RECONSTRUCTION OF THE 2012/2013 STEELHEAD SPAWNING RUN INTO THE SNAKE RIVER BASIN

Timothy Copeland, Idaho Department of Fish and Game, Nampa, Idaho
Joseph D. Bumgarner, Washington Department of Fish and Wildlife, Dayton, Washington
Alan Byrne, Idaho Department of Fish and Game, Boise, Idaho
Peter Cleary, Nez Perce Tribe, Orofino, Idaho
Lytle Denny, Shoshone Bannock Tribes, Fort Hall, Idaho
J. Lance Hebdon, Idaho Department of Fish and Game, Boise, Idaho
Christopher A. Peery, US Fish and Wildlife Service, Ahsahka, Idaho
Stuart Rosenberger, Idaho Power Company, Boise, Idaho
Edwin R. Sedell, Oregon Department of Fish and Wildlife, La Grande, Oregon
Gene E. Shippentower, Confederated Tribes of the Umatilla Indian Reservation, Pendleton, Oregon
Chuck Warren, Idaho Department of Fish and Game, Nampa, Idaho
Steven P. Yundt, US Fish and Wildlife Service, Boise, Idaho

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 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 Timothy Copeland. Order of the co-authors is alphabetical.

Suggested citation:

Copeland, T., J. D. Bumgarner, A. Byrne, P. Cleary, L. Denny, J. L. Hebdon, C. A. Peery, S. Rosenberger, E. R. Sedell, G. E. Shippentower, C. Warren, and S. P. Yundt. 2015. Reconstruction of the 2012/2013 steelhead spawning run into the Snake River basin. Report to Bonneville Power Administration, Portland, Oregon.

ABBREVIATIONS AND ACRONYMS

BON	Bonneville Dam
BPA	Bonneville Power Administration
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	Coded Wire Tag
EF	East Fork
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GSI	Genetic Stock Identification
ICH	Ice Harbor Dam
ICBTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
LGR	Lower Granite Dam
LS	Little Salmon River
LSRCP	Lower Snake River Compensation Plan
MCN	McNary Dam
MF	Middle Fork
MPG	Major Population Group
NF	North Fork
NPT	Nez Perce Tribe
NOAA	National Oceanic and Atmospheric Administration
ODFW	Oregon Department of Fish and Wildlife
PBT	Parentage Based Tagging
PIT	Passive Integrated Transponder
PTAGIS	PIT Tag Information System
QCI	Quantitative Consultants, Inc.
SBT	Shoshone Bannock Tribes
SF	South Fork
TUC	Tucannon River
WB	Whitebird Creek
WDFW	Washington Department of Fish and Wildlife

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

ABSTRACT

Steelhead trout 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 2012-2013 return of steelhead within the Snake River basin. We estimated 91,106 adipose-clipped hatchery fish, 10,695 unmarked hatchery fish, and 26,095 wild steelhead entered the Snake River during the run (July 1, 2012 to June 30, 2013), which includes fish from hatchery stocks release outside the Snake River basin. Fishery-related mortality in the Snake River basin totaled 61,421 marked hatchery fish, 445 unmarked hatchery fish, and 950 wild steelhead. Further, 16,521 marked hatchery fish, 597 unmarked hatchery fish, and 10 wild fish were removed at weirs or as part of brood stock collections. Another 13 unclipped and 91 clipped hatchery fish were estimated to leave the Snake River to enter the Walla Walla River. Potential spawners remaining in the habitat totaled 13,682 marked hatchery fish, 9,068 unmarked hatchery fish, and 24,558 wild steelhead. Losses between BON and ICH were 24.8% across all wild Snake River stocks; presumably, most are due to anthropogenic sources; however, fishery-related losses within the Snake River basin were only 5.2%. 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 ESA delisting criteria. Comparison with independent data suggested that the model provides realistic estimates for hatchery fish, but methodology for natural fish estimates needs refinement.

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. Therefore, steelhead management in the Snake River basin is complex and requires information 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 (e.g., Schrader et al. 2012, 2013). 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). Most of these fish return to areas upstream of Lower Granite Dam, except for one wild population and two hatchery stocks that return to reaches downstream of Lower Granite Dam. The location of Lower Granite Dam 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 Lower Granite Dam that impact all Snake River steelhead populations. Additionally, most wild populations spawn during the spring run-off and thus there is little information on spawning escapement (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, catch, 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 that 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 management goals and 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). 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 2012-2013 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 brood stocks of steelhead spawning in the Snake River basin during 2013 by major population group (MPG). Hatchery stocks are listed by MPG of release with an abbreviation given parentheses.

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

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 km upstream of the Pacific Ocean and 288 km 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 km downstream of the mouth of the Snake. Within the Snake River, the first dam encountered by adult steelhead is Ice Harbor Dam (ICH; river km 16). Lower Granite Dam (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 Lower Granite Dam (Tom Cooney, NOAA Fisheries, unpublished data). In general, major population groups (MPGs) are delineated by major drainage (Clearwater, Grande Ronde, Imnaha, and Salmon rivers). The Tucannon River population (downstream of Lower Granite Dam) and the Asotin Creek population (upstream of Lower Granite Dam) 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 (Ford et al. 2010). Hatchery fish are released at multiple locations (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 *US v. Oregon* agreement, some unclipped hatchery fish are released in the Tucannon River, Lolo Creek, South Fork Clearwater River, East Fork Salmon River, Yankee Fork Salmon River, and at the Sawtooth Fish Hatchery weir in the headwaters of the Salmon River.

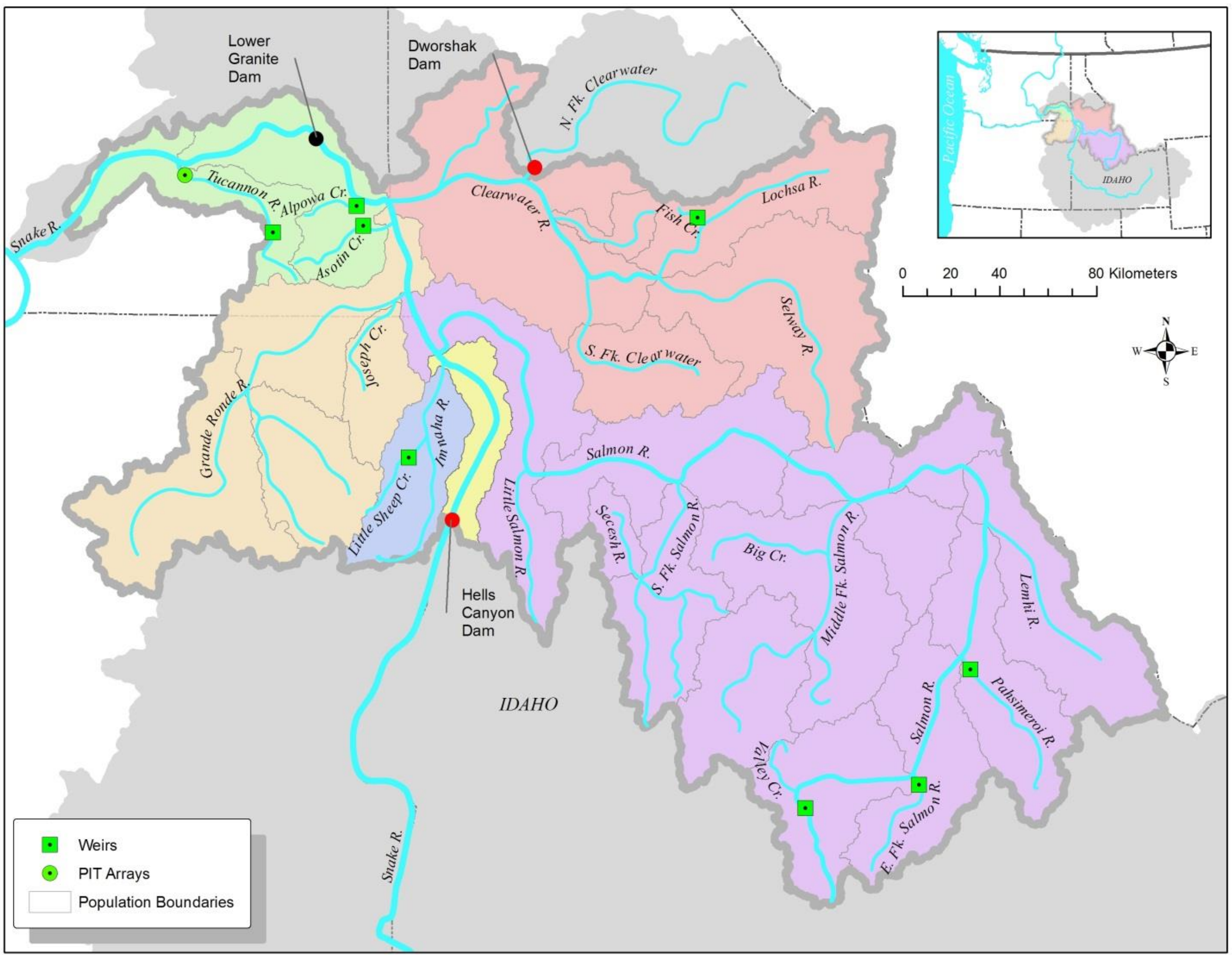

Figure 2. Snake River steelhead populations with locations of selected weirs and PIT tag antenna arrays. Major population groups are denoted by different colors.

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 more limited in spatial extent but employ a variety of gears and retention of unclipped steelhead is allowed. The Nez Perce Tribe operates a commercial gill net fishery in the Snake River between Lower Granite Dam and Hells Canyon Dam and in the main-stem Clearwater River with most effort in the Lower Granite pool. Nez Perce tribal members also pursue subsistence steelhead fisheries throughout the Clearwater River basin, with most effort in the North Fork and South Fork Clearwater rivers. Members of the Confederated Tribes of the Umatilla Indian Reservation pursue subsistence steelhead fisheries with most effort concentrated in the upper Grande Ronde River. Lastly, members of the Shoshone Bannock Tribes harvest steelhead throughout the Salmon River basin with most effort in the Yankee Fork and East Fork Salmon River.

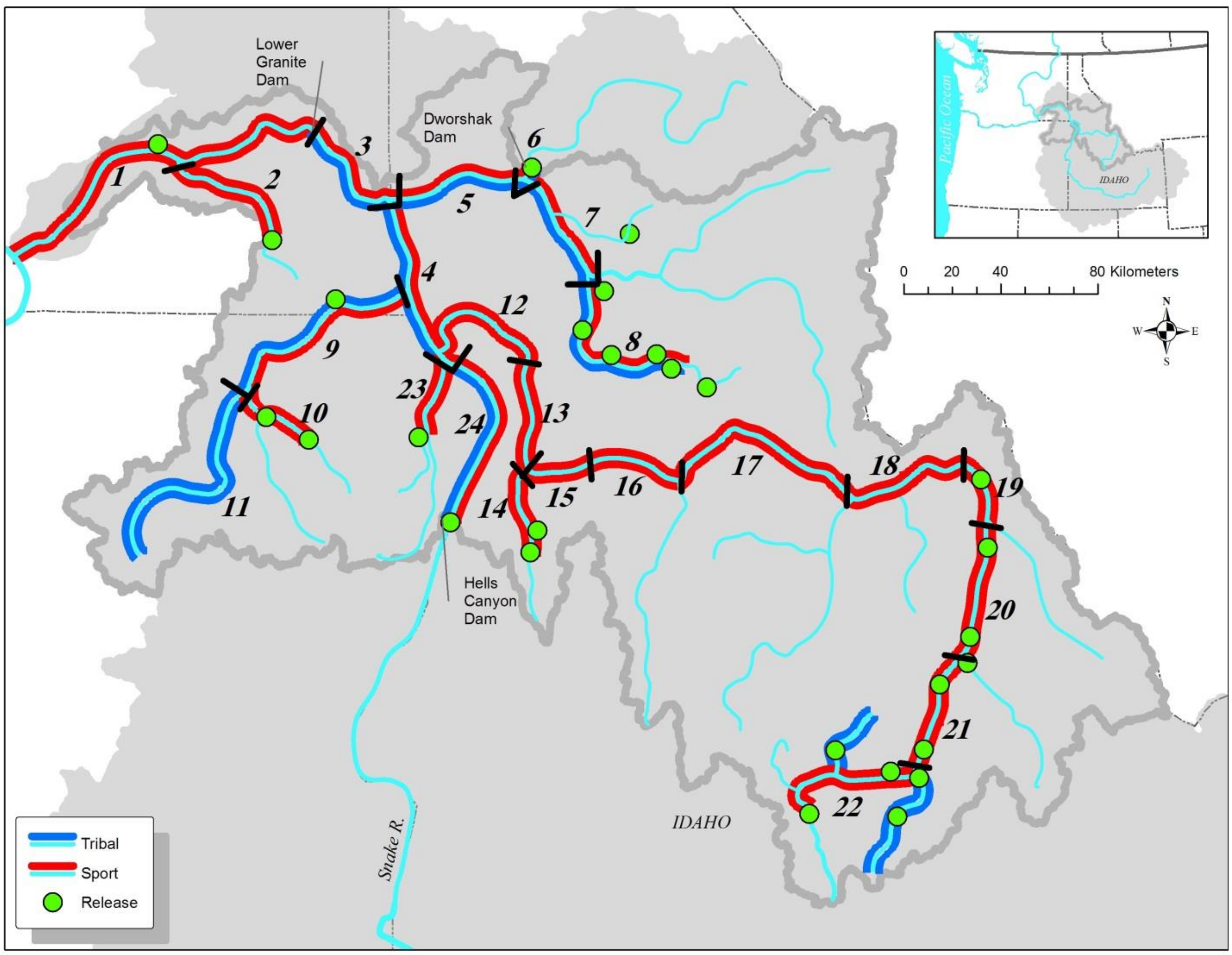

Figure 3. Location of hatchery steelhead release locations and boundaries of harvest reaches within the Snake River basin. Numbers represent the reaches represented as the smallest strata in the run reconstruction model. See Table 2 for reach descriptions.

Model development

We constructed 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 Lower Granite Dam because of the intensive sampling program operating on adult steelhead there (Schrader et al. 2012, 2013). 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 Ice Harbor Dam and Lower Granite Dam by moving fish backward to Ice Harbor Dam and then applying fisheries losses within that reach. We estimated escapement and losses upstream of Lower Granite Dam by moving fish forward. We also estimated the number of steelhead migrating across Bonneville Dam, although we were unable 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, 2012 to June 30, 2013 was based on the expanded window count (see Schrader et al. 2013 for methodology). Schrader et al. (*in prep*.) 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 Lower Granite Dam. Genetic techniques (parent-based tagging, PBT) were used to assign fish to hatchery stock (Steele et al. 2013). Release locations were aggregated within fisheries reaches (see Figure 3) to simplify accounting within the model. To assign hatchery stocks from the Clearwater and Salmon subbasins to release reach, we used PIT tag detections scaled by tagging rate (C. Warren, unpublished data) to parse each stock because of the number of release sites and the current level of hatchery accounting within those basins. Schrader et al. (*in prep*.) parsed abundance of wild fish into genetic stocks established by Ackerman and Campbell (2012) using genetic stock identification (GSI) on adult steelhead sampled at Lower Granite Dam. 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 from the most recent ESA status assessment (Ford et al. 2010). Based on genetic structure and assignment tests, Lolo Creek was aligned with the South Fork Clearwater genetic group and Chamberlain Creek with the Middle Fork Salmon group (Mike Ackerman, personal communication).

We made two adjustments to the abundance estimates based on the dam count. 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 (S. Rosenberger, unpublished data). We downloaded all PIT detections of adult steelhead in the LGR ladder during June 2012-May 2013. 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 was adjusted upward by this proportion.

Further, we found previously that abundance of Lower Snake stocks (Tucannon and Asotin populations) appeared biased high (Copeland et al. 2013). We used PIT tag detections to estimate the rate at which steelhead had been double counted at Lower Granite Dam. The re-ascension rate was calculated by dividing the number of re-ascension events by number of unique adult PIT tags detected at Lower Granite Dam (S. Rosenberger, unpublished data). 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.

Conversion Rates

We used adult PIT tag detections at Lower Granite, Ice Harbor, McNary, and Bonneville dams of Snake River basin steelhead that were tagged as juveniles to calculate conversion rates between the dams.. The PTAGIS database (www.ptagis.org) was queried for adult detections between 20 June 2012 and 31 December 2012 at Bonneville Dam 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 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 codes (HUC4), except the LGR to ICH conversion rate for Lower Snake River stocks. We calculated the ICH to LGR conversion rate 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 at Ice Harbor, McNary, and Bonneville 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 = Ice Harbor, McNary, Bonneville 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 Ice Harbor Dam. The Lower Snake stock abundance at ICH was found by dividing population-specific conversion rates from ICH to LGR by the population abundance at LGR and summing all populations.

Run Reconstruction

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

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

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:

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

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:

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

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:

$$E_{ij} = N_{ij} - N_{i,j+1} - C_{ij}. \tag{4}$$

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 to 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. IDFG estimated catch and harvest data with a post-season phone survey (Petrosky 2014). 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. 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 Nez Perce Tribe and Confederated Tribes of the Umatilla Indian Reservation were based on post-season interviews of tribal members. ODFW used a creel survey to estimate catch and harvest in the lower Grande Ronde River (reach 9) and the Imnaha River. The fisheries data for the Wallowa River and other reaches in the Oregon portions of the Grande Ronde watershed were unavailable for 2012-2013, so we used 2010-2011 data (Flesher et al. 2014) scaled to the 2012-2013 escapement at Lower Granite Dam. Likewise, 2012-2013 fishery data were unavailable for the Shoshone Bannock Tribes, so we used 2008-2009 data (Brandt 2009).

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 point of origin.

Where a wild population 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.

Table 2. Description of fishery reaches in the Snake River basin, including agencies reporting fisheries within them during 2012-2013, 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(TEH^{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})

Unlike the treatment of movement upstream of Lower Granite Dam, movement probability within the Lower Snake River is confounded with survival in the conversion rate, so modeled fish are moved before the fishery, because they have survived harvest mortality by definition. However, when reporting losses within the Lower Snake River reach, we only give fishery-related losses to maintain comparability to reaches upstream of Lower Granite Dam.

Hatchery and wild stocks from the Lower Snake (downstream of Lower Granite Dam) and Tucannon River are known to overshoot their original release location extensively (Bumgarner and Dedloff 2011); many of them cross Lower Granite Dam. Many are known to remain upstream of Lower Granite Dam while a minority (15%-25%) falls back downstream into the Lower Snake reach. We used PIT tag detections at Ice Harbor Dam, the lower Tucannon River, and Lower Granite Dam to estimate movement probabilities of wild Tucannon fish, Tucannon endemic stock hatchery fish, and Lyons Ferry stock hatchery releases moving from Ice Harbor Dam to the Tucannon River or falling back over Lower Granite Dam into the Tucannon River. 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 Lower Granite Dam. Figure 4 illustrates dataflow from Lower Granite Dam down to Bonneville Dam 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 North Fork Clearwater River (reach 6) will enter that reach. We estimated a ‘dip-in’ rate (p_{dip}) for the lower Clearwater and North Fork Clearwater rivers based on PBT analysis of tissues collected during fisheries surveys (C. Warren, unpublished data). For each MPG (e.g., Lower Snake, Salmon River):

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

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 Lower Granite Dam, including dip-in steps.

Output of the run reconstruction model is summarized into three categories: abundance at important locations, escapement after fisheries, and abundance of potential spawners in the terminal area. Abundance is estimated at Bonneville Dam, Ice Harbor Dam, Lower Granite Dam, and at the mouth of the natal river or terminal reach (except for Lower Snake stocks). Losses between Bonneville and Ice Harbor dams include all mortality sources; losses upstream of Ice Harbor Dam include only fishery-related mortality. Escapement is then the fish that avoid fishery-related mortality, assuming that natural mortality takes place only downstream of Ice Harbor Dam 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 Lower Granite Dam.

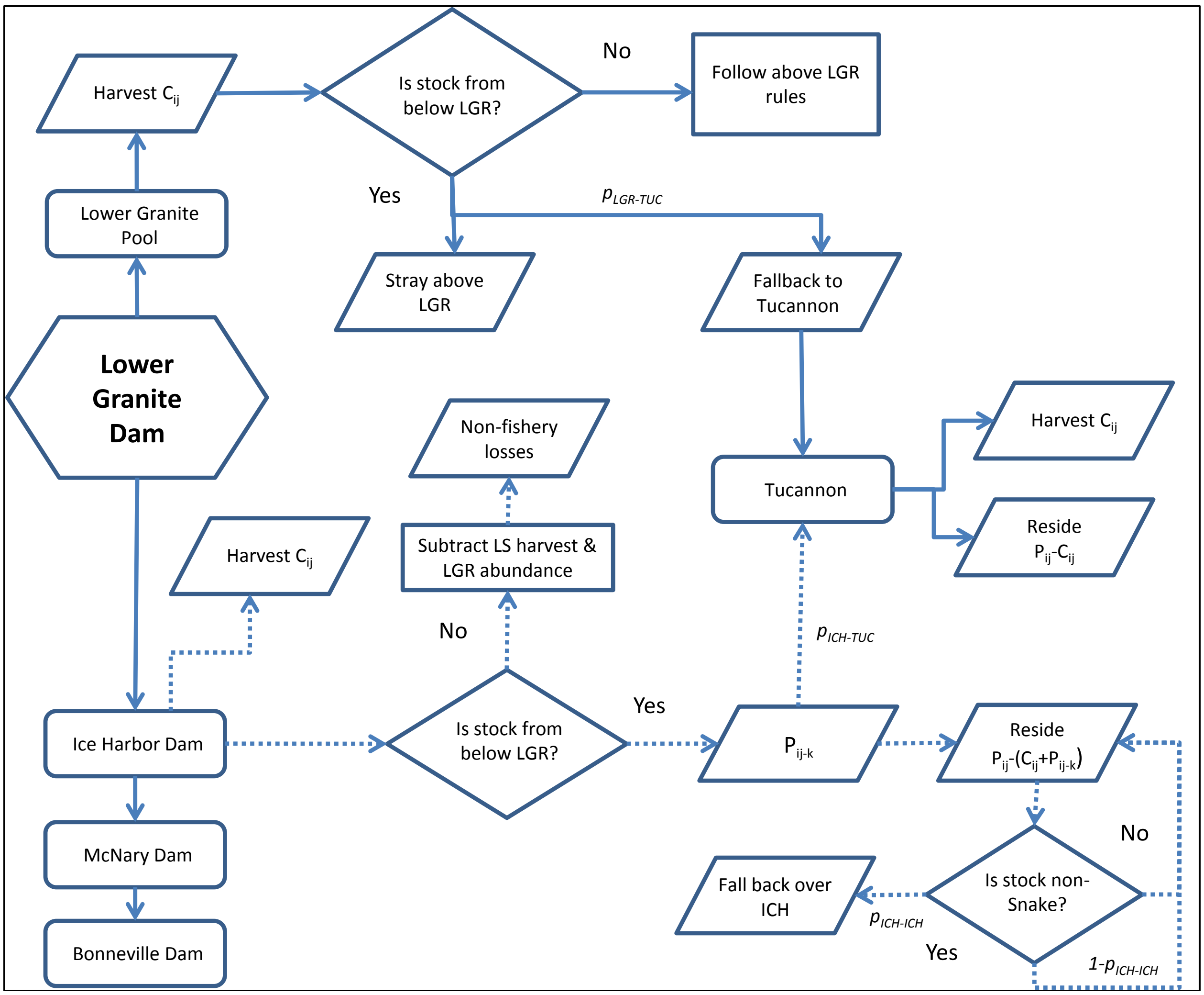

Figure 4. Flowchart for projection of abundance at Lower Granite Dam back to Bonneville Dam and movement of Lower Snake stocks between Ice Harbor Dam and Lower Granite pool.

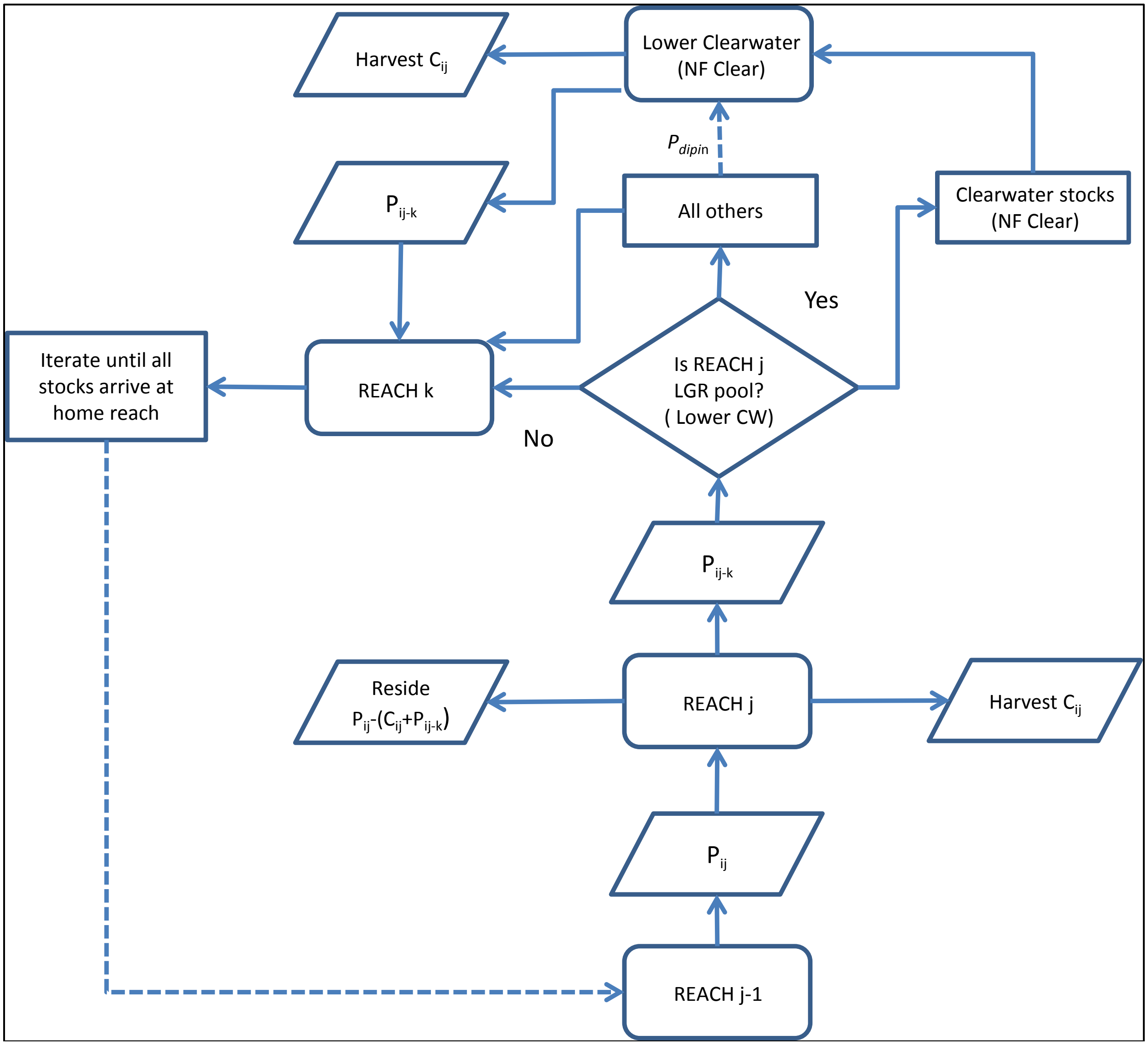

Figure 5. Flowchart for movement and fates of steelhead upstream of Lower Granite Dam. Abbreviations are explained in the text. Dip-in decisions are for non-Clearwater stocks in Lower Granite pool or for upper Clearwater/South Fork Clearwater stocks in the lower Clearwater (in parentheses).

RESULTS

Abundance at Lower Granite Dam

The preliminary abundance estimates at Lower Granite Dam for the 2012-2013 steelhead run were 22,728 wild fish, 77,313 clipped hatchery fish, and 8,984 unclipped hatchery fish (Schrader et al., *in prep*.); note these numbers include fish from hatchery stocks released outside the Snake River basin. After incorporating night passage (10.5%) and re-ascensions (12.7% for Lower Snake stocks and 1.8% for all others), the adjusted estimates were 24,396 wild fish, 84,643 clipped hatchery fish, and 9,717 unclipped hatchery fish (Tables 3 and 4). Of the 23 hatchery release groups, three were from locations outside of the Snake River basin (from the Touchet and Walla Walla rivers). The largest hatchery return group at Lower Granite Dam was bound for the Salmon River between the East Fork Salmon River and Sawtooth Fish Hatchery weir (reach 22). Most unclipped hatchery steelhead were returning to the South Fork Clearwater River or the Salmon River upstream of the East Fork. We estimated that the largest wild population was the Upper Mainstem Grande Ronde River and the smallest was the North Fork Salmon River.

Conversion Rates

We detected 857 wild steelhead and 2,683 hatchery steelhead from the Snake River basin at Bonneville Dam. Conversion rates from BON to MCN ranged from 71.5% to 82% and 76.3% to 87.4% in the hatchery and wild groups, respectively. Conversion rates from MCN to ICH and ICH to LGR for all hatchery and wild groups exceeded 90% for all hatchery and wild groups (Table 5). The conversion rate from Bonneville to McNary dam averaged 80.5% for wild steelhead and 77.9% for hatchery steelhead. Conversion rates from McNary to Ice Harbor dam averaged 93.5% for wild fish and hatchery fish. Conversion rate from Ice Harbor to Lower Granite dam averaged 97.3% for wild fish and 95.0% for hatchery fish for stocks originating upstream of Lower Granite Dam.

Abundance at Ice Harbor, McNary, and Bonneville dams

We estimated that 34,693 wild, 121,169 hatchery clipped, and 14,372 hatchery unclipped steelhead from the Snake River basin passed Bonneville Dam. Of those, 26,095 wild, 88,634 hatchery clipped, and 10,660 hatchery unclipped steelhead entered the Snake River and passed Ice Harbor Dam (Tables 3 and 4).

Table 3. The estimated abundance of wild populations at Ice Harbor (ICH), McNary (MCN), and Bonneville (BON) dams based on LGR abundance and Group HUC4 conversion rates.

Wild populations		**Abundance at**			
Name	**Group (HUC4)**	**LGR**	**ICH**	**MCN**	**BON**
Tucannon	Lower Snake wild	1,605	2,654	2,810	3,668
Asotin Creek	Asotin wild	1,133	1,133	1,204	1,558
Lower Grande Ronde	Grande Ronde wild	966	991	1,106	1,383
Wallowa	Grande Ronde wild	1,924	1,975	2,205	2,756
Joseph Creek	Grande Ronde wild	703	722	806	1,008
Upper Grande Ronde	Grande Ronde wild	2,318	2,380	2,656	3,320
Lower Clearwater	Clearwater wild	2,570	2,663	2,902	3,321
Lolo Creek	Clearwater wild	285	295	322	368
South Fork Clearwater	Clearwater wild	1,453	1,506	1,641	1,878
Lochsa	Clearwater wild	492	510	556	636
Selway	Clearwater wild	844	875	954	1,092
Little Salmon	Salmon wild	736	751	794	1,007
South Fork Salmon	Salmon wild	660	674	713	904
Secesh	Salmon wild	283	289	306	388
Chamberlain Creek	Salmon wild	314	321	340	431
Lower Middle Fork	Salmon wild	882	900	952	1,207
Upper Middle Fork	Salmon wild	940	960	1,015	1,287
Panther Creek	Salmon wild	302	308	326	413
North Fork Salmon	Salmon wild	173	177	187	237
Lemhi	Salmon wild	970	990	1,047	1,327
Pahsimeroi	Salmon wild	805	822	869	1,102
East Fork Salmon	Salmon wild	856	874	924	1,172
Upper Salmon	Salmon wild	1,034	1,056	1,117	1,416
Imnaha	Imnaha wild	2,148	2,270	2,351	2,837
Total Wild		**24,396**	**26,095**	**28,103**	**34,716**

Table 4. The estimated abundance of hatchery stocks by release sites at Ice Harbor (ICH), McNary (MCN), and Bonneville (BON) dams based on 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.

		Abundance at			
Release site (stock)	**Group (HUC4)**	**LGR**	**ICH**	**MCN**	**BON**
Snake(LF)[c]	Lower Snake hatchery	1,442	2,564	2,855	3,547
Tucannon(TEH)[u]	Lower Snake hatchery	377	852	949	1,179
Tucannon (LF)[c]	Lower Snake hatchery	589	1,047	1,166	1,449
Lolo (DWR)[u]	Clearwater hatchery	405	425	441	573
SF Clearwater (DWR)[u]	Clearwater hatchery	5,663	5,941	6,158	8,008
SF Clearwater (DWR)[c]	Clearwater hatchery	6,267	6,574	6,814	8,861
NF Clearwater (DWR)[c]	Clearwater hatchery	9,578	10,048	10,415	13,544
Clear Creek (DWR)[c]	Clearwater hatchery	2,783	2,920	3,027	3,936
Cottonwood(WLH)[c]	Grande Ronde hatchery	4,502	4,782	4,967	6,947
Wallowa (WLH)[c]	Grande Ronde hatchery	9,140	9,709	10,056	14,064
Little Salmon (OX,PAH,DWR)[c]	Salmon hatchery	8,631	9,099	9,872	12,198
Salmon sec 19 (PAH)[c]	Salmon hatchery	1,413	1,490	1,617	1,998
Salmon sec 20 (USB)[u]	Salmon hatchery	843	889	965	1,192
Salmon sec 20 (PAH)[c]	Salmon hatchery	12,863	13,560	14,712	18,179
East Fork Salmon (EFN)[u]	Salmon hatchery	1,336	1,408	1,528	1,888
Salmon sec 21 (SAW,DWR)[c]	Salmon hatchery	2,305	2,430	2,636	3,257
Salmon sec 22 (SAW)[u]	Salmon hatchery	1,086	1,145	1,242	1,535
Salmon sec 22 (SAW,USB,DWR)[c]	Salmon hatchery	14,933	15,742	17,079	21,103
Imnaha (IMH)[c]	Imnaha hatchery	1,281	1,366	1,478	1,803
Snake (OX)[c]	Hells Canyon hatchery	7,060	7,303	7,759	10,269
All Snake River basin Clipped Hatchery		**82,787**	**88,634**	**94,453**	**121,155**
All Snake River basin Unclipped Hatchery		**9,710**	**10,660**	**11,283**	**14,375**
Total Snake River Hatchery		**92,497**	**99,294**	**105,736**	**135,530**
Walla Walla (LF)[c]* & Touchet (LF)[c]*	na	1,856	2,472	--	--
Touchet (endemic)[u]*	na	7	35	--	--

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 is in the numerator. Only fish detected at Bonneville, McNary, and Ice Harbor 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	375	302	80.49%	298	269	89.80%	249	193	NA
Grande Ronde hatchery	414	296	71.50%	295	284	96.27%	273	257	94.14%
Imnaha hatchery	161	132	81.99%	132	122	92.42%	122	105	93.75%
Clearwater hatchery	632	486	76.90%	483	466	96.48%	449	428	95.32%
Hells Canyon hatchery	135	102	75.56%	102	96	94.12%	90	87	96.67%
Salmon hatchery	965	781	80.93%	779	718	92.17%	681	646	94.86%
Total hatchery	**2,682**	**2,099**		**2,089**	**1,955**		**1,864**	**1,716**	
Lower Snake wild	47	36	76.60%	36	34	94.44%	30	18	NA
Asotin wild	44	34	77.27%	34	32	94.12%	29	29	100.0%
Grande Ronde wild	60	48	80.00%	48	43	89.58%	39	38	97.44%
Imnaha wild	70	58	82.86%	58	56	96.55%	56	53	94.64%
Clearwater wild	111	97	87.39%	97	89	91.75%	86	83	96.51%
Salmon wild	71	56	78.87%	55	52	94.55%	49	48	97.96%
Total wild	**403**	**329**		**328**	**306**		**289**	**269**	

Run reconstruction

Steelhead from Lower Snake stocks residing downstream from Lower Granite Dam tended to overshoot their natal reach and pass upstream of Lower Granite Dam, some of which returned back downstream (Table 6). Conversion rates from Ice Harbor to Lower Granite dam for the Lyons Ferry stock release groups ranged from 32.0% to 56.3%, while 60.5% of the wild Tucannon fish crossed Lower Granite Dam. Of the Lower Snake fish that crossed Ice Harbor Dam (all stocks and origins), 12.0% to 48.1% were estimated to move directly to the Tucannon River and stay there. By subtraction, 0.0% to 48.0% stayed within the Lower Snake downstream of Lower Granite Dam as either mortalities or escapement. Note that these three probabilities include all possible fates for these stocks between Ice Harbor and Lower Granite dams, i.e., they sum to 1.0. A subset of the Lower Snake stocks ascending Lower Granite Dam (10.0% to 50.0%) fell back over Lower Granite Dam and entered the Tucannon River. A subset of the non-Snake steelhead that remained in the lower Snake River (4.0% to 40.0%) were eventually detected in the Walla Walla basin and considered to have fallen back over Ice Harbor Dam after the fishery.

Temporary straying of non-Clearwater 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 North Fork Clearwater River into the North Fork Clearwater River was 7.5%.

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					
Tucannon wild	0.6047	0.3953	0.0000	0.3077	0.0000
Tucannon (TEH)[u]	0.4423	0.4808	0.0769	0.3913	0.0000
Tucannon(LF)[c]	0.5625	0.2500	0.1875	0.3333	0.0000
Touchet (endemic)[u]	0.2000	0.2000	0.2000	0.5000	0.4000
Snake (LF)[c]	0.5625	0.2500	0.1875	0.3333	0.0000
Walla Walla basin					
Walla Walla (LF)[c]	0.3200	0.1600	0.4800	0.2500	0.0400
Touchet (LF)[c]	0.4000	0.1200	0.3600	0.1000	0.1200

Table 7. Computation of dip-in rates of clipped non-Clearwater Fish Hatchery stocks into the lower Clearwater River (reach 5). Hatchery stocks are grouped by region. Harvest was determined from PBT recoveries in the fishery (C. Warren, unpublished data).

Hatchery stock	Reach 5 harvest	LGR pool abundance	Dip-in rate
Lower Snake	608	2,841	0.4394
Grande Ronde	243	13,293	0.0375
Salmon	588	39,119	0.0309
Imnaha	0	1,248	0.0000
Hells Canyon	435	6,879	0.1298

Total fishery-related mortality of clipped hatchery fish within the study area was 61,421 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 1,407 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), lower Snake River (reach 1), and the upper Snake River (reach 4). The largest fishery mortality estimates of unclipped fish were in the lower Snake River (reach 1), lower Grande Ronde River (reach 9), and lower Clearwater River (reach 5). Catch and harvest in the upper Grande Ronde River (reach 11) was minimal and lumped into the Wallowa River estimates because most of the reach 11 fishery is close to the Wallowa River and focused on the Wallowa Hatchery stock.

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	245	7,624	11
2. Tucannon	7	943	2
3. Lower Granite Pool	91	2,141	0
4. Upper Snake	138	4,877	9
5. Lower Clearwater	164	10,715	128
6. North Fork Clearwater	28	2,172	6
7. Clearwater to Clear Creek	36	2,317	29
8. South Fork Clearwater	69	1,736	28
9. Lower Grande Ronde	239	3,984	93
10. Wallowa River	39	1,756	48
11. Upper Grande Ronde	0	0	0
12. Salmon to Whitebird	13	1,430	8
13. Salmon (WB-Little Salmon)	21	2,911	21
14. Little Salmon	9	2,063	43
15. Salmon (LS to Vinegar)	13	2,292	24
16. Salmon (Vinegar to SF)	16	1,216	3
17. Salmon (SF to MF)	20	1,369	20
18. Salmon (MF to NF)	34	4,181	52
19. Salmon (NF to Lemhi)	18	1,999	26
20. Salmon (Lemhi to Pahsimeroi)	12	1,178	17
21. Salmon (Pahsimeroi to EF)	15	398	32
22. Salmon (EF upstream)	156	1,889	73
23. Imnaha	12	127	4
24. Hells Canyon	12	1,421	5

Next, we report run construction summaries by MPGs beginning downstream and proceeding upstream along the Snake River. Summaries of hatchery release groups are given next to the wild populations in which they are released.

Lower Snake River MPG

Abundance of stocks from the Lower Snake major population group at Bonneville Dam was 5,226 wild fish; 1,179 unclipped Tucannon endemic stock; and 4,996 steelhead from the two Lyons Ferry clipped hatchery groups (Table 9). Losses between Bonneville Dam and Ice Harbor Dam were estimated to be 1,439 wild fish (27.5%) and 1,712 (27.7%) hatchery fish. These fish crossed Lower Granite Dam in large numbers, even stocks that were not from upstream of Lower Granite Dam. Fishery-associated losses within reaches 1 and 2 were 31 wild fish (0.8%), 8 unclipped hatchery fish (0.9%), and 1,021 clipped hatchery fish (28.3%). Losses upstream of Lower Granite Dam (reaches 3 and 4) were 32 wild fish (1.2%), four unclipped hatchery fish (1.1%), and 516 clipped hatchery fish (25.4%). Escapements were greatest for the two wild populations; however, 2,914 hatchery fish also escaped. Three non-Snake release groups raised at Lyons Ferry Fish Hatchery that were released in the Walla Walla River basin entered the study area. We estimated that over 2,500 Walla Walla basin fish passed Ice Harbor Dam and contributed to fisheries in the Snake River. We estimated that over 1,600 could have spawned within the study area (Table 10).

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							
Tucannon wild	3,668	2,654	1,605	1,519	1,095	1,537	1,095
Tucannon (TEH)[u]	1,179	852	377	592	248	592	190
Tucannon (LF)[c]	1,449	1,047	589	353	249	318	245
Snake (LF)[c]	3,547	2,564	1,442	865	607	755	599
Asotin wild	1,558	1,133	1,133	0	1,118	0	1,118
All wild	**5,226**	**3,787**	**2,738**	**1,519**	**2,213**	**1,537**	**2,213**
Clipped Hatchery	**4,996**	**3,611**	**2,031**	**1,218**	**856**	**1,109**	**844**
Unclipped Hatchery	**1,179**	**852**	**377**	**592**	**248**	**373**	**190**
All Hatchery	**6,175**	**4,463**	**2,408**	**1,810**	**1,104**	**1,482**	**1,034**
Total	**11,401**	**8,250**	**5,146**	**3,348**	**3,317**	**3,019**	**3,247**
Walla Walla basin releases							
Touchet (endemic)[u*]	--	35	7	32	3	19	3
Walla Walla & Touchet (LF)[c]	--	2,472	885	1,300	513	1,133	507

Final dispositions are known for fish removed at weirs within the Lower Snake major population group (J. Bumgarner, unpublished data). There are four weirs in the study area downstream of Lower Granite Dam: Lyons Ferry Fish Hatchery trap, Tucannon Fish Fish Hatchery weir, Penawawa Creek trap, and Deadman Creek trap. Of the Lower Snake River hatchery stocks, 221 clipped fish were removed at these weirs. Another 13 unclipped and 91 clipped hatchery fish were estimated to leave the Lower Snake River to enter the Walla Walla River, leaving 392 unclipped and 2,242 clipped hatchery steelhead at large downstream of Lower Granite Dam. For the Tucannon population, 36.8% of the potential spawners were hatchery fish. There are four weirs in the Lower Snake major population group upstream of Lower Granite Dam: Alpowa Creek, Asotin Creek, George Creek, and Ten Mile Creek. Of the Lower Snake hatchery stocks, 20 clipped and 58 unclipped fish were removed at these four weirs, leaving 1,536 hatchery fish at large. For the Asotin Creek population (all spawning areas), 58.9% of the potential spawners were hatchery fish.

Clearwater River MPG

Abundance of stocks from the Clearwater MPG at Bonneville Dam was 7,295 wild steelhead; 8,581 unclipped hatchery steelhead; and 26,341 clipped hatchery steelhead (Table 10). Between Bonneville and Ice Harbor dams we estimated that 1,446 wild fish (19.8%) and 9,014 hatchery fish (25.8%) were lost. Fishery-associated losses within the lower Snake River (reach 1) were 39 wild fish (0.7%), 42 unclipped hatchery fish (0.7%), and 1,638 clipped hatchery fish (8.4%). Losses in the Snake River upstream of Lower Granite Dam (reach 3) were 15 wild fish (0.3%), 15 unclipped hatchery fish (0.2%), and 476 clipped hatchery fish (2.6%). Losses within the Clearwater River were 119 wild fish (2.1%), 178 unclipped hatchery fish

(2.9%), and 17,131 clipped hatchery fish (94.4%). This left a deficit escapement of clipped fish in the South Fork Clearwater River. Fishery impacts on non-Clearwater stocks in the lower Clearwater River (reach 5) were estimated to be 16 wild fish, two unclipped hatchery fish, and 1,897 clipped hatchery fish. The total fishery-related losses within this reach composed of non-Clearwater fish were 18.8%, 2.5%, and 17.5% for wild, unclipped hatchery, and clipped hatchery groups, respectively. We estimated escapement in the Clearwater River was 5,526 wild fish, 5,877 unclipped hatchery fish, and 2,918 clipped hatchery fish. Clipped hatchery fish escaped the fishery in North Fork Clearwater River and Clear Creek.

Table 10. Reconstruction of wild and hatchery stocks in the Clearwater major population group. 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	3,321	2,663	2,570	2,563	2,531	2,531
NF Clearwater (DWR)^{c}	13,544	10,048	9,578	9,333	2,700	694
Clear (DWR)^{c}	3,936	2,920	2,783	2,712	610	390
Lolo wild	368	295	285	284	279	279
Lolo (DWR)^{u}	573	425	405	404	396	396
Lochsa wild	636	510	492	491	482	482
Selway wild	1,092	875	844	842	827	827
SF Clearwater wild	1,878	1,506	1,453	1,449	1,407	1,407
South Fork (DWR)^{u}	8,008	5,941	5,663	5,649	5,481	5,385
South Fork (DWR)^{c}	8,861	6,574	6,267	6,107	-392	-285
All Wild	**7,295**	**5,849**	**5,644**	**5,629**	**5,526**	**5,526**
Clipped Hatchery	**26,341**	**19,542**	**18,628**	**18,152**	**2,918**	**799**
Unclipped Hatchery	**8,581**	**6,366**	**6,068**	**6,053**	**5,877**	**5,781**
All Hatchery	**34,922**	**25,908**	**24,696**	**24,205**	**8,795**	**6,580**
Total	**42,217**	**31,757**	**30,340**	**29,834**	**14,321**	**11,920**

Final dispositions are known for fish within the Clearwater River basin that enter hatchery weirs at Dworshak Fish Hatchery (North Fork Clearwater River), Kooskia Fish Hatchery (Clear Creek, a tributary to Middle Fork Clearwater River), and Crooked River (tributary to South Fork Clearwater River). Fish collected at Kooskia Fish Hatchery are typically recycled to the fishery, as are fish in excess of broodstock needs at Dworshak Fish Hatchery. These two hatcheries operate within the Lower Clearwater population. During the 2012-2013 run, Dworshak Fish Hatchery collected 3,482 clipped hatchery fish and retained 2,006 of them. Kooskia Fish Hatchery outplanted 220 clipped hatchery fish into the South Fork Clearwater River. A total of 209 fish were collected by angling in the South Fork Clearwater River for brood stock: 113 marked hatchery fish and 96 unclipped hatchery fish (identified by dorsal fin erosion). Estimated harvest on the South Fork Clearwater clipped stock (DWR) exceeded the number of fish in the system. Using wild and unclipped hatchery fish only, we estimate 81.5% of the South Fork Clearwater spawning population was composed of hatchery fish. Unclipped hatchery fish escaped into Lolo Creek and made up 58.7% of the spawners.

Grande Ronde River MPG

Abundance of stocks from the Grande Ronde MPG at Bonneville Dam was 8,467 wild fish; and 21,011 for clipped hatchery release groups (Table 11). We estimated that 2,556 wild fish (30.2%) and 7,369 (35.1%) hatchery fish were lost between Bonneville and Ice Harbor dams. Fishery-associated losses within the lower Snake River (reach 1) were 41 wild fish (0.7%) and 1,215 clipped hatchery fish (8.4%). Losses in the basin upstream of Lower Granite Dam (reaches 3, 4, and 5) were 56 wild fish (0.9%) and 1,659 clipped hatchery fish (12.2%). Losses within the Grande Ronde River were 278 wild fish (4.7%) and 5,881 clipped hatchery fish (49.0%). We estimated escapement in the Grande Ronde River was 5,583 wild fish and 6,116 clipped hatchery fish.

Final dispositions are known for fish trapped at Wallowa Fish Hatchery, Big Canyon acclimation pond (tributary to the Wallowa River), and Cottonwood acclimation pond (at rkm 46 on the Grande Ronde River). There were 942 clipped hatchery fish removed at Cottonwood weir (J. Bumgarner, unpublished data). There were 2,497 clipped hatchery fish removed at the Wallowa Fish Hatchery and Big Canyon weirs (E. Sedell, unpublished data). We estimated 64.5% of the Lower Grande Ronde and 35.8% 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. Weir take for Wallowa Fish Hatchery is based on 2010 data. 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	1,383	991	966	957	918	918
Joseph Creek wild	1,008	722	703	696	668	668
Cottonwood (WLH)[c]	6,947	4,782	4,502	3,955	2,609	1,667
Wallowa wild	2,756	1,975	1,924	1,905	1,788	1,788
Wallowa (WLH)[c]	14,064	9,709	9,140	8,028	3,493	996
Upper Grande Ronde wild	3,320	2,379	2,318	2,297	2,203	2,203
All Wild	**8,467**	**6,067**	**5,911**	**5,855**	**5,577**	**5,577**
All Hatchery	**21,011**	**14,491**	**13,642**	**11,983**	**6,102**	**2,663**
Total	**29,478**	**20,558**	**19,553**	**17,838**	**11,679**	**8,240**

Salmon River MPG

Abundance of stocks from the Salmon MPG at Bonneville Dam was 10,891 wild fish; 4,615 unclipped hatchery releases; and 56,735 clipped hatchery release groups (Table 12). We estimated that 2,781 (25.5%) wild fish and 15,587 (25.4%) hatchery fish were lost between Bonneville and Ice Harbor dams. Losses within the lower Snake River (reach 1) were 53 wild fish (0.7%), 23 unclipped hatchery fish (0.7%), and 3,546 clipped hatchery fish (8.4%). Losses in the Snake River upstream of Lower Granite Dam (reaches 3, 4, and 5) were 74 wild fish (0.9%), 31 unclipped hatchery fish (0.9%), and 4,767 clipped hatchery fish (11.9%). Losses within the Salmon River were 111 wild fish (2.3%), 146 unclipped hatchery fish (4.5%), and 21,245 clipped hatchery fish (60.0%). We estimated escapement in the Salmon River was 7,710 wild fish, 3,092 unclipped hatchery fish, and 14,171 clipped hatchery fish.

Final dispositions are known for fish trapped at Pahsimeroi Fish Hatchery, East Fork Salmon River weir, and Sawtooth Fish Hatchery. The latter trap operates within the Upper Salmon River population. In 2013, 4,361 clipped hatchery fish were trapped by the Pahsimeroi Fish Hatchery, but 700 were re-cycled back into the fishery. Additionally, 423 steelhead of the Upper Salmon B unclipped hatchery stock were removed at the Pahsimeroi weir. Hatchery steelhead at large are assumed to remain in the main-stem Salmon River between the Lemhi and the Pahsimeroi rivers or stray into minor tributaries to that reach. We estimate 66.7% of the Pahsimeroi spawning population was composed of hatchery fish. At the East Fork Salmon weir, removals were 10 wild fish and 20 unclipped hatchery fish. Subtracting these fish leaves 71.8% of the East Fork Salmon River spawning population composed of hatchery fish, of which 39.0% were clipped fish from segregated broodstocks (Sawtooth stock released at Tunnel Rock in the main stem or Dworshak stock released in the lower East Fork). At the Sawtooth weir, a total of 3,872 clipped hatchery fish were removed. This was 564 more fish than we estimated escaped the fishery. However, counting only unclipped hatchery fish, 51.3% of the Upper Salmon population was composed of hatchery spawners. Clipped hatchery fish also escaped into the Lemhi population (38.4% of the potential spawners) and Little Salmon population (86.4% of the potential spawners).

Imnaha River MPG

Abundance of stocks from the Imnaha MPG at Bonneville Dam was 2,837 wild fish and 1,803 clipped hatchery fish. We estimated that 567 wild fish (20.0%) and 437 hatchery fish (24.2%) were lost between Bonneville and Ice Harbor dams. Abundance of wild fish at Ice Harbor and Lower Granite dams was 2,270 fish and 2,148 fish, respectively. Abundance of hatchery fish at Ice Harbor and Lower Granite dams was 1,366 fish and 1,281 fish, respectively. Losses within the lower Snake River (reach 1) were 15 wild fish (0.7%) and 114 clipped hatchery fish (8.3%). Losses in the Snake River basin upstream of Lower Granite Dam (reaches 3 and 4) were 20 wild fish (0.9%) and 135 clipped hatchery fish (10.5%). We estimate 2,128 wild steelhead and 1,146 hatchery steelhead reached the mouth of the Imnaha River. Losses within the Imnaha were 12 wild fish (0.6%) and 131 clipped hatchery fish (11.4%). We estimated escapement in the Imnaha River was 2,116 wild fish and 1,015 clipped hatchery fish.

Table 12. Reconstruction of wild and hatchery stocks in the Salmon River major population group. 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**	**Escape**	**Left to spawn**
Little Salmon wild	1,007	751	736	729	718	718
Little Salmon (PAH,OX,DWR)[c]	12,198	9,099	8,631	7,606	4,561	4,561
South Fork Salmon wild	904	674	660	654	650	650
Secesh wild	388	289	283	280	279	279
Chamberlain Creek wild	431	321	314	311	309	309
Lower Middle Fork wild	1,207	900	882	874	867	867
Upper Middle Fork wild	1,287	960	940	931	924	924
Panther Creek wild	413	308	302	299	296	296
North Fork Salmon wild	237	177	173	172	171	171
Lemhi wild	1,327	990	970	961	947	947
Salmon, sec 19 (PAH)[c]	1,998	1,490	1,413	1,245	589	589
Pahsimeroi wild	1,102	822	805	798	783	783
Salmon, sec 20 (USB)[u]	1,192	889	843	835	820	397
Salmon, sec20 (PAH)[c]	18,179	13,560	12,863	11,336	4,861	1,200
East Fork Salmon wild	1,172	874	856	848	830	820
East Fork (EFN)[u]	1,888	1,408	1,336	1,323	1,294	1,274
Salmon, sec 21 (SAW,DWR)[c]	3,257	2,430	2,305	2,032	814	814
Upper Salmon wild	1,416	1,056	1,034	1,024	926	926
Salmon, sec 22 (SAW)[u]	1,535	1,145	1,086	1,076	974	974
Salmon, sec 22 (SAW,USB,DWR)[c]	21,103	15,742	14,933	13,159	3,308	-564
All Wild	**10,891**	**8,122**	**7,955**	**7,881**	**7,700**	**7,770**
Clipped hatchery	**56,735**	**42,321**	**40,145**	**35,378**	**14,133**	**6,600**
Unclipped Hatchery	**4,615**	**3,442**	**3,265**	**3,234**	**3,088**	**2,645**
All Hatchery	**61,350**	**45,763**	**43,410**	**38,612**	**17,221**	**9,245**
Total	**72,241**	**53,885**	**51,365**	**46,493**	**24,921**	**17,015**

Final dispositions are known for fish within the Imnaha River that enter the Little Sheep Creek weir. There were 359 clipped hatchery fish arrived at the weir, of which 53 were outplanted into Big Sheep Creek. This leaves 709 clipped hatchery fish available to spawn in the habitat; therefore, 25.1% of the steelhead spawners in the Imnaha River were hatchery steelhead.

Hells Canyon MPG

Abundance at Bonneville Dam of hatchery fish released in the Hells Canyon MPG was 10,269 fish. We estimated that 2,966 fish (28.8%) were lost between Bonneville and Ice Harbor dams. Abundance at Ice Harbor and Lower Granite dams was 7,303 fish and 7,060 fish respectively. Losses within the lower Snake River (reach 1) were 612 fish (8.4%). Losses in the Snake River basin upstream of Lower Granite Dam (reaches 3, 4, and 5) were 1,146 fish (16.2%) and 1,426 fish within Hells Canyon (reach 24). We estimate 5,914 steelhead reached Hells Canyon. Loss rate within Hells Canyon of clipped hatchery fish was 24.1%. Catch data suggest that 12 unclipped fish likely died after release. We estimated escapement in Hells Canyon was 4,488 clipped hatchery fish.

Final dispositions are known for fish that enter the Hells Canyon Dam fish trap. The trap collected 139 unclipped fish and 2,889 adipose-clipped hatchery fish. All unclipped and six clipped fish were released below the dam. Subtracting these fish leaves 1,605 hatchery steelhead left to potentially spawn. We estimate that 27.1% 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 third effort to synthesize data for all wild populations and hatchery stocks across 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 Bonneville Dam bound for the Snake River totaled 34,716 wild fish, 121,155 clipped hatchery fish, and 14,375 unclipped hatchery fish. Of these, 91,106 adipose-clipped hatchery fish, 10,695 unmarked hatchery fish, and 26,095 wild steelhead entered the Snake River. Fishery-related mortality in the Snake River basin totaled 61,421 marked hatchery fish, 445 unmarked hatchery fish, and 950 wild steelhead. Further, 16,521 marked hatchery fish, 597 unmarked hatchery fish, and 10 wild fish were removed at weirs or as part of broodstock collections. Another 13 unclipped and 91 clipped hatchery fish were estimated to leave the Snake River to enter the Walla Walla River. Potential spawners remaining in the habitat totaled 14,329 marked hatchery fish, 8,989 unmarked hatchery fish, and 24,739 wild steelhead (Figure 6). Note that unclipped hatchery steelhead were (for the most part) intended to supplement natural spawning in wild populations. Losses between BON and ICH were 24.8% across all wild Snake River stocks, presumably most is due to anthropogenic sources; however, fishery-related losses within the Snake basin were only 5.2%.

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 results to independent data to assess model performance, review changes to model structure from previous versions, and close with several observations to consider for future work.

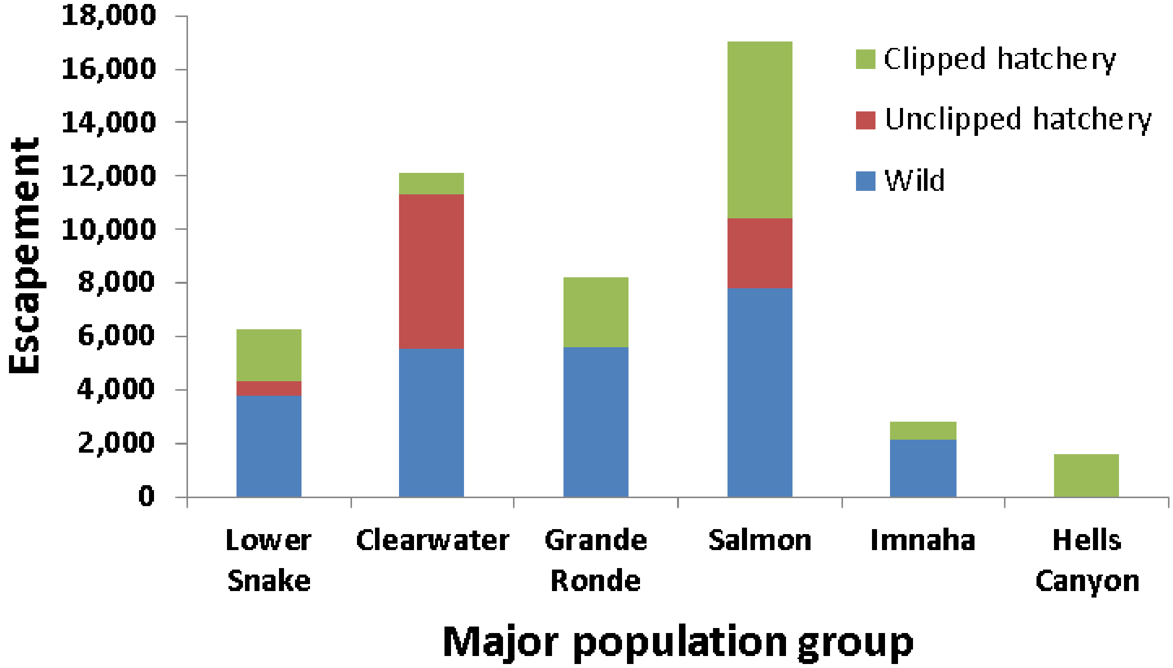

Figure 6. Comparison of steelhead escapement to the natural habitat for spawning by major population group and origin type.

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, PIT array detections in spawning streams, and redd count expansions. 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 2010 steelhead status assessment (Ford et al. 2010). The Tucannon PIT array is near the river mouth, so we used the pre-fishery abundance estimate.

The run reconstruction escapements for wild populations were less than independent estimates in three cases and greater in eight cases. The average magnitude of the overestimates was greater than for underestimates (2.9 versus 0.4 as the proportion of the independent estimate). The greatest departures were between estimates involving populations within the Lower Snake genetic reporting group. The run reconstruction estimates of this group likely include out-of-basin strays, which is consistent with estimates larger than independent data. Other large overestimates came from populations within the Upper Salmon genetic reporting group. On average, the model predictions appear optimistic. Some of this is related to genetic similarity among stocks, some is related to the use of the intrinsic potential habitat index as a metric of relative population density (and thus fish movement), and some may be due to occurrence of natural mortality, which is not 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*	1,542	157	PIT array	JDB, unpublished data
Tucannon*	384	87	Weir count	JDB, unpublished data
Asotin Creek*	1,484	1,023	Weir count	JDB, unpublished data
Alpowa Creek	478	98	Weir count	JDB, unpublished data
Fish Creek	53	95 (81-111)	Weir estimate	Copeland et al. 2014
Joseph Creek	668	1,357 (977-1,736)	Redd estimate	ERS, unpublished data
Upper Grande Ronde	2,203	3,260 (2,184-4,336)	Redd estimate	ERS, unpublished data
Pahsimeroi*	619	198	Weir count	CW, unpublished data
East Fork Salmon*	97	33	Weir count	CW, unpublished data
Upper Salmon*	328	39	Weir count	CW, unpublished data
Little Sheep Creek	403	142	Weir count	ERS, unpublished data

For hatchery stocks, there were two instances where the model predicted a negative escapement from a fishery (one out of 14 cases) or fewer fish than were collected at weirs in the reach (one out of 10 cases): in the South Fork Clearwater fishery (285 fish deficit) and at the Sawtooth weir (564 fish deficit), respectively. These instances only concerned fish subject to sport fisheries because predicted escapements for unclipped hatchery fish returning to an area with a weir were all above numbers actually collected. The magnitude of these deficits is perhaps within acceptable error for the model output. For the South Fork Clearwater and Sawtooth release groups, the deficits are 4.5% and 3.8% of the estimated abundance at Lower Granite Dam. Our conclusion is that model performance is qualitatively credible in most instances.

Model changes

We made three changes to the model for this iteration, all of which influence the abundance estimates at Lower Granite Dam. These are important because the input abundance estimate is likely to be the most important influence on the primary output: numbers of fish escaping into the spawning reaches.

The first change was the use of PBT to parse abundance of hatchery fish at Lower Granite Dam. Previously (Copeland et al. 2013, 2014) we used expansions of PIT tag detections to parse out the total abundance of clipped and unclipped hatchery fish. With this change, we avoid assuming that PIT tag shed rates are equivalent among groups (Copeland et al. 2013). Because PBT is a genetic mark, it cannot be shed. Estimates can be adjusted for non-genotyped parents (either by sampling omission or failure to amplify). Most of the parents of the hatchery steelhead that returned in the 2012-13 run were genotyped (Steele et al. 2013), which allowed us to assign 98% of the hatchery origin fish sampled at LGR. Also note that we used PBT instead of CWT recoveries to estimate straying into the lower Clearwater River fishery. No harvest of steelhead from the Imnaha hatchery stock was detected, which is puzzling because the dip-in rate computed for the 2011-2012 fishery was 20% (Copeland et al. 2014).

The second change was to use individual assignments to parse the wild steelhead into genetic stocks. Previously we used proportions derived from mixture modelling, which is thought to be more accurate than individual assignment for genetic stock assignment (Koljonen et al. 2005). However, mixture models estimated more steelhead in the Lower Snake stock than was thought reasonable and was inconsistent with independent data (Copeland et al. 2013, 2014). Comparison of the proportions we previously used for the 2011-2012 reconstruction (Copeland et al. 2014) to those reported by Ackerman et al (2014) derived from individual assignments resulted in a decrease of Lower Snake stock by almost half (from 27.8% of the LGR total to 15.2%) while other stock proportions were equivalent or increased (data not shown). In the current genetic baseline, the Lower Snake stock has high genetic diversity and therefore misallocation errors by mixture models are biased towards that stock (M. Ackerman, personal communication). The ratios of scaled model predictions to independent data for sites in the Lower Snake MPG presented in this report (Table 12) are lower for the same sites in run year 2011-2012.

The third change was the imposition of a different criterion to count re-ascension events at Lower Granite Dam. It is possible for fish to remain in the upper part of the Lower Granite Dam fish ladder yet below the first set of PIT detectors in the upper ladder for several days without exiting or being detected. Subsequent ascensions in the upper ladder resulted in the appearance of a re-ascension event. Formerly, each of these detections would count as a re-ascension event, thus inflating the estimate. As a result, re-ascension rates presented in this report are dependent on a second detection in the lower fish ladder and as a result are less than previous versions of this report, but should be less influenced by unusual behavior of a few individuals. We plan a more critical examination of fallback/re-ascension and night passage in the future.

Other considerations

We found a discrepancy between harvest estimates in the Lower Snake reach versus losses estimates from PIT tag conversion rates between Ice Harbor and Lower Granite dams. Fishery losses explain 115.4% of conversion losses of clipped fish in the Lower Snake reach. The discrepancy could arise from errors in the harvest estimate or errors in the prediction of losses in the Lower Snake (product of conversion rate and abundance estimate) or both. The absolute value of the discrepancy is 1,146 fish, which may be an indicator of the inherent error of the model, given the errors in the inputs, as is the generation of negative escapements into the South Fork Clearwater River and in the Salmon River headwaters (total = -849). The issue of the precision level acceptable to managers versus model behavior needs to be addressed before the goal of providing management advice can be attained. Note that the hatchery conversion rates include both clipped and unclipped steelhead, which will bias conversion rates of clipped stocks upward if there are significant numbers of unclipped fish released in the same HUC4. This may also indicate that our abundance estimates at Bonneville Dam are conservative. Methods to separate conversion rates of clipped and unclipped fish need to be explored.

We observed that the Columbia River (Bonneville Dam to Ice Harbor Dam) was the area of greatest loss for wild and unclipped hatchery fish. Of the wild steelhead crossing Bonneville Dam, 24.8% did not make it to Ice Harbor Dam. In contrast, fishery-related losses in the Snake River basin were 5.2%. These are fish protected under ESA (wild) or meant to supplement wild populations. In comparison, of the hatchery fish meant to mitigate for harvest losses, 26.8% of those crossing Bonneville Dam did not make it to Ice Harbor Dam. The similarity of these loss rates should be of concern for the conservation and restoration of wild steelhead in the Snake River.

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. The run reconstruction process is a good arena for critical review of the data that managers in the basin use. For example, in this report, we found inconsistencies between abundance and harvest of clipped hatchery stock. 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 ESA delisting criteria. Future improvements (for example incorporating stray rates) will improve precision and accuracy.

REFERENCES

Ackerman, M. W., and M. R. Campbell. 2012. Chinook and steelhead genotyping for genetic stock identification at Lower Granite Dam, 2011 annual report. BPA project 2010-026-00. Idaho Department of Fish and Game report 12-15. Boise.

Ackerman, M. W., N. Vu, and M. R. Campbell. 2014. Chinook and steelhead genotyping for genetic stock identification at Lower Granite Dam, 2013 annual report. BPA project 2010-026-00. Idaho Department of Fish and Game report 14-01. Boise.

Boggs, C. T., M. L. Keefer, C. A. Peery, T. C. Bjornn, and L. C. Stuehrenberg. 2004. Fallback, reascension, and adjusted fishway escapement estimates for adult Chinook salmon and steelhead at Columbia and Snake river dams. Transactions of the American Fisheries Society 133:932-949.

Brandt, S. 2009. 2009 Snake River steelhead monitor and evaluation of harvest. Shoshone Bannock Tribes, Fort Hall, Idaho.

Bumgarner, J. D., and J. Dedloff. 2011. Lyons Ferry Complex Hatchery evaluation: summer steelhead annual report 2008 and 2009 run years. Report to U.S. Fish and Wildlife Service, Lower Snake River Compensation Plan Office, Boise, Idaho. FPA 11-05.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Wauneta, and I. V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-27.

Chasco, B., R. Hilborn, and A. E. Punt. 2007. Run reconstruction of mixed-stock salmon fisheries using age-composition data. Canadian Journal of Fisheries and Aquatic Sciences. 64:1479-1490.

Copeland, T., J. Bumgarner, A. Byrne, L. Denny, J. L. Hebdon, M. Johnson, C. A. Peery, S. Rosenberger, E. R. Sedell, G. E. Shippentower, C. Stiefel, and S. P. Yundt. 2013. Reconstruction of the 2010/2011 steelhead spawning run into the Snake River basin. Report to Bonneville Power Administration, Portland, Oregon.

Copeland, T., J. Bumgarner, A. Byrne, L. Denny, J. L. Hebdon, M. Johnson, C. A. Peery, S. Rosenberger, E. R. Sedell, G. E. Shippentower, C. Stiefel, and S. P. Yundt. 2014. Reconstruction of the 2011/2012 steelhead spawning run into the Snake River basin. Report to Bonneville Power Administration, Portland, Oregon.

Dauble, D. D., and R. P. Mueller. 2000. Upstream passage monitoring: difficulties in estimating survival for adult Chinook salmon in the Columbia and Snake rivers. Fisheries 25(8):24-34.

Flesher, M. W., S. M. Warren, R. W. Carmichael, and L. R. Clarke. 2014. Lower Snake River Compensation Plan: Summer steelhead creel surveys on the Grande Ronde, Wallowa, and Imnaha rivers for the 2011-12 run year. Report to the US Fish and Wildlife Service, Lower Snake River Compensation Plan. Contract F12AC00092. Oregon Department of Fish and Wildlife, Salem.

Ford, M., T. Cooney, P. McElhany, N. Sands, L. Weitkamp, J. Hard, M. McClure, R. Kope, J. Myers, A. Albaugh, K. Barnas, D. Teel, P. Moran, and J. Cowen. 2010. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest. Draft US Department of Commerce, NOAA Technical Memorandum NOAA-TM-NWFSC-XXX.

Fryer, J. K., J. Whiteaker, and D. Kelsey. 2012. Upstream migration timing of Columbia Basin Chinook and sockeye salmon and steelhead in 2010. Columbia River Inter-Tribal Fish Commission Technical Report 12-02. Portland, Oregon.

ICBTRT (Interior Columbia Basin Technical Recovery Team). 2003. Independent populations of Chinook, steelhead, and sockeye for listed Evolutionarily Significant Units within the interior Columbia River domain. Northwest Fisheries Science Center. Seattle, Washington. Available: http://www.nwfsc.noaa.gov/trt/col/trt_pop_id.cfm.

ICBTRT (Interior Columbia Basin Technical Recovery Team). 2007. Viability criteria for application to Interior Columbia Basin salmonid ESUs. Northwest Fisheries Science Center. Seattle, Washington. Available: http://www.nwfsc.noaa.gov/trt/col/trt_viability.cfm.

Koljonen, M. L., J. J. Pella, and M. Masuda. 2005. Classical individual assignments versus mixture modeling to estimate stock proportions in Atlantic salmon (Salmo salar) catches from DNA microsatellite data. Canadian Journal of Fisheries and Aquatic Sciences 62:2143-2158.

Mallet, J. 1974. Inventory of salmon and steelhead resources, habitat, use and demands. Job performance report. Project F-58-R-1. Idaho Department of Fish and Game, Boise.

Petrosky, C. E. 2014. 2013 annual report to NOAA Fisheries, fishery management and evaluation plans 4(d) rule limit 4: the incidental take of ESA listed salmon and steelhead during conduct of recreational fisheries in Idaho. Idaho Department of Fish and Game, Boise.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press. New York.

Schrader, W. C., T. Copeland, P. Kennedy, M. W. Ackerman, K. K. Wright, and M. R. Campbell. 2012. Wild adult steelhead and Chinook salmon abundance and composition at Lower Granite Dam, spawn year 2010. Annual report 2010, BPA Projects 1990-055-00, 1991-073-00, 2010-026-00. Idaho Department of Fish and Game Report 12-16. Idaho Department of Fish and Game, Boise.

Schrader, W. C., M. P. Corsi, P. Kennedy, M. W. Ackerman, M. R. Campbell, K. K. Wright, and T. Copeland. 2013. Wild adult steelhead and Chinook salmon abundance and composition at Lower Granite Dam, spawn year 2011. Idaho Department of Fish and Game Report 13-15. Annual report 2011, BPA Projects 1990-055-00, 1991-073-00, 2010-026-00.

Starr, P., and R. Hilborn. 1988. Reconstruction of harvest rates and stock contribution in gauntlet salmon fisheries: application to British Columbia and Washington sockeye (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 45:2216-2229.

Steele, C., J. McCane, M. Ackerman, M. Campbell, M. Hess, and S. Narum. 2013. Parentage based tagging of Snake River hatchery steelhead and Chinook Salmon. Idaho Department of Fish and Game Report 13-23. Idaho Department of Fish and Game, Boise.

Stiefel, C., S. Rosenberger, and F. Bohlen. 2013. 2012 calendar year hatchery report: IPC and LSRCP monitoring and evaluation programs for the State of Idaho. Idaho Department of Fish and Game Report 13-05. Idaho Department of Fish and Game, Boise.

WDFW (Washington Department of Fish and Wildlife). 2009. Fisheries management and evaluation plan for recreational fisheries for summer steelhead, warmwater fish, sturgeon, carp, and other species in the Snake River basin. Washington Department of Fish and Wildlife, Olympia.