RECONSTRUCTION OF THE 2010/2011 STEELHEAD SPAWNING RUN INTO THE SNAKE RIVER BASIN

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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 that developed the Snake River sub-regional 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 inter-agency 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. The authors would like to acknowledge the constructive review from Mike Ackerman (Idaho Department of Fish and Game).

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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
LGD	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

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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 2010-2011 return of steelhead within the Snake River basin. This is the first effort to synthesize data for all populations and hatchery stocks across the basin. Therefore, the larger goal was to develop an analytical framework that could be refined for more rigorous evaluations in the future. We estimated 152,485 adipose-clipped hatchery fish, 23,454 unmarked hatchery fish, and 52,026 wild steelhead entered the Snake River during the study period. Fishery-related mortality totaled 96,936 marked hatchery fish, 1,385 unmarked hatchery fish, and 1,959 wild steelhead. Further, 25,031 marked hatchery fish, 5,856 unmarked hatchery fish, and 91 wild fish were removed at weirs. Potential spawners remaining in the habitat totaled 30,518 marked hatchery fish, 16,213 unmarked hatchery fish, and 49,976 wild steelhead. 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 useful framework also allows inferences regarding spatial distribution of spawners and disposition. Comparison with independent data suggested that the model provides realistic estimates for hatchery fish, but methodology for natural fish estimates needs refinement. This information will help evaluate the performance of the Snake River summer steelhead Evolutionarily Significant Unit towards escapement goals and delisting criteria. This inaugural effort focused on compilation of data from multiple collaborators and general assumptions that may limit specific conclusions; however, the resulting analytical framework can be refined for more rigorous evaluations in the future.

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 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 basin in recent years are hatchery fish (e.g., Schrader et al. 2012). 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 above Lower Granite Dam, except for one wild population and two hatchery stocks below Lower Granite Dam. The location of Lower Granite Dam facilitates an accounting of the aggregate run prior to the fish encountering the extensive fisheries above the dam. 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 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 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. The immediate objective was to estimate the disposition of the 2010-2011 return of steelhead within the Snake River basin. Previous evaluations had been done for a few wild populations in Oregon and within the hatchery programs (Pollard and Starr undated). This is the first effort to synthesize adult return data for all wild populations and hatchery stocks across the basin. Therefore, the larger goal was to develop an analytical framework that could be refined for more rigorous evaluations in the future. 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 2011 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. 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, 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, 52 km below the mouth of the Snake. Within the Snake River, the first dam encountered by adult steelhead is Ice Harbor Dam (river km 16). Lower Granite Dam, the last dam steelhead may cross, is at rkm 173. Fish passage within mainstem 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). The latter pair defines the upstream distributional limits of steelhead in the Snake basin.

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 above Lower Granite Dam (Tom Cooney, NOAA Fisheries, unpublished data). In general, populations are grouped by major drainage (Clearwater, Grande Ronde, Imnaha, and Salmon rivers). The Tucannon River population (below Lower Granite Dam) and the Asotin Creek population (above Lower Granite Dam) are considered to comprise the Lower Snake major population group (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 and tribal fisheries. In order to bolster natural production as mandated by the US vs. Oregon agreement, some unclipped hatchery fish are released in the Tucannon River, Lolo Creek, South Fork Clearwater River, Little Salmon River, East Fork Salmon River, Yankee Fork Salmon River, and at the Sawtooth Hatchery weir in the headwaters of the Salmon River.

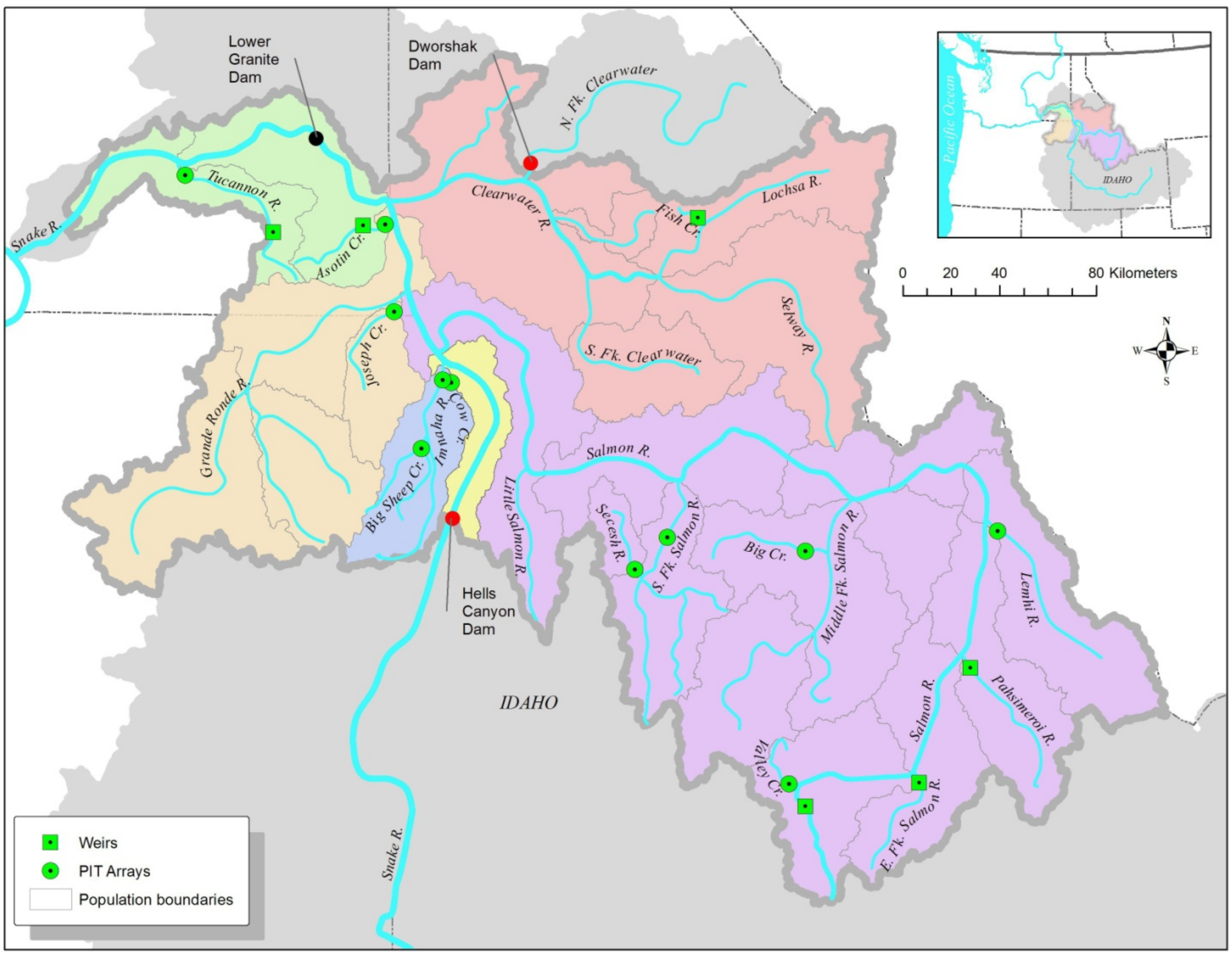

Figure 2. Snake River steelhead populations with locations of selected weirs and PIT tag antenna arrays. Major population groups are denoted by different colors.

Steelhead fisheries within the bounds of the Snake basin are complex (Figure 3). Recreational fisheries are prosecuted within the main stems of large rivers with harvest beginning in September and continuing into April, although harvest season open and closure dates may vary in some river sections. Angling gear with barbless hooks is permitted. Tribal fisheries are more limited in spatial extent but may employ a variety of gears. 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, although most effort is expended in the lower Clearwater. Nez Perce tribal members may also pursue subsistence steelhead fisheries throughout the Clearwater River basin, but most effort is expended in the North Fork and South Fork Clearwater rivers. Members of the Confederated Tribes of the Umatilla Indian Reservation may pursue subsistence steelhead fisheries over a wide area but most effort is concentrated in the upper Grande Ronde River. Lastly, members of the Shoshone Bannock Tribes may harvest steelhead throughout the Salmon River basin but most effort is concentrated in the Yankee Fork.

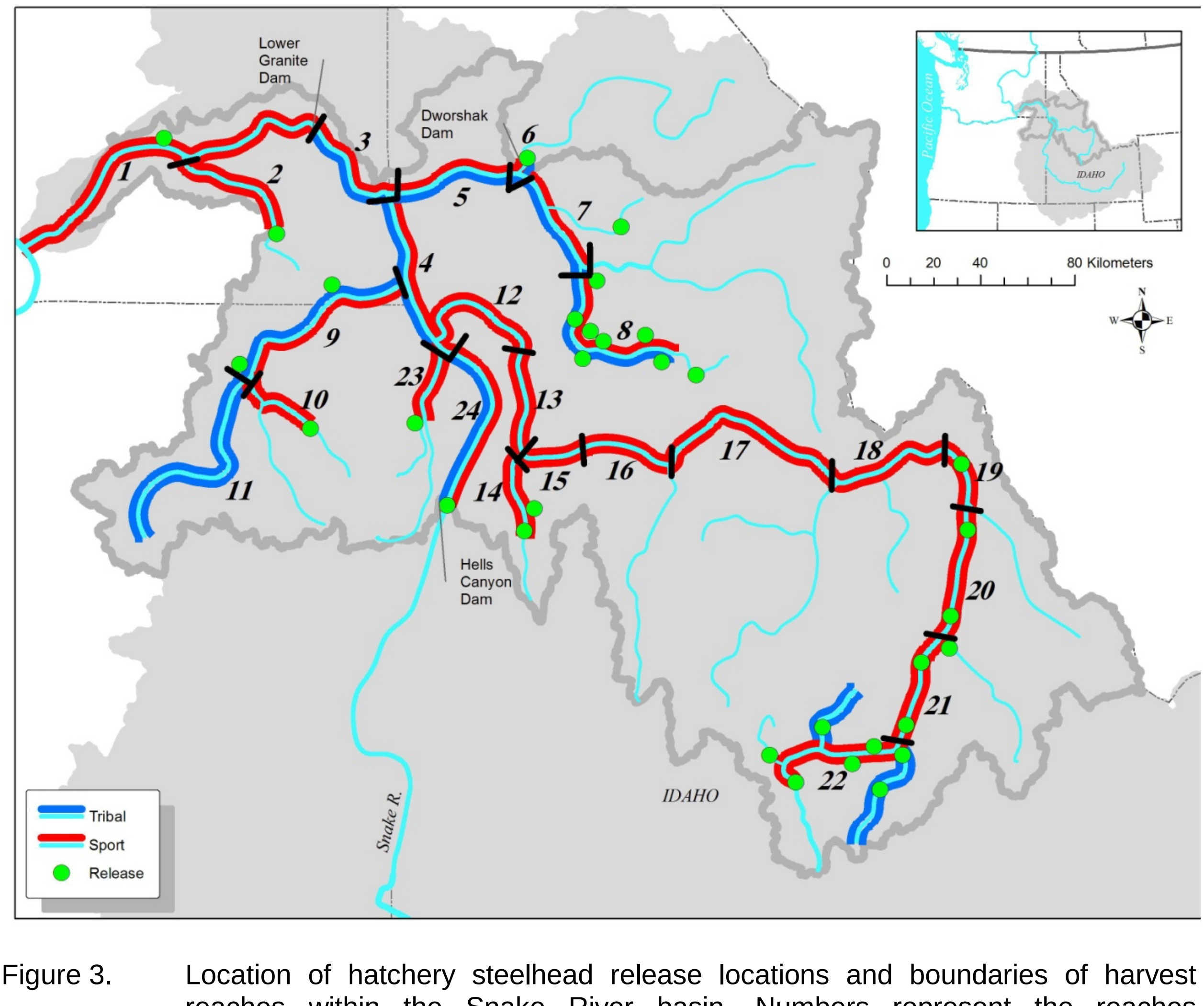

Figure 3. Location of hatchery steelhead release locations and boundaries of harvest reaches within the Snake River basin. Numbers represent the reaches represented as the smallest strata in the run reconstruction model.

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). Disposition of these fish within the Snake River basin was estimated recursively by applying the survival and movement probabilities; that is, we estimated escapement and loss to fisheries between Ice Harbor Dam and Lower Granite Dam by moving fish backward and 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. Formally, we modified the 'box-car' model developed by Starr and Hilborn (1988):

$$N_i = \sum(C_{ij} + E_{ij}),$$

where N_i is the abundance of stock *i*, *C* is the harvest (including catch-and-release mortality) of stock *i* in reach *j*, and *E* is the number of survivors staying in reach *j*. Catch in each reach is parsed to each stock in proportion to their abundance, $C_{ij} = C_j(\frac{N_{ij}}{\Sigma N_{ij}})$. After mortality occurs, fish of stock i move between reaches according to $P_{ij} = p_{i,k-j}(N_{i,k} - C_{ik})$, where P_{ij} is the number of stock *i* entering reach *j* and $p_{i,k\text{-}j}$ is the stock-specific probability of moving from reach *k* to reach *j*, where $k \neq j$. Then, escapement by reach is $E_{ij} = N_{ij} - C_{ij} - P_{i,j-k}$. We can simplify the number of terms to three: the number of fish entering a reach (P_{ij}), the number of fish that die in a reach (C_{ij}), and the probability that surviving fish will move on ($p_{i,k\text{-}j}$). Therefore, the number of fish incurring each of the three fates within a reach is determined by iterating $\sum P_{ij} = \sum(C_j \times (P_{ij}/\sum P_{ij})) + \sum(p_{i,k-j}(P_{ij} - C_{ij})) + \sum((1 - p_{i,k-j})(P_{ij} - C_{ij}))$, where the summation on the left of the equation is the number of fish entering reach *j*, the first summation on the right is the number that died in reach *j*, the second summation is the number of survivors that move to reach *k*, and the last summation is the number of survivors that stay in reach *j*.

The total abundance of steelhead crossing Lower Granite Dam from July 1, 2010 to June 30, 2011 was based on the expanded window count (see Schrader et al. 2012 for methodology). Abundance of hatchery fish was parsed to release location based on expansion of PIT tag detections at Lower Granite Dam. Release locations were aggregated within fisheries reaches (see Figure 3) to simplify accounting within the model. Abundance of wild fish was parsed into genetic reporting groups established by Ackerman and Campbell (2012) using genetic stock identification on adult steelhead sampled at Lower Granite Dam. Reporting groups were 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). We used PIT tag detections within the hydrosystem to estimate conversion of stocks from Bonneville Dam to the study area (measured at Ice Harbor Dam) and from Ice Harbor Dam to Lower Granite Dam. By these means, we were able to estimate stock abundance downstream of Lower Granite Dam.

We used river reaches defining sport fisheries to delineate the spatial detail of the run reconstruction model. The study area was further refined into nine major reaches based on relevant geographic features and then into shorter reaches if the fisheries were sufficiently complex and sufficient data were available (Figure 4). 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 based on data collected by in-season creel surveys except those provided by Idaho Department of Fish and Game (IDFG) and Washington Department of Fish and Wildlife (WDFW). IDFG estimated catch and harvest data with a post-season phone survey (Petrosky 2012). Take of wild fish by sport fisheries in Idaho was estimated based on the encounter rate of hatchery fish on a statewide basis, so we parsed the statewide take into the 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. The fisheries data for northeast Oregon were unavailable for 2010-2011, so we used 2009-2010 data scaled to the 2010-2011 escapement at Lower Granite Dam. Likewise, 2010-2011 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 exist in tributaries within a fishery reach are treated as residents of that reach, i.e., they escape to their spawning area without further mortality.

Table 2. Description of fishery reaches in the Snake River basin, including agencies reporting fisheries within them during 2010-2011, 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 [a] and clipped releases by [b].

Reach	Agencies	Resident wild and hatchery stocks
Snake River downstream of Lower Granite Dam		
Ice Harbor-Lower Granite	WDFW	Tucannon, Snake(LF [b])
Tucannon River		
Mouth to Tucannon Fish Hatchery	WDFW	Tucannon, Tucannon(TEH[a],LF[b])
Snake River upstream from Lower Granite Dam		
Lower Granite to Clearwater River	WDFW, NPT	Asotin
Clearwater to Salmon/Imnaha	WDFW, IDFG	Asotin
Salmon/Imnaha to Hells Canyon Dam	IDFG	Snake(OX[b])
Clearwater River		
Mouth to Orofino	IDFG, NPT	Lower Clearwater
North Fork Clearwater Mouth upstream to Dworshak Dam	IDFG, NPT	NF Clearwater(DWR[b])
Orofino to Clear Creek	IDFG, NPT	Lower Clearwater, Lolo, Lolo(DWR[a]), Clear Creek(DWR[b]), Lochsa, Selway

Table 2, continued.

Reach	Agencies	Resident wild and hatchery stocks
	South Fork Clearwater River	
Mouth upstream	IDFG, NPT	South Fork Clearwater, SF Clearwater(DWR[a,b])
	Grande Ronde River	
Mouth to Wallowa River	WDFW, ODFW	Lower Grande Ronde, Joseph Creek, Cottonwood(WLH[b)])
Upstream of Wallowa River	CTUIR	Upper Grande Ronde
	Wallowa River	
Mouth upstream	ODFW	Wallowa, Wallowa(WLH[b])
	Imnaha River	
Mouth upstream	ODFW	Imnaha, Imnaha(IMH[b])
	Salmon River	
Mouth to Whitebird Creek	IDFG	Little Salmon
Whitebird to Little Salmon mouth	IDFG	Little Salmon
Little Salmon River upstream	IDFG	Little Salmon, Ltl Salmon(PAH[a,b],OX[b],DWR[b])
Little Salmon mouth to Vinegar Creek	IDFG	NA
Vinegar to South Fork	IDFG	South Fork Salmon, Secesh, Chamberlain
South Fork to Middle Fork	IDFG	Chamberlain, Lower Middle Fork, Upper Middle Fork, Panther
Middle Fork to North Fork	IDFG	Panther, North Fork
North Fork to Lemhi	IDFG	Lemhi, Salmon sec 19(PAH[b])
Lemhi to Pahsimeroi	IDFG	Pahsimeroi, Salmon sec 20(PAH[b])
Pahsimeroi River to East Fork	IDFG, SBT	East Fork, Salmon sec 21(EFN[a],SAW[b],DWR[b])
East Fork upstream	IDFG, SBT	Upper Salmon, Salmon sec 22(SAW[a,b],DWR[b],USB[b])

Losses below Lower Granite Dam (as far as Bonneville Dam) were estimated using PIT tag detections at main-stem dams and in the lower Tucannon River. The PTAGIS database (www.ptagis.org) was queried for adult detections (between 20 June 2010 and 31 December 2010) of fish tagged as juveniles in the Snake River basin. Conversion rates were the proportion of PIT-tagged fish detected at a dam that were later detected at any upstream dam. We computed conversion rates by origin type (hatchery versus wild) and area of release (4^{th} field hydrologic unit code). Conversion rates were calculated based on detections at Bonneville, McNary, Ice Harbor, and Lower Granite dams. Unlike the treatment of movement above Lower Granite Dam, here movement probability is confounded with survival, so fish are moved before the fishery, because they have survived harvest mortality by definition. Fish are assumed to be detected at main-stem dams with probability 1.0 but the efficiency of in-stream PIT detectors arrays is usually less. We applied a correction to the Tucannon array detections of 0.89, which is the average detection efficiency for adult steelhead during the 2010-2011 run in the Snake River basin reported by the Integrated Status and Effectiveness Monitoring Project (QCI 2012, p. 171).

Coded wire tag (CWT) recoveries indicate that members of hatchery stocks not resident to the Clearwater River will enter the lower reaches and comprise a significant proportion of the harvest within the lower Clearwater River. Likewise, hatchery fish not returning to the North Fork Clearwater River will enter that reach. Stocks moving upstream past the mouths of these rivers were assumed to stray into them at a 6% rate before resuming their upstream path. Second, hatchery and wild stocks from the Lower Snake (below Lower Granite Dam) and Tucannon River are known to stray extensively (Bumgarner and Dedloff 2011); many of them pass their point of origin and cross Lower Granite Dam. Some remain above Lower Granite Dam and others fall 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. Of the fish that stray above Lower Granite Dam, we assumed half stop in the Lower Granite Pool and half stop in the Upper Snake reach. Fallback probabilities were applied to fish within Lower Granite pool only. Because probability of PIT tag detections is confounded with survival, fallbacks from Lower Granite pool are removed before fishery losses are subtracted and routed to their final destination (Tucannon River or Lower Snake) and are not eligible to be harvested upstream of Lower Granite Dam.

Output of the run reconstruction model is summarized into three categories: initial abundance, losses, and escapement by populations. Initial abundance is estimated as number crossing Bonneville Dam. Losses are summarized according to general geographic area: between Bonneville and Ice Harbor dams; between Ice Harbor and Lower Granite dams; between Lower Granite Dam and the natal river; and within the natal river. Losses between Bonneville and Ice Harbor dams include all mortality sources; losses above 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 below 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, we report in the text mortality and escapement within the study area of non-Snake stocks that were detected at Lower Granite Dam.

RESULTS

Model input data

The preliminary abundance estimates at Lower Granite Dam for the 2010-2011 steelhead run was 141,725 individuals for clipped hatchery fish, 22,116 unclipped hatchery fish, and 44,455 wild fish (Table 3). The PIT expansion summed across all hatchery release groups was 81% of the total hatchery return. The clipped hatchery fish were parsed into 16 releases and unclipped hatchery fish were parsed into seven releases based on proportions estimated from the PIT-tag expansion. Of the 23 hatchery release groups, three were from locations outside of the Snake basin (the Touchet and Walla Walla rivers). The largest hatchery return groups at Lower Granite Dam were from the upper Salmon River reach between the Lemhi and Pahsimeroi rivers. Other release locations with more than 10,000 adult returns were Salmon River above the East Fork, Hells Canyon, North Fork Clearwater River, Wallowa River, Little Salmon River, and South Fork Clearwater River. Most of the unclipped hatchery steelhead were returning to South Fork Clearwater River or the Salmon River above the East Fork. We estimated that the largest wild population was the Tucannon River and the smallest was North Fork Salmon River.

Total fishery-related mortality of clipped hatchery fish within the study area was 96,936 (Table 4). This number includes direct harvest as well as incidental mortality from catch-and-release handling. We did not have any catch-and-release estimates for hatchery fish in the Grande Ronde or Imnaha fisheries, so mortality estimates for those fisheries are biased low. Incidental take of unclipped steelhead was estimated at 2,360 fish, which includes unclipped hatchery fish as well as wild fish. The largest total losses of clipped hatchery fish were in the lower Grande Ronde River, lower Clearwater River, and lower Snake River reaches. The largest fishery mortality estimates of unclipped fish were in the lower Snake River, Lower Granite pool, and Imnaha River. No harvests or catches were reported in the Wallowa River or upper Grande Ronde River.

Table 3. Abundance of steelhead at Lower Granite Dam by wild population and hatchery stock derived from genetic stock identification and PIT tag expansions. Hatchery stocks are grouped by release site and stock is in parentheses. Unclipped hatchery releases are denoted by [a] and clipped releases by [b]. Asterisks indicate mid-Columbia release locations.

Wild populations		**Hatchery stocks**	
Name	**Abundance**	**Release site (stock)**	**Abundance**
Tucannon	5,861	Walla Walla (LF)[b]*	872
Asotin Creek	4,141	Touchet (endemic)[a]*	68
Lower Grande Ronde	1,177	Touchet (LF)[b]*	597
Wallowa	2,345	Snake(LF)[b]	1,030
Joseph Creek	857	Tucannon(TEH)[a]	566
Upper Grande Ronde	2,824	Tucannon (LF)[b]	2,550
Lower Clearwater	1,404	Lolo (DWR)[a]	1,291
Lolo Creek	330	SF Clearwater (DWR)[a]	7,363
South Fork Clearwater	4,535	SF Clearwater (DWR)[b]	10,505
Lochsa	1,522	NF Clearwater (DWR)[b]	18,407
Selway	2,612	Clear Creek (DWR)[b]	3,403
Little Salmon	976	Cottonwood(WLH)[b]	3,529
Chamberlain Creek	847	Wallowa (WLH)[b]	13,576
South Fork Salmon	1,463	Little Salmon (PAH)[a]	4,945
Secesh	626	Little Salmon (OX,PAH,DWR)[b]	11,671
Lower Middle Fork	1,808	Salmon sec 19 (PAH)[b]	2,927
Upper Middle Fork	1,926	Salmon sec 20 (PAH)[b]	26,212
Panther Creek	499	East Fork Salmon (EFN)[a]	1,609
North Fork Salmon	285	Salmon sec 21 (SAW,DWR)[b]	4,136
Lemhi	1,605	Salmon sec 22 (SAW)[a]	6,275
Pahsimeroi	1,330	Salmon sec 22 (SAW,USB,DWR)[b]	19,856
East Fork Salmon	1,416	Imnaha (IMH)[b]	4,039
Upper Salmon	1,711	Snake (OX)[b]	18,413
Imnaha	2,356		

Table 4. 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**
Lower Snake	260	8,214	15
Tucannon	15	1,175	7
Lower Granite Pool	242	4,904	3
Upper Snake	195	6,421	30
Lower Clearwater	197	10,427	237
North Fork Clearwater	88	6,032	70
Clearwater to Clear Creek	60	2,700	17
South Fork Clearwater	131	3,891	69
Lower Grande Ronde	182	10,622	165
Wallowa River	0	0	0
Upper Grande Ronde	0	0	0
Salmon to Whitebird	33	1,893	21
Salmon (WB-Little Salmon)	62	3,199	46
Little Salmon	102	2,335	177
Salmon (LS to Vinegar)	30	3,087	28
Salmon (Vinegar to SF)	26	908	9
Salmon (SF to MF)	75	3,211	44
Salmon (MF to NF)	127	9,132	209
Salmon (NF to Lemhi)	45	3,374	75
Salmon (Lemhi to Pahsmeroi)	42	3,640	102
Salmon (Pahsimeroi to EF)	34	1,281	62
Salmon (EF upstream)	137	3,171	170
Imnaha	233	1,653	0
Hells Canyon	44	4,083	27

We estimated conversion rates of all Snake River stocks within the Columbia River hydrosystem based on PIT tag detections (Table 5). Conversion rate from Bonneville to McNary dam averaged 79.5% for wild steelhead and 76.9% for hatchery steelhead. Conversion rates from McNary to Ice Harbor dam averaged 95.7% for wild fish and 94.5% for hatchery fish. Conversion rate from Ice Harbor to Lower Granite dam averaged 94.0% for wild fish and 94.8% for hatchery fish for stocks originating above Lower Granite Dam. Excluding wild Asotin steelhead, the conversion rate for wild steelhead averaged 96.1%.

Steelhead from Lower Snake stocks residing downstream from Lower Granite Dam tend to overshoot their natal reach to pass above Lower Granite Dam, some of which return back downstream (fallback; Table 6). Conversion rates from Ice Harbor to Lower Granite dam for the Lyons Ferry stock release groups ranged from 34.6% to 74.2%, while 51.4% of the wild Tucannon fish crossed Lower Granite Dam. Of the Lower Snake fish that crossed Ice Harbor Dam (all stocks and origins), 0.0% to 25.7% were estimated to enter the Tucannon River and stay there. By subtraction, 16.4% to 63.0% stayed within the Lower Snake below Lower Granite Dam as either mortalities or escapement. We estimated 0.0% to 19.5% of the Lower Snake fish that crossed Lower Granite Dam later fell back and entered the Tucannon River. By subtraction, 0.0% to 30.0% of fish crossing Lower Granite Dam fell back and stayed in the Lower Snake reach. These are minimums because detection sites in the Lower Snake are limited to Lyons

Ferry Hatchery and the juvenile bypass facilities at Lower Granite and Little Goose dams. The estimate for the Lyons Ferry Tucannon release entering the Tucannon River was lower than the estimate for the Touchet endemic stock, so we used the estimate for the Tucannon endemic stock for both groups in the run reconstruction model.

Table 5. Conversion rates in the hydrosystem for selected reaches, by major population group and origin.

Group and origin	Reach: Bonneville to McNary	Reach: McNary to Ice Harbor	Reach: Ice Harbor to Lower Granite
Lower Snake wild	0.8333	0.971	NA
Lower Snake hatchery	0.8031	0.9408	NA
Asotin wild	0.7959	0.9487	0.8571
Gr Ronde wild	0.7349	0.9672	0.9796
Gr Ronde hatchery	0.7484	0.9694	0.9519
Imnaha wild	0.7886	0.9278	0.9512
Imnaha hatchery	0.7341	0.9371	0.9303
Clearwater wild	0.8400	0.9281	0.9375
Clearwater hatchery	0.7581	0.9627	0.9563
Hells Canyon hatchery	0.756	0.8976	0.945
Salmon wild	0.7745	1.000	0.9744
Salmon hatchery	0.8149	0.9630	0.9541

Table 6. Movement probabilities of Lower Snake stocks within the Ice Harbor to Lower Granite reach. Rates are based on PIT tag detections.

Stock	Movement type: Ascend LGD	Enter TUC	Die/reside	Move LGD-TUC	Fallback to Lower Snake	Fallback over ICH
Tucannon	0.5143	0.2568	0.2289	0.1248	0	0
Tucannon (TEH)[a]	0.6372	0.1989	0.1639	0.1717	0.0227	0
Tucannon(LF)[b]	0.7419	0.0725	0.1856	0.1954	0.0655	0
Touchet (endemic)[a]	0.3462	0.0864	0.5674	0	0.1111	0.0769
Snake (LF)[b]	0.5263	0.0296	0.4441	0	0.3	0
Walla Walla (LF)[b]	0.4423	0	0.5577	0.0489	0.1685	0.0577
Touchet (LF)[b]	0.3704	0	0.6296	0.1124	0.1876	0.0556

Run reconstruction

We report summaries by major population groups beginning downstream and proceeding in a general upstream direction. Summaries of hatchery release groups are given next to the wild populations in which they are released.

Lower Snake River

Abundance for stocks from the Lower Snake major population group at Bonneville Dam based on the conversion rates in Table 5 was 20,482 wild fish; 1,010 unclipped Tucannon endemic stock; and 7,139 for the two Lyons Ferry clipped hatchery groups (Table 7). Substantial losses occurred before these stocks reached the Snake River (range 19.1% to 24.6%). These fish crossed Lower Granite Dam in large numbers, even stocks that were not from above Lower Granite Dam. Losses within the study area for these stocks were high both above and below Lower Granite Dam. Escapements were greatest for the two wild populations; however, 4,497 hatchery fish also escaped. In addition, several non-Snake release groups raised at Lyons Ferry Hatchery entered the study area. We did not estimate their abundance at Bonneville Dam but did estimate they contributed to fisheries and over 3,300 escaped within the study area.

Final dispositions are known for fish removed at weirs within the Lower Snake major population group (Table 7; J. Bumgarner, unpublished data). There are three weirs in the study area below Lower Granite Dam: Lyons Ferry Hatchery trap, the Almota Creek weir, and the Tucannon Fish Hatchery weir. Of the Lower Snake hatchery stocks, 779 were removed at these three weirs. Another 131 fish were detected within the Walla Walla River, leaving 3,107 clipped steelhead at large within the study area. For the Tucannon population, 33.3% of the potential spawners were hatchery fish. There are four weirs in the Lower Snake major population group above Lower Granite Dam: Alpowa Creek, Asotin Creek, George Creek, and Ten Mile Creek. Of the Lower Snake hatchery stocks, 124 were removed at these four weirs, leaving 3,723 at large. For the Asotin Creek population (all spawning areas), 28.8% of the potential spawners were hatchery fish.

Table 7. Reconstruction of wild and hatchery stocks residing in the Lower Snake major population group. Losses downstream from Ice Harbor Dam include all mortality sources. Losses upstream from ICH only include fishery-related mortality. Loss percentages are relative to the number of fish entering an area. Escapement is computed by spawning reach for wild steelhead and release location for hatchery steelhead.

		Estimated losses (%)			Escapement		Weir take	
Stock	**Abundance at BON**	**BON-ICH**	**ICH-LGD**	**Above LGD**	**ICH-LGD**	**Above LGD**	**Below LGD**	**Above LGD**
Tucannon	14,084	2,688 (19.1)	53 (0.5)	38 (0.7)	6,213	5,092	0	0
Tucannon (TEH)[a]	1,010	247 (24.6)	4 (0.5)	3 (0.5)	303	453	133	88
Tucannon (LF)[b]	4,549	1,112 (24.4)	1,220 (35.5)	166 (6.5)	326	1,701	84	32
Snake (LF)[b]	2,590	633 (24.4)	157 (8.0)	116 (8.4)	1,068	646	288	2
Asotin	6,398	1,567 (24.5)	17 (0.4)	34 (0.8)	0	4,107	0	0
Touchet (endemic)[a*]	na	na	1 (0.5)	0 (0.0)	135	60	0	0
Walla Walla & Touchet (LF)[b]	na	na	193 (5.4)	122 (8.3)	2,185	987	274	2

Clearwater River

Abundance for stocks from the Clearwater major population group at Bonneville Dam was 14,233 wild steelhead; 12,398 for the unclipped hatchery steelhead; and 46,303 for clipped hatchery steelhead (Table 8). Based on PIT tag detections, 22.0% of the wild fish and 27.0% of the hatchery fish were lost before they entered the Snake River. Loss rates of wild and unclipped hatchery Clearwater stocks were similar in the Snake River fisheries below and above Lower Granite Dam; however, clipped hatchery releases were more heavily exploited below Lower Granite Dam. Fishery-related losses were greatest within the Clearwater River fisheries for all of these stocks. Losses of clipped hatchery stocks ranged from 50.6% for the Clear Creek release group to 89.7% for the South Fork Clearwater releases. Losses for adipose-intact fish ranged from 3.4% for the Lower Clearwater wild population to 8.5% for the South Fork wild and unclipped hatchery fish. We estimated escapement in the Clearwater River was 9,606 wild fish, 7,906 unclipped hatchery fish, and 9,554 clipped hatchery fish.

Final dispositions are known for fish within the Clearwater River basin that enter hatchery weirs at Dworshak 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 Hatchery. These two hatcheries operate within the Lower Clearwater population. During the 2009-2010 run, Dworshak Hatchery collected 3,615 clipped hatchery fish but released 1,634 of them (99 were released more than once; Peery et al. 2012). We estimate 82.8% of the Lower Clearwater spawning population was composed of hatchery fish. Realized hatchery impact may be lower because Dworshak Hatchery is >5 km from the nearest spawning tributaries. The Crooked River weir only collected three hatchery fish and another 95 were collected for broodstock by angling (Stiefel et al. 2012). This leaves 65.0% of the South Fork Clearwater spawning population composed of hatchery fish, 87.6% of which were unclipped hatchery fish. Unclipped hatchery fish also escaped into Lolo Creek. We estimated 79.7% of the Lolo Creek spawning population was composed of hatchery fish.

Table 8. Reconstruction of wild and hatchery stocks residing in the Clearwater major population group. Losses above Ice Harbor Dam include only fishery-related sources.

Stock	Number at BON	Estimated losses (%) BON-ICH	ICH-LGD	Above LGD	In Clearwater	Escape	Weir take
Lower Clearwater	1,921	423 (22.0)	5 (0.3)	5 (0.4)	48 (3.4)	1,351	0
NF Clearwater (DWR)[b]	26,374	7,126 (27.0)	1,039 (5.4)	637 (3.5)	10,886 (61.3)	6,884	1,981
Clear (DWR)[b]	4,877	1,318 (27.0)	192 (5.4)	118 (3.5)	1,663 (50.6)	1,622	0
Lolo	451	99 (22.0)	1 (0.3)	1 (0.3)	25 (7.6)	304	0
Lolo (DWR)[b]	1,849	499 (27.0)	5 (0.4)	5 (0.4)	95 (7.4)	1,191	0
Lochsa	2,082	459 (22.0)	6 (0.4)	6 (0.4)	112 (7.4)	1,404	0
Selway	3,574	788 (22.0)	10 (0.4)	9 (0.3)	192 (7.4)	2,411	0
South Fork	6,205	1,368 (22.0)	17 (0.4)	16 (0.4)	383 (8.5)	4,136	0
South Fork (DWR)[a]	10,549	2,850 (27.0)	27 (0.4)	27 (0.4)	621 (8.5)	6,715	0
South Fork (DWR)[b]	15,052	4,067 (27.0)	593 (5.4)	364 (3.5)	9,093 (89.7)	1,048	98

Grande Ronde River

Abundance for stocks from the Grande Ronde major population group at Bonneville Dam was 10,346 wild fish; and 24,768 for clipped hatchery release groups (Table 9). Based on PIT tag detections, 28.9% of the wild fish and 27.5% of the hatchery fish were lost before they entered the Snake River. Within the study area, loss rates of wild and clipped hatchery Grande Ronde stocks were higher in the Snake River fisheries above Lower Granite Dam compared to below Lower Granite. Loss rates for hatchery fish were greatest within the Grande Ronde, but for wild stocks, losses within the Grande Ronde were less than total losses in the Columbia River. We estimated escapement in the Grande Ronde River was 6,959 wild fish and 4,411 clipped hatchery fish.

Final dispositions are known for fish within the Grande Ronde River that enter the three weirs operated within the area: 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 507 clipped hatchery fish removed at Cottonwood weir (J. Bumgarner, unpublished data). Subtracting these fish leaves 26.2% of the Lower Grande Ronde spawning population composed of hatchery fish. Data are not available for 2010-2011 for the two Wallowa weirs, but in the previous year 8,149 hatchery fish were collected at these weirs (E. Sedell, unpublished data). The return of clipped hatchery fish at Lower Granite Dam during the 2010-2011 run was 57.3% of the 2009-2010 run. Scaling by this factor means 4,667 clipped hatchery fish should have been removed, which is greater than the estimated escapement in the Wallowa River of 3,501 clipped hatchery fish.

Table 9. Reconstruction of wild and hatchery stocks residing in the Grande Ronde major population group. Weir take for Wallowa hatchery is based on 2010 data.

		Losses (%)					
Stock	**Abundance at BON**	**BON-ICH**	**ICH-LGD**	**Above LGD**	**In Grande Ronde**	**Escapement**	**Weir take**
Lower Grande Ronde	1,691	489 (28.9)	4 (0.3)	10 (0.8)	30 (2.6)	1,137	0
Joseph Creek	1,231	356 (28.9)	3 (0.3)	7 (0.8)	22 (2.6)	828	0
Cottonwood (WLH)[b]	5,110	1,403 (27.5)	200 (5.4)	393 (11.1)	2,226 (71.0)	910	507
Wallowa	3,368	974 (28.9)	8 (0.3)	20 (0.9)	59 (2.5)	2,266	0
Wallowa (WLH)[b]	19,658	5,396 (27.4)	770 (5.4)	1,514 (11.2)	8,561 (71.0)	3,501	4,667
Upper Grande Ronde	4,056	1,173 (28.9)	10 (0.3)	25 (0.9)	71 (2.5)	2,728	0

Salmon River

Abundance for stocks from the Salmon major population group at Bonneville Dam was 19,202 wild fish; 17,134 for the unclipped hatchery releases; and 86,551 for clipped hatchery release groups (Table 10). Based on PIT tag detections, 22.5% of the wild fish and 21.5% of the hatchery fish were lost before they entered the Snake River. Loss rates of Salmon River stocks were greater in the Snake River fisheries above Lower Granite Dam compared to below Lower Granite Dam. Loss rates for hatchery fish were greatest within the Salmon River, but for wild and unclipped hatchery stocks, losses within the Salmon River were less than total losses in the Columbia River. We estimated escapement in the Salmon River was 14,094 wild fish, 12,279 unclipped hatchery fish, and 21,401 clipped hatchery fish.

Final dispositions are known for fish within the Salmon River that enter the four weirs operated within the area: Pahsimeroi Hatchery, East Fork Salmon weir, Squaw Creek weir, and Sawtooth Hatchery (Stiefel et al. 2012). The latter two traps operate within the Upper Salmon population. In 2011, 7,916 clipped hatchery fish were removed by the Pahsimeroi Hatchery. Subtracting these fish leaves 53.0% of the Pahsimeroi spawning population composed of hatchery fish. The 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. At the East Fork Salmon weir, removals were 33 wild fish, 101 unclipped hatchery fish, and one clipped hatchery fish. Subtracting these fish leaves 66.9% of the East Fork Salmon spawning population composed of hatchery fish, most of which (53.8%) were unclipped fish from an integrated broodstock. At the two Upper Salmon weirs, a total of 7,985 hatchery fish were removed, although it was not recorded how many were clipped versus unclipped. We apportioned these fish according to the relative escapements of the two groups. Subtracting these fish leaves 26.3% of the Upper Salmon spawning population composed of hatchery fish. Hatchery fish also escaped into the Lemhi population (44.8% of the potential spawners) and

Little Salmon population (92.5% of the potential spawners). In the Little Salmon River, 40.9% of the hatchery escapement was composed of unclipped hatchery fish. Realized hatchery impacts are uncertain and may not be proportional to fish numbers in some populations because hatchery steelhead release sites are some distance from spawning tributaries.

Imnaha River

Abundance for stocks from the Imnaha major population group at Bonneville Dam was 3,386 wild fish and 6,311 for clipped hatchery fish. Based on PIT tag detections, 909 wild fish (26.8%) and 1,969 hatchery fish (31.2%) were lost before they entered the Snake River. Losses within the lower Snake River were 9 wild fish (0.4%) and 234 hatchery fish (5.8%). Losses in the basin above Lower Granite Dam were 20 wild fish (0.8%) and 450 hatchery fish (11.1%). Losses within the Imnaha were 233 wild fish (10.0%) and 1,653 hatchery fish (46.1%). We estimated escapement in the Imnaha River was 2,103 wild fish and 1,936 clipped hatchery fish.

Final dispositions are known for fish within the Imnaha River that enter the Little Sheep Creek weir. Data are not available for 2010-2011 but in the previous year 3,450 hatchery fish were collected at these weirs (E. Sedell, unpublished data). Scaling this number as done in the Wallowa River means 1,976 clipped hatchery fish should have been removed, which is greater than the estimated escapement of 1,936 clipped hatchery fish.

Table 10. Reconstruction of wild and hatchery stocks residing in the Salmon River major population group.

		Losses (%)					
Stock	**Abundance at BON**	**BON-ICH**	**ICH-LGD**	**Above LGD**	**In Salmon River**	**Escapement**	**Weir take**
Little Salmon	1,294	292 (22.6)	3 (0.3)	9 (0.9)	14 (1.4)	953	0
Little Salmon (PAH)[a]	6,604	1,421 (21.5)	18 (0.4)	43 (0.9)	128 (2.2)	4,794	0
Little Salmon (PAH,OX,DWR)[b]	15,587	3,355 (21.5)	660 (5.4)	1,302 (11.2)	3,441 (33.2)	6,928	0
Chamberlain Creek	1,122	253 (22.5)	3 (0.3)	7 (0.8)	7 (0.8)	833	0
South Fork Salmon	1,938	437 (22.5)	5 (0.3)	12 (0.8)	9 (0.6)	1,442	0
Secesh	829	187 (22.6)	2 (0.3)	5 (0.8)	4 (0.6)	617	0
Lower Middle Fork	2,396	540 (22.5)	6 (0.3)	16 (0.9)	18 (1.0)	1,774	0
Upper Middle Fork	2,553	576 (22.6)	7 (0.4)	17 (0.9)	19 (1.0)	1,890	0
Panther Creek	661	149 (22.5)	2 (0.4)	4 (0.8)	10 (2.0)	485	0
North Fork Salmon	377	85 (22.5)	1 (0.3)	2 (0.7)	4 (1.4)	279	0

Table 10 continued.

Stock	Abundance at BON	Losses (%) BON-ICH	ICH-LGD	Above LGD	In Salmon River	Escapement	Weir take
Lemhi	2,127	480 (22.6)	6 (0.4)	14 (0.9)	35 (2.2)	1,556	0
Salmon, sec 19 (PAH)[b]	3,910	842 (21.5)	166 (5.4)	326 (11.1)	1,340 (51.5)	1,261	0
Pahsimeroi	1,762	397 (22.5)	5 (0.4)	12 (0.9)	35 (2.7)	1,284	0
Salmon, sec20 (PAH)[b]	35,009	7,536 (21.5)	1,483 (5.4)	2,924 (11.2)	13,945 (59.9)	9,343	7,916
East Fork Salmon	1,876	423 (22.5)	5 (0.3)	12 (0.8)	41 (2.9)	1,363	33
East Fork (EFN)[a]	2,149	463 (21.5)	6 (0.4)	14 (0.9)	45 (2.8)	1,550	101
Salmon, sec 21 (SAW,DWR)[b]	5,525	1,190 (21.5)	234 (5.4)	461 (11.1)	2,432 (66.2)	1,243	1
Upper Salmon	2,267	511 (22.5)	6 (0.3)	15 (0.9)	78 (4.6)	1,618	0
Salmon, sec 22 (SAW)[a]	8,381	1,804 (21.5)	23 (0.3)	54 (0.9)	286 (4.6)	5,935	5,534
Salmon, sec 22 (SAW,USB,DWR)[b]	26,520	5,709 (21.5)	1,123 (5.4)	2,215 (11.2)	15,015 (85.1)	2,626	2,451

Hells Canyon

Abundance at Bonneville Dam for hatchery fish released in Hells Canyon was 28,714 fish. Based on PIT tag detections, 9,229 fish (32.1%) were lost before they entered the Snake River. Losses within the lower Snake River were 1,052 fish (5.4%). Losses in the basin above Lower Granite Dam were 4,154 fish, of which 44 were unclipped. Loss rate within Hells Canyon of clipped hatchery fish was 25.1%. We estimated escapement in Hells Canyon was 12,249 clipped hatchery fish.

Final dispositions are known for fish that enter the Hells Canyon Dam fish trap (Stiefel et al. 2012). For the 2010-2011, this trap collected 58 unclipped fish and 4,752 adipose-clipped hatchery fish. We estimate that 61.2% 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. If we assume that the wild to hatchery ratio in the habitat is the same as at the Hells Canyon trap, then 98.8% of the spawning population is composed of escaping hatchery fish.

DISCUSSION

This run reconstruction is the first 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. This inaugural effort 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 review important assumptions, compare selected results to independent data to assess model performance, highlight some notable findings, and suggest how the run reconstruction model may be improved.

Model assumptions

In order to make the problem tractable, we made several assumptions regarding how abundance was parsed into groups, how fish moved through the system, and how fishery-related losses were allocated (Table 11). The reliability of the model outputs are determined by how well these assumptions reflect reality and the sensitivity of outputs to them.

Table 11. Major assumptions made in the run reconstruction model by input type.

Input data type	Assumption
Abundance	Genetic structure is sufficient for accurate reporting group assignment
	Fish distribute themselves according to the spawning habitat index
	PIT tag shedding by hatchery fish is equivalent among groups
Movement	Fish return to point of origin (except for Lower Snake stocks)
	PIT tag detections reflect movement for Lower Snake stocks
Fishery	Mortality affects fish in proportion to their abundance (within mark type)
	All fishery impacts in unit occur simultaneously (no time step)
	Each catch is an independent event

Assumptions regarding abundance are especially important because fate of groups in the model is determined by their relative abundance when an impact occurs. We believe numbers of hatchery groups are likely more accurate because most PIT-tagged fish retain their tags through adulthood (Knudsen et al. 2009; Cassinelli et al. 2012). Although there may be differences in shed rates among stocks and release group, deviations from this assumption are likely minor compared to inaccuracies in genetic stock identification of wild fish. Beginning with the 2011/2012 spawning run, we will be able to test the validity of the assumption of equal PIT-tag shedding rates among hatchery stocks by comparing estimates based on PIT-tag expansions to estimates made via parentage-based tagging (Steele et al. 2012) for Snake River steelhead stocks.

Our assumption that genetic structure in the Snake River basin is sufficient for accurate reporting group assignment is more difficult to validate. Genetic distinctiveness is greatest for wild populations in terminal areas without hatchery programs (i.e., upper Clearwater, Middle

Fork Salmon, and South Fork Salmon genetic reporting groups; Ackerman and Campbell 2012). The South Fork Clearwater genetic reporting group is also highly differentiated despite hatchery releases in the drainage. Conversely, Ackerman and Campbell (2012) found weaker differentiation among wild stocks in regions with increased hatchery releases, that are located at lower elevations, or a combination of the two (i.e., upper Salmon, lower Salmon, lower Clearwater, Imnaha, Grande Ronde, and lower Snake genetic reporting groups). Waples et al. (1993) similarly found weak differentiation among samples from Grande Ronde, Imnaha, and Tucannon rivers. We expect that genetic stock identification estimates to highly differentiated areas will be more accurate than estimates made to areas of weaker differentiation. Lastly, non-Snake-River stocks and Hells Canyon wild fish were not represented in the Snake River genetic baseline used for this analysis. Because all fish must be assigned to a reporting group, out-of-basin and Hells Canyon wild fish were not assigned to their respective groups, rather they are assigned elsewhere. In particular, steelhead from the lower elevation areas of the Snake River basin are genetically similar to steelhead from the mid-Columbia ESU (Blankenship et al. 2011; Hess et al. 2012). We expect that out-of-basin fish from the mid-Columbia likely assign to lower Snake River reporting groups, which has likely inflated abundance estimates of the Asotin Creek and Tucannon River populations. This error should not affect fates of other groups because those impacts would accrue to the non-Snake fish once they were split from the Lower Snake populations.

The last assumption used to apportion fish from genetic reporting groups into populations was that fish distribute themselves by the weighted habitat index used by the ICBTRT (2007; see their Appendix C). This index was constructed using GIS data, temperature records, and adjusted for local knowledge of current occupancy. The index was intended to represent the intrinsic quality of a stream reach for spawning, given the geomorphic context of the landscape. It assumes that elevation *sensu stricto* does not matter, although steelhead may be more likely to use lower elevation habitats (Narum et al. 2008). Therefore, higher elevation habitat in the Salmon River may be assigned greater numbers of spawners than actually use the area. The index also does not take into account anthropogenic habitat degradation. For example, the Upper Grande Ronde population has the greatest spatial extent of any population and was assigned the highest abundance from the Grande Ronde genetic reporting group. However, there are large areas of degraded habitat within that population (BOR 2012) so the actual spawning population is likely smaller than we estimated. Caution should be used when using the ICBTRT's spawning potential ratings to make comparisons across areas that are different in hydrology, geology, or other influential characteristics (Tom Cooney, personal communication).

Movement assumptions proved hard to evaluate. Recovery of CWTs is biased by distribution of fishing effort. Nonetheless, CWT recoveries show that hatchery fish in the Salmon River may overshoot their release site and move into upstream reaches (Carl Stiefel, unpublished data). Similarly, coverage of spawning reaches by in-stream PIT tag detector arrays is incomplete (see QCI 2012). The spatial extent of the Lower Snake reach was defined by dams with efficient detectors in the fish ladders; however, fish falling back over the dams could only be detected if they re-ascended the ladder or went somewhere else with a detector array (the lower Tucannon River, Lyons Ferry Hatchery, or the juvenile bypass facilities at Lower Granite, Little Goose, and Lower Monumental dams). It is likely that more fish fell back over the dams than we calculated, i.e., some of the escapement in the Lower Granite pool may have actually been below the dam. We avoided any effects of underestimating fallback rates on escapement estimates by reporting them for the Lower Snake major population group as a whole. Further, use of tag detections confounds survival with movement probability because only survivors move. We dealt with this issue by extracting fallback of Lower Snake fish from the Lower Granite pool before the fishery but other approaches may also be appropriate.

Lastly, our model of steelhead fisheries within the Snake River was a gross oversimplification of how they actually operate. Certainly, larger fish are retained at greater rates than small ones in sport fisheries (Lewin et al. 2006); therefore, hatchery stocks with greater proportions of 2-ocean returns might be expected to bear more of the harvest. We did not take into account timing of effort and harvest (e.g., between fall and spring fisheries); this assumption would have to incorporate time-differing movements by the various stocks. Lastly, we assumed fish could only be caught once, which may likely be violated during catch-and-release seasons and in terminal fisheries.

Comparison to independent data

We compiled selected data to evaluate escapement estimates for wild steelhead (Table 12). 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. The Imnaha and Tucannon PIT arrays are 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 10 cases and greater in 10 cases. The average magnitude of the overestimates was greater than for underestimates (5.3 versus 0.5 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 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.

In some cases, run reconstruction escapements were consistent with expectations. For example, all hatchery run reconstruction escapements were above weir take. The Big Creek and Valley Creek estimates were within 5% of the independent estimates. However, there is much unresolved variation among estimates of most wild populations.

Table 12. Comparison of run reconstruction steelhead escapement scale by spawning habitat intrinsic potential to independent population estimates. Asterisks indicate units smaller or larger than populations of the same name.

Run reconstruction model		Independent data		
Unit	**Estimate**	**Estimate**	**Type**	**Source**
Tucannon*	3,643	142	PIT array	JDB, unpublished data
Tucannon*	911	202	Weir count	JDB, unpublished data
Asotin Creek*	7,062	890	PIT array	QCI 2012
Asotin Creek*	7,062	1,128	Weir estimate	Crawford et al. 2012
Fish Creek	155	494	Weir estimate	Copeland et al. 2012
Joseph Creek	828	1,357	Redd expansion	ERS, unpublished data
Joseph Creek	828	1,627	PIT array	QCI 2012
Joseph Creek	828	1,698	Weir estimate	QCI 2012
Upper Grande Ronde	2,728	3,467	Redd expansion	ERS, unpublished data
South Fork Salmon*	2,059	2,540	PIT array	QCI 2012
Secesh	617	397	PIT array	QCI 2012
Big Creek	704	687	PIT array	QCI 2012
Lemhi*	1,507	428	PIT array	QCI 2012
Pahsimeroi*	1,091	239	Weir count	Stiefel et al. 2012
East Fork Salmon*	160	72	Weir count	Stiefel et al. 2012
Valley Creek	229	232	PIT array	QCI undated
Upper Salmon*	578	96	Weir count	Stiefel et al. 2012
Imnaha	2,336	3,298	PIT array	QCI 2012
Cow Creek	24	147	PIT array	QCI 2012
Big Sheep Creek	401	765	PIT array	QCI 2012

The comparisons above are really tests of consistency rather than accuracy because errors and bias may occur in any estimate. For example, there are four Joseph Creek estimates, only two of which are close together. The estimate based on detections at the Tucannon PIT array near the river mouth was less than the count at the Tucannon hatchery weir at rkm 58. However, stray PIT-tagged wild steelhead account for about 30% of the PITs detected at the Tucannon PIT array (J. Bumgarner, unpublished data), but because their marking rate is unknown they were not included in the wild steelhead escapement estimate. Straying steelhead may also affect other PIT array estimates. Hells Canyon wild fish will be assigned somewhere. Given the lack of suitable habitat in the area, strays from Hells Canyon are likely to enter the Imnaha River. Weirs may inhibit passage (Thorstad et al. 2008), leading to estimates below what would be expected given the habitat potential. We conclude that the model is most reasonable for hatchery fish but the methods used for parsing abundance of wild fish need further investigation and refinement.

Notable findings

Interpretation of the output of this initial effort should be done with great caution because of likely violations of model assumptions and with the realization that patterns may change in time. Exact numbers are not relevant to interpretation but large contrasts should have significance. Our main intention was to provide a foundation on which to build for future years. However, there are two noteworthy results worth consideration.

Not surprisingly, fishery impacts predicted by the model varied among stocks. Harvest-related losses of clipped hatchery stocks in terminal fisheries (defined as a fishery section without harvest upstream) was greatest in the Tucannon River (87.6%) and the South Fork Clearwater (79.1%); conversely, losses in terminal fisheries were lowest in Hells Canyon (25.1%) and Little Salmon (26.6%). Estimated within-basin impacts on wild populations were greatest for the Imnaha population (10.0%) and the South Fork Clearwater (8.5%). The former impact is likely lower because we probably underestimated the abundance of the Imnaha population at Lower Granite Dam. In the case of the latter, impacts were fairly high for all Clearwater stocks (mean = 6.9%). In all other cases, within-basin impacts on wild populations were <5.0%.

This analysis is the first to allow a basinwide comparison of the performance of hatchery stocks to wild populations. Pollard and Starr (undated) previously examined hatchery-origin steelhead in the Snake River basin and found that 95% of them can be accounted for, although the accounting includes fish that remain at large. Here we estimated that 48,141 wild fish escaped to spawn in the Snake River basin compared to 40,526 hatchery fish. In general, 45.7% of the spawning population of steelhead is composed of hatchery fish, most of which are adipose-clipped (57.0%). However, as Pollard and Starr noted, these impacts are likely concentrated in specific areas because there is no evidence that a large proportion of hatchery fish stray from their release areas. In some areas, many clipped hatchery fish are not harvested or removed at weirs, e.g., in the Hells Canyon, Lower Clearwater, and Little Salmon populations. In some cases, the bulk of the spawning population are unclipped hatchery fish, e.g., Lolo Creek, South Fork Clearwater and East Fork Salmon populations, although in the latter two there are also significant number of clipped hatchery fish. Hatchery and genetic management plans call for assessment of numbers of hatchery fish escaping to spawn with reference to natural production in the areas in which hatchery fish are released. This run reconstruction model allows such a comparison.

Improvements to the model

Our immediate objective was to develop an analytical run reconstruction framework that could be refined for more rigorous evaluations in the future. The initial version was necessarily simplistic and there are several modifications that might be reasonable. However, changes should influence results in some substantial manner, otherwise those factors may be safely ignored for the sake of parsimony. As a general guideline, further elaborations need to be relevant to management and supported by data. Below are some ideas that might be explored.

Methods for parsing abundance of wild fish need further investigation and refinement; although not formally within the run reconstruction model, genetic stock identification is a primary input. Important areas (e.g., Hells Canyon stock) should be added to the genetic baseline, as acknowledged by Ackerman and Campbell (2012). We further recommend an evaluation of methods to distinguish mid-Columbia steelhead stocks so that we may account for out-of-basin strays. Correction factors need to be developed to accommodate for out-of-basin fish that assigned to Snake River stocks. Finally, we support the recommendations of Ackerman and Campbell (2012) for annual sampling to better characterize Snake River wild populations in the baseline and for evaluating methods to correct estimates using information from genetic assignments of known origin individuals. We recommend the above issues be given high priority.

Fisheries were assumed to operate in a very simplified way in the current model. To achieve a more accurate assignment of harvest impacts, a time element may need to be incorporated. Component stocks in mixed stock fisheries could have differential fishery vulnerability (Starr and Hilborn 1988), e.g., in the Lower Snake fishery reach. Addition of a time component to the model would require better harvest and movement estimates. Biases are inherent in the use of tag recoveries to infer movement probabilities. These biases need to be identified and addressed. More realistic movement rules may be desirable in any case (e.g., to address fallback rates at Lower Granite Dam).

The fates of Snake River steelhead downstream of the study area are vague in this model. Genetic baselines of all Snake River steelhead spawned in hatcheries have been constructed and will be complete beginning with brood year 2009 (Steele et al. 2012). Analysis of tissue samples collected from fish harvested in Columbia River fisheries will allow apportionment of harvest to Snake stocks all the way to river mouth. Thus, we will be able to reconstruct runs of Snake River steelhead all the way downstream to the ocean in future iterations of the model presented here.

Only fishery-related mortality was considered in the current run reconstruction model. Unlike most of the run reconstruction models reported in the literature (e.g., Bue et al. 2012, Cunningham et al. 2012), this model focuses on steelhead stocks that migrate far inland and spend a significant amount of time in freshwater during fisheries and before spawning. Therefore, natural mortality may be important. The current model structure can accommodate estimates of natural mortality if the data exist with which to compute them.

Lastly, in the current model it is assumed that the steelhead life cycle ends at spawning. It does not (Withler 1961; Busby et al. 1996). There are several efforts to collect data on post-spawn steelhead (kelts) with the thought that repeat-spawning steelhead can provide demographic benefits. If these data are suitable, a kelt disposition category could be added to the run reconstruction.

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. This information 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 will improve precision and accuracy.

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