SNAKE RIVER BASIN 2015-2016
STEELHEAD RUN RECONSTRUCTION

Photo by Carlos Camacho

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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 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 under the technical lead of Eric Stark. Order of the co-authors is alphabetical.

Suggested citation:

Stark, E. J., A. Byrne, P. J. Cleary, J. Ebel, T. Miller, D. Nemeth, S. Rosenberger, E. R. Sedell, and C. Warren. 2018. Snake River Basin 2015-2016 steelhead run reconstruction. Report to Bonneville Power Administration, Portland, Oregon.

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	4^{th} 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
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
SBT	Shoshone Bannock Tribes
SF	South Fork
TOUC	Touchet River
TRT	Technical Recovery Team
TUCA	Tucannon River
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. A run reconstruction model offers a systematic way to address information needs for management within the large and complex arena presented by Snake River steelhead. The purpose of this work is to summarize data describing the abundance of steelhead crossing Lower Granite Dam, the spatial distribution of spawning fish, and known fates/disposition. To achieve this, a group of representatives from the anadromous fishery management agencies within the Snake River basin was convened. The immediate objective was to estimate the disposition of the 2015-2016 return of steelhead within the Snake River basin. After adjusting for nighttime passage and fallback, we estimated 81,115 adipose-clipped hatchery fish, 5,099 unmarked hatchery fish, and 34,992 wild steelhead passed Lower Granite Dam (LGR) on the Snake River during spawn year 2016 (July 1, 2015 to June 30, 2016). Fishery-related mortality in the Snake River basin totaled 60,978 marked hatchery fish, 264 unmarked hatchery fish, and 1,225 wild steelhead. Further, 18,747 marked hatchery fish, 942 unmarked hatchery fish, and 92 wild fish were collected for broodstock or donated to food banks (only hatchery fish). Potential spawners remaining in the habitat totaled 30,903 clipped hatchery fish, 4,018 unclipped hatchery fish, and 34,868 wild steelhead. Snake River stocks experienced total losses of 18.2% between Bonneville Dam and Ice Harbor Dam, most presumably due to anthropogenic sources. Fishery-related losses across all Major Population Groups (MPGs) of wild steelhead within the Snake basin was 3.4%. Using the run reconstruction model, we attempted to quantify the fishery-related impacts on steelhead as they migrate to their natal or release area, and highlighted the benefits of hatchery programs. This work provides a useful framework for synthesizing data collected by fisheries managers that allows inferences regarding disposition and spatial distribution of spawning fish. The run reconstruction process is a good arena for critical review of the data that managers in the basin use. The model can be used to bridge gaps in the existing data using reasonable assumptions in a structured manner. The resulting output will help evaluate the performance of the Snake River steelhead evolutionarily significant unit (ESU) and hatchery programs towards management goals and Endangered Species Act delisting criteria.

INTRODUCTION

Steelhead trout *Oncorhynchus mykiss* 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) while hatchery programs support extensive fisheries as well as a few efforts to supplement wild production. Furthermore, hatchery supplementation programs for steelhead trout (hereafter steelhead), implemented under the 2018-2027 US vs. Oregon Management Agreement result in some unclipped hatchery releases. Therefore, steelhead management in the Snake River basin is complex and requires accurate abundance estimates to describe performance of hatchery stocks as well as impacts to the wild populations that co-exist with the hatchery programs.

Historically, the Snake River basin is believed to have supported more than half of the total 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. 2017). Currently, the progeny of 10 hatchery stocks are released within the basin and there are also 24 extant populations of wild steelhead, which are partitioned into six major groups (Table 1). All but three of these stocks return to areas upstream of Lower Granite Dam (LGR). Stocks returning downstream of LGR include one wild population and two hatchery stocks. 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. Additionally, most wild populations spawn during the spring run-off and thus there is little information on spawner abundance (Busby et al. 1996; ICBTRT 2003).

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). Run reconstruction models are capable of incorporating spatial and temporal complexity given sufficient data are available.

The purpose of this work is to summarize data describing the abundance of steelhead returning to the Snake River basin, the spatial distribution of spawning fish, and known fates/disposition. This information will help evaluate the performance of the Snake River steelhead evolutionarily significant unit (ESU) and associated hatchery programs while informing mitigation and management goals as well as ESA delisting criteria. To that end, a group of representatives from the anadromous fishery management agencies within the Snake River basin was convened, and a model framework was proposed and developed (Copeland et al. 2013, 2014, 2015; Stark et al. 2016, 2017). The objectives of this report were to estimate the disposition of the 2015-2016 return of steelhead within the Snake River basin and continue refinement of the run reconstruction model and it’s outputs. The long term goal of the workgroup is to produce a model suitable for providing management guidance to agencies in the Snake River basin. However, in the near-term, we caution that the results presented here are preliminary and should be interpreted with care.

Table 1. List of wild populations and hatchery stocks of steelhead in the Snake River basin during 2016 by major population group (MPG). Hatchery stocks are listed by MPG with their associated abbreviation, and unclipped hatchery releases are denoted by [u], clipped hatchery releases by [c].

Wild Populations	Hatchery Stocks
Lower Snake MPG	
Tucannon River	Lyons Ferry (LF[c]/WALL[c]) and Tucannon endemic (TUCA[c,u])
Asotin Creek	
Grande Ronde MPG	
Lower Grande Ronde	Wallowa (WALL[c])
Joseph Creek	
Wallowa River	Wallowa (WALL[c])
Upper Grande Ronde	
Imnaha MPG	
Imnaha River	Imnaha (IMNA[c])
Clearwater MPG	
Lower Mainstem Clearwater River	Dworshak (DWOR[c])
South Fork Clearwater River	Dworshak (DWOR[c,u]) & SF Clearwater (SFCW[c,u])
Lolo Creek	Dworshak (DWOR[u])
Selway River	
Lochsa River	
Salmon MPG	
Little Salmon River	Oxbow (OXBO[c]), Pahsimeroi (PAHS[c]), & Dworshak (DWOR[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]), Dworshak (DWOR[u]), Upper Salmon B (USAL[u])
East Fork Salmon River	East Fork natural (EFNA[u])
Upper Mainstem Salmon River	USAL[c], Sawtooth (SAWT[c,u]), & 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 historic range of steelhead in the Snake River extended to Shoshone Falls in southern Idaho (Figure 1). 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 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 Rriver rkm 16). Lower Granite Dam, the last dam steelhead may cross, is at rkm 173. Fish passage within main stem corridors is blocked at Dworshak Dam (rkm 3 on the North Fork Clearwater River) and at Hells Canyon Dam on the Snake River (rkm 397).

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

Steelhead populations are widely distributed within the Snake River basin (Figure 2). Approximately 97% of the currently accessible spawning habitat is located upstream of LGR (Tom Cooney, NOAA Fisheries, 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 fish 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. In order to bolster natural production as mandated by the 2018-2027 *United States v. Oregon* Management Agreement, some unclipped hatchery fish are released 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.

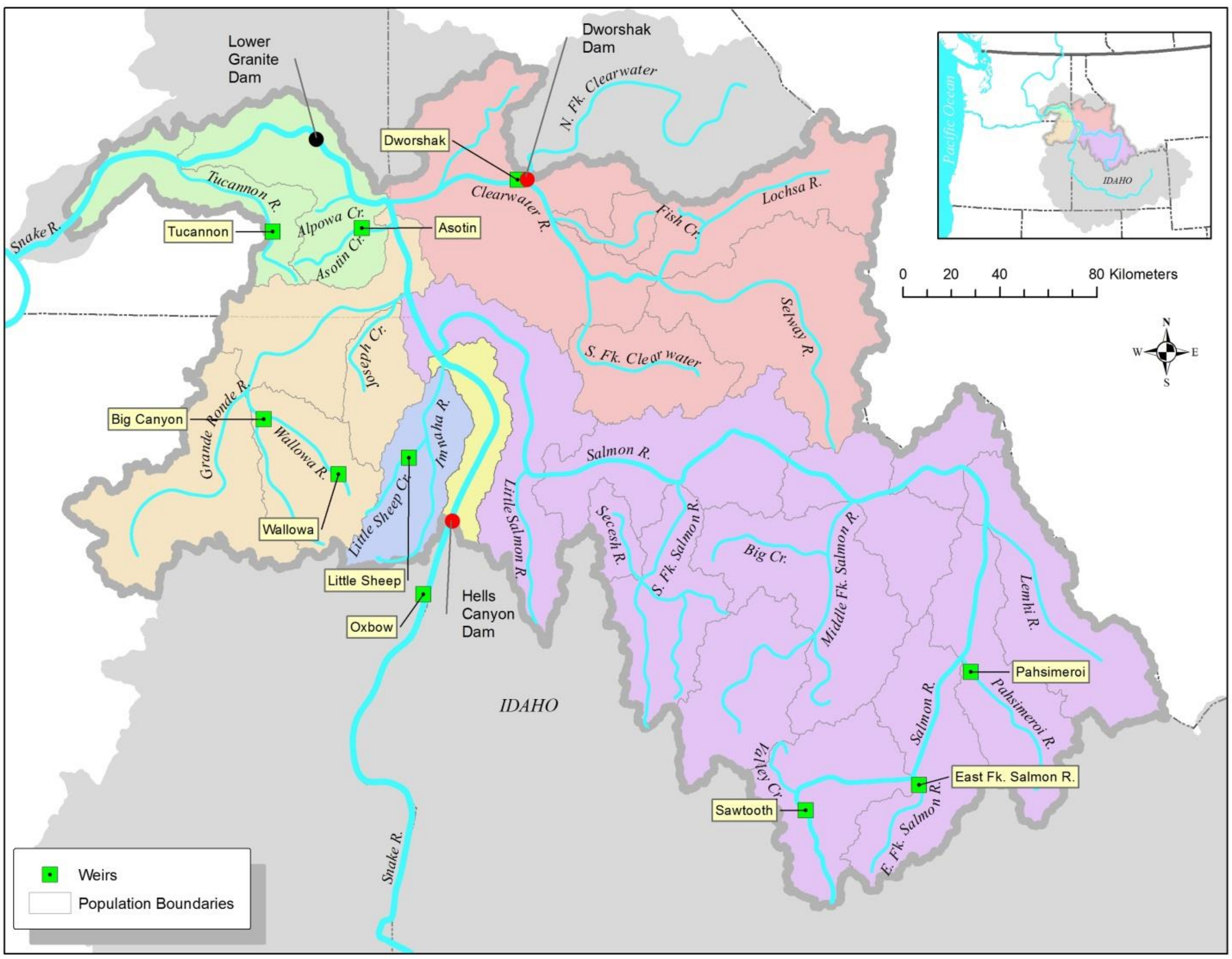

Figure 2. Snake River steelhead populations and locations of weirs. Major population groups (MPGs) are denoted by different colors.

Steelhead fisheries within the bounds of the Snake River basin are complex (Figure 3). Recreational fisheries are implemented within the main stems 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 Nez Perce Tribe (NPT) operates a commercial gill net fishery in the Snake River between LGR and Hells Canyon Dam and in the main-stem 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 Shoshone Bannock Tribes (SBT) harvest steelhead throughout the Salmon River basin with most effort in the Yankee Fork and EF Salmon River.

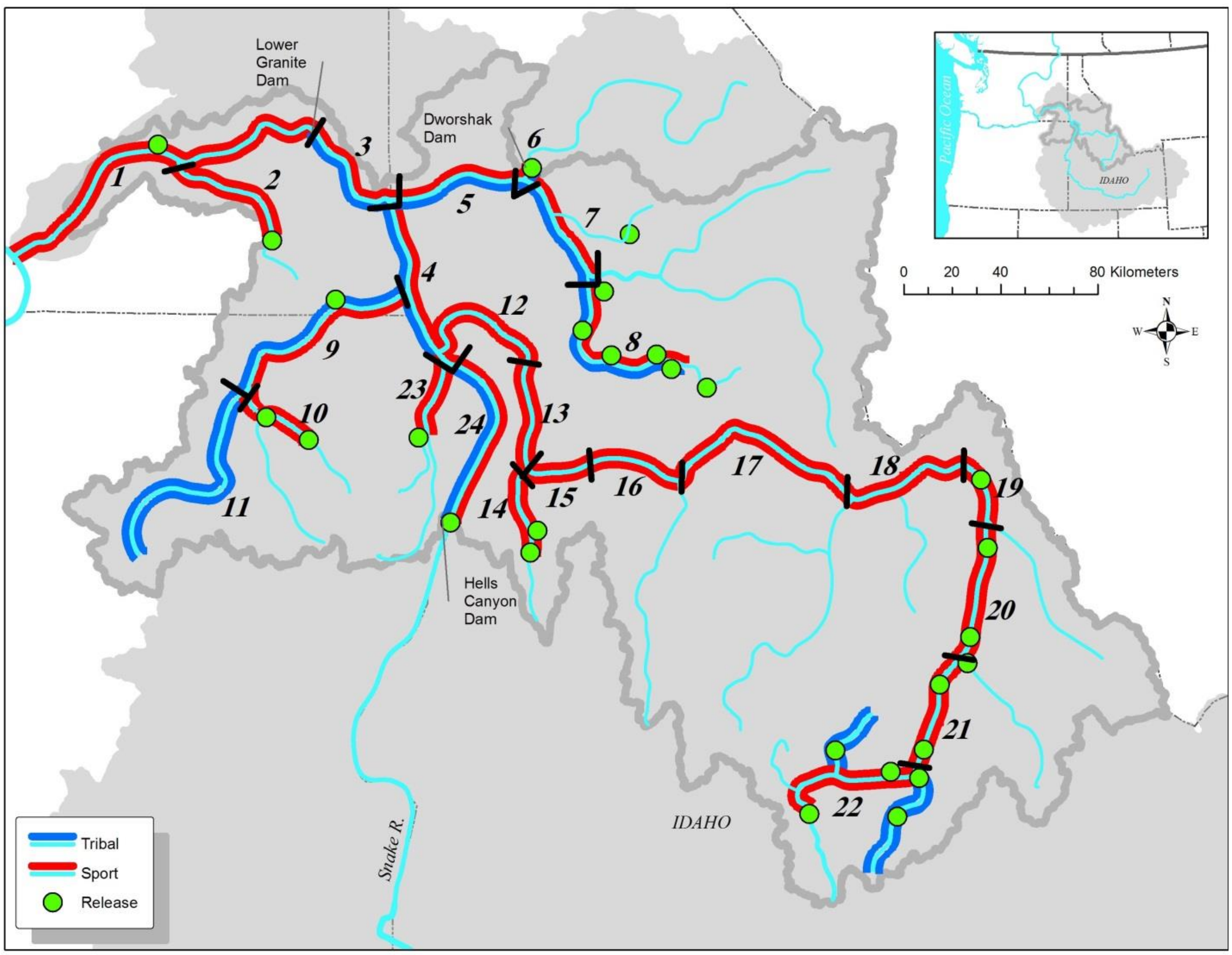

Figure 3. Location of hatchery steelhead release sites and boundaries of harvest reaches within the Snake River basin. Numbers represent the reaches represented as the smallest strata in the run reconstruction model. See Table 2 for reach descriptions.

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 because of the intensive sampling program operating on adult steelhead there (Camacho et al. 2017). Disposition of these fish 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 forward. We also estimated the number of steelhead migrating across BON, although we did not attempt to separate fishery impacts within the Columbia River from straying and natural mortality.

Abundance at Lower Granite Dam

The total abundance of steelhead crossing LGR from July 1, 2015 to June 30, 2016 was based on the expanded window count (see Camacho et al. 2017 for methodology). Camacho et al. (2017) first partitioned the window count 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 (Steele et al. 2018). Release locations were aggregated within fisheries reaches (see Figure 3) to simplify accounting within the model. Camacho et al. (2017) parsed abundance of wild fish into genetic stocks established by Powell et al. (2018) using genetic stock identification (GSI) on adult steelhead sampled at LGR. Genetic stocks are larger than the populations, so we further parsed them into populations based on the spawning area weighted by 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 Powell, 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 and 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 passive integrated transponder (PIT) tag detections of adult steelhead in the LGR ladder during June 2015-May 2016. 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 night-time 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 the abundance of Lower Snake River stocks. We found previously that abundance of Lower Snake stocks (Tucannon and Asotin populations) appeared biased high (Copeland et al. 2013, 2014, 2015). Therefore, 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 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 calculated two re-ascension rates, one for stocks upstream of LGR and another for stocks downstream of LGR. Window counts for each group (clipped and unclipped hatchery, and wild fish) was reduced by the re-ascension proportion for Lower Snake stocks and for stocks originating upstream of LGR, respectively.

Conversion Rates

We used adult PIT tag detections at LGR, ICH, MCN, 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 2015 and 31 December 2015 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 River stocks. ICH to LGR conversion rates were calculated independently for each population within the Lower Snake stock group.

Abundance at Ice Harbor, McNary, and Bonneville dams

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

$$N_{id} = {}^{N_i}/_{CR_{id}} \qquad (5)$$

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, MCN, BON dams.

Equation 5 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):

$$N_i = \sum_{j=1}^{r}(C_{ij} + E_{ij}) \quad (1)$$

where N_i = abundance of stock i at LGR,
C_{ij} = catch 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 stock *i* enters.

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

$$C_{ij} = C_j * \left(N_{ij} \Big/ \sum_{i=1}^{s} N_{ij} \right) \quad (2)$$

where C_j = 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:

$$N_{i,j+1} = p_{i,jk} * (N_{ij} - C_{ij}) \quad (3)$$

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:

$$E_{ij} = N_{ij} - N_{i,j+1} - C_{ij} \quad (4)$$

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 that were caught and released eventually died (WDFW 2009). Catch and harvest statistics were estimated by each agency in several ways. Idaho Fish and Game (IDFG) estimated catch and harvest data with a post-season phone survey (IDFG 2015). Take of wild fish by sport fisheries in Idaho was estimated statewide based on the encounter rate of hatchery fish. 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 main-stem Snake River in Washington was estimated from creel survey encounter rates and assuming 5% mortality (Trump 2015). Total take was then parsed into the appropriate fishery reaches. Harvest estimates from the NPT and CTUIR 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 1998). The fisheries estimates for the Wallowa River in Oregon were based on a regression of 2014-2015 hatchery returns to past Wallowa River ODFW harvest estimates (Flesher and Clarke 2018). Similarly, 2015-2016 fishery data were unavailable for the SBT, but in this river section we used 2008-2009 data (Brandt 2009), scaled to the 2015-2016 escapement at LGR.

We modeled upstream movement assuming wild fish returned to where they were spawned (based on genetic stock assignment) and that 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. Other modifications of movement probabilities and their bases are given below.

Unlike the treatment of movement upstream of LGR, movement probability within the Lower Snake is confounded with survival in the conversion rate, so modeled fish are moved before the fishery, because they have survived harvest mortality by definition. Although some fish can't be assigned to harvest-related mortality (i.e. may overwinter below ICH and not convert to the Lower Snake), within the Lower Snake reach we only report fishery-related losses to maintain comparability to reaches upstream of LGR.

Hatchery and wild stocks from the Lower Snake (downstream of LGR) and Tucannon are known to overshoot their original release location extensively (Bumgarner and Dedloff 2015); many of them cross LGR. Many are known to remain upstream of LGR while a minority (15%-25%) fall back downstream into the Lower Snake reach. We used PIT tag detections at ICH, the lower Tucannon, and LGR to estimate movement probabilities of wild Tucannon fish, Tucannon endemic stock (TUCA)[c,u] hatchery fish, and Lower Snake Lyons Ferry and Wallowa (LF/WALL)[c] stock hatchery releases moving from ICH to the Tucannon or falling back over LGR into the Tucannon. Fallback probabilities were applied to fish within Lower Granite pool only. Fallbacks from Lower Granite pool are removed after fishery losses are subtracted and routed to their final destination (Tucannon River) and are not eligible to be harvested downstream of LGR. Figure 4 illustrates dataflow from LGR down to BON and how Lower Snake stocks move within the study area.

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 (Warren et al. 2018). 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).

Harvest rate is computed for the grouped upstream stocks based on the assumptions that all resident 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.

Table 2. Description of fishery reaches in the Snake River basin, including agencies reporting fisheries within them during 2015-2016. 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	Agencies	Resident wild and hatchery stocks
Snake River downstream of Lower Granite Dam		
1. Ice Harbor-Lower Granite	WDFW	<u>Tucannon</u>, Snake (LF^{c}/WALL^{c})
Tucannon River		
2. Mouth to Tucannon FH	WDFW	<u>Tucannon</u>, Tucannon (TUCA^{c,u})
Snake River upstream from Lower Granite Dam		
3. Lower Granite to Clearwater River	WDFW, NPT	<u>Asotin</u>
4. Clearwater to Salmon mouth	WDFW, IDFG	<u>Asotin</u>
24. Salmon River mouth to Hells Canyon Dam	IDFG	Snake (OXBO^{c})
Clearwater River		
5. Mouth to Orofino	IDFG, NPT	<u>Lower Clearwater</u>
6. North Fork Clearwater	IDFG, NPT	NF Clearwater (DWOR^{c})
7.Orofino to Clear Creek	IDFG, NPT	<u>Lower Clearwater</u>, <u>Lolo</u>, Lolo (DWOR^{u}), Clear Creek (DWOR^{c}), <u>Lochsa</u>, <u>Selway</u>
8. South Fork Clearwater	IDFG, NPT	<u>South Fork Clearwater</u>, SF Clearwater (DWOR^{u,c}/SFCW^{u,c})
Grande Ronde River		
9. Mouth to Wallowa River	WDFW, ODFW	<u>Lower Grande Ronde</u>, <u>Joseph Creek</u>, <u>Cottonwood (GRCW^{c})</u>
10. Wallowa River	ODFW	<u>Wallowa</u>, Wallowa (WALL)
11. Upstream of Wallowa River	CTUIR	<u>Upper Grande Ronde</u>
Imnaha River		
23. Mouth upstream	ODFW	<u>Imnaha</u>, Imnaha (IMNA^{c})
Salmon River		
12. Mouth to Whitebird Creek	IDFG	<u>Little Salmon</u>
13. Whitebird to Little Salmon mouth	IDFG	<u>Little Salmon</u>
14. Little Salmon River upstream	IDFG	<u>Little Salmon</u>, Little Salmon
15. Little Salmon to Vinegar Creek	IDFG	NA
16. Vinegar to South Fork	IDFG	<u>South Fork Salmon</u>, <u>Secesh</u>, <u>Chamberlain</u>
17. South Fork to Middle Fork	IDFG	<u>Chamberlain</u>, <u>Lower Middle Fork</u>, <u>Upper Middle Fork</u>, <u>Panther</u>
18. Middle Fork to North Fork	IDFG	<u>Panther</u>, <u>North Fork Salmon</u>
19. North Fork to Lemhi	IDFG	<u>Lemhi</u>, Salmon sec 19 (PAHS^{c})
20. Lemhi to Pahsimeroi	IDFG	<u>Pahsimeroi</u>, Salmon sec 20 (USAL^{u},PAHS^{c})
21. Pahsimeroi River to East Fork	IDFG, SBT	<u>East Fork</u>, Salmon sec 21,
22. East Fork upstream	IDFG, SBT	<u>Upper Salmon</u>, Salmon sec 22 (SAWT^{u,c}, DWOR^{c}, USAL^{c})

Output of the run reconstruction model is summarized into three categories: abundance at important locations, escapement after fisheries, and spawner abundance in the terminal area. Abundance is estimated at BON, ICH, LGR, and at the mouth of the natal river or terminal reach (except for Lower Snake stocks). Losses between BON and ICH include all mortality sources; losses upstream of ICH include only fishery-related mortality. Escapement is then the fish that avoid fishery-related mortality, assuming that natural mortality takes place only downstream of ICH and in the spawning reaches. Fates of fish removed at weirs are known with certitude; therefore, we also report the number of fish that are potentially at-large within spawning reaches. Outputs are tabulated only for Snake River stocks; however, in the text we report mortality and escapement within the study area of non-Snake River stocks that were detected at LGR.

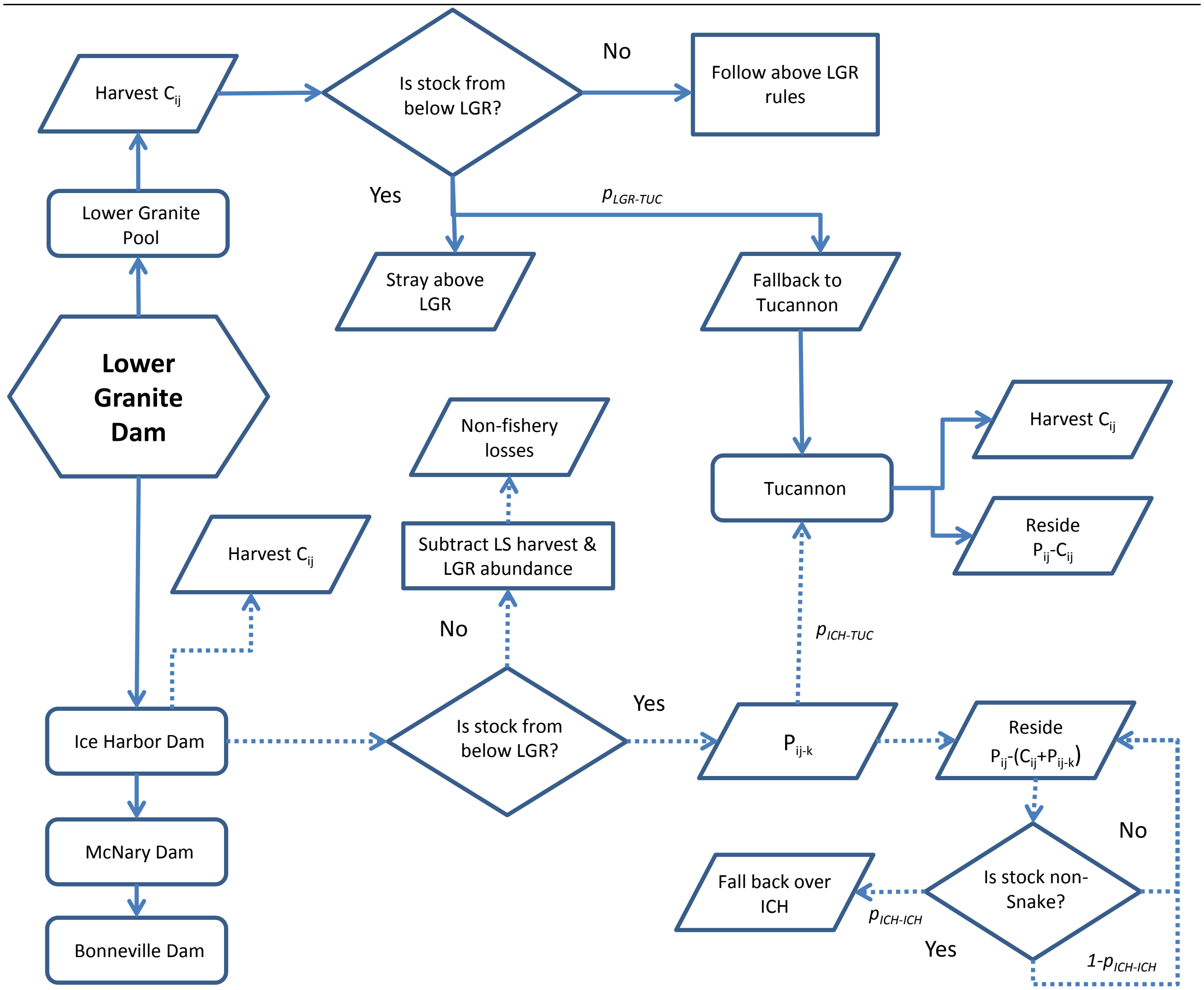

Figure 4. Flowchart for projection of abundance at Lower Granite Dam back to Bonneville Dam and movement of Lower Snake stocks between Ice Harbor Dam and Lower Granite pool.

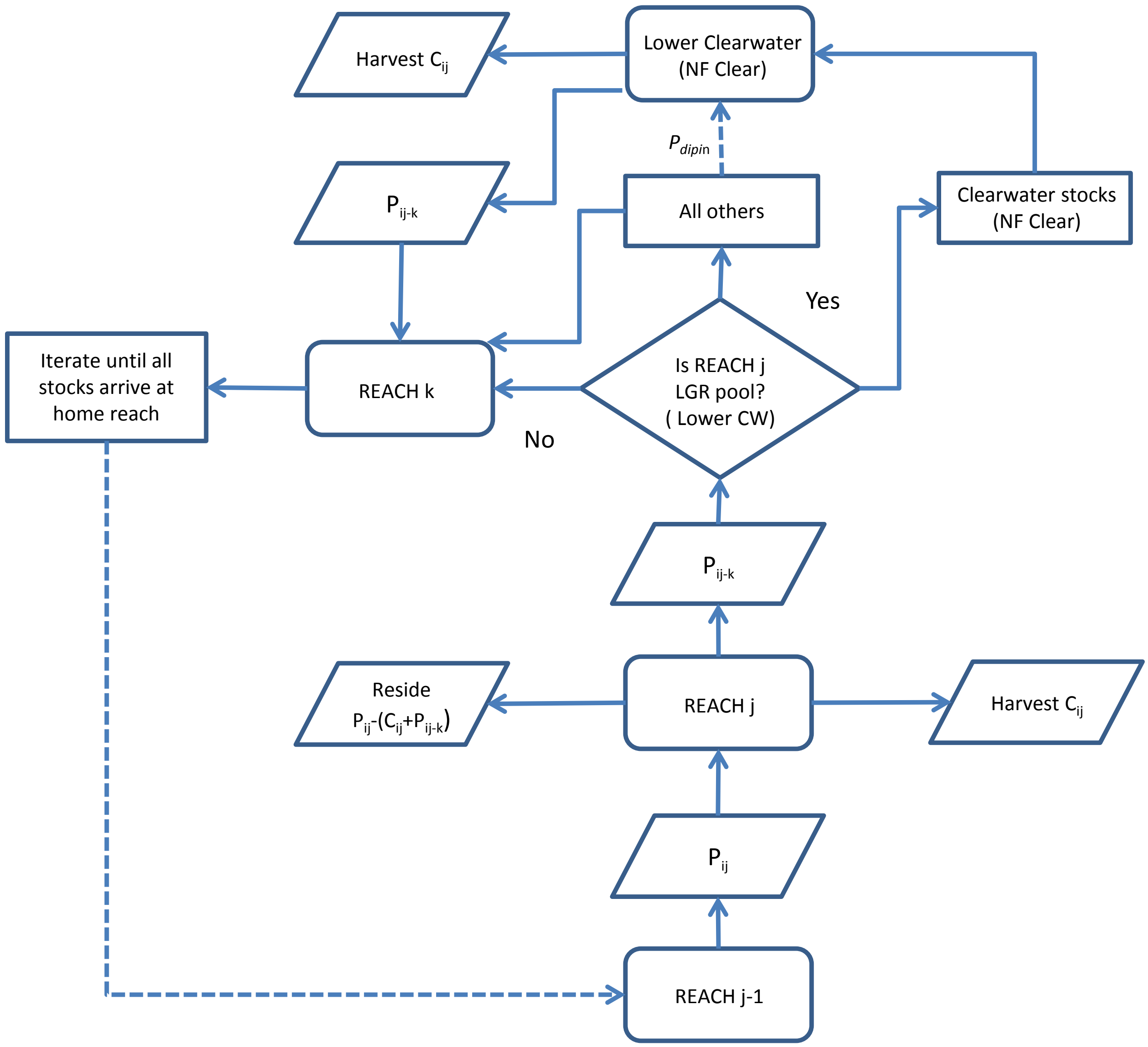

Figure 5. Flowchart for movement and fates of steelhead upstream of Lower Granite Dam. Abbreviations are explained in the text. Dip-in decisions are for non-Clearwater stocks in Lower Granite pool or for upper Clearwater/South Fork Clearwater stocks in the lower Clearwater (in parentheses).

RESULTS

Abundance at Lower Granite Dam

The preliminary (unadjusted) abundance estimates at LGR for the 2015-2016 steelhead run were 33,936 wild fish, 96,761 clipped hatchery fish, and 5,453 unclipped hatchery fish (Camacho et al. 2017). After incorporating night passage (5.87%) and re-ascensions (13.40% for Lower Snake stocks and 1.37% for all others), the adjusted estimates were 34,992 wild fish, 81,115 clipped hatchery fish, and 5,099 unclipped hatchery fish (Tables 3 and 4). Of the 30 hatchery release site-stock groups, two groups were from locations outside of the Snake basin (Touchet River and Walla Walla River). The largest hatchery return group at LGR was bound for the Salmon River between the EF Salmon River and Sawtooth Fish Hatchery (FH) on the upper Salmon River (reach 22). Most unclipped hatchery steelhead were returning to SF Clearwater River or the Salmon River between the Lemhi River and and the Pahsimeroi River. We estimated that the largest wild population was the Lower Mainstem Clearwater River, although the Upper Mainstem Grand Ronde River population was almost as large, and the smallest was the North Fork Salmon RIver.

Abundance at Ice Harbor, McNary, and Bonneville dams

Based on conversion rates (next paragraph, we estimated that 44,631 wild, 110,195 hatchery clipped, and 6,878 hatchery unclipped steelhead from the Snake River basin passed BON. Of those, 36,514 wild, 84,026 hatchery clipped, and 5,435 hatchery unclipped steelhead, respectively entered the Snake River and passed ICH (Tables 3 and 4).

Conversion Rates

We detected 600 PIT-tagged wild steelhead and 2,205 PIT-tagged hatchery steelhead from the Snake River basin at BON. Conversion rates from BON to MCN averaged 84.2% (69.7%–86.4%) for wild steelhead and 77.1% (76.1%–93.1%) for hatchery steelhead. Conversion rates from MCN to ICH and ICH to LGR exceeded 87% for all hatchery and wild groups (Table 5). Conversion rates from MCN to ICH averaged 96.3% for wild fish and 94.0% for hatchery fish. Conversion rate from ICH to LGR averaged 97.1% for wild fish and 96.8% for hatchery fish for stocks originating upstream of LGR.

Table 3 The estimated abundance of wild populations at Bonneville (BON), McNary (MCN), and Ice Harbor (ICH) dams based on Lower Granite Dam (LGR) abundance and Group HUC4 conversion rates. Estimates were adjusted for night time passage and reascencion rates.

Wild Populations		**Abundance at**			
Name	**Group (HUC4)**	**BON**	**MCN**	**ICH**	**LGR**
Tucannon River	Lower Snake wild	3,284	3,057	3,000	2,222
Asotin Creek	Asotin wild	2,254	1,892	1,691	1,570
Lower Grande Ronde	Grande Ronde wild	1,951	1,485	1,485	1,455
Joseph Creek	Grande Ronde wild	1,421	1,082	1,082	1,060
Wallowa River	Grande Ronde wild	3,887	2,959	2,959	2,900
Upper Grande Ronde	Grande Ronde wild	4,683	3,565	3,565	3,494
Imnaha River	Imnaha wild	3,821	2,948	2,783	2,733
Lower Clearwater	Clearwater wild	4,321	3,833	3,784	3,758
Lolo Creek	Clearwater wild	404	358	353	351
South Fork Clearwater	Clearwater wild	2,053	1,821	1,798	1,786
Lochsa River	Clearwater wild	1,459	1,294	1,278	1,269
Selway River	Clearwater wild	2,503	2,220	2,192	2,177
Little Salmon River	Salmon wild	1,506	1,299	1,261	1,222
South Fork Salmon	Salmon wild	1,201	1,036	1,006	975
Secesh River	Salmon wild	515	444	431	418
Chamberlain Creek	Salmon wild	452	390	379	367
Lower Middle Fork	Salmon wild	1,268	1,094	1,062	1,029
Upper Middle Fork	Salmon wild	1,350	1,164	1,130	1,095
Panther Creek	Salmon wild	459	396	385	373
North Fork Salmon	Salmon wild	263	227	220	213
Lemhi River	Salmon wild	1,475	1,272	1,235	1,197
Pahsimeroi River	Salmon wild	1,224	1,056	1,025	993
East Fork Salmon	Salmon wild	1,303	1,124	1,091	1,057
Upper Salmon	Salmon wild	1,574	1,358	1,319	1,278
Total	**All Wild**	**44,631**	**37,374**	**36,514**	**34,992**

Table 4 The estimated abundance of hatchery stocks by release site at Bonneville (BON), McNary (MCN), and Ice Harbor (ICH) dams based on Lower Granite Dam (LGR) abundance and Group HUC4 conversion rates. Abbreviations are given in Table 1. Unclipped hatchery releases are denoted by u and clipped releases by c. Asterisks indicate fish were released in the Walla Walla River basin. Estimates were adjusted for night time passage and reascencion rates.

Hatchery Populations		**Abundance at**			
Release site (stock)	**Group (HUC4)**	**BON**	**MCN**	**ICH**	**LGR**
Snake R at LF (LF/WALL)[c]	Lower Snake	1,427	995	893	540
Tucannon, Curl Lake IS (TUCA)[u]	Lower Snake	817	570	511	309
Tucannon, Marengo Bridge (TUCA)[c]	Lower Snake	271	189	170	103
NF Clearwater (DWOR)[c]	Clearwater	16,146	13,957	13,548	13,285
Lolo Creek (DWOR)[u]	Clearwater	938	811	787	772
SF Clearwater (DWOR/SFCW)[u]	Clearwater	2,556	2,209	2,144	2,102
SF Clearwater (DWOR/SFCW)[c]	Clearwater	7,185	6,211	6,029	5,912
Clear Creek (DWOR)[c]	Clearwater	1,932	1,670	1,621	1,590
Grande Ronde, Cottonwood AP (GRCW)[c]	Grande Ronde	14,625	10,786	10,403	10,128
Wallowa, Spring & Deer Creeks (WALL)[c]	Grande Ronde	22,464	16,567	15,639	15,226
Imnaha, Little Sheep Cr (IMNA)[c]	Imnaha	4,186	3,209	3,117	2,997
Little Salmon (OXBO,PAHS,DWOR)[c]	Salmon	15,027	12,193	11,677	11,221
Panther Cr Egg Boxes (PAHS)[u]	Salmon	46	37	35	34
Salmon, Lem-Pah (USAL)[u]	Salmon	873	709	678	652
Salmon, Lem-Pah (DWOR)[u]	Salmon	275	223	214	205
Salmon, Lem-Pah (PAHS)[m]	Salmon	12	9	9	9
East Fork Salmon (EFNA)[u]	Salmon	941	763	731	702
Salmon, Pah-EF (SAWT/EFNA)[c]	Salmon	3,155	2,560	2,451	2,356
Salmon, EF-Saw (USAL)[u]	Salmon	360	292	280	269
Salmon, EF-Saw (DWOR)[u]	Salmon	72	58	56	54
Salmon, EF-Saw (SAWT/DWOR/USAL)[c]	Salmon	23,766	19,284	18,468	17,748
Snake (OXBO)[c]	Hells Canyon	8,169	6,103	5,351	5,149
All Snake River basin Unclipped Hatchery		**6,878**	**5,672**	**5,435**	**5,099**
All Snake River basin Clipped Hatchery		**110,195**	**87,630**	**84,026**	**81,115**
Total Snake River Hatchery		**117,073**	**93,302**	**89,461**	**86,214**
Touchet Endemic, Wolf Fork Bridge (TOUC)[u]	Mid-Columbia	222	155	139	84
Walla Walla, McDonald Rd Bridge (LF/WALL)[c]	Mid-Columbia	169	118	106	64

Table 5. Conversion rates between selected dams in the Columbia and lower Snake rivers. The number of fish detected at a dam that were subsequently detected upriver are in the numerator. Only fish detected at Bonneville (BON), McNary (MCN), and Ice Harbor (ICH) dams are in the denominator.

Stock	N at BON	Detect at MCN	BON to MCN rate	N at MCN	Detect at ICH	MCN to ICH rate	N at ICH	Detect at LGR	ICH to LGR rate
Lower Snake hatchery	195	136	69.7%	136	122	89.7%	129	78	60.5%
Gr Ronde hatchery	499	368	73.7%	366	353	96.4%	341	332	97.4%
Imnaha hatchery	407	312	76.7%	312	303	97.1%	286	275	96.2%
Clearwater hatchery	317	274	86.4%	273	265	97.1%	258	253	98.1%
Hells Canyon hatchery	87	65	74.7%	65	57	87.7%	53	51	96.2%
Salmon hatchery	700	568	81.1%	567	543	95.8%	513	493	96.1%
Total hatchery	**2,205**	**1,723**		**1,719**	**1,643**		**1,564**	**1,473**	
Lower Snake wild	58	54	93.1%	54	53	98.1%	54	40	74.1%
Asotin wild	56	47	83.9%	47	42	89.4%	42	39	92.9%
Gr Ronde wild	67	51	76.1%	51	51	100.0%	50	49	98.0%
Imnaha wild	162	125	77.2%	125	118	94.4%	112	110	98.2%
Clearwater wild	177	157	88.7%	157	155	98.7%	147	146	99.3%
Salmon wild	80	69	86.3%	69	67	97.1%	65	63	96.9%
Total wild	**600**	**503**		**503**	**486**		**464**	**441**	

Run Reconstruction Abundance and Disposition

Steelhead from Lower Snake River stocks residing downstream from LGR tended to overshoot their natal reach and pass upstream of LGR, some of which returned back downstream (Table 6). Conversion rates from ICH to LGR for the clipped Snake River (LF/WALL)[c] and clipped and unclipped Tucannon endemic (TUCA)[c,u] release groups were 51.0% and 66.3%, respectively; while 74.1% of the wild Tucannon fish crossed LGR (Todd Miller, personal communication).

A single movement probability was estimated for the two Tucannon hatchery groups that crossed ICH, both the unclipped Tucannon endemic fish (TUCA)[u] and clipped Tucannon stock hatchery steelhead (TUCA)[c] released into the Tucannon River at Marengo Bridge (RM25). An estimated 21.3% of Tucannon hatchery fish moved directly to the Tucannon and stayed there. By subtraction, 12.5% stayed within the Lower Snake downstream of LGR as either mortalities or escapement (Todd Miller, personal communicaiton). Note that these three probabilities include all possible fates for these stocks between ICH and LGR (i.e. - they sum to 1.0). However, 66.3% of Tucannon hatchery fish ascended LGR, but 30.2% subsequently fell back below LGR and entered the Tucannon. Another 5.7% fell back below LGR, but stayed in the Lower Snake reservoirs. Lastly, only 20.4% of wild Tucannon steelhead were estimated to directly enter the Tucannon River. As a result, these wild fish exhibited the highest degree of overshoot of all Lower Snake stocks in 2015-2016, with 74.1% estimated to ascend LGR, with only 15.0% subsequently falling back to the Tucannon. (Todd Miller, personal communicaiton).

Clipped LF/WALL stock hatchery steelhead released in the mainstem Snake River at LF FH exhibited overshot and fallback as well, but with slightly different patterns from the wild and hatchery Tucannon River groups. Snake River (LF/WALL)^{c} overshot their release site in the Snake River with 12.2% entering the Tucannon River, while 36.7% died (fishery-induced or natural mortality) or resided in the the ICH pool of the Snake River. Compared to the Tucannon groups, a smaller proportion of Snake River (LF/WALL)^{c} fish ascended LGR (51.0%) and subsequently fellback to the Tucannon (4.0%), but as would be expected a greater proportion fellback below LGR to the Lower Snake River (Todd Miller, personal communicaiton).

Mid-Columbia River hatchery steelhead also overshot their release areas and ascended not only ICH, but LGR as well. Two stocks of hatchery steelhead released in the Walla Walla River basin were sampled at LGR; unclipped Touchet endemic (TOUC)^{u} and clipped Walla Walla (LF/WALL)^{c} fish. Clipped Touchet River hatchery steelhead (LF/WALL)^{c} were not sampled at LGR, but PIT tags from this stock as well as from the two Mid-Columbia stocks above were detected at both ICH and LGR, and therefore their movement probabilities were estimable.

Movement patterns across these three hatchery groups varied considerably. Clipped Walla Walla (LF/WALL)^{c} and Touchet (LF/WALL)^{c} fish exhibited similar rates of passage over and subsequent fallback below ICH, 4.8% and 7.1%, respectively (Todd Miller, personal communication), whereas a greater proportion of unclipped Touchet endemic fish (TOUC)^{u} passed ICH then fell back below (15.8%). Although no clipped Touchet fish (LF/WALL)^{c} were detected, 19.1% of clipped Walla Walla fish and 21.1% of unclipped Touchet endemic fish entered the Tucannon River. A portion of all three hatchery groups either died (fishery-induced or natural mortality) or resided in the ICH pool. However, a large portion of the clipped Walla Walla (57.1%) and clipped Touchet (53.6%) groups ascended LGR. Although most Mid-Columbia hatchery fish that ascended LGR were not detected again, 8.3% of Walla Walla and 20.0% of unclipped Touchet endemic fish subsequently fell back over LGR and entered the Tucannon River. Lastly, some clipped Walla Walla (8.3%) and clipped Touchet fish (13.3%) which passed LGR fell back below LGR. Although the number of Walla Walla basin fish estimated at LGR was not large, it’s clear these stocks are substantially straying beyond their release areas.

Dip-in rates of non-Clearwater River steelhead stocks (p_{dip}) into the lower Clearwater River varied widely (Table 7). It was highest for Lower Snake stocks (42.3%) and lowest for the Imnaha River hatchery stock, which the model estimated zero dip-in fish. Dip-in rates of Grande Ronde, Salmon River and Hells Canyon hatchery fish were 6.7%, 4.7%, and 10.9%, respectively. The Salmon River stocks composed the largest component of dip-ins in absolute numbers because of their greater abundance in Lower Granite pool, yet their dip-in rate was lower than previous return years. The dip-in rate for clipped hatchery fish that were released upstream of the NF Clearwater River, but which dipped into the NF Clearwater River was 25.4%. This dip-in rate for SF Clearwater and Clear Creek releases into the NF Clearwater is five times higher than the dip-in rate from spawn years 2013-2015 which averaged 5.6% (3.3%–7.5%). It is not clear why so many more upriver stocks dipped into the NF Clearwater in 2015-2016, but one contributing factor may have been higher river temperatures in the mainstem Clearwater River particularly in the summer/fall of 2015. Furthermore, these dip-in estimates are based on harvest data, and should be considered a minimum estimate. Therefore, it’s likely even a greater proportion of fish sought refuge in the colder NF Clearwater in 2015-2016.

Table 6. Movement probabilities of Lower Snake and Walla Walla basin wild populations and hatchery stocks within the Ice Harbor to Lower Granite reach. Rates are based on PIT tag detections. 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].

	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 (LF/WALL)[c]	0.000	0.122	0.367	0.510	0.040	0.080
Tucannon (TUCA)[c]	0.000	0.213	0.125	0.663	0.302	0.057
Tucannon (TUCA)[u]	0.000	0.213	0.125	0.663	0.302	0.057
Tucannon wild	0.000	0.204	0.056	0.741	0.150	0.025
Walla Walla basin						
Walla Walla (LF/WALL)[c]	0.048	0.191	0.238	0.571	0.083	0.083
Touchet (LF/WALL)[c]	0.071	0.000	0.464	0.536	0.000	0.133
Touchet (TOUC)[u]	0.158	0.211	0.526	0.263	0.200	0.000

Table 7. Computation of dip-in rates of clipped non-Clearwater hatchery stocks into the lower Clearwater River (reach 5). Hatchery stocks are grouped by region. Harvest was determined from PBT recoveries in the fishery (Warren et al. 2018).

Hatchery Stock	Reach 3 Harvest	LGR Pool Abundance	Dip-in Rate
Lower Snake	79	678	42.3%
Grande Ronde	458	24,793	6.7%
Salmon	583	45,413	4.7%
Imnaha	0	2,938	0.0%
Hells Canyon	151	5,031	10.9%

Total fishery-related mortality of clipped hatchery fish within the study area was 60,980 steelhead (Table 8). This number includes direct harvest as well as incidental mortality from catch-and-release handling. Incidental take of unclipped steelhead was estimated at 1,532 fish, which includes unclipped hatchery fish as well as wild fish. The largest total losses of clipped hatchery fish were in the lower Clearwater River (reach 5), the Lower Snake River (reach 1), the upper Snake River (reach 4), the NF Clearwater River (reach 6), and the Salmon River between the MF and NF Salmon River (reach 18). The largest fishery mortality estimates of unclipped fish were in the lower Snake River (reach 1), the Upper Snake River (reach 4), and the Lower Clearwater River (reach 5).

Table 8. Estimated fishery mortalities by river reach and mark type. Total fishing mortality for clipped fish includes both harvest and catch-and-release mortality.

		Clipped	
River and Reach	**Unclipped**	**Harvest**	**Catch-and-Release**
1. Lower Snake	248	6,924	13
2. Tucannon	1	19	0
3. Lower Granite Pool	65	1,986	3
4. Upper Snake	209	6,363	120
5. Lower Clearwater	220	6,859	493
6. North Fork Clearwater	46	4,242	47
7. Clearwater to Clear Creek	57	1,945	93
8. South Fork Clearwater	109	1,300	213
9. Lower Grande Ronde	135	2,851	77
10. Wallowa River	66	3,050	105
11. Upper Grande Ronde	0	0	0
12. Salmon to White Bird	11	424	16
13. Salmon (WB-Little Salmon)	56	2,492	117
14. Little Salmon	32	2,721	321
15. Salmon (LS to Vinegar)	25	1,509	59
16. Salmon (Vinegar to SF)	19	368	51
17. Salmon (SF to MF)	40	763	45
18. Salmon (MF to NF)	67	5,373	246
19. Salmon (NF to Lemhi)	26	1,752	99
20. Salmon (Lemhi to Pahsimeroi)	23	2,540	124
21. Salmon (Pahsimeroi to EF)	19	1,419	78
22. Salmon (EF upstream)	33	1,727	240
23. Imnaha	6	73	2
24. Hells Canyon	20	1,680	38
	1,532	**58,380**	**2,600**

Lower Snake River MPG

Abundance of stocks from the Lower Snake MPG at BON was comprised of 5,538 wild fish, 817 unclipped Tucannon endemic stock ($TUCA^u$), and 1,698 clipped hatchery steelhead from LF/WALL stock released at LF FH on the Snake River and the Tucannon endemic stock ($TUCA^c$) released at Marengo Bridge on the Tucannon River (Table 9). Losses between BON and ICH were estimated to be 847 wild fish (15.3%) and 941 (37.4%) hatchery fish. These fish crossed LGR in moderate numbers, even though stocks did not originate from upstream of LGR. Fishery-associated losses downstream of LGR (Reaches 1 and 2) were 59 wild fish (1.3%), 4 unclipped hatchery fish (0.8%), and 82 clipped hatchery fish (7.7%). Losses upstream of LGR (reaches 3 and 4) were 23 wild fish (0.6%), zero unclipped hatchery fish (0.0%), and 29 clipped hatchery fish (4.5%).

Final dispositions are known for fish removed at the Tucannon FH weir and other temporary weirs operated within the Lower Snake MPG (T. Miller, unpublished data). Lyons Ferry FH trap operation was discontinued after the spring of 2013 (Todd Miller, personal communication). At the Tucannon FH weir, 330 wild fish and 151 hatchery fish were trapped (72 clipped, 79 unclipped), and 50 wild and 7 unclipped hatchery fish were retained and spawned for the endemic Tucannon ($TUCA^{c,u}$) hatchery broodstock. The remaining trapped hatchery fish were either released upstream of the hatchery to spawn naturally (all 72 unclipped, 19 clipped), or recycled back to the fishery downstream of the hatchery (42 clipped). An additional 36 steelhead were trapped at the Penewawa Creek weir, including 35 wild steelhead, and one clipped Touchet River ($WALL^c$) fish. All 35 wild fish were release to spawn, and the one Touchet fish was culled. The Alkali Flats Creek weir on the Snake River was not operated in 2015-2016, thus no steelhead were trapped. Lastly, 31 additional Tucannon hatchery fish were trapped and culled at the Asotin and George Creek weirs (11 $TUCA^u$, 10 $TUCA^c$) and the Alpowa Creek weir (4 $TUCA^u$, 6 $TUCA^c$) upstream of LGR. After subtracting all retained fish, we estimated 1,264 wild fish, 302 unclipped hatchery fish ($TUCA^u$), and 426 clipped hatchery fish ($TUCA^c$) were left to spawn in the Tucannon River and Lower Snake River below LGR (Table 9). An additional 1,817 wild, 182 unclipped hatchery ($TUCA^u$), and 515 clipped hatchery ($TUCA^c$) Tucannon River fish were estimated to be left to spawn in the Lower Granite pool of the Snake River upstream of LGR.

Two groups of mid-Columbia River clipped hatchery steelhead were sampled at LGR during SY16, including an estimated 84 unclipped Touchet River releases ($TOUC^u$), and 64 clipped Walla Walla and Touchet river releases ($LF/WALL^c$). Thus, 139 unclipped Touchet and 106 clipped Walla Walla and Touchet hatchery steelhead passed ICH and contributed to fisheries in the Snake River (Table 9). But after falling back downstream over LGR, 117 mid-Columbia hatchery steelhead were estimated to have escaped (71 $TOUC^u$, 46 $LF/WALL^c$), and all of these fish were left to spawn in the Lower Snake River below LGR.

As mentioned above, a total of 148 Walla Walla basin hatchery fish passed LGR (84 $TOUC^u$, 64 $LF/WALL^c$), but after fallback to the LS, 126 escaped to the Snake River above LGR (66 $TOUC^u$, 60 $LF/WALL^c$). But once upstream of LGR, a total of 26 mid-Columbia River hatchery steelhead were trapped and culled at temporary weirs. Three unclipped Touchet endemic ($TOUC^u$) were culled above LGR (two at Asotin and George Cr weirs, one at Alpowa weir). And 23 clipped Walla Walla and/or Touchet ($LF/WALL^c$) were trapped and culled at weirs above LGR (six at Almota weir, 11 at Asotin+George weirs, and six at Alpowa weir). Thus, after these removals, 100 mid-Columbia hatchery steelhead (63 $TOUC^u$, 37 $LF/WALL^c$) were estimated left to spawn above LGR (Table 9).

Lastly, 39 clipped LF/WALL stock hatchery steelhead originally released into the Touchet River (LF/WALL[c]) were trapped and culled at temporary weirs. One was trapped and culled downstream of LGR at the Pennewawa Creek weir, and 38 were trapped and culled upstream of LGR (13 at Almota Creek weir, eight at Asotin and George Creek weirs, and 17 at Alpowa Creek weir. But, since no clipped Touchet River hatchery steelhead were found in PBT assignments of hatchery steelhead sampled during 2015-2016 adult trapping at LGR, the model estimates none were left to spawn below or above LGR (Table 9).

Final disposition of the Asotin Creek population is known via fish captured at the Asotin and George Creek weirs, the Almota, and the Alpowa weirs. The Ten Mile weir on a small tributary to the Snake River was not operated in 2015-2016. Because no hatchery fish are released within the Asotin Creek population, and since the disposition of hatchery fish from both Tucannon River and Walla Walla basin fish upstream of LGR was described above, the only group disposition remaining is wild Asotin Creek steelhead. After catch and release mortality was subtracted, 111 wild Asotin Creek steelhead were estimated to escape to the Lower Snake River below LGR, all of which were left to spawn. These fish likely wintered below LGR and strayed or died. Above LGR, 1,547 wild Asotin Creek fish were estimated to have escaped the fishery, and all of these were left to spawn (Table 9). A total of 1,110 wild Asotin Creek steelhead were captured in temporary weirs, 33 at the Almota Creek weir, 890 at Asotin and George Creek weirs, and 187 at the Alpowa weir; all were released upstream to spawn naturally.

Table 9. Reconstruction of wild and hatchery stocks in the Lower Snake MPG. Escapement is computed by spawning reach for wild steelhead and release location for hatchery steelhead. 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].

	Abundance at			Escapement		Left to Spawn	
Stock	**BON**	**ICH**	**LGR**	**ICH-LGR**	**Above LGR**	**Below LGR**	**Above LGR**
Lower Snake stocks							
Snake (LF/WALL)[c]	1,427	893	540	349	540	349	467
Tucannon wild	3,284	3,000	2,222	1,203	1,817	1,153	1,817
Tucannon (TUCA)[u]	817	511	309	309	197	302	182
Tucannon (TUCA)[c]	271	170	103	88	64	77	48
Asotin wild	2,254	1,691	1,570	111	1,547	111	1,547
All Wild	**5,538**	**4,691**	**3,792**	**1,314**	**3,364**	**1,264**	**3,364**
Unclipped Hatchery	**817**	**511**	**309**	**309**	**197**	**302**	**182**
Clipped Hatchery	**1,698**	**1,063**	**643**	**437**	**604**	**426**	**515**
All Hatchery	**2,515**	**1,574**	**952**	**746**	**801**	**728**	**697**
Total	**8,053**	**6,265**	**4,744**	**2,060**	**4,165**	**1,957**	**4,061**
Walla Walla basin releases							
Touchet (TOUC)[u]	222	139	84	71	66	71	63
Walla Walla (LF/WALL)[c]	169	106	64	46	60	46	37

Across the Lower Snake MPG more wild steelhead escaped than hatchery steelhead. But, a large portion of Lower Snake, escapement was outside of their natal stream (wild) or release area (hatchery), both above (Asotin Creek) and below LGR (Tucannon). For the Tucannon population, 24.8% of the potential spawners were hatchery fish, and for the entire Lower Snake MPG, both above and below LGR, 24.9% of spawners were of hatchery origin.

Clearwater River MPG

Abundance of stocks from the Clearwater MPG at BON was 10,740 wild steelhead; 3,366 unclipped hatchery steelhead; and 25,263 clipped hatchery steelhead (Table 10). Between BON and ICH, we estimated that 1,335 wild fish (12.4%) and 4,863 hatchery fish (17.0%) were lost. Fishery-associated losses within the lower Snake River (Reach 1) were 55 wild fish (0.28%), 16 unclipped hatchery fish (0.57%), and 1,388 clipped hatchery fish (6.6%). Losses in the Snake River upstream of LGR (LGR Pool, Reach 3) were 14 wild fish (0.15%), four unclipped hatchery fish (0.14%), and 404 clipped hatchery fish (2.0%). Losses within the Clearwater River were 199 wild fish (2.13%), 103 unclipped hatchery fish (3.73%), and 13,823 clipped hatchery fish (68.7%). Fishery impacts on non-Clearwater stocks in the lower Clearwater River (reach 5) were estimated to be 38 wild fish, 2 unclipped hatchery fish and 1,373 clipped hatchery fish. The total fishery-related losses within this reach composed of non-Clearwater fish was 22.4%, 4.7%, and 18.7% for wild, unclipped hatchery, and clipped hatchery groups, respectively. We estimated escapement in the Clearwater River was 9083 wild fish, 2,629 unclipped hatchery fish, and 6,314 clipped hatchery fish. Clipped hatchery fish escaped the fishery in the NF Clearwater River, Clear Creek, and a few in the SF Clearwater.

Final dispositions are known for fish within the Clearwater River basin that enter hatchery weirs at Dworshak FH (NF Clearwater River), Kooskia FH (Clear Creek, a tributary to MF Clearwater River), and Crooked River (tributary to SF Clearwater River). Fish collected at Kooskia FH are typically recycled to the fishery, as are fish in excess of broodstock needs at Dworshak FH. However, during 2015-2016 Kooskia FH retained many hatchery steelhead for brood needs at both Clearwater FH and Nez Perce Tribal FH. All these hatcheries operate within the Lower Clearwater population.

During the 2015-2016 run, Dworshak FH trapped 3,921 steelhead; which included 3,763 clipped hatchery, 137 unclipped hatchery, and 21 wild fish. All 21 wild fish were released to spawn naturally. A total of 1,234 hatchery fish were retained (1,137 clipped, 97 unclipped). The remaining 2,506 clipped hatchery fish were recycled back to the fishery, and remaining 39 unclipped hatchery fish released to spawn naturally. As a result, 4,105 Dworshak stock clipped hatchery steelhead were left to spawn.

During the 2015-2016 run, Kooskia FH trapped 2,074 hatchery steelhead (2,051 clipped, 23 unclipped). All 23 unclipped fish were released upstream to spawn. Of the trapped clipped hatchery fish, 948 were retained for brood (651 to Clearwater FH, 49 to Nez Perce Tribal FH, and 397 jacks to Dworshak FH). The remaining 1,103 clipped Dworshak stock hatchery steelhead were recycled back into the fishery. The model estimated 548 clipped DWOR stock hatchery steehead escaped to Clear Creek, but we know 948 fish were taken for brood. Therefore, subtracting these from the model escapement estimate leaves -400 clipped DWOR stock hatchery steelhead to spawn in Clear Creek (Table 10).

A total of 354 fish were collected by angling in the SF Clearwater River for use a localized broodstock: 236 clipped hatchery fish and 118 unclipped hatchery fish (identified by dorsal fin erosion). The model estimated 90 clipped SFCW stock hatchery steelhead escaped to the SF Clearwater River, but we know 118 were retained for the localized broodstock. Consequently, we end up with a negative value for the number of SFCW hatchery steelhead left to spawn in the SF Clearwater (-28, Table 10). These negative values demonstrate where the model estimates are clearly off from reality. Nonetheless, we estimate 54.9% of the SF Clearwater spawning population was composed of hatchery fish. Lastly, the model predicted 751 unclipped hatchery fish escaped into Lolo Creek and made up 68.8% of the spawners.

Table 10. Reconstruction of wild and hatchery stocks in the Clearwater major population group (MPG). Escapement is computed by spawning reach for wild steelhead and release location for hatchery steelhead. 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].

	Abundance at					
Stock	**BON**	**ICH**	**LGR**	**Clearwater Mouth**	**Escape**	**Left to Spawn**
Lower Clearwater wild	4,321	3,784	3,758	3,753	3,700	3,700
NF Clearwater (DWOR)[c]	16,146	13,292	13,034	12,777	5,242	4,105
Lolo Creek wild	404	353	351	350	341	341
Lolo Creek (DWOR)[u]	938	787	772	771	751	751
Clear Creek (DWOR)[c]	1,932	1,621	1,590	1,559	548	-400
SF Clearwater (DWOR)[u]	1,595	1,338	1,312	1,310	1,234	1,184
SF Clearwater (SFCW)[u]	833	699	685	684	644	408
SF Clearwater (DWOR)[c]	5,956	4,998	4,901	4,805	434	434
SF Clearwater (SFCW)[c]	1,229	1,031	1,011	991	90	-28
SF Clearwater wild	2,053	1,798	1,786	1,783	1,693	1,693
Lochsa River wild	1,459	1,278	1,269	1,267	1,233	1,233
Selway River wild	2,503	2,192	2,177	2,174	2,116	2,116
All Wild	**10,740**	**9,405**	**9,341**	**9,327**	**9,083**	**9,083**
Unclipped Hatchery	**3,366**	**2,823**	**2,768**	**2,765**	**2,629**	**2,343**
Clipped Hatchery	**25,263**	**20,942**	**20,536**	**20,132**	**6,314**	**4,111**
All Hatchery	**28,629**	**23,765**	**23,304**	**22,897**	**8,943**	**6,454**
Total	**39,369**	**33,170**	**32,645**	**32,224**	**18,026**	**15,537**

Grande Ronde River MPG

Abundance of stocks from the Grande Ronde MPG at BON was 11,942 wild fish and 37,089 for clipped hatchery release groups (Table 11). We estimated that 2,851 wild fish (23.9%) and 11,047 (29.8%) hatchery fish were lost between BON and ICH. Fishery-associated losses within the lower Snake River (Reach 1) were 55 wild fish (0.6%) and 1,728 clipped hatchery fish (6.6%). Fishery losses in the Snake River Basin upstream of LGR (Reaches 3, 4, and 5) were 77 wild fish (0.9%) and 2,518 clipped hatchery fish (9.9%). Fishery losses within the Grande Ronde River were 200 wild fish (2.3%) and 6,083 clipped hatchery fish (27.8%). We estimated escapement in the Grande Ronde River was 8,615 wild fish and 15,783 clipped hatchery fish.

Final dispositions are known for fish trapped at Wallowa FH, Big Canyon acclimation pond (tributary to the Wallowa River), and Cottonwood acclimation pond (at rkm 46 on the Grande Ronde River). There were 379 clipped hatchery fish removed at Cottonwood weir (T. Miller, unpublished data). There were 4,584 clipped hatchery fish removed at the Wallowa FH and Big Canyon weirs (E. Sedell, unpublished data). Therefore, we estimated 74.0% of the Lower Grande Ronde and 58.3% of the Wallowa spawning populations were composed of hatchery fish.

Table 11. Reconstruction of wild and hatchery stocks in the Grande Ronde major population group (MPG). 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].

	Abundance at					
Stock	**BON**	**ICH**	**LGR**	**Grande Ronde Mouth**	**Escape**	**Left to Spawn**
Lower Grande Ronde wild	1,951	1,485	1,455	1,440	1,418	1,418
Joseph Creek wild	1,421	1,082	1,060	1,049	1,033	1,033
Grande Ronde (GRCW)[c]	14,625	10,403	10,128	8,475	7,340	6,961
Wallowa wild	3,887	2,959	2,900	2,869	2,759	2,759
Wallowa (WALL)[c]	22,464	15,639	15,226	13,391	8,443	3,859
Upper Grande Ronde wild	4,683	3,565	3,494	3,457	3,405	3,405
All Wild	**11,942**	**9,091**	**8,909**	**8,815**	**8,615**	**8,615**
All Hatchery	**37,089**	**26,042**	**25,354**	**21,866**	**15,783**	**10,820**
Total	**49,031**	**35,133**	**34,263**	**30,681**	**24,398**	**19,435**

Salmon River MPG

Abundance of stocks from the Salmon River MPG at BON was 12,636 wild fish; 2,495 unclipped hatchery releases; and 62,180 clipped hatchery release groups (Table 12). We estimated that 2,057 (16.3%) wild fish and 14,415 (22.3%) hatchery fish were lost between BON and ICH. Fishery losses within the lower Snake River (Reach 1) were 61 wild fish (0.6%), 11 unclipped hatchery fish (0.6%), and 3,194 clipped hatchery fish (6.6%). Fishery losses in the Snake River upstream of LGR (reaches 3, 4, and 5) were 91 wild fish (0.9%), 16 unclipped hatchery fish (0.9%), and 4,700 clipped hatchery fish (10.1%). Fishery losses within the Salmon River were 216 wild fish (2.1%), 59 unclipped hatchery fish (3.2%), and 22,487 clipped hatchery fish (54.7%). We estimated escapement in the Salmon River was 9,871 wild fish, 1,774 unclipped hatchery fish, and 18,599 clipped hatchery fish.

Final dispositions are known for fish trapped at Pahsimeroi FH, EF Salmon weir, and Sawtooth FH. The Sawtooth FH trap operates on the Upper Salmon population. In 2016, a total of 5,444 clipped hatchery fish were trapped by the Pahsimeroi FH. Of these, 5,416 were spawned, and 28 were disposed of at the landfill. As a result, we estimated 1,633 hatchery steelhead (1,377 PAH^{c}, 197 DWOR^{u}, and 59 USAL^{u}) escaped the fishery and broodstock collection and were left to spawn in the Lemhi to Pahsimeroi (section 20). Additionally, 567 unclipped steelhead of the Upper Salmon B hatchery stock were removed at the Pahsimeroi FH weir and utilized for broodstock. Hatchery steelhead at large were assumed to remain in the main-stem Salmon River between the Lemhi and the Pahsimeroi rivers or stray into minor tributaries to that reach. Therefore, we estimated 63.2% of the Pahsimeroi spawning population was composed of hatchery fish. At the EF Salmon weir, removals were 30 wild fish and 16 unclipped hatchery fish utilized for integrated broodstock. Subtracting these fish leaves 40.0% of the EF Salmon spawning population composed of hatchery fish, of which 57.4% were clipped fish from segregated broodstocks (Sawtooth stock released at McNabb Point in the main stem Salmon River or Dworshak stock released in the lower EF Salmon). At the Sawtooth FH weir, a total of 3,466 clipped hatchery fish were removed. As a result, we estimated 1,286 clipped hatchery steelhead from Sawtooth FH and 300 unclipped fish (250 USAL, 50 DWOR) originally released into the Yankee Fork Salmon River, escaped the fishery and broodstock collection and were left to spawn, comprising 57.0% of the tributary spawning population. Clipped hatchery fish also escaped into the Little Salmon population (84.0% of the potential tributary spawners). Unclipped hatchery fish returned to Panther Creek and comprised 8.6% of the tributary spawning population.

Table 12. Reconstruction of wild and hatchery stocks in the Salmon River major population group (MPG). 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}.

	Abundance at					
Stock	**BON**	**ICH**	**LGR**	**Salmon Mouth**	**Escape**	**Left to Spawn**
Little Salmon wild	1,506	1,261	1,222	1,209	1,172	1,172
Little Salmon (OX,PAH,DWOR)^{c}	15,027	11,677	11,221	9,913	6,134	6,134
SF Salmon wild	1,201	1,006	975	964	951	951
Secesh wild	515	431	418	414	410	410
Chamberlain Creek wild	452	379	367	363	359	359
Lower Middle Fork wild	1,268	1,062	1,029	1,018	1,004	1,004
Upper Middle Fork wild	1,350	1,130	1,095	1,083	1,069	1,069
Panther Creek wild	459	385	373	369	360	360
Panther Cr Egg Boxes (PAH)^{u}	46	35	34	34	34	34
North Fork Salmon wild	263	220	213	211	207	207
Lemhi wild	1,475	1,235	1,197	1,184	1,150	1,150
Pahsimeroi wild	1,224	1,025	993	982	951	951
Salmon sec 20 (USAL)^{u}	873	678	652	645	626	59
Salmon sec 20 (DWOR)^{u}	275	214	205	203	197	197
Salmon sec 20 (PAH)^{c}	20,233	15,722	15,109	13,373	6,821	1,377
East Fork Salmon wild	1,303	1,091	1,057	1,046	1,008	978
East Fork Salmon (EFNA)^{u}	941	731	702	695	667	651
Salmon sec 21 (SAWT/EFNA)^{c}	3,155	2,451	2,356	2,086	891	879
Upper Salmon wild	1,574	1,319	1,278	1,265	1,196	1,196
Salmon sec 22 (USAL)^{u}	360	280	269	266	250	250
Salmon sec 22 (DWOR)^{u}	72	76	73	53	50	50
Salmon sec 22 (SAW/DWOR)^{c}	23,766	18,468	17,748	15,715	4,752	1,286
All Wild	**12,636**	**10,579**	**10,251**	**10,142**	**9,871**	**9,841**
Unclipped Hatchery	**2,495**	**1,938**	**1,862**	**1,844**	**1,774**	**1,191**
Clipped Hatchery	**62,180**	**48,319**	**46,434**	**41,086**	**18,599**	**9,677**
All Hatchery	**64,747**	**50,333**	**48,369**	**42,983**	**20,422**	**10,917**
Total	**77,337**	**60,877**	**58,586**	**53,091**	**30,259**	**20,724**

Imnaha River MPG

Abundance of stocks from the Imnaha MPG at BON was 3,821 wild fish and 4,186 clipped hatchery fish. We estimated that 1,038 wild fish (27.2%) and 1,069 hatchery fish (25.5%) were lost between BON and ICH. Abundance of wild fish at ICH and LGR was 2,783 fish and 2,733 fish, respectively. Abundance of hatchery fish at ICH and LGR was 3,117 fish and 2,997 fish respectively. Fishery losses within the lower Snake River (reach 1) were 17 wild fish (0.6%) and 206 clipped hatchery fish (6.9%). Fishery losses in the Snake River basin upstream of LGR (Reaches 3 and 4) were 26 wild fish (1.0%) and 307 clipped hatchery fish (10.2%). We estimate 2,707 wild steelhead and 2,690 hatchery steelhead reached the mouth of the Imnaha River. Fishery mortaltiy within the Imnaha were 6 wild fish (0.2%) and 75 clipped hatchery fish (2.8%). Therfore we estimated escapement in the Imnaha River was 2,701 wild fish and 2,615 clipped hatchery fish.

Final dispositions are known for fish within the Imnaha River that enter the Little Sheep Creek weir. There were 1,625 clipped hatchery fish trapped at the weir, but only 956 fish were retained for spawning. The remaining 669 fish were released, 154 passed over the Little Sheep Creek weir and 515 outplanted into Big Sheep Creek (E. Sedell, unpublished data). This leaves a total of 1,659 clipped hatchery fish available to spawn in the habitat, resulting in an estimated 38.1% of steelhead spawners in the Imnaha River of hatchery origin.

Hells Canyon MPG

Abundance at BON of hatchery fish released in the Hells Canyon MPG was 8,169 fish, of which 28 were unclipped (misclipped). We estimated that 1,079 fish (34.5%) were lost between BON and ICH, 10 unclipped fish, and 1,069 clipped fish. Total abundance at ICH and LGR was 5,351 fish and 5,149 fish respectively. Fishery losses within the lower Snake River (Reach 1) were 353 clipped hatchery steelhead (6.6%). Fishery mortality in the Snake River basin upstream of LGR (reaches 3, 4, and 5) were 676 fish (13.2%), again all clipped fish. We estimate 4,473 hatchery steelhead reached Hells Canyon. Fishery mortality of hatchery steelhead within Hells Canyon (reach 24) included 1,718 clipped fish, and catch data suggest 16 unclipped fish likely died after release, for at total of 1,734 fish. We estimated escapement in Hells Canyon was 2,739 hatchery fish, one unclipped (misclipped) and 2,738 clipped.

Final dispositions are known for fish that enter the Hells Canyon Dam fish trap. The trap captured 1,750 fish; 1,709 clipped and four unclipped hatchery fish, and 37 wild fish. All 37 wild fish were released below the dam. Of the 1,713 hatchery fish, 1,674 were retained. A total of 737 were spawned (734 clipped, 3 unclipped), 937 clipped hatchery fish were disposed, and 39 clipped fish were recycled back to the fishery. Subtracting these fish leaves 1,064 hatchery steelhead (all unclipped) left to potentially spawn. Thus, we estimate that 38.9% of the hatchery steelhead return to Hells Canyon was not impacted by harvest and were available to spawn or die within the population area.

DISCUSSION

This run reconstruction is our sixth effort to synthesize data for all wild populations and hatchery stocks within the Snake River basin. We attempted to quantify the fishery-related impacts on steelhead as they move to their natal or smolt release areas. In doing so, we summarized effects on natural adult populations and highlighted the benefits of hatchery programs. We estimated the steelhead run crossing BON bound for the Snake River totaled 44,631 wild fish, 110,195 clipped hatchery fish, and 6,878 unclipped hatchery fish. Of these, 84,026 adipose-clipped hatchery fish, 5,435 unmarked hatchery fish, and 36,514 wild steelhead entered the Snake River. Fishery-related mortality in the Snake River basin totaled 60,978 marked hatchery fish, 264 unmarked hatchery fish, and 1,025 wild steelhead. Further, 18,747 marked hatchery fish, 942 unmarked hatchery fish, and 92 wild fish were collected for broodstock or donated to food banks (only hatchery fish). Potential spawners remaining in the habitat totaled 30,903 clipped hatchery fish, 4,018 unclipped hatchery fish, and 34,868 wild steelhead (Figure 6). Note that most unclipped hatchery steelhead in the Snake River basin are intended to supplement natural spawning in wild populations, although a small portion of them in most years are inadvertent hatchery mis-clips. Losses between BON and ICH were 18.2% across all wild Snake River stocks, presumably most is due to anthropogenic sources. Lastly, fishery-related losses across all MPGs within the Snake basin were 3.4% on wild Snake River steelhead.

Efforts focused on compilation of data with general assumptions that may limit specific conclusions; however, the resulting analytical framework can be refined for more rigorous evaluations in the future. In the following discussion, we compare selected escapement estimates to independent data, review changes to model structure from previous versions, and close with several observations to consider for future work.

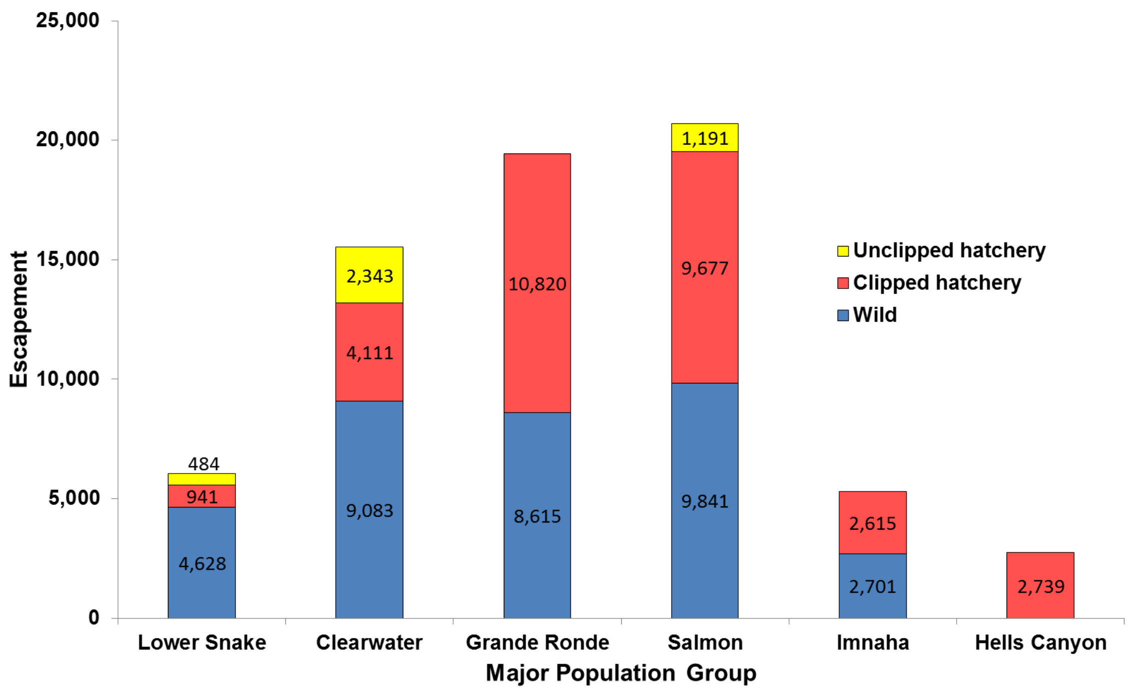

Figure 6. Comparison of steelhead escapement to the natural habitat for spawning by major population group (MPG) and origin type.

Comparison to independent data

The run reconstruction model produces estimates of escapement for all wild populations of steelhead in the Snake River basin, but in some locations (populations) our model estimates can be compared to independent abundance estimates (Table 13). We compiled select independent wild steelhead estimates, most based on In-stream PIT Tag Detections System (IPTDS) or PIT array detections in spawning streams (Orme and Kinzer 2018, Ebel in prep), but also summarized weir estimates (Dobos et al. 2017), and redd count expansions (Jonasson et al. 2017). The coverage or scale of most independent estimates were smaller than the population scales produced by the model, which follow the Interior Columbia Basin Technical Recovery Team population designations (TRT poulations, ICBTRT 2003). Therefore, in order to compare estimates equivocally, we utilized measures of steelhead spawning habitat IP, developed during the 2015 steelhead status review (NWFSC 2015), and estimated the proportion of the IP captured by each independent estimate within corresponding TRT populations. Next, we applied these proportions or weightings to the model estimates, then compared the resultant scaled model estimates to the independent estimates.

Comparison of scaled model estimates of wild steelhead escapement to independent IPTDS estimates were highly variable across populations. Seventeen out of 20 scaled model estimates (85%) were greater than the IPTDS estimate. Only three model estimates (Lolo Creek, Fish Creek, and Joseph Creek) were less than their paired independent estimate. It was encouraging that several model estimates were less than 25% different than their respective IPTDS estimate; including the Tucannon, Asotin Creek, lower Clearwater, Lolo Creek, SF Salmon, Big Creek, and NF Salmon. However, scaled model estimates for several populations departured greatly from their independent IPTDS estimates including the Wallowa, Rapid River, Lemhi, Pahsimeroi, Yankee Fork Salmon, and Upper Salmon populations. Model departure from independent estimates could be due to a variety of factors including: varying abundance of out-of-basin strays within populations and reporting groups; genetic similarity among stocks, the use of the IP habitat index as a metric of relative population density (and thus fish movement), and not accounting for natural mortality in the model. Furthermore, some have cautioned managers at the utility of the model for both wild and hatchery steelhead from the Lower Snake MPG, particularly given the complexity of their movements above and below LGR (Bumgarner, pers comm). from which the IPTDS estimates are generated.

Model changes

We continued to use PBT to parse abundance of hatchery fish at LGR, thereby avoiding potential bias of using PIT tag expansions as in previous methods (Copeland et al. 2013, 2014). Most of the parents of hatchery steelhead that returned in the 2015-16 run were genotyped (C. Steele, unpublished data), which allowed us to assign 99.8% of the hatchery origin fish sampled at LGR. Abundance estimates at LGR are adjusted for non-genotyped parents (either by sampling omission or failure to amplify). We also continue to use PBT instead of coded wire tag (CWT) recoveries to estimate straying of non-Clearwater populations into the lower Clearwater River fishery. We again used PBT assignments to release location for all groups as we did for the spawn year 2015 model, again with the exception of the Clearwater drainage DWOR stock releases. PBT assignments to release location are also allowing us to detect the presence of small groups of unclipped hatchery fish in the Snake River basin, both supplementation fish and mis-clipped mitigation releases. Although we can now estimate these numbers, they may be based upon only a few fish at LGR, likely making these estimates somewhat imprecise. Therefore, caution should be exercised in implying management decisions based on these estimates, nonetheless these small groups are reported.

Table 13. Comparison of Snake River Basin run reconstruction model spawn year 2016 wild steelhead escapement estimates, scaled by proportion of total spawning habitat intrinsic potential (IP), to In-stream PIT Tag Detection System (IPTDS) estimates, and other imdependent population estimates.

TRT Steelhead Population		Un-scaled Model Estimate	Independent Estimate		Scaled Model Estimate	PIT Array (IPTDS) Estimates*		Other Independent Estimates		
POP ID	Description		Unit	% of IP		Estimate	Sites Used	Estimate	Type	Source
SNTUC-s	Tucannon	1,153	Tucannon	60.1%	672	614	LTR	278	Array	Bumgarner (Pers Comm)
SNASO-s	Asotin Cr	1,547	Almota Cr	100.0%	1,547	1,331	ACM, PENAWC, ALMOTC, ALPOWC, TENMC2	33	Weir	Herr et al. 2018
			Alpowa Cr					187	Weir	Herr et al. 2018
			George Cr					890	Weir	Herr et al. 2018
			Asotin Cr							
CRLMA-s	Clearwater, lower mainstem	3,712	Clearwater, lower	44.6%	1,650	1,325	JUL, LAP, CLC	--	--	--
CRLOL-s	Lolo Cr	341	Lolo Cr	95.5%	341	378	LC1, LC2	--	--	--
CRSFC-s	SF Clearwater	1,693	SF Clearwater	81.8%	1,385	925	SC1, SC2	--	--	--
CRLOC-s	Lochsa	1,233	Fish Cr	7.1%	88	141	FISTRP	239	Weir	Dobos et al. 2017
GRJOS-s	Joseph Cr	1,034	Joseph Cr	99.0%	1,024	1,930	JOC	--	--	--
GRWAL-s	Wallowa	2,763	Wallowa	95.1%	2,628	941	WR1			
GRUMA-s	Grande Ronde, upper mainstem	3,408	Upper Grande Ronde	88.2%	3,006	1,605	UGR	2,572	Redds	Jonasson et al. 2017
IRMAI-s	Imnaha	2,704	Imnaha	96.0%	2,596	1,950	IR1	--	--	--
SRLSR-s	Little Salmon River	1,172	Rapid River	8.5%	100	26	RAPH	27	Weir	Dobos et al. 2017
SFMAI-s	SF Salmon	951	SF Salmon	96.3%	916	760	KRS, ESS, SFG_bb	--	--	--
SFSEC-s	Secesh	410	Secesh	99.2%	407	166	ZEN	--	--	--
MFBIG-s	MF Salmon, lower	1,004	Big Cr	37.9%	381	378	TAY	--	--	--
SRNFS-s	NF Salmon	207	NF Salmon	78.9%	163	157	NFS	--	--	--
SRLEM-s	Lemhi	1,150	Lemhi	93.1%	1,071	395	LLR, CRC	--	--	--
SRPAH-s	Pahsimeroi	951	Pahsimeroi	82.1%	781	71	PAHH	92	Weir	Dobos et al. 2017
SREFS-s	EF Salmon	978	EF Salmon	17.1%	167	92	SALEFT	71	Weir	Dobos et al. 2017
SRUMA-s	Salmon, upper mainstem	1,196	Yankee Fork Salmon	17.8%	212	45	YFK	25	Array	Ebel in prep
			Upper Salmon	31.2%	373	85	STL	73	Weir	Dobos et al. 2017

* *IPTDS estimates and sites from Orme and Kinzer 2018*

Other considerations

This year's model again estimated fewer fish were left to spawn than were known to have been retained at hatchery weirs at a couple locations. In the Clearwater MPG, the model estimated Clear Creek (Kooskia FH) and the South Fork Clearwater River (angler-captured brood) had -400 clipped DWOR stock steelhead and -28 clipped SFCW fish, respectively left to spawn (Table 10). Again, these negative values result from more fish being retained than were predicted to remain by the model. Although last year's model did not result in negative numbers, previous models often predicted negative numbers, particularly in the Upper Salmon River. Therefore, we could conclude that this year's estimate of Clear Creek ($DWOR^{c}$) and SF Clearwater ($SFCW^{c}$) hatchery fish returning to their natal reach is likely to have been underestimated and harvest for these hatchery stocks overestimated. Again, it is important to recognize the limitations of the data that go into the model when trying to interpret results.

Nonetheless, this run reconstruction effort was utilized in the 2015 ESA status review (NWFSC 2015), and likely will prove important for future status reviews by providing estimates of the proportion hatchery spawners (hatchery influence) and trends in natural origin abundance. However, higher precision estimates and greater population resolution remain elusive goals of this effort, before results can more broadly offer management guidance. Thus, before the next reporting period (return year 2016/2017) we will reconvene the entire interagency workgroup to review efforts to-date and provide recommendations for future analyses.

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 disposition and spatial distribution of spawning fish. In particular, this information is being used by LSRCP to evaluate mitigation goals, as well as by NOAA Fisheries to evaluate the performance of the Snake River steelhead ESU and ESA delisting criteria.. The run reconstruction process is a good arena for critical review of the data that managers in the basin use. The model can be used to bridge gaps in the existing data using reasonable assumptions in a structured manner. The resulting output will help future improvements (for example incorporating stray rates) will improve precision and accuracy.

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