7)	11	1 (9.1)	3 (27.3)	12	-	1 (8.3)

Table 12. Parentage-based tagging (PBT) population assignments for jack (or jill) Chinook salmon that were radio-tagged at Bonneville dam in 2013-2014. Harvested and unaccounted for (Unacct) groups include all fish in those categories that did not pass McNary Dam. 'Total tagged' refers to all fish released downstream from Bonneville Dam. Percentages in parentheses are for the total in each assignment group. Spring and summer run designations based on the U.S. v Oregon agreement (summer run begins 16 June).

	2013 Jack (spring)			**2013 Jack (summer)**			**2014 Jack (spring)**			**2014 Jack (summer)**		
PBT Hatchery	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)
Klickitat	1		1 (100)	3			2					
Tucannon	1						1					
Dworshak	12		1 (8.3)				10		1 (10.0)			
NPT Hatchery							1					
SF Clearwater	2						3					
Powell	2						10		1 (10.0)			
Grande Ronde							4					
Catherine Cr							2					
Lookingglass	9		1 (11.1)				5					
Lostine	1			3			4		1 (25.0)	2		1 (50.0)
Imnaha	2			6			2			11		
Pahsimeroi	2			2			1			1		
Rapid River	17						37		2 (5.4)			
Johnson Creek	1									3		
McCall	8			5		1 (20.0)	20		5 (25.0)	15	3 (20.0)	1 (6.7)
Sawtooth	3						7		2 (28.6)			
Total assigned	61	-	3 (4.9)	19	-	1 (5.3)	109	-	12 (11.0)	32	3 (9.4)	2 (6.3)
Total tagged[1]	205	1 (0.5)	13 (6.3)	92	-	2 (2.2)	216	1 (0.5)	25(11.6)	84	4 (4.8)	6 (7.1)
Unassigned[1]	144	1 (0.7)	10 (6.9)	73	-	1 (1.4)	107	1 (0.9)	2 (28.6)	52	1 (1.9)	4 (7.7)

[1] includes all wild-origin fish

Table 13. Genetic stock identification (GSI) population assignments for jack (or jill) Chinook salmon that were radio-tagged at Bonneville dam in 2013-2014. Harvested and unaccounted for (Unacct) groups include all fish in those categories that did not pass McNary Dam. 'Total tagged' refers to all fish released downstream from Bonneville Dam. Percentages in parentheses are for the total in each assignment group. Spring and summer run designations based on the U.S. v Oregon agreement (summer run begins 16 June).

	2013 Jack (spring)			**2013 Jack (summer)**			**2014 Jack (spring)**			**2014 Jack (summer)**		
GSI group	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)
02_WCASSP												
06_KLICKR	2		1 (50.0)	3			2			1		
07_DESCSP	7		2 (28.6)	1			12		1 (8.3)	1		
08_JOHNDR	5		3 (60.0)				1					
09_YAKIMA	8			2			21		1 (4.8)			
10_UCOLSP	21	1 (4.8)	2 (9.5)	2			41		5 (12.2)	3		
11_TUCANO	2						1					
12_HELLSC	58		4 (6.9)	14			86		7 (8.1)	15		1 (6.7)
13_SFSALM	10			12		1 (8.3)	22		6 (27.3)	21	3 (14.3)	1 (4.8)
14_CHAMBLN												
15_MFSALM	4						2					
16_UPSALM	8			5			16		2 (12.5)	3		
18_UCOLSF				35			5		1 (20.0)	33	1 (3.0)	
19_SRFALL				1								
Total assigned	168	1 (0.6)	12 (7.1)	75	-	1 (1.3)	209	-	23 (11.0)	77	4 (5.2)	2 (2.6)
Total tagged	205	1 (0.5)	13 (6.3)	92	-	2 (2.2)	216	1 (0.5)	25(11.6)	84	4 (4.8)	6 (7.1)
Unassigned	37	-	1 (2.7)	17	-	1 (5.9)	7	-	2 (28.6)	7	-	4 (57.1)

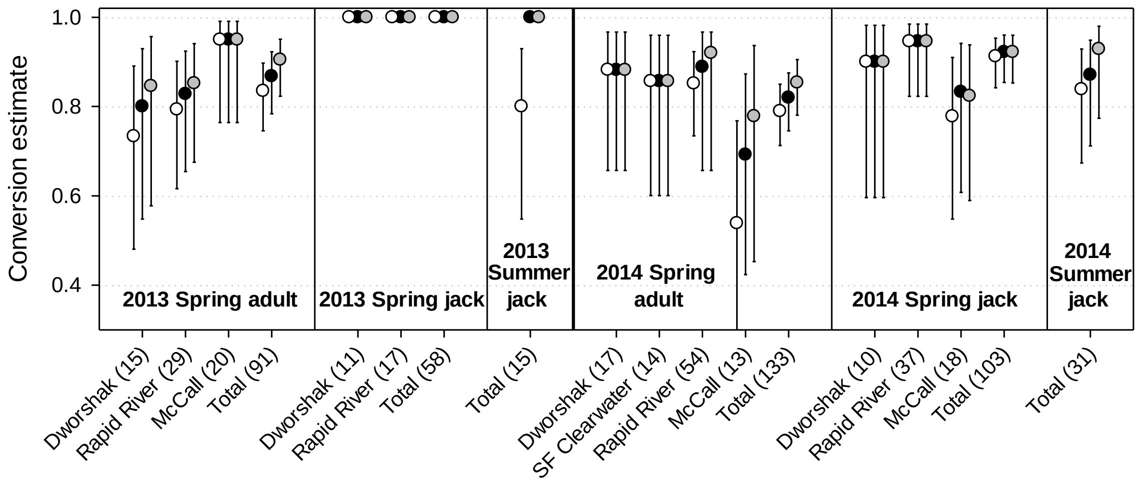

Figure 6. Annual Bonneville-McNary reach conversion point estimates with 95% Wilson binomial confidence intervals for the adult and jack Chinook salmon populations identified using parentage-based tagging (PBT). Data are for Metric A (○; tributary = unsuccessful), Metric B (●; tributary = successful) and Metric D (●; tributary and main stem harvest = censored). Solid vertical line separates data from 2013 (left) and 2014 (right). Estimates are shown for populations with ≥10 assigned individuals that originated upstream from McNary Dam and 'Total' includes all assigned fish. (Note: Metric A presumes that fish that entered tributaries between Bonneville and McNary were either permanent strays or may have been harvested; these fish were treated as successful in Metric B and were censored in Metric D.)

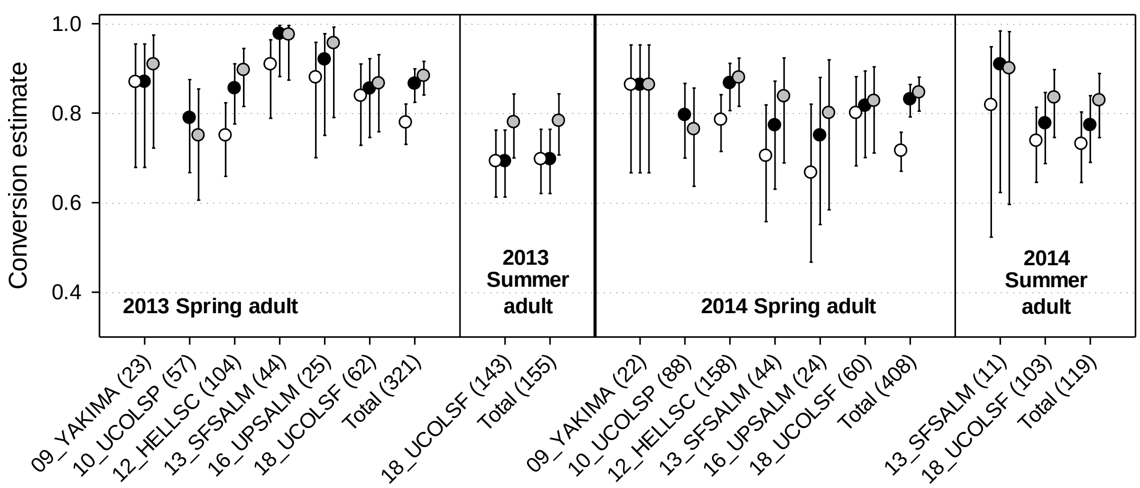

Figure 7. Annual Bonneville-McNary reach conversion point estimates with 95% Wilson binomial confidence intervals for the adult Chinook salmon populations identified using genetic stock identification (GSI). Data are for Metric A (○; tributary = unsuccessful), Metric B (●; tributary = successful) and Metric D (●; tributary and main stem harvest = censored). Solid vertical line separates data from 2013 (left) and 2014 (right). Estimates are shown for populations with ≥10 assigned individuals that originated upstream from McNary Dam and 'Total' includes all assigned fish. (Note: Metric A presumes that fish that entered tributaries between Bonneville and McNary were either permanent strays or may have been harvested; these fish were treated as successful in Metric B and were censored in Metric D.)

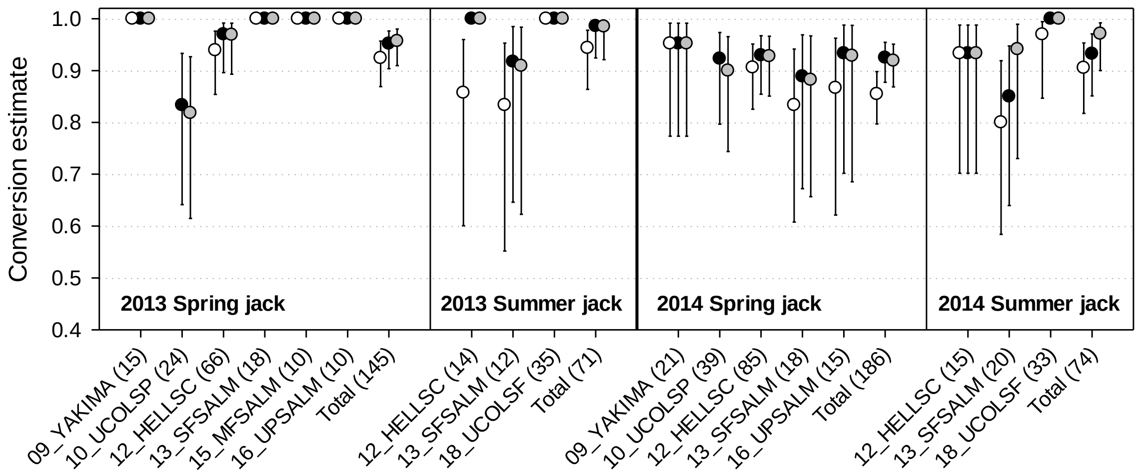

Figure 8. Annual Bonneville-McNary reach conversion point estimates with 95% Wilson binomial confidence intervals for the jack Chinook salmon populations identified using genetic stock identification (GSI). Data are for Metric A (○; tributary = unsuccessful), Metric B (●; tributary = successful) and Metric D (●; tributary and main stem harvest = censored). Solid vertical line separates data from 2013 (left) and 2014 (right). Estimates are shown for populations with ≥10 assigned individuals that originated upstream from McNary Dam and 'Total' includes all assigned fish. (Note: Metric A presumes that fish that entered tributaries between Bonneville and McNary were either permanent strays or may have been harvested; these fish were treated as successful in Metric B and were censored in Metric D.)

Reach conversion estimates: Sockeye salmon

Release-top of Bonneville. Conversion estimates for sockeye salmon were 0.932-0.975 for Metric B and 0.935-0.975 for Metric D (Figure 5). One sockeye salmon was reported harvested downstream from the dam in 2014 and 10 (2013) and 26 (2014) were unaccounted for (Appendix Table A1).

Bonneville-The Dalles. Metric B estimates were 0.905 (2013) and 0.930 (2014) and Metric D estimates were 0.931 (2013) and 0.943 (2014). Fisher-reported harvest was 11 fish (2013) and 5 fish (2014). Twenty-two to 26 were unaccounted for (Appendix Table A2).

The Dalles-John Day. Metric B estimates were 0.960 (2013) and 0.962 (2014) and Metric D estimates were 0.960 (2013) and 0.965 (2014). Only one salmon was reported harvested and 14 (2013) and 12 (2014) were unaccounted for (Appendix Table A3).

John Day-McNary. Metric B estimates were 0.988 (2013) and 0.964 (2014) and Metric D estimates were 0.991 (2013) and 0.970 (2014). One to two salmon were reported harvested in each year and 3 (2013) and 10 (2014) were unaccounted for (Appendix Table A4).

Bonneville-McNary. Metric B estimates were 0.858 (2013) and 0.863 (2014) and Metric D estimates were 0.886 (2013) and 0.879 (2014). Fisher-reported harvest in the multi-dam reach was 12 (2013) and 7 (2014) fish, and 43 (2013) and 44 (2014) were unaccounted for (Appendix Table A5).

Reach conversion estimates: early steelhead

Release-top of Bonneville. Conversion estimates for early steelhead were 0.982 (2013) and 0.971 (2014) for Metric B and were 0.982 (2013) and 0.985 (2014) for Metric D (Figure 5). Three fish were unaccounted for downstream from the dam in each year and three were reported harvested in 2014 (Appendix Table A1).

Bonneville-The Dalles. Conversion estimates were 0.861 (2013) and 0.787 (2014) for Metric B and 0.893 (2013) and 0.790 (2014) for Metric D. Ten to 12 fish entered tributaries, four to seven were reported harvested, and 16 (2013) and 39 (2014) were unaccounted for (Appendix Table A2).

The Dalles-John Day. Conversion estimates were 0.962 (2013) and 0.973 (2014) for Metric B and 0.974 (2013) and 0.977 (2014) for Metric D. Thirteen to 15 fish entered the Deschutes River, one to two were reported harvested, and three were unaccounted for in each year (Appendix Table A3).

John Day-McNary. Conversion estimates were 0.912 (2013) and 0.954 (2014) for Metric B and 0.920 (2013) and 0.975 (2014) for Metric D. Nine to 11 fish entered tributaries, two to three were reported harvested, and three to eight were unaccounted for (Appendix Table A4).

Bonneville-McNary. Conversion estimates were 0.771 (2013) and 0.738 (2014) for Metric B and 0.773 (2013) and 0.719 (2014) for Metric D. Thirty-four to 36 fish entered tributaries, eight to 11 were reported harvested, and 27-45 were unaccounted for (Appendix Table A5).

Reach conversion estimates: late steelhead

Release-top of Bonneville. Conversion estimates for late steelhead were 0.948 (2013) and 0.978 (2014) for Metric B and 0.948 (2013) and 0.978 (2014) for Metric D (Figure 5). One fish entered the Willamette River, none were reported harvested, and 13 (201) and 32 (2014) were unaccounted for (Appendix Table A1).

Bonneville-The Dalles. Conversion estimates were 0.918 (2013) and 0.891 (2014) for Metric B and 0.947 (2013) and 0.912 (2014) for Metric D. Four to ten fish entered tributaries, 14-18 were reported harvested, and 30-49 were unaccounted for (Appendix Table A2).

The Dalles-John Day. Conversion estimates were 0.951 (2013) and 0.960 (2014) for Metric B and 0.951 (2013) and 0.969 (2014) for Metric D. Sixteen to 22 fish entered the Deschutes River, 1-5 were reported harvested, and 15-25 were unaccounted for (Appendix Table A3).

John Day-McNary. Conversion estimates were 0.973 (2013) and 0.951 (2014) for Metric B and 0.981 (2013) and 0.965 (2014) for Metric D. Five to 11 fish entered tributaries, 4-7 were reported harvested, and 9-16 were unaccounted for (Appendix Table A4).

Bonneville-McNary. Conversion estimates were 0.852 (2013) and 0.817 (2014) for Metric B and 0.879 (2013) and 0.846 (2014) for Metric D. Thirty-one to 37 fish entered tributaries, 23-26 were reported harvested, and 64-80 were unaccounted for (Appendix Table A5).

Genetic assignments: steelhead

2013 (PBT). In 2013, parentage-based tagging assignments were possible for 25% of early steelhead and 74% of late steelhead (Table 14). The most abundant early groups were from Lyons Ferry (n = 20, 47% of 43 assigned) and Pahsimeroi (14, 33%) hatcheries. The most abundant late steelhead in 2013 were from Dworshak / Clearwater (323 of 459 assigned, 70%), Pahsimeroi (44, 10%), and the three Sawtooth hatchery groups (48, 10%).

PBT assignments were possible for 3 of 11 (27%) early steelhead that were voluntarily reported as harvested and 8 of 30 (27%) of those that were unaccounted for downstream from McNary Dam (Table 14). The three harvested fish were all from Lyons Ferry hatchery, while the unaccounted for group was from three sites: Lyons Ferry, Pahsimeroi, and Wallowa hatcheries. In the 2013 late group, PBT assignments were possible for 16 of 23 (70%) of harvested fish and 65 of 96 (68%) of unaccounted for fish (Table 14). The harvested fish were from three hatcheries, but primarily (88%) from the Dworshak/Clearwater group. The unaccounted for group assigned to nine different sites, but primarily to Dworshak/Clearwater (54%) and the Sawtooth groups (17%).

2014 (PBT). In 2014, PBT assignments were possible for 22% of early steelhead and 71% of late steelhead (Table 14). The most abundant early groups were from Lyons Ferry (n = 14, 30% of 43 assigned) and Pahsimeroi (12, 26%) hatcheries. The most abundant late steelhead in 2014 were from Dworshak / Clearwater (310 of 423 assigned, 73%), Pahsimeroi (35, 8%), and the three Sawtooth hatchery groups (39, 9%).

PBT assignments were possible for just 2 of 11 (18%) early steelhead voluntarily reported as harvested and 10 of 48 (21%) of those that were unaccounted for downstream from McNary Dam (Table 14). The latter group was assigned to five sites, with 30% each from the Lyons Ferry and Pahsimeroi hatcheries. In the 2014 late group, PBT assignments were possible for 19 of 26 (73%) of harvested fish and 71 of 93 (76%) of unaccounted for fish (Table 14). The harvested fish were from five hatcheries, with 79% from the Dworshak/Clearwater group. The unaccounted for group assigned to nine different sites, but primarily to Dworshak/ Clearwater (73%) and the Sawtooth groups (10%).

2013 (GSI). In 2013, GSI assignments were possible for 98% of early steelhead and 95% of late steelhead (Table 15). The most abundant early groups were from the geographically diverse MGILCS group (n = 106, 64% of 165 assigned) and UPSALM group (36, 22%). The most abundant late steelhead in 2013 were from SFCLWR (351 of 591 assigned, 59%), UPSALM (120, 20%), and MGILCS (92, 16%) groups.

GSI assignments were possible for all early steelhead that were voluntarily reported as harvested and all that were unaccounted for downstream from McNary Dam (Table 15). The 11 harvested fish were primarily (73%) from the MGILCS group and the 30 unaccounted for fish were a mix of MGILCS (60%), UPSALM (20%), and SKAMAN (17%) groups. In the 2013 late group, GSI assignments were possible for all 23 harvested fish and 92 of 96 (96%) of unaccounted for fish (Table 15). The harvested fish were from four groups, with 70% from the SFCLWR group and 13% each from the MGILCS and UPSALM groups. The unaccounted for fish assigned to four groups: SFCLWR (46%), UPSALM (27%), MGILCS (23%), and UPCLWR (3%).

2014 (GSI). GSI assignments were possible for 98% of early steelhead and 97% of late steelhead (Table 15). The most abundant early groups were again from the diverse MGILCS group (n = 121, 60% of 203 assigned) and the UPSALM group (45, 22%). The most abundant late steelhead were from SFCLWR (352 of 576 assigned, 61%), UPSALM (98, 17%), MGILCS (68, 12%), and UPCLWR (30, 5%) groups.

GSI assignments were possible for all 11 early steelhead that were voluntarily reported as harvested and 46 of 48 (96%) that were unaccounted for downstream from McNary Dam (Table 15). The 11 harvested fish were primarily (82%) from the MGILCS group and the 30 unaccounted for fish were a mix of MGILCS (46%), UPSALM (20%), and SKAMAN (15%) fish. In the late group, GSI assignments were possible for all 26 harvested fish and 92 of 93 (99%) of unaccounted for fish (Table 15). The harvested fish were from six groups, with 65% from the SFCLWR group and 4-13% each from the other groups. The unaccounted for fish were assigned to six groups but primarily to SFCLWR (59%), MGILCS (18%), and UPSALM (17%).

Population-specific Bonneville-McNary reach conversion: steelhead

Early Steelhead (PBT). In both years, two hatchery populations in the PBT-assigned early run had ≥10 early steelhead: Pahsimeroi (n = 11-14) and Lyons Ferry (n = 14-19) (Figure 9). (Note that conversion estimates in this section are for fish that passed Bonneville Dam, in contrast to the previous section which included fish that did not pass Bonneville Dam.)

Conversion estimates for the Pahsimeroi fish were 0.636-0.714 (Metric A), 0.727-0.786 (Metric B), and 0.769-0.813 (Metric D). In each year, one Pahsimeroi fish entered a tributary in the Bonneville-McNary reach and was considered an unsuccessful stray (7.1-9.1% of the totals that passed Bonneville Dam). No Pahsimeroi fish were reported as main stem harvest and three were unaccounted for each year, or 21.4-36.4% of those that passed Bonneville Dam.

Conversion estimates for the Lyons Ferry fish were 0.684-0.714 (Metric A and Metric B), and 0.700-0.769 (Metric D). No Lyons Ferry fish entered a tributary in the Bonneville-McNary reach. One to three (7.1-15.8%) were reported harvested, and three (15.8-21.4%) were unaccounted for in each year.

Late Steelhead (PBT). In the two years, five hatchery populations in the late run had ≥10 late steelhead: Pahsimeroi (*n* = 35-39), Sawtooth Shoshone-Bannock (*n* = 24-36), Dworshak (*n* = 307-319), Wallowa (*n* = 12-24), and Oxbow (*n* = 14; 2014 only) (Figure 9).

Conversion estimates for the Pahsimeroi steelhead were 0.857-0.897 (Metric A), 0.914-0.974 (Metric B), and 0.909-1.000 (Metric D). In each year, 2-3 Pahsimeroi fish entered a tributary in the Bonneville-McNary reach and were considered strays (5.7-7.7% of the totals that passed Bonneville Dam). One Pahsimeroi fish was reported in main stem harvest in 2013 (2.6%) and 3 three unaccounted for in 2014 (8.6%).

Estimates for the Sawtooth Shoshone-Bannock steelhead were 0.833-0.875 (Metric A), 0.833-0.958 (Metric B), and 0.857-0.955 (Metric D). In 2014, two fish were considered strays (8.3%). One fish was reported in main stem harvest in 2013 (2.8%) and 1-5 were unaccounted for (4.2-13.9%).

Estimates for the Dworshak steelhead were 0.762-0.818 (Metric A), 0.792-0.859 (Metric B), and 0.827-0.894 (Metric D). Nine to 13 fish were considered strays (2.9-4.1%), 14-15 were reported as main stem harvest (4.4-4.9%), and 31-49 were unaccounted for (9.7-16.0%).

Estimates for the Wallowa steelhead were 1.000 for all Metrics in 2013 and 0.583 (Metric A and B) and 0.636 (Metric D) in 2014. The 2014 group included one reported harvest (8.3%) and four unaccounted for (33.3%).

Estimates for the Oxbow steelhead were 0.714 (Metric A), 0.786 (Metric B), and 0.833 (Metric D) in 2014. The group included one stray (7.1%), one reported harvest (7.1%), and two unaccounted for (14.3%).

Early Steelhead (GSI). In both years, a majority of the GSI assignments for early steelhead were to the MGILCS group, a catchall that includes populations from mid-Columbia (including the Deschutes River) and lower Snake River tributaries (see Table 3). Bonneville-McNary reach conversion estimates were calculated for those groups that most likely originated upstream from McNary Dam. Groups with ≥10 fish included the UPPCOL group in 2013 (*n* = 11) and the UPSALM group in both years (*n* = 36-43) (Figure 10).

Estimates for the UPPCOL steelhead were 0.818 (Metric A), 0.909 (Metric B), and 1.000 (Metric D) in 2013. The group included one stray (9.1%), one reported harvest (9.1%), and no unaccounted for fish.

Estimates for the UPSALM steelhead were 0.639-0.737 (Metric A), 0.778-0.814 (Metric B), and 0.793-0.805 (Metric D). The group included 2-5 strays (4.7-13.9%), two reported harvest (5.6%, 2013), and 6-8 unaccounted for (16.7-18.6%).

Late Steelhead (GSI). Late-run steelhead groups that originated upstream from McNary Dam and that had ≥10 fish included the SFCLWR (*n* =344-349), UPCLWR (*n* = 17-30), and UPSALM (*n* = 92-105) (Figure 10).

Estimates for the SFCLWR steelhead were 0.777-0.814 (Metric A), 0.805-0.852 (Metric B), and 0.842-0.899 (Metric D). The group included 10-13 strays (2.9-3.8%), 16-17 reported harvested fish (4.7-4.9%), and 35-51 unaccounted for fish (10.2-14.6%).

Estimates for the UPCLWR steelhead were 0.765-0.833 (Metric A), 0.765-0.900 (Metric B), and 0.813-0.913 (Metric D). The group included two strays (6.7%, 2014), one reported harvested fish (5.9%, 2013), and three unaccounted for fish in each year (10.0-17.6%).

Estimates for the UPSALM steelhead were 0.804-0.848 (Metric A), 0.870-0.876 (Metric B), and 0.881-0.899 (Metric D). The group included three to six strays (2.9-6.5%), two to three reported harvested fish (2.2-2.9%), and ten unaccounted for fish in each year (9.5-10.9%).

Bonneville-McNary Conversion: Aggregate samples versus population-specific estimates

None of the four reach conversion metrics was ideally suited for comparing estimates for fish with population assignments to the aggregate radio-tagged samples because the genetic information allowed additional inference about straying vs. homing and because the aggregate sample was not sampled randomly through the entire run season. However, to provide a general sense of how population-specific estimates compared to the aggregate estimates, we selected Metric B, which treated fish that entered tributaries between Bonneville and McNary dams as successful.

In the comparison using PBT-assigned groups, equal numbers of population-specific Bonneville-McNary conversion estimates were higher than and lower than the aggregate estimates (n = 13 each, Figure 11). Population-specific conversion was ≥0.100 higher than the aggregate estimates for: McCall adult spring Chinook salmon (2013), Imnaha jack summer Chinook salmon (2014), Pahsimeroi early steelhead (2013), Pahsimeroi late steelhead (2013, 2014), and Sawtooth Shoshone-Bannock late steelhead (2014). Population-specific conversion was ≥0.100% lower than the aggregate estimates for: McCall adult spring Chinook salmon (2014), McCall jack summer Chinook salmon (2014), Lyons Ferry early steelhead (2013), and Wallowa late steelhead (2014).

In the GSI-based comparison, 28 population-specific reach conversion estimates were higher than and 12 were lower than the aggregate estimates (Figure 12). Population-specific conversion was ≥0.100 higher than the aggregate estimates for: the SFSALM adult spring Chinook salmon (2013), SFSALM adult summer Chinook salmon (2014), UCOLSF jack Chinook salmon (2014), and UPPCOL early steelhead (2013). Population-specific conversion was ≥0.100 lower than the aggregate estimates only for the UCOLSP jack spring Chinook salmon (2013); importantly, the UCOLSP reporting group likely included fish that originated in the Bonneville-McNary reach.

Table 14. Parentage-based tagging (PBT) population assignments for steelhead that were radio-tagged at Bonneville dam in 2013-2014. Harvested and unaccounted for (Unacct) groups include all fish in those categories that did not pass McNary Dam. 'Total tagged' refers to all fish released downstream from Bonneville Dam. Percentages in parentheses are for the total in each assignment group.

	2013 Early steelhead			**2013 Late steelhead**			**2014 early steelhead**			**2014 Late steelhead**		
PBT Hatchery	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)	PBT (*n*)	Harvest *n* (%)	Unacct *n* (%)
Pahsimeroi	14		3 (21.4)	44	1 (2.3)	5 (11.4)	12	1 (8.3)	3 (25.0)	35		3 (8.6)
Oxbow	1			8		3 (37.5)	10		2 (20.0)	14	1 (7.1)	2 (14.3)
Sawtooth[1]				6		1 (16.7)				6	1 (16.7)	1 (16.7)
Sawtooth [2]	4			40	1 (2.5)	9 (22.5)	5		1 (20.0)	27		4 (14.8)
Sawtooth[3]				2		1 (50.0)				6		
Dworshak /CW				323	14 (4.3)	35 (10.8)				310	15 (4.8)	52 (16.8)
Little Sheep Cr				2		1 (50.0)				3		2 (66.7)
Wallowa	2		1 (50.0)	27		8 (29.6)	1		1 (100)	12	1 (8.3)	4 (33.3)
Cottonwood	2			7		2 (28.6)	3			3	1 (33.3)	1 (33.3)
Touchet							1					
Lyons Ferry	20	3 (15.0)	4 (20.0)				14	1 (7.1)	3 (21.4)	7		2 (28.6)
Total assigned	43	3 (7.0)	8 (18.6)	459	16 (3.5)	65 (14.2)	46	2 (4.3)	10 (21.7)	423	19 (4.5)	71 (16.8)
Total tagged[4]	169	11 (6.5)	30 (17.8)	620	23 (3.7)	96 (15.5)	208	11 (5.3)	48 (23.1)	592	26 (4.4)	93 (15.7)
Unassigned[4]	*126*	*8 (6.3)*	*22 (17.5)*	*161*	*7 (4.3)*	*31 (19.3)*	*162*	*9 (5.6)*	*38 (23.5)*	*169*	*7 (4.1)*	*22 (13.0)*

[1] East Fork Salmon River; [2] IDFG and Shoshone-Bannock outplants; [3] upper Salmon B-group (original source: Clearwater)
[4] includes all wild-origin fish

Table 15. Genetic stock identification (GSI) population assignments steelhead that were radio-tagged at Bonneville dam in 2013-2014. Harvested and unaccounted for (Unacct) groups include all fish in those categories that did not pass McNary Dam. 'Total tagged' refers to all fish released downstream from Bonneville Dam. Percentages in parentheses are for the total in each assignment group.

	2013 Early steelhead			**2013 Late steelhead**			**2014 early steelhead**			**2014 Late steelhead**		
GSI group	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)	GSI (*n*)	Harvest *n* (%)	Unacct *n* (%)
02_LOWCOL										1		
03_SKAMAN	7		5 (71.4)				13	1 (7.7)	7 (53.8)	1	1 (100)	
04_WILLAM				1			1					
06_KLICKR	1						10		5 (50.0)	3		
07_MGILCS	106	8 (7.5)	18 (17.0)	92	3 (3.3)	22 (23.9)	121	9 (7.4)	21 (17.4)	68	3 (4.4)	17 (25.0)
08_YAKIMA	3		1 (33.3)	1			3		1 (33.3)	1		
09_UPPCOL	11	1 (9.1)		4			8		2 (25.0)	7	1 (14.3)	
10_SFCLWR				351	16 (4.6)	42 (12.0)				352	17 (4.8)	54 (15.3)
11_UPCLWR				17	1 (5.9)	3 (17.6)	1			30		3 (10.0)
12_SFSALM				4			1		1 (100)	8		1 (12.5)
13_MFSALM	1			1						7	2 (28.6)	1 (14.3)
14_UPSALM	36	2 (5.6)	6 (16.7)	120	3 (2.5)	25 (20.8)	45	1 (2.2)	9 (20.0)	98	2 (2.0)	16 (16.3)
Total assigned	165	11 (6.7)	30 (18.2)	591	23 (3.9)	92 (15.6)	203	11 (5.4)	46 (22.7)	576	26 (4.5)	92 (16.0)
Total tagged	169	11 (6.5)	30 (17.8)	620	23 (3.7)	96 (15.5)	208	11 (5.3)	48 (23.1)	592	26 (4.4)	93 (15.7)
Unassigned	4	-	-	29	-	4 (13.8)	5	-	2 (40.0)	16	-	1 (6.3)

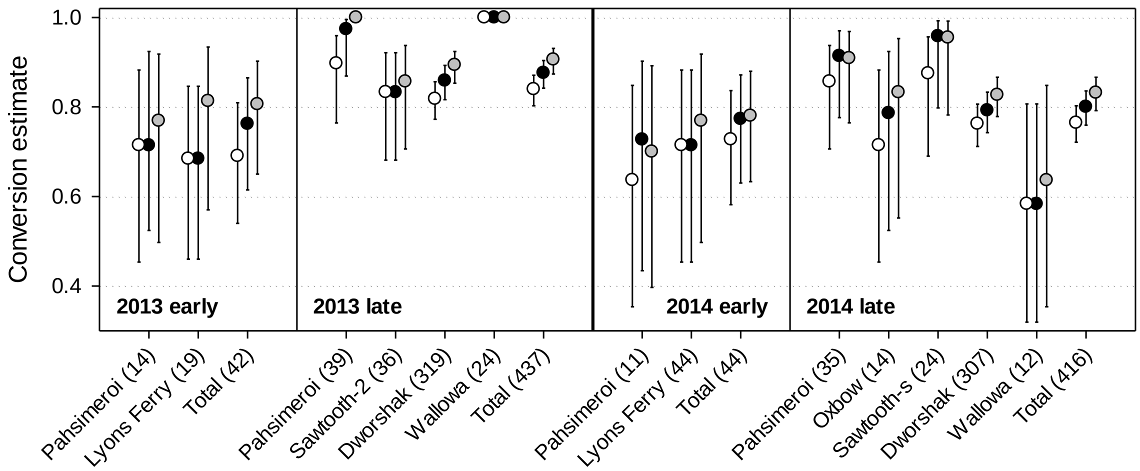

Figure 9. Annual Bonneville-McNary reach conversion point estimates with 95% Wilson binomial confidence intervals for the adult steelhead populations identified using parentage-based tagging (PBT). Data are for Metric A (○; tributary = unsuccessful), Metric B (●; tributary = successful) and Metric D (●; tributary and main stem harvest = censored). Solid vertical line separates data from 2013 (left) and 2014 (right). Estimates are shown for populations with ≥10 assigned individuals that originated upstream from McNary Dam and ‘Total’ includes all assigned fish. (Note: Metric A presumes that fish that entered tributaries between Bonneville and McNary were either permanent strays or may have been harvested; these fish were treated as successful in Metric B and were censored in Metric D.)

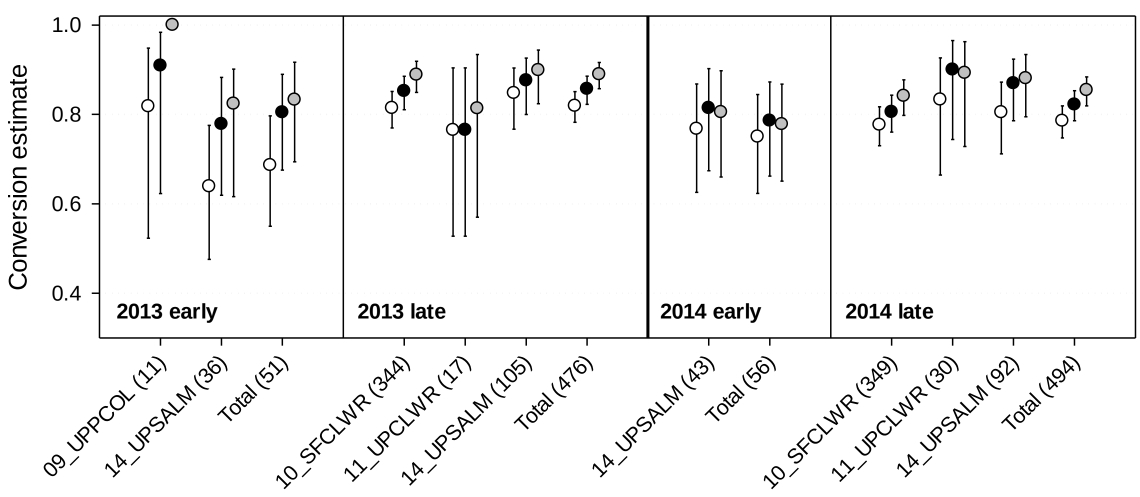

Figure 10. Annual Bonneville-McNary reach conversion point estimates with 95% Wilson binomial confidence intervals for the adult steelhead populations identified using genetic stock identification (GSI). Data are for Metric A (○; tributary = unsuccessful), Metric B (●; tributary = successful) and Metric D (●; tributary and main stem harvest = censored). Solid vertical line separates data from 2013 (left) and 2014 (right). Estimates are shown for populations with ≥10 assigned individuals that originated upstream from McNary Dam and ‘Total’ includes all assigned fish. (Note: Metric A presumes that fish that entered tributaries between Bonneville and McNary were either permanent strays or may have been harvested; these fish were treated as successful in Metric B and were censored in Metric D.)

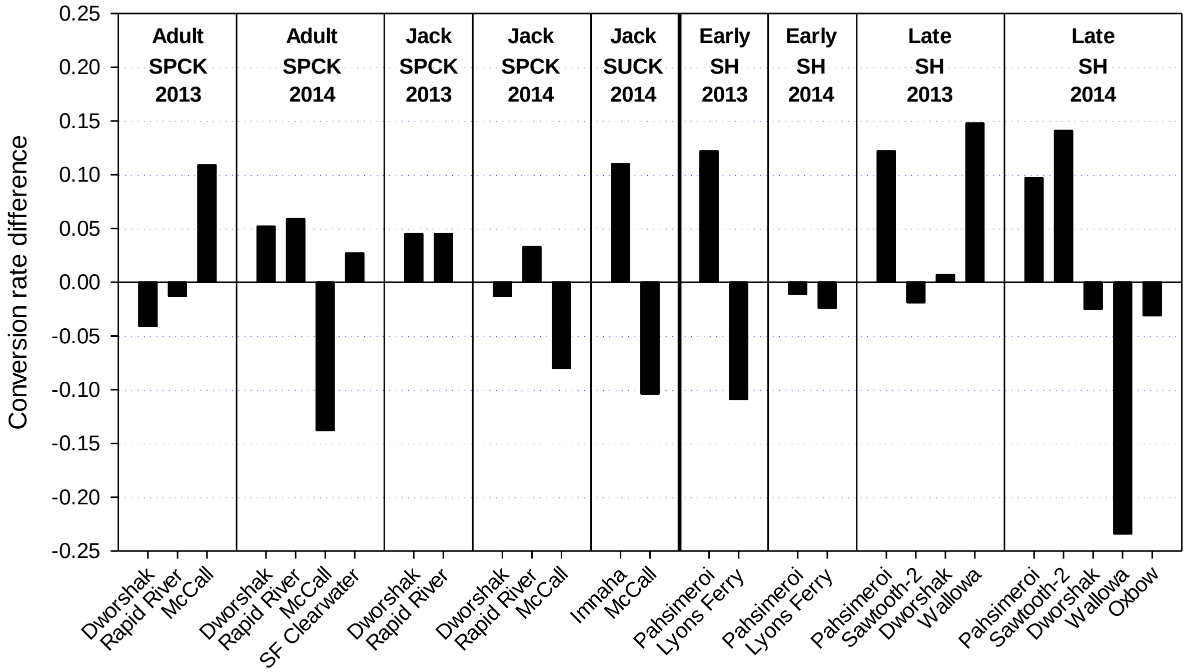

Figure 11. Differences in Bonneville-McNary conversion estimates for Chinook salmon and steelhead populations assigned using parentage-based tagging (PBT) versus the full radio-tagged samples. Differences in Metric B calculated as: Population estimate – full sample estimate. Positive values indicate the population estimates were higher than the full sample estimates.

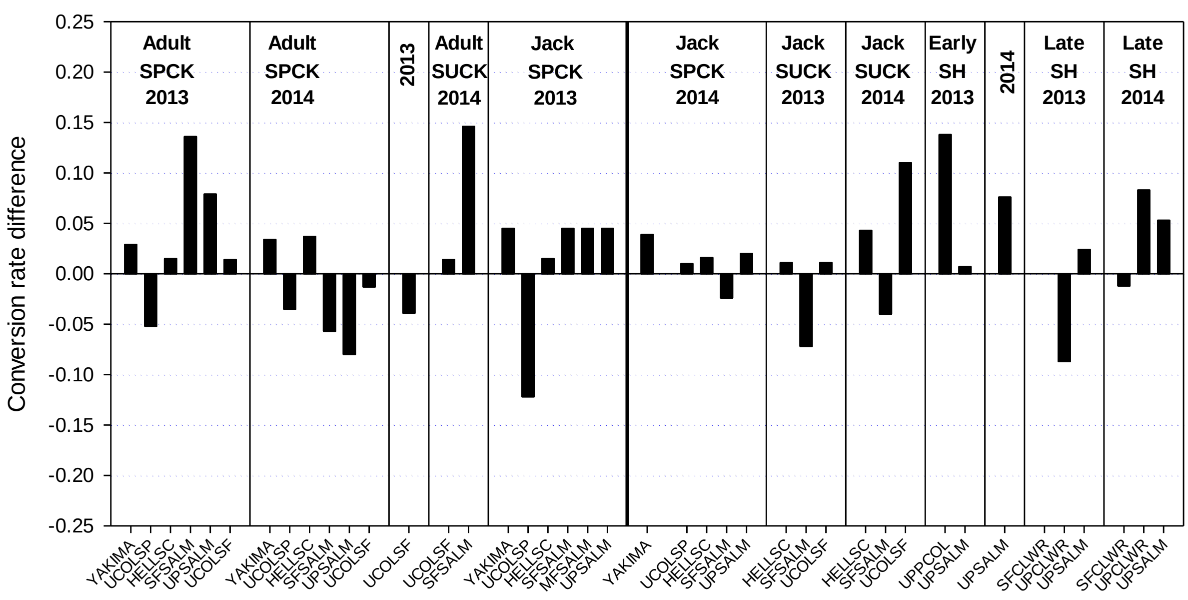

Figure 12. Differences in Bonneville-McNary conversion estimates for Chinook salmon and steelhead populations assigned using genetic stock identification (GSI) versus the full radio-tagged samples. Differences in Metric B calculated as: Population estimate – full sample estimate. Positive values indicate the population estimates were higher than the full sample estimates.

Covariate effects: Overview

The following sections summarize the results from tests of association between individual covariates (fish traits, injuries, environmental conditions, and fallback behavior) and reach conversion rates. Given the large number of tests, we report the statistically significant results only, but all results are shown in Tables 16-20. The multi-model comparison is reported separately below. Note that the presented results are for conversion Metric B (tributary entry = successful migration); results were broadly similar for Metric D. Spring- and summer-run Chinook salmon were combined for these analyses to increase statistical power. Early- and late-run steelhead are reported separately.

Individual covariate effects: Adult Chinook salmon

Year. Conversion rates were similar ($P > 0.05$) in 2013 and 2014 in all reaches (Table 16).

Origin. Hatchery adults had lower conversion (0.951) than wild adults (0.981) from release past Bonneville Dam in 2013 ($\chi^2 = 4.0$, $P = 0.047$) and with both years combined (conversion = 0.958 and 0.979, respectively; $\chi^2 = 4.4$, $P = 0.036$). Hatchery fish also had lower survival (0.879) that wild fish (0.937) through the Bonneville-The Dalles reach in 2013 ($\chi^2 = 5.9$, $P =$ 0.015) and with both years combined (0.873 and 0.925, respectively; $\chi^2 = 8.7$, $P = 0.003$).

Sex. Conversion rates were similar ($P > 0.05$) for males and females in all reaches.

Size. Larger adult salmon had lower conversion through the Bonneville-The Dalles reach in 2013 ($F = 6.3$, $P = 0.013$) and with both years combined ($F = 4.1$, $P = 0.042$). Larger fish also had lower conversion through the John Day-McNary reach in 2014 ($F = 9.8$, $P = 0.002$) and with both years combined ($F = 11.2$, $P < 0.001$) and through the multi-dam Bonneville-McNary reach in 2014 ($F = 17.5$, $P < 0.001$) and with both years combined ($F = 8.8$, $P = 0.003$). Mean fork lengths of successful and unsuccessful fish differed in all reaches by ~3-5 cm.

Injuries. In the release-Bonneville reach, adults with fresh marine mammal injuries had lower conversion (0.918) than those with old mammal injuries (0.980) and no mammal injuries (0.973) ($\chi^2 = 6.2$, $P = 0.046$) in 2013.

In the John Day-McNary reach, fish with head injuries had lower conversion (0.837, $n = 22$) than those with no head injuries (0.960, $n = 428$) in 2013 ($\chi^2 = 4.6$, $P = 0.032$).

In the multi-dam Bonneville-McNary reach, fish with descaling > 10% had higher conversion (0.823, $n = 990$) than those with ≤ 10% descaling (0.753, $n = 170$) ($\chi^2 = 4.7$, $P =$ 0.030) with both years combined.

Environmental. Date, water temperature, or flow effects were evident in all reaches except the Bonneville-The Dalles reach (Table 16). Given the general collinearity among these seasonal covariates, we report only temperature results below.

Table 16. Results of χ^2 tests (categorical covariates) and generalized linear models (continuous covariates) to assess their relationship with reach conversion rates (Metric B) for adult Chinook salmon. Spring- and summer-run fish were combined. Note that sample sizes vary by covariate and reach.

	Release-BO			BO-TD			TD-JD			JD-MN			BO-MN		
Covariate	‘13	‘14	Both	‘13	‘14	Both	‘13	‘14	Both	‘13	‘14	Both	‘13	‘14	Both
Year	n/a	n/a	-	n/a	n/a	-	n/a	n/a	*	n/a	n/a	-	n/a	n/a	-
Origin[1]	**	-	**	**	*	***	-	-	-	-	-	-	-	-	-
Sex[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FL	-	-	-	-	**	**	-	-	-	*	***	***	-	**	**
Mam Inj	**	-	-	-	-	-	-	-	-	-	-	-	-	-	
Head Inj[1]	-	-	-	-	-	*	-	-	-	**	-	*	-	*	*
Descale	-	*	-	-	-	-	-	-	-	*	-	*	*	-	**
Gillnet[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Date	**	*	***	-	-	-	**	**	***	**	***	***	**	***	***
Flow	-	*	-	-	-	-	**	-	*	*	-	**	*	-	-
Temp	**	*	**	-	-	-	**	*	***	**	***	***	**	***	***
Fallback	n/a	n/a	n/a	***	*	***	***	-	***	-	-	-	***	-	***

[1] $n \leq 10$ per year in one or more categories
[2] Unknown sex fish excluded
* $P < 0.10$; ** $P < 0.05$; *** $P < 0.005$

In the release-Bonneville reach, conversion rates were lower early in the migration when water temperature was lower. Mean temperatures were 13.72 °C for unsuccessful fish (n = 20) and 15.05 °C for successful fish (n = 577) in 2013 (F = 6.9, P = 0.009) and with both years combined (unsuccessful fish *mean* = 12.98 °C, n = 37; successful fish *mean* = 14.22 °C, n = 1,160) (F = 7.1, P = 0.008).

In the The Dalles-John Day reach, conversion rates decreased as water temperature increased. Mean temperatures on the date of The Dalles passage were 16.41 °C for unsuccessful fish (n = 40) and 15.45 °C for successful fish (n = 468) in 2013 (F = 7.5, P = 0.007) and with both years combined (unsuccessful fish *mean* = 15.95 °C, n = 65; successful fish *mean* = 14.78 °C, n = 928) (F = 12.5, P < 0.001).

In the John Day-McNary reach, conversion rates decreased as water temperature increased in 2013, 2014, and with both years combined ($5.4 \leq F \leq 25.3$, $P \leq 0.021$). Mean water temperature on the date of John Day passage for the unsuccessful groups were 16.41 °C (2013, n = 20), 17.56 °C (2014, n = 16), and 17.11 °C (both years, n = 36); means for successful fish were 15.57 °C (2013, n = 417), 14.08 °C (2014, n = 415), and 14.82 °C (both years, n = 832).

Fallback. Fish that fell back at Bonneville Dam before passing or not passing The Dalles Dam (i.e., fallback events that occurred after fish passed The Dalles Dam were excluded) had much lower conversion (0.522, n = 23) through the Bonneville-The Dalles reach than those that did not fall back (0.926, n = 554) in 2013 (χ^2 = 44.0, P < 0.001) and with both years combined (fallback fish = 0.660, n = 50; no fallback = 0.911, n = 1,110) (χ^2 = 33.4, P < 0.001).

Fish that fell back at either Bonneville or The Dalles dams before passing or not passing John Day Dam had lower conversion (0.778, n = 45) through the The Dalles-John Day reach than those that did not fall back (0.936, n = 465) in 2013 (χ^2 = 14.1, P < 0.001) and with both years combined (fallback fish = 0.844, n = 77; no fallback = 0.942, n = 995) (χ^2 = 11.2, P < 0.001).

Fish that fell back at Bonneville, The Dalles, or John Day dams before passing or not passing McNary Dam had much lower conversion (0.657, n = 70) through the Bonneville-McNary reach than those that did not fall back (0.826, n = 507) in 2013 (χ^2 = 11.3, P < 0.001) and with both years combined (fallback fish = 0.704, n = 115; no fallback = 0.825, n = 1,045) (χ^2 = 9.9, P = 0.002).

Individual covariate effects: Jack Chinook salmon

Year. Jack conversion through the The Dalles-John Day reach was higher in 2013 (1.000) than in 2014 (0.973) (χ^2 = 7.5, P = 0.006) (Table 17). Conversion was also higher in 2013 (0.966) than in 2014 (0.907) through the multi-dam Bonneville-McNary reach (χ^2 = 8.4, P = 0.004).

Origin. Wild jacks had lower conversion (0.971) than hatchery jacks (1.000) through the John Day-McNary reach in 2013 (χ^2 = 3.9, P = 0.050). The difference was not statistically significant when we controlled for small sample sizes (i.e., there were ≤ 5 unsuccessful fish in some cells). (Note that half as many jacks as adults were radio-tagged each year.)

Sex. We conducted no tests because a large majority of jacks were males.

Table 17. Results of χ^2 tests (categorical covariates) and generalized linear models (continuous covariates) to assess their relationship with reach conversion rates (Metric B) for jack Chinook salmon. Spring- and summer-run fish were combined. Note that sample sizes vary by covariate and reach.

	Release-BO			BO-TD			TD-JD			JD-MN			BO-MN		
Covariate	'13	'14	Both	'13	'14	Both	'13	'14	Both	'13	'14	Both	'13	'14	Both
Year	n/a	n/a	-	n/a	n/a	**	n/a	n/a	**	n/a	n/a	-	n/a	n/a	***
Origin[1]	-	-	-	-	-	-	-	-	-	**	-	-	-	-	-
Sex[2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
FL	-	-	-	-	-	*	-	-	-	-	-	*	-	-	-
Mam Inj	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Head Inj[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Descale	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Gillnet[1]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Date	-	-	-	-	-	-	-	-	-	**	-	*	-	-	-
Flow	-	-	-	**	-	-	-	-	-	*	-	*	-	-	-
Temp	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Fallback	n/a	n/a	n/a	-	-	-	-	-	-	-	-	-	-	-	-

[1] $n \leq 10$ per year in one or more categories
[2] Unknown sex fish excluded; jack Chinook almost all males so no test
* P < 0.10; ** P < 0.05; *** P < 0.005

Injuries. There were no differences ($P > 0.05$) in reach conversion rates associated with any injury types. Note that very few jacks had gillnet marks.

Environmental. Early jacks were somewhat less likely to pass through the John Day-McNary reach in 2013 (F = 4.8, $P = 0.030$), but only four jacks were in the unsuccessful group. Unsuccessful fish encountered lower flow than successful fish in The Dalles-John Day reach in 2013 (F = 7.7, $P = 0.006$), but only six jacks were in the unsuccessful group.

Fallback. There were no differences ($P > 0.05$) in reach conversion rates associated with fallback, in part because overall jack conversion was high and fallback percentages were generally low in both years.

Individual covariate effects: Sockeye salmon

Year. Sockeye salmon conversion through the release-Bonneville reach was higher in 2013 (0.972) than in 2014 (0.932) ($\chi^2 = 7.1$, $P = 0.008$) (Table 18). Conversion was also higher in 2013 (0.988) than in 2014 (0.964) through the John Day-McNary reach ($\chi^2 = 4.2$, $P = 0.041$).

Origin. No tests were performed because a large majority of sockeye salmon were wild.

Sex. Conversion rates were similar ($P > 0.05$) for males and females in all reaches.

Size. Larger salmon had lower conversion than smaller salmon through the Bonneville-The Dalles reach with both years combined (F = 5.8, $P = 0.016$). Large fish also had lower conversion through the The Dalles-John Day reach in 2014 (F = 6.3, P =0.013) and with both years combined (F = 4.0, $P = 0.047$). In the multi-dam Bonneville-McNary reach, large fish had lower conversion than smaller fish in 2014 (F = 12.4, $P < 0.001$) and with both years combined (F = 10.0, $P = 0.002$). Differences in means were ~1-3 cm in all comparisons.

Injuries. Salmon with head injuries had lower conversion (0.750, $n = 8$) through the release-Bonneville reach than those that did not have head injuries (0.936, $n = 0.936$) in 2014 ($\chi^2 = 4.3$, $P = 0.038$). Those with head injuries also had lower conversion (0.750, $n = 12$) than those without head injuries (0.920, $n = 748$) through the Bonneville-The Dalles reach in 2013 (with injury = 0.667, $n = 6$; without injury = 0.908, $n = 382$) ($\chi^2 = 4.0$, $P = 0.046$) and with both years combined ($\chi^2 = 4.5$, $P = 0.034$).

Salmon with old marine mammal injuries had lower conversion (0.824, $n = 51$) than those with fresh injuries (0.962, $n = 26$) or no injuries (0.922, $n = 683$) through the Bonneville-The Dalles reach with both years combined ($\chi^2 = 6.8$, $P = 0.033$).

Environmental. Warmer water temperature was consistently associated with lower conversion rates for sockeye salmon. In the release-Bonneville reach, mean temperatures were 17.99 °C for unsuccessful fish ($n = 11$) and 17.47 °C for successful fish ($n = 388$) in 2013 (F = 4.3, $P = 0.040$). In the Bonneville-The Dalles reach, mean temperatures were 17.80 °C for unsuccessful fish ($n = 63$) and 17.56 °C for successful fish ($n = 697$) with both years combined (F = 4.9, $P = 0.027$). In the The Dalles-John Day reach, mean temperatures were 18.36 °C for unsuccessful fish (n = 14) and 17.68 °C for successful fish (n = 337) in 2013 (F = 7.3, P = 0.007). In the John Day-McNary reach, mean temperatures were 18.37 °C for unsuccessful fish (n = 12) and 17.45 °C for successful fish (n = 316) in 2014 (F = 6.8, P = 0.010) and were 18.38 °C for unsuccessful fish (n = 16) and 17.55 °C for successful fish (n = 639) with both years combined (F = 8.5, P = 0.004). In the multi-dam Bonneville-McNary reach, mean temperatures were higher for unsuccessful fish (17.80-17.82 °C) than for successful fish (17.53-17.55 °C) in 2013, 2014, and with both years combined ($4.5 \leq F \leq 9.8$, $P \leq 0.035$).

Fallback. Sockeye salmon that fell back at Bonneville Dam before passing or not passing The Dalles Dam (i.e., fallback events that occurred after fish passed The Dalles Dam were excluded) had lower conversion (0.706, n = 17) through the Bonneville-The Dalles reach than those that did not fall back (0.914, n = 371) in 2013 (χ^2 = 8.1, P = 0.004) and with both years combined (fallback fish = 0.813, n = 32; no fallback = 0.922, n = 728) (χ^2 = 4.8, P =0.028).

Table 18. Results of χ^2 tests (categorical covariates) and generalized linear models (continuous covariates) to assess their relationship with reach conversion rates (Metric B) for sockeye salmon. Note that sample sizes vary by covariate and reach.

	Release-BO			BO-TD			TD-JD			JD-MN			BO-MN		
Covariate	'13	'14	Both	'13	'14	Both	'13	'14	Both	'13	'14	Both	'13	'14	Both
Year	n/a	n/a	***	n/a	n/a	-	n/a	n/a	-	n/a	n/a	**	n/a	n/a	--
Origin[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sex[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FL	-	-	-	-	*	**	-	**	**	-	*	-	-	***	***
Mam Inj	-	-	-	*	-	**	-	-	-	-	-	-	-	-	-
Head Inj[1]	-	**	*	**	-	**	-	-	-	-	-	-	-	-	-
Descale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillnet[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Date	-	-	-	-	*	**	*	-	-	-	**	***	**	*	***
Flow	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
Temp	**	-	-	-	*	**	**	-	-	-	**	***	**	**	***
Fallback	n/a	n/a	n/a	***	-	**	-	-	-	-	-	-	-	-	-

[1] $n \leq 10$ per year in one or more categories
[2] Unknown sex fish excluded
* $P < 0.10$; ** $P < 0.05$; *** $P < 0.005$

Individual covariate effects: Early steelhead

Year. Conversion rates were similar ($P > 0.05$) in 2013 and 2014 in all reaches (Table 19).

Origin. Conversion rates were similar ($P > 0.05$) for hatchery and wild fish in all reaches in both years.

Sex. Females had lower conversion (0.964) than males (1.000) through the release-Bonneville reach in 2013 (χ^2 = 3.1, P = 0.079). Conversion rates were similar ($P > 0.05$) for males and females in all other reaches in both years.

Table 19. Results of χ^2 tests (categorical covariates) and generalized linear models (continuous covariates) to assess their relationship with reach conversion rates (Metric B) for early steelhead. Note that sample sizes vary by covariate and reach.

	Release-BO			BO-TD			TD-JD			JD-MN			BO-MN		
Covariate	‘13	‘14	Both	‘13	‘14	Both	‘13	‘14	Both	‘13	‘14	Both	‘13	‘14	Both
Year	n/a	n/a	-	n/a	n/a	*	n/a	n/a	-	n/a	n/a	-	n/a	n/a	-
Origin[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sex[2]	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FL	-	-	-	-	-	**	-	-	-	-	-	-	-	-	*
Mam Inj	-	-	-	-	**	**	-	-	-	-	**	-	-	-	-
Head Inj[1]	-	***	-	-	-	-	-	-	-	-	-	-	-	-	-
Descale	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-
Gillnet[1]	-	-	-	**	-	-	-	n/a	-	-	n/a	-	-	-	-
Date	-	-	-	-	-	*	-	*	-	-	-	*	-	-	-
Flow	-	-	-	**	-	-	-	-	-	-	-	*	**	*	-
Temp	-	-	-	**	-	-	n/a	n/a	n/a	n/a	n/a	n/a	*	-	-
Fallback[1,3]	n/a	n/a	n/a	-	**	**	-	-	-	-	-	-	***	-	***

[1] $n \leq 10$ per year in one or more categories
[2] Unknown sex fish excluded; [3] Post-spawn fallback by kelts not included
* $P < 0.10$; ** $P < 0.05$; *** $P < 0.005$

Size. Larger steelhead had lower conversion than smaller steelhead through the Bonneville-The Dalles reach with both years combined (F = 6.3, P = 0.012). The difference in mean fork lengths was ~2.5 cm. A similar effect was found for the Bonneville-McNary reach (F = 3.6, P = 0.058).

Injuries. Early steelhead with head injuries had lower conversion (0.833, n = 12) than those with no head injuries (0.980, n = 196) in 2014 (χ^2 = 8.6, P = 0.003). Fish with gillnet marks had lower conversion (0.571, n = 7) than steelhead without gillnet marks (0.874, n = 159) through the Bonneville-The Dalles reach in 2013 (χ^2 = 5.2, P = 0.023). Steelhead with fresh marine mammal injuries had lower conversion (0.611, n = 18), than those with old injuries (0.952, n = 21) and those with no injuries (0.785, n = 163) in 2014 (χ^2 = 6.8, P = 0.034); the pattern was similar with both years combined (χ^2 = 6.3, P = 0.043). In contrast, steelhead with no marine mammal injuries had higher conversion (1.000, n = 11) than those with old injuries (0.824, n = 17) or no mammal injuries (0.971, n = 102) through the John Day-McNary reach in 2014 (χ^2 = 7.7, P = 0.021).

Environmental. In the Bonneville-The Dalles reach, mean temperatures were 19.91 °C for unsuccessful fish (n = 23) and 20.46 °C for successful fish (n = 143) in 2013 (F = 4.9, P = 0.029). The 2013 unsuccessful group also encountered lower mean flow (211 kcfs, 5,717 cms) than successful fish (189 kcfs, 5,341 cms) (F = 7.9, P = 0.006). The unsuccessful group passed Bonneville about six days earlier, on average. These patterns carried over into the Bonneville-McNary reach, with lower temperature and higher flow for the unsuccessful fish (Table 19). Environmental variables did not reach the $P < 0.05$ threshold in other reaches.

Fallback. In contrast with the other runs, early steelhead that fell back at Bonneville, The Dalles, or John Day dams before passing McNary dam in 2013 had higher conversion (0.956, n = 45) through the Bonneville-McNary reach than those that did not fall back (0.703, n = 121) (χ^2 = 11.9, P < 0.001). The pattern was similar with both years combined: conversion from Bonneville-McNary was 0.892 for 65 steelhead that fell back and 0.723 for 303 steelhead that did not fall back (χ^2 = 8.3, P = 0.004).

In contrast, early steelhead that fell back at Bonneville Dam had lower conversion from Bonneville-The Dalles (0.333, n = 6) than those that did not fall back (0.801, n =196) in 2014 (χ^2 = 7.6, P = 0.006, note small sample size). The pattern was similar with both years combined (χ^2 = 4.4, P = 0.036).

Individual covariate effects: Late steelhead

Year. Conversion from release past Bonneville Dam was higher in 2014 (0.978, n = 591) than in 2013 (0.948, n = 620) (χ^2 = 7.4, P = 0.007). There were no statistical differences (P > 0.05) between years in the other reaches (Table 20).

Origin. In 2013, wild steelhead had lower conversion (0.884) than hatchery steelhead (0.936) through the Bonneville-The Dalles reach (χ^2 = 4.7, P = 0.031), through the John Day-McNary reach (wild = 0.949, hatchery = 0.985) (χ^2 = 5.1, P = 0.024), and through the multi-dam Bonneville-McNary reach (wild = 0.788, hatchery = 0.884) (χ^2 = 9.6, P = 0.002).

Sex. Males had lower conversion (0.885) than females (0.923) through the Bonneville-The Dalles reach with both years combined (χ^2 = 4.7, P = 0.030). Males also had lower conversion (0.764) than females (0.881) through the Bonneville-McNary reach in 2014 (χ^2 = 12.7, P < 0.001) and with both years combined (males = 0.794, females = 0.873) (χ^2 = 13.2, P < 0.001).

Size. In the release-Bonneville reach, unsuccessful steelhead were smaller (*mean* = 63.6 cm) than successful steelhead (*mean* = 71.4 cm) (F = 17.0, P < 0.001) in 2013. In contrast, unsuccessful fish in 2013 were larger (*mean* = 76.8 cm) than successful fish (*mean* =70.9 cm) in the Bonneville-The Dalles reach (F = 14.1, P < 0.001).

Injuries. In 2013, late steelhead with head injuries had lower conversion (0.846, n = 78) than steelhead without head injuries (0.931, n = 506) through the Bonneville-The Dalles reach (χ^2 = 6.5, P = 0.011). Head injuries were also associated with lower conversion through the The Dalles-John Day reach (head injury = 0.894, n = 66; no head injury = 0.959, n = 467) (χ^2 = 5.3, P = 0.021), and through the multi-dam Bonneville-McNary reach (head injury = 0.731, n = 78; no head injury = 0.872, n = 506) (χ^2 = 10.7, P = 0.001) in 2013.

In 2014, late steelhead with fresh marine mammal injuries had lower conversion (0.820) than those with old injuries (0.874) and those with no injuries (0.912) (χ^2 = 6.6, P = 0.037) through the Bonneville-The Dalles reach. The pattern was similar with both years combined (χ^2 = 10.3, P = 0.006).

Table 20. Results of χ^2 tests (categorical covariates) and generalized linear models (continuous covariates) to assess their relationship with reach conversion rates (Metric B) for late steelhead. Note that sample sizes vary by covariate and reach.

	Release-BO			BO-TD			TD-JD			JD-MN			BO-MN		
Covariate	'13	'14	Both	'13	'14	Both	'13	'14	Both	'13	'14	Both	'13	'14	Both
Year	n/a	n/a	**	n/a	n/a	-	n/a	n/a	-	n/a	n/a	*	n/a	n/a	-
Origin[1]	-	-	-	**	-	-	-	-	-	**	-	*	***	-	-
Sex[2]	-	-	-	-	*	**	**	*	-	-	-	*	-	***	***
FL	***	-	**	***	-	*	-	-	-	-	-	-	*	-	-
Mam Inj	-	-	-	-	**	**	-	-	-	-	-	-	-	-	-
Head Inj[1]	-	-	**	**	-	-	**	-	*	-	-	-	***	-	*
Descale	*	-	*	*	**	**	-	-	-	-	-	-	-	**	*
Gillnet[1]	-	-	-	-	-	*	-	-	-	-	**	*	-	**	**
Date	-	*	***	-	-	-	-	-	-	-	-	-	-	-	-
Flow	***	-	***	-	-	**	-	-	-	-	-	-	-	-	**
Temp	*	-	***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-	-	-
Fallback[1,3]	n/a	-	*	**	-	***	***	***	***	***	-	***	***	-	-

[1] $n \leq 10$ per year in one or more categories
[2] Unknown sex fish excluded; [3] Post-spawn fallback by kelts not included
* $P < 0.10$; ** $P < 0.05$; *** $P < 0.005$

Steelhead with >10% descaling had lower conversion (0.879) through the Bonneville-The Dalles reach than those with ≤10% descaling (0.956) in 2014 ($\chi^2 = 4.7$, $P = 0.030$) and with both years combined ($\chi^2 = 7.0$, $P = 0.008$). Also in 2014, descaled fish had lower conversion through the Bonneville-McNary reach (>10% descaling = 0.801, ≤10% descaling = 0.901) ($\chi^2 = 5.1$, $P = 0.023$).

In 2014, steelhead with gillnet marks had lower conversion (0.875) than those with no gillnet marks (0.958) through the John Day-McNary reach ($\chi^2 = 5.4$, $P = 0.020$) and through the Bonneville-McNary reach (gillnet mark = 0.685, no mark = 0.830) ($\chi^2 = 6.9$, $P = 0.009$).

Environmental. In the release-Bonneville reach, mean flow on the release date was 112.8 kcfs (3,194 cms) for unsuccessful fish ($n = 32$) and was 103.4 kcfs (2,928 cms) for successful fish ($n = 588$) (F = 18.0, $P < 0.001$) in 2013. With both years combined, unsuccessful fish in the Bonneville-The Dalles reach encountered lower mean flow (92.2 kcfs, 2,610 cms) than successful fish (99.1 kcfs, 2,806 cms) (F = 4.5, $P = 0.035$); results were similar for the Bonneville-McNary reach (F = 4.1, $P = 0.044$). Water temperature data were not available for most of the fall in both years.

Fallback. Late steelhead that fell back had lower conversion through all reaches in 2013 (Table 20). In the Bonneville-The Dalles reach, those that fell back at Bonneville Dam before passing The Dalles Dam had lower conversion (0.667, $n = 6$) than those that did not fall back (0.921, $n = 581$) ($\chi^2 = 5.1$, $P = 0.024$). The pattern was similar with both years combined (note small samples of fallback fish). In the The Dalles-John Day reach, fish that fell back at Bonneville or The Dalles dams before passing John Day Dam had much lower conversion

(0.600-0.750) than those that did not fall back (0.966-0.988) in both years (χ^2 = 14.3-147.3, P < 0.001).

In the John Day-McNary reach, steelhead that fell back at Bonneville, The Dalles, or John Day dams before passing McNary Dam had lower conversion (0.886, n = 35) than those that did not fall back (0.980, n = 452) (χ^2 = 11.1, P < 0.001) in 2013 and with both years combined (0.893 for fallback fish versus 0.967 for non-fallback fish; χ^2 = 7.9, P = 0.005). Similarly, in the multi-dam Bonneville-McNary reach, fish that fell back at Bonneville, The Dalles, or John Day dams before passing McNary dam in 2013 had lower conversion (0.764, n = 110) than those that did not fall back (0.872, n = 477) (χ^2 = 8.3, P = 0.004).

Covariate effects: Multi-model comparisons

A total of 16-18 models were compared using ΔAIC_c for each of the reaches for adult and jack Chinook salmon, steelhead, and sockeye salmon (Table 21). The most parsimonious models are shown in Table 22. Based on ΔAIC_c, from one to several additional models had statistical support (i.e., $\Delta AIC_c < 4.0$) in many run×reach combinations. In most cases there was considerable covariate overlap in the models with support and parameter estimates for statistically significant (P < 0.05) covariates were also generally similar across models. In all models, conversion Metric B was the dependent variable.

Adult Chinook salmon. Across reaches, a variety of models were identified as most parsimonious for the adult Chinook salmon (Table 21). The environmental model was selected for the release-Bonneville reach, with conversion increasing as water temperature increased. The fish traits model was selected for the Bonneville-The Dalles reach: wild fish, smaller fish, and those with no downstream fallback events had higher conversion. Only water temperature was selected for the The Dalles-John Day reach, with lower conversion for fish that encountered warmer water. The combined environment + traits model was selected for both the John Day-McNary and the multi-dam Bonneville-McNary reaches. In these reaches, smaller fish, those that did not fall back, and those that encountered cooler water had higher conversion rates (Table 22).

Jack Chinook salmon. As in the assessment of individual covariates (Table 17), there were few statistically significant models in the multi-model comparison for jack Chinook salmon (Table 22). In part, this was due to the generally high conversion rates for jacks. The year-only model was selected for both the Bonneville-The Dalles and Bonneville-McNary reaches, with higher conversion in 2013 versus 2014.

Sockeye salmon. The models selected for sockeye salmon indicated a year effect (release-Bonneville, John Day-McNary reaches) as well as a consistent negative effect of water temperature. Warm temperatures were associated with lower conversion through the Bonneville-The Dalles, John Day-McNary, and Bonneville-McNary reaches. Larger sockeye salmon had lower conversion through the Bonneville-The Dalles and The Dalles-John Day reaches, perhaps suggesting a greater vulnerability to harvest for larger fish. Fallback at Bonneville Dam was associated with lower Bonneville-The Dalles conversion.

Early steelhead. The top models selected for early steelhead had different variables in each reach (Table 23). Only two were statistically significant at $P < 0.05$: larger steelhead were less likely to survive through the Bonneville-The Dalles reach and fish that fell back were more likely to survive through the Bonneville-McNary reach than those that did not fall back.

Late steelhead. The models selected for late steelhead indicated that females consistently had higher conversion than males (Bonneville-The Dalles, The Dalles-John Day, Bonneville-McNary reaches) (Table 23). Steelhead that fell back had lower conversion than those that did not fall back through the Bonneville-The Dalles, John Day-McNary, and Bonneville-McNary reaches. Three different injury types were associated with lower conversion: marine mammal injuries (Bonneville-The Dalles), gillnet marks (Bonneville-McNary), and head injuries (Bonneville-McNary). Lower conversion was associated with later migration date (release-Bonneville) and with low flow (Bonneville-The Dalles).

Table 21. List of models included in the multi-model comparison for each reach and run. 'Partial' indicates that some, but not all, of the parameters were used in the model; corresponds with the individual parameters.

Model parameter(s)	Adult Chinook	Jack Chinook	Sockeye	Steelhead
Trait: Sex	Yes	No	Yes	Yes
Trait: Origin	Yes	Yes	No	Yes
Trait: Length	Yes	Yes	Yes	Yes
Trait: Fallback[1]	Yes	Yes	Yes	Yes
Injury: Descaling	Yes	Yes	Yes	Yes
Injury: Marine Mammal	Yes	Yes	Yes	Yes
Injury: Gillnet	Yes	No	Yes	Yes
Injury: Head	Yes	Yes	Yes	Yes
Environment: Year	Yes	Yes	Yes	Yes
Environment: Flow	Yes	Yes	Yes	Yes
Environment: Temperature	Yes	Yes	Yes	No
Traits: Sex + Origin + Length + Fallback	Yes	Partial	Partial	Yes
Injuries: Descaling + Mammal + Gillnet + Head	Yes	Partial	Yes	Yes
Environment: Year + Flow + Temperature	Yes	Yes	Yes	Partial
Traits + Injuries	Yes	Partial	Partial	Yes
Traits + Environment	Yes	Partial	Partial	Partial
Injuries + Environment	Yes	Partial	Yes	Partial
Full model: Traits + Injuries + Environment	Yes	Partial	Partial	Partial

[1] Fallback not included in Release-Bonneville reach models and post-spawn fallback by kelts were excluded

Table 22. The most parsimonious ('Best') model identified using AIC_c and ΔAIC_c for each run×reach combination. The dependent parameter was reach conversion Metric B. Parameter estimates with 95% likelihood ratio confidence intervals are shown for statistically significant covariates below each model, with reference value in parentheses where applicable. * $P < 0.05$, ** $P < 0.005$. (Note: all continuous variables were standardized.)

Run	Reach	'Best' model
Chinook - Adult	Release-Bonneville[1]	Year+Flow+Temperature
		** *Temperature: 0.589 (0.221-1.006)*
	Bonneville-The Dalles	Sex+Origin+Length+Fallback
		* *Origin(W): 0.523 (0.124-0.929)*
		* *Length: -0.231 (-0.427 to -0.035)*
		** *Fallback(0): 1.553 (0.887-2.185)*
	The Dalles-John Day	Temperature
		** *Temperature: -0.503 (-0.769 to -0.245)*
	John Day-McNary	Year+Flow+Temperature+Sex+Origin+Length+Fallback
		** *Temperature: -1.293 (-1.929 to -0.745)*
		* *Length: -0.392 (-0.720 to -0.072)*
		** *Fallback(0): 1.449 (0.440 to 2.365)*
	Bonneville-McNary	Year+Flow+Temperature+Sex+Origin+Length+Fallback
		** *Temperature: -0.366 (-0.545 to -0.191)*
		* *Origin(W): 0.333 (0.018 to 0.649)*
		* *Length: -0.187 (-0.338 to -0.037)*
		** *Fallback(0): 0.826 (0.68 to 1.268)*
Chinook – Jack[2]	Release-Bonneville[1]	Mammal injury
	Bonneville-The Dalles	Year
		* *Year(2013): 1.081 (0.186-2.113)*
	The Dalles-John Day	Year
	John Day-McNary	Flow
	Bonneville-McNary	Year
		* *Year(2013): 1.056 (0.342-1.848)*
Sockeye[3]	Release-Bonneville[1]	Year+Flow+Temperature+Sex+Length
		** *Year(2013): 1.195 (0.437-2.044)*
	Bonneville-The Dalles	Year+Flow+Temperature+Sex+Length+Fallback
		** *Temperature: -0.396 (-0.663 to -0.131)*
		** *Length: -0.483 (-0.796 to -0.182)*
		* *Fallback(0): 1.275 (0.228-2.185)*
	The Dalles-John Day	Length
		* *Length: -0.401 (-0.797 to -0.006)*
	John Day-McNary	Year+Flow+Temperature+Sex+Length+Fallback
		* *Year(2013): 1.800 (0.562-3.346)*
		* *Temperature: -1.192 (-2.191 to -0.384)*
	Bonneville-McNary	Year+Flow+Temperature+Sex+Length+Fallback
		** *Length: -0.495 (-0.743 to -0.257)*
		** *Temperature: -0.399 (-0.612 to -0.187)*

[1] Fallback not included
[2] Sex and gillnet marks not included for Chinook jacks
[3] Origin not included for sockeye

Table 23. The most parsimonious ('Best') model identified using AIC_c and ΔAIC_c for each steelhead run×reach combination. The dependent parameter was reach conversion Metric B. Parameter estimates with 95% likelihood ratio confidence intervals are shown for statistically significant covariates below each model, with reference value in parentheses where applicable. * $P < 0.05$, ** $P < 0.005$. (Note: all continuous variables were standardized and post-spawn fallback by kelts excluded.)

Run	Reach	'Best' model
Steelhead – Early	Release-Bonneville[1]	Sex
	Bonneville-The Dalles	Length
		* *Length -0.351 (-0.629 to -0.081)*
	The Dalles-John Day	Head Injury
	John Day-McNary	Flow
	Bonneville-McNary	Fallback
		* *Fallback(0) -1.166 (-2.075 to -0.404)*
Steelhead – Late	Release-Bonneville[1]	Year+Flow+Date+Sex+Origin+Length
		** *Date -0.402 (-0.802 to 0.007)*
	Bonneville-The Dalles	Full model
		* *Sex (F) 0.451 (0.038 to 0.871)*
		* *Fallback(0) 2.264 (0.539 to 3.899)*
		* *Marine Mammal(fresh) -0.744 (-1.254 to -0.219)*
		* *Flow 0.302 (0.036 to 0.580)*
	The Dalles-John Day	Sex+Origin+Length+Fallback
		* *Sex (F) 1.007 (0.325 to 1.736)*
		* *Fallback(0) 3.335 (2.645 to 4.042)*
	John Day-McNary	Year+Flow+Date+Sex+Origin+Length+Fallback
		* *Origin(W) -0.698 (-1.378 to -0.012)*
		* *Fallback(0) 1.298 (0.231 to 2.219)*
	Bonneville-McNary	Full model
		* *Sex (F) 0.595 (0.270 to 0.926)*
		* *Fallback(0) 0.585 (0.114 to 1.037)*
		* *Gillnet(N) 0.645 (0.100 to 1.162)*
		* *Head injury(N) 0.662 (0.120 to 1.177)*

Fallback percentages and rates

The fallback percentages (unique fish that fell back divided by the number of unique fish that passed a dam) and fallback rates (total fallback events divided by the unique number that passed a dam) in this section include all events, regardless of when they occurred with regards to reach passage. As such, these summaries differ from those that assessed the association between fallback and reach conversion, where only events that occurred before a fish passed the upstream dam in a reach were included. Not included in the fallback summary below are post-spawn events by presumed outmigrating steelhead kelts. These post-spawn events occurred in spring and most had supporting detection data in spawning tributaries prior to fallback.

Adult Chinook salmon. Fallback percentages were 5.2-6.1% (Bonneville), 3.2-7.9% (The Dalles), 1.9-3.6% (John Day), and 2.5-3.8% (McNary) (Table 24). Most individuals fell back only one time at a single dam, though some fell back 2-3 times at a single dam resulting in fallback rates that ranged from 0.0-1.3% higher than percentages.

We examined reascension rates of fish that fell back to indirectly assess potential sea lion predation on fallback fish in both years. We could not know if any fish was eaten by a marine mammal from the telemetry data and we note that failing to reascend a dam after falling back may be caused by several factors (e.g., overshoot behavior). In 2013, 23 unique adult spring Chinook salmon fell back once each at Bonneville Dam in May when sea lions were potentially present in the Bonneville tailrace. Of these 23 fallback events, 17 (74%) were followed by upstream passage at Bonneville Dam (i.e., the fish reascended a ladder). Of the six that did not reascend, one was reported harvested downstream and five had unknown fate. For comparison, there were 18 fallback events by adult Chinook salmon at Bonneville Dam in June and July after departure of sea lions and 12 of the events (67%) were followed by a reascension.

In 2014, there were 25 fallback events by 21 unique adult Chinook salmon at Bonneville Dam in April and May when sea lions were likely present in the tailrace. Twenty-two of the events (88%) were followed by reascension at Bonneville Dam. For comparison, there were nine events by nine unique adults in June and July and all but one (89%) were followed by reascension. Though sample sizes were small for this comparison in both 2013 and 2014, there was no evidence to suggest that fallback fish were being heavily predated by sea lions in April and May (when sea lions were present) at higher rates than in June-July.

Jack spring–summer Chinook salmon. Fallback percentages for jacks were generally similar to or slightly lower than those for adults (Table 24). Percentages were 2.6-5.6% (Bonneville), 3.9-5.9% (The Dalles), 2.0-2.9% (John Day), and 4.4-4.9% (McNary) (Table 24). Most individuals fell back only one time at a single dam, though some fell back 2-3 times resulting in fallback rates that ranged from 0.0-1.5% higher than percentages.

We assessed potential sea lion predation on fallback fish in both years, but the low numbers of jack fallback events at Bonneville Dam made it difficult to assess the potential relationship. In 2013, six jacks fell back seven times in May when sea lions were likely present; all events were followed by ladder reascensions. Just one summer jack fell back at the dam (four times) in 2013, and it also reascended after each event. In 2014, nine unique jacks fell back in April-May and all reaascended. Another nine fell back in June-July, and they also reascended. These behaviors do not suggest that predation was a high risk for jack Chinook salmon.

Sockeye salmon. Fallback percentages were 4.3-5.0% (Bonneville), 2.3-2.9% (The Dalles), 4.8-5.5% (John Day), and 1.2-1.6% (McNary) (Table 24). Most individuals fell back only one time at a single dam, though some fell back 2-3 times resulting in fallback rates that ranged from 0.0-0.3% higher than percentages. The exception was at Bonneville Dam in 2013, when two sockeye salmon fell back at Bonneville Dam 9 and 12 times, respectively. The first was an ad-clipped fish last detected at Wells Dam; the second was unclipped and was last detected at the Little White Salmon River (fate = unaccounted for). These multiple-fallback fish resulted in a much higher fallback rate (10.4%) than percentage (5.0%) at Bonneville Dam.

Early steelhead. Fallback percentages were quite variable across dams and – to a lesser degree – between years. Estimates were at 1.8-4.0% (Bonneville), 2.3-4.9% (The Dalles), 7.2-8.2% (John Day), and 17.0-21.8% (McNary) (Table 25). Fallback rates were higher than percentages at The Dalles in 2014, at John Day in both years, and at McNary Dam in 2014. In each case, 1-2 fish fell back twice each. There was considerable evidence that the high fallback percentage and rate at McNary Dam was associated with tributary overshoot behavior. Many fallback steelhead were subsequently detected in the John Day River, including 9 of 15 (60%) in 2013 and 19 of 24 (79%) in 2014. Some fish were also detected on PIT antennas in the Umatilla River (there was no radio antenna in the Umatilla River).

Late steelhead. Fallback percentages were 0.3-4.5% (Bonneville), 3.6-10.7% (The Dalles), 3.1-3.8% (John Day), and 4.3-5.1% (McNary), with the higher estimates in 2013 in all years (Table 25). Fallback rates were higher by up to 4.3%, with the largest difference at The Dalles Dam in 2013 where 13 fish fell back twice and five fell back three times. There was evidence of tributary overshoot fallback in late steelhead, with 7 of 23 (30%, 2013) and 3 of 18 (17%, 2014) subsequently detected in the John Day River.

Table 24. 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 sockeye and Chinook salmon at Bonneville, The Dalles, John Day and McNary dams in 2013-2014.

Run	Dam	Year	Passed dam[1]	Unique FB fish	Total FB events	Fallback %	Fallback rate
Adult Chinook	Bonneville	2013	573	35	42	6.1%	7.3%
		2014	573	30	34	5.2%	5.9%
	The Dalles	2013	504	40	47	7.9%	9.3%
		2014	474	15	18	3.2%	3.8%
	John Day	2013	439	16	17	3.6%	3.9%
		2014	431	8	8	1.9%	1.9%
	McNary	2013	405	10	12	2.5%	3.0%
		2014	390	15	20	3.8%	5.1%
Jack Chinook	Bonneville	2013	271	7	11	2.6%	4.1%
		2014	288	16	18	5.6%	6.3%
	The Dalles	2013	253	14	16	5.5%	6.3%
		2014	256	10	11	3.9%	4.3%
	John Day	2013	244	5	6	2.0%	2.5%
		2014	238	7	9	2.9%	3.8%
	McNary	2013	229	10	10	4.4%	4.4%
		2014	224	11	13	4.9%	5.8%
Sockeye	Bonneville	2013	383	19	40	5.0%	10.4%
		2014	370	16	16	4.3%	4.3%
	The Dalles	2013	345	10	10	2.9%	2.9%
		2014	343	8	8	2.3%	2.3%
	John Day	2013	331	16	17	4.8%	5.1%
		2014	330	18	19	5.5%	5.8%
	McNary	2013	321	4	4	1.2%	1.2%
		2014	315	5	5	1.6%	1.6%

[1] only includes fish that retained radio transmitters

Table 25. 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 at Bonneville, The Dalles, John Day, and McNary dams in 2013-2014. Fallback events that occurred after spawning (i.e., by kelts) were not included.

Run	Dam	Year	Passed dam[1]	Unique FB fish	Total FB events	Fallback %	Fallback rate
Steelhead (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%
Steelhead (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%

[1] only includes fish that retained radio transmitters

Discussion

Study constraints

There were three important constraints to this study: the late start to Chinook salmon tagging in 2013, the exclusion of PIT-tagged known-origin fish in both years, and temperature related restrictions on tagging of steelhead during August and September of both years. Due primarily to delays in contracting, no Chinook salmon were tagged in April 2013, although nearly 29,000 adults and 2,000 jacks passed in the month. Previous studies of population-specific run timing (e.g., Keefer et al. 2004b; Hess et al. 2014) have shown that Clearwater, Salmon, Icicle, Wind, and John Day River Chinook salmon are among the earliest spring migrants. These populations would therefore have been under-sampled in the 2013 study year, resulting in reach conversion and tributary turnoff estimates that differ from the runs at large. No tagging in April 2013 also reduced any potential inferences regarding sea lion predation effects on Chinook salmon. With respect to interpreting the telemetry data, we note that any tagged salmon killed by a marine mammal in the Bonneville tailrace would largely be indistinguishable from any tagged salmon that may have migrated downstream to spawn in a lower tributary.

Similarly, other research programs, in particular the Comparative Survival Study, were concerned that radio tagging known-origin (i.e., PIT-tagged) salmon and steelhead could bias the results of on-going research programs such as of smolt-to-adult (SAR) survival estimates, and were unable to provide access to these adults for our study. Unfortunately, thousands of jack and adult Chinook salmon and steelhead have PIT tags and represent substantial portions of the runs passing Bonneville Dam. The PIT-tagged Chinook salmon and steelhead disproportionately originate from interior populations in the Snake, mid- and upper-Columbia River basins. Selection against these known-origin groups for radio-tagging – many of which are from the ESA-listed groups that are the motivation for the conversion rate study – was an unfortunate methodological constraint. In addition to not being able to partition FCRPS loss for these groups, we were unable to directly estimate straying into lower Columbia River tributaries using the PIT-tag origin information; straying by interior populations is a contributing factor for conversion rates below performance standards (Keefer et al. 2008a; Keefer and Caudill 2014). Although the genetic evaluation my partially addresses these population-specific information gaps, sample sizes for some listed populations was low.

Our original sampling plan specified tagging one half of the steelhead in proportion to the total run (‘base sample’) to provide representative conversion estimates. The second half would also be tagged in proportion to the run starting in September to provide a later sample of individuals more likely to overwinter in the FCRPS Hydrosystem to address other objectives. However, restrictions on tagging related to water temperatures at Bonneville Dam in combination with an unusually long period of warm temperatures there resulted in a large gap in sampling during 2013 (Figure 2). Tagging was similarly restricted during summer 2014 and consequently conversion estimates reported here may or may not reflect the conversion rates for the overall runs.

An additional limitation was the lack of water temperature data collection at The Dalles and John Day dams in fall. The gap limited our ability to assess temperature effects on steelhead from both the early and late groups. The early group was affected because many early migrants temporarily use the cool water tributaries in mid-summer before resuming migration in September or October (Keefer et al. 2009). Although Columbia River temperatures typically decline in mid- to late September, conditions remain warm often well into October, and a thorough assessment of this important environmental covariate was not possible.

Reach conversion and ‘loss’ rates: full samples

Reach conversion estimates for all three groups indicated that the highest unaccounted for ‘loss’ occurred in the Bonneville-The Dalles reach. Of the totals unaccounted for downstream from McNary Dam, 38-48% of adult Chinook salmon, 33-53% of jack Chinook salmon, 31-42% of sockeye salmon, 53-81% of early steelhead, and 48-57% of late steelhead were in the Bonneville-The Dalles reach. A relatively large percentage (37%) of the late steelhead group that was unaccounted for was below Bonneville Dam in 2013; this was unusually high relative to other years and we are unsure what may have prompted this result.

The relatively high ‘loss’ rates in the Bonneville-The Dalles reach were unsurprising given the fisheries effort in the Bonneville reservoir and results of previous telemetry studies (e.g., Keefer et al. 2005). Harvest of radio-tagged fish that was not reported to us and mortality associated with gillnet dropout and catch-and-release recreational fisheries are presumed to contribute to the unaccounted for rates in this reach (and others). It is also possible that transmitter loss was a contributing factor, although the installation of PIT detection arrays at The

Dalles Dam and inside the Deschutes River mouth substantially reduced the likelihood that unaccounted for fish passed the The Dalles Dam undetected. Some additional unaccounted for fish may have entered Bonneville reservoir tributaries undetected, though we think the incidence of this was low given redundancy between radiotelemetry sites, PIT detection sites, and recapture data from tributary hatcheries and fisheries.

In almost all reaches, jack Chinook salmon had among the highest Metric B and Metric D conversion rates, sockeye salmon estimates tended to be intermediate, and adult Chinook salmon and steelhead estimates were relatively lower. This study was one of the first to radio-tag jack Chinook salmon, and the survival differences between jacks and adults are not well understood at this time. However, we suspect that the relatively high jack survival is related to lower harvest effort. It is also possible that there is higher unreported harvest of radio-tagged adult Chinook salmon, higher gillnet encounter rates for adults, higher indirect mortality for adults that escape gill nets, increased risk of mortality following fallback by adults or other size-selective mortality agents. We also note the lack of a temperature effect on fate in jacks compared to adult Chinook salmon suggests additional factors were also at play. Some of these same size-related mechanisms may explain the relatively high survival of sockeye salmon, a hypothesis that has some support in the lower conversion rates for larger sockeye salmon. It is also possible that the jacks and sockeye salmon use different migratory routes than adult Chinook salmon or steelhead (i.e., jacks and sockeye salmon may be exposed to lower fishery effort than the behaviorally thermoregulating steelhead; Keefer et al. 2009).

Tributary turnoff: Full samples

Tributary entry in the study reach varied widely among species and runs. On average, 19% of adult spring Chinook salmon versus 4% of adult summer Chinook salmon entered tributaries between Bonneville and McNary dams. Similarly, more spring jack Chinook salmon (12%) than summer jacks (7%) entered tributaries. These patterns reflected the prevalence of summer-run Chinook salmon originating from populations upstream from the Columbia River-Snake River confluence. Lower than average proportions of adult Chinook salmon entered the Wind and Little White Salmon rivers in 2013-2014 compared to in several previous radiotelemetry studies (e.g., Keefer et al. 2004b, 2005), again perhaps as a result of the study start date in 2013, but perhaps also because previously PIT-tagged fish were excluded from radio-tagging (i.e., many Wind River salmon are PIT-tagged). Tributary distributions for the Chinook salmon age classes were generally quite similar, with ~ 4-7% of each entering Bonneville reservoir tributaries, ~ 2-3% in the Deschutes River, and ~ 2-6% in the John Day and Umatilla rivers.

A total of five sockeye salmon (<1%) were last recorded in lower Columbia River tributaries. As described above, we think these were unlikely to be fish seeking spawning sites as there are no populations in the study reach other than the newly-established Deschutes River population. Notably, no radio-tagged sockeye salmon were detected in the Deschutes River. It is possible that some of the five were strays. It is also possible that one or more transmitters were from fish that were harvested but not reported to us and in-air tags were detected at the tributary receivers.

Far more early steelhead (39%) than late steelhead (8%) were last detected in tributaries between Bonneville and McNary dams. This was almost certainly because the late-migrating "B-group" fish primarily originate from the Snake River basin (Brannon et al. 2004). The early group entered tributaries in the Bonneville pool (~5%), the Deschutes River (~8%), the John Day River (~ 14%), and the Umatilla River (~ 3%). From previous studies using known-origin (PIT-tagged) steelhead and from the genetic data collected in this study, it is likely that some of these fish were temporary strays that were harvested while using tributaries for thermal refuge (Keefer et al. 2009) or were permanent strays (Keefer et al. 2008a).

Fallback at Bonneville Dam and potential sea lion predation

The target population for this study component was Chinook salmon that fell back at Bonneville Dam in April and May when California and Steller sea lions are actively preying on salmon in the tailrace. There is a concerned speculation that fallback salmon may be at greater risk of predation, both because they are exposed to sea lions for longer periods or on more than one occasion (i.e., 'double jeopardy') and because they may suffer injuries during fallback that make them more vulnerable.

In previous observation- and telemetry-based predation studies (e.g., Stansell et al. 2010; Keefer et al. 2012), predation rates on Chinook salmon varied widely among weeks, but the highest rates tended to be on the earliest migrants when salmon abundance is low (and per capita risk to salmon is highest). The best opportunity to estimate whether there is a double jeopardy predation risk for fallback salmon is likely in April, followed by May. In the two study years, substantial majorities (74-88%) of both adult and jack Chinook salmon that fell back at Bonneville Dam in April and May subsequently reascended a fishway at the dam (though we note early season adults were not tagged in 2013). These reascension rates were similar to those for Chinook salmon that fell back at the dam in June-July. Although small sample sizes limited our analyses, the available data do not suggest that fallback salmon were predated at unusually high (or low) rates in the spring (i.e., that the individual risk of predation was substantially higher after fallback when sea lions were present). Unfortunately – from an analytical perspective – we recorded few fallbacks by the early migrants most at risk of predation.

It is also possible that sea lions in the Bonneville reservoir may have predated some fish in that reach. At least four sea lions were present in the reservoir in 2013 (Stuart Ellis, CRITFC, *personal communication*) and some were reported in 2014. It is unlikely that these animals had a substantive effect on the Bonneville-The Dalles conversion rate estimates.

Fallback in relation to reach conversion

There was considerable evidence that fallback at dams reduced conversion rates for adult Chinook salmon in both study years, but especially in 2013. Reach conversion estimates were ~16-40% lower for fallback fish in three of the four reaches in 2013 and ~10-25% lower with the combined 2013-2014 data. This is consistent with the reduced survival to tributaries we have reported for much larger radio-tagged samples of spring–summer Chinook salmon in previous study years (Keefer et al. 2005). In contrast to the 2005 summary, Chinook salmon that fell back in 2013 and entered a downstream tributary (i.e., potential 'overshoot' fish; Keefer et al. 2008c) were considered unsuccessful for the conversion estimate in the upstream reach. The lower reach conversion associated with fallback therefore was not equivalent to a 10-25% mortality effect. In the current report, we also evaluated the effects on conversion of downstream fallback before fish passed through a reach. This is a modest change from methods used in the first study year (Keefer et al. 2014) that we think better captures the reach survival effects of fallback because fallback events that occurred after a fish passed a reach were excluded; the method should have captured the direct effects (i.e., mortality associated with fallback for fish that did not pass a reach) and the potential delayed effects of fallback on upstream conversion rates.

The fallback percentages for adult Chinook salmon (1.9-7.9%, *mean* = 4.3%) were generally lower than reported in 1996-2001 by Boggs et al. (2004). In part, this was a consequence of no tagging in April 2013 (fallback rates tend to be higher for spring than summer Chinook salmon) and because powerhouse priority at Bonneville Dam was for Powerhouse 1 in the Boggs et al. (2004) study, an operation associated with higher fallback.

Fallback percentages for jack Chinook salmon were slightly lower (2.0-5.6%, *mean* = 4.0%) than for adults. However, there was no evidence that jack fallback resulted in reduced reach conversion. In fact, most jacks that fell back either passed McNary Dam, entered tributaries between Bonneville and McNary dams, or were harvested (i.e., few were unaccounted for). The apparent difference in fallback effects between jacks and adults is currently unknown, but jacks may be less vulnerable to harvest (i.e., they may pass through gillnets and may be released by recreational anglers). Jacks also may suffer fewer injuries during fallback than the larger-bodied adults or may fall back via different routes than adults. The radiotelemetry array was not configured to assess route-specific fallback for most of the study period.

Fallback percentages for sockeye salmon at the lower Columbia dams (1.2-5.0%, *mean* = 3.5%) were lower than or similar to those reported for radio-tagged sockeye salmon in 1997 by Reischel and Bjornn (2003) and Naughton et al. (2006). The 1997 migration was characterized by very high flow and spill, which contributed to higher fallback in that year. In 2013-2014, sockeye salmon that fell back had lower reach conversion estimates in several reaches, but only fallback at Bonneville Dam had a statistically significant effect: Bonneville-The Dalles conversion was ~10-20% lower for those that fell back at The Dalles Dam than those that did not.

Fallback percentages were highly variable for early steelhead (*range* = 1.8% at Bonneville in 2013 to 21.8% at McNary in 2014, *mean* = 8.4%) and moderately variable for late steelhead (*range* = 0.3% at Bonneville in 2014 to 10.7 at The Dalles in 2013, *mean* = 4.4%). Differences between the early and late fish were likely due to differences in river environment (i.e., no spill conditions during the migration of most late-run fish) and factors associated with fish origin (i.e., a majority of late run fish were from the Snake River). For example, the high fallback percentage at McNary Dam by early migrants included many that subsequently entered the John Day River, a behavior that has been termed 'overshoot' (Keefer et al. 2008b). In contrast, many prespawn fallback events by the late-run fish occurred during winter and early spring, and these movements have been associated with overwintering and homing behaviors (Keefer et al. 2008d, 2014a).

The relationship between fallback and steelhead conversion also differed between the early and late groups. Early steelhead was the only run in the study that had conversion rates through the Bonneville-McNary reach that were statistically higher for fallback fish than for non-fallback fish. This was surprising given that early fallback fish had lower conversion through the Bonneville-The Dalles reach. In contrast, fallback by late-run steelhead was associated with conversion rates that were ~10 to >25% lower than for fish that did not fall back, particularly through the John Day-McNary reach and Bonneville-The Dalles reaches.

Covariate effects on reach conversion

We examined the relationships between reach conversion and a suite of potential covariates using two strategies: 1) by testing individual covariates, and 2) by using an information theoretic model selection process. These methods generally produced complimentary results and indicated that a combination of fish traits, fallback behavior, and river environment was associated with upstream migration success in the studied runs.

In the multi-model comparison, adult Chinook salmon traits that were statistically associated with conversion rates included origin (one reach) and fish length (three reaches). The origin result indicated that wild salmon had higher conversion than hatchery salmon, possibly indicating a recreational harvest effect. Larger Chinook salmon had lower conversion, which may also reflect harvest processes, such as selection for larger fish. In addition, late-run (i.e., summer Chinook salmon) were larger, on average, than earlier migrants and so it is possible that some of the apparent size effect was associated with temperature-related effects. As noted above, fallback behavior was consistently predictive of lower conversion for adult Chinook salmon, as was exposure to warmer water temperature.

Statistically important covariates for sockeye salmon were similar to those for adult Chinook salmon. Exposure to warm water temperature by later migrants within year was associated with notably lower reach conversion, even though mean exposure was typically < 1 °C higher for the unsuccessful fish than for the successful fish. Larger sockeye salmon were less likely than smaller sockeye to survive through several reaches. This may indicate fishery-related effects, with smaller fish less likely to be harvested or less likely to suffer other adverse outcomes from encounters with fisheries. Fallback effects were less pronounced for sockeye salmon than adult Chinook salmon, but had a negative overall effect on conversion, as described above.

The temperature effects identified for adult Chinook salmon and sockeye salmon were consistent with several recent studies of temperature exposure during upstream migration. Our sockeye salmon results were similar to those from the Naughton et al. (2005) radiotelemetry study where much lower survival was observed for late-run Columbia River sockeye salmon that encountered warm water temperatures. Results were also consistent with a late-timing, warm water effect on survival reported for Snake River sockeye salmon in a 2000 radiotelemetry study (Keefer et al. 2008d) and in recent evaluations using PIT-tagged sockeye salmon in the

Columbia basin over multiple years (Keefer et al. 2014b; Crozier et al. 2014). Other regional sockeye salmon studies also support a strong relationship between high water temperature and adult mortality (e.g., Hyatt et al. 2003; *review* by Hinch et al. 2012). Data from PIT-tagged Snake River spring–summer Chinook salmon also indicate a negative temperature-survival relationship (Keefer et al. 2014b). However, the effect on spring Chinook salmon is lower relative to sockeye salmon, perhaps due to the earlier migration timing (and lower mean temperature exposure) of Chinook salmon. The lack of temperature effects in jack Chinook salmon may have been related to lower sample sizes in this group or to biological differences in susceptibility to temperature effects due to body size differences or other factors.

In the multi-model comparison for early steelhead, few covariates were statistically associated with reach conversion rates. In part, this may have reflected relatively small sample sizes for this group in each year. In the statistically significant ($P < 0.05$) models, large steelhead were less likely to survive through the Bonneville-The Dalles reach and fish that fell back had higher survival through the multi-dam reach than those that did not fall back, as described above. By comparison, several covariates were identified in the comparison of models for late-run steelhead. Males generally had lower conversion rates than females (note that in-hand sex assignment error may have affected this result) , fish that fell back at dams had lower conversion rates than those that did not fall back, and several injury types were associated with lower conversion rates. There was some evidence that, within the late-run samples, earlier-timed migrants had higher reach survival.

Use of genetic data for evaluating reach conversion and straying

Genotyping a majority of the radio-tagged Chinook salmon and steelhead was an important methodological advance relative to many previous adult salmon and steelhead radiotelemetry studies because it allowed us to treat many fish as known-origin. This greatly affected how tributary turnoff in the lower was interpreted, because tributary entry was considered migration success in the absence of genetic data but could be considered unsuccessful straying once the genetic data were available. The genetic information also made it possible to estimate conversion rates that were more directly relevant to FCRPS performance standards than rates based solely on monitoring radio-tagged fish of unknown origin.

The genetic assignments were two-tiered (PBT and GSI), and both methods had some limitations that affected interpretation of results. The PBT data were remarkably precise with respect to origin hatchery because fish could be linked to specific hatchery-spawned parents (Hess et al. 2011; Steele et al. 2013). However, the PBT assignments were necessarily limited to hatchery fish and available genotyped parents were primarily from Snake River hatcheries. Therefore, all wild-origin radio-tagged fish and those from hatcheries outside of the Snake River basin could not be PBT-assigned. The wild fish, in particular, are management and conservation priorities. The genetic stock identification (GSI) assignments were less geographically specific than PBT assignments, which made data interpretation somewhat more challenging, especially for the UCOLSP (spring Chinook salmon) and MGILCS (steelhead) reporting groups. The wide spatial extent of these two reporting groups largely derives from a legacy of inter-basin hatchery transfers, such as the use of upper Columbia River spring-run Chinook salmon in lower Columbia River tributary hatcheries. Despite these challenges, GSI did allow much larger proportions of the radio-tagged samples to be assigned to regional populations, including wild fish and hatchery fish from sites outside the Snake River basin.

We used the genetic information to address three general research questions: (1) the origin of fish that were reported as harvested or were unaccounted for in the study reach; (2) identification of strays from populations upstream from McNary Dam into lower Columbia River tributaries; and (3) population-specific conversion rates.

Harvested and unaccounted for fish – Among the PBT-assigned adult spring Chinook salmon, ~4-5% was voluntarily reported as harvested in the lower Columbia River and ~14-23% was unaccounted for. Multiple source hatcheries were identified in both the harvested and unaccounted for groups, as would be expected in the mixed-stock gillnet fisheries that occur in the reservoirs and in recreational fisheries for hatchery-origin fish. Relatively few adult summer Chinook salmon were assigned to PBT hatcheries, limiting evaluation for this group. Few PBT-assigned jack Chinook salmon were reported harvested from either run, whereas jacks that were unaccounted for (~5-11% of each run-year) originated from a variety of Snake River hatcheries. Reported harvest rates for the early-run (~4-7%) and late-run (~4-5%) steelhead with PBT assignments also indicated that fish originated from multiple hatcheries, particularly within the more abundant late-run samples. Unaccounted for PBT steelhead (19-22% of early-run and 14-17% of late-run fish) were from 2-3 hatcheries (early) and 9-10 hatcheries (late) in approximate proportion to their abundance in the samples. Hatchery-specific sample sizes were highly variable, making direct among-hatchery comparisons of rates difficult.

The GSI-assigned fish represented many more populations than the PBT-assigned groups. However, patterns were qualitatively similar in that fish that were reported harvested and those that were unaccounted for downstream from McNary Dam were represented in most GSI reporting groups. There was little evidence indicating that some groups were disproportionately harvested or contributed to ‘loss’ in the study reach across years. Among the adult Chinook salmon, an exception was that unaccounted for rates were relatively high (>40%) for the KLICKR (Klickitat River) and DESCSP (Deschutes River spring-run) fish in 2013, though sample sizes were quite small. Among the jacks, unaccounted for rates were relatively high (27%) for the SFSALM (South Fork Salmon River) spring-run fish in 2014. Harvested steelhead were from four (early-run) and seven (late-run) GSI reporting groups and unaccounted for steelhead were from seven (early) and six (late) groups. Relatively high proportions of fish from the mixed-stock SKAMAN early run (both years) and MGILCS late run (both years) groups were unaccounted for. Many of these fish presumably originated in the study reach and may have been more vulnerable to harvest, including in lower tributary reaches, than steelhead from the upriver populations.

Straying – The genetic data paired with radiotelemetry and PIT-tag detections suggested that small percentages of the studied populations strayed from sites upstream from McNary Dam into lower Columbia River tributaries. Among the PBT-assigned groups (aggregated across hatcheries), the highest stray rates were for the late-run (~4%) and early-run (~4-7%) steelhead, followed by spring-run adult Chinook salmon (~3%). Summer-run adult Chinook and jack Chinook salmon had the lowest estimated stray rates (~0-3%) in aggregate. Many individual PBT and GSI groups had no reported strays, while others had estimates above 10%. We note again, however, that sample sizes were small for several groups. In general, the stray rate estimates inferred in this study were consistent with the rates reported in the recent review of Columbia River adult salmon and steelhead straying (Keefer and Caudill 2014). As noted above, the fish identified as strays in our study likely had a variety of fates, including harvest while temporarily using tributaries, harvest near tributary mouths and then in-air transport past radio receivers, or permanent straying and possible inter-breeding with local populations. Differentiating these outcomes is a persistent challenge in straying studies (Keefer and Caudill 2014).

Bonneville-McNary reach conversion – The genetic data helped capture some of the among-population variability in conversion rates through the Bonneville-McNary study area. Differences in conversion among specific hatchery groups (PBT-assigned fish), among the broader GSI reporting groups, and among the full mixed-stock radio-tagged samples typically ranged from a couple percentage points to ±10% for some paired comparisons. We are hesitant to draw many conclusions about among-population differences in survival from two years of genetic data, particularly given the large differences in sample sizes among population both within and between years. Among PBT-assigned groups, we were most confident in the conversion estimates for Dworshak late-run steelhead, which had >300 fish in each year. The largest samples of PBT-assigned Chinook salmon were the 30-54 spring-run adults from Rapid River hatchery; most other Chinook salmon hatcheries had fewer than 20 fish per year. The most abundant GSI-assigned samples were from the HELLSC and UCOLSP (adult and jack spring Chinook salmon), UCOLSF (adult and jack summer Chinook salmon), the SFCLWR and UPSALM (late steelhead) and MGILCS (early steelhead) reporting groups. Several of these groups were mixed origin and therefore more challenging to compare across populations and years.

In conclusion, the genetic data provide a unique and useful baseline for future reach conversion evaluations. The combination of radiotelemetry and genetic data provide some of the most complete information on the relationship between fish origin and adult fate during migration, but a combination of genetic data and PIT-tag detections could provide a close analog. Future studies could examine the suite of factors that presumably contributed to the among-population differences in reach conversion. These likely include harvest regulations that treat fin-clipped and non-clipped fish differently, variation in harvest vulnerability associated with fish size and migration timing, variation in the likelihood of temporary or permanent straying, and perhaps underlying differences in fish condition across populations.

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Appendix A. Conversion rate data summaries.

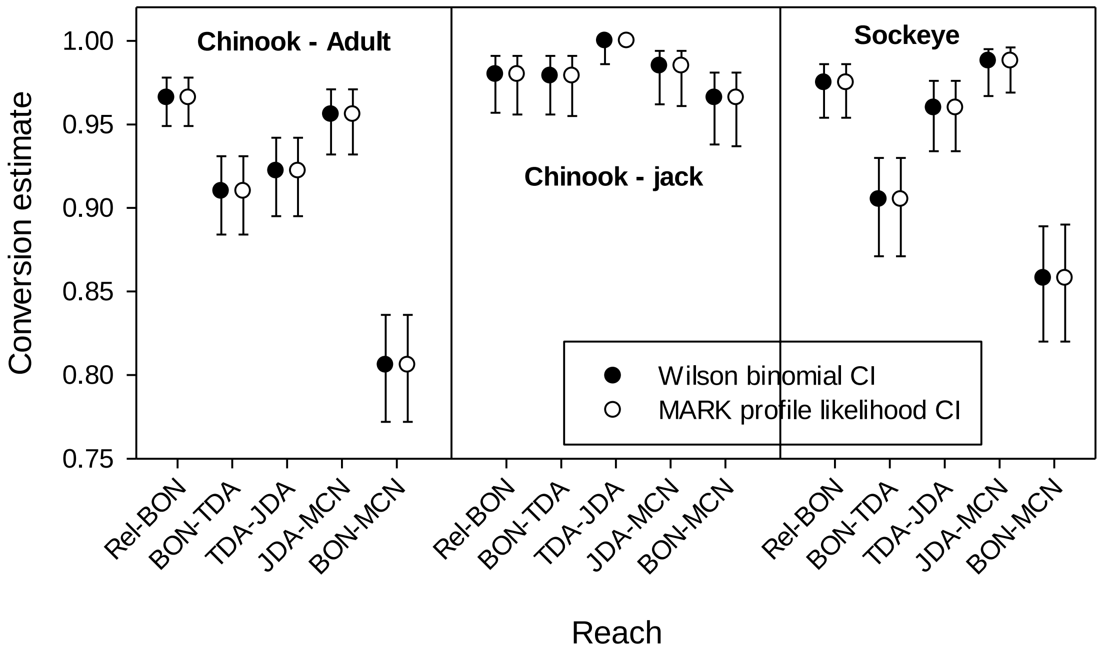

Figure A1. Comparison of reach conversion estimates and 95% confidence intervals calculated using Cormack-Jolly-Seber (CJS) survival models in program MARK (○) and the Wilson method for binomial proportions in R package binom (●). Data were generated from the combined 2013 radiotelemetry and PIT-tag detection histories and all estimates were rounded to three decimal places. Rel = release downstream from Bonneville; BON = top of Bonneville; TDA = top of The Dalles; JDA = top of John Day; MCN = top of McNary.

Table A1. Conversion rates from release past Bonneville Dam, with all input data. Metric A = minimum survival, unadjusted for fisher-reported harvest or tributary turnoff; Metric B = fish that entered tributaries between Bonneville and McNary Dam were successful; Metric C = tributary fish were successful and fisher-reported harvested fish were censored; Metric D = tributary fish and fisher-reported harvested fish were censored.

			Entered	Passed	Entered	Fisher-		Conversion estimates			
Reach	Year	Run	reach	reach	tributary	reported harvest	Unknown	A	B	C	D
Rel-BO	2013	Sp Chinook Adult	412	395	0	0	17	0.959	0.959	0.959	0.959
Rel-BO	2013	Su Chinook Adult	185	182	0	2	1	0.984	0.984	0.995	0.995
Rel-BO	2013	Sp-Su Chinook Adult	597	577	0	2	18	0.966	0.966	0.970	0.970
Rel-BO	2014	Sp Chinook Adult	465	452	0	1	12	0.972	0.972	0.974	0.974
Rel-BO	2014	Su Chinook Adult	135	130	0	0	4	0.963	0.963	0.963	0.963
Rel-BO	2014	Sp-Su Chinook Adult	600	582	0	1	16	0.970	0.970	0.972	0.972
Rel-BO	2013	Sp Chinook Jack	205	200	0	0	5	0.976	0.976	0.976	0.976
Rel-BO	2013	Su Chinook Jack	92	91	0	0	1	0.989	0.989	0.989	0.989
Rel-BO	2013	Sp-Su Chinook Jack	297	291	0	0	6	0.980	0.980	0.980	0.980
Rel-BO	2014	Sp Chinook Jack	216	208	0	0	8	0.963	0.963	0.963	0.963
Rel-BO	2014	Su Chinook Jack	83	82	0	1	0	0.988	0.988	1.000	1.000
Rel-BO	2014	Sp-Su Chinook Jack	299	290	0	1	8	0.970	0.970	0.973	0.973
Rel-BO	2013	Sockeye	398	388	0	0	10	0.975	0.975	0.975	0.975
Rel-BO	2014	Sockeye	399	372	0	1	26	0.932	0.932	0.935	0.935
Rel-BO	2013	Steelhead-Early	169	166	0	0	3	0.982	0.982	0.982	0.982
Rel-BO	2013	Steelhead-Late	620	587	1	0	32	0.947	0.948	0.948	0.948
Rel-BO	2014	Steelhead-Early	208	202	0	3	3	0.971	0.971	0.985	0.985
Rel-BO	2014	Steelhead-Late	591	578	0	0	13	0.978	0.978	0.978	0.978

Table A2. Conversion rates from the top of Bonneville Dam to the top of The Dalles Dam, with all input data. Metric A = minimum survival, unadjusted for fisher-reported harvest or tributary turnoff; Metric B = fish that entered tributaries between Bonneville and McNary Dam were successful; Metric C = tributary fish were successful and fisher-reported harvested fish were censored; Metric D = tributary fish and fisher-reported harvested fish were censored.

Reach	Year	Run	Entered reach	Passed reach	Entered tributary	Fisher-reported harvest	Unknown	Conversion estimates A	B	C	D
BO-TD	2013	Sp Chinook Adult	395	347	14	9	27	0.878	0.914	0.935	0.933
BO-TD	2013	Su Chinook Adult	182	163	1	7	11	0.896	0.901	0.937	0.937
BO-TD	2013	Sp-Su Chinook Adult	577	510	15	16	38	0.884	0.910	0.936	0.934
BO-TD	2014	Sp Chinook Adult	452	362	33	14	43	0.801	0.874	0.902	0.894
BO-TD	2014	Su Chinook Adult	131	123	1	2	5	0.939	0.947	0.961	0.961
BO-TD	2014	Sp-Su Chinook Adult	583	485	34	16	48	0.832	0.890	0.915	0.910
BO-TD	2013	Sp Chinook Jack	200	189	6	1	4	0.945	0.975	0.980	0.979
BO-TD	2013	Su Chinook Jack	91	87	3	0	1	0.956	0.989	0.989	0.989
BO-TD	2013	Sp-Su Chinook Jack	291	276	9	1	5	0.948	0.979	0.983	0.982
BO-TD	2014	Sp Chinook Jack	208	187	10	0	11	0.899	0.947	0.947	0.944
BO-TD	2014	Su Chinook Jack	82	73	3	1	5	0.890	0.927	0.938	0.936
BO-TD	2014	Sp-Su Chinook Jack	290	260	13	1	16	0.897	0.941	0.945	0.942
BO-TD	2013	Sockeye	388	351	0	11	26	0.905	0.905	0.931	0.931
BO-TD	2014	Sockeye	372	346	0	5	22	0.930	0.930	0.943	0.943
BO-TD	2013	Steelhead-Early	166	133	10	7	16	0.801	0.861	0.899	0.893
BO-TD	2013	Steelhead-Late	587	535	4	18	30	0.911	0.918	0.947	0.947
BO-TD	2014	Steelhead-Early	202	147	12	4	39	0.728	0.787	0.803	0.790
BO-TD	2014	Steelhead-Late	578	505	10	14	49	0.874	0.891	0.913	0.912

Table A3. Conversion rates from the top of The Dalles Dam to the top of John Day Dam, with all input data. Metric A = minimum survival, unadjusted for fisher-reported harvest or tributary turnoff; Metric B = fish that entered tributaries between Bonneville and McNary Dam were successful; Metric C = tributary fish were successful and fisher-reported harvested fish were censored; Metric D = tributary fish and fisher-reported harvested fish were censored.

Reach	Year	Run	Entered reach	Passed reach	Entered tributary	Fisher-reported harvest	Unknown	Conversion estimates A	B	C	D
TD-JD	2013	Sp Chinook Adult	347	309	18	3	17	0.890	0.942	0.951	0.948
TD-JD	2013	Su Chinook Adult	163	141	2	4	16	0.865	0.877	0.899	0.898
TD-JD	2013	Sp-Su Chinook Adult	510	450	20	7	33	0.882	0.922	0.934	0.932
TD-JD	2014	Sp Chinook Adult	362	328	19	3	12	0.906	0.959	0.967	0.965
TD-JD	2014	Su Chinook Adult	123	113	0	3	7	0.919	0.919	0.942	0.942
TD-JD	2014	Sp-Su Chinook Adult	485	441	19	6	19	0.909	0.948	0.960	0.959
TD-JD	2013	Sp Chinook Jack	189	184	5	0	0	0.974	1.000	1.000	1.000
TD-JD	2013	Su Chinook Jack	87	83	4	0	0	0.951	1.000	1.000	1.000
TD-JD	2013	Sp-Su Chinook Jack	276	267	9	0	0	0.967	1.000	1.000	1.000
TD-JD	2014	Sp Chinook Jack	187	172	10	1	4	0.920	0.973	0.978	0.977
TD-JD	2014	Su Chinook Jack	73	71	0	1	1	0.973	0.973	0.986	0.986
TD-JD	2014	Sp-Su Chinook Jack	260	243	10	2	5	0.935	0.973	0.981	0.980
TD-JD	2013	Sockeye	351	337	0	0	14	0.960	0.960	0.960	0.960
TD-JD	2014	Sockeye	346	333	0	1	12	0.962	0.962	0.965	0.965
TD-JD	2013	Steelhead-Early	133	113	15	2	3	0.850	0.962	0.977	0.974
TD-JD	2013	Steelhead-Late	535	487	22	1	25	0.910	0.951	0.953	0.951
TD-JD	2014	Steelhead-Early	147	130	13	1	3	0.884	0.973	0.979	0.977
TD-JD	2014	Steelhead-Late	505	469	16	5	15	0.929	0.960	0.970	0.969

Table A4. Conversion rates from the top of John Day Dam to the top of McNary Dam, with all input data. Metric A = minimum survival, unadjusted for fisher-reported harvest or tributary turnoff; Metric B = fish that entered tributaries between Bonneville and McNary Dam were successful; Metric C = tributary fish were successful and fisher-reported harvested fish were censored; Metric D = tributary fish and fisher-reported harvested fish were censored.

			Entered	Passed	Entered	Fisher-		Conversion estimates			
Reach	Year	Run	reach	reach	tributary	reported harvest	Unknown	A	B	C	D
JD-MN	2013	Sp Chinook Adult	309	291	9	0	9	0.942	0.971	0.971	0.970
JD-MN	2013	Su Chinook Adult	141	129	1	4	7	0.915	0.922	0.949	0.919
JD-MN	2013	Sp-Su Chinook Adult	450	420	10	4	16	0.933	0.956	0.964	0.963
JD-MN	2014	Sp Chinook Adult	328	303	20	3	2	0.924	0.985	0.994	0.993
JD-MN	2014	Su Chinook Adult	113	98	1	7	7	0.867	0.876	0.934	0.933
JD-MN	2014	Sp-Su Chinook Adult	441	401	21	10	9	0.909	0.957	0.979	0.978
JD-MN	2013	Sp Chinook Jack	184	175	5	0	4	0.951	0.978	0.978	0.978
JD-MN	2013	Su Chinook Jack	83	83	0	0	0	1.000	1.000	1.000	1.000
JD-MN	2013	Sp-Su Chinook Jack	267	258	5	0	4	0.966	0.985	0.985	0.985
JD-MN	2014	Sp Chinook Jack	172	166	4	0	2	0.965	0.988	0.988	0.988
JD-MN	2014	Su Chinook Jack	71	69	1	1	0	0.972	0.986	1.000	1.000
JD-MN	2014	Sp-Su Chinook Jack	243	235	5	1	2	0.967	0.988	0.992	0.992
JD-MN	2013	Sockeye	337	333	0	1	3	0.988	0.988	0.991	0.991
JD-MN	2014	Sockeye	333	321	0	2	10	0.964	0.964	0.970	0.970
JD-MN	2013	Steelhead-Early	113	92	11	2	8	0.814	0.912	0.928	0.920
JD-MN	2013	Steelhead-Late	487	163	11	4	9	0.951	0.973	0.981	0.981
JD-MN	2014	Steelhead-Early	130	115	9	3	3	0.885	0.954	0.976	0.975
JD-MN	2014	Steelhead-Late	469	441	5	7	16	0.940	0.951	0.965	0.965

Table A5. Conversion rates from the top of Bonneville Dam to the top of McNary Dam, with all input data. Metric A = minimum survival, unadjusted for fisher-reported harvest or tributary turnoff; Metric B = fish that entered tributaries between Bonneville and McNary Dam were successful; Metric C = tributary fish were successful and fisher-reported harvested fish were censored; Metric D = tributary fish and fisher-reported harvested fish were censored.

			Entered	Passed	Entered	Fisher-		Conversion estimates			
Reach	Year	Run	reach	reach	tributary	reported harvest	Unknown	A	B	C	D
BO-MN	2013	Sp Chinook Adult	395	291	41	11	52	0.737	0.841	0.865	0.848
BO-MN	2013	Su Chinook Adult	182	129	4	15	34	0.709	0.731	0.796	0.791
BO-MN	2013	Sp-Su Chinook Adult	577	420	45	26	86	0.728	0.806	0.844	0.830
BO-MN	2014	Sp Chinook Adult	452	303	72	20	57	0.670	0.830	0.868	0.842
BO-MN	2014	Su Chinook Adult	131	98	2	12	19	0.748	0.763	0.840	0.838
BO-MN	2014	Sp-Su Chinook Adult	583	401	74	32	76	0.688	0.815	0.862	0.841
BO-MN	2013	Sp Chinook Jack	200	175	16	1	8	0.875	0.955	0.960	0.956
BO-MN	2013	Su Chinook Jack	91	83	7	0	1	0.912	0.989	0.989	0.988
BO-MN	2013	Sp-Su Chinook Jack	291	258	23	1	9	0.877	0.966	0.969	0.966
BO-MN	2014	Sp Chinook Jack	208	166	24	1	17	0.798	0.913	0.918	0.907
BO-MN	2014	Su Chinook Jack	82	69	4	3	6	0.841	0.890	0.924	0.920
BO-MN	2014	Sp-Su Chinook Jack	290	235	28	4	23	0.810	0.907	0.920	0.911
BO-MN	2013	Sockeye	388	333	0	12	43	0.858	0.858	0.886	0.886
BO-MN	2014	Sockeye	372	321	0	7	44	0.863	0.863	0.879	0.879
BO-MN	2013	Steelhead-Early	166	92	36	11	27	0.554	0.771	0.826	0.773
BO-MN	2013	Steelhead-Late	587	463	37	23	64	0.789	0.852	0.887	0.879
BO-MN	2014	Steelhead-Early	202	115	34	8	45	0.569	0.738	0.768	0.719
BO-MN	2014	Steelhead-Late	578	441	31	26	80	0.763	0.817	0.855	0.846

Appendix B. Supplementary material on genetic data.

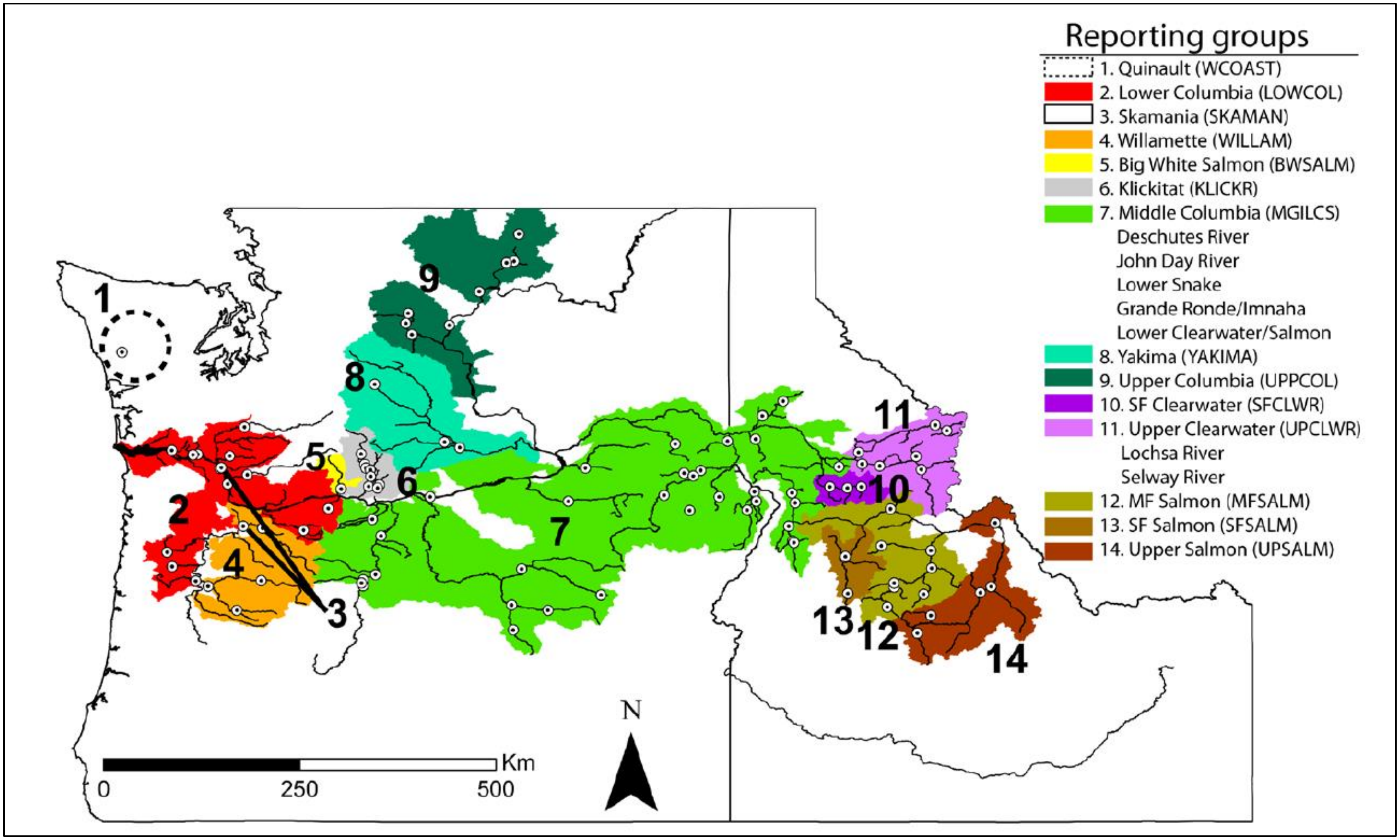

Figure B1. Map of reporting groups used in genetic stock identification (GSI). Source: Hess et al.(2015): 2013 Annual Report: Genetic assessment of Columbia River stocks. Report.. Columbia River Inter-Tribal Fish Commission.

Source references for the microsatellites used in genetic stock identification (GSI) and the single nucleotide polymorphisms (SNPs) used in parentage-based tagging (PBT) genetic analyses:

1) Chinook salmon microsatellites: Seeb, L. W. and 19 coauthors. 2007. Development of a standardized DNA database for Chinook salmon. Fisheries 32(11):540-552.

Table 1. Microsatellite loci standardized for Chinook salmon. Reference, curator agency, and observed number of alleles are given for baseline Version 1.1.

2) Chinook salmon SNPs: Narum, S., N. Campbell, A. Matala, and J. Hess. 2010. Genetic assessment of Columbia River stocks, 2009 Annual Report. Columbia River Inter-Tribal Fish Commission, Portland, OR.

Appendix 1. Chinook salmon descriptive statistics from analysis of the Chinook salmon SNP baseline of 52 collections. Column heading are: (n) sample size with complete genotype, (A) mean number of observed alleles , (He)_ Expected Heterozygostiy, (Ho) Observed Heterozygosity, (Fis) Fixation Index, (Fst(mean)) among-collection variation per locus, and (%p) percentage of polymorphic loci. Values in bold identify number of significant HWE deviations.

3) Steelhead microsatellites: Blankenship, S. M. and 12 coauthors. 2011. Major lineages and metapopulations in Columbia River *Oncorhynchus mykiss* are structured by dynamic landscape features and environments. Transactions of the American Fisheries Society 140:665-684.

4) Steelhead SNPs: Matala, A. P., M. W. Ackerman, M. R. Campbell, and S. R. Narum. 2014. Relative contributions of neutral and non-neutral genetic differentiation to inform conservation of steelhead trout across highly variable landscapes. Evolutionary Applications 7(6):682-701.

Table S2. List of 191 SNP markers assayed for O. mykiss in the Columbia River Basin. The minor allele frequency (MAF), locus-specific F_{ST}*, and observed heterozygosity (*H_o*) are the mean values among all populations, with respect to lineage-of-origin.*