SNAKE RIVER BASIN 2019-2020
STEELHEAD RUN RECONSTRUCTION

Photo by Joseph Hirsch

Steelhead Run Reconstruction Workgroup

FOREWORD AND ACKNOWLEDGEMENTS

Reconstruction of steelhead runs into the Snake River was identified as a key part of the Anadromous Salmonid Monitoring Strategy developed for the Columbia River basin by the management agencies in 2009. The co-managers who developed the Snake River subbasin strategy were Idaho Department of Fish and Game, Nez Perce Tribe, Oregon Department of Fish and Wildlife, Confederated Tribes of the Umatilla Indian Reservation, Washington Department of Fish and Wildlife, and the Shoshone-Bannock Tribes. The run reconstruction objective was developed into a proposal by the Nez Perce Tribe and Idaho Department of Fish and Game and approved for funding by Bonneville Power Administration in 2011. In 2012, an interagency workgroup was convened comprised of representatives of the agencies above and two other entities that operate or monitor steelhead hatcheries in the Snake basin: the US Fish and Wildlife Service (through the Lower Snake River Compensation Plan office) and the Idaho Power Company. The report that follows is a joint product of the workgroup.

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ABBREVIATIONS AND ACRONYMS

BON	Bonneville Dam
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	Coded Wire Tag
EF	East Fork
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FH	Fish Hatchery
GSI	Genetic Stock Identification
HUC4	4th field Hydrologic Unit Code
ICH	Ice Harbor Dam
IDFG	Idaho Department of Fish and Game
IP	Intrinsic Potential
IPTDS	In-stream PIT Tag Detections System
LF	Lyons Ferry
LGR	Lower Granite Dam
MCN	McNary Dam
MF	Middle Fork
MPG	Major Population Group
NFH	National Fish Hatchery
NF	North Fork
NPT	Nez Perce Tribe
ODFW	Oregon Department of Fish and Wildlife
PBT	Parentage Based Tagging
PIT	Passive Integrated Transponder
PTAGIS	PIT Tag Information System
RKM	River Kilometer
SBT	Shoshone Bannock Tribes
SF	South Fork
TOUC	Touchet River
TRT	Technical Recovery Team
TUCA	Tucannon River
USFWS	US Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

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ABSTRACT

Steelhead trout *Oncorhynchus mykiss* in the Snake River basin are the focus of a variety of harvest and conservation programs. Information needs for management of Snake River steelhead within this large and complex arena can be systematically addressed using a run reconstruction model. The purpose of this work is to summarize data describing the abundance of steelhead crossing Lower Granite Dam (LGR) and estimate the fishery-related impacts on both hatchery and wild steelhead as they migrate to their natal or release area in the Snake River basin. The model provides an analytical tool whose outputs can be used to bridge gaps in the existing data using reasonable assumptions in a structured manner. Representatives from the anadromous fishery management agencies within the Snake River basin collaborate to complete a run reconstruction for Snake River steelhead, which have been modeled since 2011. In this report our objective was to estimate the disposition of steelhead within the Snake River basin from July 1, 2019 to June 30, 2020 (spawn year 2020). After adjusting for nighttime passage and fallback, we estimated 9,771 wild steelhead, 2,449 unmarked hatchery steelhead, and 23,646 adipose-clipped hatchery steelhead passed LGR on the Snake River during spawn year 2020. Fishery-related steelhead mortality in the Snake River basin upstream of Ice Harbor Dam totaled 390 wild, 197 unmarked hatchery, and 8,864 marked hatchery fish. An additional 158 wild, 426 unclipped hatchery, and 7,069 clipped hatchery fish were collected for broodstock, culled, or donated to food banks (only hatchery fish). Snake River wild steelhead stocks experienced total losses of 21.8% between Bonneville Dam and Ice Harbor Dam. Fishery-related losses across all Major Population Groups of wild steelhead within the Snake River basin was 3.5%. Model results will allow Snake River basin managers to evaluate fishery impacts on wild steelhead, evaluate hatchery program performance, and help evaluate the performance of the Snake River steelhead evolutionarily significant unit.

INTRODUCTION

Steelhead trout *Oncorhynchus mykiss* (hereafter steelhead) in the Snake River basin are the focus of a variety of harvest and conservation programs. Wild populations are listed as threatened under the Endangered Species Act (ESA). However, most wild fish spawn during the spring run-off resulting in little information on spawner abundance (Busby et al. 1996; ICBTRT 2003). Extensive hatchery programs for steelhead are implemented under the 2018-2027 US vs. Oregon Management Agreement to mitigate for lost fisheries through the release of marked (adipose fin clipped) steelhead, and to supplement wild production with unclipped releases. Therefore, steelhead management in the Snake River basin is complex and requires accurate abundance estimates to describe hatchery performance and impacts to the wild populations.

The Snake River basin is believed to have historically supported more than half of the steelhead production in the Columbia River basin (Mallet 1974). While this is still the case (Fryer et al. 2012), the bulk of the returns to the Snake River basin in recent years are hatchery origin (Camacho et al. 2019). Currently, the progeny of 11 hatchery stocks are released within the basin where 24 populations of wild steelhead, partitioned into six major groups, remain (Table 1). All but three of the hatchery stocks, and one wild population, return to areas upstream of Lower Granite Dam (LGR). Stocks returning downstream of LGR include the unclipped ($TUCA^{u}$) and clipped ($TUCA^{c}$) Tucannon River hatchery stocks, the Lyons Ferry Fish Hatchery clipped ($WALL^{c}$) stock, and the Tucannon River wild population.

A run reconstruction model (Starr and Hilborn 1988; Chasco et al. 2007) offers a systematic way to address information needs for management within the large and complex arena presented by Snake River steelhead. Most frequently, run reconstruction models synthesize abundance, take (harvest, brood, and incidental mortality), and migration rates to recursively estimate abundance at points downstream of the terminal area (Quinn and Deriso 1999). The location of LGR facilitates an accounting of the aggregate run prior to the fish encountering extensive fisheries upstream of the dam. There are also fisheries from the mouth of the Snake River to LGR that impact all Snake River steelhead populations.

The purpose of this work is to estimate the abundance of steelhead at major locations in their migration and estimate fishery impacts to unclipped hatchery releases and wild populations in the Snake River basin. This information will help evaluate the performance of the Snake River steelhead evolutionarily significant unit (ESU) and associated hatchery programs, inform mitigation and management goals, and ESA delisting criteria. Collaborators from the anadromous fishery management agencies within the Snake River basin have developed a model framework (Copeland et al. 2013, 2014, 2015; Stark et al. 2016, 2017, 2018, 2019a, 2019b, 2021) to meet these goals. Since the initiation of this collaborative effort, fishery impact rates for adipose intact steelhead (wild and hatchery unclipped) returning to the Snake River basin estimated from this model have been adopted as a tool for monitoring the take of listed Snake River steelhead in recreational fisheries operated by the states of Idaho, Oregon, and Washington. This report has been restructured to report results directly addressing this management need.

Table 1. List of wild populations of steelhead spawning in the Snake River basin during 2019-2020 (spawn year 2020, SY20) by major population group (MPG). Hatchery stocks are listed by MPG with their associated abbreviation, unclipped hatchery releases by ^{u}, clipped hatchery releases by ^{c}.

Wild populations	Hatchery stocks
Lower Snake MPG	
Snake River	Lyons Ferry FH (WALL^{c})
Tucannon River	Tucannon endemic (TUCA^{u}), Tucannon (TUCA^{c})
Asotin Creek	
Grande Ronde MPG	
Lower Grande Ronde	Grande Ronde, Cottonwood AP (GRCW^{c})
Joseph Creek	
Wallowa River	Wallowa (WALL^{c})
Upper Grande Ronde	
Imnaha MPG	
Imnaha River	Imnaha, Big & Little Sheep Cr (IMNA^{c})
Clearwater MPG	
Lower Mainstem Clearwater River	Dworshak (DWOR^{c})
Lolo Creek	Dworshak (DWOR^{u})
Clear Creek	Dworshak (DWOR^{c})
South Fork Clearwater River	Dworshak (DWOR^{c,u}), SF Clearwater (SFCW^{c,u})
Lochsa River	
Selway River	
Salmon MPG	
Little Salmon River	Oxbow (OXBO^{c}), Pahsimeroi (PAHS^{c}), Upper Salmon B (USAL^{c})
South Fork Salmon River	
Secesh River	
Chamberlain Creek	
Lower Middle Fork Salmon River	
Upper Middle Fork Salmon River	
Panther Creek	Pahsimeroi (PAHS^{u})
North Fork Salmon River	
Lemhi River	
Pahsimeroi River	Pahsimeroi (PAHS^{c}), Upper Salmon B (USAL^{u}), Dworshak (DWOR^{u})
East Fork Salmon River	East Fork natural (EFNA^{u})
Upper Mainstem Salmon River	Upper Salmon B (USAL^{u,c}), Sawtooth (SAWT^{c}), Dworshak (DWOR^{c})
Hells Canyon MPG	
Hells Canyon (extirpated)	Oxbow (OXBO)^{c}

METHODS

Study Area

The study area is the portion of the Snake River basin that is currently accessible to anadromous fish. The Snake River is the largest tributary to the Columbia River and has its confluence with the Columbia 522 river kilometers (rkm) upstream of the Pacific Ocean and 288 rkm upstream of Bonneville Dam (BON), the first dam returning steelhead ascend after leaving the ocean (Figure 1). The last mainstem Columbia River dam steelhead cross before reaching the Snake River is McNary Dam (MCN), 52 rkm downstream of the mouth of the Snake River. Within the Snake River, the first dam encountered by adult steelhead is Ice Harbor Dam (ICH; Snake River rkm 16). Lower Granite Dam, the last dam steelhead may cross, is at rkm 173. The historic range of steelhead in the Snake River extended upstream to Shoshone Falls in southern Idaho (Figure 1), but fish passage is now blocked at Hells Canyon Dam (rkm 397). In addition, Dworshak Dam on the North Fork Clearwater River (rkm 3) blocks steelhead access in this tributary to the Snake River.

Figure 1. The Snake River basin (light gray), the portion accessible to adult steelhead (dark gray), and selected features of the migration route within the Columbia River basin.

Wild steelhead populations are widely distributed within the Snake River basin (Figure 2), where approximately 97% of the accessible spawning habitat is located upstream of LGR (Tom Cooney, NOAA Fisheries retired, unpublished data). In general, major population groups (MPGs) are delineated by major drainages (Clearwater, Grande Ronde, Imnaha, and Salmon rivers). The Tucannon River population (downstream of LGR) and the Asotin Creek population (upstream of LGR) comprise the Lower Snake MPG. The population within the minor tributaries of the Snake River in Hells Canyon (upstream of the Imnaha River) is considered to be functionally extirpated (NWFSC 2015).

Hatchery steelhead are released at multiple locations throughout the Snake River basin (Figure 3). In general, most hatchery fish are marked by an adipose fin clip (hereafter clipped) and are vulnerable to recreational fisheries within and downstream of the Snake River basin. Some unclipped hatchery steelhead are released to supplement natural production as mandated by the 2018-2027 *United States v. Oregon* Management Agreement. These releases occur in the Tucannon River, Lolo Creek, South Fork (SF) Clearwater River, Panther Creek, the mainstem Salmon River between the Lemhi River and Pahsimeroi River, East Fork (EF) Salmon River, and Yankee Fork Salmon River. Egg boxes placed into Beaver Creek, a tributary to Panther Creek, are part of the Shoshone-Bannock Tribes (SBT) fishery program.

Steelhead fisheries within the bounds of the Snake River basin are complex (Figure 3). Recreational fisheries are implemented within the mainstem of large rivers with harvest beginning in September and continuing into April, although the open and closure dates may vary in some river sections. Angling gear with barbless hooks is permitted, and only clipped steelhead may be retained. Tribal fisheries are potentially open within all portions of the Snake River basin until closed but are generally limited in spatial extent to boundaries shown in Figure 3. Tribal Fisheries employ a variety of gears, and retention of unclipped steelhead is allowed. The NPT operates a commercial gill net fishery in the Snake River between LGR and Hells Canyon Dam and in the mainstem Clearwater River with most effort in the Lower Granite pool. NPT tribal members also pursue subsistence steelhead fisheries throughout the Clearwater River basin, with most effort in the North Fork (NF) and SF Clearwater rivers. Members of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) pursue subsistence steelhead fisheries with most effort concentrated in the upper Grande Ronde River. Lastly, members of the SBT harvest steelhead throughout the Salmon River basin with most effort in the Yankee Fork and EF Salmon River.

Model Development

We developed a run reconstruction model with an input vector of abundances and transition matrices composed of survival and movement probabilities. The input vector was based on group abundances at LGR derived from an intensive sampling program operating on adult steelhead (Lawry et al. 2020). Disposition of steelhead within the Snake River basin was estimated recursively by applying survival and movement probabilities. We estimated escapement and loss to fisheries between ICH and LGR by moving fish downstream to ICH and then applying fisheries losses within that reach. We estimated escapement and losses upstream of LGR by moving fish upstream. We estimated the number of steelhead migrating across BON using passive integrated transponder (PIT) tag conversion rates, although we did not attempt to separate fishery impacts within the Columbia River from straying and natural mortality.

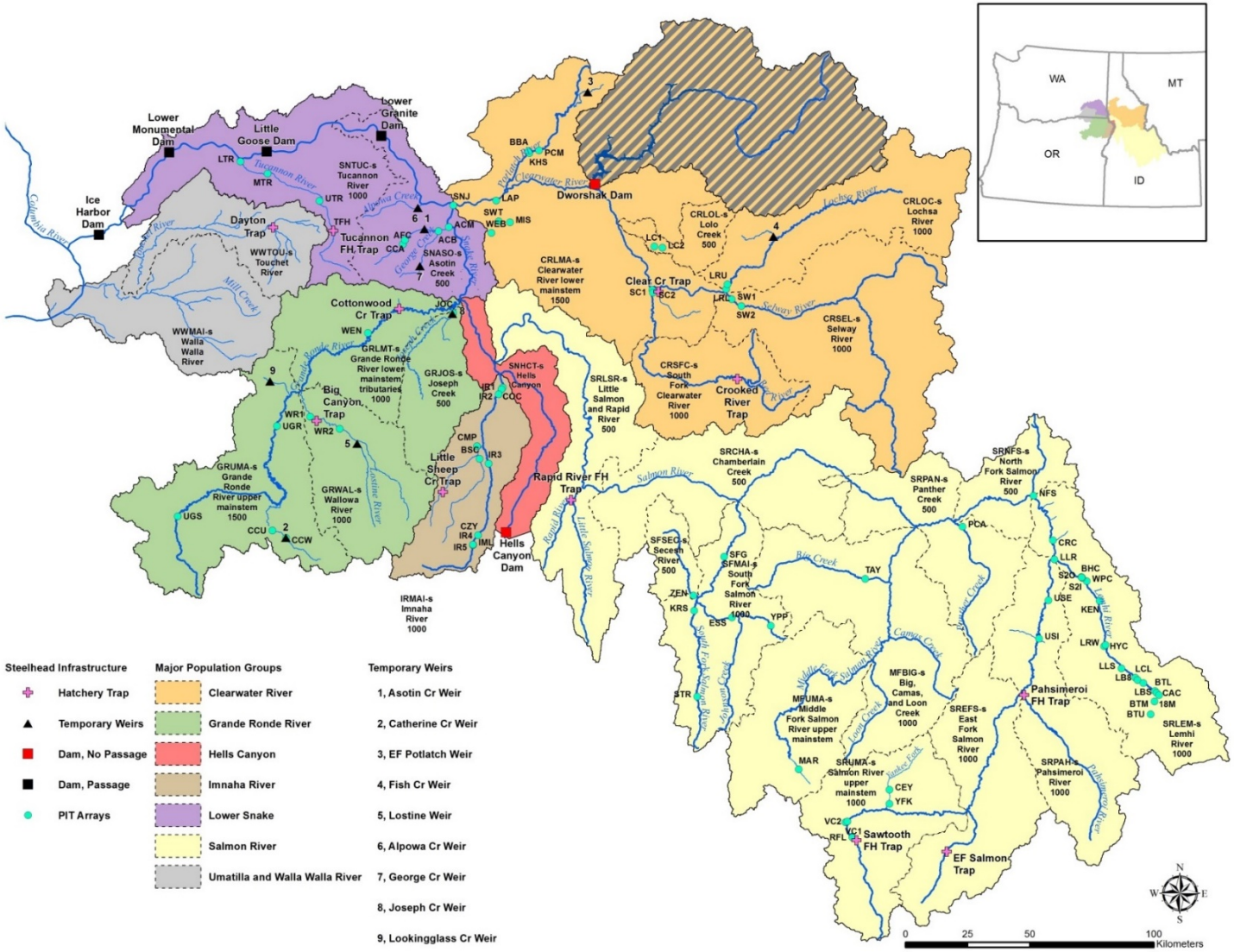

Figure 2. Snake River steelhead Major Population Groups (MPGs), technical recovery team (TRT) populations, Minimum Abundance Thresholds (MATs); and monitoring infrastructure including hatchery traps, temporary weirs, and PIT arrays.

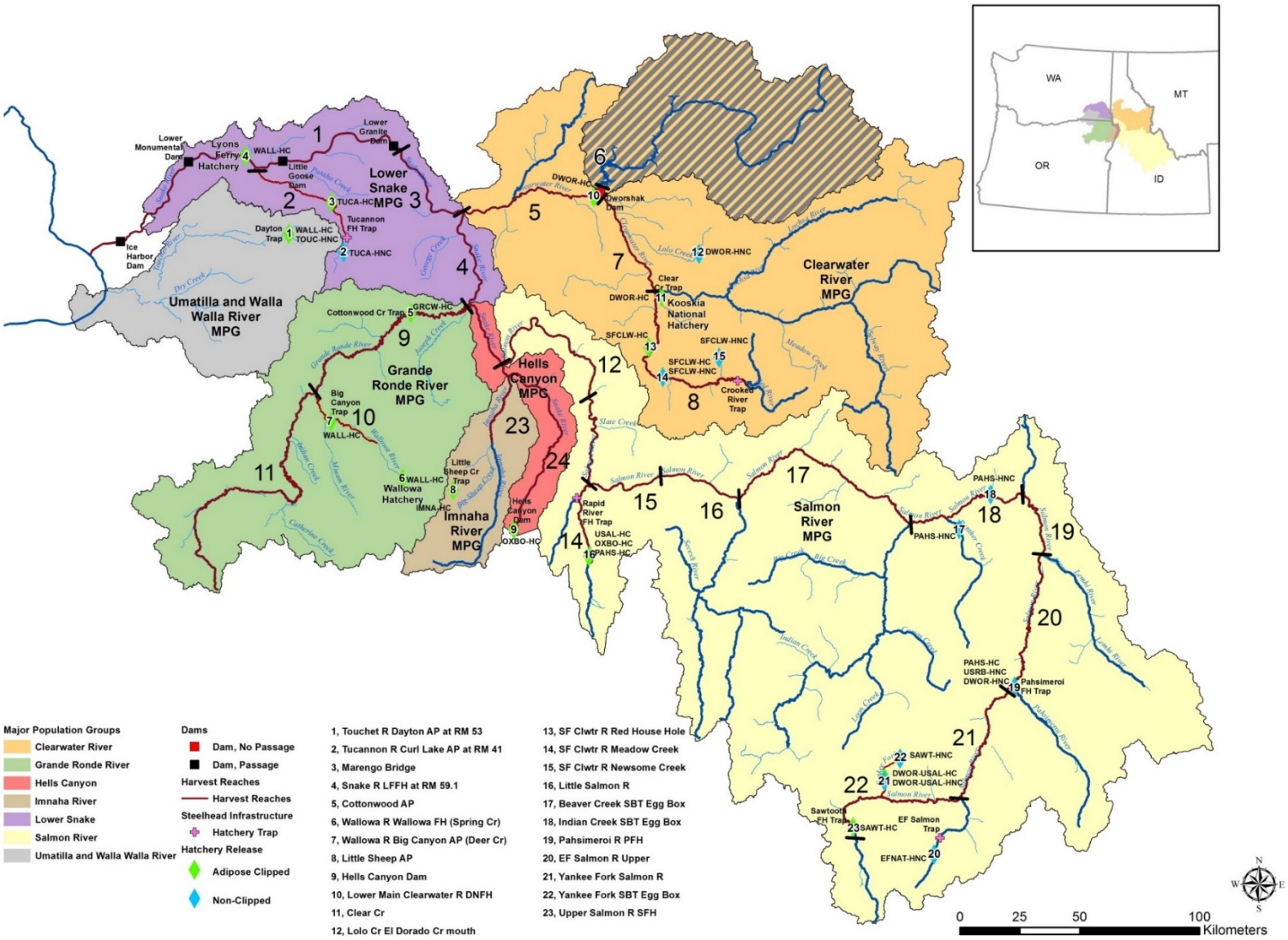

Figure 3. Hatchery steelhead release sites, stock and mark-type of release, and boundaries of harvest reaches within the Snake River basin. See Table 2 for harvest reach descriptions.

Abundance at Lower Granite Dam

The total abundance of steelhead crossing LGR from July 1, 2019 to June 30, 2020 was based on the expanded window count (see Lawry et al. 2020 for methodology). The window count is first partitioned into clipped hatchery fish, unclipped hatchery fish, and wild fish. We further parsed abundance of clipped and unclipped hatchery fish to release location based on samples collected at LGR. Parentage Based Tagging (PBT) genetic techniques were used to assign fish to hatchery stock (see Delomas et al. [2020] for methodology). Release locations were aggregated within fisheries reaches (see Figure 3) to simplify accounting within the model. Baum et al. (2022) parsed abundance of wild fish into genetic stocks using genetic stock identification (GSI) on adult steelhead sampled at LGR (see Hargrove et al. [2021] for methodology). Genetic stocks are larger than the populations, so we further parsed them into populations based on the weighted intrinsic potential of the currently occupied streams (ICBTRT 2007). Based on genetic structure and assignment tests, Lolo Creek was aligned with the SF Clearwater genetic group and Chamberlain Creek with the Middle Fork (MF) Salmon group (John Hargrove, IDFG/PSMFC, personal communication).

We made two adjustments to the LGR abundance estimates based on expanded window counts. First, the total dam count is biased low because some fish pass outside of counting hours (Dauble and Mueller 2000; Boggs et al. 2004). We estimated the proportion of fish that were detected outside the normal counting hours (0400 to 2000 PST from April 1-October 31, 0600-1600 PST from November 1 to December 31 and March 1 to March 31) to adjust the total window count for night passage, similar to that performed by Young et al. (2012) for fall Chinook Salmon. We downloaded all PIT tag detections of adult steelhead in the LGR ladder during June 2019-May 2020. Detections of fish tagged as adults at LGR were excluded because the recent tagging event may influence fish behavior and the probability of night passage. Remaining PIT tags with nighttime detections were flagged and counted. Because the PIT detectors are upstream from the counting window, a 15-minute buffer was added (e.g., 0415–2015). Passage dates of PIT tags mirrored the count data, so we did not stratify the data and a simple proportion was used. The window count for each group (clipped and unclipped hatchery, and wild fish) was adjusted upward by this proportion.

The second adjustment was to account for steelhead that re-ascended the adult ladder. We used PIT tag detections to estimate the rate at which steelhead had been double counted at LGR. The re-ascension rate was calculated by dividing the number of re-ascension events by the number of unique adult PIT tags detected at LGR (Young et al. 2012). It is possible for some fish to remain in the ladder for an extended period, so a re-ascension event was defined as a second detection in the lower ladder following a previous detection. We found previously that abundance of Lower Snake stocks (Tucannon and Asotin populations) appeared biased high (Copeland et al. 2013, 2014, 2015). Therefore, we estimated two re-ascension rates, one for populations in the Clearwater River, Grande Ronde River, Imnaha River, and Salmon River MPGs and another for populations in the Lower Snake River MPG. Window counts for each group (clipped and unclipped hatchery, and wild fish) were reduced by the re-ascension proportion for Lower Snake stocks and for stocks originating upstream of LGR, respectively.

Conversion Rates and Abundance at Downriver Dams

We used adult PIT tag detections at LGR, ICH, and BON dams, of Snake River basin steelhead that were tagged as juveniles, to calculate conversion rates between dams. The PIT Tag Information System (PTAGIS database, www.ptagis.org) was queried for adult detections

between 1 June 2019 and 31 December 2020 at BON and subsequent detections of these fish at the upstream dams. Conversion rates were the proportion of PIT-tagged fish detected at a dam that were later detected at any upstream dam. Some fish were missed at each dam because of system inefficiencies or tag collision (near simultaneous passage in the detector field) but are included in the numerator if they were detected farther upstream. The denominator contains only the number of tags actually detected at the downstream dam of the reach in question. We computed conversion rates for hatchery and wild fish by summing all releases within the Snake River basin 4th field Hydrologic Unit Code (HUC4), except the ICH to LGR conversion rate for Lower Snake stocks. ICH to LGR conversion rates were calculated independently for each population within the Lower Snake stock group.

Using the conversion rates we estimated stock abundance downstream of LGR at ICH, and BON dams as:

$$N_{id} = {}^{N_i}/_{CR_{id}} \tag{1}$$

where N_i = abundance of stock *i* at LGR,
N_{id} = abundance of stock *i* at dam *d*,
CR_{id} = conversion rate of stock *i* from dam *d* to LGR,
d = ICH and BON dams.

Equation 1 was used for all hatchery stocks and wild populations to calculate the stock abundance at all dams except the Lower Snake wild and hatchery stocks at ICH. The Lower Snake stock abundance at ICH was found by dividing population-specific conversion rates from ICH to LGR by the population abundance at LGR and summing all populations.

Run Reconstruction

Formally, we modified the 'box-car' model developed by Starr and Hilborn (1988):

$$N_i = \sum_{j=1}^{r}\left(C_{ij} + E_{ij}\right) \tag{2}$$

where N_i = abundance of stock i at LGR,
C_{ij} = Fishery mortality of stock i in reach j,
E_{ij} = survivors of stock i that remain in reach j after the fishery has occurred,
r = number of reaches entered by stock *i*.

Catch of stock *i* in reach *j* is assumed to be in proportion to their abundance in the reach:

$$C_{ij} = C_j * \left({}^{N_{ij}}/_{\sum_{i=1}^{s} N_{ij}}\right) \tag{3}$$

where Cj = total catch in reach j,
N_{ij} = abundance of stock i entering reach j,
s = number of stocks in reach j.

After fishery mortality occurs, fish of stock *i* move to the next reach upstream as:

$$N_{i,j+1} = p_{i,jk} * (N_{ij} - C_{ij}) \tag{4}$$

where $N_{i,j+1}$ = abundance of stock *i* that move from reach *j* into reach *j+1,*
$p_{i,jk}$ = probability of stock *i* moving from reach *j* to reach *k.*

Escapement of stock i in reach j is then:

$$E_{ij} = N_{ij} - N_{i,j+1} - C_{ij} \quad (5)$$

Within each reach we estimate the number of fish of each stock *i* that were caught (C_{ij}); moved to the next reach ($N_{i,j+1}$); or remained in the reach (*Eij*).The basic concept is that these equations are iterated in each consecutive reach starting downstream and proceeding upstream towards the release reach for hatchery fish and the natal reach for wild populations. Below, we will describe how this concept has been altered in the actual application.

We used 24 river reaches to define sport fisheries and delineate the spatial detail of the run reconstruction model (Figure 3, Table 2). Total fishery mortality in each reach was the sum of harvest and incidental catch-and-release mortality. Unless otherwise specified, we assumed that 5% of the fish caught and released eventually died (WDFW 2009). Catch and harvest statistics were estimated by each agency. Idaho Fish and Game (IDFG) estimated catch and harvest data with a post-season mail survey (IDFG 2019). Take of wild fish by sport fisheries in Idaho was estimated statewide based on the encounter rate of hatchery fish estimated from roving creel surveys in the Clearwater and Salmon rivers. We parsed the statewide take of unclipped steelhead into the Idaho fishery reaches based on proportion of the reported unclipped steelhead catch in each reach. Washington Department of Fish and Wildlife (WDFW) used harvest estimates derived from angler returns of catch record cards. Take of wild steelhead by sport fisheries in the mainstem Snake River in Washington was estimated from creel survey encounter rates and assumed a 5% mortality (Trump 2015). Total take was then parsed into the appropriate fishery reaches. Harvest estimates from the NPT were based on post-season interviews of tribal members. Oregon Department of Fish and Wildlife (ODFW) used a creel survey to estimate catch and harvest in the Lower Grande Ronde River (reach 9) and the Imnaha River (Carmichael et al. 1988). The harvest estimates for the Wallowa River in Oregon were based on current hatchery returns and a regression ($r^2 = 0.73$) of past hatchery returns to past Wallowa River ODFW harvest estimates (M. Flesher, personal communication). Catch and release of unclipped fish during the 2019-2020 return was estimated by applying the average proportion unclipped release numbers represented of the total harvest number averaged across years to the total harvest in 2019-2020 (M. Flesher, personal communication).

We modeled upstream movement assuming wild fish returned to where they were spawned (based on genetic stock assignment) and hatchery fish returned to their smolt release location. Therefore, fish moved with $p_{i,k-j} = 1.0$ if reach *k* was not the reach of hatchery smolt release, or wild fish origin. Where wild populations extended over more than one reach, we used the weighted intrinsic potential (IP) spawning area (ICBTRT 2007) within the reach as a proportion of the population total to define probability of upstream movement and reach residence. Hatchery fish returned to a point of release; therefore, all release points within a reach were combined. Specific fishery reach definitions and their resident stocks are given in Table 2. Stocks that return to tributaries within a fishery reach are treated as residents (E_{ij}) of that reach, i.e., they escape to their spawning area without further mortality.

Table 2. Description of fishery reaches in the Snake River basin, including agencies reporting fisheries within them during 2019-2020. Hatchery stocks are listed by release site with stock abbreviation in parentheses. Abbreviations are given in Table 1. Unclipped hatchery releases are denoted by ^{u} and clipped releases by ^{c}. Reach numbers correspond to those in Figure 3. Wild population names are underlined.

Reach	Reporting agency	Resident Wild and Hatchery Stocks
Snake River downstream of Lower Granite Dam		
1. Ice Harbor-Lower Granite	WDFW	Tucannon, Snake R, LFFH (WALL^{c})
Tucannon River		
2. Mouth to Tucannon FH	WDFW	Tucannon, Tucannon R (TUCA^{u,c})
Snake River upstream from Lower Granite Dam		
3. LGR to Clearwater mouth	WDFW, NPT	Asotin
4. Clearwater to Salmon mouth	WDFW, IDFG	Asotin
24. Salmon mouth to Hells Canyon Dam	IDFG	Snake R, Hells Canyon Dam (OXBO^{c})
Clearwater River		
5. Mouth to Orofino	IDFG, NPT	Lower Clearwater
6. North Fork Clearwater	IDFG, NPT	NF Clearwater R (DWOR^{c})
7. Orofino to Clear Creek	IDFG, NPT	Lower Clearwater, Lolo Creek, Clear Creek (DWOR^{c}), Lochsa, Selway
8. South Fork Clearwater	IDFG, NPT	SF Clearwater, SF Clearwater R (DWOR^{u,c}) & (SFCW^{u,c})
Grande Ronde River		
9. Mouth to Wallowa River	WDFW, ODFW	Lower Grande Ronde, Joseph Creek, Grande Ronde R, Cottonwood AP (GRCW^{c})
10. Wallowa River	ODFW	Wallowa, Wallowa R (WALL^{c})
11. Upstream of Wallowa River	ODFW	Upper Grande Ronde
Imnaha River		
23. Mouth upstream	ODFW	Imnaha, Imnaha R (IMNA^{c})
Salmon River		
12. Mouth to Whitebird Creek	IDFG	Little Salmon
13. Whitebird to Little Salmon mouth	IDFG	Little Salmon
14. Little Salmon River upstream	IDFG	Little Salmon, Little Salmon R (PAHS/USAL/OXBO/^{c})
15. Little Salmon to Vinegar Creek	IDFG	NA
16. Vinegar Creek to South Fork	IDFG	SF Salmon, Secesh, Chamberlain Cr
17. South Fork to Middle Fork	IDFG	Chamberlain Cr, Lower MF Salmon, Upper MF Salmon
18. Middle Fork to North Fork	IDFG	Panther Cr, NF Salmon
19. North Fork to Lemhi	IDFG	Lemhi
20. Lemhi to Pahsimeroi	IDFG	Pahsimeroi, Salmon R, Lem-Pah (DWOR/USAL^{u}) & (PAHS^{c})
21. Pahsimeroi to East Fork	IDFG	EF Salmon, Salmon R, Pah-EF (EFNA^{u})
22. East Fork upstream	IDFG	Upper Salmon, Salmon R, EF-Saw (USAL^{u}) & (SAWT/USAL/DWOR^{c})

Movement probabilities below LGR are directly estimated from PIT tag conversion rates, which incorporate loses to the fishery. Therefore, fish are moved before the fishery downstream of LGR.

Hatchery and wild stocks from the Lower Snake (downstream of LGR) and Tucannon are known to overshoot their original release location (Bumgarner and Dedloff 2015) and cross LGR, where most (75%-85%) will remain upstream of the dam. We used PIT tag detections at ICH, the Lower Tucannon River, and LGR to estimate movement probabilities of wild Tucannon fish, Tucannon endemic stock ($TUCA^{c,u}$) hatchery fish, and clipped Lower Snake River ($WALL^{c}$) stock hatchery releases moving from ICH to the Tucannon River or falling back over LGR into the Tucannon River. Fallback probabilities were applied to fish within the Lower Granite pool only. Fallbacks from the Lower Granite pool are removed after fishery losses are subtracted and routed to their final destination (Tucannon River). They are not eligible to be harvested downstream of LGR. Figure 4 illustrates dataflow below LGR.

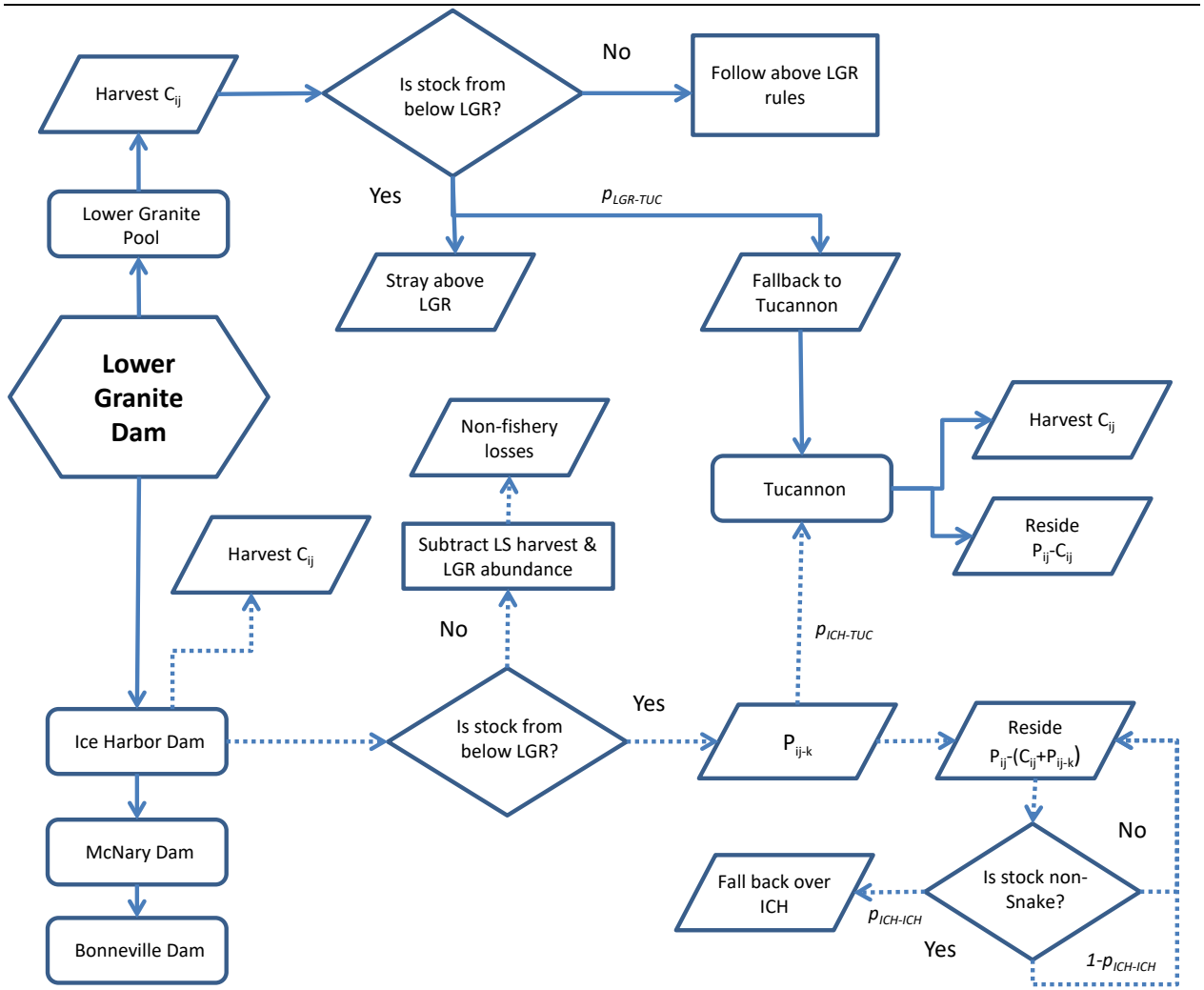

Figure 4. Flowchart for projection of Lower Granite Dam abundance back to Bonneville Dam and movement of Lower Snake stocks between Ice Harbor Dam and Lower Granite pool.

Hatchery stocks not resident to the Clearwater River will enter the Lower Clearwater River (reach 5) and comprise a significant proportion of the harvest (Stiefel et al. 2013). Likewise, hatchery fish released upstream of the Orofino Bridge (reach 7) will enter the NF Clearwater River (reach 6). We estimated a 'dip-in' rate (p_{dip}) for the Lower Clearwater and NF Clearwater rivers based on PBT analysis of tissues collected during fisheries surveys (Alex LeCheminant, IDFG, unpublished data). For each MPG (e.g., Lower Snake, Salmon River):

$$p_{idip} = {H_{ir}}/{(N_{r-1} * h_i)} \tag{6}$$

where H_{ir} = harvest of stock *i* in the Lower Clearwater or the NF Clearwater rivers,
N_{r-1} = abundance of stock *i* in the reach downstream,
r =5 for Lower Clearwater and 6 for NF Clearwater,
h = harvest rate of the resident stock (all Clearwater in r=5 or NF Clearwater in r=6).

Estimated rates for Hells Canyon (170%) and the Imnaha River (107%) hatchery fish in spawn year 2020 exceeded what would be possible under the model, and the annual average rate of 30% was substituted for these values.

Harvest rate is computed for the grouped upstream stocks based on the assumptions that all upstream fish move with probability 1.0 and that all stocks are harvested in proportion to their abundance. After calculating H_{ir}, surviving fish not bound for the reach in question fall back from the 'dip-in' reach and continue their movement upstream. Figure 5 illustrates dataflow for reaches upstream of LGR, including dip-in steps.

Output of the run reconstruction model is summarized into abundance at important locations and fishery impacts. Abundance is estimated at BON, ICH, LGR, and natal river reaches (except for Lower Snake stocks). Losses between BON and ICH include all mortality sources, but losses upstream of ICH include only fishery-related mortality. Therefore, abundance estimates are only reported at BON, ICH, and LGR. Fates of fish removed at weirs are reported in Table A1. Outputs are tabulated only for Snake River stocks; however, in the text we report mortality within the study area of non-Snake River stocks that were detected at LGR.

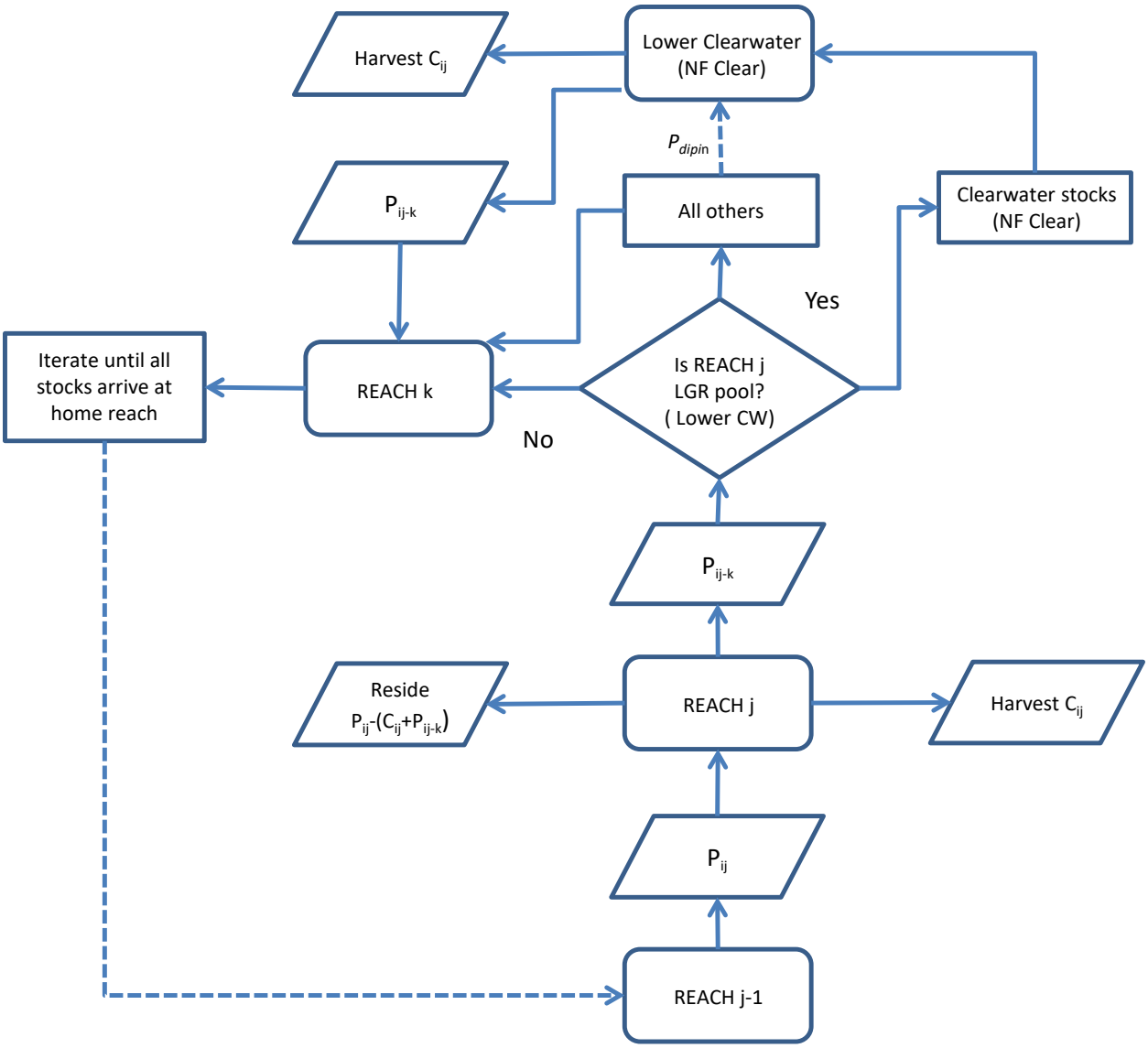

Figure 5. Flowchart for movement and fates of steelhead upstream of Lower Granite Dam. Abbreviations are explained in the text. Dip-in decisions are for non-Clearwater stocks in Lower Granite pool or for upper Clearwater/South Fork Clearwater stocks in the Lower Clearwater (in parentheses).

RESULTS

Abundance at Lower Granite Dam

The preliminary (unadjusted) abundance estimates at LGR for the 2019-2020 steelhead run were 9,634 wild fish, 2,323 unclipped hatchery fish, and 22,453 clipped hatchery fish. After incorporating night passage (8.38%) and re-ascensions (34.00% for Lower Snake stocks and 2.04% for all others), the adjusted estimates were 9,771 wild fish, 2,449 unclipped hatchery fish, and 23,646 clipped hatchery fish (Tables A2 and A3). Of the 28-hatchery release site-stock groups present at LGR, four groups were from locations outside of the Snake basin (two from the Touchet River, one from the Walla Walla River, and one from the Methow River; Table A3).

Conversion Rates and Estimated Abundance at Downriver Dams

We detected 201 PIT-tagged wild steelhead and 602 PIT-tagged hatchery steelhead from the Snake River basin at BON. Conversion rates from BON to ICH averaged 76.4% (67.4%–83.9%; Table 3). For stocks originating upstream of LGR, average conversion rates from ICH to LGR were similar (98.6% for wild and 98.7% for hatchery steelhead; Table 3).

Table 3. Adult steelhead conversion rates between selected dams in the Columbia and lower Snake rivers during 2019-2020. The number of fish detected at Bonneville Dam that were subsequently detected upriver are in the numerator. Only fish detected at Bonneville and Ice Harbor dams are in the denominator.

Stock	N at BON	Detect at ICH	BON to ICH rate	N at ICH	Detect at LGR	ICH to LGR rate
Lower Snake hatchery	98	76	77.6%	76	44	NA
Gr Ronde hatchery	135	91	67.4%	89	87	97.8%
Imnaha hatchery	73	56	76.7%	55	54	98.2%
Clearwater hatchery	73	59	80.8%	58	58	100.0%
Hells Canyon hatchery	43	31	72.1%	30	30	100.0%
Salmon hatchery	180	144	80.0%	141	139	98.6%
Total hatchery	**602**	**457**		**449**	**412**	
Lower Snake wild	22	16	72.7%	15	9	NA
Asotin wild	35	25	71.4%	25	25	100.0%
Gr Ronde wild	28	22	78.6%	21	20	95.2%
Imnaha wild	40	31	77.5%	30	29	96.7%
Clearwater wild	45	35	77.8%	36	36	100.0%
Salmon wild	31	26	83.9%	26	26	100.0%
Total wild	**201**	**155**		**153**	**145**	

We estimated that 14,419 wild, 3,027 hatchery unclipped, and 31,359 hatchery clipped steelhead from the Snake River basin passed BON based on PIT tag conversion rates. Of those, 11,274 wild, 2,454 unclipped hatchery, and 23,973 clipped hatchery steelhead entered the Snake River and passed ICH (Table 4).

Table 4. Adult steelhead abundance by hatchery stock or MPG at Ice Harbor Dam (ICH) and estimated fishery impact rate (in parentheses) during 2019-2020.

Hatchery stock or MPG	Hatchery clipped	Hatchery unclipped	Wild
Lower Snake	659 (0.1%)	50 (0.0%)	2,783 (0.6%)
Grande Ronde	6,356 (32.3%)	63 (4.8%)	3,664 (3.9%)
Imnaha	1,119 (18.9%)	5 (0.0%)	784 (4.5%)
Clearwater	5,064 (41.9%)	1,512 (8.9%)	1,380 (5.4%)
Hells Canyon	1,545 (41.0%)	0 (0.0%)	NA
Salmon	9,230 (41.4%)	824 (7.2%)	2,663 (4.5%)
Total	**23,973 (36.9%)**	**2,454 (8.0%)**	**11,274 (3.5%)**

Steelhead Movements

Steelhead exhibit diverse movement patterns within the Snake River basin while being subjected to fishery impacts in the form of harvest or catch and release mortality. This run reconstruction model incorporates known stock movements in the form of estimated movement probabilities to successive river sections when they are available. For example, Lower Snake River stocks residing downstream from LGR tend to overshoot their natal reach and pass upstream of LGR. Estimated movement probabilities of stocks originating below LGR are summarized in Table 5.

Table 5. Movement probabilities determined from PIT tag detections of Lower Snake and Walla Walla basin wild and hatchery steelhead within the Ice Harbor Dam (ICH) to Lower Granite Dam (LGR) reach during return year 2019-2020 (Todd Miller, personal communication). Hatchery stocks are listed by release site with stock abbreviation in parentheses (see Table 1). Unclipped hatchery releases are denoted by ^{u} and clipped releases by ^{c}.

	Movement type					
	ICH Pool			LGR Pool		
Wild population/ hatchery stock	**Pass ICH, fallback below ICH**	**Enter TUC**	**Die/ reside**	**Ascend LGR**	**Pass LGR, fallback to Tucannon**	**Pass LGR, fallback below LGR**
Lower Snake basin						
Snake River (WALL^{c})	0.000	0.125	0.333	0.542	0.000	0.077
Tucannon (TUCA^{c})*	0.000	0.188	0.188	0.625	0.000	0.100
Tucannon (TUCA^{u})	0.000	0.188	0.188	0.625	0.100	0.100
Tucannon wild	0.000	0.300	0.300	0.400	0.000	0.000
Walla Walla basin						
Walla Walla (WALL^{c})	0.500	0.000	0.500	0.500	0.000	1.000
Touchet (WALL^{c})	0.154	0.077	0.231	0.692	0.000	0.222
Touchet (TOUC^{u})	0.105	0.105	0.421	0.474	0.222	0.222

Mid-Columbia River hatchery steelhead also overshot their release areas and ascended LGR. Three stocks of hatchery steelhead released in the Walla Walla River basin were sampled at LGR in return year 2019-2020; unclipped Touchet endemic stock (TOUC^{u}) released at Wolf Fork Bridge, clipped Touchet stock (WALL^{c}) fish release at Dayton AP, and clipped Walla Walla River (WALL^{c}) fish released at McDonald Road Bridge. PIT tags from these three mid-Columbia stocks released in the Walla Walla were detected at both ICH and LGR, and therefore their movement probabilities were estimable and summarized in Table 5. In addition, one stock of hatchery steelhead released into the Methow River basin was sampled at LGR.

Many non-Clearwater steelhead stocks are attracted into the lower Clearwater River in late summer and early fall by cold water discharges from Dworshak Dam on the lower NF Clearwater River. The dip-in rates of non-Clearwater River steelhead stocks (p_{dip}) into the Lower Clearwater River are summarized in Table 6. Note that creel survey harvest estimates were used to calculate dip-in rates (Table 6) in the lower Clearwater River (reach 5), whereas total estimated recreational harvest in the Idaho portion of the fishery (Tables 7-9) was developed from mail surveys. Therefore, harvest estimates reported in Table 6 and Tables 7-9 differ because they were generated using different methods.

Table 6. Computation of dip-in rates of clipped non-Clearwater hatchery stocks into the Lower Clearwater River (reach 5) in return year 2019-2020. Hatchery stocks were grouped by region, and harvest was determined from PBT recoveries in the fishery (Alex LeCheminant, IDFG, unpublished data).

Hatchery stock	Creel harvest	LGR pool abundance	Dip-in rate
Lower Snake	0	421	0.0%
Grande Ronde	26	5,958	14.0%
Salmon	25	8,740	9.2%
Imnaha	35	1,054	30.0%
Hells Canyon	78	1,482	30.0%
Clearwater	150	4,858	NA

We were unable to estimate the dip-in rate for clipped hatchery fish that were released upstream of the NF Clearwater River and used the average across the previous four spawn years (28.8%). This average is nearly five times greater than the mean rate observed during spawn years 2013-2015 (6.0%). It is not clear why a greater proportion of upriver stocks dipped into the NF Clearwater in spawn years 2016-2019. Mainstem Clearwater River temperatures, upstream of the NF Clearwater, were not exceedingly warm like in the late summer/fall of 2015, as previously suggested as a contributing factor.

Movement probabilities between fishery reaches used in the run reconstruction model are reported by hatchery release group or wild population in Table A4.

Steelhead Fishery Impacts

Snake River basin steelhead are subjected to fishery impacts from harvest and catch and release mortality. Overall impact rates were estimated to be 36.9% for hatchery clipped, 8.0% for hatchery unclipped, and 3.5% for wild steelhead above ICH (Table 4). Total fishery-related mortality of clipped hatchery fish within the study area was 8,864 steelhead (Table 7). This number includes direct harvest as well as incidental mortality from catch-and-release handling. Incidental take of unclipped steelhead was estimated at 587 fish, which includes 197 unclipped hatchery fish (Table 8) and 390 wild fish (Table 9). The largest harvests of clipped hatchery fish were in the Upper Snake River (reach 4) and the North Fork Clearwater River (reach 6; Table 7). The largest fishery mortality estimates of unclipped fish were in the Upper Snake River (reach 4) and the Lower Clearwater River (reach 5; Tables 8 and 9).

Table 7. Estimated fishery mortalities of clipped hatchery steelhead due to both harvest and catch and release handling by river reach and hatchery stock in 2019-2020.

	Hatchery stock						
River and Reach	**Lower Snake**	**Grande Ronde**	**Imnaha**	**Hells Canyon**	**Clearwater**	**Salmon**	**Out-of-basin**
1. Lower Snake	3	26	4	6	20	37	0
2. Tucannon	14	0	0	0	0	0	7
3. Lower Granite Pool	1	22	4	5	16	30	1
4. Upper Snake	0	620	108	152	0	911	0
5. Lower Clearwater	0	55	21	30	322	54	0
6. North Fork Clearwater	0	0	0	0	1,286	0	0
7. NF Clearwater to Clear Creek	0	0	0	0	157	0	0
8. South Fork Clearwater	0	0	0	0	321	0	0
9. Lower Grande Ronde	0	675	0	0	0	0	0
10. Wallowa River	0	655	0	0	0	0	0
11. Upper Grande Ronde	0	0	0	0	0	0	0
12. Salmon mouth to White Bird	0	0	0	0	0	591	0
13. Salmon (WB-Little Salmon)	0	0	0	0	0	467	0
14. Little Salmon	0	0	0	0	0	249	0
15. Salmon (LS to Vinegar)	0	0	0	0	0	319	0
16. Salmon (Vinegar to SF)	0	0	0	0	0	108	0
17. Salmon (SF to MF)	0	0	0	0	0	125	0
18. Salmon (MF to NF)	0	0	0	0	0	256	0
19. Salmon (NF to Lemhi)	0	0	0	0	0	90	0
20. Salmon (Lemhi to Pahsimeroi)	0	0	0	0	0	78	0
21. Salmon (Pahsimeroi to EF)	0	0	0	0	0	31	0
22. Salmon (EF upstream)	0	0	0	0	0	472	0
23. Imnaha	0	0	74	0	0	0	0
24. Hells Canyon	0	0	0	441	0	0	0
Total	**18**	**2,053**	**211**	**634**	**2,122**	**3,818**	**8**

Table 8. Estimated fishery impacts to unclipped hatchery steelhead by river reach and hatchery stock in 2019-2020.

	Hatchery stock				
River and Reach	**Lower Snake**	**Grande Ronde**	**Imnaha**	**Clearwater**	**Salmon**
1. Lower Snake	0	0	0	2	0
2. Tucannon	0	0	0	0	0
3. Lower Granite Pool	0	0	0	6	3
4. Upper Snake	0	1	0	0	11
5. Lower Clearwater	0	0	0	34	1
6. North Fork Clearwater	0	0	0	18	0
7. NF Clearwater to Clear Creek	0	0	0	23	0
8. South Fork Clearwater	0	0	0	52	0
9. Lower Grande Ronde	0	1	0	0	0
10. Wallowa River	0	1	0	0	0
11. Upper Grande Ronde	0	0	0	0	0
12. Salmon mouth to White Bird	0	0	0	0	4
13. Salmon (WB-Little Salmon)	0	0	0	0	4
14. Little Salmon	0	0	0	0	0
15. Salmon (LS to Vinegar)	0	0	0	0	3
16. Salmon (Vinegar to SF)	0	0	0	0	1
17. Salmon (SF to MF)	0	0	0	0	1
18. Salmon (MF to NF)	0	0	0	0	5
19. Salmon (NF to Lemhi)	0	0	0	0	1
20. Salmon (Lemhi to Pahsimeroi)	0	0	0	0	3
21. Salmon (Pahsimeroi to EF)	0	0	0	0	0
22. Salmon (EF upstream)	0	0	0	0	5
23. Imnaha	0	0	0	0	0
24. Hells Canyon	0	0	0	0	17
Total	**0**	**3**	**0**	**135**	**59**

Table 9. Estimated wild steelhead fishery impacts by river reach and major population group (MPG) in 2019-2020.

	MPG				
River and Reach	**Lower Snake**	**Grande Ronde**	**Imnaha**	**Clearwater**	**Salmon**
1. Lower Snake	3	4	1	0	0
2. Tucannon	4	0	0	0	0
3. Lower Granite Pool	5	11	2	4	8
4. Upper Snake	6	42	9	0	33
5. Lower Clearwater	0	10	5	32	4
6. North Fork Clearwater	0	0	0	8	0
7. NF Clearwater to Clear Creek	0	0	0	17	0
8. South Fork Clearwater	0	0	0	13	0
9. Lower Grande Ronde	0	62	0	0	0
10. Wallowa River	0	13	0	0	0
11. Upper Grande Ronde	0	0	0	0	0
12. Salmon mouth to White Bird	0	0	0	0	20
13. Salmon (WB-Little Salmon)	0	0	0	0	14
14. Little Salmon	0	0	0	0	4
15. Salmon (LS to Vinegar)	0	0	0	0	6
16. Salmon (Vinegar to SF)	0	0	0	0	2
17. Salmon (SF to MF)	0	0	0	0	5
18. Salmon (MF to NF)	0	0	0	0	9
19. Salmon (NF to Lemhi)	0	0	0	0	1
20. Salmon (Lemhi to Pahsimeroi)	0	0	0	0	2
21. Salmon (Pahsimeroi to EF)	0	0	0	0	2
22. Salmon (EF upstream)	0	0	0	0	11
23. Imnaha	0	0	18	0	0
24. Hells Canyon	0	0	0	0	0
Total	**18**	**142**	**35**	**74**	**121**

Finally, 7,069 clipped hatchery fish, 426 unclipped hatchery fish, and 158 wild fish were collected for broodstock or donated to food banks (only hatchery fish; Table A1).

DISCUSSION

This run reconstruction is our tenth spawn year of synthesizing abundance and fishery impacts on wild populations and hatchery stocks within the Snake River basin. We estimated the fishery-related impacts on steelhead as they move to their natal or smolt release areas. In doing so, we summarized effects on natural populations and highlighted the benefits of hatchery programs.

Lower Snake stocks, which originate downstream of LGR, have exhibited much higher fallback and re-ascension rates than steelhead stocks originating upstream of LGR. From spawn

year 2012-2020 the average fallback and re-ascension rates for stocks originating below LGR were approximately 13-fold higher than for stocks originating above LGR. In spawn year 2020 Lower Snake steelhead exhibited an average fallback and re-ascension rate of 34%, which was higher than the average (26.1%) observed during spawn years 2012-2020 (12.7%-36.0%). Fallback and re-ascension for Snake River basin steelhead stocks originating upstream of LGR was estimated at 2.4% in SY20, which was lower than the average rate (4.5%) observed in spawn years 2012-2020 (0.7-20.6%). We would have overestimated the aggregate steelhead abundance at LGR by 4% if fallback and re-ascension rates were not applied.

Parentage based tagging assignments to release location allow us to detect the presence of small groups of unclipped hatchery fish in the Snake River basin. For example, small numbers of mis-clipped hatchery steelhead intended for fishery mitigation releases are identified in the unclipped hatchery steelhead sample along with fish from releases intended to supplement natural spawning in wild populations in the Snake River basin. The estimated sizes of these groups are imprecise because they are based upon only a few fish at LGR. These small groups were reported, but caution should be exercised when basing management decisions on these estimates due to their lack of precision.

SUMMARY

We have developed a tool for comparative use by steelhead managers in the Snake River basin. This work provides a useful framework for synthesizing data collected by fisheries managers that allows inferences regarding abundance, disposition, and fishery impacts. It is important to recognize the limitations of the data that go into the model when trying to interpret results. Nonetheless, this information is being used by managers in the basin to assess fishery impacts, the LSRCP to evaluate mitigation goals, and NOAA Fisheries to evaluate the performance of the Snake River steelhead ESU relative to ESA delisting criteria. The run reconstruction process provides an arena for critical review of the data used by managers in the basin. The model bridges gaps in the existing data using reasonable assumptions in a structured manner. However, higher precision estimates and greater population resolution remain goals of this effort.

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APPENDIX A: DATA USED TO PARAMETERIZE THE 2019-2020 STEELHEAD RUN RECONSTRUCTION MODEL.

Table A1. Hatchery trap and weirs adult steelhead retention summary by origin for return year 2019-2020.

Hatchery trap or weir	Hatchery clipped	Hatchery unclipped	Wild
Lyons Ferry FH	73	6	0
Tucannon FH	1	13	23
Penawawa Cr	11	0	0
Alpowa Cr	9	0	24
George Cr	0	0	24
Asotin Cr	7	0	37
Tenmile Cr	2	1	20
Dworshak FH	1,158	13	0
Kooskia FH	2	0	0
South Fork Clearwater angler caught	206	120	0
Cottonwood Cr acclimation pond	883	0	1
Big Canyon	387	0	0
Wallowa FH	806	0	0
Lookingglass FH	1	0	0
Little Sheep Cr	290	0	2
Oxbow FH	613	0	0
Pahsimeroi FH	1,614	244	0
East Fork Salmon River	0	29	27
Sawtooth FH	1,006	0	0
Total	**7,069**	**426**	**158**

Table A2. Estimated abundance of wild steelhead populations at Lower Granite Dam in return year 2019-2020.

Wild population	MPG	Abundance
Tucannon River	Lower Snake	868
Asotin Creek	Lower Snake	613
Lower Grande Ronde	Grande Ronde	570
Joseph Creek	Grande Ronde	415
Wallowa River	Grande Ronde	1,136
Upper Grande Ronde	Grande Ronde	1,368
Imnaha River	Imnaha	758
Lower Clearwater	Clearwater	506
Lolo Creek	Clearwater	80
South Fork Clearwater	Clearwater	408
Lochsa River	Clearwater	142
Selway River	Clearwater	244
Little Salmon River	Salmon	186
South Fork Salmon	Salmon	74
Secesh River	Salmon	31
Chamberlain Creek	Salmon	71
Lower Middle Fork	Salmon	199
Upper Middle Fork	Salmon	212
Panther Creek	Salmon	138
North Fork Salmon	Salmon	79
Lemhi River	Salmon	443
Pahsimeroi River	Salmon	367
East Fork Salmon	Salmon	391
Upper Salmon	Salmon	472
Total		**9,771**

Table A3. Estimated abundance of steelhead hatchery stocks by release site at Lower Granite Dam in return year 2019-2020. Unclipped, mis-clipped, and clipped hatchery fish have ^{u}, ^{m}, and ^{c} superscripts, respectively.

Hatchery release site (stock)	Group (HUC4)	Abundance
Snake R, Lyons Ferry FH (WALL^{m})	Lower Snake	5
Snake R, Lyons Ferry FH (WALL^{c})	Lower Snake	288
Tucannon R (TUCA^{u})	Lower Snake	24
Tucannon R (TUCA^{c})	Lower Snake	96
Snake R (OXBO^{c})	Hells Canyon	1,545
NF Clearwater R (DWOR^{m})	Clearwater	236
NF Clearwater R (DWOR^{c})	Clearwater	3,056
Clear Creek (DWOR^{c})	Clearwater	669
SF Clearwater R (DWOR/SFCW^{u})	Clearwater	1,212
SF Clearwater R (DWOR/SFCW^{m})	Clearwater	64
SF Clearwater R (DWOR/SFCW^{c})	Clearwater	1,339
Grande Ronde R (GRCW^{m})	Grande Ronde	19
Grande Ronde R (GRCW^{c})	Grande Ronde	1,817
Wallowa R (WALL^{m})	Grande Ronde	43
Wallowa R (WALL^{c})	Grande Ronde	4,396
Imnaha R (IMNA^{m})	Imnaha	5
Imnaha R (IMNA^{c})	Imnaha	1,099
Little Salmon R (PAHS^{m})	Salmon	14
Little Salmon R (PAHS/USAL/DWOR/OXBO^{c})	Salmon	2,217
Salmon R, Lem-Pah (DWOR/USAL^{u})	Salmon	354
Salmon R, Lem-Pah (PAHS^{m})	Salmon	15
Salmon R, Lem-Pah (PAHS^{c})	Salmon	3,003
Salmon R, Pah-EF (EFNA^{u})	Salmon	221
Salmon R, EF-Saw (DWOR/USAL^{u})	Salmon	184
Salmon R, EF-Saw (SAWT^{m})	Salmon	25
Salmon R, EF-Saw (SAWT/USAL/DWOR^{c})	Salmon	3,879
Snake River basin unclipped hatchery steelhead		**2,454**
Snake River basin Clipped hatchery steelhead		**23,973**
Total Snake River basin hatchery Steelhead		**26,427**

Table A4. Movement matrix used in the run reconstruction model for return year 2019-2020.

Movement Path	Asotin Creek	Tucannon River	Lower Grande Ronde	Upper Grande Ronde	Wallowa River	Joseph Creek	Imnaha River	Lower Clearwater	Lolo Creek	South Fork Clearwater	Lochsa River	Selway River	Little Salmon River
3→1	-	-	-	-	-	-	-	-	-	-	-	-	-
3→2	-	-	-	-	-	-	-	-	-	-	-	-	-
3→5	-	-	0.1402	0.1402	0.1402	0.1402	0.2997	1	1	1	1	1	0.0916
3→4	0.8456	-	0.8598	0.8598	0.8598	0.8598	0.7003	-	-	-	-	-	0.9084
4→3	-	-	-	-	-	-	-	-	-	-	-	-	-
4→9	-	-	1	1	1	1	-	-	-	-	-	-	-
4→12	-	-	-	-	-	-	-	-	-	-	-	-	1
4→23	-	-	-	-	-	-	1	-	-	-	-	-	-
4→24	-	-	-	-	-	-	-	-	-	-	-	-	-
5→(3 or 4)	1	1	1	1	1	1	1	-	-	-	-	-	1
5→6	-	-	-	-	-	-	-	-	0.2884	0.2884	0.2884	0.2884	-
5→7	-	-	-	-	-	-	-	-	0.7116	0.7116	0.7116	0.7116	-
6→7	-	-	-	-	-	-	-	-	1	1	1	1	-
7→8	-	-	-	-	-	-	-	-	-	0.7529	-	-	-
9→10	-	-	-	-	1	-	-	-	-	-	-	-	-
9→11	-	-	-	1	-	-	-	-	-	-	-	-	-
12→13	-	-	-	-	-	-	-	-	-	-	-	-	0.7986
13→14	-	-	-	-	-	-	-	-	-	-	-	-	0.7396
14→15	-	-	-	-	-	-	-	-	-	-	-	-	-
15→16	-	-	-	-	-	-	-	-	-	-	-	-	-
16→17	-	-	-	-	-	-	-	-	-	-	-	-	-
17→18	-	-	-	-	-	-	-	-	-	-	-	-	-
18→19	-	-	-	-	-	-	-	-	-	-	-	-	-
19→20	-	-	-	-	-	-	-	-	-	-	-	-	-
20→21	-	-	-	-	-	-	-	-	-	-	-	-	-
21→22	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A4. Continued

Movement Path	South Fork Salmon	Secesh River	Chamberlain Creek	Lower Middle Fork	Upper Middle Fork	Panther Creek	North Fork Salmon	Lemhi River	Pahsimeroi River	East Fork Salmon	Upper Salmon	Touchet (TOUC[u])
3→1	-	-	-	-	-	-	-	-	-	-	-	0.2222
3→2	-	-	-	-	-	-	-	-	-	-	-	0.2222
3→5	0.0916	0.0916	0.0916	0.0916	0.0916	0.0916	0.0916	0.0916	0.0916	0.0916	0.0916	-
3→4	0.9084	0.9084	0.9084	0.9084	0.9084	0.9084	0.9084	0.9084	0.9084	0.9084	0.9084	-
4→3	-	-	-	-	-	-	-	-	-	-	-	-
4→9	-	-	-	-	-	-	-	-	-	-	-	-
4→12	1	1	1	1	1	1	1	1	1	1	1	-
4→23	-	-	-	-	-	-	-	-	-	-	-	-
4→24	-	-	-	-	-	-	-	-	-	-	-	-
5→(3 or 4)	1	1	1	1	1	1	1	1	1	1	1	1
5→6	-	-	-	-	-	-	-	-	-	-	-	-
5→7	-	-	-	-	-	-	-	-	-	-	-	-
6→7	-	-	-	-	-	-	-	-	-	-	-	-
7→8	-	-	-	-	-	-	-	-	-	-	-	-
9→10	-	-	-	-	-	-	-	-	-	-	-	-
9→11	-	-	-	-	-	-	-	-	-	-	-	-
12→13	1	1	1	1	1	1	1	1	1	1	1	-
13→14	-	-	-	-	-	-	-	-	-	-	-	-
14→15	1	1	1	1	1	1	1	1	1	1	1	-
15→16	1	1	1	1	1	1	1	1	1	1	1	-
16→17	-	-	0.6915	1	1	1	1	1	1	1	1	-
17→18	-	-	-	-	-	0.8790	1	1	1	1	1	-
18→19	-	-	-	-	-	-	-	1	1	1	1	-
19→20	-	-	-	-	-	-	-	-	1	1	1	-
20→21	-	-	-	-	-	-	-	-	-	1	1	-
21→22	-	-	-	-	-	-	-	-	-	-	1	-

Table A4. Continued

Movement Path	Touchet (WALL[c])	Walla Walla R (WALL[c])	Methow R (WELL)	Snake R, Lyons Ferry FH (WALL[m])	Snake R, Lyons Ferry FH (WALL[c])	Tucannon R (TUCA[u])	Tucannon R (TUCA[c])	Snake R (OXBO[c])	NF Clearwater R (DWOR[m])	NF Clearwater R (DWOR[c])	Clear Creek (DWOR[c])	SF Clearwater R (DWOR/SFCW[u])	SF Clearwater R (DWOR/SFCW[m])
3→1	-	-	-	-	-	0.1000	0.1000	-	-	-	-	-	-
3→2	0.2222	1	-	0.0769	0.0769	0.1000	0.1000	-	-	-	-	-	-
3→5	-	-	-	-	-	-	-	0.2997	1	1	1	1	1
3→4	-	-	-	-	-	-	-	0.7003	-	-	-	-	-
4→3	-	-	-	-	-	-	-	-	-	-	-	-	-
4→9	-	-	-	-	-	-	-	-	-	-	-	-	-
4→12	-	-	-	-	-	-	-	-	-	-	-	-	-
4→23	-	-	-	-	-	-	-	-	-	-	-	-	-
4→24	-	-	-	-	-	-	-	1	-	-	-	-	-
5→(3 or 4)	1	-	-	1	1	1	1	1	-	-	-	-	-
5→6	-	-	-	-	-	-	-	-	1	1	0.2884	0.2884	0.2884
5→7	-	-	-	-	-	-	-	-	-	-	0.7116	0.7116	0.7116
6→7	-	-	-	-	-	-	-	-	-	-	1	1	1
7→8	-	-	-	-	-	-	-	-	-	-	-	1	1
9→10	-	-	-	-	-	-	-	-	-	-	-	-	-
9→11	-	-	-	-	-	-	-	-	-	-	-	-	-
12→13	-	-	-	-	-	-	-	-	-	-	-	-	-
13→14	-	-	-	-	-	-	-	-	-	-	-	-	-
14→15	-	-	-	-	-	-	-	-	-	-	-	-	-
15→16	-	-	-	-	-	-	-	-	-	-	-	-	-
16→17	-	-	-	-	-	-	-	-	-	-	-	-	-
17→18	-	-	-	-	-	-	-	-	-	-	-	-	-
18→19	-	-	-	-	-	-	-	-	-	-	-	-	-
19→20	-	-	-	-	-	-	-	-	-	-	-	-	-
20→21	-	-	-	-	-	-	-	-	-	-	-	-	-
21→22	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A4. Continued

Movement Path	SF Clearwater R (DWOR/SFCW[c])	Grande Ronde R (GRCW[m])	Grande Ronde R (GRCW[c])	Wallowa R (WALL[m])	Wallowa R (WALL[c])	Imnaha R (IMNA[m])	Imnaha R (IMNA[c])	Little Salmon R (PAHS[m])	Little Salmon R (PAHS/USAL/DWOR/OXBO[c])	Salmon R, Lem-Pah (USAL/DWOR[u])	Salmon R, Lem-Pah (PAHS[m])	Salmon R, Lem-Pah (PAHS[c])
3→1	-	-	-	-	-	-	-	-	-	-	-	-
3→2	-	-	-	-	-	-	-	-	-	-	-	-
3→5	1	0.1402	0.1402	0.1402	0.1402	0.2997	0.2997	0.0916	0.0916	0.0916	0.0916	0.0916
3→4	-	0.8598	0.8598	0.8598	0.8598	0.7003	0.7003	0.9084	0.9084	0.9084	0.9084	0.9084
4→3	-	-	-	-	-	-	-	-	-	-	-	-
4→9	-	1	1	1	1	-	-	-	-	-	-	-
4→12	-	-	-	-	-	-	-	1	1	1	1	1
4→23	-	-	-	-	-	1	1	-	-	-	-	-
4→24	-	-	-	-	-	-	-	-	-	-	-	-
5→(3 or 4)	-	1	1	1	1	1	1	1	1	1	1	1
5→6	0.2884	-	-	-	-	-	-	-	-	-	-	-
5→7	0.7116	-	-	-	-	-	-	-	-	-	-	-
6→7	1	-	-	-	-	-	-	-	-	-	-	-
7→8	1	-	-	-	-	-	-	-	-	-	-	-
9→10	-	-	-	1	1	-	-	-	-	-	-	-
9→11	-	-	-	-	-	-	-	-	-	-	-	-
12→13	-	-	-	-	-	-	-	1	1	1	1	1
13→14	-	-	-	-	-	-	-	1	1	-	-	-
14→15	-	-	-	-	-	-	-	-	-	1	1	1
15→16	-	-	-	-	-	-	-	-	-	1	1	1
16→17	-	-	-	-	-	-	-	-	-	1	1	1
17→18	-	-	-	-	-	-	-	-	-	1	1	1
18→19	-	-	-	-	-	-	-	-	-	1	1	1
19→20	-	-	-	-	-	-	-	-	-	1	1	1
20→21	-	-	-	-	-	-	-	-	-	-	-	-
21→22	-	-	-	-	-	-	-	-	-	-	-	-

Table A4. Concluded

Movement Path	Salmon R, Pah-EF (EFNA[b])	Salmon R, EF-Saw (DWOR/USAL[b])	Salmon R, EF-Saw (SAWT[m])	Salmon R, EF-Saw (SAWT/USAL/DWOR[c])
3→1	-	-	-	-
3→2	-	-	-	-
3→5	0.0916	0.0916	0.0916	0.0916
3→4	0.9084	0.9084	0.9084	0.9084
4→3	-	-	-	-
4→9	-	-	-	-
4→12	1	1	1	1
4→23	-	-	-	-
4→24	-	-	-	-
5→(3 or 4)	1	1	1	1
5→6	-	-	-	-
5→7	-	-	-	-
6→7	-	-	-	-
7→8	-	-	-	-
9→10	-	-	-	-
9→11	-	-	-	-
12→13	1	1	1	1
13→14	-	-	-	-
14→15	1	1	1	1
15→16	1	1	1	1
16→17	1	1	1	1
17→18	1	1	1	1
18→19	1	1	1	1
19→20	1	1	1	1
20→21	1	1	1	1
21→22	-	1	1	1