SNAKE RIVER BASIN STEELHEAD
2014/2015 RUN RECONSTRUCTION

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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.

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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
GSI	Genetic Stock Identification
HUC4	4^{th} field Hydrologic Unit Code
ICH	Ice Harbor Dam
IDFG	Idaho Department of Fish and Game
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
TUC	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 was convened of representatives from the anadromous fishery management agencies within the Snake River basin. The immediate objective was to estimate the disposition of the 2014-2015 return of steelhead within the Snake River basin. After adjusting for nighttime passage and fallback, we estimated 112,986 adipose-clipped hatchery fish, 9,600 unmarked hatchery fish, and 46,271 wild steelhead entered the Snake River during the run (July 1, 2014 to June 30, 2015). Fishery-related mortality in the Snake River basin totaled 64,067 marked hatchery fish, 486 unmarked hatchery fish, and 1,678 wild steelhead. Further, 14,445 marked hatchery fish, 613 unmarked hatchery fish, and 68 wild fish were collected for broodstock or donated to food banks (only hatchery fish). Potential spawners remaining in the habitat totaled 35,430 marked hatchery fish, 7,904 unmarked hatchery fish, and 44,645 wild steelhead. Losses between Bonneville Dam and Ice Harbor Dam were 24.8% across all wild Snake River stocks, presumably most is due to anthropogenic sources, fishery-related losses within the Snake basin was only 3.3%. 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 US vs. Oregon agreement result in some unclipped releases of hatchery steelhead. Therefore, steelhead management in the Snake 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 fish (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 five 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 the 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 towards mitigation and management goals as well as ESA delisting criteria. To that end, a group was convened of representatives from the anadromous fishery management agencies within the Snake River basin. A model framework was proposed and development begun (Copeland et al. 2013, 2014, 2015; Stark et al. 2016a). It is the goal of the group to have a model suitable for providing management guidance after five years of work (by the 2015-2016 run reconstruction). The objectives of this report are to estimate the disposition of the 2014-2015 return of steelhead within the Snake River basin and continue refinement of the run reconstruction model. We caution the reader that the results presented here are preliminary and should be interpreted with care.

Table 1. List of wild populations and hatchery stocks of steelhead released in the Snake River basin during 2015 by major population group (MPG). Hatchery stocks are listed by MPG of release with an abbreviation given parentheses.

Wild Populations	Hatchery Stocks
Lower Snake	
Tucannon River	Lyons Ferry (LF[c]) & Tucannon endemic (TUC[u])
Asotin Creek	
Grande Ronde	
Lower Grande Ronde	Wallowa (WLH[c])
Joseph Creek	
Wallowa River	Wallowa (WLH[c])
Upper Grande Ronde	
Imnaha	
Imnaha River	Imnaha (IMH[c])
Clearwater	
Lower Mainstem Clearwater River	Dworshak (DWR[c])
South Fork Clearwater River	Dworshak (DWR[c,u])
Lolo Creek	Dworshak (DWR[u])
Selway River	
Lochsa River	
Salmon	
Little Salmon River	Oxbow (OX[c]), Pahsimeroi (PAH[c]), & Dworshak (DWR[c])
South Fork Salmon River	
Secesh River	
Chamberlain Creek	
Lower Middle Fork Salmon River	
Upper Middle Fork Salmon River	
Panther Creek	Pahsimeroi (PAH[u])
North Fork Salmon River	
Lemhi River	Pahsimeroi (PAH[c])
Pahsimeroi River	Pahsimeroi (PAH[c]) & Upper Salmon B (USB[u])
East Fork Salmon River	East Fork natural (EFN[u])
Upper Mainstem Salmon River	USB[c], Sawtooth (SAW[c,u]), & Dworshak (DWR[c])
Hells Canyon	
Hells Canyon (extirpated)	Oxbow (OX[c])

[c] *clipped hatchery releases*
[u] *unclipped hatchery releases*

METHODS

Study area

The study area is the portion of the Snake River basin that is currently accessible to anadromous fish. Historic range of steelhead in the Snake River extended all the way 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. Within the Snake River, the first dam encountered by adult steelhead is Ice Harbor Dam (ICH; Snake Rriver rkm 16). LGR, 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 *United States v. Oregon* Management Agreement, some unclipped hatchery fish are released in the Tucannon River (TUC), 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.

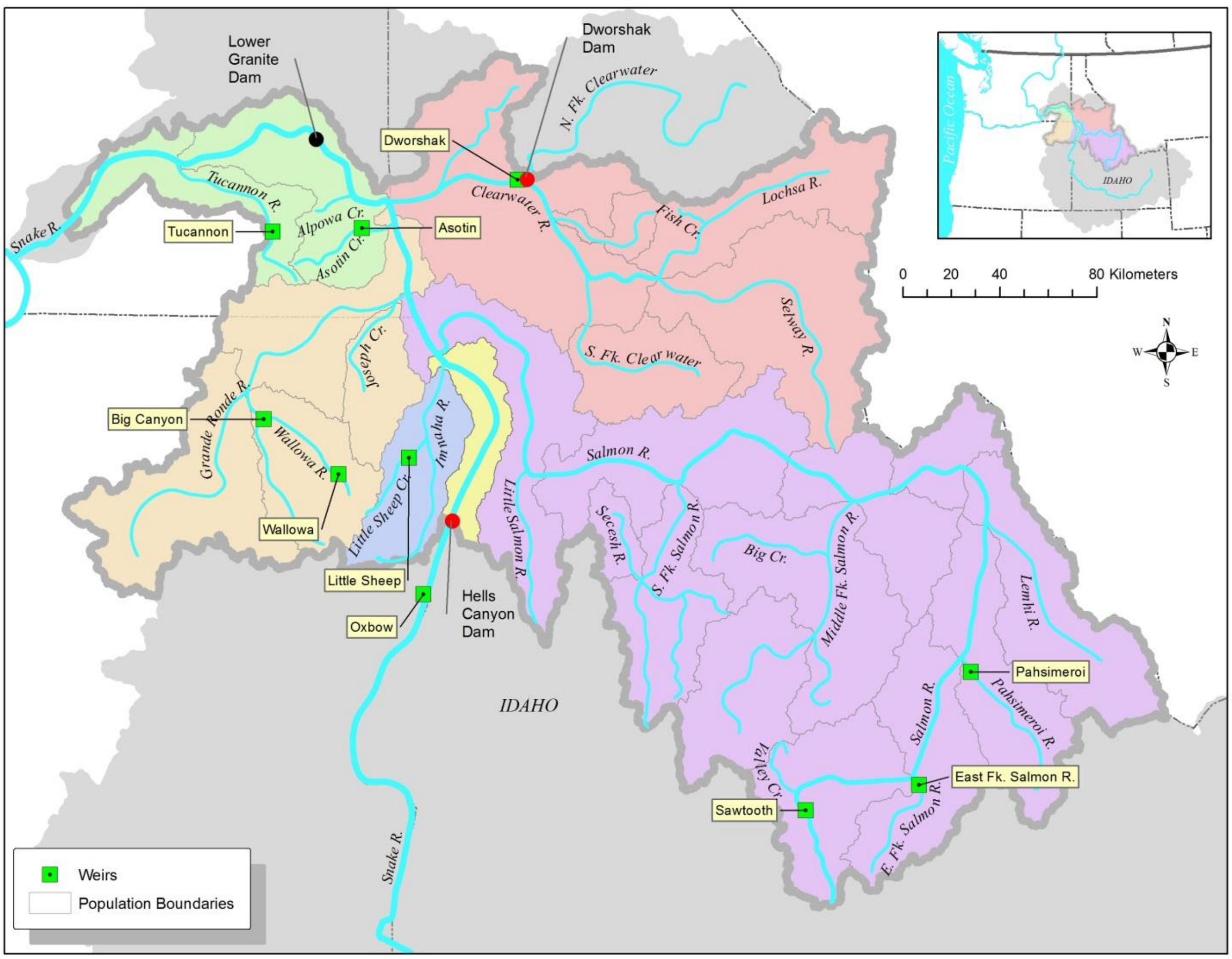

Figure 2. Snake River steelhead populations and locations of weirs. Major population groups (MPGs) are denoted by different colors.

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.

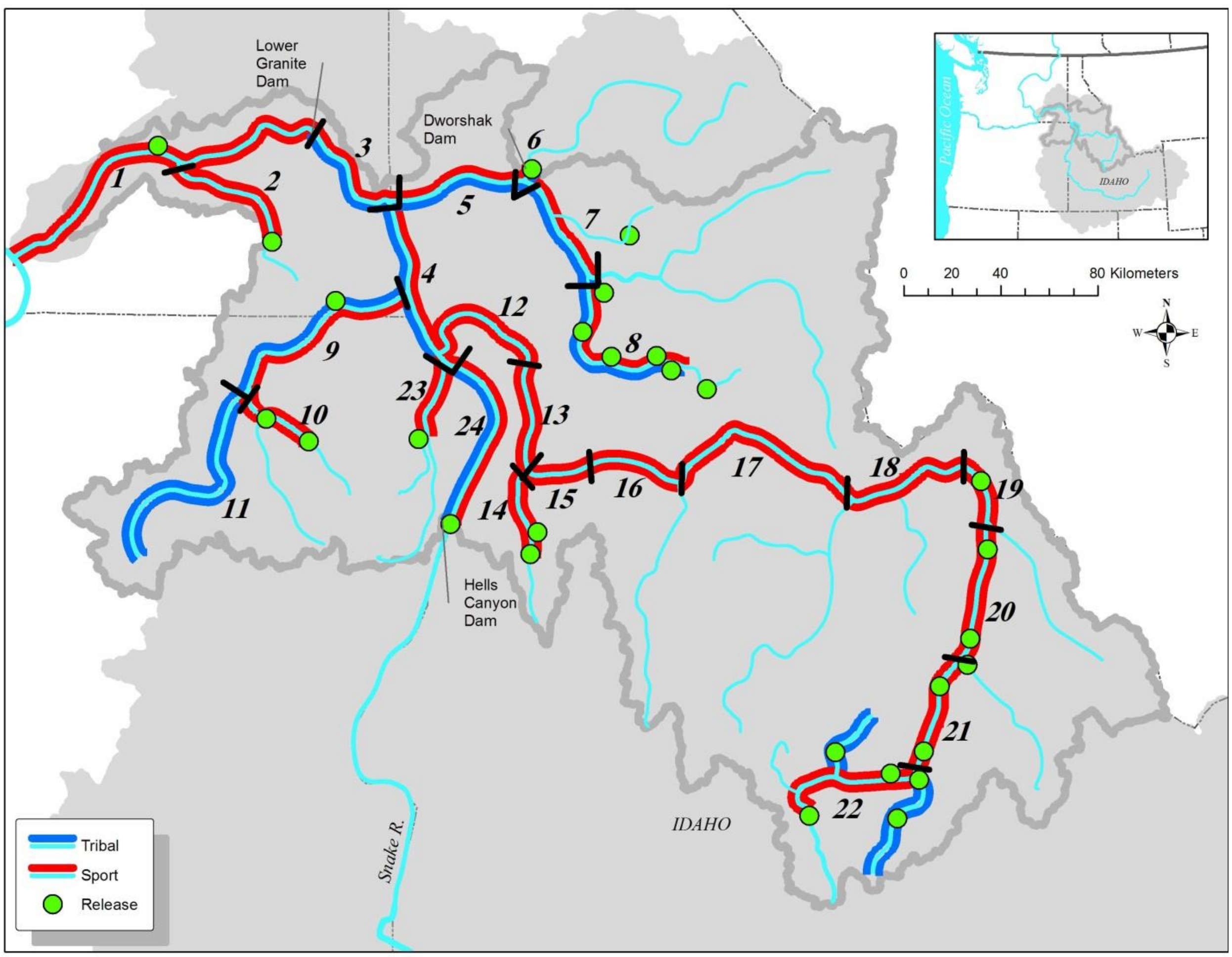

Figure 3. Location of hatchery steelhead release sites and boundaries of harvest reaches within the Snake River basin. Numbers represent the reaches represented as the smallest strata in the run reconstruction model. See Table 2 for reach descriptions.

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, 2014 to June 30, 2015 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. 2016). 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 Ackerman et al. (2016) 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 (Mike Ackerman, 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 2014-May 2015. 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 (TUC 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 2014 and 31 December 2014 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 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. 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. 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 (Ted Sedell, personal communication). Similarly, 2014-2015 fishery data were unavailable for the SBT, but in this river section we used 2008-2009 data (Brandt 2009), scaled to the 2014-2015 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 $p_{i,k\text{-}j}$ = 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 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 TUC 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%) falls back downstream into the Lower Snake reach. We used PIT tag detections at ICH, the lower TUC, and LGR to estimate movement probabilities of wild TUC fish, TUC endemic stock hatchery fish, and Lyons Ferry (LF) stock hatchery releases moving from ICH to the TUC or falling back over LGR into the TUC. 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 (TUC) 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. 2017). For each MPG (e.g., Lower Snake, Salmon River):

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

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 2014-2015, and stocking reaches for hatchery stocks. 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	Tucannon, Snake(LF^{c})
Tucannon River		
2. Mouth to Tucannon Fish Hatchery	WDFW	Tucannon, Tucannon (TUC^{u},LF^{c})
Snake River upstream from Lower Granite Dam		
3. Lower Granite to Clearwater River	WDFW, NPT	Asotin
4. Clearwater to Salmon/Imnaha	WDFW, IDFG	Asotin
24. Salmon/Imnaha to Hells Canyon Dam	IDFG	Snake (OX^{c})
Clearwater River		
5. Mouth to Orofino	IDFG, NPT	Lower Clearwater
6. North Fork Clearwater	IDFG, NPT	NF Clearwater (DWR^{c})
7.Orofino to Clear Creek	IDFG, NPT	Lower Clearwater, Lolo, Lolo (DWR^{u}), Clear Creek (DWR^{c}), Lochsa, Selway
8. South Fork Clearwater	IDFG, NPT	South Fork Clearwater, SF Clearwater (DWR^{u,c})
Grande Ronde River		
9. Mouth to Wallowa River	WDFW, ODFW	Lower Grande Ronde, Joseph Creek, Cottonwood (WLH$^{c)}$
10. Wallowa River	ODFW	Wallowa, Wallowa (WLH^{c})
11. Upstream of Wallowa River	CTUIR	Upper Grande Ronde
Imnaha River		
23. Mouth upstream	ODFW	Imnaha, Imnaha (IMH^{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, Ltl Salmon (PAH^{c},OX^{c},DWR^{c})
15. Little Salmon to Vinegar Creek	IDFG	NA
16. Vinegar to South Fork	IDFG	South Fork Salmon, Secesh, Chamberlain
17. South Fork to Middle Fork	IDFG	Chamberlain, Lower Middle Fork, Upper Middle Fork, Panther
18. Middle Fork to North Fork	IDFG	Panther, North Fork Salmon
19. North Fork to Lemhi	IDFG	Lemhi, Salmon sec 19 (PAH^{c})
20. Lemhi to Pahsimeroi	IDFG	Pahsimeroi, Salmon sec 20 (USB^{u},PAH^{c})
21. Pahsimeroi River to East Fork	IDFG, SBT	East Fork, Salmon sec 21 (EFN^{u},SAW^{c},DWR^{c})
22. East Fork upstream	IDFG, SBT	Upper Salmon, Salmon sec 22 (SAW^{u,c},DWR^{c},USB^{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 stocks that were detected at LGR.

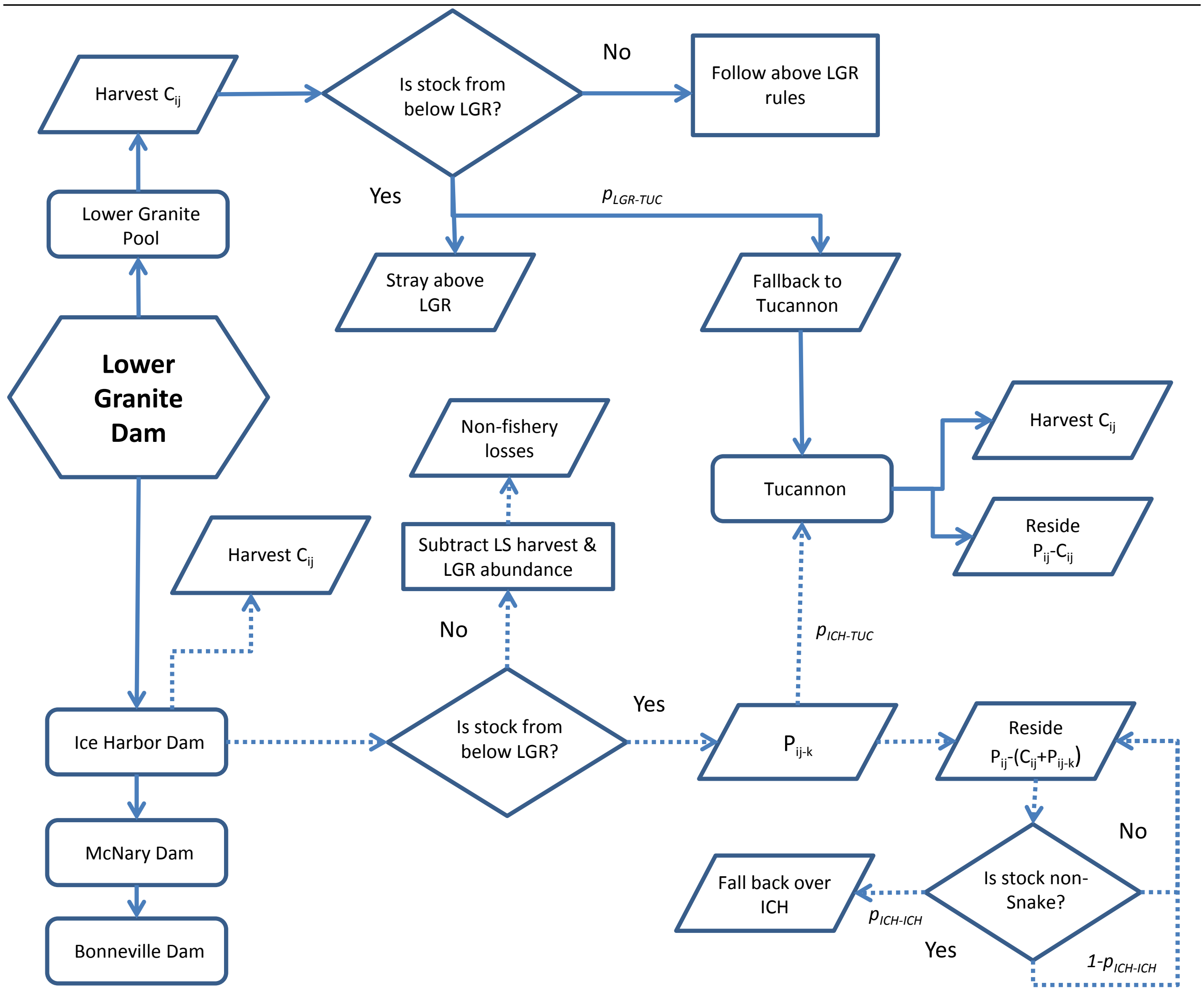

Figure 4. Flowchart for projection of abundance at Lower Granite Dam back to Bonneville Dam and movement of Lower Snake stocks between Ice Harbor Dam and Lower Granite pool.

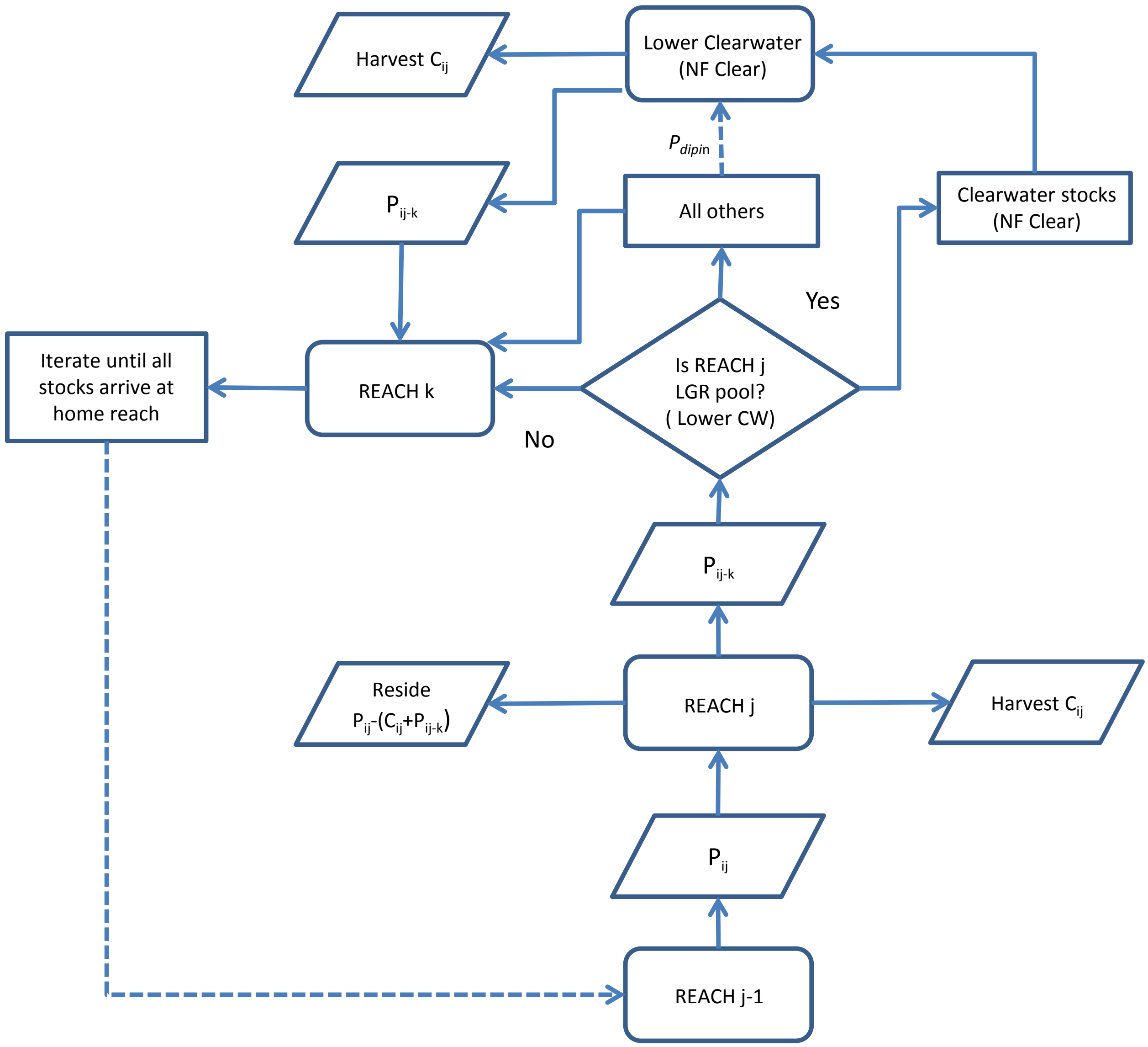

Figure 5. Flowchart for movement and fates of steelhead upstream of Lower Granite Dam. Abbreviations are explained in the text. Dip-in decisions are for non-Clearwater stocks in Lower Granite pool or for upper Clearwater/South Fork Clearwater stocks in the lower Clearwater (in parentheses).

RESULTS

Abundance at Lower Granite Dam

The preliminary (unadjusted) abundance estimates at LGR for the 2014-2015 steelhead run were 45,789 wild fish, 110,408 clipped hatchery fish, and 9,397 unclipped hatchery fish (Camacho et al. 2017). After incorporating night passage (6.51%) and re-ascensions (21.32% for Lower Snake stocks and 3.48% for all others), the adjusted estimates were 46,271 wild fish, 104,366 clipped hatchery fish, and 9,701 unclipped hatchery fish (Tables 3 and 4). Of the 24 hatchery release groups, one group was from a location outside of the Snake basin (from the Touchet River). The largest hatchery return group at LGR was bound for the Salmon River between the EF Salmon River and Sawtooth FH on the upper Salmon River (reach 22). Most unclipped hatchery steelhead were returning to SF Clearwater River or the EF Salmon River. We estimated that the largest wild population was the Upper Mainstem Grande Ronde River, although the Lower Clearwater River population was almost as large, and the smallest was the North Fork Salmon RIver.

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	5,709	5,020	4,823	2,923
Asotin Creek	Asotin wild	3,046	2,350	2,218	2,064
Lower Grande Ronde	Grande Ronde wild	2,732	2,071	2,027	1,882
Wallowa River	Grande Ronde wild	5,443	4,126	4,038	3,750
Joseph Creek	Grande Ronde wild	1,989	1,508	1,476	1,371
Upper Grande Ronde	Grande Ronde wild	6,555	4,969	4,863	4,516
Imnaha River	Imnaha wild	4,927	3,695	3,503	3,336
Lower Clearwater	Clearwater wild	5,994	4,812	4,641	4,454
Lolo Creek	Clearwater wild	689	553	533	512
South Fork Clearwater	Clearwater wild	3,504	2,813	2,713	2,604
Lochsa River	Clearwater wild	1,309	1,051	1,014	973
Selway River	Clearwater wild	2,247	1,804	1,740	1,670
Little Salmon River	Salmon wild	2,387	1,753	1,753	1,698
South Fork Salmon	Salmon wild	1,690	1,241	1,241	1,202
Secesh River	Salmon wild	725	532	532	515
Chamberlain Creek	Salmon wild	884	649	649	629
Lower Middle Fork	Salmon wild	2,480	1,821	1,821	1,764
Upper Middle Fork	Salmon wild	2,641	1,939	1,939	1,878
Panther Creek	Salmon wild	874	642	642	622
North Fork Salmon	Salmon wild	500	367	367	356
Lemhi River	Salmon wild	2,808	2,062	2,062	1,998
Pahsimeroi River	Salmon wild	2,330	1,711	1,711	1,658
East Fork Salmon	Salmon wild	2,480	1,821	1,821	1,764
Upper Salmon	Salmon wild	2,998	2,201	2,201	2,132
Total	**All Wild**	**66,941**	**51,511**	**50,328**	**46,271**

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**
Tucannon (TUC)[u]	Lower Snake hatchery	1,397	1,065	937	515
Tucannon (LF)[c]	Lower Snake hatchery	0	0	0	0
Snake (LF)[c]	Lower Snake hatchery	10,392	7,924	6,969	3,829
NF Clearwater (DWOR)[c]	Clearwater hatchery	17,671	14,550	14,257	14,048
Lolo Creek (DWOR)[u]	Clearwater hatchery	550	453	444	437
SF Clearwater (DWOR)[u]	Clearwater hatchery	6,297	5,185	5,081	5,006
SF Clearwater (DWOR)[c]	Clearwater hatchery	11,296	9,301	9,114	8,980
Clear Creek (DWOR)[c]	Clearwater hatchery	5,001	4,118	4,035	3,976
Cottonwood (WLH)[c]	Grande Ronde hatchery	14,039	9,869	9,609	9,198
Wallowa (WLH)[c]	Grande Ronde hatchery	21,151	14,868	14,095	13,492
Imnaha (IMH)[c]	Imnaha hatchery	6,464	5,070	4,831	4,463
Little Salmon (OX,PAH,DWOR)[c]	Salmon hatchery	18,555	14,532	13,927	13,252
Panther Cr Egg Boxes (PAH)[u]	Salmon hatchery	57	45	43	41
Salmon sec 19 (PAH)[c]	Salmon hatchery	1,989	1,558	1,493	1,421
Salmon sec 20 (USB)[u]	Salmon hatchery	600	470	451	429
Salmon sec 20 (DWOR)[u]	Salmon hatchery	616	483	463	440
Salmon sec 20 (PAH)[c]	Salmon hatchery	14,639	11,466	10,988	10,456
East Fork Salmon (EFN)[u]	Salmon hatchery	3,144	2,462	2,360	2,245
Salmon sec 21 (SAW/DWOR)[c]	Salmon hatchery	4,044	3,168	3,036	2,890
Yankee Fork Smolts (SAW)[u]	Salmon hatchery	824	645	618	588
Salmon sec 22 (USALB/SAW)[c]	Salmon hatchery	25,707	20,134	19,295	18,361
Snake (OX)[c]	Hells Canyon hatchery	11,853	9,542	9,244	8,933
	All Snake River basin Unclipped Hatchery	**13,485**	**10,808**	**10,396**	**9,701**
	All Snake River basin Clipped Hatchery	**150,949**	**116,558**	**111,649**	**104,366**
	Total Snake River Hatchery	**164,434**	**127,366**	**122,045**	**114,068**
Touchet (LF)[c]*	NA	30	23	20	11

Abundance at Ice Harbor, McNary, and Bonneville dams

We estimated that 66,941 wild, 150,949 hatchery clipped, and 13,485 hatchery unclipped steelhead from the Snake River basin passed BON. Of those, 50,328 wild, 111,649 hatchery clipped, and 10,396 hatchery unclipped steelhead, respectively entered the Snake River and passed ICH (Tables 3 and 4).

Conversion Rates

We detected 895 PIT-tagged wild steelhead and 2,803 PIT-tagged hatchery steelhead from the Snake River basin at BON. Conversion rates from BON to MCN ranged from 70.3% to 82.3% and 73.4% to 87.9% in the hatchery and wild groups, respectively. Conversion rates from MCN to ICH and ICH to LGR exceeded 88% for all hatchery and wild groups (Table 5). The conversion rate from BON to MCN averaged 77.7% for wild steelhead and 78.3% for hatchery steelhead. Conversion rates from MCN to ICH averaged 95.2% for wild fish and 96.6% for hatchery fish. Conversion rate from ICH to LGR averaged 95.7% for wild fish and 94.8% for hatchery fish for stocks originating upstream of LGR.

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, McNary, and Ice Harbor dams are in the denominator.

Stock	BON	at MCN	MCN rate	MCN	at ICH	ICH rate	ICH	at LGR	LGR rate
Lower Snake hatchery	219	167	76.3%	166	146	88.0%	135	73	NA
Gr Ronde hatchery	542	381	70.3%	379	369	97.4%	351	336	95.7%
Imnaha hatchery	408	320	78.4%	318	303	95.3%	289	267	92.4%
Clearwater hatchery	368	303	82.3%	298	292	98.0%	272	268	98.5%
Hells Canyon hatchery	159	128	80.5%	128	124	96.9%	119	115	96.6%
Salmon hatchery	1,107	867	78.3%	864	828	95.8%	785	747	95.2%
Total hatchery	**2,803**	**2,166**		**2,153**	**2,062**		**1,951**	**1,806**	
Lower Snake wild	116	102	87.9%	102	98	96.1%	88	62	NA
Asotin wild	162	125	77.2%	125	118	94.4%	115	107	93.0%
Gr Ronde wild	62	47	75.8%	47	46	97.9%	42	39	92.9%
Imnaha wild	128	96	75.0%	96	91	94.8%	84	80	95.2%
Clearwater wild	284	228	80.3%	225	217	96.4%	199	191	96.0%
Salmon wild	143	105	73.4%	104	104	100.0%	96	93	96.9%
Total wild	**895**	**703**		**699**	**674**		**624**	**572**	

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 Lyons Ferry stock release groups ranged from 30.0% to 53.1%, while 66.7% of the wild TUC fish crossed LGR. Of the Lower Snake fish that crossed ICH (all stocks and origins), 3.0% to 29.6% were estimated to move directly to the TUC and stay there. By subtraction, 7.8% to 43.8% stayed within the Lower Snake downstream of LGR as either mortalities or escapement. Note that these three probabilities include all possible fates for these stocks between ICH and LGR (i.e. - they sum to 1.0). Between 5.9% and 31.0% of the Lower Snake stocks ascending LGR fell back over LGR and entered the TUC. Similarly, 7.5% to 27.0% of the non-Snake steelhead that remained in the lower Snake River were eventually detected in the Walla Walla basin and considered to have fallen back over ICH after the fishery.

Temporary straying of non-Clearwater River steelhead stocks (p_{dip}) into the lower Clearwater River varied widely (Table 7). It was highest for Lower Snake stocks and lowest for Salmon River stocks with the other MPGs closer to the Salmon River estimate. However, Salmon River stocks composed the largest component of dip-ins in absolute numbers because of their greater abundance in Lower Granite pool. 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 7.0%. However, because the dip-in rate is based on harvest data, this should be considered a minimum estimate.

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				
Wild Population/ Hatchery Stock	**Ascend LGR**	**Enter TUC**	**Die/ Reside**	**Fallback over LGR, enter TUC**	**Fallback over ICH**
Lower Snake basin					
Snake (LF)[c]	0.5313	0.0313	0.4375	0.0588	0.0000
Tucannon (TUC)[u]	0.5612	0.2959	0.1429	0.3091	0.0000
Tucannon wild	0.6667	0.2549	0.0784	0.1176	0.0000
Walla Walla basin					
Touchet (LF)[c]	0.5000	0.0172	0.4828	0.1724	0.1034

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. 2017).

Hatchery Stock	Reach 5 Harvest	LGR Pool Abundance	Dip-in Rate
Lower Snake	416	4,339	33.2%
Grande Ronde	291	21,975	4.6%
Salmon	276	44,894	2.1%
Imnaha	236	4,336	18.9%
Hells Canyon	84	8,658	3.4%

Total fishery-related mortality of clipped hatchery fish within the study area was 68,632 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 1,473 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), Upper Snake River (reach 4), and the Lower Clearwater River (reach 5).

Lower Snake River MPG

Abundance of stocks from the Lower Snake MPG at BON was 8,236 wild fish, 1,397 unclipped TUC endemic stock, and 10,338 steelhead from the two Lyons Ferry FH clipped hatchery groups (Table 9). Losses between BON and ICH were estimated to be 1,633 wild fish (19.8%) and 3,865 (32.9%) hatchery fish. These fish crossed LGR in large numbers, even though stocks did not originate from upstream of LGR. Fishery-associated losses within reaches 1 and 2 were 36 wild fish (0.5%), 5 unclipped hatchery fish (0.5%), and 581 clipped hatchery fish (8.4%). Losses upstream of LGR (reaches 3 and 4) were 29 wild fish (0.6%), two unclipped hatchery fish (0.4%), and 416 clipped hatchery fish (9.6%).

Final dispositions are known for fish removed at Tucannon Fish Hatchery weir within the Lower Snake MPG (T. Miller, unpublished data). Lyons Ferry Hatchery trap operation was discontinued after the spring of 2013 (Todd Miller, personal communication). At the Tucannon Fish Hatchery weir, 337 wild fish and 181 hatchery fish were trapped, and 31 wild and 11 hatchery fish were retained for the endemic Tucannon (TUC^{u}) hatchery stock. An additional 236 steelhead were trapped at the Penewawa Creek weir: 154 wild fish, one unclipped TUC^{u}, and 81 adipose-clipped Tucannon River LF stock fish (LF^{c}). All wild fish were released to spawn above the weir, and all 82 hatchery fish were spawned for the TUC^{u} broodstock. No steelhead were trapped at the Alkali Flats Creek weir in 2014-2015. Lastly, 22 additional TUC^{u} and 63 LF^{c} Tucannon hatchery fish were trapped and retained at the Asotin and George Creek weirs (16 TUC^{u}, 48 LF^{c}) and the Alpowa Creek weir (6 TUC^{u}, 15 LF^{c}) upstream of LGR. After subtracting all retained fish, we estimated 2,609 wild fish, 883 unclipped hatchery fish (TUC^{u}), and 3,433 clipped hatchery fish (LF^{c}) were left to spawn in the Tucannon River and Lower Snake River below LGR (Table 9). An additional 2,132 wild, three unclipped hatchery (TUC^{u}), and 2,480 clipped hatchery (LF^{c}) Tucannon River fish were estimated to be left to spawn in the Lower Granite pool of the Snake River upstream of LGR.

Table 8. Estimated fishery mortalities by river reach and mark type. Mortality for clipped fish is divided into harvest and catch-and-release mortality.

		Clipped	
River and Reach	Unclipped	Harvest	Catch-and-Release
1. Lower Snake	272	7,812	13
2. Tucannon	6	132	0
3. Lower Granite Pool	127	3,453	5
4. Upper Snake	229	6,146	98
5. Lower Clearwater	218	8,910	630
6. North Fork Clearwater	41	5,253	257
7. Clearwater to Clear Creek	48	2,378	164
8. South Fork Clearwater	103	2,249	234
9. Lower Grande Ronde	90	3,894	198
10. Wallowa River	0	2,110	70
11. Upper Grande Ronde	0	0	0
12. Salmon to White Bird	25	1,336	31
13. Salmon (WB-Little Salmon)	34	2,577	159
14. Little Salmon	41	3,292	238
15. Salmon (LS to Vinegar)	21	2,267	59
16. Salmon (Vinegar to SF)	20	501	20
17. Salmon (SF to MF)	37	1,055	46
18. Salmon (MF to NF)	67	4,934	236
19. Salmon (NF to Lemhi)	30	1,718	133
20. Salmon (Lemhi to Pahsimeroi)	17	1,430	83
21. Salmon (Pahsimeroi to EF)	11	623	69
22. Salmon (EF upstream)	13	1,416	155
23. Imnaha	0	242	6
24. Hells Canyon	23	1,948	52

We estimated 20 non-Snake River clipped hatchery steelhead (LF stock) that were released in the Touchet River of the Walla Walla basin of Washington, passed ICH and contributed to fisheries in the Snake River (Table 9). But after falling back downstream over LGR, 19 were estimated to have escaped, and 15 were left to spawn in the Lower Snake River below LGR. A total of eleven fish passed LGR, but after fallback to the LS, five escaped to the Snake River above LGR, and three were estimated left to spawn there (Table 9). Lastly, although they were not found among hatchery fish trapped and sampled for PBT at LGR, three additional Walla Walla basin hatchery fish were trapped and retained above LGR; one unclipped Touchet River endemic (TOU^u) fish, one Walla Walla River clipped LF stock fish at the Asotin Creek weir, and one Walla Walla River clipped LF stock fish at the Alpowa weir.

Final disposition of the Asotin Creek population is known via fish captured at Asotin Creek, Ten Mile, and Alpowa weirs. 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. However, 931 wild fish were captured at the Asotin

Creek weir, 33 at the Ten Mile weir, and 158 at the Alpowa weir; all were released upstream to spawn naturally. After harvest was removed, 144 wild Asotin Creek steelhead were estimated to escape to the Lower Snake River below LGR; however, none were left to spawn. These fish likely wintered below LGR and strayed or died. Above LGR, 2,040 wild Asotin Creek fish were estimated to have escaped the fishery, all of these were left to spawn (Table 9).

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**	**LGR**	**LGR**	**LGR**	**LGR**
Lower Snake stocks							
Tucannon wild	5,190	4,385	2,923	2,640	2,132	2,640	2,132
Tucannon (TUC)[u]	1,397	937	515	894	25	894	25
Snake (LF)[c]	10,338	6,933	3,809	3,433	2,480	3,433	2,480
Asotin wild	3,046	2,218	2,064	144	2,040	0	2,040
All Wild	**8,236**	**6,603**	**4,987**	**2,784**	**4,172**	**2,640**	**4,172**
Unclipped Hatchery	**1,397**	**937**	**515**	**894**	**25**	**894**	**25**
Clipped Hatchery	**10,338**	**6,933**	**3,809**	**3,433**	**2,480**	**3,433**	**2,480**
All Hatchery	**11,735**	**7,870**	**4,324**	**4,327**	**2,505**	**4,327**	**2,505**
Total	**19,971**	**14,473**	**9,311**	**7,111**	**6,677**	**6,967**	**6,677**
Walla Walla basin releases							
Touchet (LF)[c]	30	20	11	19	5	15	5

Escapements for this MPG were greater for hatchery populations in the Tucannon River and Lower Snake River below LGR, but greater for wild populations in Asotin Creek and the Snake River above LGR. For the Tucannon population, 62.1% of the potential spawners were hatchery fish, and for the entire Lower Snake MPG, both above and below LGR, 49.6% of spawners were of hatchery origin.

Clearwater River MPG

Abundance of stocks from the Clearwater MPG at BON was 13,743 wild steelhead; 6,847 unclipped hatchery steelhead; and 33,968 clipped hatchery steelhead (Table 10). Between BON and ICH, we estimated that 3,102 wild fish (22.6%) and 7,884 hatchery fish (19.3%) were lost. Fishery-associated losses within the lower Snake River (reach 1) were 49 wild fish (0.5%), 26 unclipped hatchery fish (0.5%), and 1,774 clipped hatchery fish (6.5%). Losses in the Snake River upstream of LGR (LGR Pool, reach 3) were 22 wild fish (0.2%), 11 unclipped hatchery fish (0.2%), and 824 clipped hatchery fish (3.1%). Losses within the Clearwater River were 188 wild fish (1.8%), 177 unclipped hatchery fish (3.3%), and 17,535 clipped hatchery fish (67.0%). Fishery impacts on non-Clearwater stocks in the lower Clearwater River (reach 5) were estimated to be 32 wild fish, 3 unclipped hatchery fish and 1,256 clipped hatchery fish. The total fishery-related losses within this reach composed of non-Clearwater fish were 22.1%, 4.8%, and 14.1% for wild, unclipped hatchery, and clipped hatchery groups, respectively. We estimated escapement in the Clearwater River was 10,003 wild fish, 5,255 unclipped hatchery fish, and 8,614 clipped hatchery fish. Clipped hatchery fish escaped the fishery in NF Clearwater River and Clear Creek.

Final dispositions are known for fish within the Clearwater River basin that enter hatchery weirs at Dworshak Fish Hatchery (NF Clearwater River), Kooskia Fish Hatchery (Clear Creek, a tributary to MF Clearwater River), and Crooked River (tributary to SF Clearwater River). Fish collected at Kooskia Fish Hatchery are typically recycled to the fishery, as are fish in excess of broodstock needs at Dworshak Hatchery. These two hatcheries operate within the Lower Clearwater population. During the 2014-2015 run, Dworshak Fish Hatchery collected 3,723 clipped hatchery fish, 1,502 were retained for broodstock, and the remaining 2,221 were recycled back to the fishery. As a result, 3,176 Dworshak stock clipped hatchery steelhead were left to spawn During the 2014-2015 run, Kooskia Fish Hatchery trapped 224 clipped hatchery fish; all were recycled back into the fishery. Thus, in Clear Creek 1,897 clipped Dworshak stock hatchery steelhead were left to spawn. A total of 345 fish were collected by angling in the SF Clearwater River for broodstock: 187 clipped hatchery fish and 158 unclipped hatchery fish (identified by dorsal fin erosion). Therefore, we estimate 72.1% of the SF Clearwater spawning population was composed of hatchery fish. Lastly, the model predicted unclipped hatchery fish escaped into Lolo Creek and made up 46.0% 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	5,994	4,641	4,454	4,445	4,396	4,396
NF Clearwater (DWR)^{c}	17,671	14,257	14,048	13,620	4,678	3,176
Lolo Creek wild	689	533	512	511	501	501
Lolo Creek (DWR)^{u}	550	444	437	436	427	427
Clear (DWR)^{c}	5,001	4,035	3,976	3,854	1,897	1,897
SF Clearwater (DWR)^{u}	6,297	5,081	5,006	4,996	4,828	4,670
SF Clearwater (DWR)^{c}	11,296	9,114	8,980	8,706	2,039	1,852
SF Clearwater wild	3,504	2,713	2,604	2,598	2,519	2,519
Lochsa River wild	1,309	1,014	973	971	952	952
Selway River wild	2,247	1,740	1,670	1,666	1,635	1,635
All Wild	**13,743**	**10,641**	**10,213**	**10,191**	**10,003**	**10,003**
Unclipped Hatchery	**6,847**	**5,525**	**5,443**	**5,432**	**5,255**	**5,097**
Clipped Hatchery	**33,968**	**27,406**	**27,004**	**26,180**	**8,614**	**6,925**
All Hatchery	**40,815**	**32,931**	**32,447**	**31,612**	**13,869**	**12,022**
Total	**54,558**	**43,572**	**42,660**	**41,803**	**23,872**	**22,025**

Grande Ronde River MPG

Abundance of stocks from the Grande Ronde MPG at BON was 16,719 wild fish and 28,535 for clipped hatchery release groups (Table 11). We estimated that 4,315 wild fish (25.8%) and 4,831 (16.9%) hatchery fish were lost between BON and ICH. Fishery-associated losses within the lower Snake River (reach 1) were 57 wild fish (0.5%) and 1,531 clipped hatchery fish (6.5%). Fishery losses in the basin upstream of LGR (reaches 3, 4, and 5) were 101 wild fish (0.9%) and 2,637 clipped hatchery fish (11.6%). Fishery losses within the Grande Ronde River were 91 wild fish (0.8%) and 6,004 clipped hatchery fish (30.4%). We estimated escapement in the Grande Ronde River was 11,327 wild fish and 13,740 clipped hatchery fish.

Final dispositions are known for fish trapped at Wallowa Hatchery, Big Canyon acclimation pond (tributary to the Wallowa River), and Cottonwood acclimation pond (at rkm 46 on the Grande Ronde River). There were 316 clipped hatchery fish removed at Cottonwood weir (T. Miller, unpublished data). There were 3,315 clipped hatchery fish removed at the Wallowa Hatchery and Big Canyon weirs (E. Sedell, unpublished data). Therefore, we estimated 65.1% of the Lower Grande Ronde and 52.9% 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	2,732	2,027	1,882	1,866	1,851	1,851
Joseph Creek wild	1,989	1,476	1,371	1,359	1,348	1,348
Cottonwood (WLH)^{c}	7,020	9,609	9,198	7,835	6,291	5,975
Wallowa wild	5,443	4,038	3,750	3,716	3,687	3,687
Wallowa (WLH)^{c}	21,515	14,095	13,492	11,909	7,449	4,134
Upper Grande Ronde wild	6,555	4,863	4,516	4,477	4,441	4,441
All Wild	**16,719**	**12,404**	**11,519**	**11,418**	**11,327**	**11,327**
All Hatchery	**28,535**	**23,704**	**22,690**	**19,744**	**13,740**	**10,109**
Total	**45,254**	**36,108**	**34,209**	**31,162**	**25,067**	**21,436**

Salmon River MPG

Abundance of stocks from the Salmon River MPG at BON was 22,854 wild fish; 4,625 unclipped hatchery releases; and 64,934 clipped hatchery release groups (Table 12). We estimated that 6,072 (26.6%) wild fish and 18,101 (25.8%) hatchery fish were lost between BON and ICH. Fishery losses within the lower Snake River (reach 1) were 525 wild fish (3.1%), 169 unclipped hatchery fish (4.9%), and 1,729 clipped hatchery fish (3.6%). Fishery losses in the Snake River upstream of LGR (reaches 3, 4, and 5) were 135 wild fish (0.8%), 29 unclipped hatchery fish (0.8%), and 5,168 clipped hatchery fish (11.2%). Fishery losses within the Salmon River were 243 wild fish (1.5%), 67 unclipped hatchery fish (2.0%), and 21,222 clipped hatchery fish (51.6%). We estimated escapement in the Salmon River was 15,879 wild fish, 3,314 unclipped hatchery fish, and 19,994 clipped hatchery fish.

Final dispositions are known for fish trapped at Pahsimeroi Hatchery, EF Salmon weir, and Sawtooth Hatchery. The Sawtooth FH trap operates on the Upper Salmon population. In 2015, a total of 3,758 clipped hatchery fish were trapped by the Pahsimeroi Hatchery. Although only 1,217 of these were spawned and carcasses distributed to the public; the remainder (2,541) were outplanted into kids fishing ponds (406) or given as carcasses to the public, the local foodbank, the Shoshone-Paiute Tribe, Shoshone-Bannock Tribe; and some were disposed of at the landfill. As a result, we estimated 824 clipped hatchery steelhead from Pahsimeroi FH escaped the fishery and broodstock collection and were left to spawn. Additionally, 411 unclipped steelhead of the Upper Salmon B hatchery stock were removed at the Pahsimeroi 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 36.7% of the Pahsimeroi spawning population was composed of hatchery fish. At the EF Salmon weir, removals were 26 wild fish and 11 unclipped hatchery fish utilized for integrated broodstock. Subtracting these fish leaves 66.8% of the EF Salmon spawning population composed of hatchery fish, of which 35.5% 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 weir, a total of 3,849 clipped hatchery fish were removed. As a result, we estimated 2,301 clipped hatchery steelhead from Sawtooth FH and 568 unclipped fish released into the Yankee Fork escaped the fishery and broodstock collection and were left to spawn, comprising 58.2% of the spawning population. Clipped hatchery fish also escaped into the Lemhi population (26.2% of the potential spawners) and Little Salmon population (81.8% of the potential spawners). Unclipped hatchery fish returned to Panther Creek and comprised 6.3% of the 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 River Mouth**	**Escape**	**Left to Spawn**
Little Salmon wild	2,387	1,753	1,698	1,684	1,641	1,641
Little Salmon (OX,PAH,DWOR)[c]	18,555	13,297	13,252	11,784	7,372	7,372
SF Salmon wild	1,690	1,241	1,202	1,192	1,184	1,184
Secesh wild	725	532	515	511	507	507
Chamberlain Creek wild	884	649	629	624	620	620
Lower Middle Fork wild	2,480	1,821	1,764	1,749	1,736	1,736
Upper Middle Fork wild	2,641	1,939	1,878	1,863	1,850	1,850
Panther Creek wild	874	642	622	617	609	609
Panther Cr Egg Boxes (PAH)[u]	57	43	41	41	41	41
North Fork Salmon wild	500	367	356	353	349	349
Lemhi wild	2,808	2,062	1,998	1,981	1,950	1,950
Salmon sec 19 (PAH)[c]	1,989	1,493	1,421	1,264	692	692
Pahsimeroi wild	2,330	1,711	1,658	1,644	1,614	1,614
Salmon sec 20 (USB)[u]	600	451	429	426	417	6
Salmon sec 20 (DWOR)[u]	616	493	440	107	105	105
Salmon sec 20 (PAH)[c]	14,510	10,891	10,364	9,213	4,582	824
East Fork Salmon wild	2,480	1,821	1,764	1,749	1,715	1,678
East Fork Salmon (EFN)[u]	3,144	2,360	2,245	2,225	2,184	2,173
Salmon sec 21 (SAW/DWOR)[c]	4,044	3,036	2,890	2,570	1,197	1,197
Upper Salmon wild	2,998	2,201	2,132	2,114	2,063	2,063
Yankee Fork Salmon (SAW)[u]	824	618	588	583	568	568
Salmon sec 22 (SAW/DWOR)[c]	25,707	19,295	18,361	16,318	6,150	2,301
All Wild	**22,854**	**16,782**	**16,257**	**16,122**	**15,879**	**15,842**
Unclipped Hatchery	**5,241**	**3,965**	**3,743**	**3,382**	**3,314**	**2,892**
Clipped Hatchery	**64,805**	**48,012**	**46,288**	**41,148**	**19,994**	**12,387**
All Hatchery	**70,046**	**51,977**	**50,031**	**44,530**	**23,308**	**15,279**
Total	**92,843**	**68,716**	**66,247**	**60,611**	**39,146**	**31,080**

Imnaha River MPG

Abundance of stocks from the Imnaha MPG at BON was 4,927 wild fish and 6,464 clipped hatchery fish. We estimated that 1,424 wild fish (28.9%) and 1,633 hatchery fish (25.3%) were lost between BON and ICH. Abundance of wild fish at ICH and LGR was 3,503 fish and 3,336 fish, respectively. Abundance of hatchery fish at ICH and LGR was 4,831 fish and 4,463 fish respectively. Fishery losses within the lower Snake River (reach 1) were 167 wild fish (4.8%) and 368 clipped hatchery fish (7.6%). Fishery losses in the Snake River basin upstream of LGR (reaches 3 and 4) were 35 wild fish (1.0%) and 692 clipped hatchery fish (15.5%). We estimate 3,301 wild steelhead and 3,771 hatchery steelhead reached the mouth of the Imnaha River. Fishery mortaltiy within the Imnaha were 0 wild fish (0.0%) and 242 clipped hatchery fish (6.4%). Therfore we estimated escapement in the Imnaha River was 3,301 wild fish and 3,529 clipped hatchery fish.

Final dispositions are known for fish within the Imnaha River that enter the Little Sheep Creek weir. There were 1,080 clipped hatchery fish trapped at the weir, but only 654 fish were retained for spawning. The remaining 426 fish were released, 71 passed over the Little Sheep Creek weir and 355 outplanted into Big Sheep Creek (E. Sedell, unpublished data). This leaves a total of 2,875 clipped hatchery fish available to spawn in the habitat; therefore, 46.6% of the steelhead spawners in the Imnaha River were hatchery steelhead.

Hells Canyon MPG

Abundance at BON of hatchery fish released in the Hells Canyon MPG was 11,853 fish, of which 29 were unclipped. We estimated that 2,609 fish (22.0%) were lost between BON and ICH, 7 unclipped fish, and 2,602 clipped fish. Total abundance at ICH and LGR was 9,244 fish and 8,933 fish respectively. Fishery losses within the lower Snake River (reach 1) were 598 hatchery steelhead, all clipped fish (6.5%). Fishery mortality in the Snake River basin upstream of LGR (reaches 3, 4, and 5) were 1,020 fish (11.4%), again all clipped fish. We estimate 7,913 steelhead reached Hells Canyon. Fishery mortality of hatchery steelhead within Hells Canyon (reach 24) included 1,954 clipped fish, and catch data suggest 5 unclipped fish likely died after release, for at total of 1,959 fish (24.8)%. We estimated escapement in Hells Canyon was, 16 unclipped hatchery fish, and 5,938 clipped hatchery fish.

Final dispositions are known for fish that enter the Hells Canyon Dam fish trap. The trap collected 763 fish; 44 unclipped and 719 adipose-clipped hatchery fish, All unclipped fish were released below the dam. Of the 719 clipped hatchery fish retained, 540 were spawned and 94 were disposed of. Subtracting these fish leaves 5,219 hatchery steelhead (5,203 clipped, 16 unclipped) left to potentially spawn. Thus, we estimate that 66.0% of the hatchery return to Hells Canyon were not accounted for by harvest impacts and were available to spawn or die within the population area.

DISCUSSION

This run reconstruction is our fifth 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 release areas. In doing so, we summarized effects on natural populations and highlighted the benefits of hatchery programs. We estimated the steelhead run crossing BON bound for the Snake River totaled 66,941 wild fish, 150,949 clipped hatchery fish, and 13,485 unclipped hatchery fish. Of these, 111,649 adipose-clipped hatchery fish, 10,396 unmarked hatchery fish, and 50,328 wild steelhead entered the Snake

River. Fishery-related mortality in the Snake River basin totaled 64,067 marked hatchery fish, 486 unmarked hatchery fish, and 1,678 wild steelhead. Further, 14,445 marked hatchery fish, 613 unmarked hatchery fish, and 68 wild fish were collected for broodstock or donated to food banks (only hatchery fish). Potential spawners remaining in the habitat totaled 35,430 clipped hatchery fish, 7,904 unclipped hatchery fish, and 44,645 wild steelhead (Figure 6). Note that unclipped hatchery steelhead were (for the most part) intended to supplement natural spawning in wild populations, although a small portion of them were inadvertent hatchery mis-clips. Losses between BON and ICH were 24.8% across all wild Snake River stocks, presumably most is due to anthropogenic sources, and fishery-related losses within the Snake basin were 3.3%.

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.

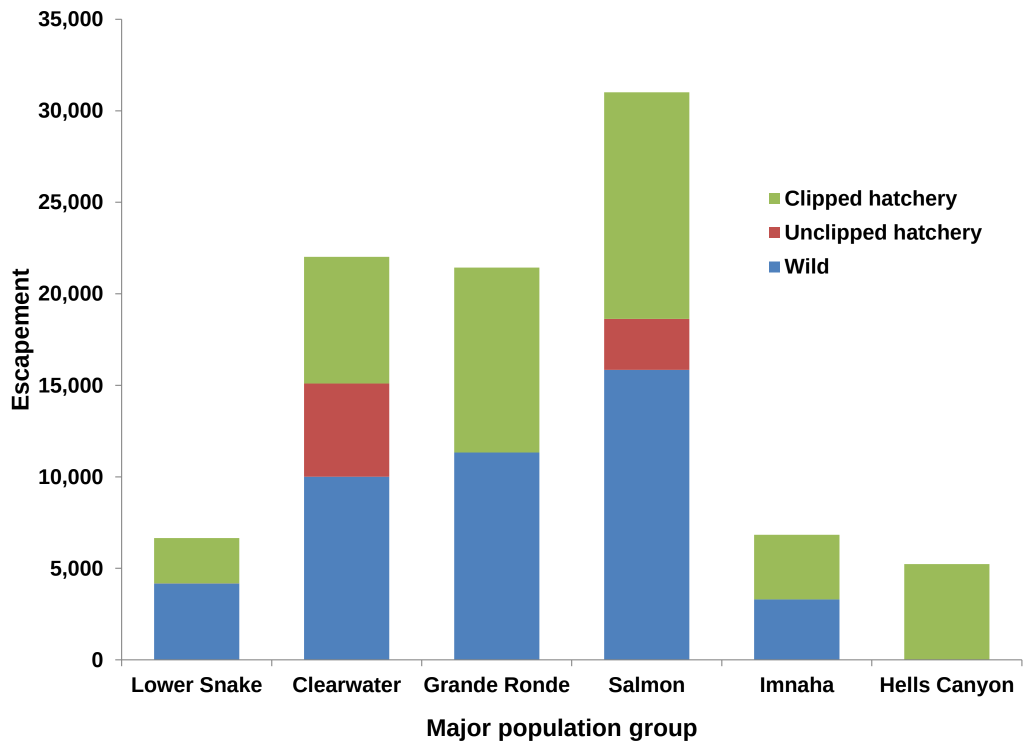

Figure 6. Comparison of steelhead escapement to the natural habitat for spawning by major population group (MPG) and origin type.

Comparison to independent data

We compiled selected data to evaluate escapement estimates for wild steelhead (Table 13). These data were population estimates based on weir counts (T. Miller, unpublished data; Stark et al. 2016b), PIT array detections in spawning streams (K. See, Quantitative Consultants Inc., BPA Project # 2003-017-00, unpublished data), and redd count expansions

(Jonasson et al. 2016). The coverage of most of these independent estimates was smaller than the population level, so we used relative amount of weighted intrinsic spawning habitat potential to scale our escapement estimates to the independent data. In a few cases, the scale of the independent estimate was less than a defined spawning aggregate, so we estimated the proportion of habitat captured by the independent estimate within the spawning aggregate from the maps in the 2015 steelhead status assessment (NWFSC 2015). The Tucannon PIT array is near the river mouth, so we used the pre-fishery abundance estimate.

Half of the run reconstruction escapements for wild populations were less than independent estimates half were greater than the independent estimates. The average magnitude of the overestimates was greater than for underestimates (3.3 versus 1.9, as the proportion of the independent estimate). The greatest proportional departures between the run reconstruction estimates and independent estimates were found for the Fish Creek, Wallowa River, and Upper Salmon populations. Nonetheless, significant departures between estimates were found across genetic reporting groups. 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 intrinsic potential habitat index as a metric of relative population density (and thus fish movement); and occurrence of natural mortality, which is not accounted for in the model.

Table 13. Comparison of run reconstruction wild steelhead escapements scaled by spawning habitat intrinsic potential to independent population estimates. Asterisks indicate units smaller or larger than populations of the same name. Confidence intervals are in parentheses.

Scaled model prediction		**Independent data**		
Unit	**Estimate**	**Estimate**	**Type**	**Source**
Tucannon*	1,063	278 (174-280)	PIT array	TM, unpublished data
Asotin Creek*	648	931	Weir count	TM, unpublished data
Alpowa Creek	260	158	Weir count	TM, unpublished data
Fish Creek	105	453 (423-486)	Weir estimate	Stark et al. 2015
Lolo Creek	501	561 (470-688)	PIT array	KS, unpublished data
SF Clearwater R	1,597	935 (761-1,081)	PIT array	KS, unpublished data
Joseph Creek	1,348	3,023 (2,633-3,358)	PIT array	KS, unpublished data
Wallowa R	3,687	917 (777-1,052)	PIT array	KS, unpublished data
Upper Grande Ronde	4,441	4,837 (2,946-6,728)	Redd estimate	Jonasson et al. 2016
SF Salmon R	1,184	1,713 (1,495-1,975)	PIT array	KS, unpublished data
Big Creek	516	818 (402-1,644)	PIT array	KS, unpublished data
Pahsimeroi*	310	130	Weir count	Stark et al. 2015
East Fork Salmon*	559	910	Weir count	Stark et al. 2015
Yankee Fork Salmon R	272	82	PIT array	KS, unpublished data
Upper Salmon*	611	73	Weir count	Stark et al. 2015
Imnaha	3,301	2361 (2,081-2,662)	PIT array	KS, unpublished data

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 2014-15 run were genotyped (C. Steele, unpublished data), which allowed us to assign 94.0% 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. The only significant change to the run reconstruction model itself was that we used PBT assignments to release location for all groups for the first time, with one exception, Clearwater drainage DWOR stock releases. And we anticipate the next reconstruction will have PBT assignments to release location for every group, thereby not relying on proportions of releases by location to apportion harvest. 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. Caution should be therefore be exercised in implying management decisions based on these estimates, but nonetheless these small groups are reported.

Other considerations

This year's model predicted more hatchery fish remained after subtracting harvest, than were known to be collected at hatchery weirs. This was not the case last year in the Upper Salmon River, where less fish were predicted to remain than were actually collected for brood. Therefore, compared to previous years, we could conclude that our estimate of hatchery fish which made it to their natal reach is less likely to be an underestimate and the harvest for these hatchery stocks is less likely to have been 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 2015/2016) 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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