Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye

2016 Annual Report

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GLOSSARY OF TERMS

ADMB	AD Model Builder optimization software (free to download at www.admb-project.org)
AIC	Akaike Information Criterion: -2 ln (Likelihood) + 2p, where p = #parameters.
AICc	Akaike's information criterion for small sample sizes: $AIC + [2p(p + 1)]/[n - p - 1]$, where p = # parameters/ n = sample size.
ANCOVA	Analysis of covariation.
AP	Refers to acclimation ponds used as smolt acclimation and release sites for certain hatchery programs. For example, CATH AP refers to the Lookingglass hatchery AP at Catherine Creek.
A-run steelhead	Summer steelhead distributed throughout the Columbia Interior Domain distinguished from B-run steelhead by earlier adult migration timing, younger ocean-age (primarily 1-salt adults), and smaller adult size.
BH	Beverton-Holt
BKD	Bacterial Kidney Disease: a serious salmonid disease which can cause death or health impairment in both juveniles and adults.
BLUPs	Best Least Unbiased Predictions
BOA	Bonneville Dam adult fish ladder
BON	Bonneville Dam

BPA	Bonneville Power Administration
B-run steelhead	Summer steelhead originating from the Clearwater and Salmon rivers of Idaho that differ from A-run stocks in their later adult migration timing, older ocean-age (primarily 2-salt adults), and larger adult size.
BY	Brood Year
C0, C_0	Refers to the group of in-river control PIT-tagged smolts, (i.e., the number of PIT-tagged smolts at LGR that migrate through the hydrosystem without being bypassed at any of the Snake River collector dams). This group includes both fish that survived to reach the ocean and fish that may have died before reaching the ocean. This group of fish is most representative of the untagged run of the river.
C1, C_1	Refers to untransported PIT-tagged smolts which enter the detection/collection facility at one or more of the collector projects. Unlike untagged smolts, they are returned to the river so reach survival estimates are possible.
C_1_t	C_1 fish within Group T are bypassed fish that are representative of the untagged run of the river. They are detected at the Snake River detection/collection facility mostly prior to the start of transportation program.
C_1_r	C_1 fish within Group R are bypassed both prior and during the transportation season. They are used in the evaluation of the effects of detection and bypass passage relative to passage without detection at the three Snake River collection facilities (LGR, LGS, and LMN).
Capture history	The record of detections of PIT-tagged fish including date/sequence, location, and disposition.
CATH	Catherine Creek Acclimation Pond

CBFWA	Columbia Basin Fish and Wildlife Authority
CC	Catherine Creek
CH0, CH_0	Subyearling Chinook
CH1, CH_1	Yearling Chinook
CHH	Hatchery Chinook salmon
CHW	Wild Chinook salmon
CI	Confidence Interval
CJS	Cormack-Jolly-Seber. The multiple mark-recapture survival estimation method that is employed using the PIT-tag detections from the array of detection sites in the Snake and Columbia Rivers.
CLW	Clearwater River
CLWH-SP	Clearwater Hatchery Spring Chinook
CO	Coho
CRI	Cumulative Risk Initiative
CRITFC	Columbia River Inter-Tribal Fish Commission
CSS	Comparative Survival Study
CSSOC	CSS Oversight Committee
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTWSRO	Confederated Tribes of the Warm Springs Reservation of Oregon

CV	Coefficient of variation
CWT	Coded-Wire Tag
D	The estuary and ocean survival rate of Snake River transported fish relative to fish that migrate in-river through the FCRPS. It is a ratio of SARs similar to the *TIR*, except the starting point for juvenile outmigrating fish is below Bonneville Dam. This is an index of the post-Bonneville survival of transported and non-transported fish.
Delayed mortality	Delayed mortality is the component of mortality that takes place in the estuary and during early ocean residence that is related to earlier life stage anthropogenic impacts downstream migration. Delayed mortality is expressed after fish pass through the hydrosystem.
Detection history	The record of detections of PIT-tagged fish including date/sequence, location, and disposition.
DEV	Productivity Deviate Model
Differential delayed mortality	*D*, the estuary and ocean survival rate of Snake River transported fish relative to fish that migrate in-river through the FCRPS. It is a ratio of SARs similar to the *TIR*, except the starting point for juvenile outmigrating fish is below Bonneville Dam.
Differential mortality	Difference in instantaneous mortality rates between Snake River populations and downriver populations of stream-type Chinook salmon that migrate through fewer dams. Measured as the difference in ln(recruit/spawner) or ln(SAR) between population groups.
Direct mortality	Mortality incurred within the hydrosystem.
DPS	Distinct Population Segment

DWOR	Dworshak National Fish Hatchery
ENT	Entiat River
ESA	Endangered Species Act
ESU	An Evolutionarily Significant Unit. A population that is considered distinct for purposes of conservation and is defined under the Endangered Species Act.
FCRPS	Federal Columbia River Power System
FGE	Fish Guidance Efficiency: Proportion of the living fish passing the powerhouse that were detected in the smolt collection system.
FPC	Fish Passage Center
FSR	Freshwater spawning and rearing
FTT	Fish Travel Time. The number of days a fish spends migrating through the reservoirs and past dams or through defined reaches.
FWP	NPCC's Fish and Wildlife Program
Group R	PIT-tagged fish that have been pre-assigned to follow the default return-to-river operations at all transportation facilities (LGR, LGS, LMN, and MCN) throughout the entire migration season.
Group T	PIT-tagged fish that have been pre-assigned to the monitor-mode operations which routes the PIT-tagged fish to pathways identical to the untagged run of the river fish (e.g., back to river prior to the initiation of transportation and to raceways during transportation) at all transportation facilities (LGR, LGS, LMN, and MCN) throughout the entire migration season.

GR, GRN	Grand Ronde River or Basin
GRA	Lower Granite Dam adult fish ladder
GRI	Grand Ronde/Imnaha
GRIMPG	Grand Ronde/Imnaha Major Population Group
HCD	Hells Canyon Dam
HO (Holdover)	Juvenile fall Chinook salmon that does not actively migrate through the hydrosystem during the summer or fall after emergence, or in the year released, and instead passes after the PIT-tag detection systems have shut down for winter at the dams, or during the following spring.
HSOX	Hatchery sockeye
ICTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IHR	Ice Harbor Dam
IMN	Imnaha River or basin
Instantaneous mortality rate	Denoted as '*Z*', the rate of exponential population decline.
IPC	Idaho Power Company
ISAB	Independent Scientific Advisory Board
ISRP	Independent Scientific Review Panel
JDA	John Day Dam
JDMA	John Day Mainstem

JMMF	John Day Middle Fork
JDNF	John Day North Fork
JOH	Johnson Creek
LC model	Life-Cycle Model
LCX model	Environmentally influenced life-cycle model
LCH	Life Cycle Hydro Model
LGO	Little Goose Dam adult fish ladder
LGR	Lower Granite Dam
LGR equivalents	An estimate of the number of smolts at LGR for each of the three study categories (C_0, C_1, and T_0 or T_X_t) that includes the fish that perish before reaching and passing Little Goose and Lower Monumental dams.
LGS	Little Goose Dam
LM	Linear regression model
LMN	Lower Monumental Dam
LOS	Lostine River
LSRCP	Lower Snake River Compensation Plan
MAR	Marsh Creek
MAT	Minimum Abundance Threshold
MCA	McNary Dam adult fish ladder

MCMC	Markov Chain Monte Carlo (simulations using a Metropolis Hastings algorithm native to AD Model Builder software)
MCN	McNary Dam
ME	Mixed effects model
MET	Methow River
MFS	Middle Fork, Salmon River
MIN	Minam River
MLE	Maximum Likelihood Estimation
MP	Pacific Macropthalmia
MPG	Major Population Group. A subgroup or stratum of populations within a salmon ESU or steelhead DPS distinguished from other populations by similar genetic and demographic characteristics.
MY	Smolt migration year
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
NOAA-Fisheries	National Oceanic and Atmospheric Administration, Fisheries
NPCC	Northwest Power and Conservation Council, present name of the Northwest Power Planning Council
NPH	Number of Power House passages for smolts
NPT	Nez Perce Tribe

ODFW	Oregon Department Fish and Wildlife
OE Model	Observation error form of the LCH model
Overall SAR	The SAR that includes the survival of all outmigrating smolts weighted across their different in-river and transport route experiences; the SAR of an entire brood of smolts, irrespective of their route of passage through the hydrosystem.
OXBH	Oxbow Hatchery
PATH	Plan for Analyzing and Testing Hypotheses
Pathway probability	The probability an individual smolt faces at LGR of falling into a particular outmigration pathway. The pathways are: (1) transported at LGR; (2) transported at LGS; (3) transported at LMN; or (4) migrate in-river through the entire hydrosystem.
PDO	Pacific Decadal Oscillation
PE	Process error estimation model
PIT-tag	Passive Integrated Transponder tag. Glass-encapsulated transponders, 11–12 mm in length with a unique identification code, which can be implanted into a fish's abdomen using a hand-held syringe. These tags are generally retained and function throughout the life of the fish. The tag's code can be read and recorded with an electronic scanner installed at a fixed site or hand held.
PITPH	Powerhouse contact rate derived from PIT-tag data.
POV	Poverty Flat
PRD	Priest Rapids Dam

PTAGIS	PIT-tag Information System. Regional depository and clearing house for the Columbia Basin PIT-tag release and detection information.
PTES	PIT Tag Effects Study
PTRANS	Index used to predict the fraction of juveniles that are transported.
RIS	Rock Island Dam
RAPH	Rapid River Hatchery
RM&E	Research, Monitoring and Evaluation
RMIS	Regional Mark Information System
RR	Run Reconstruction
RRE	Rocky Reach Dam
R/S	Recruits per spawner or mature fish at the point of recruitment (R) divided by the number of spawners in the parent generation (S).
Rsg	Spawning grounds recruits
RSWs	Removable spillway weirs
RY	Adult return year
SAL	Salmon River or Salmon River Basin
Salt (e.g. 1-salt, 2-salt, etc.)	Refers to adult return age as the number of years in the ocean. Used similarly for all species in the CSS reports. A "1-salt" for Chinook is also a jack adult return.

S	Reach- or life-stage specific survival. Estimates can be made from hatchery of release to Lower Granite Dam, Lower Granite Dam to Little Goose Dam, Lower Granite Dam to Bonneville Dam, and so forth.
SAR	Smolt-to-Adult-Return rate. The survival rate of a population from a beginning point as smolts to an ending point as adults. SARs are calculated from LGR to LGR and can also be estimated at BON to BON or LGR, or below BON to BON. SARs for populations could be for wild only, hatchery-origin, or both combined. The populations can be defined as those being transported, being left in the river to migrate, or all smolts combined regardless of their route of passage.
SAWT	Sawtooth Hatchery
SBT	Shoshone-Bannock Tribes
SFS	South Fork of Salmon River
SFTAFM	State, Federal, and Tribal Anadromous Fish Managers
SMP	Smolt Monitoring Program
SOX	Sockeye
S.o1, SO1	Survival during the first year of ocean life.
S.oa	Marine survival rates from the stage smolts enter the estuary to adult return.
SPS	Salmon population summaries
S_R	In-River Survivals
S-R, S/R	Spawner-Recruit data.

SRI	Survival Rate Index: The residuals from a fit of stock recruitment function to a given period of brood years.
SRP	Scientific Review Panel
ST	Steelhead
S_T	S_T is the assumed direct transportation survival rate (0.98) adjusted for in-river survival to the respective transportation sites for those fish transported from LGS or LMN.
STUFA	State Tribal and U.S. Fisheries Agencies
STH	Hatchery summer steelhead
STW	Wild summer steelhead
SUL	Sulphur Creek
Survival Rate	Number of fish alive after a specific time interval or life stage, divided by the initial number.
T_0	Refers to LGR equivalent transported smolts. First-time detected fish in the transported from LGR, LGS, or LMN pathways form this category. The numbers of fish transported from LGS or LMN are expanded by the inverse of the in-river survival rates from LGR to the respective transport sites.
TDA	The Dalles Dam

T_X_t	Refers to LGR equivalent transported smolts in pre-assigned Group T. Both first-time and prior detected fish in the transported from LGR, LGS, or LMN pathways form this category. The numbers of fish transported from LGS or LMN are expanded by the inverse of the in-river survival rates from LGR to the respective transport sites. This group of fish is directly representative of the untagged run of the river fish being transported in years with the later start of transportation.
TIR	Transport/In-river, the ratio of SARs that relates survival of transported fish to in-river migrants. The ratio is the SAR of fish transported from LGR to BON and returning as adults, divided by the SAR of fish outmigrating from LGR to BON and returning to LGR as adults.
TSWs	Temporary spillway weirs
TWX	Trawling operation by NMFS in the lower Columbia River in the vicinity of Jones Beach that detects PIT-tagged fish.
UCOL	Upper Columbia River
UPW	Upwelling
USACE	U.S. Army Corp of Engineers
USFWS	U.S. Fish and Wildlife Service
USR	Upper Salmon River
WDFW	Washington Department of Fish and Wildlife
WEN	Wenaha River (Snake Basin) or Wenatchee River (Upper Columbia Basin)

WTT	Water Travel Time. Water velocity in the mainstem migratory corridor is generally expressed as the average time (in days) it takes for a water particle to travel through a river reach (water travel time) during a specified period.
YIN	Yakama Indian Nation
Z	The total instantaneous mortality rate (rate of exponential population decline) of a population cohort. Mathematically, *Z* is the negative natural logarithm of survival divided by median fish travel time.

EXECUTIVE SUMMARY

The 2016 Comparative Survival Study Annual Report continues to update the historical time series life-cycle monitoring data and includes enhancements to analyses based upon review comments and recommendations from the fishery management agencies, tribes, and the Northwest Power and Conservation Council's Independent Scientific Advisory Board (ISAB). This report includes complete return data for wild and hatchery Chinook salmon and steelhead (all Snake River returns are to Lower Granite Dam). For wild and hatchery spring/summer Chinook, 3-salt returns from smolt migration year 2013, and 2-salt returns from smolt migration year 2014 are included in this Annual Report. For fall Chinook, 3-salt returns from smolt migration year 2012, and 2-salt returns from smolt migration year 2013 are included in this Annual Report. For wild and hatchery steelhead, 2-salt returns from migration year 2013 are included in this Annual Report. Finally, for Snake River hatchery sockeye, 2-salt returns from smolt migration year 2014 are included in this Annual Report.

Mark groups in 2016 were consistent with groups utilized in 2015. In addition to overall smolt-to-adult return rates (SARs) for aggregate Snake River wild steelhead and Chinook salmon, the CSS has continued to pursue the development of SAR and life cycle metrics at the Major Population Group (MPG) level when sample size was adequate. These MPG-level SARs are provided for both Lower Granite to Lower Granite and Lower Granite to Bonneville, with and without jacks (1-salt) for Chinook salmon. In addition, Chapter 4 now includes estimates of overall SARs (RRE-to-BOA and MCN-to-BOA) for Okanogan River sockeye and wild summer Chinook from above Wells Dam. The CSS continues to strive to improve life cycle monitoring metrics for wild populations of salmon and steelhead, and continues to work with fishery managers to improve tagging coverage of wild populations from tributary traps.

The long-term CSS objective of linking stages of the salmon life cycle, the factors influencing survival at each life stage, and understanding how each factor affects survival at later life stages, continues. The retrospective analyses of past years provided the foundation for the development and inclusion of prospective analyses in the 2016 report. The analyses presented in Chapter 2 utilize the life cycle model to predict the long-term effects of four experimental spill alternatives on population recovery. The experimental spill levels are defined in terms of the limits of total dissolved gas (TDG) produced at each project. The prospective analyses considered the relative benefit in adult returns and smolt-to-adult returns of four operational scenarios, the Biological Opinion (BiOp), 115%/120%, 120%, and 125% spill levels under high, average and low flow conditions. The analyses do not predict absolute SARs but rather examine the relative change among the four scenarios with increasing spill for fish passage. This analysis

predicts that higher SARs and long-term abundance increases can be achieved by increasing spill levels, and that the benefits of spill are sensitive to flows. The immediate benefits of increased flow levels, combined with the long-term benefits of habitat actions predict potential recovery of populations to up to three fold increases in abundance above levels predicted by BiOp level spill.

The time series analyses of juvenile fish passage characteristics, fish travel time, instantaneous mortality, and reach survival probability relative to environmental variables was updated to include the 2015 outmigration. Multiple regression analyses, mixed effect model structures and multimodel inference methods were utilized to evaluate juvenile fish passage characteristics relative to environmental variables. This time series of data incorporates within- and across-year variation and demonstrates a high degree of contrast in reach survival probability over this timeframe. Overall, conclusions from the 2016 analyses are consistent with past years findings, that across river reaches and species, water travel time, spill, and Julian date are important variables in predicting reach survival probability. In addition, the number of dams with surface spillway structures was somewhat important for steelhead and subyearling Chinook but not important for spring/summer Chinook. It is important to note that although water transit times in 2015 were similar to 2001, a record low flow year, estimates of mean fish travel time, instantaneous mortality and reach survival probabilities were not dramatically different than recent years and showed substantial improvements over the fish survival and travel time estimates from 2001. The primary difference in the outmigration conditions between 2001 and 2015 was the provision of spill for fish passage. In addition, the instantaneous mortality rates tended to be lower under conditions of higher spill levels.

Overall SARs are the net effect of SARs for the different routes of in-river passage and juvenile transportation. Overall SAR and route of passage SARs are consistent with past year's findings. None of the passage routes have resulted in SARs that met the NPCC SAR objectives for Snake River wild spring/summer Chinook and steelhead. The relative effectiveness of transportation has been observed to decline as in-river conditions and survival rates improve. PIT-tag SARs for Middle Columbia wild spring Chinook and wild steelhead generally fell within the 2%–6% range of the NPCC SAR objectives. Incorporating the 2015 adult returns in this Annual Report shows that the trends seen in all but two past years of CSS monitoring continue. The overall SARs for Upper Columbia and Snake River populations of salmon and steelhead are not meeting the 2%–6% regional goal, while middle Columbia populations are meeting the regional SAR goals in most years.

In this report, the analyses of SARs relative to estimates of population productivity which began in the 2015 CSS Annual Report has been expanded and is presented in Chapter 5. This represents the continuation of a longer-term effort, which will incorporate effects of density dependence on observed productivity to evaluate population responses relative to SAR rates. Analyses in this Chapter support objectives of the Columbia River Basin Fish and Wildlife Program (NPCC 2014), encouraging a regional review of the NPCC SAR objectives relative the survival of populations needed to achieve salmon and steelhead recovery and harvest goals. New to the 2016 Annual Report are the comparisons of Snake River SARs and steelhead population productivity for Fish Creek (Clearwater Major Population Group (MPG)) and Rapid River (Salmon MPG), which complement those for Snake River spring/summer Chinook. Analyses in

this report include spring/summer chinook population data from the Middle Fork Salmon River MPG that is primarily in wilderness and has little potential for improvement to tributary habitat or survival during the egg-to-smolt life stage. Major population declines of Snake River wild spring/summer Chinook were associated with SARs less than 1% and increased life-cycle productivity occurred when SARs exceeded 2%. Snake River wild steelhead population declines were associated with brood year SARs less than 1%, and increased life-cycle productivity occurred in the years that brood year SARs exceeded 2%. Pre-harvest SARs in the range of 4% to 6% are associated with historical levels of productivity for Snake River wild spring/summer Chinook. Although there are fewer SAR estimates for John Day River spring Chinook, historical levels of productivity appear to be achieved with pre-harvest SARs in the range of 4%-7%

Results of analyses of smolt to adult return, TIR, and delayed mortality for fall Chinook were consistent with past year's analyses. These results indicate that the smolt transportation program for juvenile fall Chinook salmon does not adequately mitigate for the adverse effects of development and operation of the Snake and Columbia rivers hydropower projects on fall Chinook juvenile survival and adult returns. Consistent with past years analyses, overall SARs of fall Chinook salmon were low compared to SARs for spring/summer Chinook salmon and steelhead. As in past years, the need to increase marking of fall chinook in order to address the entire passage distribution and population is needed. The CSS continues to work with the Nez Perce Tribe to improve fall Chinook marking coverage.

This report presents an update of the bypass effects analyses presented in the 2010 CSS Annual Report. This analysis examined the effect of juvenile salmon and steelhead powerhouse passage encounters on smolt to adult return rates. The juvenile downstream migration history of juvenile salmon and steelhead detected at Bonneville Dam was analyzed relative to their adult return to Bonneville Dam. This analysis showed that juvenile salmon and steelhead that had powerhouse bypass collection system encounters had lower smolt to adult return rates. At all dams, logit SARs were 12-13% lower at each dam for Chinook smolts encountering juvenile bypass system compared to those fish that avoided the bypass system. These 12-13% differences imply that the odds of survival from BON to BOA decreased by 11-12% for each of the juvenile bypass systems between John Day and Lower Granite Dam. For steelhead, logit SARs were 9-13% lower at each dam, implying 8% to 12% reductions in the odds of survival from BON to BOA for each of the juvenile bypass systems between John Day and Lower Granite dams.

The Draft CSS Annual Report for 2016 included an update of previous analyses of age at maturity. The ISAB provided extensive comments and recommendations on the draft chapter which will require some time to complete. In order to meet reporting deadlines, Chapter 8 Age at Maturity is not included in the final CSS Annual Report for 2016. AN addendum to the report, addressing the ISAB comments and recommendations will be completed in January 2017 and posted with the Final Annual Report.

CHAPTER 1
INTRODUCTION

The Comparative Survival Study (CSS; BPA Project 199602000) began in 1996 with the objective of establishing a long-term data set of annual estimates of the survival probability of generations of salmon from their outmigration as smolts to their return to freshwater as adults to spawn (smolt-to-adult return rate; SAR). The study was implemented to address the question of whether collecting juvenile fish at dams, transporting them downstream of Bonneville Dam (BON), and then releasing them was compensating for the effect of the Federal Columbia River Power System (FCRPS) on the survival of Snake Basin spring/summer Chinook salmon that migrate through the hydrosystem.

The CSS is a long-term study within the Northwest Power and Conservation Council's Columbia Basin Fish and Wildlife Program (NPCC FWP) and is funded by the Bonneville Power Administration (BPA). Study design and analyses are conducted through a CSS Oversight Committee (CSSOC) with representation from Columbia River Inter-Tribal Fish Commission (CRITFC), Idaho Department of Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife Service (USFWS), and Washington Department of Fish and Wildlife (WDFW). The Fish Passage Center (FPC) coordinates the PIT-tagging efforts, data management and preparation, and CSSOC work. All draft and final written work products are subject to regional technical and public review and are available electronically on FPC and BPA websites: FPC: http://www.fpc.org/documents/CSS.html and BPA: http://www.cbfish.org/Report.mvc/SearchPublications/SearchByTextAndAuthorAndDate/Index.aspx.

This CSS Annual Report includes 21 years of SAR data for wild Snake River spring/summer Chinook (1994–2014), 18 years of SAR data for Snake River hatchery spring/summer Chinook (1997–2014), 17 years of SAR data for Snake River wild and hatchery steelhead (1997–2013), and six years of SAR data for Snake River sockeye (2009–2014). There are seven years of SAR data for Snake River hatchery fall Chinook (2006–2012), and four years of Snake River wild fall SAR data spanning the years 2006–2011. For mid-Columbia and upper-Columbia fall Chinook there are varying numbers of years available. There are 14 years of SAR data for Hanford Reach wild fall Chinook (2000–2013), three years of SAR data for wild Deschutes River fall Chinook (2011–2013), and six years of SAR data for both Spring Creek NFH and Little White Salmon NFH fall Chinook (2008–2013). Spring and summer Chinook and sockeye returns from outmigration year 2014 should be considered preliminary, as they include only 2-salt returns and may change with the addition of 3-salt returns next year. Similarly, 2013 migration year fall Chinook returns include only 2-salt adults. The CSS has actively provided Passive Integrated Transponder (PIT) tags for most of these groups since outmigration year 1997.

The primary purpose of the 2016 Annual Report is to update the time series of smolt-to-adult survival probability data and related parameters with additional years of data since the completion of the CSS 10-year Retrospective Summary Report (Schaller et al. 2007). The 10-year report provided a synthesis of the results from this ongoing study, the analytical approaches employed, and the evolving improvements incorporated into the study as reported in CSS annual progress reports. This current report specifically addresses the constructive comments of the regional technical review conducted by the Independent Scientific Advisory Board and

Independent Scientific Review Panel (ISAB and ISRP 2007) and recent comments on the CSS study from the ISAB (2016).

All study fish used in this report were uniquely identifiable based on a PIT tag implanted in the body cavity during (or before) the smolt life stage and retained through their return as adults. These tagged fish can then be detected as juveniles and adults at many locations of the Snake and Columbia rivers. The number of individuals detected from a population of tagged fish declines, on average, over time, allowing estimation of survival probability. Comparisons of estimated survival probability over different life stages between fish with different experiences in the hydro-system (e.g., transportation vs. in-river migrants and migration through various numbers of dams) are possible as illustrated in Figure 1.1. The locations of commonly used tagging and release sites are identified in Figures 1.2 through 1.5.

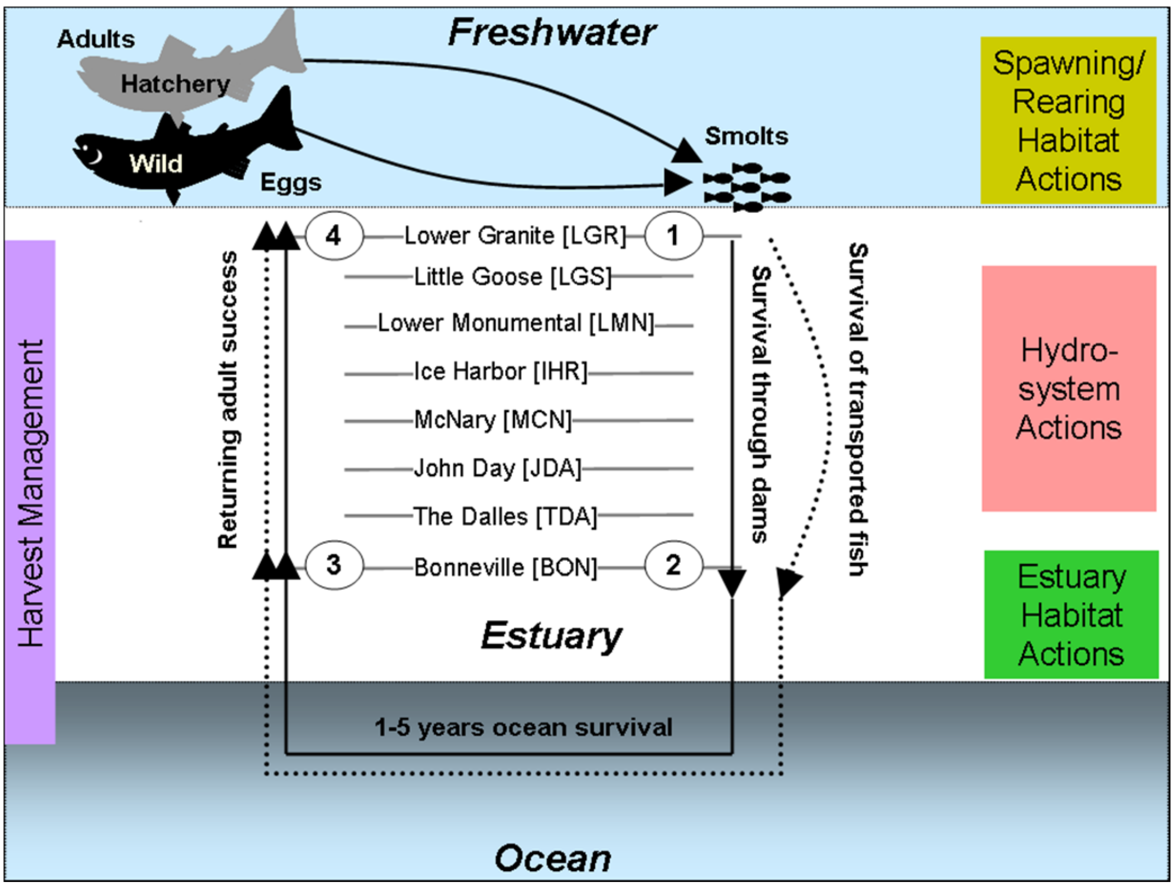


Figure 1.1. A simplified sketch of salmonid life cycle originating in the Snake River basin above LGR. Survival metrics from different portions of the life cycle inform various management questions (e.g., regarding hydrosystem, estuary, or habitat actions, etc.). Both naturally spawned and hatchery produced smolts arrive at LGR dam. The four reference points are: (1) smolts at LGR tailrace; (2) smolts at tailrace of BON/barge release; (3) adults at BON; and (4) adults at LGR. Although the study is not limited to these, some key parameters in the CSS are: (1) Overall SAR calculated from 1 to 3 and 1 to 4; (2) SAR by out-migration type (transported, C0, C1) from 1 to 4; (3) differential survival (transport, C0) from 1 to 4 is TIR; (4) differential survival (transport, C0) from 2 to 4 is D; (5) adult success is often estimated from 3 to 4.

Throughout this report we organized groups of stocks primarily according to major population group (MPG)/evolutionarily significant unit (ESU) boundaries (e.g., Snake River, Mid-Columbia River, and Upper Columbia River). However, we add the caveat that our presentations of Snake River aggregate stocks do not include stocks below Lower Granite Dam. Also, Carson National Fish Hatchery is actually located within the Lower Columbia Chinook ESU but we present it here as a Mid-Columbia group, partly for simplicity, as it is the only Lower Columbia group presented, but also because its lineage is from upriver stocks and its location is upstream of Bonneville Dam.

Development of the Comparative Survival Study

Beginning in 1981, collection of fish at lower Snake River dams and transportation to below Bonneville dam was institutionalized as an operational program by the U.S. Army Corps of Engineers (USACE). The intention was to mitigate for mortality impacts associated with the FCRPS, and thus to increase survival of spring/summer Chinook salmon. However, abundance of Snake River spring/summer Chinook salmon continued to decline. Fisheries that had been conducted at moderate levels in the Columbia River mainstem during the 1950s and 1960s were all but closed by the mid-1970s. In 1992, the Snake River spring/summer Chinook salmon ESU was listed under the federal Endangered Species Act (ESA). Spawning ground survey results in the mid-1990s indicated virtually complete brood year failure for some wild populations. For hatchery fish, low abundance of returning hatchery adults was a concern as the Lower Snake River Compensation Plan (LSRCP) hatcheries began to collect program brood stock and produce juveniles.

The motivation for the CSS began with the region's fishery managers expressing concern that the benefits of transportation were less than anticipated (Olney et al. 1992, Mundy et al. 1994, and Ward et al. 1997). Experiments conducted by the National Marine Fisheries Service (NMFS) prior to the mid-1990s sought to assess whether transportation increased survival beyond that of smolts that migrated in-river through the dams and impoundments.

Regional opinions concerning the efficacy of transportation ranged from transportation being the best option to mitigate for the impacts of the FCRPS, to the survival of transported fish was insufficient to overcome those FCRPS impacts. Although the survival of fish transported around the FCRPS could be demonstrated to be generally higher than the survival of juveniles that migrated in the river, evidence on whether transportation contributed to significant increases in adult abundance of wild populations was unavailable. If the overall survival probability (egg to spawner) was insufficient for populations to at least persist, the issue would be moot (Mundy et al. 1994).

The foundational objectives of the CSS design translate these issues about the efficacy of transportation into key response variables. The CSS uses the following two aspects for evaluating the efficacy of transportation: (1) empirical SARs compared to those needed for survival and recovery of the ESU; and (2) SAR comparisons between transport and in-river migration routes. In this broader context, the primary objective is to answer: "Are the direct and delayed impacts of the configuration and operation of the FCRPS sufficiently low to ensure that cumulative life-cycle survival is high enough to recover threatened and endangered populations?" The secondary objective is to answer: "Is the survival of transported fish (SAR) higher than the survival (SAR) of fish migrating in-river?" Beginning in 2003, the NPCC Fish

and Wildlife Program adopted the goal to achieve smolt-to-adult survival probabilities (SARs) in the range of 2% to 6% (average 4%) for federal ESA-listed Snake and Upper Columbia river salmon and steelhead. The objective continued through 2009 and most recently the amended 2014 Fish and Wildlife Program (NPCC 2003, 2009, 2014). Combining these objectives, effectiveness of transportation is assessed by whether (1) the overall $SAR_{(LGR\text{-}to\text{-}LGR)}$ meets the NPCC regional objective (2%–6% with 4% average) for the ESU and (2) the SAR of fish collected at Snake River dams and diverted into barges is higher than that of fish that migrate through reservoirs and pass these dams via the spillways and turbines.

The design and implementation of the CSS improved upon shortcomings of the methods that had previously been used to estimate and compare survival probability for transported fish and non-transported (in-river migrating) fish. These shortcomings resulted from the collection and handling protocols, the marking and recovery technology, the study objectives, the definition and use of a control population, and the inconsistency and duration of survival studies (Olney et al. 1992, Mundy et al. 1994, and Ward et al.1997). Transported and in-river groups were handled differently in the first juvenile fish studies. Whereas transported fish were captured at dams, tagged, and placed in trucks or barges, some in-river control groups of fish were transported back upstream for release. Thus, unlike the unmarked outmigrating run-at-large, these marked in-river fish were therefore subjected to the same hydrosystem impacts multiple times whether they were subsequently collected and transported or remained in-river. The early mark-recapture studies used coded-wire tags (CWT) and freeze brands to mark juveniles collected at the dams. Therefore, Snake River basin origin of individuals could not be identified, and CWT information could be obtained only from sacrificed fish. Evidence suggested that the process of guiding and collecting fish for either transport or bypass contributed to juvenile fish mortality and was cumulative when fish were bypassed multiple times. If such mortality differentially impacted the study fish, and was not representative of the in-river migrant run-at-large, measures of the efficacy of transportation would be biased.

All CSS study fish are uniquely identified with a PIT tag, and the use of this technology has provided substantial improvements in the evaluation of the efficacy of transportation. To ensure that all CSS study fish, whether transported or migrating in-river, experience the same effects from handling (thus improving the utility of an in-river control group relative to transportation), hatchery-reared fish are tagged at hatcheries and wild fish are tagged at subbasin and mainstem outmigrant traps upstream of the FCRPS (Figures 1.2–1.5). PIT-tagged juveniles are released near their marking station, allowing the numbers of fish and distribution across subbasins of origin to be predetermined. Recapture information can be collected without sacrificing fish, and automated detection stations reduce impacts from trapping and handling.

PIT-tag detectors at mainstem dams in the Columbia and Snake rivers now allow passage dates and locations to be recorded for both juvenile and adult PIT-tagged fish and provide the ability to link that information to the characteristics of each fish at time and location of release (Figures 1.2–1.5). With sufficient numbers of fish tagged, survival probability throughout the life-cycle can be compared across release groups, subbasins, ESUs, species or race, major population group, rearing type (i.e., hatchery vs. wild), unique life history experiences (e.g., transported vs. in-river), and outmigration seasons. The CSS PIT-tagging design and application allows the use of the Cormack-Jolly-Seber (CJS; see Appendix A) method with multiple mark-recapture information. This method is used to estimate a population of PIT-tagged smolts alive in the tailrace of Lower Granite Dam and to estimate their survival through the hydrosystem.

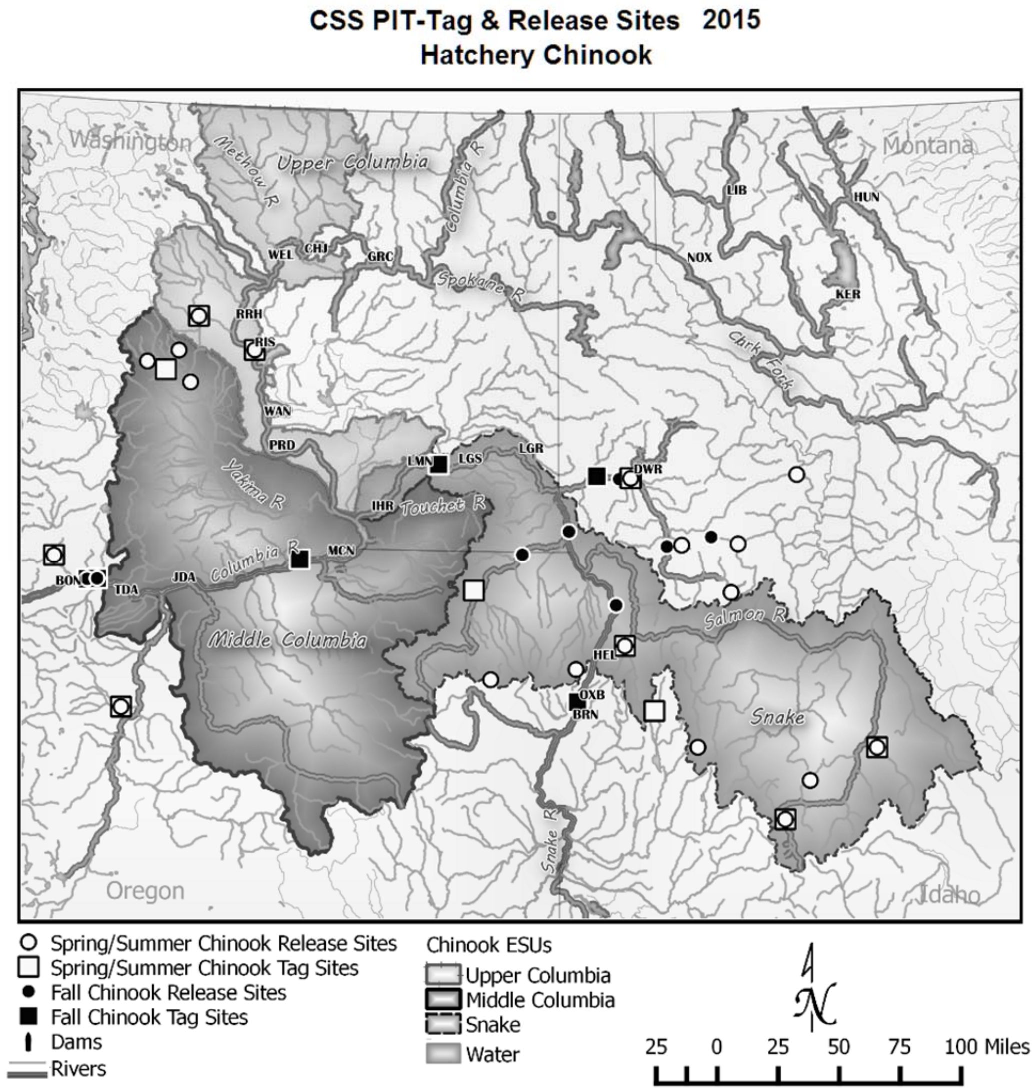


Figure 1.2. CSS PIT-tag release locations for Hatchery spring/summer Chinook and fall Chinook in the Columbia River Basin.

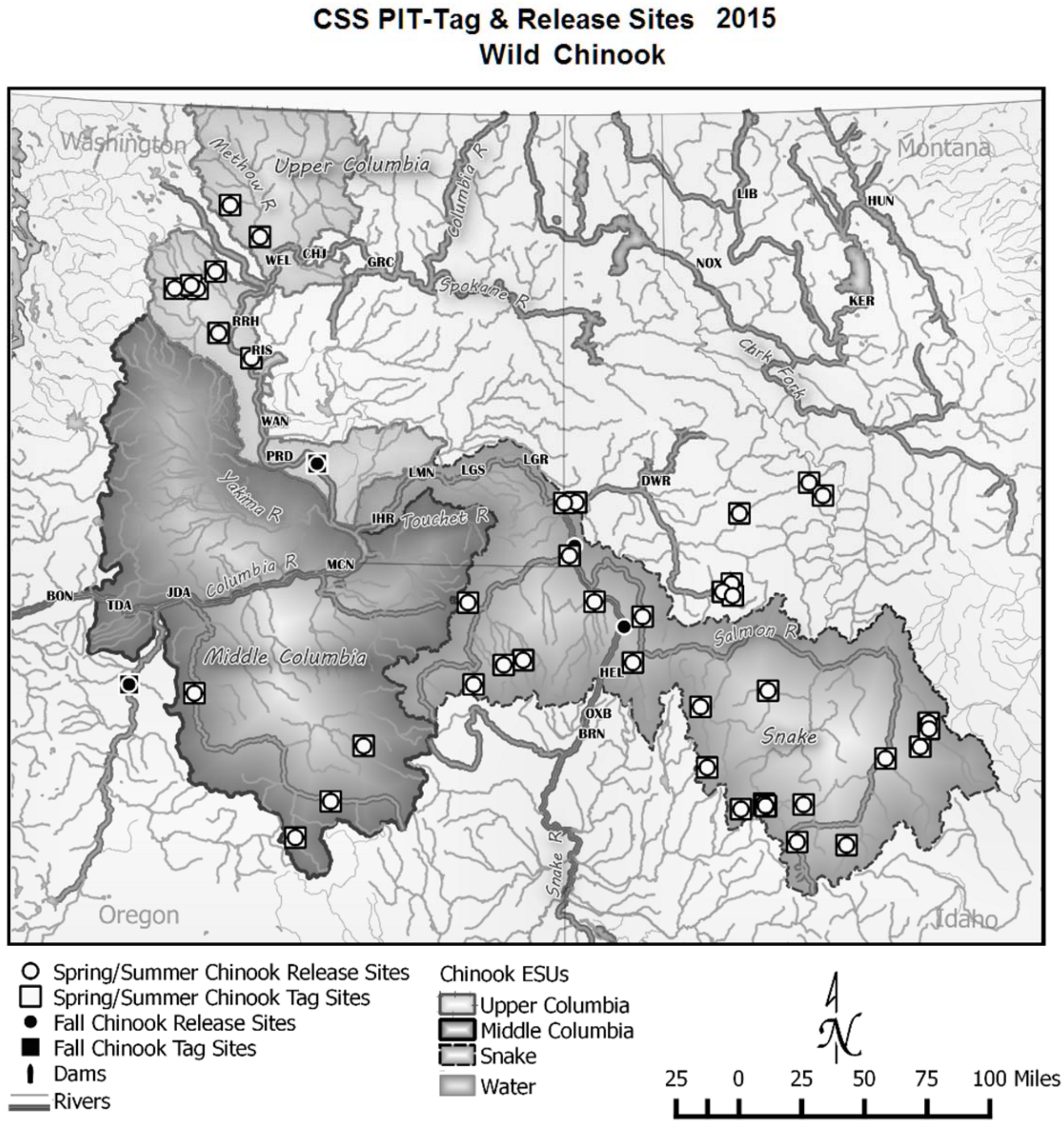


Figure 1.3. CSS PIT-tag release locations for wild spring/summer Chinook and fall Chinook in the Columbia River Basin.

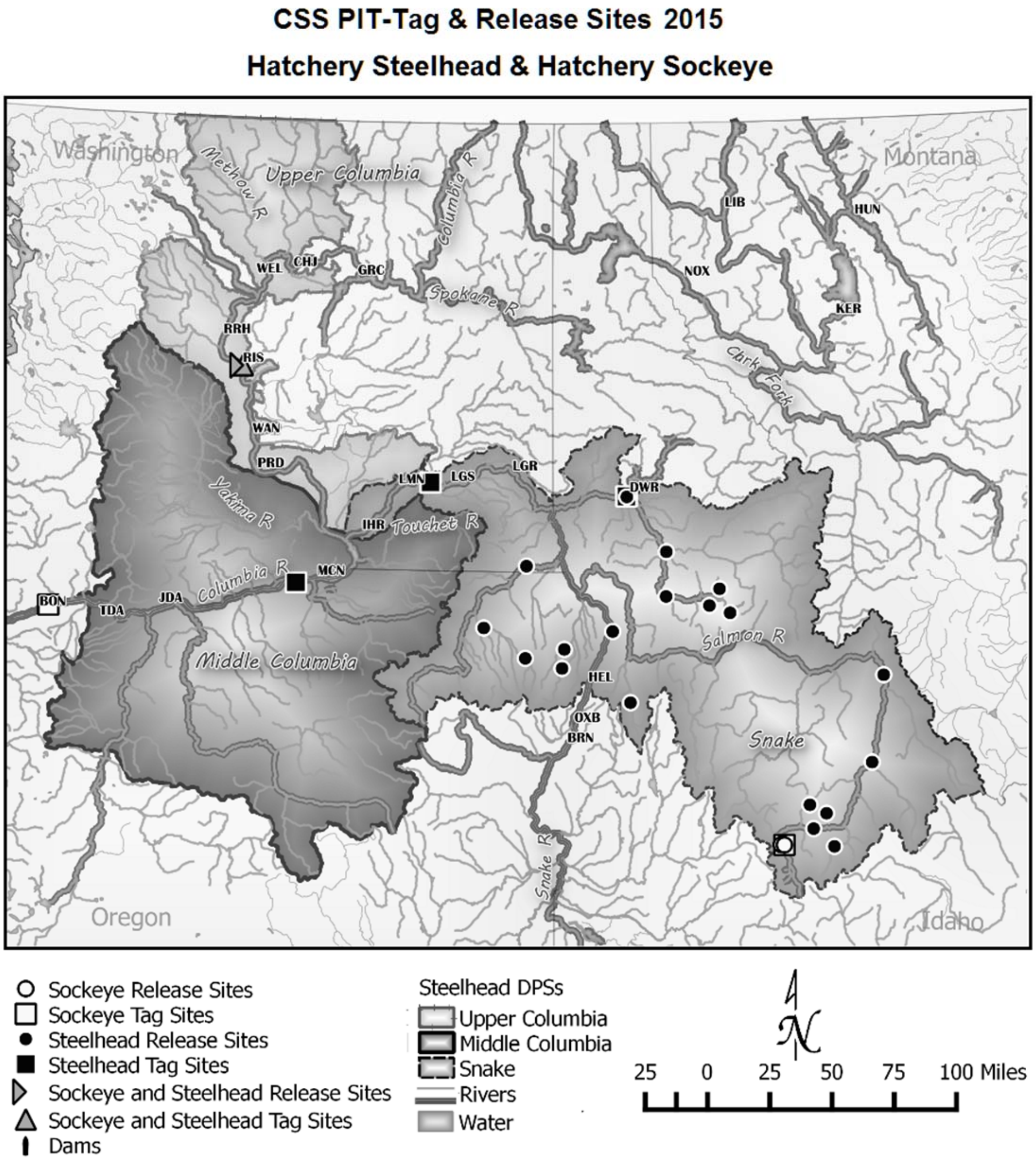


Figure 1.4. CSS PIT-tag release locations for hatchery steelhead and sockeye in the Columbia River Basin.

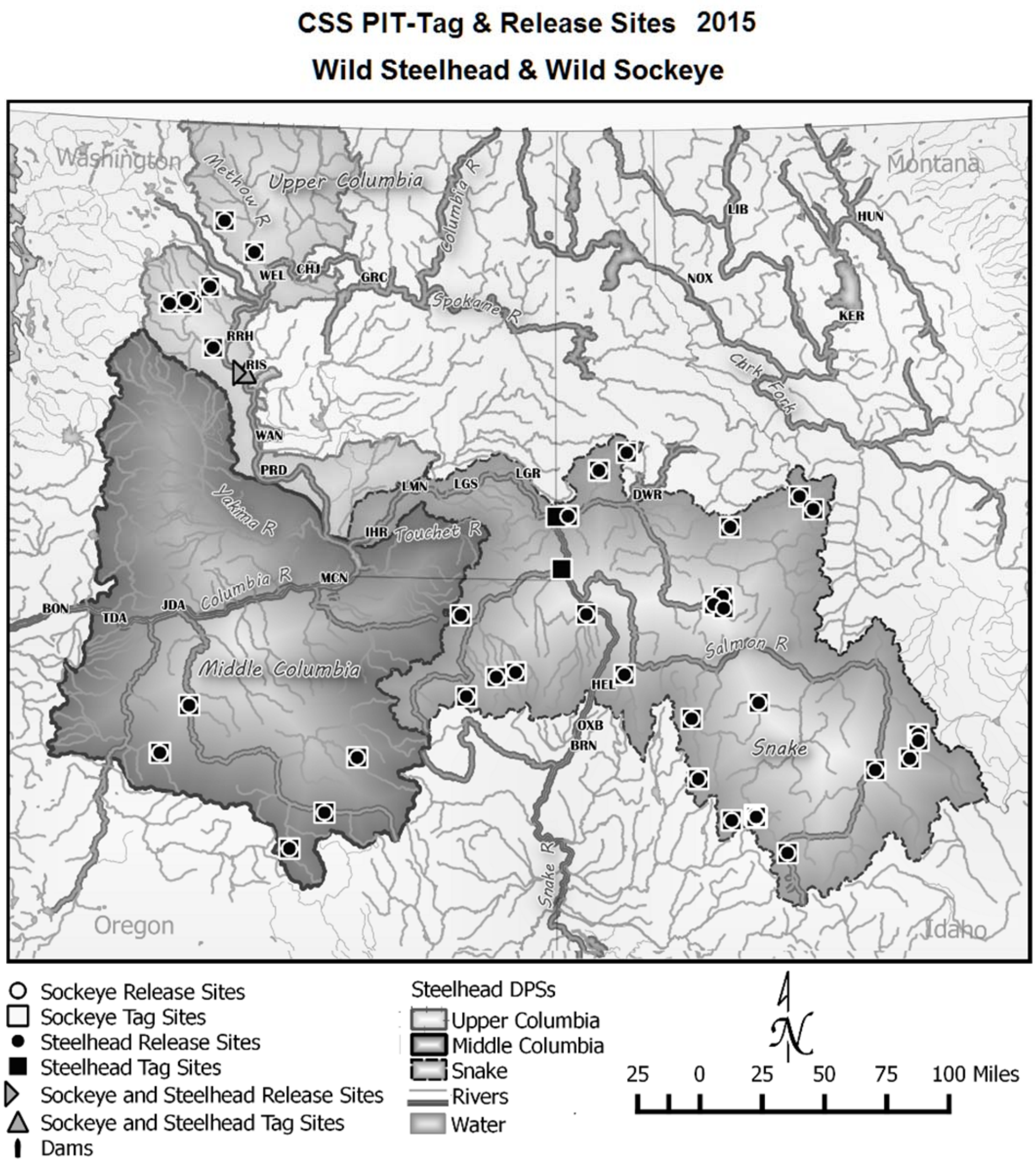


Figure 1.5. CSS PIT-tag release locations for wild steelhead and sockeye in the Columbia River Basin.

Data generated in the Comparative Survival Study

The Comparative Survival Study (CSS) is a management-oriented, large scale monitoring study of spring/summer/fall Chinook, steelhead, and sockeye. The CSS was designed to address several of the basin-wide monitoring needs and to provide demographic and other data for Snake

River and Columbia River wild and hatchery salmon and steelhead populations. One product of the CSS is annual estimates of SARs for Snake River hatchery and wild steelhead and salmon. Estimation of the overall, aggregate SARs of fish that are transported and those that migrate entirely in-river is key to evaluation of avoidance of jeopardy (i.e., put at risk of extinction) as well as progress toward recovery goals. Monitoring survival probability over the entire life-cycle can help identify where survival bottlenecks are occurring, which is critical input for informed management decisions (Good et al. 2007). The CSS also examines environmental factors associated with life-cycle survival probability and evaluates the hypothesized mechanisms for variations in those probabilities.

Generally we estimated the survival of various life stages through known release and detected return numbers of PIT-tagged fish. The PIT tags in juvenile fish are potentially read as the fish pass through the coils of detectors installed in the collection/bypass channels at six Snake and Columbia River dams, including Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), McNary (MCN), John Day (JDA), and Bonneville (BON) (Figure 1.2–Figure 1.5). When tags are read, their fish identification number and the time/date of detection is recorded. Upon arrival at LGR, LGS and LMN, Snake River smolts can travel through three different routes of passage: (1) over the spillway via typical spillway, removable spillway weir (RSW), or temporary spillway weir (TSW), or (2) into the powerhouse where smolts either subsequently pass through the turbines, or (3) are diverted with screens and pipes into the collection and bypass facility. Those smolts that pass over the spillway or through the turbines are not detected. Juvenile detection probabilities for each dam can range from 5%–90% and depend on interactions between species, dam, environmental conditions, and facility operations while smolts are passing.

The first three dams in the Lower Snake River (LGR, LGS, and LMN) have facilities for holding and transporting smolts. During transportation operations, smolts without PIT tags that enter the collection facility are generally put in trucks or barges and transported to below BON. Transportation at MCN used to begin in July after the completion of the spring outmigration and did not affect the Columbia River groups currently studied in the CSS (e.g., spring out-migrating steelhead and Chinook). Transportation has been discontinued at McNary Dam. There is not a transportation program at JDA or BON. Additional PIT-tag detections can be obtained from a special trawling operation (TWX) by NMFS in the lower Columbia River in the vicinity of Jones Beach. Returning adults with PIT tags are detected in the fish ladders at LGR with nearly 100% probability. PIT-tag detection capability for returning adults has been added at BON, TDA, Ice Harbor (IHR), MCN, LMN, and LGS over the past several years, allowing for additional analyses. PIT-tag detection capability also exists in nearly all major tributaries such as the Deschutes and John Day rivers.

A specific goal of the CSS has been to develop long-term indices of SAR ratios between transported and in-river fish. A common comparison, termed “Transport: In-river” ratio, or TIR, is the SAR of transported fish divided by the SAR of in-river fish, with SAR being estimated for smolts passing LGR and returning as adults back to the adult detector at LGR (GRA). Additionally, overall SARs from LGR to the adult detector at BON (BOA) are provided (see Chapter 4). Estimates of TIR address the question of whether transportation provides an overall benefit to smolt-to-adult survival, compared to leaving smolts to migrate in-river, through the hydrosystem, as currently configured. The overall value of transportation in avoiding jeopardy and promoting recovery depends on the extent to which it circumvents direct mortality (i.e., to

smolts within the hydrosystem) and indirect mortality (i.e., to smolts after passing BON) caused as a result of passage through the hydrosystem. In the CSS, this indirect mortality is referred to as "delayed" or "latent" mortality. Because TIR compares SARs starting from collector projects, it does not by itself provide a direct estimate of delayed mortality specific to transported fish (see below for a description and use of "*D*", which is an estimate of transportation-related delayed mortality).

Related to TIR is *D*, the ratio between SARs of transported fish and in-river fish from downstream of BON as smolts back to LGR as adults (BON-to-GRA SARs). *D* excludes mortality occurring during juvenile salmon passage between Lower Granite and Bonneville dams and captures any differences in mortality between transported smolts and in-river migrants that occurs after BON juvenile passage (i.e., from ocean residence through return as adults to LGR). $D = 1$ indicates that there is no difference in the survival probability of transported or in-river fish after hydrosystem passage. $D < 1$ indicates that transported smolts die at a higher rate after passing BON compared to in-river smolts that have migrated through the hydrosystem. $D > 1$ indicates that transported fish have higher survival after passing BON compared to in-river fish. *D* has been used extensively in modeling the effects of the hydrosystem on Snake River Chinook salmon (Kareiva et al. 2000; Peters and Marmorek 2001; Wilson 2003; Zabel et al. 2008).

Estimation and comparison of annual SARs for hatchery and wild groups of smolts with different hydrosystem experiences between common start and end points are made for three categories of fish passage:

1. tagged fish that are collected at Snake River dams (LGR, LGS or LMN), and transported (T);
2. tagged fish collected at Snake River dams and returned to the river (C_1), or
3. tagged fish that have not been collected at the Snake River dams (C_0).

The year 2006 marked an important change in fish transportation operations within the FCRPS. Transportation operations from 1997–2005 began ~ April 1st and encompassed most of the emigrating groups of CSS-marked fish. In 2006, the transportation operational protocol was altered at the three Snake River collector dams. The start of transportation was delayed at LGR until April 20 in 2006 and generally until on or about May 1 from 2007 through 2016. During 2010, as an example, transportation began on April 25. The start of transportation at LGS and LMN was delayed further to account for smolt travel time between projects, typically ranging from 4 to 12 days later than LGR depending on the year and fish travel times. This change in operations affected the CSS study because the transportation protocol now allows a portion of the population to migrate entirely in-river through the hydrosystem before transportation begins.

This 2006 management change coincided with the CSS change in methods that pre-assigned fish to bypass or transport routes, rather than forming transport and in-river cohorts at Snake River collector projects as was done through 2005. The new CSS approach facilitated evaluation of the 2006 change in transportation strategy. Prior to 2006, computers at the dams selected which fish were to be routed to transportation during the out-migration based on order of passage; an example would be one of every four fish detected would be routed to transport. This would occur when the transportation proportion was 0.25 and then every fourth fish was chosen to be transported while the other three were returned to river. The new method randomly pre-assigns the tagged fish to two different study groups prior to their emigration through the hydrosystem. This is accomplished through FPC coordination with various marking agencies.

By knowing what PIT tags are used for marking, FPC randomly assigns individual PIT tags to two groups, and passes this information on to the separation-by-code facilities at each dam. One group (denoted as Group T in this report) reflects the untagged population. These tagged fish are routed in "Monitor-Mode," which means they are routed the same way as the untagged smolts at each of the collector dams where transportation occurs. The other group (denoted as Group R in this report) follows the default return-to-river routing for PIT-tagged fish at each collector dam throughout the season. The primary utility of the R group is to augment the sample size used in the CJS model, but these PIT tags are also included in other analyses where applicable. During the emigration, upon entering the bypass facilities at the transportation sites, two things can happen. If transportation is taking place, Group T fish are transported and Group R fish are bypassed. If transportation is not taking place, both groups are bypassed. Combining Groups T and R provides a composite group (Group CRT) comparable to what has been used in the CSS in all migration years through 2005. For the analyses in this report, we use Group CRT to estimate CJS reach survival probability and detection probabilities. See Appendix A for a detailed description as well as diagrams showing how R and T group assignments are used in computations.

The transport category can fall into two subcategories. The first is termed T_0 and includes those smolts that were detected for the first time at a collector dam in the hydrosystem and transported. This action was typical for nearly all transported smolts prior to 2006 — before the transportation delay began. After the initiation of the delayed transportation protocol, transported smolts included both those *never previously detected* and those that *were previously detected*. Concordant with this operational change, the CSS included both types in the transport category and referred to these as T_X in most cases for years after 2005. The estimation of TIRs and *D* will have T_X replace T_0 smolts in migration years after 2005, while C_0 smolts are estimated the same in all years (i.e., the total smolt population at LGR minus LGR equivalents of detected fish at LGR, LGS, and LMN; see Appendix A for formulas).

The SARs and the ratios of SARs in this report are estimated for the entire migration year. For years prior to 2006, the SARs developed for each of the study categories (transported, C_0 and C_1) are weighted by the proportion of the run-at-large (untagged and tagged fish) represented by these categories to provide overall annual SARs (see Chapter 2 in Tuomikoski et al. 2009 for formulas). A direct estimation of overall annual SARs is possible beginning in 2006 where PIT-tagged study fish are pre-assigned prior to release into a monitor-mode group (Group T) that passes through the collector dams in the same manner as untagged smolts. Both the estimated smolt numbers and adult return data for Group T provide a direct estimation of the annual overall SARs beginning with the 2006 migrants. Because no transported smolts and only a small number of in-river smolts are enumerated at BON, the BON-to-GRA SAR is estimated from the LGR-to-GRA SAR, adjusted by annual in-river survival probability estimates (through the hydrosystem) and assumed average direct transport survival probability from empirical studies.

Overview of Bootstrapping Estimation Approach

Over the years, we have developed a computer program to estimate the following quantities with confidence intervals: survival from hatchery release to LGR; reach survival estimates between each of the dams equipped with PIT-tag detectors; survival from smolt arrival at LGR dam until return to LGR or BON as adults ($SAR_{LGR\text{-}to\text{-}GRA}$ and $SAR_{LGR\text{-}to\text{-}BOA}$); survival

from smolt at BON to LGR as adults (BON-to-GRA SAR); and the ratio of these SARs for smolts with different hydrosystem passage experience (TIR and *D*). Assessment of the variance of estimates of survival probability and ratios is necessary to describe the precision of these estimates for statistical inference and to help monitor actions to mitigate effects of the hydro-system. For a number of the quantities described above, theoretical estimates of variance are tractable. However, variance components of other quantities are often unknown or are extremely complicated and thus impracticable to estimate using theoretical variances. Therefore, a naïve bootstrap method was used to describe uncertainty around parameter estimates, where the point estimate was first calculated from the original sample, then the PIT-tag data were re-sampled with replacement to create 1,000 bootstrap replications. These 1,000 simulated samples were used to produce a distribution of values that describe the mean and variance associated with the point estimate. From the set of 1,000 iterations, 80%, 90%, and 95% non-parametric bootstrap confidence intervals (Efron and Tibshirani 1993) were computed for each parameter of interest. Peterman (1990) argued that in fisheries, the cost associated with wrong decisions resulting from Type II errors can exceed those from Type I errors and, in part, recommended using an alpha of 0.10 instead of 0.05. The 90% confidence intervals used in the CSS annual reports were chosen in an attempt to better balance the making of Type I (rejecting a true null hypothesis) and Type II (accepting a false null hypothesis) errors for comparison among study groups of fish for the various parameters of interest.

The CSS has begun exploring the use of a weighted bootstrap for use with groups of fish that have unequal marking across the population. In particular, PIT-tag marking at McCall National Fish Hatchery is done unequally among smolts from two different brood stock breeding types. Half the PIT-tags are implanted in each sub-population although those populations are unequal (making up one third and two thirds of the total release). The CSS has developed a prototype method that is presented in Appendix H that reweights the bootstrap draws so that each iteration reflects the proportions of the population. The resulting bootstrap population of tags reflects the underlying population proportions. Testing to date has shown the method works as expected. The method is still in development, but is included in Appendix H, for review.

CSS PIT-tagging operations and sources of study fish

An overall goal of CSS is to emphasize marking wild fish and to mark wild populations as representatively as possible. Part of that effort involves marking wild fish at finer geographic scales by relying more on traps located in tributaries and reducing marking at mainstem traps. This allows marking wild fish at the Major Population Group (MPG) level versus at the Ecologically Significant Unit (ESU) level. Although truly representative marking is likely impossible, given constraints on fish handling, trapping operations during peak runoff and other limitations to sampling, the CSS has implemented changes to marking to attempt to improve representativeness of major population groups, transition toward finer geographic scale marking, and reduce the handling of listed hatchery stocks. To accomplish these goals, CSS reduced or eliminated marking at mainstem traps in the Clearwater and Salmon rivers in 2015, and transitioned those tags to traps in tributaries higher up in the watersheds.

The Clearwater River trap (operated by IDFG) was located near the confluence of the Clearwater and Snake rivers. Operations at this trap were ceased in 2015 and tags were moved to traps in the Lochsa River (operated by IDFG) and South Fork Clearwater River (operated by Nez Perce Tribe). Two other new traps are planned to begin operation by 2016. The emphasis

for these new traps is marking wild steelhead throughout the Clearwater Basin MPG. The CSS Oversight Committee worked with IDFG and NPT to reallocate tags from the Clearwater trap to these new locations. Similarly, marking at the Salmon River trap was modified in 2015 in an attempt to reduce handling of listed hatchery Chinook at the trap. Marking was modified by implementing a weekly quota, thus assuring that tags were available for marking into late May.

Also, some tagging was moved from the Salmon River Trap to new traps operated by IDFG and the Shoshone-Bannock Tribe (SBT) higher up in tributaries. These new traps include, Valley Creek, East Fork Salmon River, and North Fork Salmon River. This allows more targeted marking of MPG-level populations of both wild yearling spring/summer Chinook as well as wild steelhead. Finally, approximately 10,000 tags previously allocated for hatchery Chinook at Dworshak NFH were reallocated to marking of wild Chinook and wild steelhead at tributary traps throughout the Clearwater and Salmon river basins.

Trap operations at the Grande Ronde River trap (rkm 2) were modified in 2015 in an attempt to reduce handling of listed hatchery Chinook. Because these modifications had the potential to reduce wild Chinook and steelhead marking at this trap, the CSS coordinated with ODFW to include two additional Grande Ronde River tributary traps into the CSS analyses. These two traps are the Upper Grande Ronde trap (rkm 299) and the Grande Ronde trap near Elgin (rkm 160).

Wild and hatchery smolts are marked with glass-encapsulated, passive integrated transponders (PIT) that are 9 to 12 mm in length and have a unique code to identify individual fish. These PIT tags are normally implanted into the fish’s body cavity using a hand-held syringe, and are generally retained and function throughout the life of the fish. Snake River basin wild and hatchery Chinook and steelhead used in the CSS analyses were obtained from all available marking efforts above LGR. Wild Chinook from each tributary (plus fish tagged at the Snake River trap near Lewiston) were represented in the PIT-tag aggregates for migration years 1994 to 2014. The sample sizes for each group with tags provided by the CSS from 1994–2014 are presented in Appendix C at the end of this report.

During 2010, tagging operations began in cooperation with WDFW on wild Chinook and steelhead in the Upper Columbia basin. These cooperative tagging efforts are ongoing at the time of this report.

Snake River hatchery yearling spring and summer Chinook were PIT-tagged for the CSS at specific hatcheries within the four drainages above LGR including the Clearwater, Salmon, Imnaha, and Grande Ronde rivers. Hatcheries that accounted for a major portion of Chinook production in their respective drainages were selected. Since study inception in 1997, the CSS has PIT-tagged juvenile Chinook at Rapid River, Dworshak, McCall, and Lookingglass hatcheries. Two Chinook stocks are tagged for the CSS at Lookingglass Hatchery: an Imnaha River stock released into the Imnaha River and a Catherine Creek stock released in the Grand Ronde River drainage. This latter stock became available to the CSS in 2001 after the Lookingglass Hatchery complex changed its operation to rear only stocks endemic to the Grande Ronde River basin. The CSS has also contributed PIT tags to additional Lower Snake River Compensation Plan (LSRCP) hatcheries including spring (since 2006) and summer (since 2011) Chinook from Clearwater Hatchery in the Clearwater River basin, summer Chinook from Pahsimeroi Hatchery (since 2008), and spring Chinook from Sawtooth Hatchery (since 2007) in the Salmon River basin.

From 2009 to 2012, Snake River hatchery sockeye were tagged at Oxbow (Oregon) and Sawtooth hatcheries as part of a short-term Corps of Engineers study. These have been the only available marks for hatchery sockeye in the Snake River basin in large enough numbers to estimate SARs. The total number of tagged sockeye smolts from Oxbow has been approximately one-fifth of that from Sawtooth, and thus the Oxbow group provided a more limited data set with respect to the CSS. However, the Sawtooth group sample size has been adequate for estimation of various CSS parameters. To maintain a time-series of PIT-tagged Snake River Basin hatchery sockeye amenable to the CSS study design, the CSS and IDFG began cooperatively marking Sawtooth hatchery sockeye in 2013, and this is expected to continue through 2015. In 2015, sockeye hatchery operations transitioned to Springfield Hatchery. In 2015, the CSS and IDFG PIT-tagged hatchery sockeye from both Sawtooth and Springfield hatcheries. Beginning in 2016, CSS tags will be provided for releases of sockeye from Springfield Hatchery, as sockeye will no longer be reared at Sawtooth Hatchery. This tagging program meets hatchery monitoring needs for the Snake River sockeye salmon hatchery program and maintains the CSS time-series for Snake River Basin hatchery sockeye.

Wild steelhead smolts from each tributary (plus fish tagged at the Snake River trap near Lewiston) were represented in the PIT-tag aggregates for migration years 1997 to 2014. Hatchery steelhead from each tributary, plus PIT-tag releases in the mainstem Snake River at the Lewiston trap and below Hells Canyon Dam, were represented in the PIT-tag aggregates for migration years 1997 to 2007 with more extensive PIT-tagging of hatchery steelhead beginning in 2008. This increased again in 2009 with the addition of the Niagara Springs Hatchery production. With the greater coverage of hatchery steelhead above LGR, separation of metrics into A- and B-runs and by basin are now possible. Snake River stocks designated as B-run differ from A-run stocks in their later adult migration timing, older ocean-age (primarily 2-salt adults), and larger adult size.

The PIT-tagged wild Chinook and wild steelhead used in the CSS may be PIT-tagged as part of the CSS or for other research (discussed further in the next section) and at certain times of the year, multiple age classes of fish were being PIT-tagged. We employed date and/or length constraints specific to the migration year, species, and basin of interest to exclude cohorts of smolts that outmigrated in other years. This was necessary since estimates of collection efficiency and survival must reflect a single year. We used information on the year fish are observed outmigrating through the FCRPS along with tagging size and tagging date to identify where multiple cohorts occur and the constraints that should be applied. As a general example, for Snake River wild Chinook, we often found that limiting the tagging season to a 10-month period from ~ July 25 to ~ May 20 the following year reduced the instances of overlapping age classes. For Snake River wild steelhead, we typically found that size at tagging was a useful parameter for removing a high proportion of fish that reside an extra year or two in freshwater beyond the desired migration year of study (Berggren et al. 2005b; Berggren et al. 2006). Generally for Snake River wild steelhead, excluding smolts marked below 130 mm and above 300 mm reduced the instances of multiple year classes and allowed the tagging season to be a full 12 months. These base constraints were adjusted for individual outmigration years. For John Day wild Chinook, limiting the tagging season from October until June often was enough to exclude other year classes of fish.

Similar methods were used for Deschutes River steelhead (marked at Trout Creek) and John Day River steelhead. To assemble the data for Deschutes River steelhead, we found very

little evidence of multiple year classes being marked in a single calendar year and utilized nearly all marks until early June from the spring of each calendar year with a lower length constraint of approximately 100 mm in certain years. To assemble the John Day wild steelhead marks we included wild steelhead marked at sites within the John Day River south fork, middle fork, and mainstem. For these groups, we used smolts marked from July through June when available (up to 11 months) and length constraints that increased from approximately 90 mm to 120 mm across this date range.

Some new groups were added in the 2014 Annual Report (McCann et al. 2014). In addition to overall SARs for aggregate Snake River wild Steelhead and Chinook, when sample sizes allowed, Chapter 4 now includes overall SAR estimates for wild steelhead and Chinook at the MPG level. These MPG-level SARs are provided for both LGR-to-GRA and LGR-to-BOA, and with and without jacks (1-salt) for Chinook. In addition, Chapter 4 now includes estimates of overall SARs (MCN-to-MCA and MCN-to-BOA) for Yakima River wild Chinook and Yakima River hatchery Chinook (i.e., Cle Elum Hatchery), and Yakima River wild steelhead. Additional fall Chinook groups in Chapter 5 include the Little White Salmon, Spring Creek hatchery fall Chinook releases, Hanford Reach wild fall Chinook, and Deschutes River wild fall Chinook. Finally, in cooperation with the Nez Perce Tribe, CSS provided funding for marking Lyons Ferry hatchery subyearling fall Chinook in 2015. Approximately 44,400 PIT-tagged juveniles were released at two acclimation facilities (Captain John Rapids and Pittsburgh Landing) located on the Snake River.

Two new groups were added to the 2016 CSS Report. Wild Okanogan River sockeye were added; marking this group is a joint project of CRITFC and Okanogan Nation Alliance. This has been a pilot project for CSS since MY 2013. The 2016 CSS report will have SARs (RRE-BOA, MCN-BOA) for MY 2013 & 2014. In addition, wild summer Chinook from above Wells Dam have been added. Upon request from Colville Tribe, 2016 CSS Report will include SARs for upper Columbia wild summer Chinook (RRE-BOA, MCN-BOA) for MY 2011-2013 (and possibly 2014).

Coordination and pre-assignments during 2016

Marked fish utilized in the CSS may be from groups PIT-tagged specifically for this program or may be from marked groups planned for other research studies. Wherever possible the CSS makes use of mark groups from other research and coordinates with other marking programs to meet CSS requirements in order to reduce costs and handling of fish. To that end, the CSS has a history of collaboration and is currently cooperating with several other agencies in the marking and pre-assignment of smolts. All of the smolts marked and pre-assigned during the 2016 migration year are outlined in Tables 1.1–1.3 (these releases will be analyzed in future reports).

The CSS will continue coordination efforts to avoid redundancy and save costs as recommended by the ISAB/ISRP reviews (2007 and 2009). Collaboration on Snake River basin hatchery fish in recent years includes those with the marking programs of the LSRCP. Specifically this includes IDFG, ODFW, and WDFW (Table 1.1). Additionally, the CSS has collaborated with Idaho Power Company (IPC), Nez Perce Tribe, USFWS, and many others.

Table 1.1. Snake River hatchery groups marked for the 2016 smolt outmigration that have all or part of their PIT tags provided by the CSS. Many groups have tags cooperatively provided by the CSS and other entities. The hatchery, species, tag funding sources and tag totals are shown for each. Through cooperative efforts pre-assignments are carried out by either the CSS or the other associated agencies.

		PIT-Tag Funding Source [1]							
Hatchery	**Species**	**IDFG/LSRCP**	**CSS**	**IPC**	**ODFW/LSRCP**	**USFWS**	**WDFW/LSRCP**	**NPT/LSRCP**	**Total**
Rapid River	Sp. Chinook		32,000	20,000					52,000
McCall	Su. Chinook	20,000	32,000						52,000
Clearwater	Sp. & Su. Chinool	59,400	27,200						86,600
Kooskia	Sp. Chinook		3,100			5,700			8,800
Pahsimeroi	Su. Chinook		6,400	16,000					22,400
Sawtooth	Sp. Chinook	16,000	6,400						22,400
Magic Valley	Steelhead	16,000	18,800						34,800
Hagerman	Steelhead	12,000	5,200						17,200
Niagara Springs	Steelhead		9,700	13,000					22,700
Clearwater	Steelhead	12,700	5,400					3,400	21,500
Lookingglass (Imnaha AP)	Sp. Chinook		21,000						21,000
Lookingglass (Catherine Creek)	Sp. Chinook		21,000						21,000
Irrigon (Grande Ronde, Imnaha)	Steelhead		14,000		23,000				37,000
Dworshak	Sp. Chinook		42,000						42,000
Dworshak	Steelhead		11,400			21,500			32,900
Lyons Ferry (Cottonwood AP)	Steelhead		2,000				4,000		6,000
Springfield	Sockeye	12,200	39,800						52,000
Lyons Ferry (Captain Johns and Pittsburg Landing)	Fa. Chinook		52,000					4,000	56,000
Grand Total		148,300	349,400	49,000	23,000	27,200	4,000	7,400	608,300

[1]Tag funding Sources are: Idaho Fish and Game (IDFG), Idaho Pwer Company (IPC), Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), Comparative Survival Study (CSS), Nez Perce Tribe (NPT), and Lower Snake River Compensation Plan (LSRCP).

[1] Tag funding Sources are: Idaho Fish and Game (IDFG), Idaho Power Company (IPC), Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), Comparative Survival Study (CSS), the Nez Perce Tribe (NPT), and Lower Snake River Compensation Plan (LSRCP).

Coordination and cooperation have been part of the marking efforts on wild fish throughout the history of the CSS. The CSS has coordinated with the Smolt Monitoring Program (SMP) over several years of both studies. During the 2010 marking, a new study group was added to the CSS through collaboration with WDFW: wild steelhead and Chinook marked in the upper Columbia are now included in the study (Table 1.2). Metrics and analyses on these groups are included in Chapter 4 of this report.

Table 1.2. Wild fish marked for the 2016 smolt outmigration that have all or part of their PIT tags provided by the CSS. Many groups have tags cooperatively provided by the CSS and other studies. The location of marking, species, tag funding sources and tag totals are shown for each. Through cooperative efforts pre-assignments are carried out by the CSS on these groups except for the Chiwawa Trap and Lower Wenatchee Trap (i.e., Upper Columbia Basin).

		PIT-Tag Funding Source [1]					
Location	**Wild Species**	**SMP**	**CSS**	**IDFG**	**ODFW**	**WDFW**	**Total**
Clearwater/Salmon Tributaries	CH/St		46,000	40,000			86,000
Snake and Salmon Traps	CH/St	8,800	6,200				15,000
Grande Ronde Trap	CH/St	4,000	1,400				5,400
Grande Ronde Tributaries	CH/St		4,600		8,200		12,800
Asotin Creek Trap	St		1,500			3,500	5,000
Entiat, Methow, Chiwawa, Wenatchee Tributaries	CH/St		30,000				30,000
Grand Total		12,800	89,700	40,000	8,200	3,500	154,200

1 Tag funding sources are: Smolt Monitoring Program (SMP), Idaho Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW). PIT-tags are provided for both wild Chinook and wild steelhead at some locations but the actual numbers captured and tagged by species are not known until after the outmigration is complete.

Fish to be utilized in the CSS from groups planned for other research studies during 2016 are shown in Table 1.3. In the future, the CSS will continue to review on-going and planned programs in the Middle and Upper Columbia River regions, to establish stock-specific or aggregate groups of marks in those regions to support CSS analysis and develop demographic survival data for those stocks.

Table 1.3. Groups marked in 2016 (through August 1) that do not include PIT tags provided by the CSS but are included in the study. The location of marking/hatchery, species, primary marking agency and tag totals are shown for each.

		PIT-tag Marking Agency[1]						
Location/Hatchery	**Species**	**NPT[2]**	**ODFW**	**USFWS**	**YINN**	**SMP**	**COLV**	**Total**
Wild Groups								
Imnaha Trap (Imnaha Basin)	CH/ST	9,000						9,000
Above Wells/Okanogan River	Su. Chinook						15,000	15,000
John Day River	CH/ST		10,000					10,000
Trout Creek (Deschutes Basin)	Steelhead		700					700
Yakima (Satus, Toppenish, and Ahtanum Creeks)	Steelhead				200			200
Hatchery Groups								
Carson NFH	Sp. Chinook			14,000				14,000
Cle Elum	Sp. Chinook				40,000			40,000
Leavenworth NFH	Sp. Chinook					15,000		15,000
Warm Springs NFH	Sp. Chinook			13,000				13,000
Hatchery + Wild								
RIS Yearling	Chinook					4,000		4,000
RIS subyearling	Chinook					4,800		4,800
RIS	Steelhead					4,000		4,000
RIS	Sockeye					3,400		3,400
Grand Total		9,000	10,700	27,000	40,200	31,200	15,000	133,100

1 Tag funding sources are: Nez Perce Tribe (NPT), Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife (USFWS), Yakama Indian Nation (YINN), and Smolt Monitoring Program (SMP). PIT-tags are provided for both wild Chinook and wild steelhead at some locations, but the actual numbers captured and tagged by species is not known until after the outmigration is complete.

2 Pre-assigned by NPT.

Historic in-river conditions and transportation

The environmental conditions experienced by outmigrating juvenile yearling Chinook and steelhead have varied considerably over the 20-year historical context of the CSS (Figure 1.6). The spring spill program has been in place since 1996 though some years with low flows (2001, 2004, and 2005) also had the lowest median spill percentages over these years. In 2007, low flows were accompanied by high spring spill percentages and low transportation percentages. This was the first time that spill was provided under such low flows. Migration years 2010 and 2013 were similar in this regard. In contrast, 2008, 2009 and 2012 had medium flows and 2011 had high flows, all of which were accompanied with high spill.

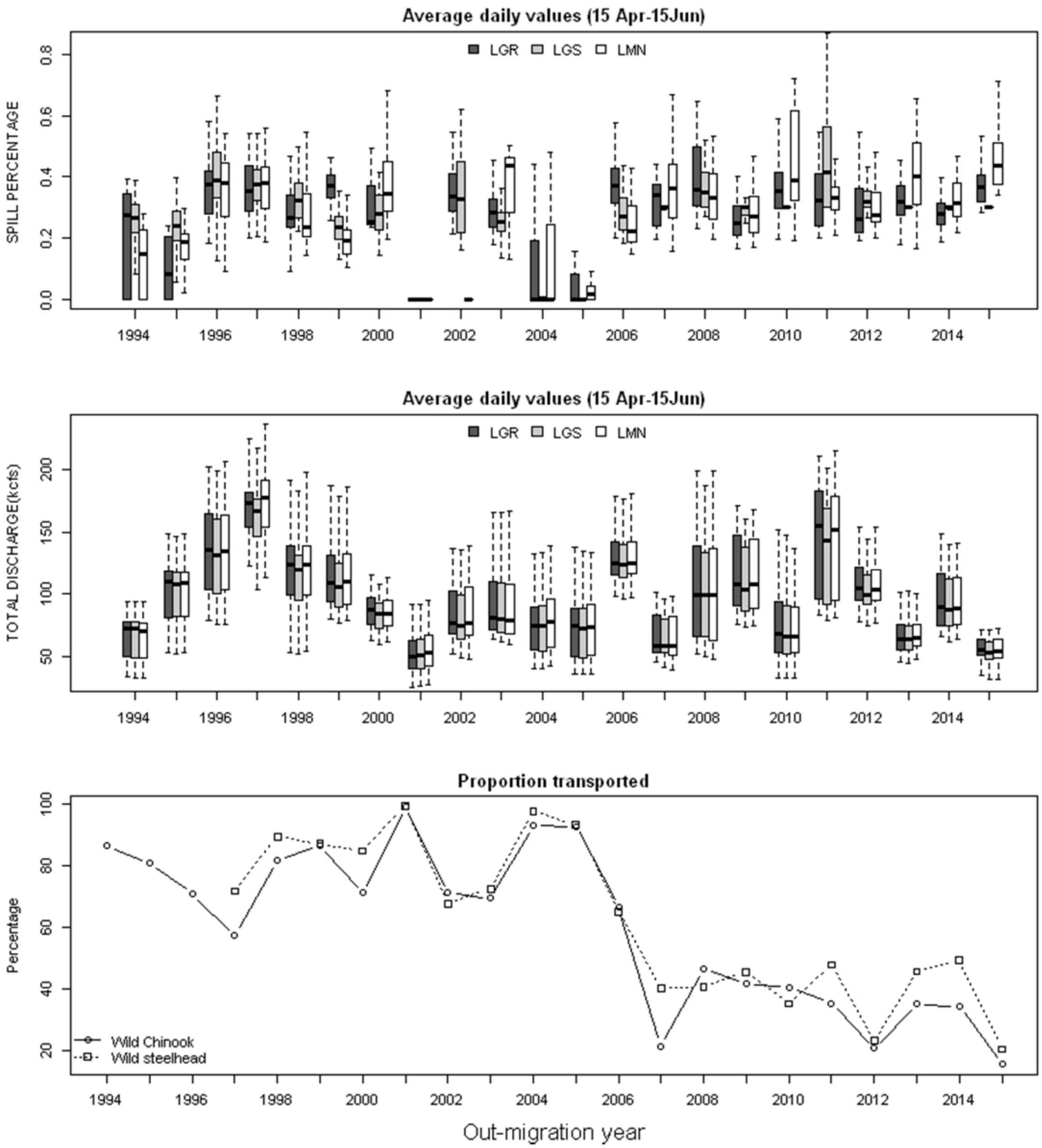


Figure 1.6 The top, middle, and bottom panels are summaries of spill percentage, flow, and the proportion transported over the historical context of the CSS at Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams. The top two panels are boxplot summaries of average daily spill percentages and average daily flows at the three primary transportation dams. The proportion transported is shown for the wild Snake River stocks involved in the CSS as expressed by population proportion of T_0 fish in migration years before 2006 (Table 7.7 and Table 7.13 in the 2009 CSS annual report, and Appendix D of 2016 CSS annual report). The proportion transported for migration year 2015 was estimated for this report.

Transportation protocol has varied over the years of the study as well. The transportation program underwent a change in operations during 2006. Transportation was delayed at LGR

until April 20 in 2006, April 25 in 2010, May 1 in 2007–2009 and 2011, and May 2 in 2012–2015. These years included a similar (but lagged) start date at LGS and LMN. The delayed start date was combined with an increased spill percentage as compared with 2004 and 2005, and resulted in a lower proportion of wild smolts being transported. Smolt outmigration timing also should affect transportation percentage and these results vary by stock. The highest transport percentages of CSS PIT-tagged wild smolts occurred in 2001, 2004, and 2005. Conversely, 2015 had one of the lowest transportation percentages in recent years and much lower than other years with comparable flows. The higher spill percentage and delay of transportation contributed to a lower percentage of wild smolts transported. Typically for years after 2005 about 40 percent of the PIT-tagged Snake River wild stocks were transported.

Draft Report Organization

The draft report has eight chapters, including this introduction, followed by three appendices. Each of the following sections addresses a specific question or set of questions relating to the objectives of the CSS, its constituent data, analytical methods, and the comments by the ISAB as well as other reviewers.

Chapter 2 presents a life cycle modeling analysis that relies on the statistical results obtained from the 2015 life cycle model fitting to examine how alternative spill levels can help population recovery. Four alternative spill scenarios are examined. Each spill scenario predicts a rate of powerhouse passage at low flow, average flow, and high flow. The effect of powerhouse passage on in-river and ocean survival is predicted as a consequence of each spill/flow combination, and the life cycle model is used to predict the effect of each spill scenario on SARs and long term abundances for six Snake River Spring Chinook populations. Results are preliminary and SARs should be viewed as relative estimates of the effects of different spill scenarios.

Chapter 3 updates the time series of data on juvenile travel time, instantaneous mortality, and survival with data from 2015. Models are developed to evaluate the relationships between water transit time, spill proportions, spillway weirs, water temperature, and seasonality to juvenile travel time, instantaneous mortality rates, and survival. The species evaluated include juvenile yearling Chinook salmon, subyearling Chinook salmon, sockeye salmon, and steelhead as they migrate through the reaches from Lower Granite Dam to McNary Dam, Rock Island Dam to McNary Dam, and McNary Dam to Bonneville Dam.

Chapter 4 summarizes overall smolt-to-adult return rates (SARs) for wild and hatchery salmon and steelhead populations from the Snake River, Mid-Columbia and Upper Columbia regions. Overall SARs of Snake River wild spring/summer Chinook and steelhead fell well short of the Northwest Power and Conservation council's (NPCC) 2% - 6% SAR objectives, while those from the mid-Columbia region generally fell within this range. For Snake River populations, none of the passage routes (in-river or juvenile transportation) have provided SARs within the range of the NPCC objectives; the relative effectiveness of transportation decreases as in-river conditions improve and survivals increase. SARs of wild and hatchery populations were highly correlated within and among regions, suggesting that common environmental factors were influencing survival rates.

Chapter 5 examines the association of SARs to life-cycle productivity for wild spring/summer Chinook and steelhead populations. Major population declines of Snake River spring/summer Chinook and steelhead are associated with SARs less than 1%, and increased life-cycle productivity has occurred in years that SARs exceeded 2%. Pre-harvest SARs in the range of 4% to 6% are associated with historical (pre-FCRPS) productivity for Snake River spring/summer Chinook. Historical levels of productivity for John Day river spring Chinook are associated with pre-harvest SARs in the range of 4% to 7%.

Chapter 6 presents SARs by route of passage and TIRs for Snake River fall Chinook from migration years 2006 to 2012. The chapter considers predicted holdover probability for removing fish from SAR estimation using prediction analysis methods. Simulations were run to assess the range of potential bias in SARs based on holdover detections and late season migrants. The chapter also includes overall SAR data for hatchery and wild subyearling Chinook from the Mid-Columbia Region.

Chapter 7 evaluates the effects of juvenile bypass systems on delayed mortality as measured by SARs of juvenile fish alive at Bonneville Dam. Data from PIT-tag detection histories from migration years 2006 to 2013 provide an opportunity to assess whether bypass passage experiences continue to influence SARs under the recent operation and configuration of the FCRPS dams. The analysis of hatchery and wild Snake River spring/summer Chinook salmon and steelhead uses a similar analytical approach as Tuomikoski et al. (2010). A better understanding of the delayed effects of passage through bypass systems could assist hydrosystem and fishery managers in developing operations that would address the total impacts of project operations on life-cycle survival rates.

Chapter 8 which was included in the DRAFT report examined PIT-tag-based data on age-at-maturity for eleven stocks of spring/summer Chinook salmon in the Columbia River Basin. The ISAB provided extensive and detailed recommendations for consideration of additional analytical approaches. In order to thoroughly address the ISAB review comments and recommendations additional time is required. For that reason this chapter has been removed from the final report. Work on this analysis will continue in order to address ISAB recommendations in a final analyses.

Appendix A updates the CSS time series of juvenile in-river survival from LGR to BON (termed SR), transported and in-river SARs, TIRs and *D* for Snake River hatchery and wild spring/summer Chinook, steelhead, and sockeye. Prior to the 2012 CSS Annual Report, these data were presented in Chapter 2 (SR) and Chapter 4 (SARs, TIR, and *D*). Patterns of TIR and in-river survival probability are also updated for Snake River wild spring/summer Chinook and steelhead.

Appendix B contains tables of the overall SARs that are presented in Chapter 4.

Appendix C describes sources of PIT-tagged fish in the study.

Appendix D contains the dam-specific transportation SARs in terms of adult returns to LGR for Snake River transported fish from LGR, LGS, and LMN.

Appendix E includes the estimates of the proportion of the run-at-large that experiences passage through transportation, bypass, or without detection for Snake River groups.

Appendix F updates the returning age composition of adults for the Snake, Upper Columbia, and Lower Columbia river groups.

Appendix G presents BOA-GRA adult upstream passage success rates by return year for wild Snake River spring/summer Chinook.

Appendix H presents a weighted bootstrap procedure that can be used to estimate SARs for PIT-tag groups that are marked disproportionately. The weighted approach uses a population proportions as weights for drawing tags for each bootstrap run. The method is underdevelopment and is proposed to be used for hatchery release groups where known proportions of sub-populations are disproportionately marked. The weighted bootstrap allows the estimation of confidence intervals using the bootstrap methodology.

Appendix I summarizes the 2016 CSS annual meeting held on April 20, 2016, at the Ambridge Event Center in Portland, Oregon

Appendix J includes the CSS Oversight Committee responses to comments on the draft 2015 CSS report.

CHAPTER 2
LIFE CYCLE MODELING EVALUATION OF ALTERNATIVE SPILL EXPERIMENT SCENARIOS

The CSS began developing life cycle models in 2013 for the purpose of examining survival at specific life stages, which is an important component of Adaptive Management (Holling 1978), and also a key element of NOAA's Biological Opinion on the operation of the Federal Columbia River Power System (FCRPS). Since its inception, the life cycle modeling initiative has explored the potential to assess tributary smolt production, mainstem passage survival, first year ocean survival, and adult return rates. Empirical validation to abundance data and environmental time series provided a detailed perspective of spatial and temporal variability in SAR estimates, while separating survival into freshwater and ocean components. Detailed separation of life stages included separating the juvenile migrants into transported and untransported fish for downstream migration, as well as the distinction that transported and untransported fish experience different survivals upon ocean entry.

The life cycle model was used to compare the predicted relative impacts that two key factors would have on long-term abundance increases: 1. Freshwater production as a function of habitat restoration, and 2. Survival in the mainstem as a function of hydrosystem operations. The 2015 life cycle modeling analysis examined the potential for abundance to increase as a result of these two factors influencing survival across the life cycle. Freshwater productivity was of interest because numerous habitat improvement activities are underway, and the benefits of those activities can likely be expected to result in increases in productivity and capacity. Hydrosystem operations were of interest because they have been shown to affect survival during juvenile migration and also survival at ocean entry.

This 2016 life cycle modeling analysis relies on the statistical results of past life cycle model fitting to examine how alternative spill levels can influence SARs and long-term return abundances, and therefore improve long-term population recovery. Four alternative spill levels are examined. Each spill level predicts a rate of powerhouse passage at three flow levels (high flow, average flow, and low flow). The effect of powerhouse passage on in-river and ocean survival is predicted as a consequence of each the twelve spill/flow combinations, and the life cycle model is used to predict the effect on SARs and long-term abundances for six Snake River Spring Chinook populations.

We present a prospective contrast of the twelve spill scenarios by simulating future population trends. We simulate using the powerhouse passage rates expected under each spill scenario and using the parameters that were estimated during the model fitting procedures. The most recent five years of escapements are used to initialize populations, and future conditions are produced by simulating time series that are consistent with historical patterns and/or in line with anticipated management decisions. We present results by simulating long-term abundance trends thousands of times using random draws from the range of parameters values estimated during model fitting. Simulations are statistically summarized by displaying median values and ranges of predicted SARs and long-term return abundances at different combinations of spill levels and flows, and freshwater productivities and capacities.

Introduction and background

While the CSS survival metrics that have been developed using detections of PIT-tagged salmon and steelhead typically exclude the portion of the life cycle upstream of the uppermost dam (i.e., Lower Granite (LGR) for most of the Snake River spring/summer Chinook ESU and steelhead DPS), the CSS SARs are very useful for validating long-term datasets of SARs and Recruits-per-Spawner (R/S) developed from run reconstructions (see Petrosky and Schaller 2010; Hall and Marmorek 2013). These long-term datasets based on run reconstruction have the advantage of providing population-specific estimates of spawner abundance along with estimates of smolt production. Across populations, the smolt-to-adult return rate is a common currency that can be used to evaluate population survival trends. The smolt-to-adult return rate incorporates smolt survival during downstream passage through the hydrosystem, along with survival in the estuary and ocean until time of adult return.

Because population-specific survival from tagging to adult return is very low (in the vicinity of 1%), the number of tagged adults that return and are also detected is small for most populations, and therefore population-specific survival estimates are highly variable with the rates of tagging seen in most populations. In order to estimate SARs from LGR to LGR with adequate precision, SAR estimates are often aggregated by release group rather than reported by individual population. Further limiting detectability, as adults return upstream of the FCRPS, their dispersal to numerous spawning areas and natal tributaries presents logistical challenges to detect PIT tags, precluding survival estimates. Combining all tags from several populations in a basin results in SAR estimates coming from hundreds of returning adults instead of from return abundances as low as 10 or 20.

In 2013, the CSS developed several modeling approaches that linked models of freshwater spawning and rearing (FSR) with models that characterized variation in smolt-to-adult return rates. Capitalizing on the availability of population-specific adult and smolt abundance data, we modeled multiple populations within a common demographic group. We used empirical FSR metrics from the Grande Ronde/Imnaha Major Population Group (MPG) (Snake River spring/summer Chinook ESU). The MPG is relatively data rich compared to the other four Snake River MPGs. The Grande Ronde contains seven populations compared to a low of two populations in the lower Snake MPG and a high of nine populations in the Middle Fork Salmon MPG (ICTRT 2007). These seven populations occupy a range of habitats of varying complexity, size, human land use and historical land use impacts. Similarly, these seven populations vary in terms of their population sizes and productivity. The variabilities in characteristic conditions means that the populations can be used to contrast expected recovery trends if conditions are improved at the FSR stages versus improved at the juvenile outmigration stage.

Relative numbers of 3, 4, and 5-year old fish can be used to infer survival during the time between juvenile outmigration past BON and the end of the first year in the ocean. We focussed on the combined estuary and first year ocean survival (S.o.1) because early ocean survival is considered very crucial in the life history of salmonids. Ocean survival probabilities have been associated with indices of ocean conditions such as the Pacific Decadal Oscillation (PDO) (Mantua et al., 1997), upwelling indices indicative of primary production, and sea surface temperature (Petrosky and Schaller 2010). Additionally, evidence has emerged that environmental conditions in the river affect the physical condition of out-migrating fish, and influence the rate of

mortality after the fish enter the ocean (Petrosky et al. 2001; Budy et al. 2002). Petrosky and Schaller (2010) showed that S.o.1 varied with PDO, upwelling and a variable describing juvenile interaction with powerhouses. An index of the effect of coming in contact with all powerhouses was created (termed NPH) where each powerhouse that fish come into contact with is discounted by the spill amount and spill efficiency. For example, a 50% spill can reduce a powerhouse contact from as high as 1.0 to as low as 0.5 (see Petrosky and Schaller (2010)). The study found that the sum of the spill-adjusted powerhouse contact values (NPH) was negatively correlated with survival below BON and during the first year in the ocean. That result was corroborated by the CSS life cycle modeling analysis presented in the 2013 annual report.

In 2014, the CSS life cycle modeling effort took on a more detailed analysis of survival through the hydrosystem, further partitioning mainstem passage survival into transported and untransported life histories, and accounting for survival differences both during these two routes of passage, as well as survival differences that occur upon ocean entry. The 2015 life cycle modeling analysis was aimed at providing a quantitative assessment of the relative life cycle production benefits of improving survival conditions in the spawning and rearing versus improving survival conditions during juvenile outmigration through the mainstem. It used the same basic population prediction methods and statistical fitting methods developed in the 2013 and 2014 CSS reports, but the 2015 analysis included additional years of abundance and survival data, and reconstructed population specific in-river harvest using US v OR Technical Advisory Committee (TAC) estimates of Zone 6 and commercial harvest, and included brood stock removals and upstream conversion rates. The 2015 analysis provided a comparison of the potential benefits of managing FSR habitat for increased productivity and capacity versus the potential benefit of managing the hydrosystem. The analysis was a retrospective simulation of potential FSR and hydrosystem actions evaluated at historically observed mainstem and ocean conditions. It contrasted a predicted reconstruction of present day return abundances across a range of possible alternative FSR and hydrosystem actions.

This 2016 analysis builds upon the 2015 framework, but with the distinction that the 2016 analysis evaluates long-term projected return abundances. It is a prospective analysis instead of a retrospective analysis. We use the same estimated productivity and capacity rates, and the same parameters that predict the magnitudes of the effects of hydrosystem and environmental conditions on in-river route of passage and ocean survivals. To represent future unobserved environmental conditions, we simulate time series of in-river and ocean variables that are either drawn randomly from historical values, or simulated to represent conditions similar to historical or expected future conditions.

Data

There are three types of data used in this analysis: 1. forcing variables used to predict survival (environmental and anthropogenic data), 2. empirical abundances (juvenile and adult) used for comparison with predicted abundances, and 3. survival rates used to compare to the predicted trends in survival.

This analysis focuses on spring/summer Chinook salmon in the Grande Ronde basin. The Snake River spring/summer chinook ESU contains several major population aggregates in Idaho,

Washington and Oregon. The Grande Ronde/Imnaha Major Population Group (MPG) consists of several populations migrating into the Snake river. The Grande Ronde River (GR), Catherine Creek (CC), Lostine/Wallowa (LOS), Minam (MIN), Wenaha (WEN), and Imnaha (IMN) are six populations making up the GRIMPG, and are the focus of this analysis. The Northwest Fisheries Science Center of the National Marine Fisheries Service (NMFS) publishes salmon population summaries annually (SPS[1]). These summaries include annual estimates of the number of spawners, the age compositions of spawners, the proportion of hatchery fish on spawning grounds, and harvest rates. The annual record can be used to account for the number of fish of each age from each spawning year (or brood year) that later return to spawn, including those that were caught in fisheries or collected for hatchery brood stock. The full account of this is called a brood table and is used in this analysis for each of the six listed populations of the MPG. We selected the time period for which all populations were monitored and environmental data were available. Thus, early years where not all populations were monitored were not included. Adult returns were available up until 2013, meaning that three year old returns from brood year 2010 were accounted for, along with four year old returns from 2009, and five year olds from 2008. This results in a multi-population brood table spanning the brood years 1964 to 2008, where 2008 is the most recent brood year where all ages of adults have been observed on spawning grounds. We used conversion rates, Zone 6 harvest estimates, and commercial harvest estimates from TAC Biological Assessment Tables to reconstruct the number of adults that would have been present at the mouth of the Columbia, based on the number that were observed on the spawning grounds. Those numbers are used to compare to predicted returns to the mouth. Tributary harvest rates and collection for brood stock, which are also used in this back-calculation, were obtained from ODFW population reconstruction tables.

One facet of this analysis is focussed on the effects of environmental conditions in the Columbia River during smolt outmigration, and environmental conditions in the ocean when smolts enter their ocean residency stage. We use a powerhouse contact rate derived from PIT tag data (PITPH) to predict in-river and ocean survival (Appendix J, McCann et al., 2015). The PITPH index uses the PIT tag detection rate and an estimated fish guidance efficiency to estimate the fraction of fish passing through the powerhouse (bypass and turbine routes combined). This is predicated on the fact that the actual number passing through the powerhouse is the number of bypass detections divided by the guidance efficiency. PITPH implicitly captures traditional spill and surface passage. The index is the sum of the fractions passing through the powerhouses of all projects combined. In this year's analysis, we use a PITPH index that incorporated additional PIT tag data at Ice Harbor. The PITPH index calculated in previous years was based on limited telemetry data, whereas the new PITPH index incorporates detections collected from 2005 to 2011, after the juvenile detection system was installed. When spill is low (less than 40%), the new method of calculating the index predicts lower powerhouse passage at Ice Harbor than the old method. This translates to powerhouse passage rates that are predicted to be up to 0.4 units lower with the new method, but only affecting years with spill less than 40%. The new index is predominantly lower by less than 0.4 units until the early 1990's, but the maximum deviation still only accounts for a 0.4 unit change in an aggregate index that is mostly in the 4-6 unit range.

We also used an index of water travel time (WTT) to predict in-river survival. WTT is

[1]https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:home:0

obtained by dividing the total volume of reservoirs by the flow rate, with adjustments in McNary pool to account for Columbia River versus Snake River flows (Tuomikosky et al., 2012). To predict the fraction of juveniles that are transported, we use an index (PTRANS) that was reported in the 2014 CSS annual report. For early ocean survival, we use the PDO in May, the upwelling index (UPW) in April, and additionally, we formulated a mechanism by which the ocean survival of in-river migrants is also affected by PITPH. The time series of environmental conditions is shown in Figure . The time series of environmental conditions is shown in Figure 2.1. PITPH appears to generally reflect the number of powerhouses in place and the proportion of total flow that has occurred as spill at each project over the time series. This time series encompasses a period of time when several changes took place in the hydrosystem. Fewer powerhouses were operational in the hydrosystem until the mid 1970's, so PITPH was lower. The transmission capabilities were limited prior to the construction of the DC and AC Intertie transmission lines, which resulted in a considerable amount of uncontrolled spill. As a consequence of this construction, the occurrence of uncontrolled spill declined. Full transportation as a mitigation measure was implemented for several years and no spill occurred at the transport projects. In addition, several planned spill programs were in place, including the Spill Memorandum of Agreement prior to the 1992 Biological Opinion. Subsequent increases in spill levels occurred through the series of Biological Opinions until the 2008 Biological Opinion. The most significant changes in spill came after 2005, when a court opinion granted the summer spill portion of the National Wildlife Federation's request for injunctive relief to provide spill to gas cap limits at Lower Granite, Little Goose, Lower Monumental, and McNary dams.

Juvenile data (Favrot 2012[2]) are available for four of the six populations in the MPG: Catherine Creek, the Grande Ronde River, the Lostine/Wallowa and the Minam river. Data are not available for each year for each population, but the range was between 1992 to 2009, and some missing years are excluded from model fitting procedures.

We use SAR and in-river survival rates S_R obtained from PIT tag data for migration years 1994 to 2012. Prior to 1992, SARs were obtained by dividing the returns to the mouth of the Columbia River by number of smolts at the upper dam (Petrosky and Schaller, 2010). For 1980 and prior migration years, data from Williams et al. (2001) were used for in-river survival rates. 1981-1984 in-river survival rates are from Marmorek and Peters (1998). We derived yearly variance estimates for SARs ($\sigma^2_{SAR,y}$) by assuming a normal distribution in bootstrapped estimates and using the 90% confidence numbers to calculate a variance based on the upper and lower 90% values being at the value of the bootstrapped SAR $\pm 1.645\sigma_{SAR,y}$. Yearly variance estimates $\sigma^2_{S_{R,y}}$ for in-river survival were derived the same way.

Methods

In previous life cycle model analyses, we statistically fit detailed population dynamics models that predicted smolt production, survival through the hydrosystem, and survival in the ocean. We estimated the parameters that best fit trends in abundance and survival. In this 2016 analysis we use the results of statistical fitting as the basis for predicting abundance trends under alternative potential changes to both tributary and mainstem survival. We use an Alternative

[2]https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=P128637

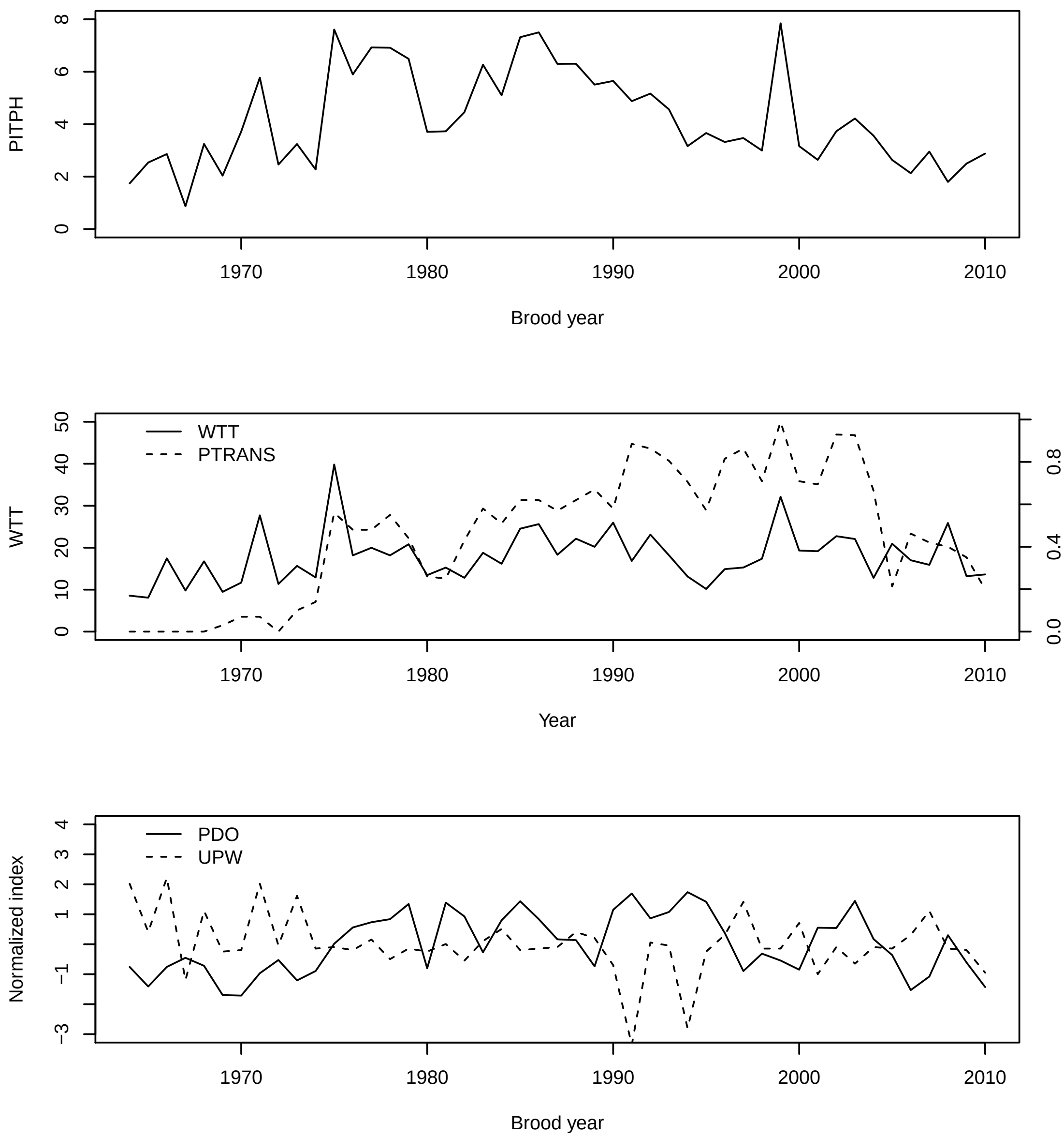


Figure 2.1: PITPH (upper panel) WTT and Transport (middle panel) and ocean environmental conditions (lower panel) used in model predictions.

Treatment Evaluation (ATE) that compares the potential relative benefit of a level of improvement to juvenile passage survival to a level of improvement in freshwater spawning and rearing productivity. The ATE method factors the uncertainty in parameter estimates into predictions, and therefore predicts the range of possible outcomes from each alternative treatment level.

Models

Typically, freshwater salmonid production is described in terms of spawners, eggs, fry, parr and smolts. Ricker (1954) and Beverton and Holt (1957) provided fundamentals useful in establishing spawner/recruit relationships. Both assume density dependence, and both are valid to describe survival between life history stages. The Beverton-Holt (BH) stock recruitment relationship is a somewhat more generic representation of density dependent survival, simply because it does not assume overcompensation, which is not realistic at every stage, nor even for spawner to smolt survival at low densities. We use a BH function to characterize survival between stages, though density dependence is only modeled at the smolt production stage, not in the mainstem, nor ocean stages.

Figure 2.2 shows the correlations between log of recruits per spawner for each population in the MPG. We see that recruits per spawner are correlated among populations, and nearly as correlated to the environmental indices, indicating that a large portion of the variability can be explained from the mainstem outward. The correlations should be expected to have some noise due to fluctuations caused by any density dependence in the tributaries, but correlation with the indices provides a basis for building a common relationship. At the very least, we know that populations spawn and rear as juveniles in distinctly different spatial areas, then migrate to the ocean using the same pathway. The potential effect of distinct migration timing is not considered. We predict freshwater smolt production of distinct populations and merge those populations together into a single migration unit, sharing common outmigration dynamics and a combined in-river/first year ocean survival, before maturing on a common maturation schedule and returning to spawn after 1, 2, or 3 winters in the ocean (see Figure 2.3). Migration through the mainstem explicitly distinguishes between transported and in-river juveniles migrating through the hydrosystem. This distinction is clearly formulated in the model description (Equations [2.9]-[2.11]), where it can be seen that each population has a transported and an in-river survival probability, and once the fish enter the ocean, the transported and in-river fish have different survival probabilities.

To estimate parameters, brood years 1964-2008 of observed spawners are used to predict age class returns from each brood year, and the predicted returns from observed data are compared to observed returns. The statistical estimation assumes that the age of returns are measured without error, and differences between observations and predictions are the result of errors in prediction, known as a process error model (Quinn and Deriso, 1999). We fit the model to empirical juvenile abundance data, adult abundance data, empirical in-river survival, and empirical SARs. We predict smolts from the combined natural and hatchery spawners on the spawning grounds, but the returning adults are compared to natural returns only, meaning that hatchery fish on the spawning ground contribute to production and their offspring are counted as natural production. We perform the model fitting using maximum likelihood estimation (MLE)

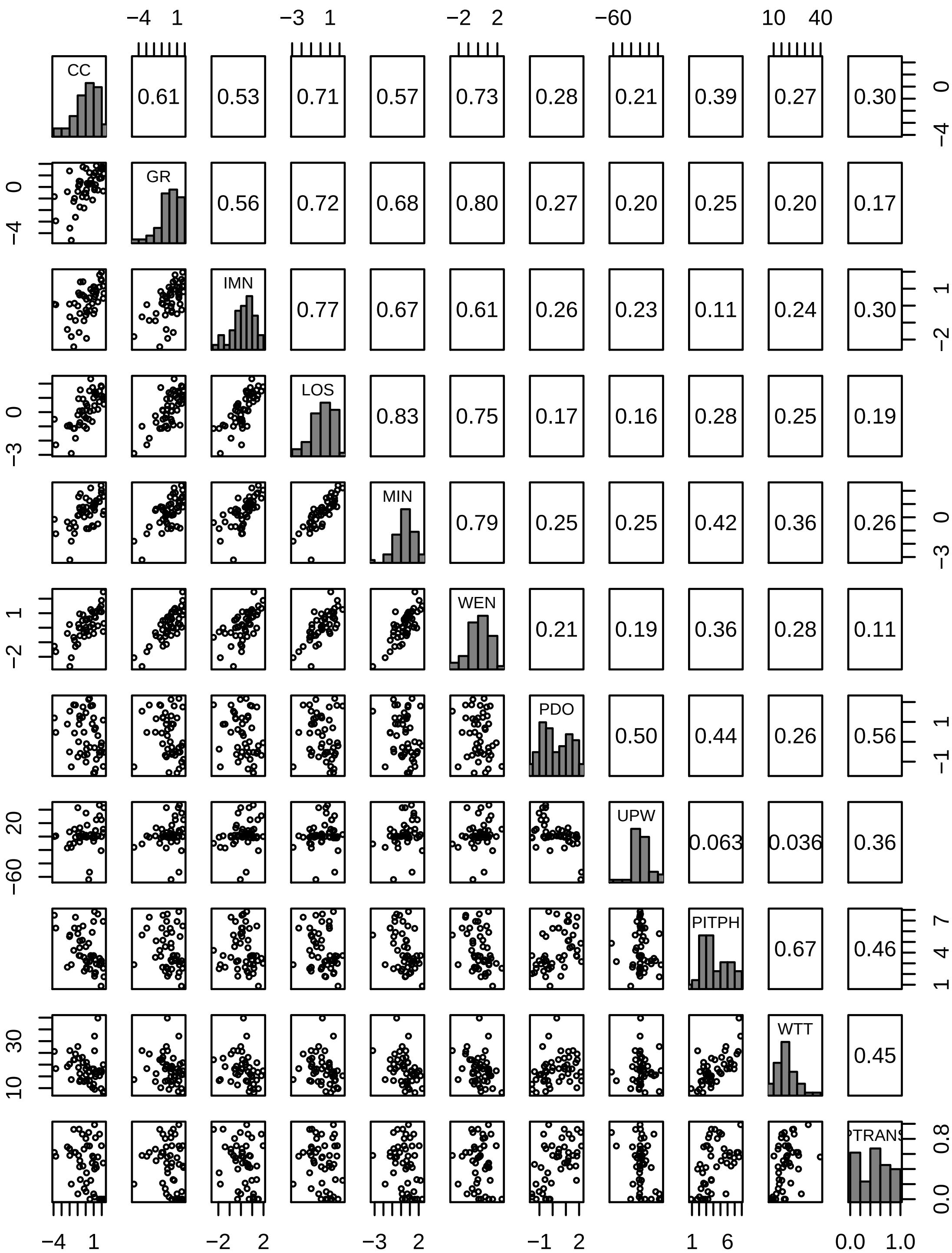


Figure 2.2: Correlation plots of log(R/S) of each population with PDO, UPW, PITPH, WTT, and PTRANS. Brood years 1964-2008 are included.

techniques, and we additionally explore the variability in the estimated rates using Markov Chain Monte Carlo simulations (a Bayesian technique).

Equations [2.1] - [2.8] describe the life cycle from spawners to adults for a single brood year. Upper case letters are state variables of predicted (indicated by ^) or observed life history stages. Lower case letters and Greek symbols are either estimated parameters, fixed parameters, or derived parameters. Table 2.1 describes each parameter and variable in the model, and whether it's estimated, fixed, derived, or predicted. Smolts in brood year t from population p are predicted from spawners as

$$\hat{M}_{p,t+2} = \frac{a_p S_{p,t}}{1 + a_p S_{p,t}/b_p} \qquad [2.1]$$

where a_p is the productivity for population p. Adults in the ocean following one winter in the ocean are predicted by the relationship

$$\hat{O}_{1,p,t+3} = \overbrace{\tau_{t+2} \underbrace{0.98}_{Barge} \underbrace{s_{T,t+2}}_{Ocean} \hat{M}_{p,t+2}}^{Transported} + \overbrace{(1-\tau_{t+2}) \underbrace{s_{R,t+2}}_{River} \underbrace{s_{H,t+2}}_{Ocean} \hat{M}_{p,t+2}}^{Inriver} \qquad [2.2]$$

where τ_t is the proportion of juveniles transported estimated from PIT tag data. Transported fish are assumed to have transportation survival probability of 98%. $s_{T,t}$ is the survival in year t of ocean entry from the tailrace of Bonneville dam for transported juveniles. $s_{R,t}$ is the in-river survival in year t of non-transported fish. $s_{H,t}$ is the survival in year t of ocean entry from the tailrace of Bonneville dam for in-river migrants. The number of 1-salt fish (three years old) that mature and migrate to spawn is given by

$$\hat{R}_{3,p,t+3} = m_1 \hat{O}_{1,p,t+3} \qquad [2.3]$$

where m_1 is the maturation rate of 1-salt fish. The predicted abundance of 2-salt fish after the second year in the ocean is

$$\hat{O}_{2,p,t+4} = s_2(1-m_1)\hat{O}_{1,p,t+3} \qquad [2.4]$$

where s_2 is the survival probability in the second year. The number of maturing 2-salt fish (four years old) that return to spawn is

$$\hat{R}_{4,p,t+4} = m_2 \hat{O}_{2,p,t+4} \qquad [2.5]$$

where m_2 is the maturation rate of 2-salt fish. The predicted abundance of 3-salt fish after the third year in the ocean is

$$\hat{O}_{3,p,t+5} = s_3(1-m_2)\hat{O}_{2,p,t+4} \qquad [2.6]$$

All fish are assumed to return after the third winter (five years old) in the ocean, i.e,

$$\hat{R}_{5,p,t+5} = \hat{O}_{3,p,t+5} \qquad [2.7]$$

The number of spawners is the sum of the run of each age class of fish not harvested, where there is a harvest rate $h_{p,t}$ for each population p and each year t.

$$\hat{S}_{p,t} = \hat{R}_{3,p,t}(1-h_{p,t+3}) + \hat{R}_{4,p,t}(1-h_{p,t+4}) + \hat{R}_{5,p,t}(1-h_{5,t+5}) \qquad [2.8]$$

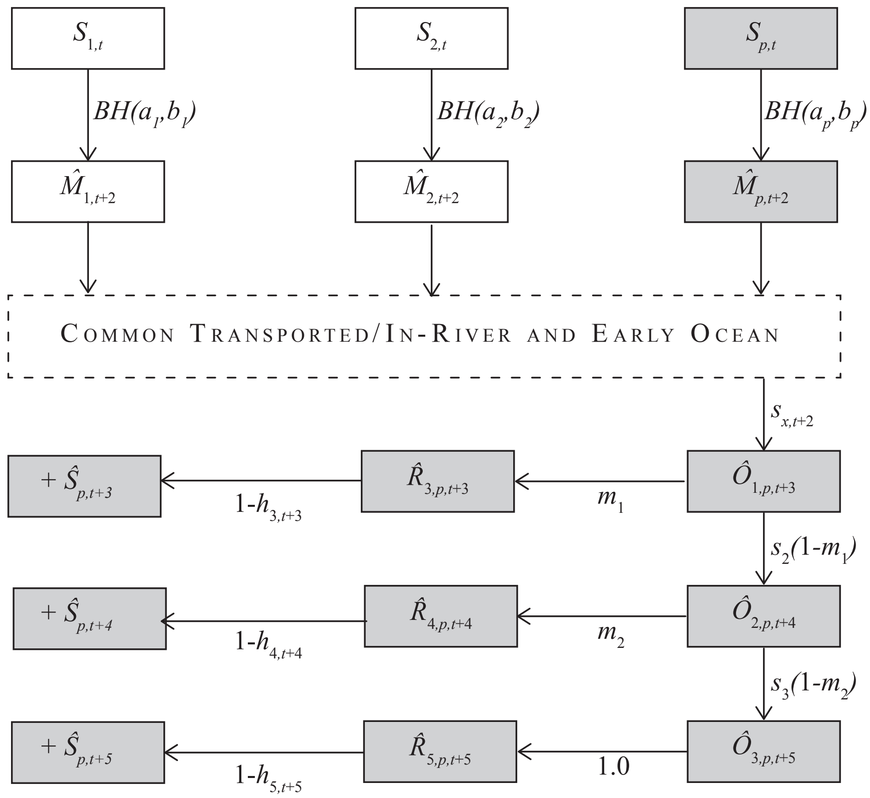


Figure 2.3: Diagram of the structure of the multiple population life cycle model. Shaded boxes indicate the trajectory of a single population. Before entering the common mainstem and early ocean phases, all parameters are unique to spawning populations. Afterwards, all populations share the same parameters. Spawners, smolts, ocean abundances, and returns are all indexed to brood year and population. Survival between the smolt stage and the end of the first year in the ocean ($\hat{S}_{x,t+2}$, where x denotes either transported (T) or in-river migrants (H)) is predicted differently for transported and in-river fish (Equations [2.9]-[2.11]). The + symbol before $\hat{S}_{p,t+a}$ indicates that unfished returns of age a are being added to the total number of spawners in year $t + a$.

Table 2.1: Description of variables and parameters used in Equations [2.1] to [2.12]. All variables are time-indexed to brood year t. Parameters and variables indexed by population p have dimension 6. Parameters estimated directly are indicated. Parameters derived from auxiliary data and estimated parameters indicate equation of origin.

Variable	Parameter	Description (year t, population p)	Value
$\hat{M}_{p,t+2}$		Brood year t Smolts	Equation [2.1][1]
$\hat{O}_{1,p,t+3}$		Brood year t first year ocean resident	Equation [2.2]
$\hat{R}_{3,p,t+3}$		Brood year t 1-salt returns	Equation [2.3][1]
$\hat{O}_{2,p,t+4}$		Brood year t second year ocean residents	Equation [2.4]
$\hat{R}_{4,p,t+4}$		Brood year t 2-salt returns	Equation [2.5][1]
$\hat{O}_{3,p,t+5}$		Brood year t third year ocean residents	Equation [2.6]
$\hat{R}_{5,p,t+5}$		Brood year t 3-salt returns	Equation [2.7][1]
$\bar{R}_{p,j,i}$		Mean recruitment for spill scenario j, MCMC iteration i	Calculated
$\hat{S}_{p,t}$		Brood year t spawners	Equation [2.8][1]
$S\hat{A}R_t$		Brood year t SAR	Equation [2.12][1]
	$h_{p,t}$	Harvest rate for population p year t	Derived[2]
	a_p	Spawner to smolt productivity for population p	Estimated
	b_p	Spawner to smolt capacity for population p	Estimated
	$s_{R,t}$	Survival of in-river migrants from LGR to BON	Equation [2.9]
	$s_{H,t}$	Early ocean survival of in-river migrants	Equation [2.10]
	$s_{T,t}$	Early ocean survival of transported fish	Equation [2.11]
	τ_t	Proportion of fish transported	CSS estimate[3]
	s_2	Survival through second ocean winter	0.6[4]
	s_3	Survival through third ocean winter	0.7[4]
	m_1	Maturation rate after first ocean winter	0.02[4]
	m_2	Maturation rate after second ocean winter	Estimated
	δ_R	$s_{R,t}$ In-river logistic intercept	Estimated
	δ_{PH}	$s_{R,t}$ In-river logistic PITPH coefficient	Estimated
	δ_{WTT}	$s_{R,t}$ In-river logistic WTT coefficient	Estimated
	γ_H	$s_{H,t}$ Early ocean logistic in-river intercept	Estimated
	γ_T	$s_{T,t}$ Early ocean logistic transport intercept	Estimated
	γ_{PDO}	$s_{1,t}$ Early ocean logistic PDO coefficient	Estimated
	γ_{UPW}	$s_{1,t}$ Early ocean logistic UPW coefficient	Estimated
	γ_{PH}	$s_{1,t}$ Early ocean logistic PITPH coefficient	Estimated

[1] Observed quantities (without ^) also represented for these variables.
[2] https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:home:0
[3] CSS 2013 annual report.
[4] Fixed value.

The model predicts three survival probabilities through the hydrosystem until the end of the first year in the ocean: 1. the in-river survival probability $S_{R,t}$, 2. the first year ocean survival probability of in-river migrating fish that are exposed to conditions in the hydrosystem $S_{H,t}$, and 3. the first year ocean survival probability of transported fish $S_{T,t}$. The predicted SAR is calculated from smolts and adult returns not harvested.

$$logit(s_{R,t}) = \delta_R + \delta_{PH} PITPH_t + \delta_{WTT} WTT_t \qquad [2.9]$$

$$logit(s_{H,t}) = \gamma_H + \gamma_{PDO} PDO_t + \gamma_{UPW} UPW_t + \gamma_{PH} PITPH_t \qquad [2.10]$$

$$logit(s_{T,t}) = \gamma_T + \gamma_{PDO} PDO_t + \gamma_{UPW} UPW_t \qquad [2.11]$$

$$SAR_t = \frac{\hat{R}_{3,p,t+3} + \hat{R}_{4,p,t+4} + \hat{R}_{5,p,t+5}}{\hat{M}_{p,t+2}} \qquad [2.12]$$

Survivals are linear in logit space, with intercepts δ_R, γ_H, and γ_T. $\delta_{PH,WTT}$ and $\gamma_{PH,PDO,UPW}$ are slope coefficients that predict the magnitude of influence of environmental factors. PITPH is implemented in such a way as to allow the parameter estimation to predict if it is significant in both in-river and early ocean survivals. The logit transform is used here because it allows the search algorithm in the statistical fitting procedure to choose values of the δs and γs in the range $(-\infty, \infty)$ without causing the survival estimate to leave the range (0,1).

Model fitting

Parameters are estimated by comparing the predicted to observed smolt and adult abundances, as well as comparing predicted to observed in-river survival and overall SARs. The abundance comparisons include comparing the total returning adult fish of each age $R_{a,t}$ to the returns of each age in the NMFS population summary data, and comparing the predicted smolts to observed smolts. The returns at age for each year in the NMFS data are obtained by adding the spawners of a given age to the catch and hatchery broodstock collection, if any. The parameter estimates are obtained by minimizing the negative log-likelihoods of the following Equations:

$$\mathscr{L}_{R_{p,a}}\left(R_{a,t}|\Theta_p\right) = \prod_{t=1}^{n} \frac{1}{\sigma_{R_{p,a}}\sqrt{2\pi}} \exp\left[-\frac{\left(log(R_{p,a,t}) - log(\hat{R}_{p,a,t})\right)^2}{2\sigma^2_{R_{p,a}}}\right] \qquad [2.13]$$

where Θ_p is the set of parameters a_p and b_p for p=1...6, m_1, and m_2, and also the δs and γs that predict survivals in Equations [2.9]-[2.11]. $\sigma^2_{R_{p,a}}$ is the process error variance of the prediction of returning spawners at age. The likelihood term for smolts (Equation [2.14]) uses the same form, but uses observed and predicted juvenile numbers for the populations that had juvenile surveys and is given by

$$\mathscr{L}_{M_p}\left(M_{p,t}|\Theta_p\right) = \prod_{t=1}^{n} \frac{1}{\sigma_{M_p}\sqrt{2\pi}} \exp\left[-\frac{\left(log(M_{p,t}) - log(\hat{M}_{p,t})\right)^2}{2\sigma^2_{M_p}}\right] \qquad [2.14]$$

We treat the prediction of the returns at age and smolt data as having unknown σ^2_R and we

minimize the negative log-likelihood while substituting the maximum likelihood estimate for σ^2_R into the likelihood equations. The substitution of this nuisance parameter with its MLE reduces the number of parameters that need to be estimated. This is done for both process and observation error assumptions. The MLE for $\hat{\sigma}^2_R$ is given by

$$\hat{\sigma}^2_{R_{p,a}} = \sum_t \frac{(log(R_{a,p,t}) - log(\hat{R}_{a,p,t}))^2}{n} \quad [2.15]$$

The same assumption was made for juvenile data, so $\hat{\sigma}^2_{M_p}$ is estimated using a similar substitution. The empirical in-river survival probability estimates (S_R) and the SAR are also included in likelihoods. The in-river survival likelihood is given by

$$\mathscr{L}_{s_R}\left(s_{R,t}|\Theta_R\right) = \prod_{t=1}^{T_R} \frac{1}{\sigma_{s_{R,t}}\sqrt{2\pi}} \exp\left[-\frac{(log(s_{R,t}) - log(\hat{s}_{R,t}))^2}{2\sigma^2_{s_{R,t}}}\right] \quad [2.16]$$

where the $\sigma_{s_{R,t}}$ come from the CSS 2013 annual report, and result in an inverse variance weighting of the in-river survival estimates for this likelihood term. The likelihood for the SAR is given by

$$\mathscr{L}_{SAR}\left(SAR_t|\Theta_{SAR}\right) = \prod_{t=1}^{T_{SAR}} \frac{1}{\sigma_{SAR}\sqrt{2\pi}} \exp\left[-\frac{\left(log(SAR_t) - log(S\hat{A}R_t)\right)^2}{2\sigma^2_{SAR}}\right] \quad [2.17]$$

where σ_{SAR} is treated the same way as in the abundance likelihoods, with the estimate of the standard deviation being substituted into the likelihood.

The likelihoods and the life cycle model were coded and implemented using the AD Model Builder optimization software (ADMB, free to download at www.admb-project.org). The package is designed for large scale non-linear optimization problems and is commonly used in fisheries stock assessments. We find the best fit to the data by minimizing the sum of all the negative logarithms of the likelihoods, which is equivalent to maximizing the product of the likelihoods. Rather than report the values of the maximum likelihood parameter estimates, we report the range of variability in parameter estimates by performing Markov Chain Monte Carlo (MCMC) simulations using a Metropolis Hastings algorithm native to the ADMB package. The MCMC simulations produce samples of the posterior probability densities of each parameter. We simulated a chain of 1,000,000 samples after a burn-in period of 100,000 samples. We assumed an uninformative prior distribution for each parameter, so the limits of the range of the sampling distributions are bounded, but the shape of the distribution is predicted by the data. Sampling from the chain of parameter estimates obtained from the MCMC simulations, we produced frequency histograms that show the shapes of the distributions of parameter estimates. Whereas the maximum likelihood estimation provides estimates of each parameter at the mode, and an estimate of the variance in each parameter evaluated near the mode, the posterior densities reflect the frequency with which given parameter values are chosen at random and found to explain the data better than alternative random choices (the essence of MCMC simulation). We present the posterior distributions in lieu of point estimates because this provides a better sense of how well

the model was able to fit all abundance and survival data sources, and gives us a relative sense of how well the data might have been explained by parameter values higher and lower than the most probable combination of parameters.

Prospective simulation

Parameters determine survival rates in relation to environmental conditions, as well as how recruitment differs among populations because of estimated productivities and capacities. We can use estimated parameter values to simulate projected future population trends by initializing the model with recent spawning abundances. Once the model predicts the adult returns, it can propagate population trends multiple generations into the future without the need for additional empirical spawning abundances. We can use the projected population trends as the basis for evaluating the relative benefits of alternative spill scenarios. Further, we can project the population trend response to these spill scenarios across ranges of potential changes to freshwater habitat conditions, and therefore the effect habitat restoration could have on freshwater productivity and capacity. Further still, by looking at the predicted response across ranges of variability in parameter estimates, we can examine the variability in the population trend response to spill and habitat restoration.

We use the life cycle model to predict the long-term effects of four experimental spill alternatives on population recovery. The experimental spill levels are defined in terms of the limits of total dissolved gas (TDG) produced at each project.

BiOp Maintain spill levels according to the regulations consistent with the current Biological Opinion.

115%/120% Increase spill up to limits of 120% TDG in the tailraces and 115% TDG in the forebay.

120% Increase spill up to a limit of 120% TDG in tailraces and forebays.

125% Increase spill up to a limit of 125% TDG in tailraces and forebays.

The actual spill percentage or volume to produce specified TDG levels depends on flows at each project (Appendix J, McCann et al., 2015). Since the goal of evaluating different spill scenarios is to evaluate the effect of spill on PITPH, each experimental level is evaluated at three flow levels (high, average, and low flow), which produces a total of twelve spill scenarios. Each scenario predicts a different value of PITPH, which was evaluated with spill caps applied to the hourly flow data at all eight projects from April 1 through August 31. We used flow levels from specific years as surrogates for high, average, and low years. We used 2011 to represent a typical high flow year, 2009 to represent an average year, and 2010 to represent a low flow year. These three years represent a range of flow conditions relative to the historic data (1929 to 2012). The three years also represent operations that reflect the most recent configuration and operation of the FCRPS. While 2010 was not a low flow year when the whole spring and summer period is considered, the flows that took place during the spring period being modeled were considerably less than other years. We also used historical water transit times from 2011, 2009, and 2010 for the high, average, and low flow scenarios. The resulting values are in Table 2.2. Since the future projections lack the historical record of environmental conditions that existed during the statistical model fitting, time series of environmental variables need to be provided as model inputs. These

Table 2.2: PITPH and WTT values used for each spill and flow level.

Scenario	Spill level	Flow[1]	PITPH	WTT (days)
1	BIOP	High	2.99	13
2	BIOP	Average	3.06	16
3	BIOP	Low	1.95	26
4	115%/120%	High	2.37	13
5	115%/120%	Average	2.16	16
6	115%/120%	Low	0.87	26
7	120%	High	2.12	13
8	120%	Average	1.88	16
9	120%	Low	0.80	26
10	125%	High	1.01	13
11	125%	Average	0.44	16
12	125%	Low	0.28	26

[1] Flow were assumed to correspond to observed years
High=2011, Average=2009, Low=2010

inputs include: a powerhouse passage index, water travel time, PDO, upwelling, harvest rates, proportion transported, and conversion rates. Transport was set at 20% for all future years to reflect the declining rate of transport in recent years. The rest of the variables are described below.

PITPH The prospective simulations use powerhouse passage index values predicted for each of the twelve spill scenarios. PITPH values were produced using an estimate obtained from a statistical fitting of passage rates at known spill levels and known flow levels. Historical passage rates derived from PIT tag data were compared to flow and spill data to estimate the effectiveness of spill levels across a range of flow levels for each project. The cumulative powerhouse passage rate was obtained by summing the project rates. A powerhouse passage index specific to a combination of spill alternatives and flows was used for all future years, e.g., a BiOp spill at low flow would yield a value of PITPH, which would be assumed every year into the future. The methods to obtain these values are discussed in Appendix J of the CSS 2015 Annual Report.

WTT We used the water transit times from 2011, 2009, and 2010 to represent WTT in high flow, average flow, and low flow.

PDO The Pacific Decadal Oscillation is a statistical calculation of oceanographic conditions that does not have a mechanism for prospective prediction, but the historical record can be described as a temporally autocorrelated time series. In order to simulate future population trends in relation to the PDO effect that was estimate in the statistical fitting, something other than an average value needs to be used, otherwise none of the inter-annual variability in its effect on ocean survival will be simulated. To produce a "PDO-like" time series we note that the PDO is normalized and roughly generates decadal cycles, but the predominant factor relevant to producing simulated future time series is that it vary from year to year,

reach similar peaks and valleys to a historical record, and sustain increases and decreases predominantly for about 5 years before reversing direction. Ultimately, a simulated PDO need only produce a cyclical trend similar in frequency and magnitude to the PDO. We generate PDO time series by creating a time series of random draws from a normal distribution $\epsilon_t \sim N(0, 1)$. We then generate an AR(1) autocorrelation sequence, setting $\text{PDO}_1 = \epsilon_1$, and $\text{PDO}_t = 0.5\text{PDO}_{t-1} + 0.7\epsilon_t$ for $t \in (2, n)$. We then normalized the simulated PDO index to ensure the range of values was on the same scale as the empirical PDO.

UPW The upwelling index has no cyclical trend, nor is it correlated with the PDO, nor does it have a discernible temporal trend. To generate a future time series, we simply sampled the historical time series at random.

Harvest Historical harvest rates of Snake River Spring Chinook have varied from as high as 70% in the late 1960's to under 10% in recent years. Those ranges of total exploitation rates are a combination of sequential harvests in commercial and sport sectors in the lower Columbia, Zone 6 harvest, tributary harvests, and brood stock removal. Regulations at current return abundances call for lower river and Zone 6 rates not to exceed 17%. Since we are simulating population recovery potential, return abundances can be expected to increase if management scenarios are effective. We therefore modeled harvest rates to increase as return abundances increase. We modeled the harvest rate to increase asymptotically to 40%, and to reach 20% at an aggregate run abundance of 5000 for all populations.

Conversion Rate Conversion rates represent adult losses net of harvest, e.g., a conversion rate of 0.5 means that 2 adults would need to return to the mouth of the Columbia so that 1 adult could make it to the spawning ground. Those losses represent all factors not related to harvest, including predation loss, pre-spawn mortality, adult passage related mortality, and other causes. In recent years, conversion rates have been fairly high, and historically they were comparatively low because less passage infrastructure was in place. In an attempt to capture the variability, but contain the rate in the range of values of recent years where passage infrastructure is more representative of future conversion rates, we drew values at random from the most recent 20 years of conversions rates, which produced simulated future time series of conversion rates in the range of 60% to nearly 100%.

Each prospective simulation draws upon several things: 1. the underlying parameters that predict survival in relation to environmental conditions, 2. the projected environmental conditions, and 3. the alterations to underlying conditions that make up the basis for an alternative management scenario. In the hydrosystem, those are the four spill alternatives evaluated at three flow levels. In freshwater, the alterations are presumed levels of productivity or capacity that could be achieved via habitat improvements. Prospective simulations can capture all combinations of these alterations to the full life cycle, and represent the predicted outcomes in terms of the predicted uncertainty that arises from the underlying uncertainty in parameter estimates.

Alternative Treatment Evaluation

The MCMC simulations build a sequence of vectors of parameter values by generating values at random, and accepting or rejecting randomly generated vectors in proportion to the

relative likelihoods of predicting empirical data. The sequence building proposes a potential improvement to the fit with a randomly generate alternative parameter vector. The proposed new vector is accepted or rejected based on relative likelihoods. Eventually, a sequence of a desired number of samples is produced, which contains many combinations of parameters. The more likely combinations appear in the chain more frequently than the less likely ones, so if we draw randomly from the posterior chain thousands of times, we tend to draw the more likely ones more often. With each draw, we can produce a simulated population trend that is different from another draw. We can simulate thousands of different population predictions, and the predictions themselves take on distributions. As a result, we can simulate a population trend where the conditions can be the same as historical conditions, i.e., same environmental and anthropogenic conditions, or we can simulate a trend where we manipulate key underlying aspects of the system to mimic a scenario or question of interest. The result of simulating contrasting scenarios provides a sense of how much change to overall system behavior can be expected from relative changes to underlying conditions. Those can either be natural biotic (change in food or competitors), natural abiotic (changes to climate and the environment), or anthropogenic (changes in exploitation or hydrosystem operations).

We used the posterior densities as a basis for simulating ranges of possible population trends when alternative spill levels are assumed under the three flow levels. The Alternative Treatment Evaluation (ATE) uses a 10,000 samples of parameter values drawn from the MCMC posterior chain to simulate future population trends until 2050. It initializes population projections with empirical spawners from 2010-2014 and parameters from a posterior sample, and uses simulated conditions in future years (PITPH, WTT, PDO, UPW, TRANS, commercial and Zone 6 harvest, and upstream migration survival) to predict subsequent spawners of each age in years 2015-2050. Predicted returning spawners in each year after the first complete brood year returns in 2015 are used to predict successive generations, meaning the model spawns new generations from predicted returns and does not require empirical spawners past 2014.

For our ATE analysis, we posed two questions: 1. What is the potential for changes to spawning and rearing productivity to increase long-term adult return abundance?, and 2. What is the potential for changes to hydrosystem operations to increase average long-term adult return abundance and SARs? To address these questions, we simulated prospective population trends and looked at average long-term return abundances and SARs. We simulated population trends 10,000 times by drawing parameter values randomly from the posterior chain saved from the MCMC simulations. 10,000 simulated population trends were produced for each of the twelve spill scenarios, which produces 10,000 population trends for each population, and therefore an average return abundance for each of the six population for each of the twelve scenarios. Comparing relative return abundance averages provides an indication of the relative benefits of the spill scenarios to each of the populations. We simulated for 35 years and used the last 10 years of complete brood returns to evaluate performance. We report averages over the period 2036 to 2045.

We also examined the potential for the relative benefits of spill scenarios to differ among populations. To examine the effect of different spill levels, we simulated average long-term abundances and calculated the average recruitment abundance and SARs from each population . We used the following logic:

1. Start with scenario $j = 1$
2. Get PITPH$_j$ and WTT$_j$ for scenario j from Table 2.2
3. Set PITPH$_t$ = PITPH$_j$ for all years t
4. Set WTT$_t$ = WTT$_j$ for all years t
5. Draw a set of parameters Θ_i from the posterior chain
6. Simulate population trends from initial spawning abundances and calculate $\bar{R}_{p,j,i}$ for each population p, where $\bar{R}_{p,j,i}$ is the average recruitment to the spawning ground indexed by brood year, and averaged over the last ten years simulated.
7. Calculate $S\bar{A}R_{p,j,i}$ for each population p, where $S\bar{A}R_{p,j,i}$ is the average SAR in the last ten years simulated.
8. Return to step 5 until i = 10,000 draws of Θ_i
9. Return to step 1 and set j = j + 1 until the 12^{th} scenario
10. Use the 6 x 12 x 10,000 $\bar{R}_{p,j,i}$ and $S\bar{A}R_{p,j,i}$ arrays to show the quantile ranges of predicted average abundance and SARs from 2036 to 2045 for each population p of each spill scenario j.

To examine the potential effect of changes in productivity, we simulated $\bar{R}_{p,j,i}$ at four different spill levels across a productivity range of 50-250 smolts per spawner. Simulations were evaluated at average flow conditions only. Similar predictions at high or low flows would be relative to $\bar{R}_{p,j,i}$s evaluated at the MLE of productivity (i.e., $\bar{R}_{p,j,i}$ would be higher for low flows and lower for high flows). We stepped through the following procedure:

1. Get PITPH$_j$ and WTT$_j$ for scenario j = 2 from Table 2.2
2. Set PITPH$_t$ = PITPH$_j$ for all years t
3. Set WTT$_t$ = WTT$_j$ for all years t
4. Set a_p = 50 for each of the 6 population productivities and replace the value drawn from the chain with a_p.
5. Draw a set of parameters Θ_i from the posterior chain.
6. Simulate population trends from initial spawning abundances and calculate $\bar{R}_{p,j,i}$ for each population p, where $\bar{R}_{p,j,i}$ is the average recruitment to the spawning ground indexed by brood year, and averaged over the last ten years simulated, where i is the iteration, and j is the level of a_p.
7. Go back to step 5 and repeat for 10,000 draws of Θ_i.
8. Go back to step 4 using a_p+10 until all 21 values the range $a_p \in$ [50-250] have been simulated.
9. Return to step 1 and set j equal to scenarios 5, 8, and 11
10. Use the 6 x 21 x 10,000 $\bar{R}_{p,j,i}$ array to show the quantile range of predicted average abundance from 2036 to 2045 for each population p of each level j.

To examine the potential effect of changes in capacity, we used a capacity range of 5000-50000 smolts, and simulated $\bar{R}_{p,j,i}$ at four different spill levels evaluated at average flow conditions. We stepped through the following procedure:

1. Get PITPH$_j$ and WTT$_j$ for scenario j = 2 from Table 2.2
2. Set PITPH$_t$ = PITPH$_j$ for all years t

3. Set WTT_t = WTT_j for all years t
4. Set b_p = 5000 for each of the 6 population productivities and replace the value drawn from the chain with b_p.
5. Draw a set of parameters Θ_i from the posterior chain.
6. Simulate population trends from initial spawning abundances and calculate $\bar{R}_{p,j,i}$ for each population p, where $\bar{R}_{p,j,i}$ is the average recruitment to the spawning ground indexed by brood year, and averaged over the last ten years simulated, where i is the iteration, and j is the level of a_p.
7. Go back to step 5 using b_p+5000 until all 10 values the range $b_p \in$ [5000-50000] have been simulated.
8. Go back to step 4 and repeat for 10,000 draws of Θ_i.
9. Return to step 1 and set j equal to scenarios 5, 8, and 11
10. Use the 6 x 21 x 10,000 $\bar{R}_{p,j,i}$ array to show the quantile range of predicted average abundance from 2036 to 2045 for each population p of each level j.

Results

We fit the model to juvenile abundance data, adult abundance data, and in-river survival and SARs using likelihood Equations [2.13]-[2.17]. We examined every possible model combination of including or excluding PITPH and WTT for predicting S_R with PITPH and WTT, and for predicting S_H and S_T with PDO, UPW, and PITPH (only S_H). Using AIC values to evaluate the top fitting model, the best fit occurred when PITPH and WTT were both included in the prediction of S_R, when PDO, UPW, and PITPH were included in the prediction of S_H, and when PDO and UPW were included in the prediction of S_T. This implies that the overall SAR has an in-river survival component that is affected by PITPH as well as an ocean survival that is affected by PITPH, i.e., hydrosystem effects predict variability in early ocean survival (a.k.a: delayed mortality). The top model was greater than 4 AIC units better fitting than the second best model, and was used as the basis for doing MCMC simulations and performing the ATE analysis.

Rather than present the point estimates of each variable, we present the posterior distributions from samples of the MCMC chain (see Figure 2.4). The histograms show the relative frequency of parameter values when 1,000 samples are drawn at random from an MCMC simulation chain of one million estimates after a burn-in of one hundred thousand samples. Means and standard deviations are shown above each histogram. The MCMC plots illustrate the relative certainty in parameter estimates. The narrower the range of predicted values, the more informative the data were to explaining that parameter. In general, parameter estimation was bounded to restrict the search algorithm to look within biologically plausible ranges. In the case of productivity parameters like the Imnaha and Minam productivities, the estimates indicate that productivities might be higher than the allowed range, but the productivity was bounded to search between about 20 and 1000 smolts per spawner (actually, between 3 and 7 in log-space), which should be broad enough to fit any spawner to smolt relationship (approximately 0.4-40% egg to smolt survival). Possible explanations for this are under reported spawners, strong hatchery influence on spawning grounds, or over reported smolt abundance, all of which would elevate apparent smolts per spawner.

Figure 2.5 shows the correlations between environmental indices and predicted survival.

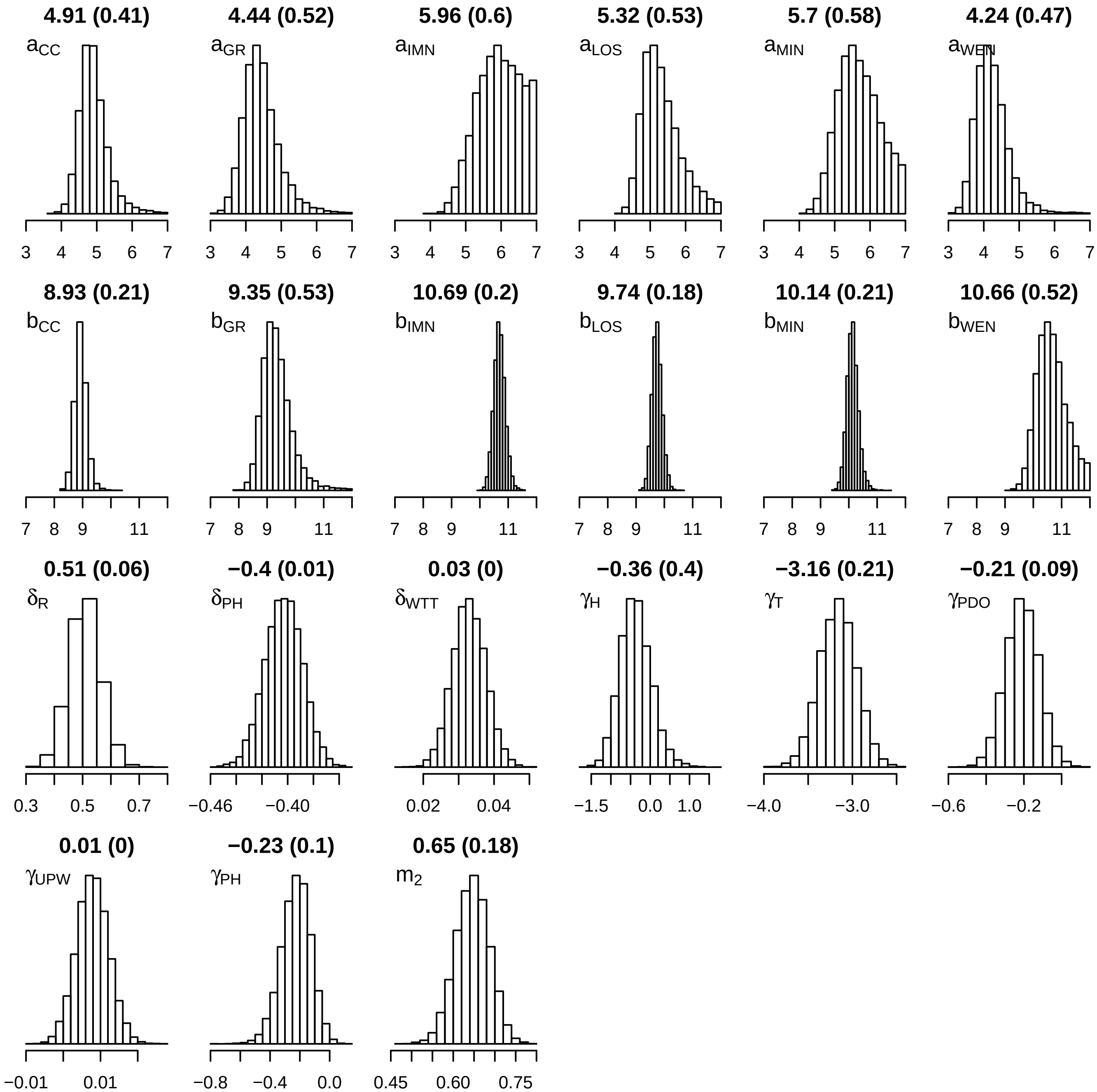


Figure 2.4: Posterior estimates of the model parameters for the model. Each histogram shows frequency of samples from parameter values coming from a Markov chain of length 1,000,000, sampled 10,000 times. Estimated means (and standard deviations) for each posterior sample appear at the top of each histogram. The top row contains the log productivities for CC, GR, IMN, LOS, MIN and WEN respectively. The second row contains log capacities for the same populations. The remaining posterior panels are labeled with corresponding symbols.

We see that the predicted $s_{R,t}$ is most related to PITPH (a negative relationship). There are strong correlations between PITPH and both $s_{R,t}$ and $s_{H,t}$. $s_{T,t}$ shows a very strong correlation with PDO and also with UPW – stronger than the correlation between $s_{H,t}$ and UPW.

By separating hydro passage into transported and in-river migrants, we were able to further examine the effect of transportation. Predicted $S_{H,t}$ and $S_{T,t}$ are shown in Figure 2.6, and $S_{T,t}$ is consistently predicted to be lower than $S_{H,t}$. The predicted survival of in-river migrants are shown along with empirical data as well. The predicted SAR in Figure 2.6 is higher than the empirical SAR derived from the aggregate of the Snake River PIT tag data, possibly indicating that the Grande Ronde / Imnaha populations survive better than the Snake aggregate, but alternatively, this could be compensation for the fact that the predicted in-river survival is lower than the empirical trend in recent years. Figure 2.5 indicates that lower early ocean survival of transported fish may be attributable to the PDO, which is seen to have a higher correlation with $S_{T,t}$ than with $S_{H,t}$. The upwelling index is also only somewhat correlated with $S_{T,t}$, not with $S_{H,t}$. These two correlations suggest that transported fish are more sensitive to ocean conditions than in-river migrants, but the in-river migrants are modeled to be sensitive to PITPH, whereas transported fish are only modeled to be sensitive to PDO and UPW.

The model fitting results are shown in Figures 2.7 and 2.8. Since all populations are forced to follow the same mainstem and ocean dynamics, yet do not experience the same FSR dynamics, we do not expect that all models fit their respective abundance data in the same way. CC and GR predicted recruits are negatively biased in the first half of of the time series. The remaining populations do not appear to have the same negative temporal bias in the same early time period, and overall the IMN, LOS, MIN, and WEN predicted population trends are consistent with empirical observations, i.e., a declining trend from the late 1960's until around 1990, then an increase. The smolts per spawner fit (Figure 2.8) shows density dependence in all four populations for which smolt data were available.

Figure 2.9 shows the relative performance of the twelve spill scenarios across all six populations. The three assumed flow levels are represented in clusters of three (high, average, and low flow) in each four of the BiOp, 115%/120%, 120%, and 125% spill levels. The general pattern is that increasing the spill level produces an increase in the total average number of returning spawners, but within each spill level, the low flow scenario produces more returns than the high and average flow conditions. This is a product of the fact that the spill is more effective at lower flow, i.e., when spilling to the same TDG target, a smaller fraction of fish will go through the powerhouse in low flow years because of increased spill efficiency. The shaded boxes represent the 25% to 50% quartiles of average adult return abundances ($\bar{R}$) from a sample of 10,000 simulations drawing parameters from the joint posterior distribution of parameters. The whiskers extend the range to the outer 10% and 90%. Variation in simulated outcomes comes from the variability in parameter estimates, as well as the variability in the simulated PDO. The Upper Grande Ronde and Wenaha show the most variability in $\bar{R}$, likely owing to the fact that the combined uncertainty in productivity and capacity yielded more uncertainty in simulated outcomes.

Figure 2.10 shows the predicted average SARs for all six populations to LGR. The average SARs are not adjusted for harvest, meaning that the rate assumes adult returns to LGR after harvest and adult interdam losses. The SARs reflect the simulated harvest where the harvest rate

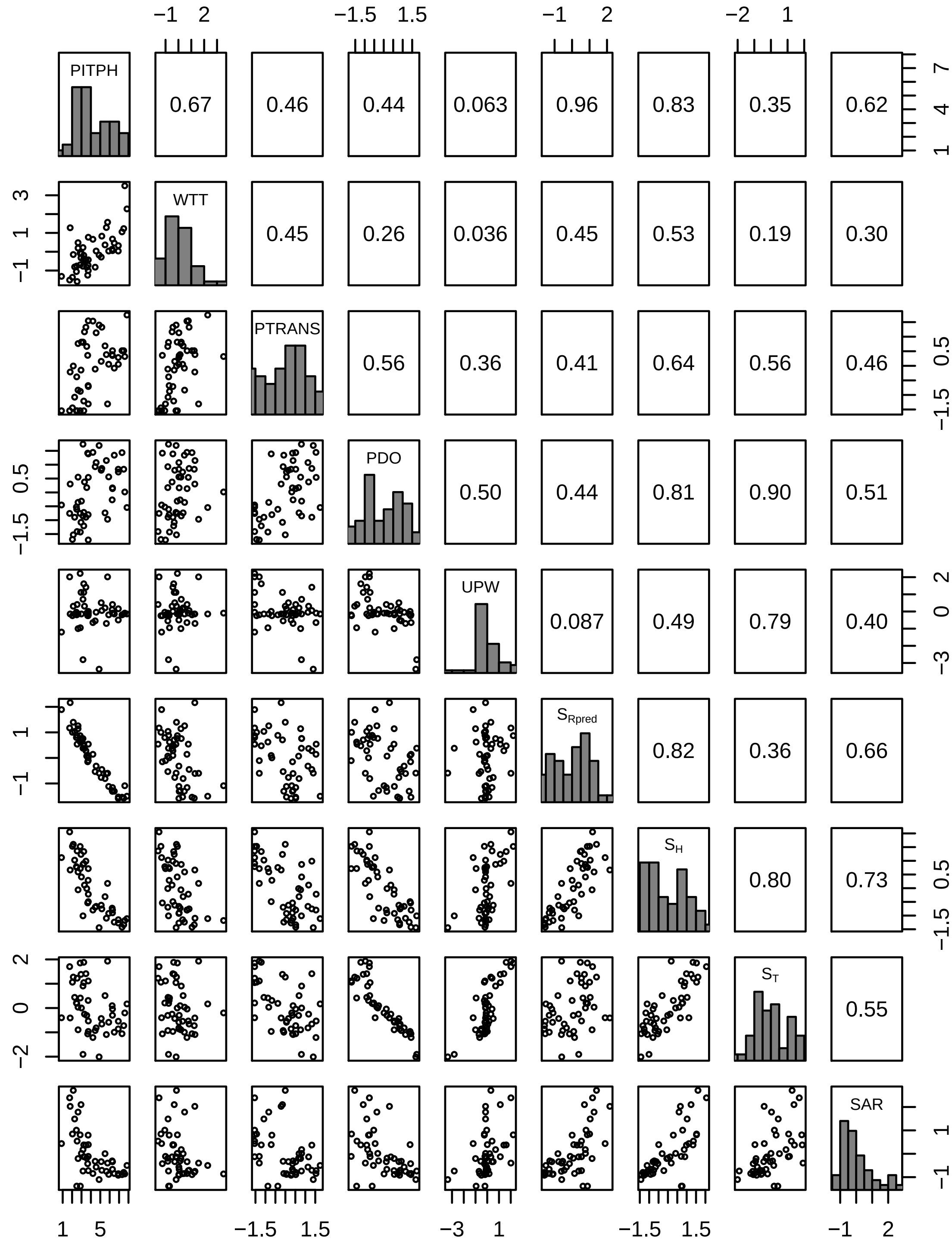
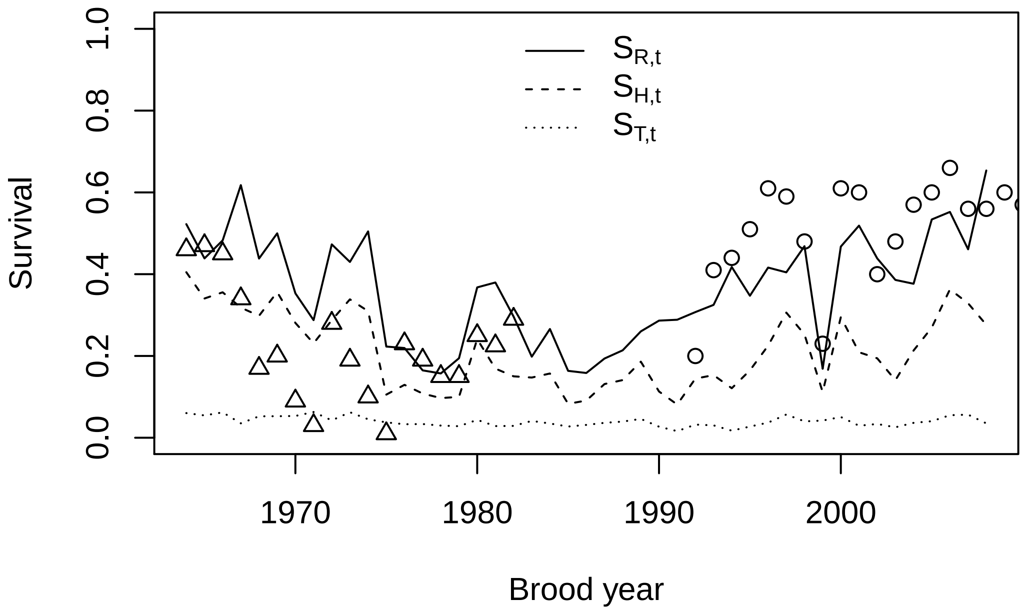


Figure 2.5: Correlations between estimated in-river, transported, and early ocean survival, and environmental indices. The lower diagonal shows the scatter plots between variables. The upper diagonal shows the correlation coefficients.



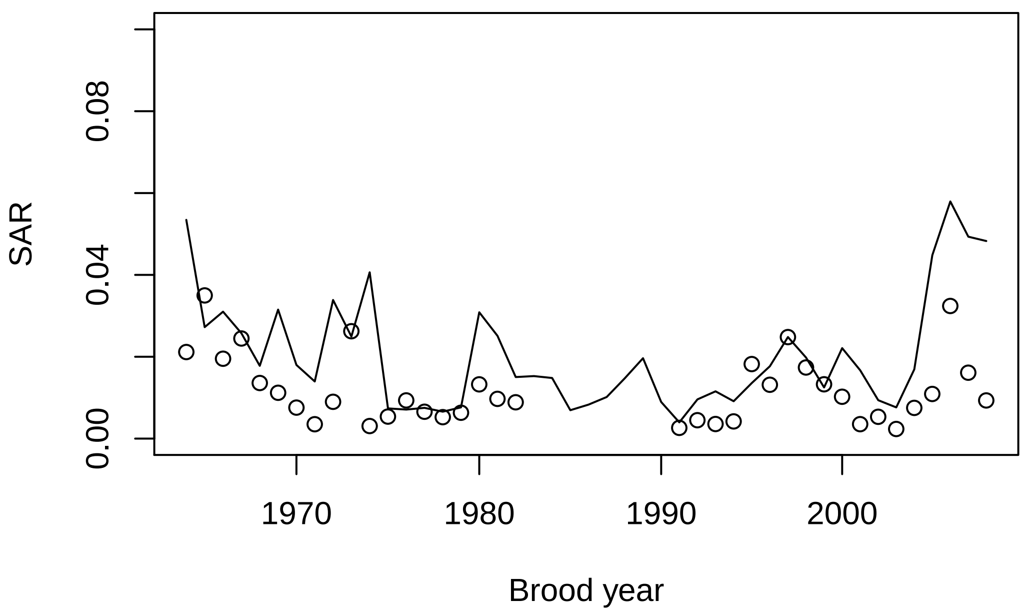


Figure 2.6: Upper panel shows observed in-river survival (circles) and predicted in-river survival S_R, early ocean survival for in-river S_H migrants, and early ocean survival for transported fish S_T. Circles show the PIT tag derived estimates of in-river survival. Triangles show the pre 1985 migration year in-river survival rates from Williams et al. (2001) and Marmorek and Peters (1998). Lower panel shows observed (circles) and predicted SAR (line).

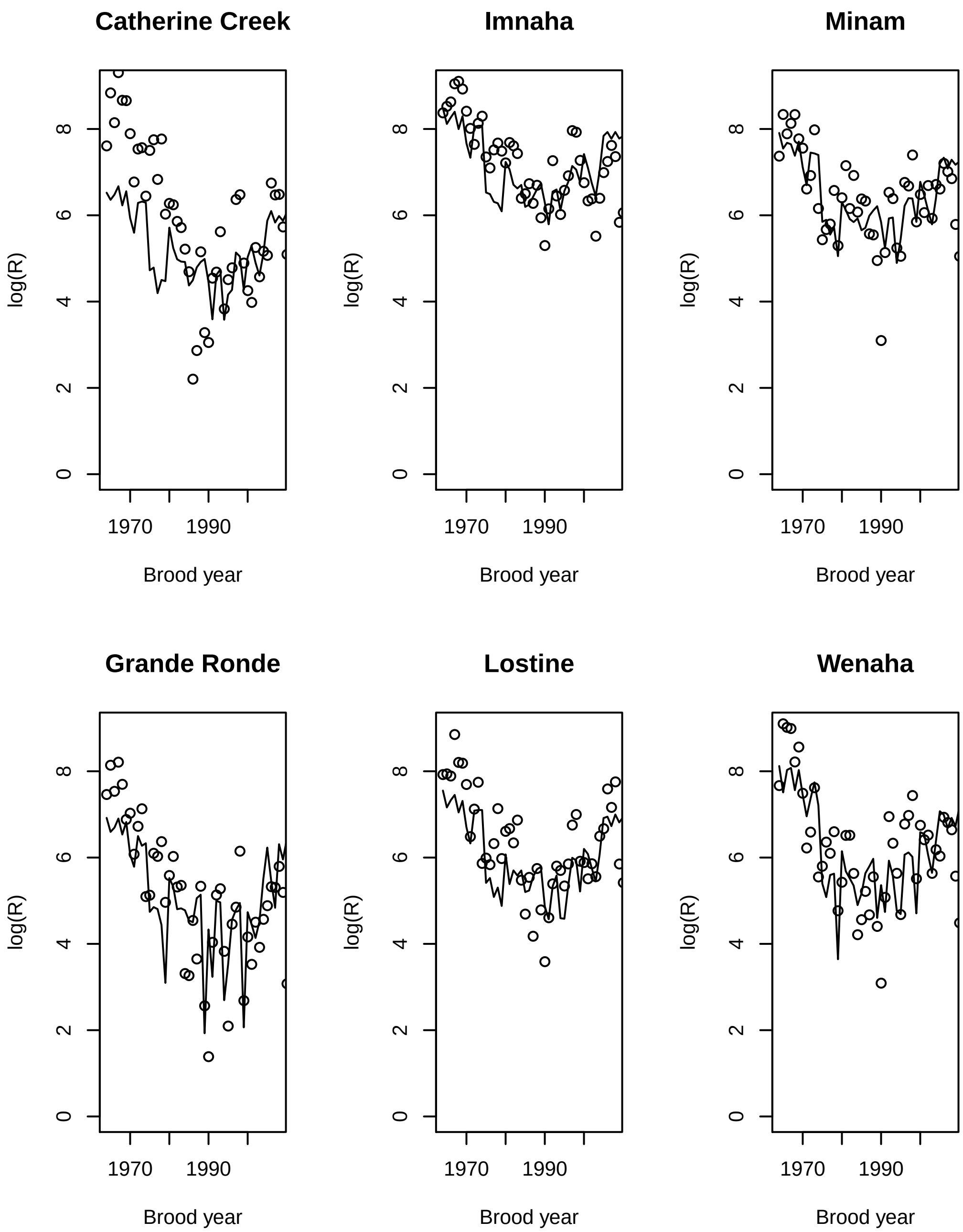


Figure 2.7: Observed (circles) and the predicted (line) recruits for each brood year.

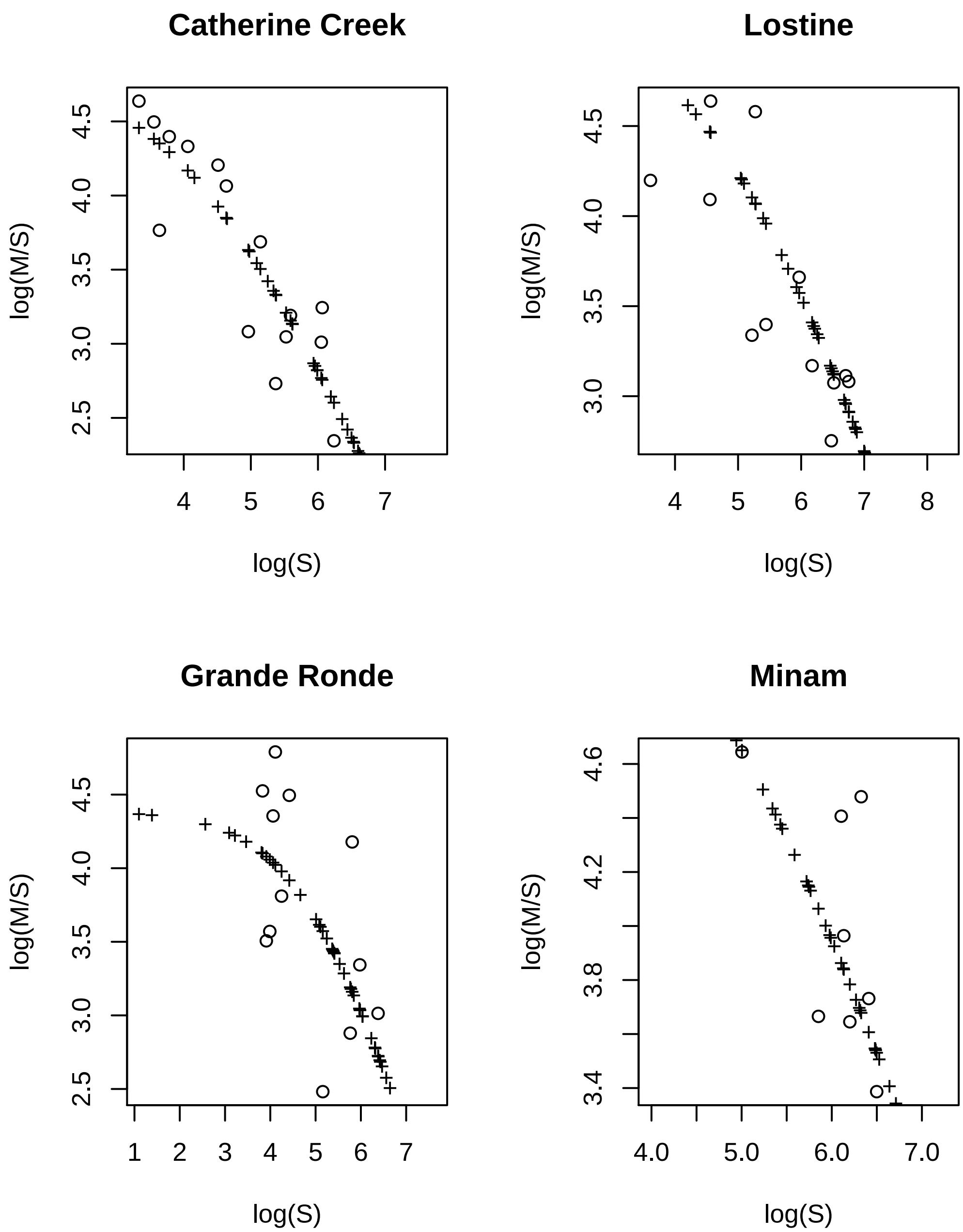


Figure 2.8: Observed (circles) and the predicted (plus symbols) smolts per spawner vs spawners.

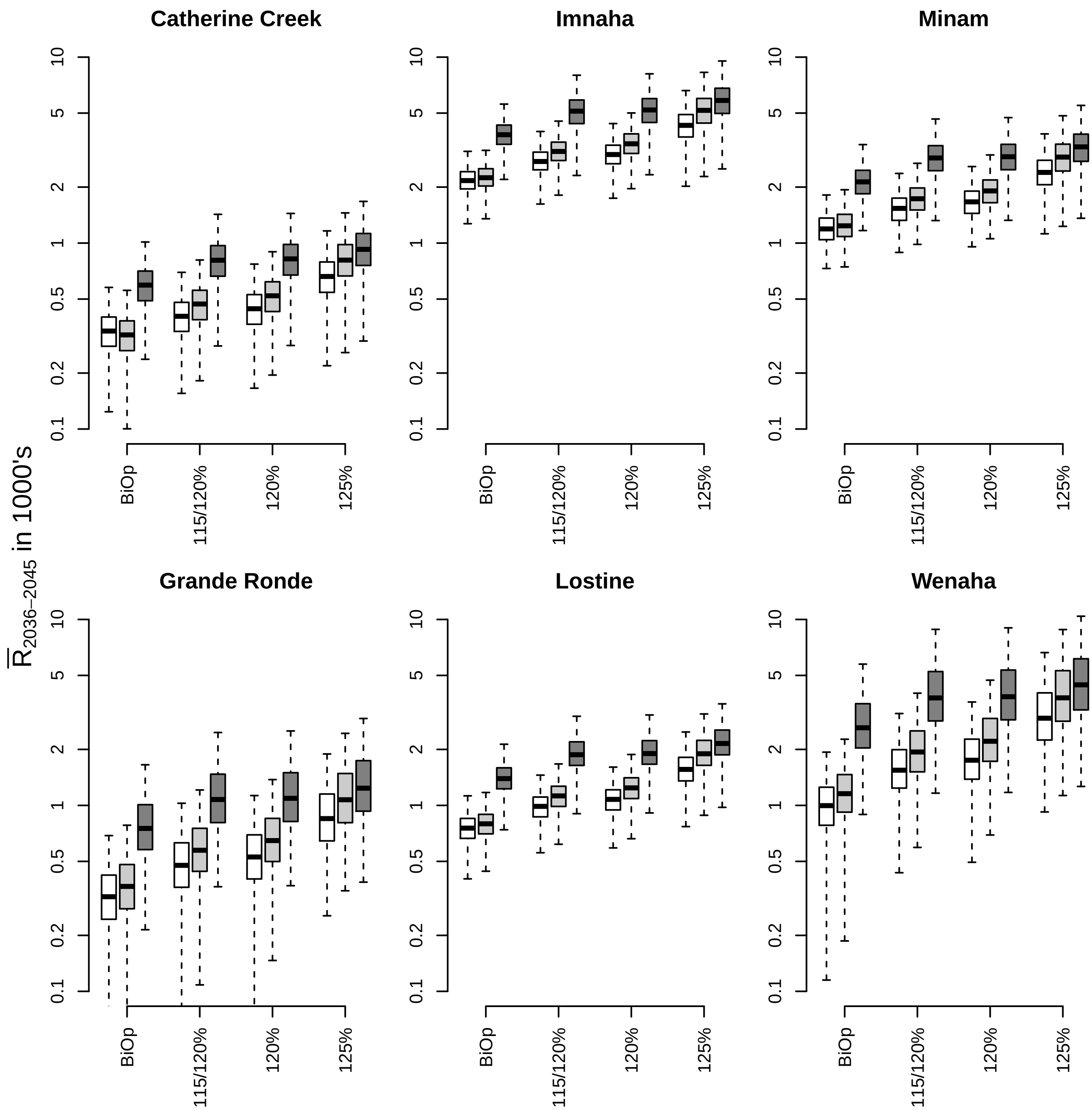


Figure 2.9: Sensitivity analysis of predicted long-term average predicted average abundance between 2036 and 2045 ($\bar{R}$ in log scale) at all combinations of spill levels and flow levels. Each cluster of three bars represent high flow (white boxes), average flow (light grey boxes), and low flow (dark grey boxes). Boxes represent the 25%-75% quartiles. Whisker represent the outer 10% and 90%. Median values are shown with dark horizontal lines inside boxes.

increases asymptotically to a maximum of 40%, attaining a rate of 20% at 5000 total Grand Ronde / Imnaha returns to the mouth. The SAR can be viewed as more of a smolt to Spawner ratio, because it also captures what would otherwise have been considered tributary harvest and broodstock removals. As with the $\bar{R}$ shown in Figure 2.9, spilling to high TDG levels increases SARs, and all spill levels show the highest SAR at the lowest flow. At most spill levels, there is a greater than two fold increase in the SAR at low versus high flows. Across spill levels, there is approximately a two fold increase in the SAR when increasing TDG cap level from BiOp levels to the 125% level. Interestingly, there is an apparent net decrease in the SAR for the Catherine Creek population at BiOp level spills when the assumed flow levels decrease from high to average flows. This is only evident in the Catherine Creek population. The most likely explanation for this is that Catherine Creek is the population with the lowest capacity, and thus is limited in total production, which can interact with harvest rates in a depensatory way because of the way the simulated harvest rates increase as the total MPG returns increase. At the lower total life cycle productivities implicit in lower spill rates, the effect is that slightly higher in-river juvenile migration survival increase total MPG returns enough to drive the harvest rate up, and the Catherine Creek population suffers the consequence of being the weaker stock in a mixed stock complex. The effect is present, but less noticeable in the returns (see Figure 2.9). Figure 2.11 shows that the SARs at the mouth of the Columbia are the same for all populations, confirming that harvest is the cause.

Relative performances of spill scenarios can also be evaluated using the ratio of the median of long-term average return abundances to the BiOp level spill prediction at each flow level. Figure 2.12 shows the median $\bar{R}$ (of the 10,000 predicted $\bar{R}$s) at a given spill level for each flow level compare to the median BiOp level spill for the same flow level. There is nearly a 50% gain from BiOp to 115%/120% for all flow levels, but only high and average flows show noticeable gains in the transition from 120% spill to 125% spill. The ratio of the medians is shown without uncertainty to make the trend in the ratios more apparent. The same trend can be seen when the ratio of each independent simulation is shown with associated uncertainty (see Figure 2.13). This perspective only illustrates what performance would look like if spill were increased relative to BiOp at a given flow, and only if spill levels were sustained every year, and flows remained at the same level every year. Looking at ratios of median $\bar{R}$s for each flow level relative to high flows at BiOp, the importance of flow levels is more apparent. Figure 2.14 shows the ratio of the median predicted $\bar{R}$ at each spill scenario at a flow level to median predicted $\bar{R}$ atBiOp spill and high flow. The flow level alone explains about a 100% improvement or more at a BiOp level spill when comparing low to high flow. The highest incremental gains come at average and high flows when spill is increased to 125%, but we see that relative to low flow BiOp spill, average and low flows show higher relative gains.

Figure 2.15 shows the effect of spilling, but evaluated across a range of productivities for each population. Each line represents one of the four spill levels evaluated at average flows for each of the spill levels (BiOp, 115%/120%, 120%, and 125%). The lines represent the median predicted $\bar{R}$ from 10,000 simulations. The figure is intended to demonstrate the relative change in $\bar{R}$ across a range of productivities at four spill scenarios. Uncertainty around each line cannot be shown without obfuscating the contrast among spill scenarios, but can be inferred from Figure 2.9, where the variability at the estimated productivity is shown for each spill scenario at average flow. The grey shaded area in Figure 2.15 corresponds to the 25%-75% quartile range of

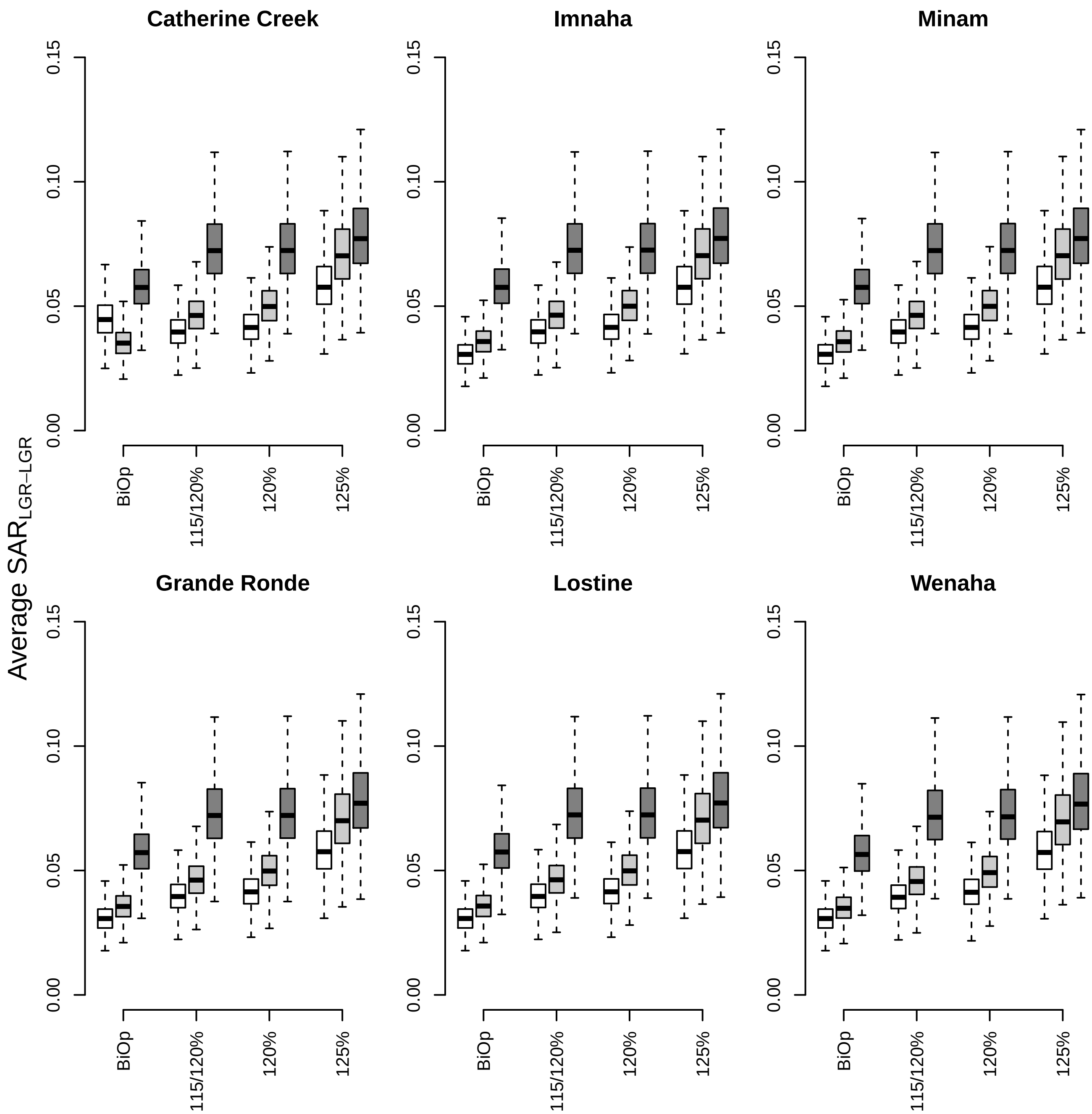


Figure 2.10: Sensitivity analysis of predicted long-term average SAR at LGR between 2036 and 2045 at all combinations of spill levels and flow levels. Each cluster of three bars represent high flow (white boxes), average flow (light grey boxes), and low flow (dark grey boxes). Boxes represent the 25%-75% quartiles. Whisker represent the outer 10% and 90%. Median values are shown with dark horizontal lines inside boxes.

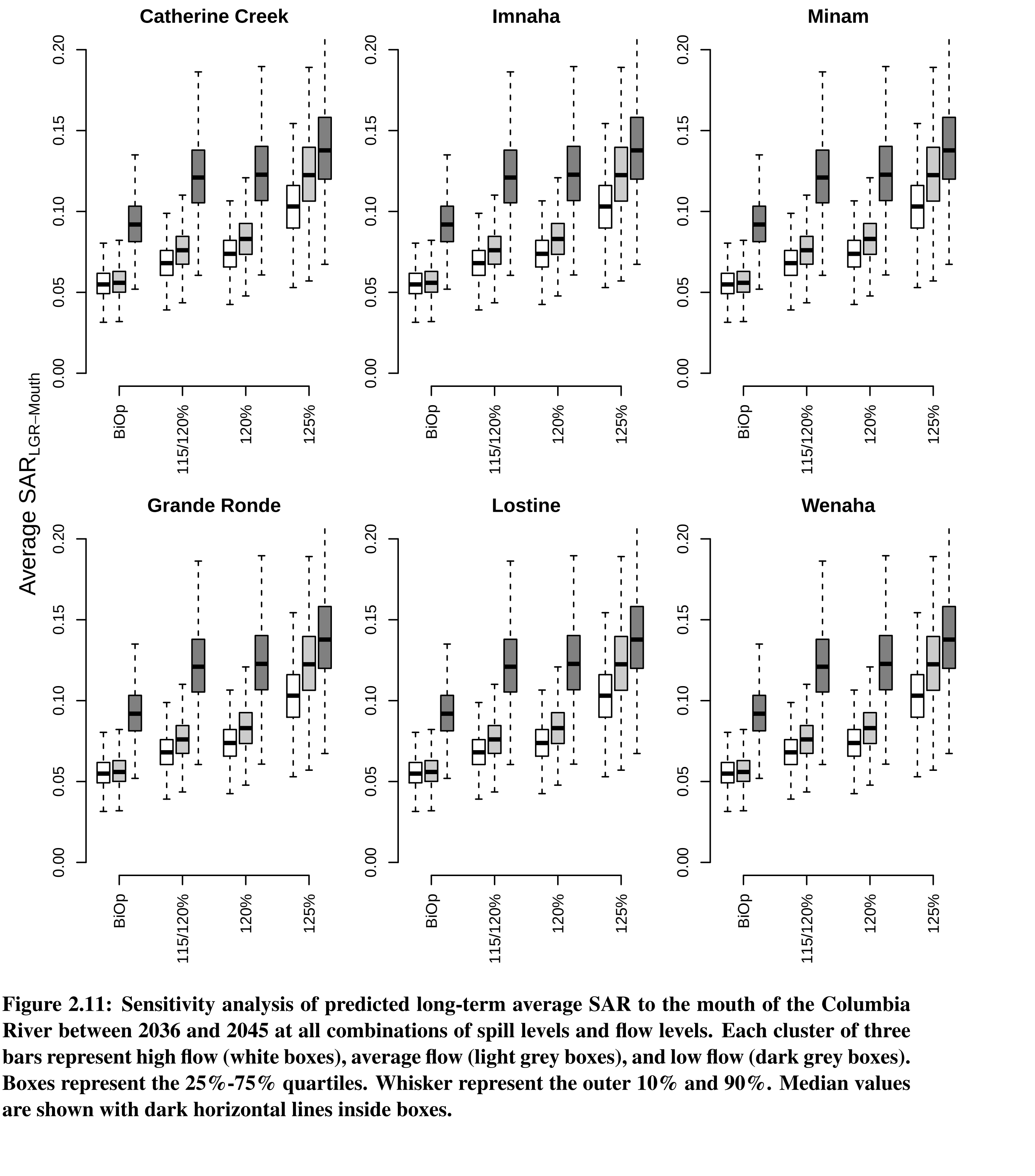


Figure 2.11: Sensitivity analysis of predicted long-term average SAR to the mouth of the Columbia River between 2036 and 2045 at all combinations of spill levels and flow levels. Each cluster of three bars represent high flow (white boxes), average flow (light grey boxes), and low flow (dark grey boxes). Boxes represent the 25%-75% quartiles. Whisker represent the outer 10% and 90%. Median values are shown with dark horizontal lines inside boxes.

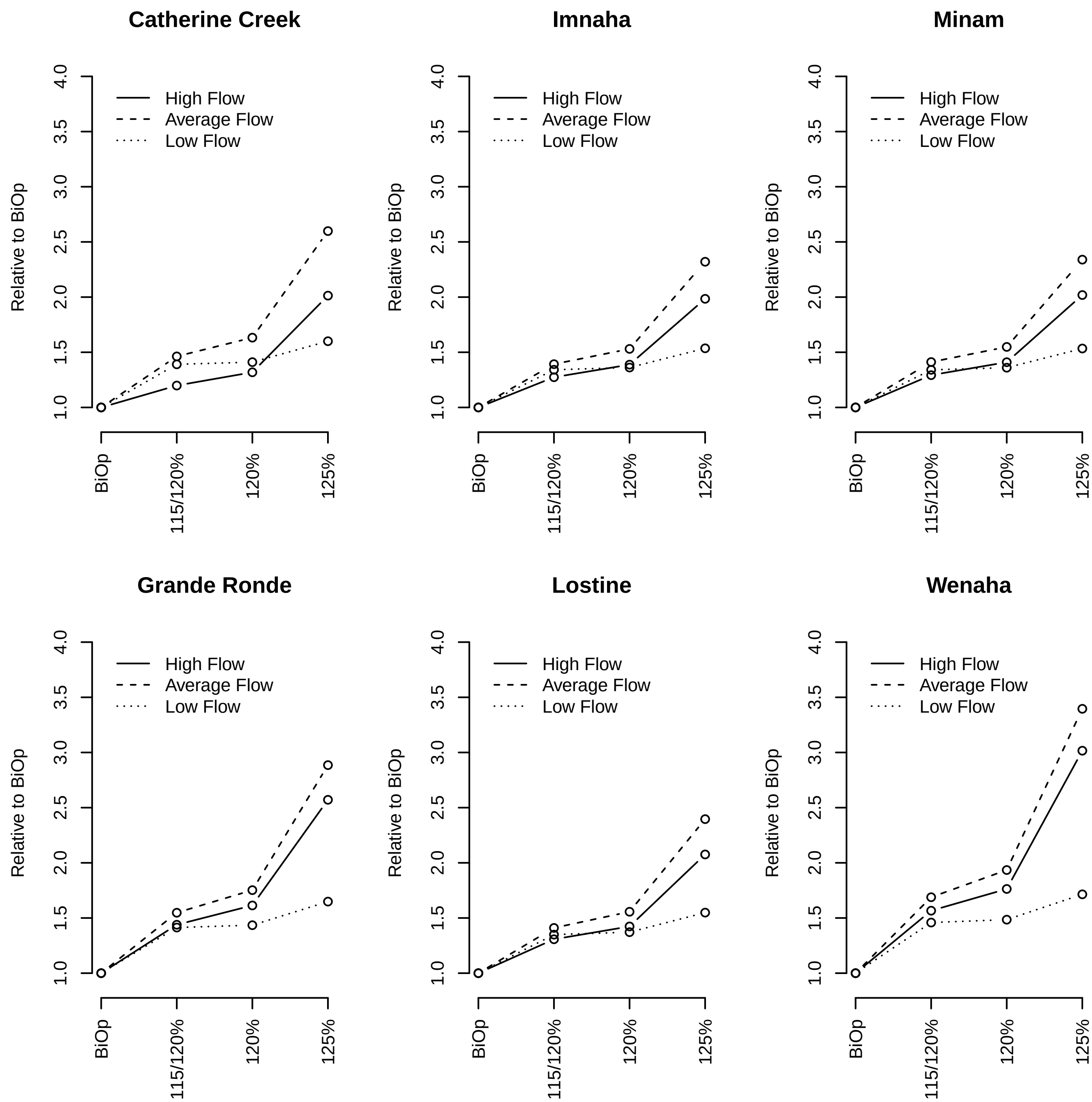


Figure 2.12: Sensitivity analysis of predicted long-term average return abundance between 2036 and 2045 at each flow level when compared to BiOp spill at each flow level.

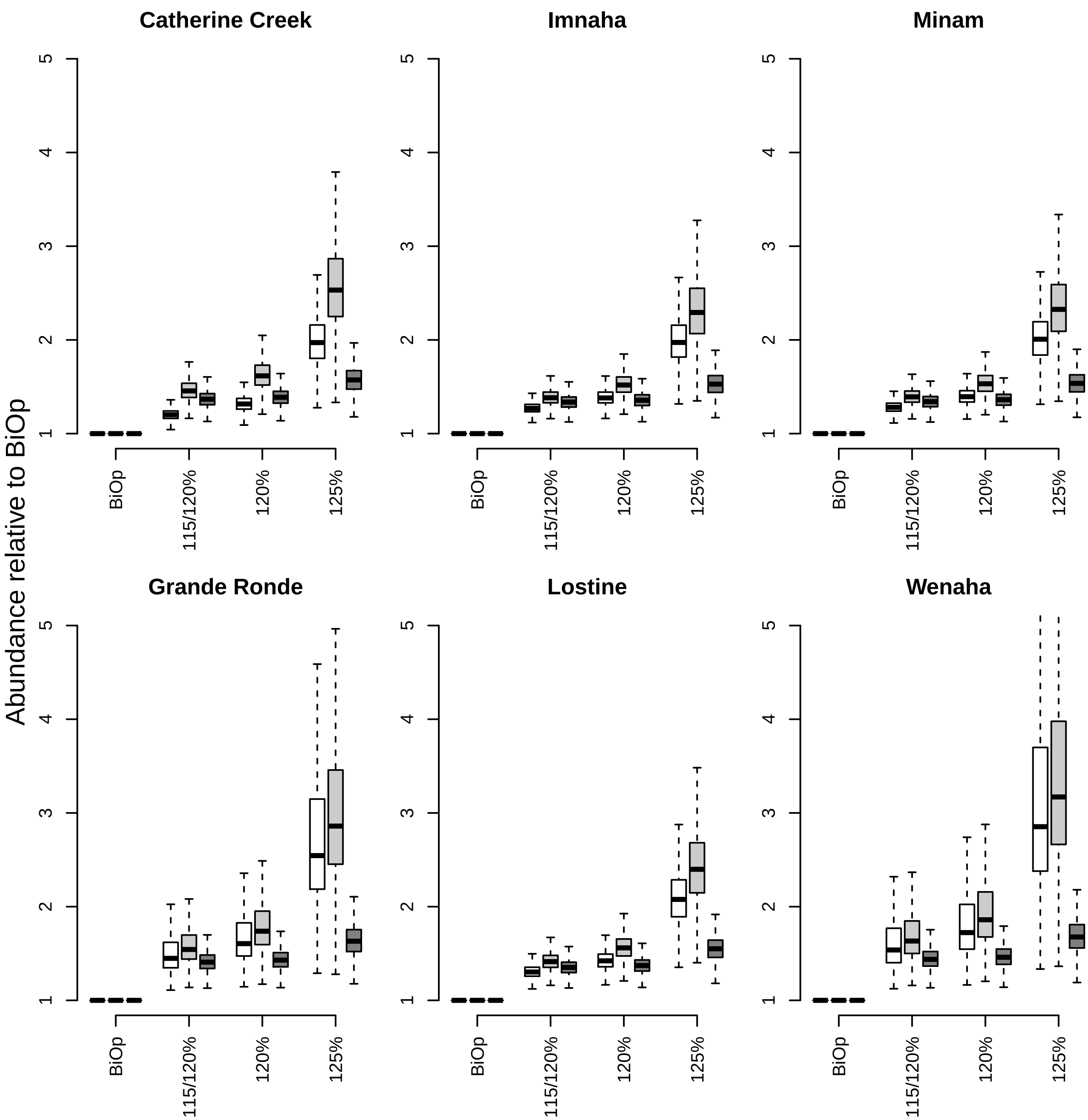


Figure 2.13: Comparison of the ratio of simulated long-term average return abundance between 2036 and 2045 at each flow level when compared to BiOp spill at each flow level. Each cluster of three bars represent high flow (white boxes), average flow (light grey boxes), and low flow (dark grey boxes) ratios of predicted average abundances to BiOp level spills for that flow level. Boxes represent the 25%-75% quartiles. Whisker represent the outer 10% and 90%. Median ratio values are shown with dark horizontal lines inside boxes.

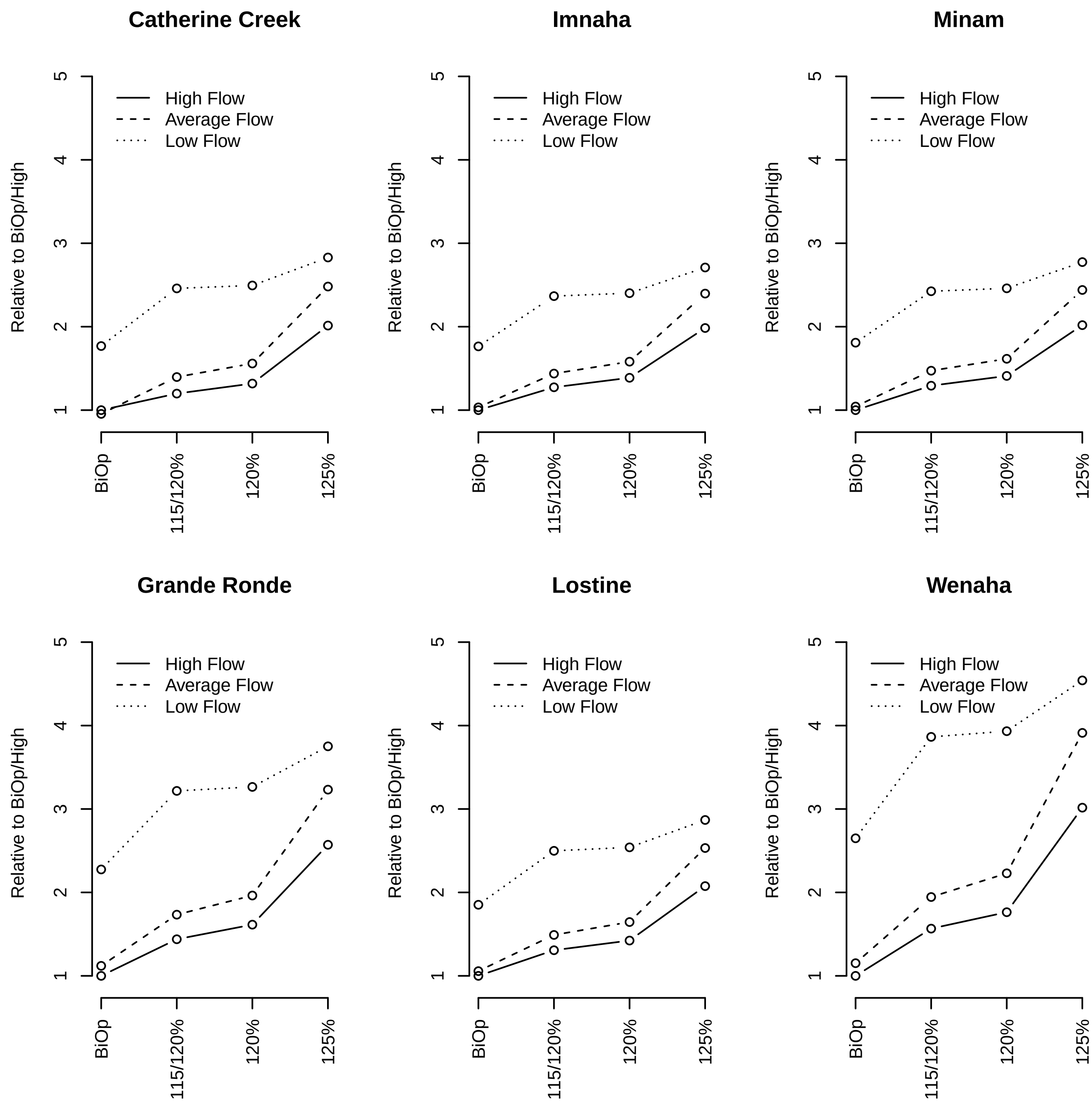


Figure 2.14: Sensitivity analysis of predicted long-term average return abundance between 2036 and 2045 at each flow level when compared to BiOp spill at a high flow level.

uncertainty in the productivity estimate, so improvements to productivity would fall to the right of the shaded area. The general pattern is that larger gains from increased spill are realized by populations that have high capacity (Imnaha and Wenaha), and that the gain is greater still if the productivity is high (Imnaha).

In all six population, there is a predicted increase in $\bar{R}$ if productivity is increased, but unless capacity is relatively high, the gains are not very significant. The Imnaha, Minam, and Wenaha have the highest capacities, and therefore predict larger gains in average abundance from increases in productivity. There are no cases where increasing freshwater productivity has more influence on $\bar{R}$ than increasing spill levels.

Figure 2.16 shows the effect of spilling, but evaluated across a range of capacities for each population. Like the productivity comparisons, the lines represent the median predicted $\bar{R}$ from 10,000 simulations at four spill scenarios. At the levels of SARs simulated, freshwater productivity does little to limit $\bar{R}$ when population trends are projected across a range of capacities. This is because as long as average SARs are sufficient to return enough adults to replace the number of parents that produced those smolts, the only thing limiting population increase is capacity. The shaded areas represent the 25%-75% quartile range of estimated value of the capacity estimated from the posterior chain of parameter estimates which, if no action were taken, is the level of benefit expected from increasing spill.

Discussion

We examined the predicted benefits of spill levels across high, average, and low flows, and found that predicted SARs and long-term average return abundances respond positively to increased spill. We found that the most significant benefits to SARs occur at the highest TDG limit spill levels, at the lowest flow levels. We also found that low flows are predicted to contribute more significantly to increases in SARs at BiOp level spills than at higher levels of spill. However, at higher assumed flow levels, the life cycle model predicted that the highest TDG limit spill level (125% TDG) produced a larger incremental benefit to SARs than the transition upward from the lower spill levels.

The MCMC posteriors show the range of variability in the δ_{PH} parameter estimate to be very narrow with estimates of approximately δ_{PH} = -0.4 and $\hat{\sigma}_{\delta_{PH}}$ = 0.01. To put that in context, the estimated in-river survival at average levels of PITPH and WTT is estimated to be around 0.37 with δ_R = 0.51. That would be the estimated survival at average historical levels of PITPH and WTT, meaning that it is not the highest survival possible with PITPH and WTT at their most favorable values. If we consider values of PITPH of 3 and 0.3, representing high and low spill scenario values, then the in-river survival is predicted to increase from 0.42 to 0.70 at average WTT values (by adding -0.4 times a difference of PITPH = -2.7 to the logistic term in Equation [2.9]). This implies that PITPH is capable of explaining shift in in-river survival of about 0.28 across the range of spill scenario PITPH values. There is slightly more variation in the estimate of γ_H ($\hat{\sigma}_{\gamma_H}$ = 0.22), but the effect is similar to how PITPH affects early ocean survival of in-river migrants. The model predicts that at average PDO and UPW conditions, PITPH can explain an increase in first year ocean survival.

We presented the relative benefits of changes to freshwater production parameters and

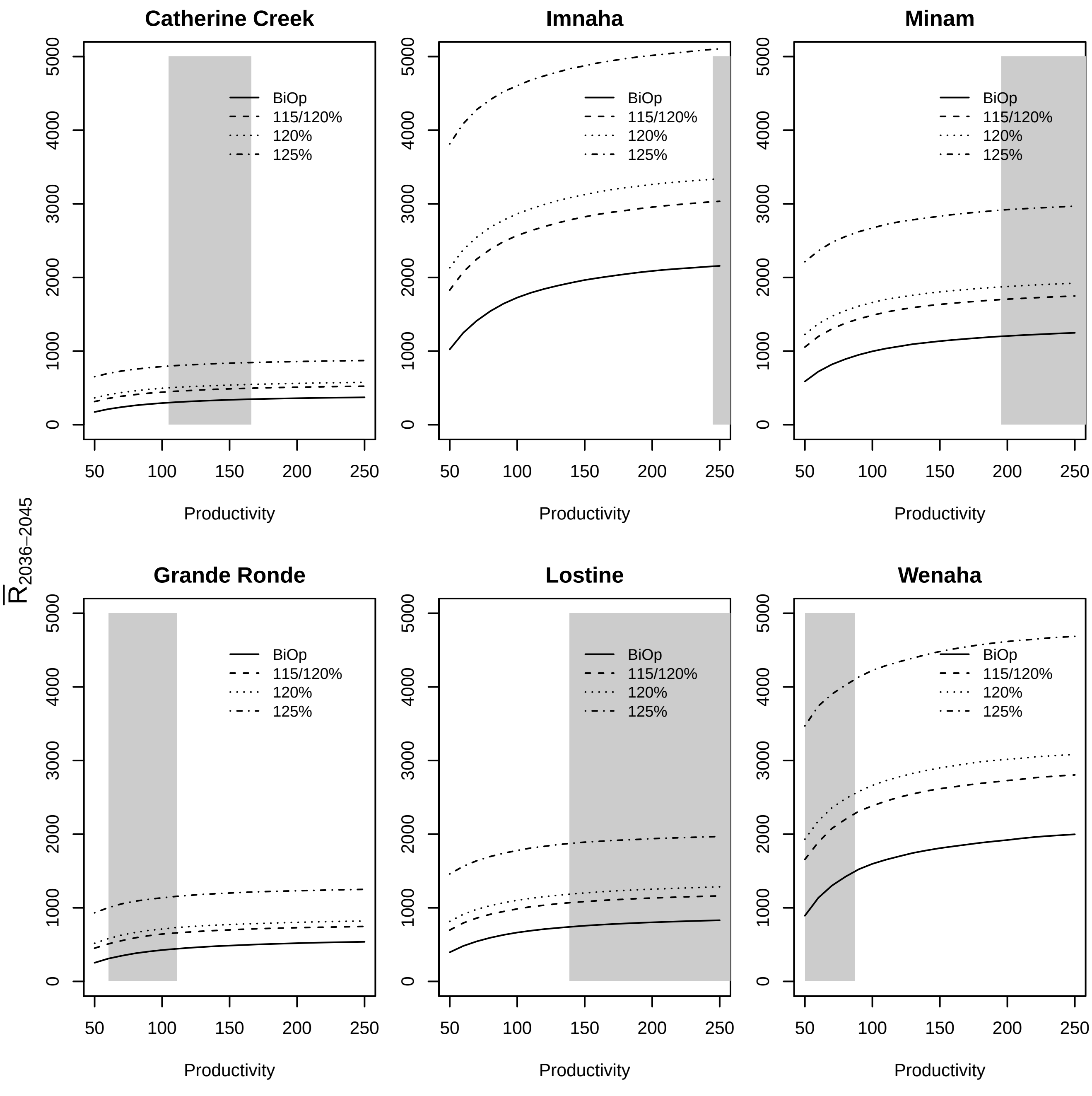


Figure 2.15: Sensitivity analysis of predicted long-term average return abundance between 2036 and 2045 when tributary productivities span the range from 50 to 250 smolts per spawner. The lines are the median ($\bar{R}$) predicted average return abundance at four spill levels evaluated at average flows. Grey shaded areas denote the estimated range of variability in the productivity parameters evaluated from posterior distributions.

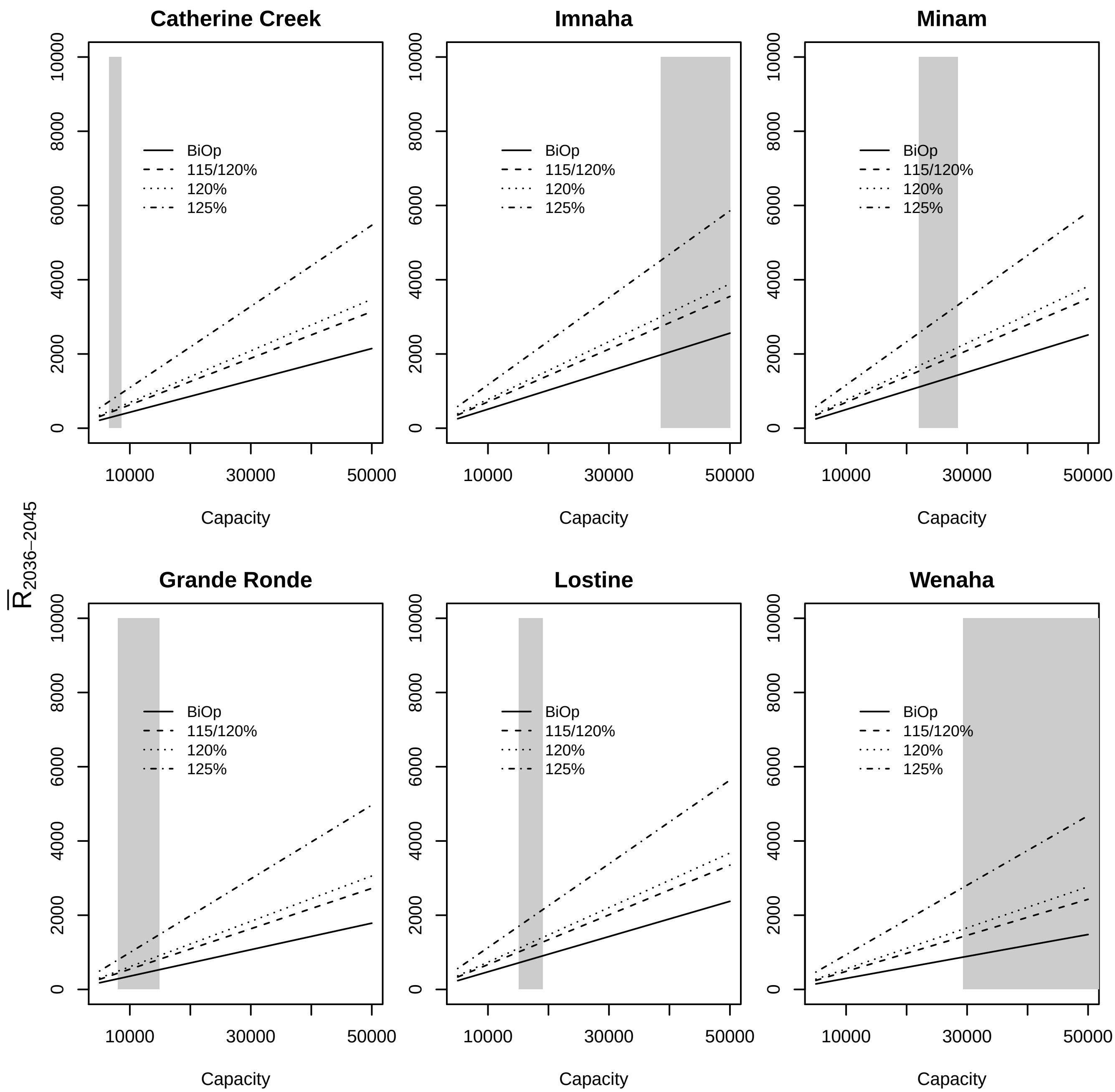


Figure 2.16: Sensitivity analysis of predicted long-term average abundance between 2036 and 2045 ($\bar{R}$) when tributary capacities span the range from 5000 to 50000 smolts. The lines are the median ($\bar{R}$) predicted return average abundance at four spill levels evaluated at average flows. Grey shaded areas denote the estimated range of variability in the capacity parameters evaluated from posterior distributions.

changes to hydrosystem operations. Simulations show that the relative average return abundance (see Figure 2.9) benefits are predominantly limited by capacity. The range of benefit from additional spill was a two to three fold increase in average return abundance evaluated at average flow levels, with the most extreme case being a 4.3 fold increase in average return abundance from a BiOp spill level at high flows compared to a 125% TDG spill level at low flows in the Wenaha (which has the highest estimated capacity). Looking more closely at how increased spill interacts with changes to productivity and capacity, we found that most of the potential gains from productivity came from populations that have low productivities and high capacities (see Figures 2.15 and 2.16), and the benefits came from increasing productivity up to 150 smolts per spawner, but not much beyond that unless the capacity was exceptionally high.

Increasing spill levels provides a benefit regardless of the productivity or capacity. When we look at the potential benefits of increasing capacity at different spill levels, the contrast across populations is not as strong. This is because the benefit of increasing in-river survival of juvenile migrants is more significant than the differences in freshwater productivities. From these results it seems apparent that benefits obtained from increases to productivities are ultimately bounded by capacities, as are the benefit obtainable from increased spill, but with the distinction that the increased average abundances predicted from increasing productivities by 50 smolts per spawner are less than the benefit of going from a BiOp spill scenario to the next higher TDG level spill. We also note that there is a more significant relative improvement in long-term average abundance going from a BiOp to 115%/120% level of spill than the next increase to 120% TDG.

The analysis shows that there are predicted benefits from increasing spill levels at all levels of flow, but most significantly at low flows, which is when spill efficiency is highest. Those benefits not only exceed the benefits of habitat actions aimed at productivity increases, but they are more immediately implementable. Ultimately, habitat actions are required to bring population abundances back to historical levels, but increased spill scenarios provide a timely means of increasing SARs and abundances. Looking at the results on a case by case basis for each population, we note that there are some obvious contrasts. The Imnaha and Minam both have good productivity and capacities, but being partially in Wilderness Areas, are not likely recipients of any habitat actions . The Upper Grande Ronde and Catherine Creek, on the other hand, have very low estimated capacities, and the Upper Grande Ronde has a very low productivity. Both of these could benefit from habitat improvements, but private land ownership within the drainages impedes and delays habitat restoration action on significant portions of the drainages, making it difficult to effect change with the speed and intensity required. On the other hand increased spill levels could have immediate benefit, and we have shown that increasing from BiOp to 115%/120% levels could lead to about a 50% increase in return abundances, and spill to a 125% TDG level could lead to about a three fold increase at current productivity and capacity levels. It seems on first glance at the predicted sensitivity to productivity increases that changes are ineffectual relative to increased spill levels, but this view does not account for the natural outcome that increasing productivity inherently involves improving areas that currently have very low productivity, and by doing so opens up new areas for spawning and rearing. Adding areas of improved productivity reduces the burden on other areas to support production, which has the effect of increasing capacity simultaneously. In short, capacity increases are implicit in actions to increase productivity.

We have shown that increases in $\bar{R}$ can be effected by three different means, and that the relative gains from productivity improvements can be dependent on capacity limits in freshwater spawning and rearing. We have shown that increasing spill levels can increase predicted median $\bar{R}$ by up to 4.3 fold if capacity is high enough, and generally by 2 fold or more, depending on flow levels. Because the magnitude of the performance gain at low flows is highest going from BiOp to 115%/120%, it seems an obvious minimum operation alternative to spill at 115%/120% at low flows. The performance gains in the next transition to 120% are not predicted to be as high, i.e., an apparent diminishing return. The final transition to 125% TDG level spill predicts a more significant gain in predicted median $\bar{R}$ than the previous increment. At average and high flows, the relative increases in $\bar{R}$ are gradual and consistent, without the diminishing returns seen at lower flows. Figure 2.9 and 2.10 show these gradual and diminishing returns of performance across spill scenarios.

We note that predicted average SARs are higher (in the range of 0.02-0.06) than empirically observed SARs (less than 0.005 to about 0.03 in recent years since court mandated spills), but we emphasize that the analysis is intended to gauge relative expected increases in SARs, not predict absolute SARs. The higher estimate is consistent with the positive bias seen in the comparison of predicted and empirical SARs. The reasons for the bias are unclear at the current stage of the analysis. It could be because too much weight is being given to fitting older SARs and in-river survivals, or it could be because the SARs are derived from the entire Snake River aggregate and are being compared to predicted SARs based on predicted returns of populations in the Grande Ronde / Imnaha MPG. Fitting to abundance data may actually predict higher SARs than the Snake River aggregate SAR, or alternatively, the abundance data may contain a bias that predicts a higher SAR. We have also assumed a 20% transportation rate for simulation purposes, which is lower than the average of 37% transportation between 2007 and 2012 migration years. Since we predict transported fish survive in the ocean at a lower rate than in-river migrants, we would expect our simulation analysis to predict higher overall SARs than if the transportation rate was higher.

Focussing not on the absolute magnitude of the SARs, but rather on the relative predicted change in SARs with increased spill, the predicted increase from the 0.02-0.06 range at BiOp spill to the 0.06-0.08 range at 125% spill can be interpreted by the change in PITPH. The 125% scenario represents PITPH values of 0.28-1.01 across all flows, as opposed to the range of 1.95-3.06 at BiOp spill. These numbers can be compared to the SARs of John Day Chinook, which experience five less powerhouses than Snake River Chinook. John Day SARs are in the 0.02-0.08 range. PITPH averages about 2.7 across all flow levels in the BiOp scenario for Snake River Chinook crossing 8 dams. If John Day Chinook cross only 3 dams, then the PITPH should be in the vicinity of a 3/8th fraction of PITPH, which is 1.00. The 120% scenario is the closest to having an average PITPH of 1.00 across all flow levels, and its predicted SARs are similar to those of the John Day.

We predicted $\bar{R}$ across a range of assumed fixed freshwater productivity levels and capacity levels that differed from the estimated values of the parameters. We also predicted $\bar{R}$ across a range of fixed alternative hydrosystem operational levels. The predicted $\bar{R}$s show the relative predicted outcome under those fixed conditions and provides an indication of the relative behavior of the populations. This oversimplifies operational and biological realities, but

nonetheless provides a perspective of the relative benefits that can be expected. The comparative benefits from tributary actions assumed that productivity and capacity would immediately take on fixed values reflecting improved conditions. This means that when we look at the predicted value of $\bar{R}$ at 150 smolts per spawner, we are assuming that demographic rates applied immediately from 2010 on onward, however it's important to keep in mind that any treatment intended to effect an increase in productivity or capacity would involve a lag time before reaching the target rate. For comparative purposes it's still meaningful to see the relative gain across a range of productivities, but in reality it can take a long time for any changes to habitat to translate to increases in productivity. The same goes for capacity. Furthermore, just like freshwater conditions won't remain static, it clearly can't be the case that flows will always be one of the three levels examined. Notwithstanding the limitation of the static assumptions in the model predictions, presenting the relative outcomes still gives us a sense of how much life cycle survival can improve when year to year variability in flow and operational conditions occur. What we have shown is that an increase in $\bar{R}$ is predicted to occur if spill is increased, and that the relative increase depends on the flow and the spill scenario. While flows will vary from year to year, the results show that there is a measurable predicted increase in $\bar{R}$ with increased spill, and the increase is relative to flow.

We have shown that abundance can increase as a result of alternative treatments. A target $\bar{R}$ can be achieved by means of selecting a target productivity, capacity, or alternative spill level. In either of the three cases, there may be implementation issues or time lag issues. Despite any caveats to the limitations in attaining productivity or capacity improvements however, it must be noted that action both in freshwater and in the hydrosystem is likely to be most effective, and gains obtained from reducing PITPH via increased spill serve as a buffer for potential implementation lags in productivity and capacity treatments. Ultimately, where habitat improvements are needed, they provide the highest long-term abundance gains, particularly where capacity is increased, but the immediate benefits of increasing spill are evident and should be considered vital to recovering abundances.

Conclusions

The results presented in this analysis demonstrate the relative sensitivity of long-term return abundance to changes in freshwater production parameters and hydrosystem operations. Relying on the empirical estimates of life cycle model parameters, and particularly the finding that a PIT tag based indicator of powerhouse passage is a significant determinant of in-river survival and early ocean survival, we demonstrated that alternative spill scenarios can have varying degrees of influence on population recovery, depending on the productivities and capacities of the populations. We found that populations with low capacities (eg: Catherine Creek, Upper Grande Ronde, and to a lesser extent the Lostine) don't realize as much benefit from increasing freshwater productivity as population with higher capacities, but it is expected that habitat improvements aimed at increasing productivity would benefit capacity as well, so the actual gains need to account for the dual benefit of habitat improvements.

This analysis predicted that average return abundances and SARs increase with higher spill. The results are preliminary in the sense that the simulated future conditions are speculative and have a strong influence on predicted survival. The predicted outcomes represent

approximations of the relative magnitude of increased survival and return abundance that are predicted relative to spill levels. The results are presented as contrasts under different fixed flow conditions, which can be used to provide guidance in the application of spill at relative approximate flow levels. We find that at low flows, substantial gains in performance are predicted to occur if spill levels are increased from BiOp levels to the 115%/120% TDG levels. Approximately a 50% increase in average return abundances was predicted. 125% spill levels in years of high flows predicted greater than two fold increases in return abundances, with some population receiving greater benefits from higher spills because of their high freshwater spawning and rearing capacities. This analysis predicts that higher SARs and long-term abundance increases can be achieved by increasing spill levels, and that the benefits of spill are sensitive to flows. The immediate benefits of increased flow levels, combined with the long-term benefits of habitat actions predict potential recovery of populations to up to three fold increases in abundance above levels predicted by BiOp level spill.

CHAPTER 3
EFFECTS OF THE IN-RIVER ENVIRONMENT ON JUVENILE TRAVEL TIME, INSTANTANEOUS MORTALITY RATES AND SURVIVAL

The CSS is an important component of ongoing Research, Monitoring and Evaluation (RM&E) and Data Management studies in the Columbia River Basin. This long-term study provides specific information on management actions in the region, specifically the role of the smolt transportation program, flow augmentation, and spill for the recovery of listed salmon and steelhead stocks. In addition to providing a time series of SAR data, the CSS provides data on smolt out-migration timing, juvenile migration rates and travel times, juvenile reach survivals, and evaluates these parameters for the purpose of informing management and recovery decisions related to those stocks.

As a long-term study, the CSS has included PIT-tagged smolts from a variety of basins, locations, species and rear-types in an effort to arrive at, among other goals, a holistic view of juvenile demographic parameters and their relationships to hydrosystem management actions in the FCRPS. This chapter summarizes data collected on groups of juvenile salmonids from the Snake River basin, which consisted of yearling spring/summer Chinook salmon, subyearling (fall) Chinook salmon, steelhead and sockeye salmon. We also summarize and analyze groups of yearling spring/summer Chinook salmon, sockeye salmon, and steelhead originating in the upper Columbia River, from Rock Island Dam to McNary Dam.

This chapter uses information-theoretic model selection techniques (Burnham and Anderson 2002) to update the multiple regression models of fish travel time, instantaneous mortality rates and survival probabilities from Chapter 3 of the 2015 Annual Report (McCann et al. 2014). These analyses address an interest of the ISAB/ISRP for finer-scale analyses of the relationships between survival and specific operational actions or environmental features (ISAB 2006). In this chapter we continue the process of summarizing and synthesizing the results that have been obtained to date through the CSS on the responses of juvenile yearling (spring/summer) and subyearling (fall) Chinook salmon, sockeye salmon and steelhead to conditions experienced within the hydrosystem. These analyses evaluate the effects of management actions on fish travel times and in-river juvenile survival probabilities, while directly accounting for model uncertainty, measurement uncertainty, and environmental variation.

Methods

Study area and definitions

In this chapter, we define the Snake Basin migration corridor as the overall reach between Lower Granite Dam (LGR) and Bonneville (BON) Dam (Figure 3.1). There are six dams between LGR and BON: Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), and The Dalles (TDA). We divided the Snake Basin migration corridor into two reaches for summarizing fish travel time, instantaneous mortality rates, and survival probabilities: LGR–MCN and MCN–BON. We also define the upper Columbia River migration corridor as the river reach between Rock Island Dam (RIS) and

McNary Dam. There are two dams between RIS and MCN: Wanapum Dam and Priest Rapids Dam. We define fish travel time (FTT) as the time spent migrating the LGR–MCN, RIS–MCN or MCN–BON reach and expressed this in days. We used Cormack-Jolly-Seber (CJS) methods to estimate survival probabilities through the three reaches based on detections at the dams and in a PIT-tag trawl operating below BON (Cormack 1964, Jolly 1965, Seber 1965, Burnham et al. 1987).

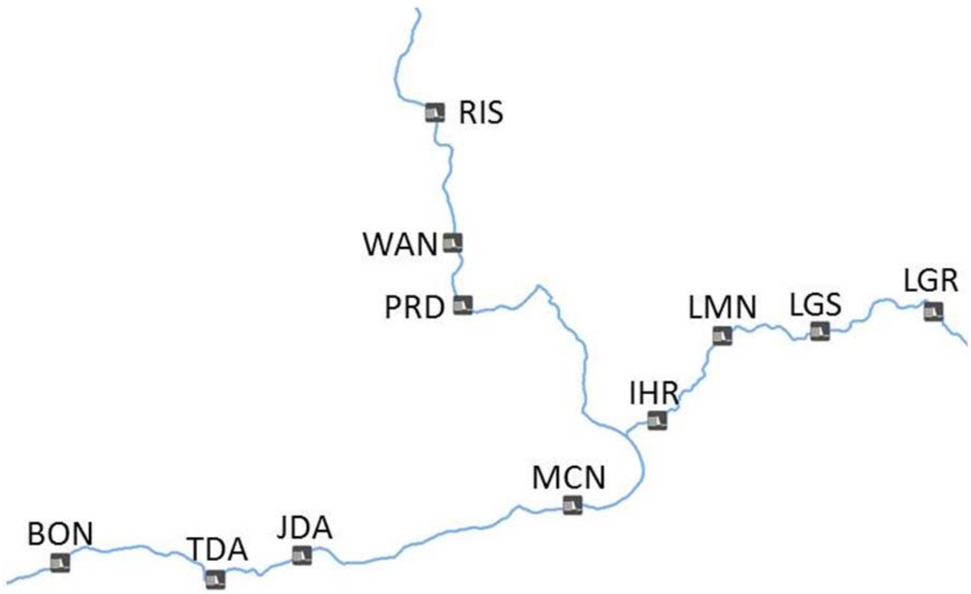


Figure 3.1 Location of dams and river reaches analyzed. Labels refer to Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMN), Ice Harbor Dam (IHR), Rock Island Dam (RIS), Wanapum Dam (WAN), Priest Rapids Dam (PRD), McNary Dam (MCN), John Day Dam (JDA), The Dalles Dam (TDA), and Bonneville Dam (BON).

Multiple regression modeling

The goal of the multiple regression models is to evaluate finer-scale analyses of the relationships between survival probabilities and specific operational actions or environmental features during the juvenile outmigration. Toward this goal, we calculated and summarized within-year (weekly or multi-weekly) fish travel time, instantaneous mortality rate, and survival probability estimates for juvenile yearling Chinook, subyearling Chinook, and steelhead across years of the CSS. We also calculated and summarized seasonal estimates of fish travel time, instantaneous mortality rate, and survival probabilities for sockeye salmon in the LGR–MCN and RIS–MCN reaches. The yearling Chinook, steelhead and sockeye used in this analysis consisted of fish PIT-tagged both at hatcheries and fish traps upstream of LGR and those tagged and released at LGR. Due to sufficient numbers of PIT-tagged hatchery and wild yearling

Chinook available, analyses in the LGR–MCN reach were conducted separately for hatchery and wild yearling Chinook. Due to the limited number of PIT-tagged steelhead available, hatchery and wild steelhead were combined for analyses in the LGR–MCN reach. Similarly, hatchery and wild sockeye were combined for analyses in the LGR–MCN and RIS–MCN reaches. The subyearling fall Chinook analyzed in the LGR–MCN reach were tagged at hatcheries. Analyses on yearling Chinook and steelhead in the RIS–MCN reach consisted of both hatchery and wild fish. Analyses on the MCN–BON reach included hatchery and wild yearling Chinook and steelhead from the Snake River, hatchery-marked fish from the Mid-Columbia River, and fish marked and released at MCN.

Fish travel time

We utilized a cohort-based approach for characterizing mean fish travel times for weekly or bi-weekly groups of juvenile Chinook salmon and steelhead. Individual fish detected at LGR with PIT tags were assigned to a weekly cohort group (i) according to the week of their detection. Cohorts were identified by the Julian day of the midpoint of the weekly cohort. For example, the April 1–7 release cohort was identified by Julian day 94 (April 4). We calculated mean fish travel time as the mean number of days between release at LGR until detection at MCN for each fish subsequently detected at MCN. In preliminary analyses, we used Box-Cox power transformations to determine whether the FTT_i data needed to be transformed in order to better approximate normality of the residuals and reduce heteroscedasticity in subsequent regressions. These preliminary analyses indicated that a log-transformation was most appropriate. We calculated mean FTT_i for each weekly release cohort of both yearling Chinook and steelhead, in both the LGR–MCN and MCN–BON reaches. Because the number of PIT-tagged sockeye was low and the juvenile sockeye migration season is relatively narrow, we calculated annual estimates of LGR–MCN FTT and RIS–MCN FTT for sockeye. For yearling Chinook and steelhead in the RIS–MCN reach, three 2-week release cohorts were used and were defined based on detection date at RIS. Similarly, for hatchery subyearling fall Chinook in the LGR–MCN reach, four 2-week release cohorts were used and were defined based on detection date at LGR.

For yearling Chinook, we calculated mean FTT_i for eight weekly cohorts from April 1 through May 26 in the LGR–MCN reach. Separate estimates were developed for hatchery and wild rearing types of yearling Chinook. In the MCN–BON reach, hatchery and wild yearling Chinook were combined and we calculated mean FTT_i for six weekly cohorts from April 26 through June 5. For steelhead, we calculated mean FTT_i for six weekly cohorts from April 17 through May 28 in the LGR–MCN reach. In the MCN–BON reach, we calculated mean FTT_i for six weekly cohorts of steelhead from April 27 through June 7. Hatchery and wild rearing types of steelhead were combined for both reaches. The number of cohorts by reach, species, and rearing type are summarized in Table 3.1.

Table 3.1 Reaches, species, rearing type, and number of FTT cohorts that were analyzed for the 2016 Annual Report.

Reach	Species	Rearing type	Cohorts	Cohort Period
LGR-MCN	steelhead	hatchery and wild	108	1-week
LGR-MCN	yearling Chinook	wild	140	1-week
LGR-MCN	yearling Chinook	hatchery	137	1-week
LGR-MCN	sockeye	hatchery and wild	18	annual
LGR-MCN	subyearling Chinook	hatchery and wild	58	2-week
RIS-MCN	steelhead	hatchery and wild	51	2-week
RIS-MCN	yearling Chinook	hatchery and wild	51	2-week
RIS-MCN	sockeye	hatchery and wild	17	annual
MCN-BON	steelhead	hatchery and wild	101	1-week
MCN-BON	yearling Chinook	hatchery and wild	102	1-week

Because FTT_i is calculated only using individuals that survive the migration, under conditions of a constant instantaneous mortality rate, the observed travel times will be underestimated to some degree due to the loss (i.e., mortality) of individuals with long travel times (i.e., those with slower migration speeds). As a result, the estimates of mean *FTT* can exhibit a small degree of negative bias relative to the expected travel times of all fish in the release cohort, which includes both the observed individuals that survive and unobserved individuals that do not survive (Tuomikoski et al. 2013, Appendix J). This effect has been observed and known since 1989 (FPC 1990). The degree of bias appears to be a function of both the travel times of the release cohort and the instantaneous mortality rate, with higher levels of bias expected under conditions of long travel times and high mortality rates (Tuomikoski et al. 2013, Appendix J). Simulations indicate that the degree of bias is less than 10% under most conditions that have been observed within the FCRPS (Tuomikoski et al. 2013, Appendix J).

Survival Probabilities

We estimated the survival probabilities for each weekly cohort of wild Chinook, hatchery Chinook and the combined hatchery and wild steelhead in the LGR–MCN reach using standard CJS methods over migration years 1998–2015. We also estimated annual survival probabilities for sockeye in the LGR–MCN reach over 1998–2015. Due to lower numbers of PIT-tagged fish detected and released at MCN, we developed survival probability estimates for three, 2-week cohorts for yearling Chinook and two 3-week cohorts for steelhead in the MCN–BON reach over migration years 1999–2015. For hatchery subyearling Chinook in the LGR–MCN reach we developed survival probability estimates for four 2-week release cohorts over migration years 1998–2015. In the RIS–MCN reach, we developed survival probability estimates for three 2-week release cohorts of yearling Chinook and steelhead. We calculated Chi-square adjusted variances (using the $\hat{c}$ variance inflation factor, the ratio of the deviance divided by the degrees of freedom) for each survival probability estimate ($\hat{S}$) (Burnham et al. 1987:244–246). The number of cohorts by reach, species, and rearing type are summarized in Table 3.2.

Table 3.2 Reaches, species, rearing type, and number of survival cohorts that were analyzed for the 2016 Annual Report.

Reach	Species	Rearing type	Cohorts	Cohort Period
LGR-MCN	steelhead	hatchery and wild	98	1-week
LGR-MCN	yearling Chinook	wild	113	1-week
LGR-MCN	yearling Chinook	hatchery	112	1-week
LGR-MCN	sockeye	hatchery and wild	17	annual
LGR-MCN	subyearling Chinook	hatchery and wild	53	2-week
RIS-MCN	steelhead	hatchery and wild	48	2-week
RIS-MCN	yearling Chinook	hatchery and wild	41	2-week
RIS-MCN	sockeye	hatchery and wild	17	annual
MCN-BON	steelhead	hatchery and wild	27	3-week
MCN-BON	yearling Chinook	hatchery and wild	42	2-week

Instantaneous mortality rates

In 2003, the ISAB offered the suggestion that "an interpretation of the patterns observed in the relation between reach survival and travel time or flow requires an understanding of the relation between reach survival, instantaneous mortality, migration speed, and flow" (ISAB 2003). Consistent with that suggestion, we developed an approach for estimating instantaneous mortality rates for juvenile salmonids (Schaller et al. 2007). Ricker (1975) provides a numerical characterization of survival, also known as the exponential law of population decline (Quinn and Deriso 1999):

$$S = \frac{N_t}{N_0} = e^{-Zt}, \qquad [3.1]$$

where S is a survival probability, N_t is the number of individuals alive at time t, N_0 is the number of individuals alive at time $t = 0$, and Z is the instantaneous mortality rate, in units of t^{-1}. The exponential law of population decline provides a useful framework for understanding the interrelationships between instantaneous mortality rates, time, and survival. If instantaneous mortality rates vary over time, Z represents the arithmetic mean mortality rate over the time period (Keyfitz 1985:18–19). This property of Z may be useful for capturing mortality rates for smolts in the Columbia Basin, which may experience different mortality rates over time. For example, if mortality rates experienced through a reservoir differ from mortality experienced through a dam, then the instantaneous mortality rate Z represents the arithmetic mean mortality rate over that period of migration through the reservoir and dam combination. Rearranging Eqn. 3.1, we estimated Z using

$$\hat{Z} = \frac{-\log_e(\hat{S})}{t} \qquad [3.2]$$

In our application, we calculated instantaneous mortality rates (in units of d^{-1}) for each survival cohort using Eqn. 3.2. We used the CJS estimates of survival probability for each

cohort ($\hat{S}_i$) in the numerator and used the mean $F\hat{T}T_i$ in the denominator of Eqn. 3.2. This approach for estimating instantaneous mortality rates incorporates the variability in cohort migration rates, which can vary substantially over the migration season. This approach for estimating instantaneous mortality also differs from most applications where the instantaneous mortality rate is defined for a fixed time step, such as a year or fixed within-year period. In our application, the mean *FTT* for each cohort determines the time step over which the instantaneous mortality rate is calculated and defined.

While individuals in each release cohort have variable individual *FTT's*, we used the mean $F\hat{T}T_i's$ in the denominator of Eqn. 3.2 to characterize the cohort-level central tendency in the amount of time required to travel a reach. Combining the cohort-level survival probability estimates ($\hat{S}_i$) with the cohort-level mean $F\hat{T}T_i$ estimates, we estimated the cohort-level instantaneous mortality rates ($\hat{Z}_i$) using Eqn. 3.2. As discussed above, estimates of mean *FTT* can exhibit a small degree of negative bias due to the loss of individuals with long travel times. This can, in turn, result in a small degree of positive bias in the instantaneous mortality rate estimates (Tuomikoski et al. 2013, Appendix J). However, simulation results indicate that the degree of bias is less than 5% under most conditions that have been observed within the FCRPS (Tuomikoski et al. 2013, Appendix J).

Both $-\log_e(\hat{S}_i)$ and mean $F\hat{T}T_i$ are random variables subject to sampling and process error. To calculate the variance of $\hat{Z}_i$, we used the formula for the variance of the quotient of two random variables (Mood et al. 1974):

$$\text{var}(\hat{Z}_i) = \text{var}\left(\frac{-\log(\hat{S})}{F\hat{T}T}\right) \cong \left(\frac{-\log(\hat{S})}{F\hat{T}T}\right)^2 \left(\frac{\text{var}[-\log(\hat{S})]}{-\log(\hat{S})^2} + \frac{\text{var}[F\hat{T}T]}{F\hat{T}T^2} - \frac{2cor(-\log(\hat{S}), F\hat{T}T) \cdot \sqrt{\text{var}[-\log(\hat{S})] \cdot \text{var}[F\hat{T}T]}}{-\log(\hat{S}) \cdot F\hat{T}T}\right), \quad [3.3]$$

Empirical (Peterman 1981) and theoretical (Hilborn and Walters 1992) analyses support the assumption that $\hat{S}$ tends to be log-normally distributed, and therefore $-\log_e(\hat{S})$ would tend to be normally distributed. To estimate the variance of $-\log_e(\hat{S}_i)$ we used the approximation provided by Blumenfeld (2001) for log-normally distributed random variables:

$$\text{var}[-\log_e(\hat{S})] = \log_e(1 + [CV(\hat{S})]^2). \quad [3.4]$$

Environmental variables

The environmental variables associated with each cohort were generated based on fish travel time and conditions at each dam along the reaches. Travel time for each cohort between dams was estimated, and we calculated the average spill percentage, temperature (based on tailwater total dissolved gas monitoring data, downloaded from the USACE website: www.nwd-wc.usace.army.mil/cgi-bin/dataquery.pl), and total water transit time (WTT) as indicators of conditions each group experienced while passing through the reach. Water transit time was calculated by dividing the total volume of reservoirs by the flow rate, and with adjustments in McNary pool to account for Columbia River versus Snake River flows. Conditions at downstream dams were averaged over a 7-day window around the median passage date at each

dam, and the travel time to the next dam was used to adjust the start date of the calculations. For example, steelhead travel time from LGR to LGO for the earliest release cohort in 2005 (detected at LGR from 4/17 to 4/23) was estimated to be 5.0 days based on 378 detections. Average environmental variables over the time period of April 22 to April 28 at LGO were then calculated. At each downstream dam, environmental variables were calculated in a similar manner. The rationale behind using the 7-day window around the median passage date is to develop an index of exposure to the environmental variables analyzed (e.g., spill, water transit time, temperature) that aligns with the timing of smolt passage at each dam. The 7-day windows were selected because the vast majority of smolts pass during these 7-day windows around the median passage date and experience the spill, temperature, and water transit times that occur within these windows. Since no PIT-tag detection data were available until 2005 at IHR, travel time to IHR was estimated as 43% of the total travel time from LMN to MCN (corresponding to the distance to IHR relative to the distance to MCN). The overall reach environmental variables were the average of these dam-specific calculated values for spill percentage and temperature, whereas for water transit time the sub-reach values were summed to estimate the total reach water transit time. In addition to these environmental predictor variables, we also used Julian date as a predictor variable to help capture seasonal effects not reflected in these environmental variables. We use Julian date of release to characterize effects such as degree of smoltification, photoperiod, predator abundance/activity, or fish length that may demonstrate a consistent pattern within- and across-years, but is not already captured by the other environmental variables. The use of Julian date of release as an attempt to capture seasonal effects is a common modeling strategy for these data (Berggren and Filardo 1993, Smith et al. 2002, Williams et al. 2005). We also developed a variable that enumerated the number of dams with spillway surface passage structures (e.g., removable spillway weirs [RSWs], temporary spillway weirs [TSWs], or adjustable spillway weirs [ASWs]) in place over the years of observation. Building on the results of last year's report (McCann et al. 2015, Appendix J), we also developed an index of the expected number of powerhouse passage experiences based on the project-specific spill proportions, flow levels, and the presence of spillway weirs for spring/summer Chinook salmon and steelhead.

Multi-model inference

We used multi-model inference techniques (Burnham and Anderson 2002) to evaluate the associations between the environmental variables and mean *FTT* and instantaneous mortality (*Z*). Our objectives were to account for model selection uncertainty and to synthesize results on the relative importance of environmental factors on fish travel time and instantaneous mortality across the set of species and reaches that have been monitored. We evaluated seven environmental factors that have previously been identified (Tuomikoski et al. 2013) as being associated with *FTT* and/or *Z*: Julian day of fish release from the dam at the starting point of the reach (LGR, RIS, or MCN), Julian day squared, average proportion spill, expected number of powerhouse passage experiences, total water transit time, average water temperature, and the number of dams with spillway surface passage structures. Because the powerhouse passage variable was developed using proportion spill and the presence of surface passage structures, either the powerhouse passage variable or the combination of proportion spill and number of spillway weirs was used in the models. Based on previous results, evaluations of the quadratic effect of Julian day was limited to the yearling Chinook salmon fish travel time models. Because each environmental factor was considered plausible based on previous evaluations, we evaluated all possible model combinations of the predictor variables (all subsets regression). We

calculated Akaike's information criterion for small sample sizes (AIC_C) for each combination of the predictor variables. In cases where all six variables were applicable, there were 64 possible model combinations of the predictor variables. In cases where some of the variables were not applicable (e.g., Julian day for sockeye) there were fewer possible model combinations of the variables.

As mentioned above, Box-Cox power transformations indicated that a $\log_e$-transformation was most appropriate for the *FTT* data. Therefore we modeled $\log_e(FTT)$ as the response variable in all analyses. The $\log_e$ transformations were also implemented to help reduce heteroscedasticity and improve linearity.

During the smolt outmigration, individuals within each release cohort tend to spread out as they migrate downstream (Zabel and Anderson 1997). With sequential release cohorts, fast-migrating individuals within one release cohort may overlap to some degree with the slower-migrating individuals of the previous cohort in downstream reaches and vice versa (Tuomikoski et al. 2013, Appendix J). In addition, prior growth and rearing conditions may similarly influence the migration rates of individuals across cohorts within a migration year. As a result, the cohorts may lack complete independence and share some degree of correlation. However, mixed-effects models (Pinheiro and Bates 2000) can be used to properly account for the lack of independence among sample units (Millar and Anderson 2004, Chavez 2010). Preliminary analyses indicated that mixed-effects models with migration year (i.e., random intercept) and Julian day (i.e., random slope) as random effects frequently improved model fit based on AIC_C. The full model for evaluating the effects of environmental and management factors on FTT was of the form:

$$\log_e(F\hat{T}T_{y,j}) = \beta_0 + \beta_1 \cdot X_{1,y,j} + ...\beta_6 \cdot X_{6,y,j} + b_y + b_j \cdot X_{1,y,j} + \varepsilon_{y,j}, \quad [3.5]$$

where β_0, β_1,...,β_6 are fixed-effect parameters used to describe the relationship between environmental variables $X_1, X_2, ..., X_6$ and $\log_e(FTT)$, b_y is a random effect of migration year (y) with $b_y \sim N(0, \sigma_y^2)$, b_j is a random effect of Julian day (j) with $b_j \sim N((0, \sigma_j^2)$, and $\varepsilon_{y,j} \sim N(0, \sigma_\varepsilon^2)$. This full, mixed-effects model is termed the "MY + Day" model, as it includes all of the environmental variables as fixed effects, plus a random intercept for Migration Year (MY) and a random slope for the effect of Julian day of release (Day). In addition to the full model described above, we also considered simpler, reduced-model forms with: (1) only the random intercept for Migration Year, termed the "MY" model, and (2) a standard Linear Regression model without random effects, termed the "LR" model. The model form with the lowest AIC_C among the three forms evaluated (i.e., the MY + Day, MY, or LR model forms) was selected for use in subsequent analyses.

We also utilized Box-Cox power transformations to determine the most appropriate transformation of the $\hat{Z}_i$ for each of the ten species-reach combinations that have been monitored. The Box-Cox analyses indicated that a square-root transformation was most appropriate for the instantaneous mortality rate models. Preliminary analyses indicated that mixed-effects models with migration year (i.e., random intercept) and Julian day (i.e., random slope) as random effects occasionally improved model fit based on AIC_C. The full model for evaluating the effects of environmental and management factors on *Z* were of the form:

$$sqrt(\hat{Z}_{y,j}) = \beta_0 + \beta_1 \cdot X_{1,y,j} + ...\beta_5 \cdot X_{5,y,j} + b_y + b_j \cdot X_{1,y,j} + \varepsilon_{y,j}, \quad [3.6]$$

where $\beta_0, \beta_1, ..., \beta_5$ are fixed-effect parameters used to describe the relationship between environmental variables $X_1, X_2, ..., X_5$ and sqrt(Z), b_y is a random effect of migration year (y) with $b_y \sim N(0, \sigma_y^2)$, b_j is a random effect of Julian day (j) with $b_j \sim N((0, \sigma_j^2)$, and $\varepsilon_{y,j} \sim N(0, \sigma_\varepsilon^2)$. This full, mixed-effects model is termed the "MY + Day" model, as it includes all of the environmental variables as fixed effects, plus a random intercept for Migration Year (MY) and a random slope for the effect of Julian day of release (Day). In addition to the full model described above, we also considered simpler, reduced-model forms with: (1) only the random intercept for Migration Year, termed the "MY" model, and (2) a standard Linear Regression model without random effects, termed the "LR" model. The model form with the lowest AIC_C among the three forms evaluated (i.e., the MY + Day, MY, or LR model forms) was selected for use in subsequent analyses. Because there were large differences in the precision of the $\hat{Z}_i$, we used inverse coefficient of variation weighting in the fitting process for modeling instantaneous mortality rates.

The models were ranked according to AIC_C, the model with the minimum AIC_C was identified, and Akaike weights (w_i) were calculated for each model (Burnham and Anderson 2002). Using the AIC_C-ranked set, we calculated model-averaged predictions for the FTT and Z of each of the ten species-reach combinations. Model-averaged predictions were calculated using:

$$\hat{\hat{\theta}} = \sum_{i=1}^{R} w_i \hat{\theta}, \quad [3.7]$$

where $\hat{\hat{\theta}}$ denotes the model-averaged prediction of $\hat{\theta}$ (i.e., *FTT* or *Z*) across the R models and w_i denotes the Akaike weight for model $i = 1, 2, ..., R$ (Burnham and Anderson 2002). Model-averaged coefficients were calculated in a similar manner, along with unconditional variance estimates for the coefficients using the methods described in Burnham and Anderson (2002).

The sets of best fitting models were also used to evaluate the relative importance of each predictor variable used in the regressions (Burnham and Anderson 2002). The relative variable importance is a quantitative measure of the degree to which variables are consistently included among the best-fitting models based on AIC_C, relative to the other variables that were considered. The relative variable importance for variable j among a set of R models is calculated as

$$\sum_{i=1}^{R} w_i I_j(g_i), \quad [3.8]$$

where w_i is the Akaike weight for model i and $I_j(g_i)$ is an indicator variable equal to one if variable j is in model i (g_i) and equal to zero otherwise. Variables with relative variable importance values near one are consistently in the top fitting models while variables with relative variable importance values near zero are rarely, if ever, included in the top fitting models.

Survival modeling approach

Our approach for modeling survival probabilities utilized the exponential mortality model (Eqn. 3.1), allowing the predicted instantaneous mortality rates Z_i and the mean FTT_i's to vary in response to environmental factors. Using our best-fitting model predictions for Z^*_i and FTT^*_i (Eqns. 3.5 and 3.6), predicted survival probabilities were calculated as:

$$S^*_i = e^{-Z^*_i \cdot FTT^*_i}, \quad [3.9]$$

where Z^*_i is the predicted instantaneous mortality rate, FTT^*_i is the predicted mean FTT_i, and S^*_i is the predicted survival probability for period *i*, calculated by exponentiating the negative product of Z^*_i and FTT^*_i. It is important to note that although the estimates of *FTT* and *Z* may include a small degree of bias due to the loss of individuals with long travel times, the survival probability predictions generated using Eqn. 3.9 show no evidence for bias (Tuomikoski et al. 2013, Appendix J).

Summarizing goodness of fit

We used the coefficient of determination (R^2) to characterize the goodness of fit for the models used to predict fish travel time, instantaneous mortality and survival. The coefficient of determination was calculated as the squared Pearson correlation coefficient between estimates of fish travel times and instantaneous mortality rates and the back-transformed, model-averaged predictions for fish travel times and instantaneous mortality rates. For survival probabilities, the coefficient of determination was calculated as the squared Pearson correlation coefficient between estimates of survival and the survival predictions generated using Eqn. 3.9. The coefficient of determination reflects the proportion of variance explained by the models.

Results

Estimates of mean $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$ of cohorts of juvenile yearling and subyearling Chinook, steelhead, and annual estimates of sockeye along with predicted values for these parameters are shown in Figures 3.2, 3.3, and 3.4. In the LGR–MCN reach, mean $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$ varied considerably over the period of 1998–2015, both within- and across-years. While there were some special cases, mean $F\hat{T}T_i$ generally decreased over the season, $\hat{S}_i$ both increased and decreased over the season, and $\hat{Z}_i$ increased over the season. Within-year estimates of $\hat{S}_i$ varied by up to 39 percentage points for both wild yearling Chinook and steelhead, and by up to 32 percentage points for hatchery yearling Chinook. Across all years and cohorts, estimates of $\hat{S}_i$ varied by up to 64 percentage points for yearling Chinook and 76 percentage points for steelhead. The large within- and across-year variation in $\hat{S}_i$ demonstrates a high degree of contrast in $\hat{S}_i$ over this 1998–2015 timeframe. It is important to note that although water transit times in 2015 were similar to 2001, estimates of mean $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$ were not dramatically different than recent years and showed marked improvements over the estimates from 2001. The

primary difference in the outmigration conditions between 2001 and 2015 was the provision of spill.

In the MCN–BON reach, cohorts of yearling Chinook and steelhead demonstrated within-year mean $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$ patterns similar to those observed in the LGR–MCN reach, varying considerably both within- and across-years (Figures 3.2, 3.3, and 3.4). For both species, mean $F\hat{T}T_i$ generally decreased over the migration season. Yearling Chinook in 2001 demonstrated the largest within-year variation in mean $F\hat{T}T_i$, ranging from 22 days early in the season to 8 days late in the season (Figure 3.2). Due to imprecision in the estimates of $\hat{S}_i$, general patterns in the estimates of $\hat{S}_i$ and $\hat{Z}_i$ in the MCN–BON reach were difficult to discern (Figures 3.3 and 3.4). For both Chinook and steelhead, $\hat{Z}_i$ generally increased over the season. Steelhead $\hat{S}_i$ generally decreased over the season, but no general patterns were evident for Chinook $\hat{S}_i$.

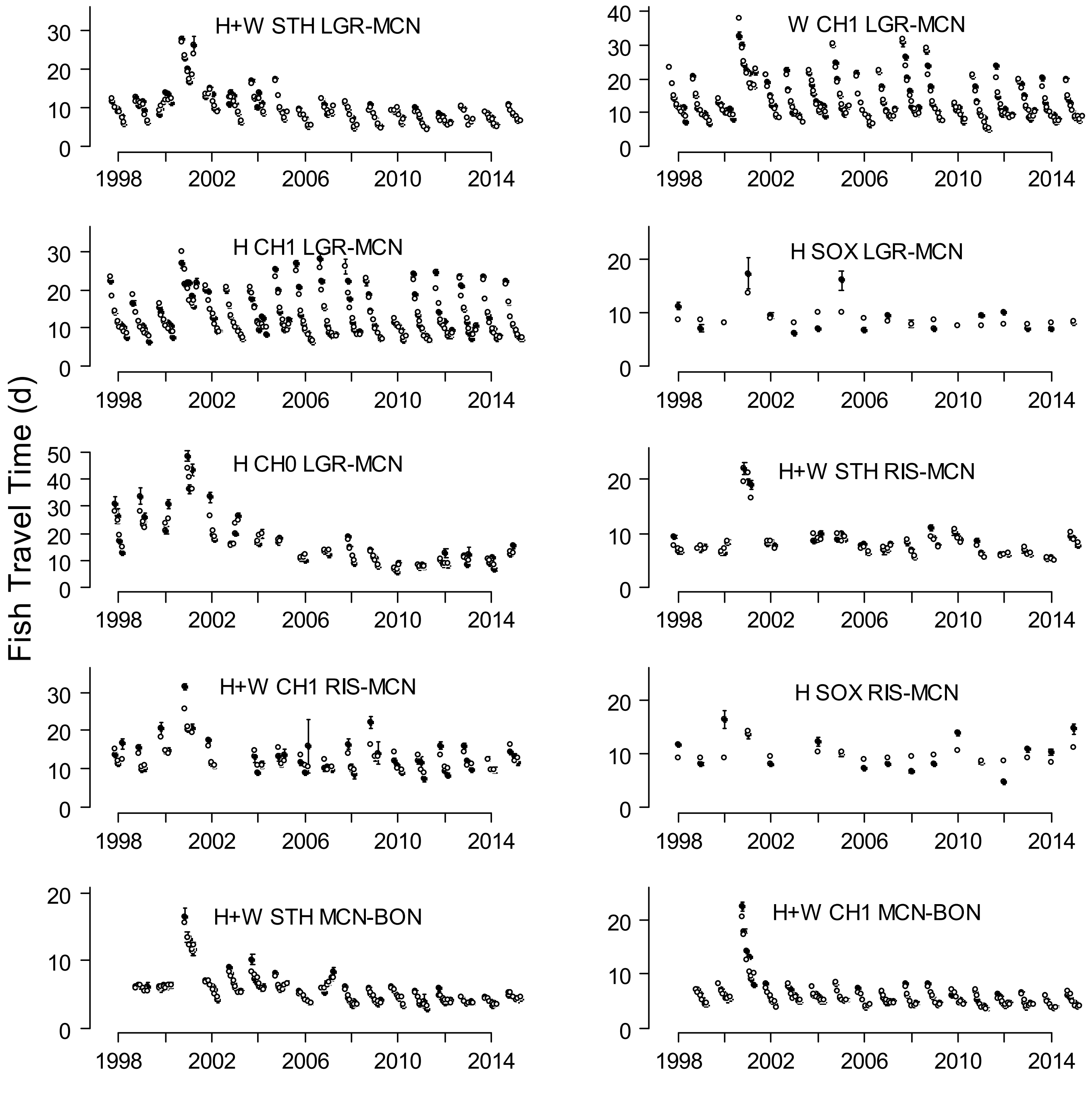


Figure 3.2 Estimates of mean Fish Travel Time (in days, black circles) and predicted mean Fish Travel Time (open circles) for release cohorts of hatchery (H) and wild (W) steelhead (STH), yearling Chinook (CH1), subyearling Chinook (CH0), sockeye (SOX) in the LGR–MCN, RIS–MCN and MCN–BON reaches, 1998–2015. The error bars represent +/- 1 SE.

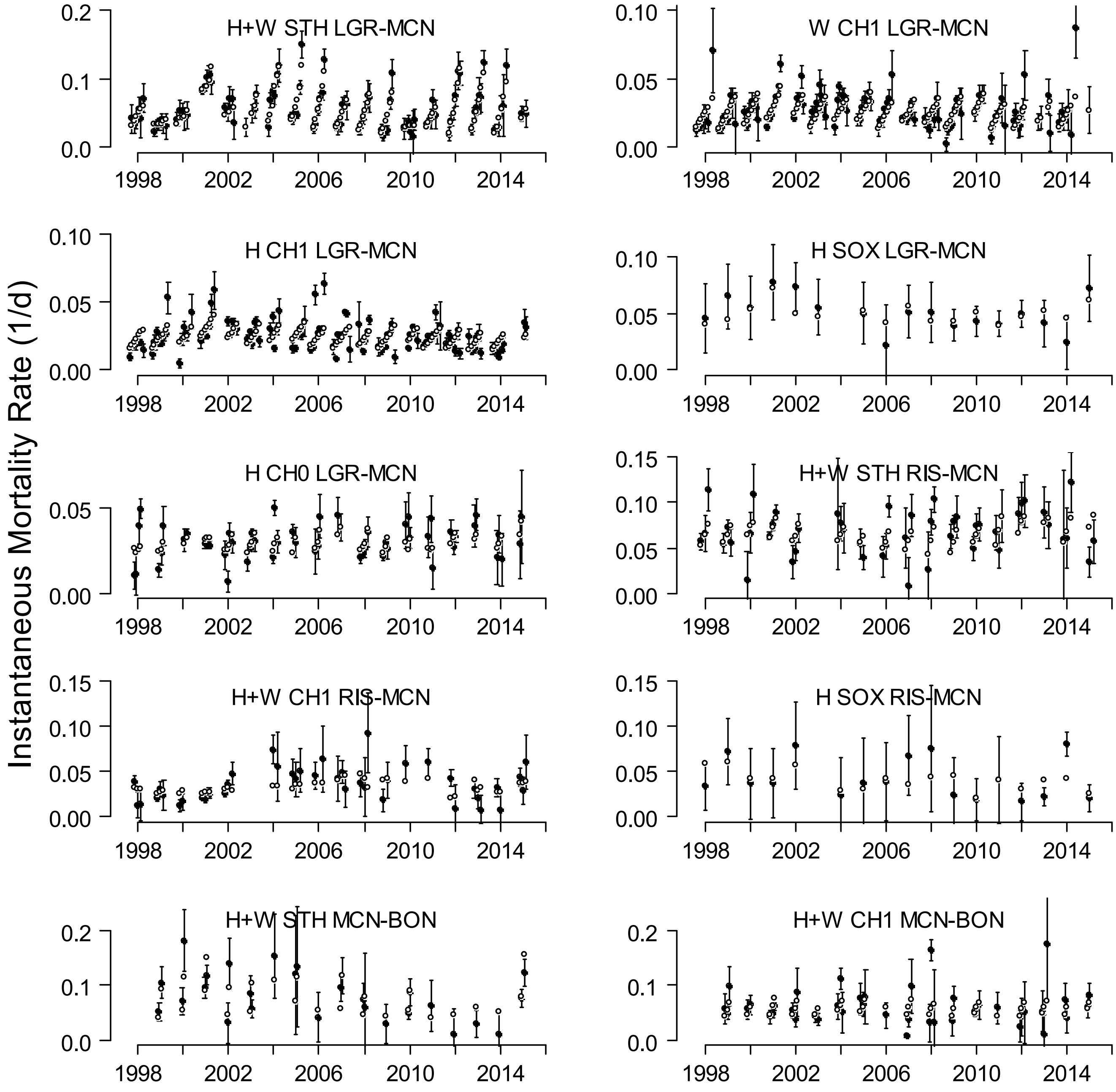


Figure 3.3 Estimates of instantaneous mortality rates, *Z* (y-axis, d^{-1}, black circles) and predicted *Z* (open circles) for release cohorts of hatchery (H) and wild (W) steelhead (STH), yearling Chinook (CH1), subyearling Chinook (CH0), sockeye (SOX) in the LGR–MCN, RIS–MCN and MCN–BON reaches, 1998–2015. The error bars represent +/- 1 SE.

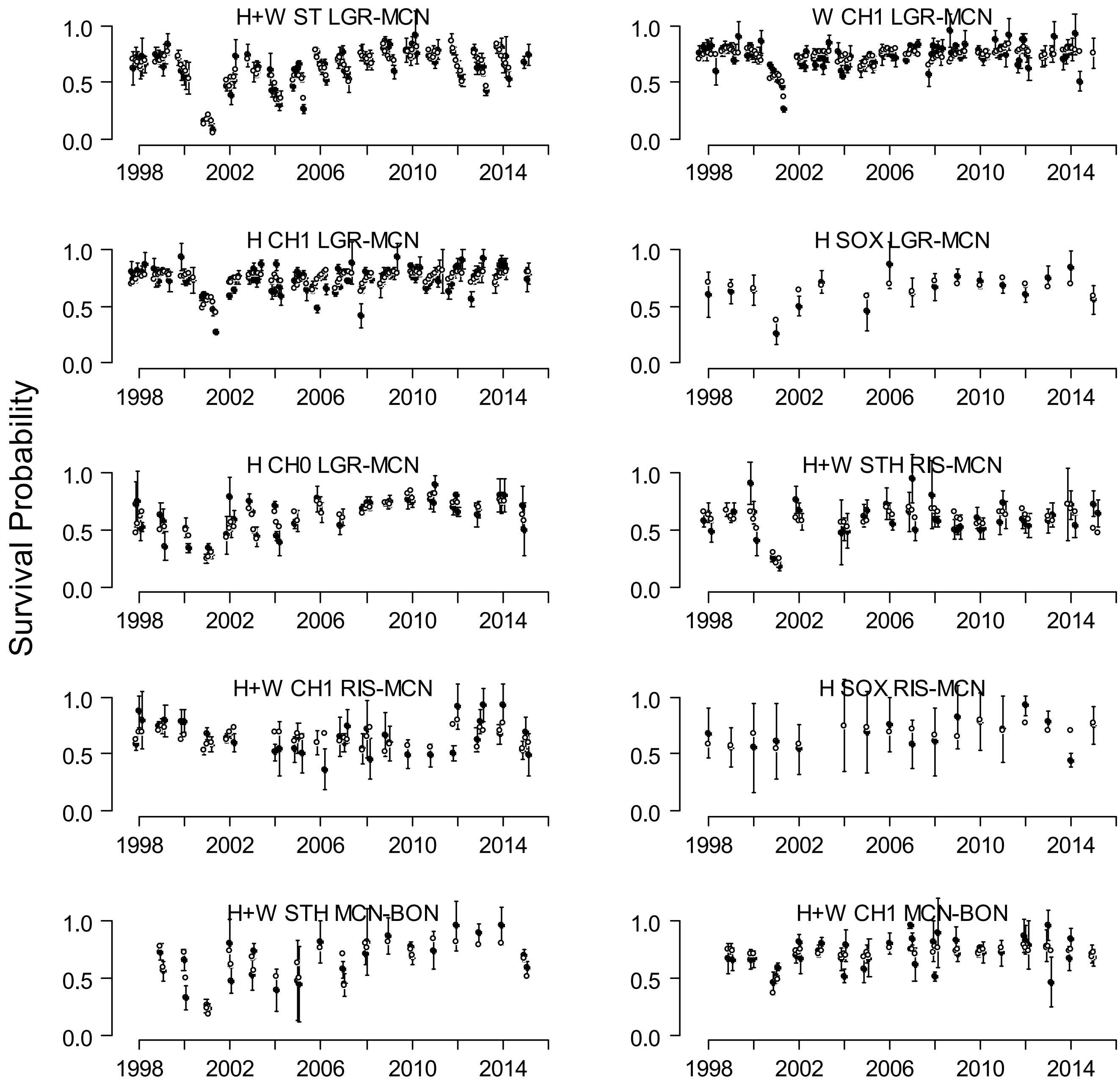


Figure 3.4 Estimates of in-river survival probability (black circles) and predicted in-river survival probability (open circles) for release cohorts of hatchery (H) and wild (W) steelhead (STH), yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and sockeye salmon (SOX) in the LGR–MCN, RIS–MCN and MCN–BON reaches, 1998–2015. The error bars represent +/- 1 SE.

In the RIS–MCN reach, cohorts of yearling Chinook, steelhead, and sockeye demonstrated within-year mean $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$ patterns similar to those observed in the LGR–MCN and MCN–BON reaches, varying considerably both within- and across-years (Figures 3.2,

3.3, and 3.4). For yearling Chinook and steelhead, mean $F\hat{T}T_i$ generally decreased over the migration season. Yearling Chinook in 2001 demonstrated the largest within-year variation in mean $F\hat{T}T_i$, ranging from 31 days early in the season to 20 days late in the season (Figure 3.2). Due to imprecision in the estimates of $\hat{S}_i$, general patterns in the estimates of $\hat{S}_i$ and $\hat{Z}_i$ in the RIS–MCN reach were difficult to discern (Figures 3.3 and 3.4). For both Chinook and steelhead, $\hat{Z}_i$ generally increased over the season. Steelhead $\hat{S}_i$ generally decreased over the season, but no general patterns were evident for Chinook $\hat{S}_i$.

Model-averaged coefficients and relative variable importance values indicated that Julian day, water transit time, spill, and the number of dams with spillway surface passage structures frequently were important factors for describing variability in *FTT* (Figure 3.5). The signs of the model coefficients for these variables indicated that juvenile yearling and subyearling Chinook, steelhead and sockeye migrated faster as water velocity increased (i.e., WTT was reduced) and as spill percentages increased. Relative variable importance values and the signs of the model coefficients indicated that juvenile yearling Chinook and steelhead also migrated faster as the season progressed. Because we were not able to develop within-season estimates of *FTT* for sockeye, we were not able to determine whether sockeye share similar increases in migration speed as Julian day increases. For steelhead in both the LGR–MCN and the MCN–BON reaches, wild yearling Chinook in the LGR–MCN reach, and subyearling Chinook in the LGR–MCN reach, the number of dams with spillway surface passage structures in place in combination with high spill levels was an important factor for characterizing variability in *FTT*, with the increasing number of surface passage structures at Little Goose, Lower Monumental, Ice Harbor and John Day dams reducing FTTs. However, for steelhead in the LGR–MCN and MCN–BON reaches, the relative variable importance values were high for the surface passage variable but low for the spill variable. Because surface passage structures require spill to function, a metric such as the proportion passing through spill may be a better measure for capturing the joint effects of variable spill levels and the installation of surface passage structures over time. Model-averaged coefficients and relative variable importance values indicated that steelhead, sockeye and yearling Chinook in the RIS–MCN reach all had faster FTT when WTT was reduced. Model-averaged predictions captured a very high degree of the variation in mean *FTT* of all species and reaches (Table 3.3).

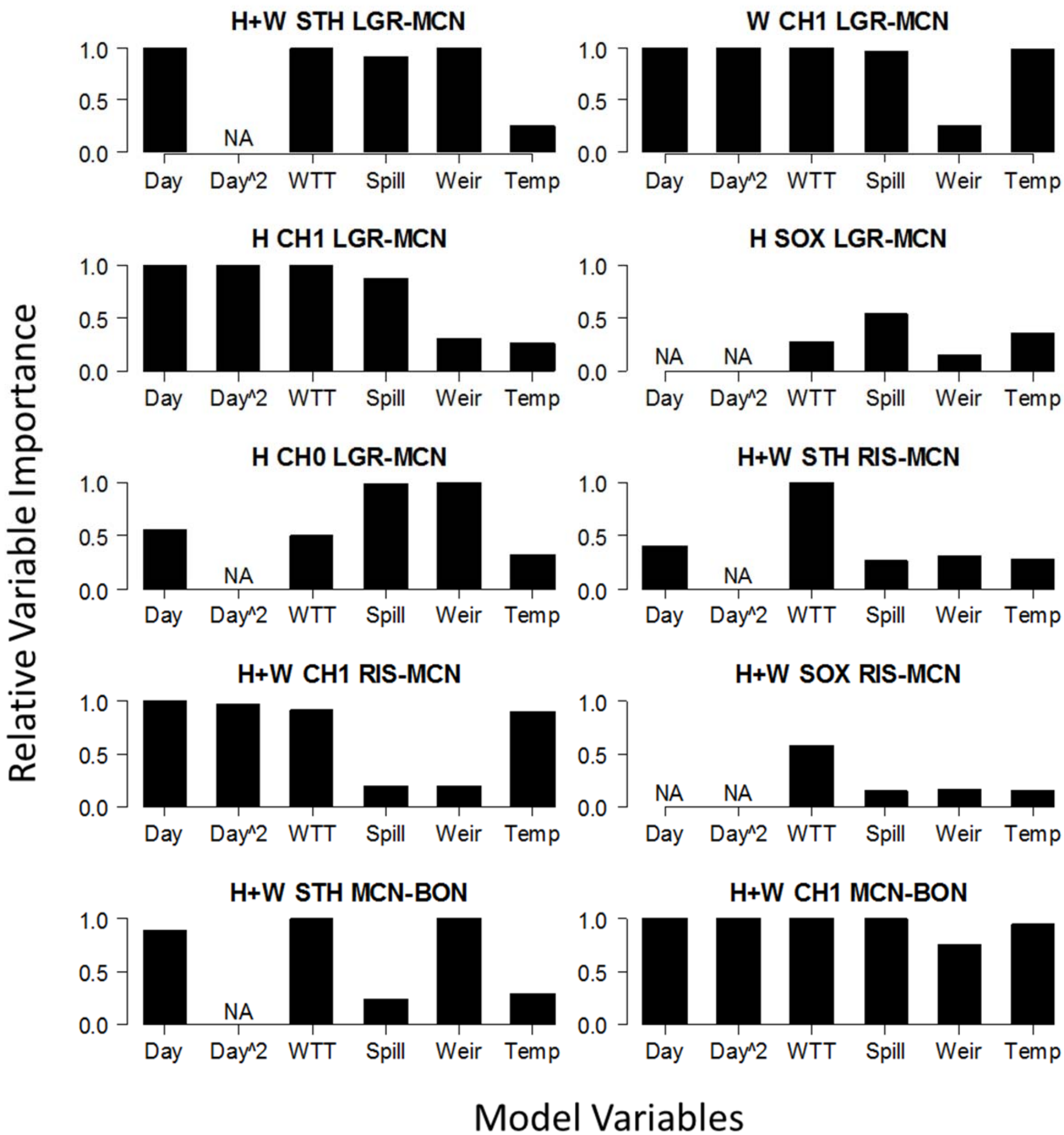


Figure 3.5 Relative variable importance values (y-axis) for fish travel time (FTT) models on release cohorts of hatchery (H) and wild (W) steelhead (STH), yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and sockeye salmon (SOX) in the LGR–MCN, RIS–MCN and MCN–BON reaches, 1998–2015. Model variables included: Julian day of cohort release (Day), the quadratic effect of Julian day of cohort release (Day^2), water transit time (WTT), average spill proportion (Spill), the number of dams with spillway weirs (Weir), and water temperature (Temp).

Table 3.3 Coefficient of determination values (R^2) in models characterizing yearling and subyearling Chinook salmon, steelhead, and sockeye salmon fish travel time (FTT), instantaneous mortality rates (*Z*) and in-river survival probabilities within the LGR–MCN, RIS–MCN and MCN–BON reaches. Model forms with the lowest AIC_C are identified and include the standard linear regression model (LR), a mixed-effect model with migration year as a random effect (MY), and a mixed-effect model with both migration year and Julian day as random effects (MY + Day).

			FTT		Z		Survival
Reach	Species	Rearing type	Model form	R^2	Model form	R^2	R^2
LGR-MCN	steelhead	hatchery and wild	MY + Day	0.97	MY + Day	0.86	0.91
LGR-MCN	yearling Chinook	wild	MY + Day	0.97	MY	0.36	0.43
LGR-MCN	yearling Chinook	hatchery	MY + Day	0.94	MY	0.29	0.51
LGR-MCN	sockeye	hatchery and wild	LR	0.53	LR	0.41	0.63
LGR-MCN	subyearling Chinook	hatchery and wild	MY + Day	0.94	LR	0.20	0.68
RIS-MCN	steelhead	hatchery and wild	MY	0.94	LR	0.30	0.52
RIS-MCN	yearling Chinook	hatchery and wild	MY	0.80	LR	0.15	0.19
RIS-MCN	sockeye	hatchery and wild	LR	0.26	LR	0.33	0.24
MCN-BON	steelhead	hatchery and wild	MY + Day	0.97	LR	0.53	0.76
MCN-BON	yearling Chinook	hatchery and wild	MY	0.96	MY	0.16	0.31

Model-averaged coefficients and relative variable importance values indicated that Julian day of release, spill, and water temperature were frequently the most important factors for characterizing the variability in *Z* (Figure 3.6). The signs of the model-averaged coefficients indicated that *Z* tended to increase over the migration season and as water temperatures increased, and tended to decrease as spill levels increased. Exceptions to these patterns included sockeye in both the RIS–MCN and LGR–MCN reaches, where the sign of the model-averaged coefficient suggested that *Z* decreased with increasing water temperatures. In addition, the increased number of surface passage structures was an important factor for reducing *Z* for sockeye in the LGR–MCN reach based on relative variable importance and the model-averaged coefficient values (Figure 3.6). Model-averaged predictions captured a moderate-high degree of the variation in *Z* across species and reaches (Table 3.3).

Combining the models for predicting mean FTT and *Z* resulted in generally high accuracy in predicting reach survival probabilities for the species-reach combinations that we examined (Table 3.4). As mentioned above, the models developed for FTT explained a very high proportion of the observed variation in FTT. Although the models for *Z* explained a lower proportion of the variability in *Z*, when the models for FTT and *Z* were combined to make predictions for survival probabilities, a relatively high proportion of the variation was captured. These results show that the models developed by the CSS are effective for characterizing and understanding sources of variation in the migration rates, mortality rates and survival probabilities of yearling and subyearling Chinook, steelhead and sockeye.

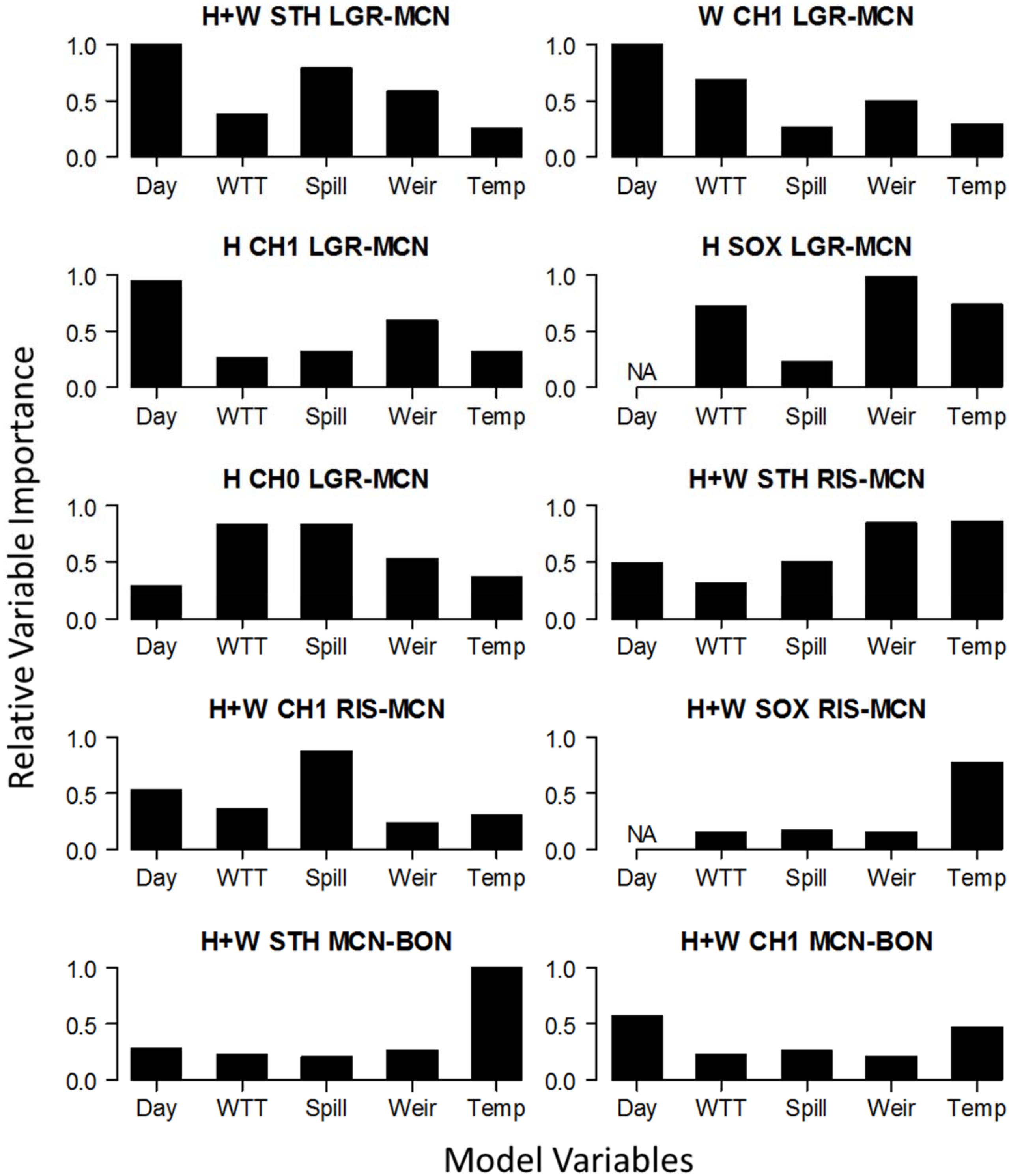


Figure 3.6 Relative variable importance values (y-axis) for instantaneous mortality rate (*Z*) models on release cohorts of hatchery (H) and wild (W) steelhead (STH), yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and sockeye salmon (SOX) in the LGR–MCN, RIS–MCN and MCN–BON reaches,

1998–2015. Model variables included: Julian day of cohort release (Day), water transit time (WTT), average spill proportion (Spill), the number of dams with spillway weirs (Weir), and water temperature (Temp).

Discussion

In this analysis we provided an extensive synthesis of the patterns of variation in juvenile yearling and subyearling Chinook, steelhead and sockeye fish travel time and survival within the hydrosystem. In addition to these commonly used metrics of fish travel time and survival, we also developed and reported estimates of instantaneous mortality rates, along with estimates of precision for those rates. We observed substantial variation in mean fish travel time, survival, and instantaneous mortality rates both within- and across-years.

Across the species and reaches that were evaluated, some consistent patterns emerge. Model-averaged coefficients and relative variable importance values indicated that fish travel time is fastest when WTT is reduced (i.e., higher water velocity) and spill levels are high. These results reflect the responses to the conditions that fish experience as they migrate through the series of reservoirs and dams in the hydropower system. The effect of WTT most likely influences the amount of time required to transit the reservoirs, with faster WTT resulting in faster fish travel time through the reservoirs. Faster WTT may also influence the amount of time required to migrate through the forebay, concrete, and tailrace areas of the dams. The effect of spill percentages most likely influences the amount of time required to migrate through the forebay, concrete and tailrace areas of the dams themselves. In the case of steelhead and subyearling Chinook, we found evidence that as the number of dams with surface passage structures has increased, fish travel times have declined, but there was less evidence of this for yearling Chinook.

There are also consistent patterns in terms of the factors that tend to influence the instantaneous mortality rates. Model-averaged coefficients and relative variable importance values indicated that mortality rates tend to increase over the migration season and with water temperature. In addition, the instantaneous mortality rates tend to be lower under conditions of higher spill levels. Potential mechanisms for the pattern of increasing mortality rates over the migration season and with water temperature could include (1) declining smolt energy reserves or physiological condition over the migration season and with water temperature, (2) increasing predation rates on smolts over the migration season and with water temperature, (3) increases in disease susceptibility or disease-related mortality over the migration season and with water temperature, or (4) some combination of these often interrelated mechanisms. Potential mechanisms for lower mortality rates with increasing spill levels include reduced forebay and tailrace predation levels as spill levels increase and increased spillway passage route proportions and reduced turbine passage route proportions with increased spill levels. For sockeye in the LGR-MCN reach, the increased number of dams with surface passage structures was associated with a reduction in mortality rates. It is interesting to note that there was an indication that mortality rates of sockeye appear to decline with increasing water temperatures (Figure 3.6). Although the data for sockeye are somewhat limited, this differential response to water temperature for sockeye compared to other species warrants further investigation. The combination of factors that influence fish travel time and instantaneous mortality are the factors that influence survival, and the results indicate that individual factors may be important to one or both of these rates (FTT and *Z*, Figures 3.5 and 3.6).

Generally, models for *FTT* fit significantly better than those for *Z* or survival. Analyses suggest that there are two reasons for this. First, the *FTT* data are relatively more variable (i.e., greater $CV_{cohorts}$, Tables 3.1 and 3.2), which provides relatively more variation to explain in *FTT* than for *Z* or survival. Second, the *FTT* data have greater precision than the *Z* or survival data, which helps to separate signals from sampling noise (Tables 3.1 and 3.2). Among the species analyzed, steelhead survival rates are more variable than yearling Chinook salmon, possibly due to greater sensitivity to environmental conditions. Although there is little that can be done to influence the variability among cohorts in response to the environmental and management factors that they experience, increasing precision of the Z and survival estimates is expected to increase the amount of variability that is explained.

These results indicate that improvements to fish travel time, mortality rates and survival may be possible through management actions that reduce WTT and increase spill percentages. There are only two means for reducing WTT: reducing reservoir elevations and/or increasing flow rates. Currently, only the reservoirs in the lower Snake River are maintained near their minimum operating elevations during the fish migration season. The McNary, John Day, The Dalles and Bonneville projects all operate several feet above their minimum operating elevations during the fish migration season. Even without a change in flow levels, the data indicate that there is opportunity to reduce fish travel time and increase survival through the MCN-BON reach if these four projects were to operate at their minimum operating pools. The data also indicate that there is an opportunity to reduce fish travel time and increase survival throughout the FCRPS through increases in spill levels up to the tailrace dissolved gas limits. Currently, none of the projects voluntarily operate up to the dissolved gas limit spill levels on a 24-hour basis. If all the projects were to do so, the data indicate that fish travel times are expected to be reduced, and as a consequence survival probabilities would be expected to increase.

The models developed and presented in this analysis could serve as a basis for conducting adaptive management experiments on the FCRPS. The models quantify the expected improvements that would occur through reductions in WTT and increases in spill percentages, and how those improvements may vary over the migration season. The essence of adaptive management is implementing experimental management actions and monitoring the biological responses to those management actions. The PIT-tagged fish that are released annually provide a reliable means for monitoring these types of adaptive management experiments. One recent example of an adaptive management experiment is the implementation of court-ordered summer spill at the Snake River collector projects. The PIT-tag data revealed a dramatic improvement in travel time and survival for subyearling fall Chinook salmon following the implementation of court-ordered summer spill. Similar adaptive management experiments, such as reducing WTT in the MCN–BON reach or dissolved gas limit spill operations on a 24-hour basis, could reveal similarly dramatic improvements for yearling and subyearling Chinook, steelhead and sockeye.

We see these models as powerful tools for continued development, evaluation, and refinement of alternative hypotheses on the effects of various environmental and management factors on smolt survival probabilities and migration rates. However, improvements in the precision (i.e., measurement error) of the survival estimates in the MCN–BON reach and the RIS–MCN reach could be useful for further evaluating the effects of various environmental and management factors. In these two reaches, confidence intervals are relatively wide, making it difficult to separate process variability from measurement error. There are two means for improving precision of these survival estimates: increasing the number of PIT-tagged fish or

increasing the detection probabilities at the dams. Increasing the number of PIT-tagged fish that are released would help improve precision, but it likely would require a large increase to substantially improve precision. In contrast, we believe that increasing the detection efficiency through spillway detection systems has a greater potential to improve the precision in the survival estimates. In addition to helping improve survival estimate precision, spillway detection systems could also help further elucidate emerging issues of delayed mortality associated with powerhouse passage relative to spillway passage. Further work is needed to evaluate where a spillway detection system would be most beneficial, but we see this as an important issue that should be pursued within the region.

CHAPTER 4
PATTERNS IN ANNUAL OVERALL SARS

Success of any hydrosystem mitigation strategy will require achievement of smolt-to-adult survival rates sufficient to meet recovery and rebuilding objectives, in combination with a program to maintain or achieve adequate survival in other life stages. An independent peer review of the transportation program in the early 1990s (Mundy et al. 1994) concluded: "[u]nless a minimum level of survival is maintained for listed species sufficient for them to at least persist, the issue of the effect of transportation is moot."

The Northwest Power and Conservation Council (NPCC 2003, 2009, 2014) adopted a goal of achieving overall SARs (including jacks) in the 2%–6% range (4% average; 2% minimum) for federal ESA-listed Snake River and upper Columbia River salmon and steelhead. For the populations in these listed groups, an overall SAR is the SAR that includes the survival of all outmigrating smolts weighted across their different in-river and transport route experiences; it is the SAR of an entire cohort of smolts, irrespective of their route of passage through the hydrosystem. The NPCC (2009) Fish and Wildlife Program objectives for unlisted populations or listed populations downstream of the Snake River and Upper Columbia River basins are to "significantly improve the smolt-to-adult return rates (SARs) for Columbia River Basin salmon and steelhead, resulting in productivity well into the range of positive population replacement."

The NPCC (2009 and 2014) also adopted a strategy to identify the effects of ocean conditions on anadromous fish survival and use this information to evaluate and adjust inland actions. The NPCC noted that while we cannot control the ocean, we can monitor ocean conditions and related salmon survival and take actions to improve the likelihood that Columbia River salmon can survive varying ocean conditions. A better understanding of the conditions salmon face in the ocean can suggest which factors will be most critical to survival, and thus provide insight as to which actions taken inland will provide the greatest restoration benefit. Analyses in this chapter address the extent to which wild spring/summer Chinook and steelhead population aggregates may be meeting the NPCC (2014) biological objectives. Parameters estimated in the CSS allow for partitioning from SARs estimates of marine survival rates from the stage smolts enter the estuary to adult return, *S.oa* (Haeseker et al. 2012), and first year ocean survival rates, *S.o1* (Wilson 2003; Zabel et al. 2006; Petrosky and Schaller 2010; Tuomikoski et al. 2012). These survival rates can then be used to evaluate ocean and smolt migration factors that may influence ocean survival as called for in the Fish and Wildlife Program (NPCC 2009).

The NPCC 2%–6% SAR objectives are consistent with analyses conducted by the Plan for Analyzing and Testing Hypotheses (PATH), in support of the 2000 Biological Opinion of the Federal Columbia River Power System (FCRPS). Marmorek et al. (1998) found that median SARs of 4% were necessary to meet the NMFS interim 48-year recovery standard for Snake River spring/summer Chinook; meeting the interim 100-year survival standard required a median SAR of at least 2%. The NPCC (2009 and 2014) SAR objectives did not specify the points in the life cycle where Chinook smolt and adult numbers should be estimated. However, the original PATH analysis for Snake River spring/summer Chinook was based on SARs calculated as adult

and jack returns to the uppermost dam (Marmorek et al. 1998). PATH analyses also did not identify specific SARs necessary for steelhead survival and recovery. However, before completion of the FCRPS, steelhead SARs were somewhat greater than those of spring/summer Chinook (Marmorek et al. 1998). The Interior Columbia River Technical Recovery Team (ICTRT 2007) developed biological recovery criteria based on the Viable Salmonid Population concepts (McElhany et al. 2000). Additional SAR objectives may be associated with the ICTRT recovery criteria for abundance and productivity when adopted or incorporated into a Recovery Plan, as well as with the objectives identified in Fish and Wildlife Program subbasin plans, and other State and Tribal fishery management plans. The Independent Scientific Advisory Board (ISAB 2012) review of the 2012 CSS draft annual report also highlighted the NPCC SAR objectives as an important regional programmatic issue. Regardless of specific future SAR objectives, the same types of data and analytical methods will be required to evaluate the overall effectiveness of hydrosystem actions in addressing recovery and mitigation goals. The time series of SARs, which the CSS is developing for various populations throughout the Columbia Basin, will be invaluable in addressing multiple long-term programmatic goals and objectives. To address these multiple objectives, we present bootstrapped SARs and confidence intervals based on CSS PIT-tagged adult returns to both Bonneville Dam (BOA) and the uppermost dam for Snake River and Yakima River fish (e.g., Lower Granite Dam, GRA; and McNary Dam, MCA). Alternative SAR objectives will likely require enumerating smolts and adults at different locations, depending on how broadly the objective is defined. That is, different adult accounting locations would be required if a SAR objective was defined narrowly for population persistence or more broadly to maintain productive natural populations with sustainable fisheries. A SAR objective for persistence may need to account for adults returning to the spawning grounds, whereas broader objectives would also need to account for adults returning to various locations to meet harvest objectives (e.g., subbasin or Columbia River mouth).

Most SAR estimates in this report are based on smolts at the uppermost FCRPS dam with juvenile detection capability (Lower Granite, McNary, John Day or Bonneville), and adults at either Bonneville Dam or the uppermost dam. PIT-tagged smolts and returning adults from the upper Columbia region pass an additional three to five Public Utility District (PUD) dams upstream of MCN (Wenatchee — three dams, Entiat — four dams, Methow — five dams) that do not have full juvenile PIT tag detection capabilities. Therefore, smolt migration mortality that occurs upstream of MCN is not accounted for in these SAR estimates and the portion of the life cycle and hydrosystem migration experience represented is less than that for SAR estimates for the Snake River and Mid-Columbia salmon and steelhead populations. We have made preliminary comparisons of the overall SAR estimates for wild groups to the NPCC 2%–6% SAR objectives, recognizing additional accounting for harvest, straying and other upstream passage losses may be needed in the future as NPCC and other SAR objectives are clarified. We also compare SARs of hatchery groups to the 2%-6% SAR objectives, recognizing that hatchery stocks have different mitigation and management objectives than wild populations.

To compare historical population productivity in the smolt-to-adult life stage necessitates accounting for changes in mainstem harvest rates and upstream passage success (Petrosky and Schaller 2010). Mainstem Columbia River harvest rates decreased markedly in the 1970s following construction of the FCRPS and the decline in abundance and productivity of upriver Columbia and Snake River populations. Therefore, we also present a time series of SARs for Snake River wild spring/summer Chinook and steelhead based on smolts at the uppermost dam to adult returns to the Columbia River mouth for the 1964 to 2013 (steelhead) or 2014 (Chinook)

smolt migration years; this time frame spans completion of the FCRPS, decreases in Columbia River harvest rates, and a period of variable ocean conditions.

The NPCC 2%–6% SAR objective for Chinook addresses the total adult return including jacks (i.e., 1-salt male Chinook). Therefore, in this chapter we present estimates of overall Chinook SARs with jacks included and the CSS standard reporting statistic of SARs with jacks excluded. Most other Chinook analyses in this and previous reports, are based strictly on adults (age 2-salt and older). These calculations include the generation of SARs by study category, TIR, *D*, and adult upstream migration success rates. By using only 2-salt and older returning spring/summer Chinook adults in the estimation of the key CSS parameters, we are assuring that the results will be more directly reflective of the primary spawning populations (females and older males) in each Chinook ESU, region or subbasin. This is consistent with previous population viability (persistence) analyses (Marmorek et al. 1998; STUFA 2000; Karieva et al. 2000; Deriso et al. 2001; Peters and Marmorek 2001; Wilson 2003; Zabel et al. 2006; ICTRT 2007).

The primary objectives for Snake River wild and hatchery spring/summer Chinook and steelhead are to update the long-term SAR data series for CSS study fish, and to begin reporting SARs at finer geographic scales. In the 2016 annual report, we also estimate SARs of wild spring/summer Chinook groups from the Grande Ronde/Imnaha, South Fork Salmon, Middle Fork Salmon, Upper Salmon and Clearwater Major Population Groups (MPGs) for smolt migration years 2006–2014. (Note: we further subdivided SARs into subbasin for the Grande Ronde/Imnaha MPG in this report). The overall SARs are presented for all 21 years of PIT-tagged wild spring/summer Chinook data and 18 years of PIT-tagged hatchery spring/summer Chinook data. Overall SARs for Snake River aggregate wild and aggregate hatchery steelhead are presented for 17 years beginning in 1997. We also calculated SARs for Snake River wild steelhead at an MPG level (Clearwater, Grande Ronde, Imnaha, Salmon) and for A-run and B-run wild steelhead, smolt migration years 2006–2013. SARs are calculated as adult returns to either Bonneville Dam (BOA) or Lower Granite Dam (GRA).

Personnel involved with the CSS, Lower Snake River Compensation Plan (LSRCP), and Idaho Power Company (IPC) coordinated efforts to increase the PIT tagging of Snake River hatchery spring/summer Chinook and steelhead. All Snake Basin hatchery spring/summer Chinook major production releases upstream of Lower Granite Dam now have representative PIT tag releases with the addition of groups from Clearwater Hatchery spring Chinook (first year representation, 2006), Sawtooth Hatchery spring Chinook (2007), Pahsimeroi Hatchery summer Chinook (2008) and Clearwater Hatchery summer Chinook (2011). Increased hatchery steelhead tagging began in migration year 2008 so key parameters could be estimated at a finer resolution of run-type and subbasin for Grande Ronde River A-run (GRN-A), Imnaha River A-run (IMN-A), Salmon River A-run (SAL-A), Hells Canyon Dam A-run (HCD-A), Salmon River B-run (SAL-B), and Clearwater River B-run (CLW-B) steelhead groups.

The objective for Snake River sockeye is to continue the data series of SARs. PIT tagging of Snake River hatchery sockeye began in migration year 2009 as a Corps of Engineers study and is continuing under the CSS; we report the overall SARs from Sawtooth and Oxbow hatcheries for migration years 2009–2014.

The primary objective for mid-Columbia River (BON to PRD) wild and hatchery spring Chinook and steelhead is to update SAR data series for subbasins in this region. Overall SARs

for smolt migration years 2000–2014 are presented for wild spring Chinook from the John Day River and Yakima River. For hatchery spring Chinook, overall SARs from 2000 to 2014 are presented for Carson and Cle Elum hatcheries and for Warm Springs Hatchery spring Chinook during 2007–2014. Overall SARs are also presented for wild steelhead from the John Day River (2004–2013), Deschutes River (2007–2012) and Yakima River (2002–2013). SARs are calculated as adult returns to Bonneville Dam (BOA), and for Yakima stocks as adult returns to both McNary Dam (MCA) and BOA.

The primary objectives for upper Columbia River (above PRD) wild and hatchery spring Chinook and steelhead are to develop and update SAR data series for subbasins in this region, and to begin SAR data series for wild summer Chinook and sockeye. We estimated MCN–BOA SARs for wild spring Chinook from the Entiat/Methow River (2006–2014) and Wenatchee River (2007–2014); Leavenworth hatchery spring Chinook (2000–2014); wild steelhead (Wenatchee, Entiat and Methow rivers from 2006 to 2013); and hatchery steelhead released into the Wenatchee River (2003–2013). Because of the limited ability to detect PIT-tagged juvenile out-migrants in the Columbia River upstream of MCN, the CSS has begun to estimate SARs of Upper Columbia wild spring Chinook and steelhead populations upstream from Rocky Reach Dam (RRE) using smolt abundance estimates at RRE for smolt migration years 2008–2013 (through 2014 for spring Chinook). In the 2016 report, we added a new group for wild summer Chinook upstream of Wells Dam for smolt migration years 2011-2013. We also added a new group for Okanogan River sockeye, in coordination with the Okanogan Nation Alliance (ONA) for wild juveniles tagged in the Okanogan River Basin (primarily in Osoyoos and Skaha lakes); RRE-BOA SARs are estimated for smolt migration years 2013-2014. In addition, we have included time series of SARs using Fish Passage Center Smolt Monitoring Program (SMP) tagging of combined hatchery/wild groups of yearling Chinook, subyearling Chinook, steelhead and sockeye at Rock Island Dam (RIS) in an attempt to develop SARs that include a fuller portion of the migration experience through the hydrosystem. In this report, SARs are calculated as adult returns to Bonneville Dam (BOA) and in future reports CSS will also report SARs as adult returns to McNary (MCA), Priest Rapids and other PUD dams as adult detection capability allows.

Methods

Overall SARs are based on PIT-tagged fish that experienced the same conditions as untagged smolts under a given year's fish passage management scenario. Beginning in migration year 2006, this "run at large" group in the Snake River was represented by the Group T (Chapter 1 and Figure A.1). Prior to 2006 in the Snake River, we estimated the proportion of run at large represented by each study group T_0, C_0 and C_1. The CSS 2009 Annual Report (Tuomikoski et al. 2009) found good agreement between overall SARs computed with the pre-2006 and 2006 methods.

Estimation of 90% confidence intervals for annual SARs applicable to all mark populations

Nonparametric 90% confidence intervals are computed around the estimated annual overall SARs for both Snake and Columbia River basin PIT-tagged salmonid populations. The nonparametric bootstrapping approach of Efron and Tibshirani (1993) is used where first, the

point estimates are calculated from the sample for each population, and then the data are re-sampled with replacement to create 1,000 simulated samples (Berggren et al.2002, Chapter 4). These 1,000 iterations are used to produce a distribution of annual SARs from which the value in the 50th ranking is the lower limit and value in the 951st ranking is the upper limit of the resulting 90% nonparametric confidence interval.

Snake River basin populations originating above Lower Granite Dam

Estimation of overall annual SARs for pre-2006 smolt migration years

Annual estimates of LGR-to-GRA SAR reflective of the run-at-large for wild steelhead, hatchery steelhead, wild spring/summer Chinook, and hatchery spring/summer Chinook that out-migrated in 1997 (1994 for wild Chinook) to 2005 are made by weighting the SARs computed with PIT-tagged fish for each respective study category by the proportion of the run-at-large transported and remaining in-river. The proportions of the run-at-large reflected by each of the CSS study categories C_0, C_1 and T_0 were estimated as follows. First, the number of PIT-tagged smolts t_j that would have been transported at each of the three Snake River collector dams (j = 2 for LGR, j = 3 for LGS, and j = 4 for LMN) if these fish had been routed to transportation in the same proportion as the run-at-large is estimated. This estimation uses run-at-large collection and transportation data for these dams from the SMP in the weighting. The total estimated number transported across the three Snake River collector dams in LGR equivalents equals $T_0^* = t_2+t_3/S_2+t_4/(S_2S_3)$, where S_2 is the LGR-to-LGS reach survival rate and the product S_2*S_3 is the LGR-to-LMN reach survival rate. When a portion of the collected run-at-large fish is being bypassed as occurred in 1997, then there will be a component of the PIT-tagged fish also in that bypass category (termed C_1^* in this discussion). In most years, the C_1^* is at or near zero. When run-at-large bypassing occurs, $C_1^* = (T_0 + C_1) - T_0^*$. The sum of estimated smolts in categories C_0 (calculated using Equation A.2 from Appendix A), T_0^*, and C_1^* is divided into each respective category's estimated smolt number to provide the proportions to be used in the weighted SAR computation.

The proportion of the run-at-large that each category of PIT-tagged fish represents is then multiplied by its respective study category-specific SAR estimate, i.e., $SAR(C_0)$, $SAR(C_1)$, and $SAR(T_0)$, and summed to produce an annual overall weighted $SAR_{LGR\text{-}to\text{-}LGR}$ for each migration year except 2001 as follows:

$$\begin{aligned} SAR_{Annual} &= w\left(T_0^*\right) * SAR\left(T_0\right) \\ &+ w\left(C_0^*\right) * SAR\left(C_0\right) \\ &+ w\left(C_1^*\right) * SAR\left(C_1\right) \end{aligned}$$

where,

$$T_0^* = \left(t_2\right) + \left(\frac{t_3}{S_2}\right) + \left(\frac{t_4}{S_2 * S_3}\right)$$

and,

$$C_1^* = (T_0 + C_1) - T_0^*$$

reflect the number of PIT-tag smolts in transport and bypass categories, respectively, if collected PIT-tag smolts were routed to transportation in the same proportion as run-at-large; and

$$w(T_0^*) = \frac{T_0^*}{(T_0^* + C_0 + C_1^*)}$$

is the transported smolt proportion,

$$w(C_0) = \frac{C_0}{(T_0^* + C_0 + C_1^*)}$$

is the non-detected (LGR, LGS, LMN) smolt proportion, and

$$w(C_1^*) = 1 - w(T_0^*) - w(C_0)$$

is the bypass (LGR, LGS, LMN) smolt proportion.

Estimation of overall annual SARs in smolt migration year beginning 2006

With the approach of pre-assigning part of the PIT-tagged release group into a monitor-mode group (called Group T) that follows the routing of the untagged population through collector dams, fewer parameters (than was the case before 2006) need to be estimated during intermediate steps before arriving at the final overall SAR estimate. The estimation of the annual overall SAR is simply the number of returning adults in Group T divided by the estimated number of smolts arriving LGR (both detected and undetected). The estimated number of PIT-tagged smolts arriving LGR is obtained by multiplying the release number in Group T by the estimated S_1 (survival rate from release to LGR tailrace) obtained from running the CJS model on the total release. Group T reflects the untagged fish passage experience under a given year's

fish passage management actions. SARs for this report represent adult returns through September 16, 2016.

Characterizing the relationship between ln(TIR) and in-river survival (S_R) – Snake River wild Chinook and steelhead

The parameter TIR is a comparison of smolt to adult survival rates for two disparate out-migration types: one where fish are collected from the river and transported via barge around the series of dams and reservoirs and one where fish are allowed to migrate in-river. Survival during the smolt stage aboard the transportation barges is assumed to be high (see Appendix A, equation A.16), whereas in-river survival through the hydrosystem (S_R) for smolts is quite variable across years (Appendix A). Therefore, the effectiveness of transportation as measured using the TIR should be partly dependent on the magnitude of juvenile in-river survival. Higher survival in-river should result in lower TIR.

We evaluated the hypothesis that TIRs were related to the in-river survival of wild Chinook and wild steelhead cohorts. Estimates of smolt survival (S_R) from Lower Granite Dam to Bonneville Dam were available as part of the estimation of SARs. Data from migration years 1994 to 2013 were included in the analysis. These data (S_R) were presented in Appendix A. Methods of estimation can also be found in Appendix A. We then used the ratio of transport SAR (Tx) to in-river SAR (C0) expressed as Tx/C0 or TIR.

Various transformation options for the TIR response variable were evaluated. Based on evaluation of quantile plots of transformed data the natural log transformation appeared most useful for normalizing the data. Information theoretic regression analysis was used to evaluate both transformations of the explanatory variable (S_R) and whether to evaluate each species together or by using separate coefficients for species. We evaluated all models using multi-model comparisons based on AICc.

Middle and Upper Columbia River basin populations

Estimation of overall annual SARs in all smolt migration years

Estimation of overall SARs for mid-Columbia and upper Columbia spring Chinook and steelhead and for upper Columbia summer Chinook and sockeye uses an estimate of the respective PIT-tagged smolt population arriving at the first monitored Columbia River dam below its release location and the corresponding Bonneville Dam (and McNary Dam for Yakima populations) detections of returning adults. PIT-tagged smolt numbers of Leavenworth and Cle Elum Hatchery spring Chinook, for example, are estimated at MCN and exclude PIT-tagged smolts transported from MCN during the NOAA transportation studies of 2002 to 2005. PIT-tagged smolt numbers of John Day River wild spring Chinook and steelhead are estimated at JDA, and those of Deschutes River (Trout Creek) wild steelhead are estimated at BON. Numbers of PIT-tagged spring Chinook smolts from Carson Hatchery are estimated at BON in years when the release-to-BON survival rate is estimated <1. An overall SAR from hatchery release as smolt to BON as adult is also estimated for Carson Hatchery and Warm Springs Hatchery spring Chinook in all available years. Nonparametric 90% confidence intervals are

estimated with the same bootstrapping protocol as used for the Snake River stocks. SARs represent adult returns through September 16, 2016.

Survival rate time series: SAR, S.oa and S.o1

The CSS has compiled a historical time series of SARs for Snake River wild spring/summer Chinook and steelhead beginning in 1964 prior to completion of the FCRPS. For years prior to the CSS PIT-tag based estimates, SARs were based on run reconstruction (RR) of smolt numbers at the uppermost Snake River dam and adults returning to the Columbia River from literature sources (Raymond 1988; Marmorek et al. 1998; Petrosky et al. 2001; Petrosky and Schaller 2010).

As requested in the ISAB/ISRP (2007) review of the CSS Ten-Year Retrospective Report (Schaller et al. 2007), we continued the comparison of Snake River wild spring/summer Chinook SARs based on PIT-tags and RR for 1996–2012, with an objective of evaluating hypotheses for possible sources of bias in both the PIT-tag and RR SARs.

Ocean survival rates (*S.oa*) from smolts entering the estuary (at BON) to adults returning to GRA or the Columbia River mouth and first year ocean survival (*S.o1*) estimates were back-calculated from the overall SAR estimates for Snake River wild spring/summer Chinook and steelhead while taking into account year-to-year variability in hydrosystem survival and age composition of returning adults to the Columbia River mouth. In this Chapter the term survival rate refers to survival through a fixed life stage.The method of deconstructing SARs into first year ocean survival rates used here is described in Petrosky and Schaller (2010), and is consistent with approaches used in STUFA (2000; Appendix D), Wilson (2003), and Zabel et al. (2006). Both *S.oa* and *S.o1* represent marine survival of in-river migrants. Transported smolts are expressed as in-river equivalents by adjusting their Bonneville arrival numbers by the estimate of *D* (Petrosky and Schaller 2010). Although this differential delayed mortality is likely expressed primarily during the early marine stage, we apply it to the downstream migration stage (system survival), because it simplifies calculation of the early ocean survival rate and is consistent with earlier analyses (cited above). *S.oa* is calculated as the survival rate of in-river migrants below Bonneville Dam to adult return (including jacks) to both Lower Granite Dam and the Columbia River mouth. *S.o1* is back-calculated from the age-structured recruits to the Columbia River mouth, assuming 80% annual survival of sub-adults. This is consistent with other cohort-based Chinook modeling studies (e.g., Pacific Salmon Commission 1988), and assigns all ocean survival rate variability to the *S.o1* life stage. Estimates of *S.oa* and/or *S.o1* can then be used to evaluate ocean and smolt migration factors that may influence ocean survival as called for in the Fish and Wildlife Program (NPCC 2009).

In this report, we present estimates of SAR, *S.oa* and *S.o1* based on CSS PIT-tag data for Snake River wild Chinook and steelhead (smolt migration years 1994–2013 and 1997–2013, respectively). Estimates of SAR, *S.oa* and *S.o1* based on run reconstruction for years prior to 1994 (Chinook) or 1997 (steelhead) were presented in the 2012 CSS annual report (Tuomikoski et al. 2012, Tables 4.40 and 4.41).

Results

Snake River Overall SARs

Historical Snake River wild spring/summer Chinook SARs (upper dam smolts-to-Columbia River returns, jacks included) decreased four-fold from pre-FCRPS completion in the 1960s to post-FCRPS during the 1990s and 2000s (Figure 4.1). No estimates of wild spring/summer Chinook smolt numbers or SARs were available for 1985–1992 due to insufficient marking those years (Petrosky et al. 2001). The geometric mean SAR during 1964–1969 was 4.3% compared to 1.0% during 1994–1999 and 1.1% since 2000.

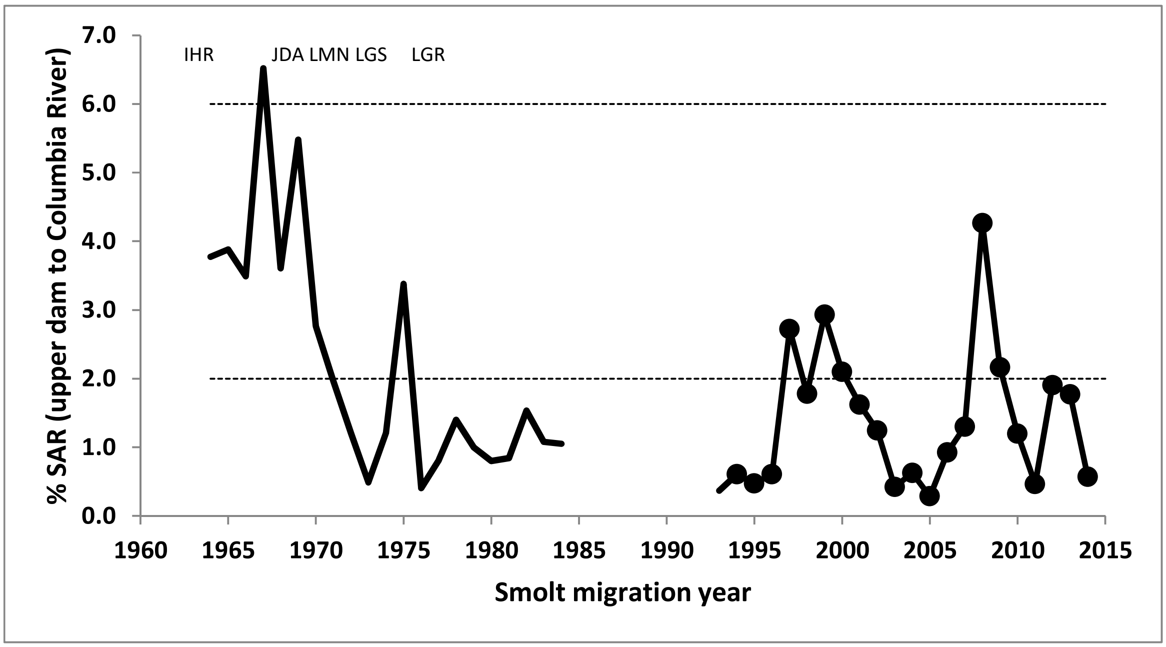


Figure 4.1 SARs from smolts at uppermost Snake River dam to Columbia River returns (including jacks) for Snake River wild spring/summer Chinook, 1964-2014. Dam construction sequence was: 1961-IHR, 1968-JDA, 1969-LMN, 1970-LGS, 1975-LGR. SARs based on run reconstruction (1964-1984 and 1993, solid line) and CSS PIT tags (1994-2013, dots and solid line). The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference; SAR for 2014 is complete through 2-salt returns only.

SARs (LGR-to-GRA, jacks included) of PIT-tagged Snake River wild spring/summer Chinook had a geometric mean of 0.87% and exceeded the NPCC's minimum SAR objective of 2% in only two migration years (1999 and 2008) during the period 1994–2014 (Table B.1; Figure 4.2 top left plot). LGR-GRA SARs with jacks included were about 9% higher (geometric mean of SAR ratios) than SARs with jacks excluded (Table B.1). SARs based on jack and adult returns to BOA were about 25% greater (geometric mean of SAR ratios) than SARs based on returns to GRA (Table B.2) because of the combined effect of dam passage loss, straying and Zone 6 harvest. The CSS also estimated Snake River wild spring/summer Chinook SARs at an MPG scale for the 2006–2014 smolt migration years. SARs were correlated (average r = 0.86) and appeared generally similar among the Snake River spring/summer Chinook MPGs, except that the SARs (LGR-GRA, jacks included) of the unlisted, reintroduced Clearwater River Chinook were somewhat lower (geometric mean 0.58%) than the range of SARs for the other

MPGs (0.97% to 1.32%; Tables B.3–B.14; Figure 4.3). SARs were highest in 2008 and very low in 2006 and 2011 for all MPGs.

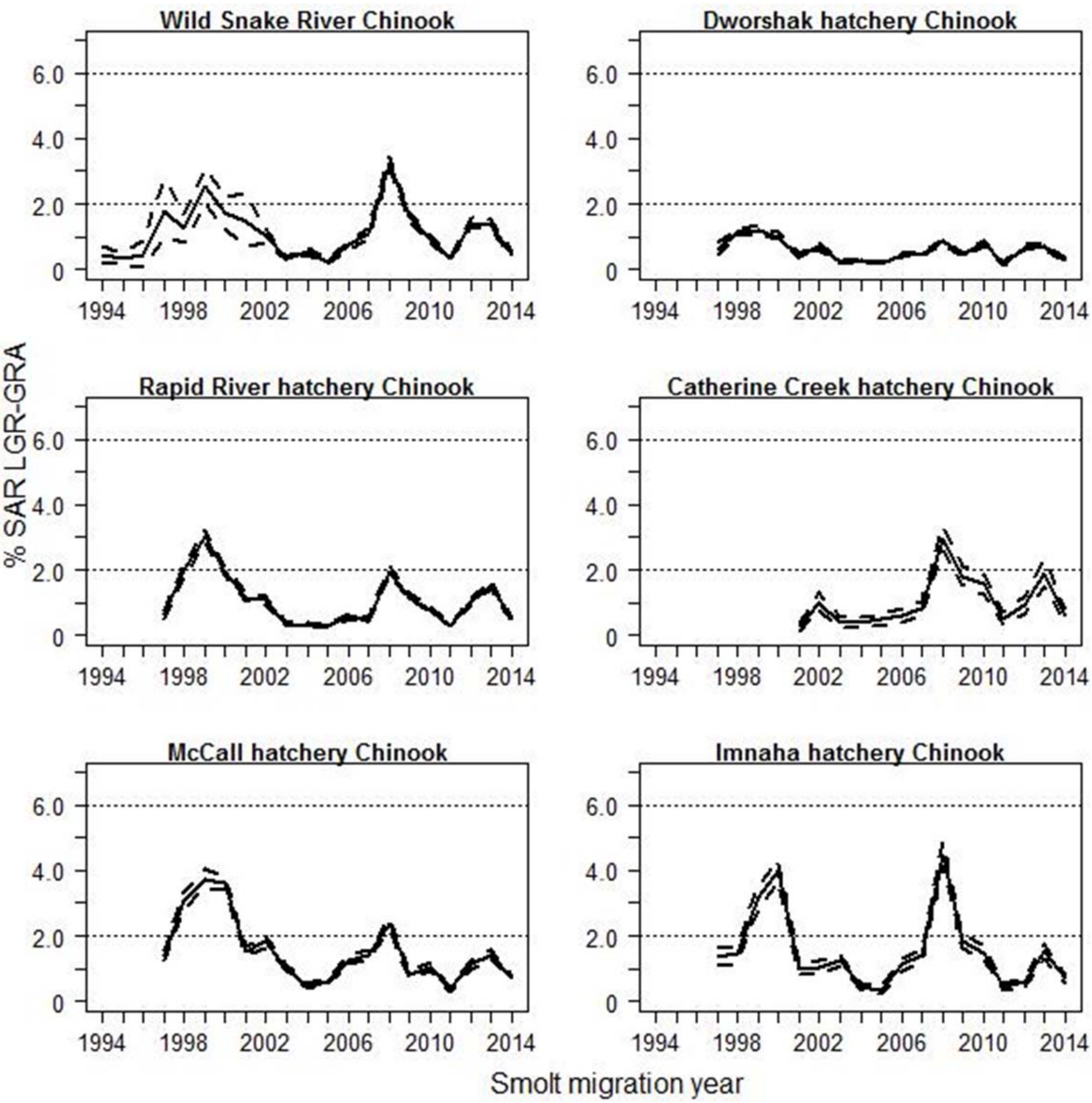


Figure 4.2. Bootstrapped LGR-to-GRA SAR (with jacks included) and upper and lower CI for Snake River wild spring/summer Chinook and five Snake River hatchery groups for migration years 1994–2014. Migration year 2014 is complete through 2-salt returns only. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

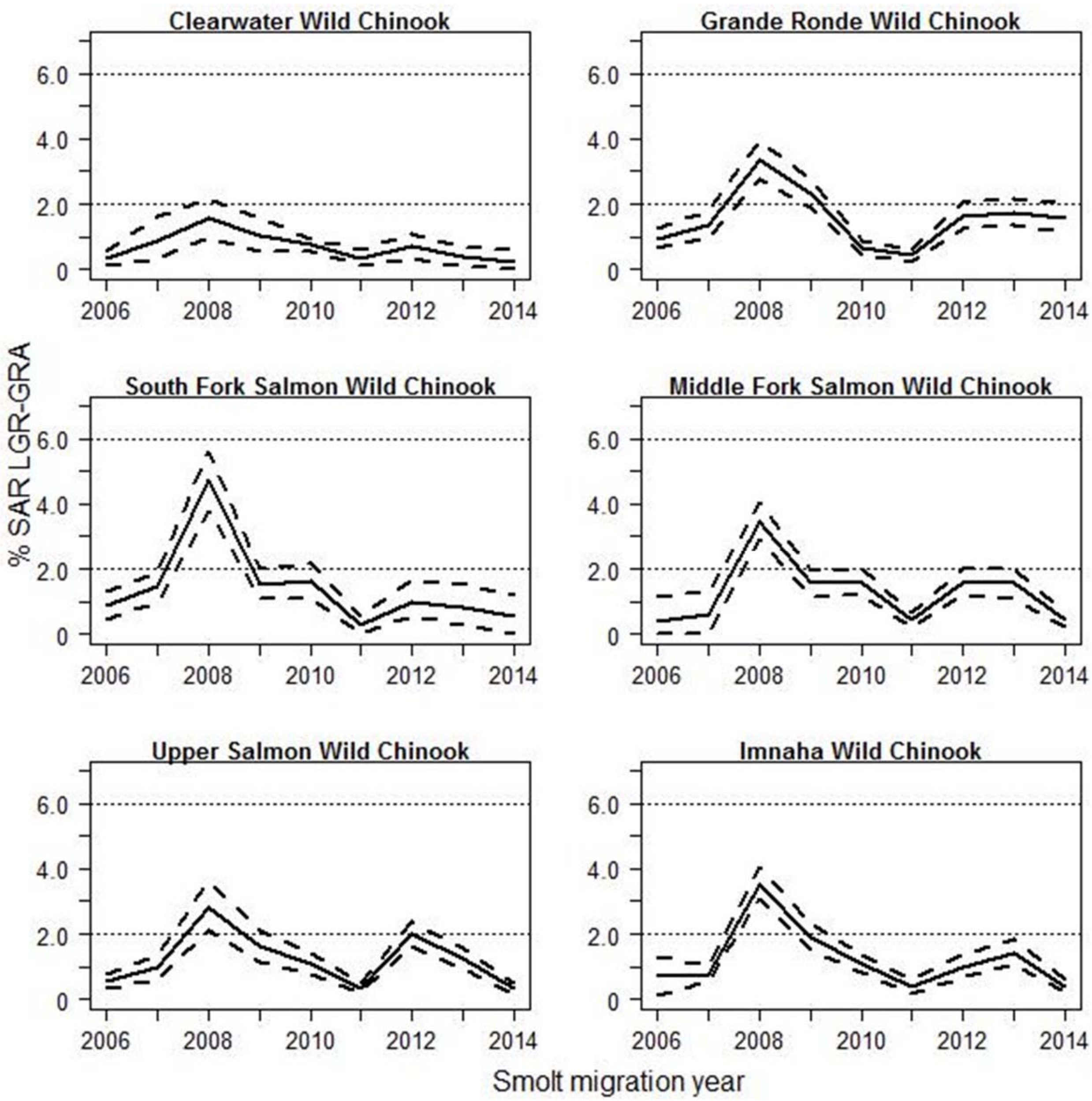


Figure 4.3. Bootstrapped LGR-to-GRA SAR (with jacks included) Snake River wild spring/summer Chinook Major Population Groups for smolt migration years 2006–2014. Migration year 2014 is complete through 2-salt returns only. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

The estimated overall SARs for Snake River hatchery spring and summer Chinook varied by hatchery and year (Figure 4.2; Tables B.15-B.24). LGR-GRA SARs (jacks included) for Dworshak hatchery spring Chinook averaged (geometric mean) 0.51% and did not exceed 2% in any year during 1997–2014 (Table B.15). LGR-GRA SARs for Rapid River hatchery spring Chinook averaged 0.83% and exceeded 2% in a single year (1999; Table B.17). Catherine Creek hatchery Chinook SARs from 2001 through 2014 averaged 0.80% and exceeded 2% only in 2008 (Table B.19). In general, the two hatchery summer Chinook populations had higher SARs

than the hatchery spring Chinook populations. LGR-GRA SARs for McCall hatchery summer Chinook averaged (geometric mean) 1.27% and exceeded 2% in four years (1998–2000 and 2008; Table B.21). LGR-GRA SARs for Imnaha hatchery summer Chinook averaged 1.19% and exceeded 2% in three years (1999, 2000 and 2008; Table B.23). Although some difference in magnitude of SARs between groups was noted, the trends in the overall SARs (LGR-GRA) of Snake River wild and hatchery Chinook groups were similar and highly correlated (average r = 0.79) during 1997–2014.

The estimated overall SARs for additional Snake River hatchery spring and summer Chinook groups for migration years 2006–2014 are presented in Figure 4.4 and Tables B.25–B.32. LGR-to–GRA SARs (jacks included) for Clearwater Hatchery spring Chinook, Sawtooth Hatchery spring Chinook, Pahsimeroi Hatchery summer Chinook and Clearwater Hatchery summer Chinook varied by year within a range generally similar to other CSS hatchery Chinook groups. However, the estimated LGR-to-GRA SAR for Pahsimeroi Hatchery summer Chinook was exceptionally low in 2014 (0.02%).

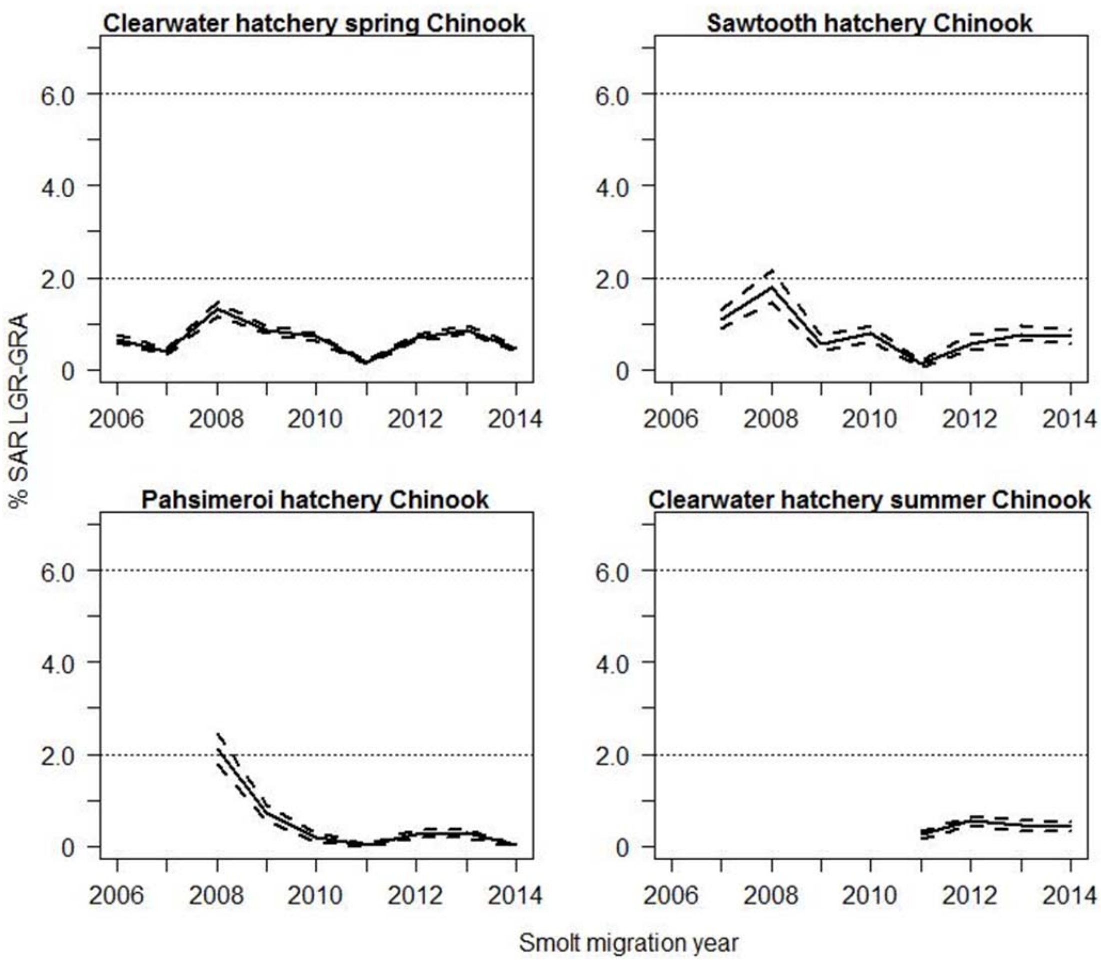


Figure 4.4. Bootstrapped LGR-to-GRA SAR (with jacks included) and upper and lower CI for four additional Snake River hatchery groups for migration years 2006-2014. Migration year 2014 is complete through 2-salt returns only. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

Snake River wild steelhead SARs (upper dam smolts-to-Columbia River returns) decreased nearly four-fold from the 1960s (pre-FCRPS completion) to the 1990s and 2000s (Figure 4.5). The geometric mean SAR during 1964–1969 was 7.2% compared to 1.9% during 1990–1999 and 2.5% during 2000–2013. Snake River wild steelhead and wild spring/summer Chinook SARs were highly correlated (r = 0.69) during the 1964–2013 period when aligned by smolt migration year.

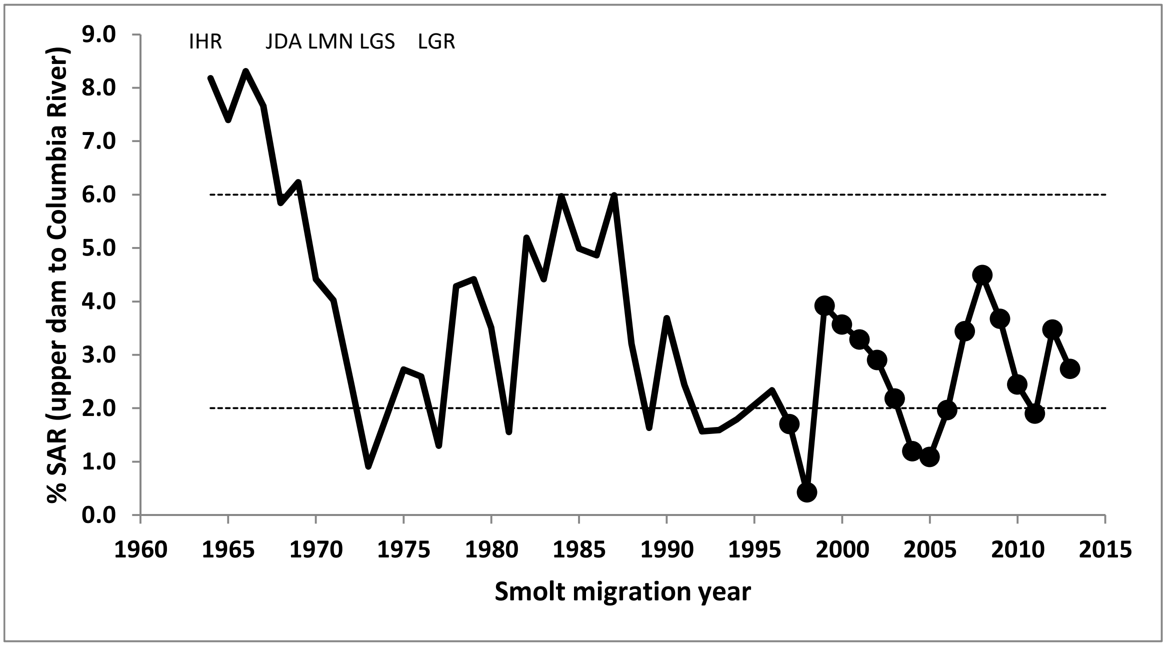


Figure 4.5. SARs from smolts at uppermost Snake River dam to Columbia River returns for Snake River wild steelhead, 1964–2013. Dam construction sequence was: 1961-IHR, 1968-JDA, 1969-LMN, 1970-LGS, 1975-LGR. SARs based on run reconstruction (1964-1996, solid line) and CSS PIT tags (1997–2013, dots and solid line). The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

The geometric mean SAR (LGR-to-GRA) of PIT-tagged Snake River wild steelhead was 1.62% during the period 1997–2013 (Table B.33; Figure 4.6 top plot); SAR point estimates exceeded the NPCC's minimum SAR objective of 2% in eight of 17 migration years (statistically significant in four years). SARs based on adult returns to BOA were about 37% greater (when comparing geometric mean of SAR ratios) than SARs based on returns to GRA (Table B.33) because of the combined effect of adult dam passage loss, straying and Zone 6 harvest. We also estimated Snake River wild steelhead SARs at an MPG level and for Snake River wild A-run and wild B-run aggregates (Tables B.34–B.39; Figure 4.7) for juvenile migration years 2006–2013. SARs were correlated (average r = 0.60) among the wild steelhead MPGs. Precision of the SAR estimate was poor for Grande Ronde wild steelhead and reasonable for other wild steelhead MPGs except 2008 for Imnaha River wild steelhead. The geometric mean LGR–GRA SAR for the wild A-run group (2.24%) was about 38% higher than for the B-run group (1.62%) during 2006–2013.

The estimated overall SARs (LGR-to-GRA) for Snake River hatchery steelhead averaged 1.26% (geometric mean for 1997–2013) and significantly exceeded 2% only in 2008 (Table B.40; Figure 4.6, bottom plot). Overall SARs (LGR-to-GRA) of Snake River wild and hatchery steelhead aggregate groups were not strongly correlated (r = 0.33) during 1997–2013, although wild and hatchery SARs are tracking more closely (r = 0.87) in the six years since we improved hatchery group representation in 2008.

The first juvenile migration year with sufficient numbers of PIT-tagged smolts to estimate SARs for subbasin- or run-specific (e.g. Imnaha Basin A-run) Snake River hatchery steelhead stocks was 2008. Estimated overall SARs (LGR–GRA) were higher for A-run hatchery steelhead than for B-run hatchery steelhead in 2008–2013; SARs of Clearwater River B-run hatchery steelhead exceeded those from the Salmon River (Table B.41–B.46; Figure 4.8).

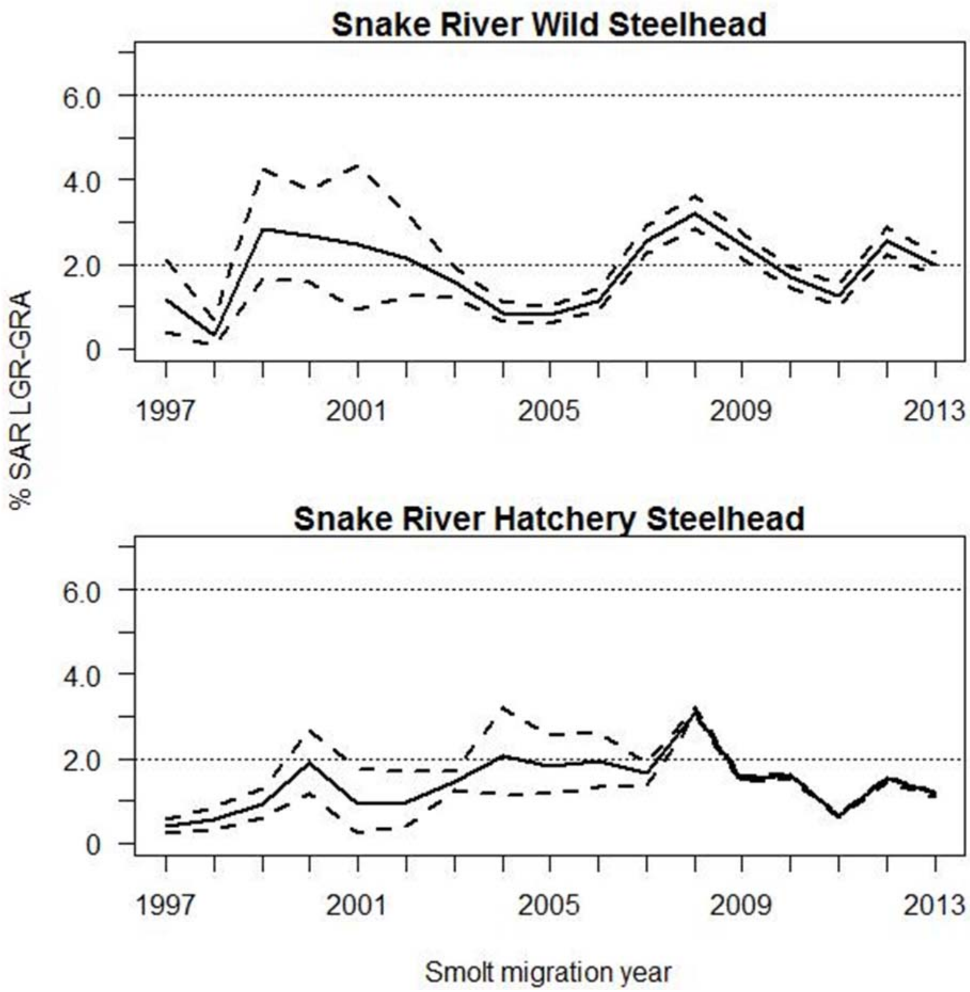


Figure 4.6. Bootstrapped LGR-to-GRA SAR and upper and lower CI for Snake River wild and hatchery steelhead for migration years 1997–2013. The 2008-2013 hatchery steelhead estimates represent the weighted mean for the 5 groups. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

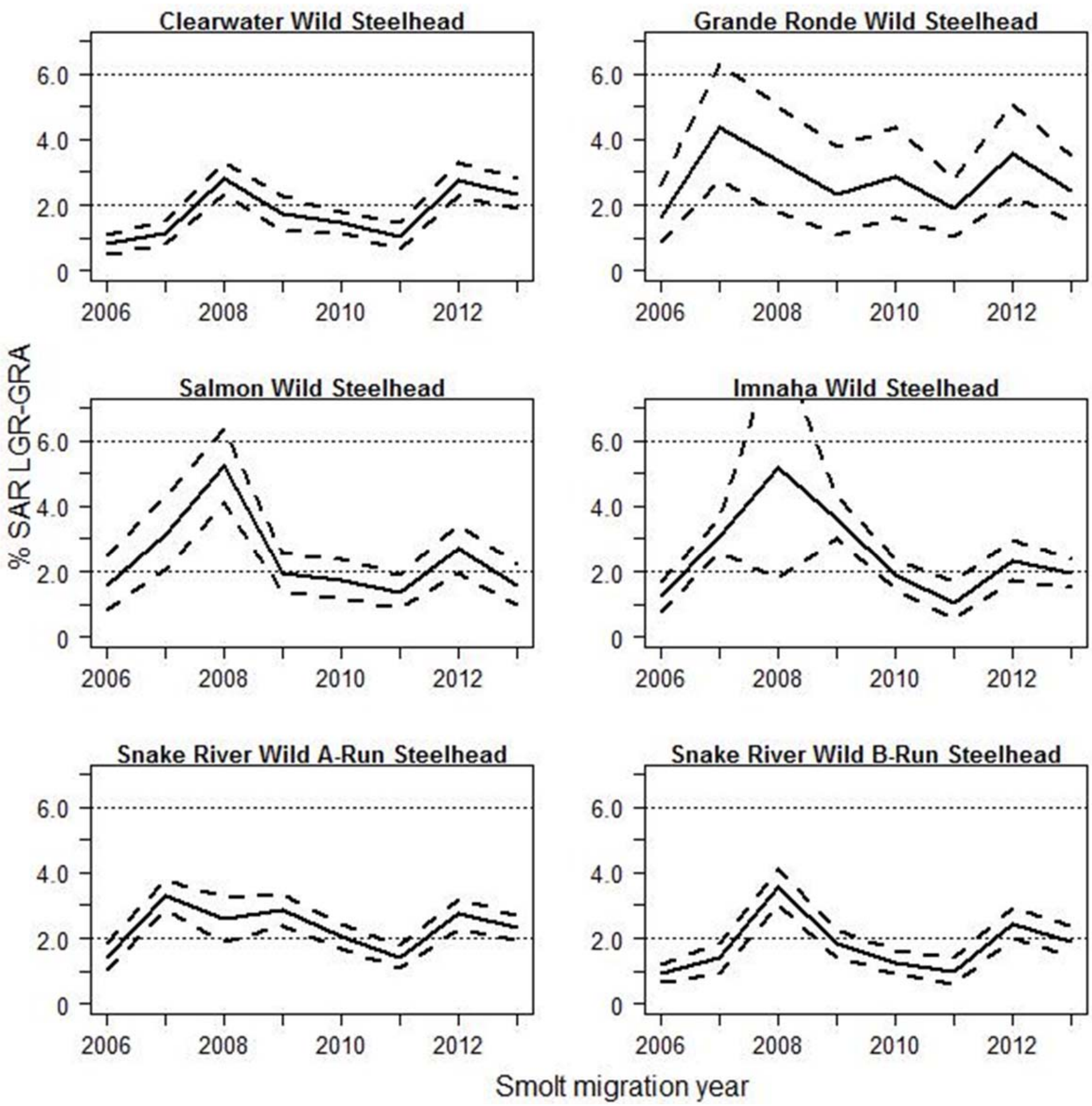


Figure 4.7. Bootstrapped LGR-to-GRA SAR and upper and lower CI for Snake River wild steelhead MPGs and aggregate wild A-run and wild B-run steelhead for migration years 2006–2013. The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference.

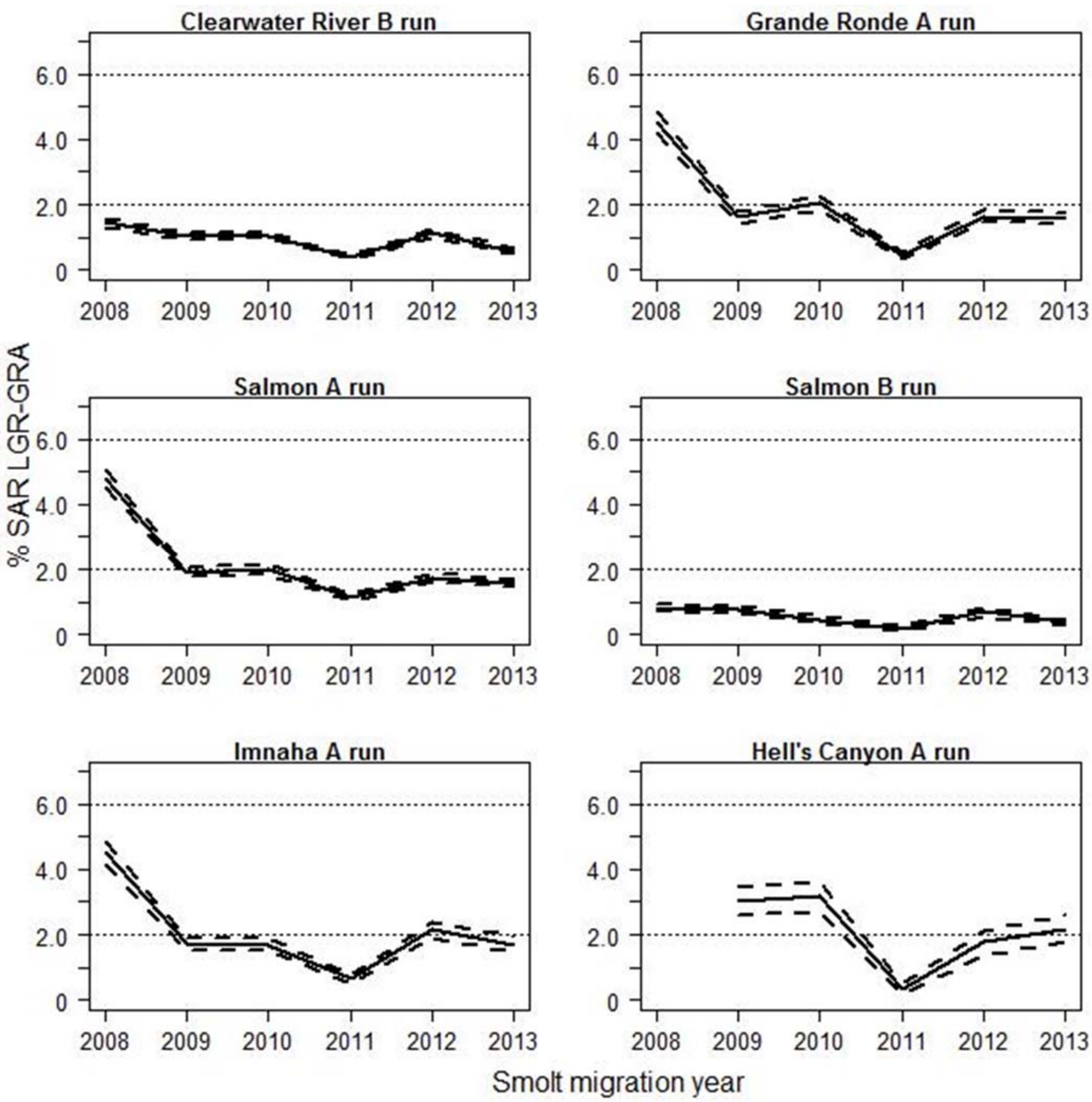


Figure 4.8. Bootstrapped LGR-to-GRA SAR and upper and lower CI for Snake River hatchery steelhead groups for migration years 2006–2013. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

SARs of Snake River hatchery sockeye varied by year and hatchery group during smolt migration years 2009–2014 (Table B.47; Figure 4.9). The estimated SAR LGR-to-GRA for Sawtooth sockeye ranged from 0.10% to 1.15% (2009-2014), whereas Oxbow sockeye SARs ranged from 0.39% to 2.26% (2009–2014). Differences in size at release between Oxbow and Sawtooth may explain some of the between-hatchery difference in SARs, particularly in 2011 and 2012. Typically, Oxbow hatchery smolts average about 45 g, while Sawtooth hatchery sockeye smolts average about 15 g, similar in size to natural origin smolts (M. Peterson, IDFG, pers. comm.). In 2011 and 2012, Sawtooth Hatchery smolts were smaller than normal, averaging only 8 to 9 g. In 2010 all PIT-tagged sockeye were routed in-river. There were very few incidentally transported PIT-tagged fish in 2010, whereas 33% of run-at-large juvenile sockeye were transported in 2010 (FPC 2014). Therefore, an estimate of overall SAR LGR-to-GRA was

not possible in 2010 for the Sawtooth hatchery group. Sample size was limited for the Oxbow hatchery sockeye group; estimation of SAR to either GRA or BOA was not possible for the Oxbow group in 2010 and 2013. Sawtooth and Oxbow groups were coded wire tagged (CWT), in addition to PIT tagged, through the 2013 release to assist with brood stock management of returning adults. The double tagging may have influenced SARs in these years (see Chapter 6 in 2014 CSS annual report). Beginning with the 2014 release, CWT marking has been discontinued because parental based tagging methods have now been developed for brood stock management. Sockeye production has been phased out at Sawtooth Hatchery as of migration year 2016, with production (and the CSS mark group) being shifted to Springfield Hatchery. Both the Sawtooth and Springfield groups were PIT tagged for the 2015 transition year.

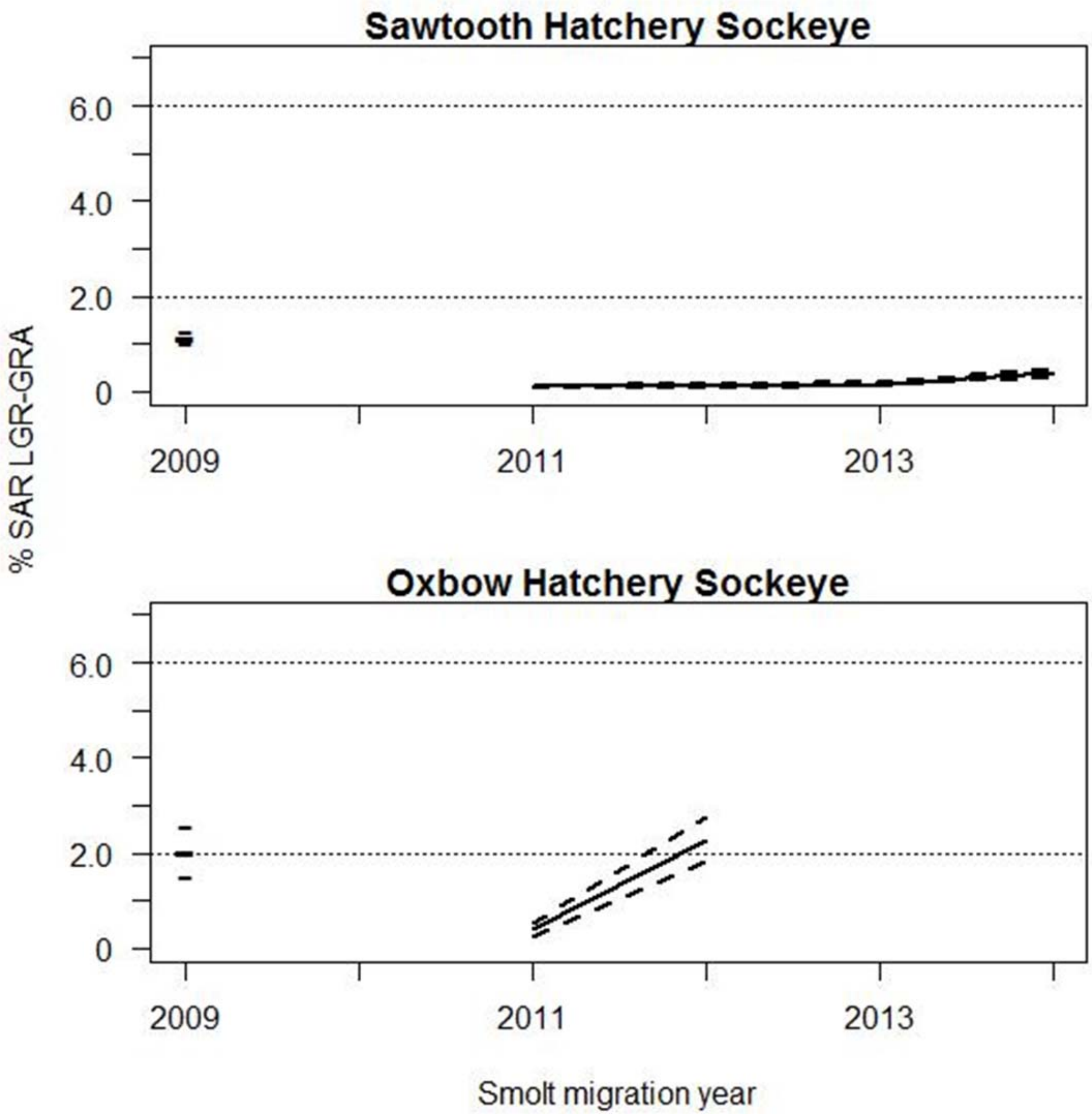


Figure 4.9. Bootstrapped LGR-to-GRA SAR and upper and lower CI for Snake River hatchery sockeye groups for migration years 2009–2014. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

Characterizing the relationship between ln(TIR) and in-river survival (S_R) – Snake River wild Chinook and steelhead

The best fitting models based on AICc weights (Burnham and Anderson 2002) all had natural log transformed Sr (Table 4.1). We dropped models that included untransformed reach survival because their relative weights combined were less than 0.01. In addition, the top two models had components that were species specific. The top ranked model had a species specific intercept while the second ranked model included a species specific slope. We chose the top fitting model of the form *ln(TIR) = ln(sr) + species*, which included a species specific intercept and a common slope for survival.

Table 4.1. Information theoretic ranking of models predicting ln(TIR). The table summarizes attributes of the top models considered. The best fitting models included species specific model components, either specific intercept or slope and log transformed Sr (in-river survival).

Model	AIC_C	ΔAIC_C	w_i
ln(sr) + species	83.1	0.00	0.44
ln(sr) + log(sr):species	83.9	0.83	0.29
ln(sr)	85.1	1.99	0.16
ln(sr) * species	86.0	2.87	0.11

We used the top model based on AICc to illustrate the relationship between ln(TIR) and reach survival (Table 4.2; Figure 4.10).

Table 4.2. Parameter coefficients and standard errors from top model.

Parameter	Estimate	Std. error
Intercept	2.1867	0.3788
$\ln(S_R)$	-4.0533	0.6982
Species(ST)	0.4882	0.2120

Reach survival had a negative effect on ln(TIR) (Figure 4.10). As survival increased ln(TIR) decreased. The model predictions were used to estimate the reach survival at which ln(TIR) would decrease below 0 indicating a negative effect of transportation on SAR. Based on the model predicted steelhead TIR would drop below zero when juvenile reach survival increased above 0.74, indicating that transport would no longer mitigate for hydrosystem effects

when in-river survival was above that point. For yearling Chinook the model predicted that at reach survivals above 0.55 the ln(TIR) would drop below zero.

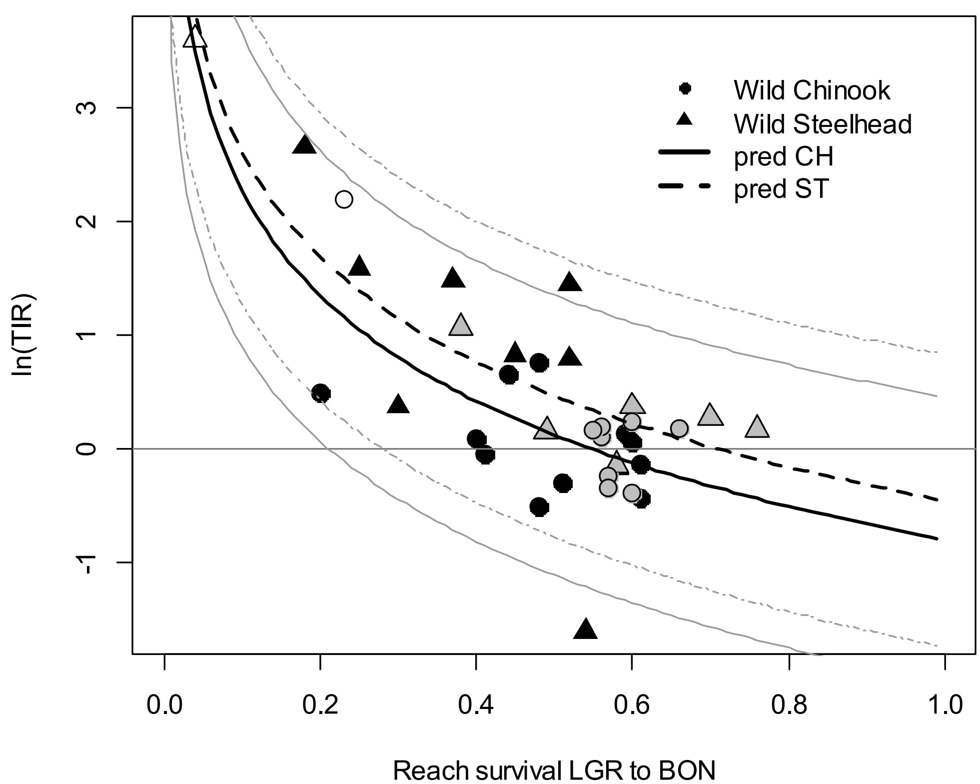


Figure 4.10. Plot of ln(TIR) versus reach survival (SR) for wild yearling Chinook and wild steelhead from the Snake River for the juvenile migration years 1994 to 2015. The two open symbols are migration year 2001 which had low flow and zero spill. The gray data points are migration years with court-ordered spill and delayed start to transportation (2006–2015). Curves shown are predictions from the common slope and species-specific intercept model using ln(SR) shown in Table 4.2. Thinner lines represent the 95% prediction intervals for the model. The model predicts that TIR will be less than one when juvenile Chinook survival is 0.55 or higher and juvenile steelhead survival is 0.74 or higher.

Mid-Columbia River Overall SARs

In contrast to Snake River spring/summer Chinook and steelhead, no historical SAR data sets exist for the mid-Columbia Region extending back to pre-FCRPS completion. The Yakama Nation fisheries staff estimated SARs of Yakima River natural origin spring Chinook based on run reconstruction of smolts at Chandler Dam to adults to the Yakima River mouth, beginning in smolt migration year 1983. Subbasin-to-subbasin SARs for Yakima River wild spring Chinook had a geometric mean of 2.4%, ranging from 0.6% to 13.4% during 1983–2001 (Yakima Subbasin Summary; YIN and WDFW 2004). In addition, the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) have operated a smolt trap on the Warm Springs

River since the late 1970s, from which it may be possible to calculate wild spring Chinook SARs using run reconstruction methods. These longer-time series run reconstruction SAR estimates for mid-Columbia spring Chinook would be useful in future analyses.

The geometric mean SAR (JDA-to-BOA, including jacks) of PIT-tagged John Day River wild spring Chinook was 3.85% during the 15-year period 2000–2014 (Table B.70; Figure 4.11). John Day wild spring Chinook SAR point estimates exceeded the NPCC's minimum SAR objective of 2% in all migration years except 2011, and were significantly greater than 2% in all but three years (2005, 2006 and 2011). The PIT-tagged John Day River spring Chinook group represents an aggregate of three wild populations: the North Fork, Middle Fork, and upper mainstem John Day rivers. The geometric mean SAR (MCN-to-MCA) of Yakima River wild spring Chinook was 2.39% during 2002–2013 (no PIT-tagged smolts were released in 2010 or 2014). Yakima wild spring Chinook SAR point estimates exceeded the minimum 2% in six of 11 migration years, and were significantly greater than 2% in five years (Table B.72). Yakima River wild Chinook SARs based on BOA returns were 7% greater than those based on MCA returns (Tables B.71 and B.72). SARs of John Day and Yakima River wild spring Chinook averaged (geometric mean of ratio; based on BOA returns) 3.5 times and 2.3 times, respectively, those of Snake River wild spring/summer Chinook (Table B.2), and the wild SARs were correlated (average r = 0.72) between regions during the period 2000–2014.

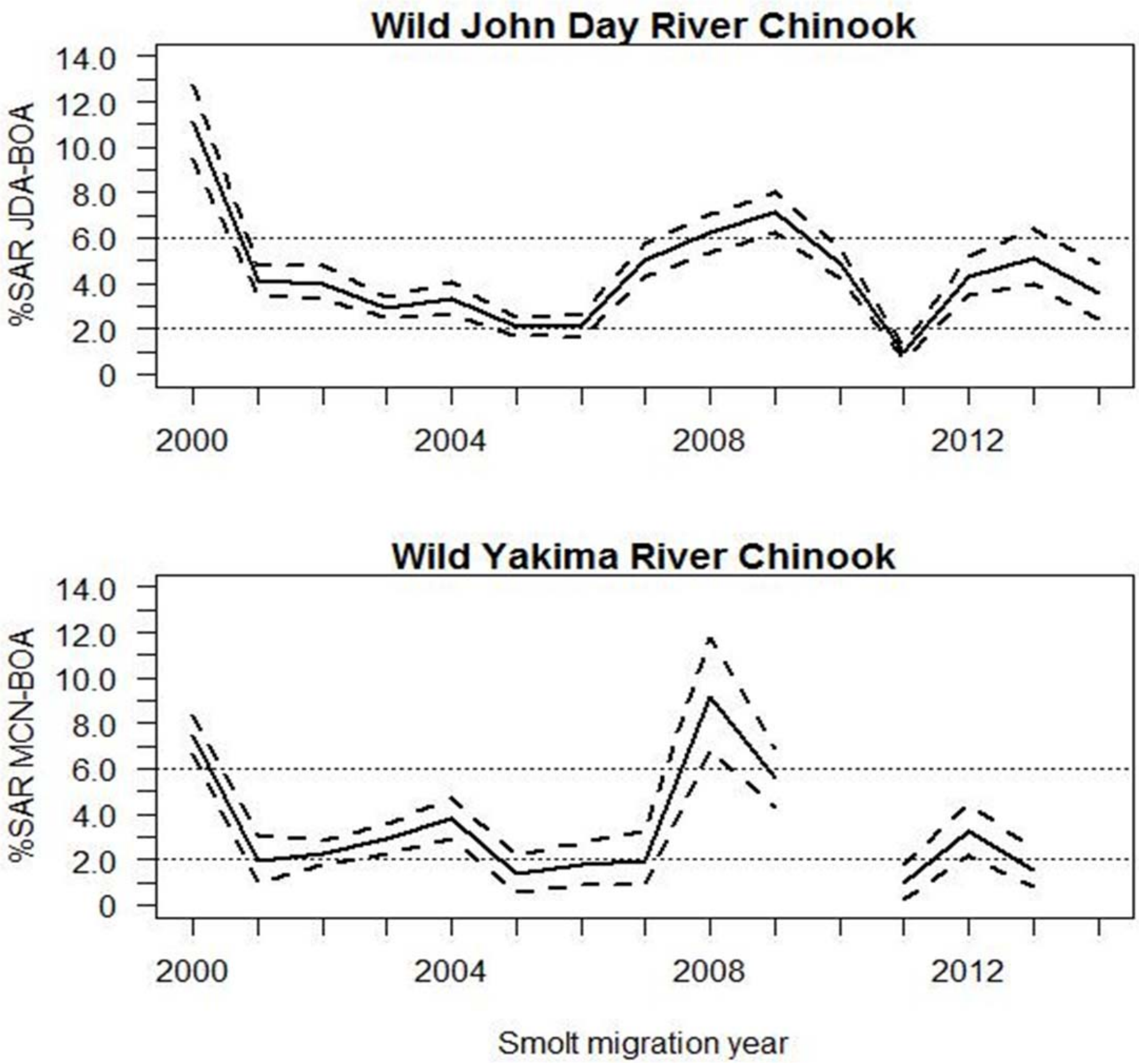


Figure 4.11. Bootstrapped SAR (including jacks) and upper and lower CI for wild spring Chinook from the John Day and Yakima rivers in the mid-Columbia region for migration years 2000–2014. Smolts are estimated at upper dam; adults are enumerated at BOA. Migration year 2014 is complete through 2-salt returns only; no PIT tagged smolts were released in the Yakima River in 2010 and 2014. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

The estimated overall SARs (including jacks) for mid-Columbia River hatchery spring Chinook varied by hatchery and year (Tables B.73-B.76; Figure 4.12). BON-to-BOA SARs for Carson Hatchery spring Chinook averaged (geometric mean) 0.95% during 2000–2014 (Table B.73). Estimated BON-BOA SARs for Warm Springs National Fish Hatchery spring Chinook 2010–2014 averaged 1.10% (Table B.74). MCN-BOA SARs for Cle Elum Hatchery spring Chinook averaged 1.53% and were 8% higher than MCN-MCA SARs (Tables B.75 and B.76). The hatchery populations in the mid-Columbia region had much lower SARs than the John Day and Yakima wild spring Chinook populations. Although a difference in magnitude of SARs between groups was noted, the overall SARs of mid-Columbia wild and hatchery spring Chinook groups were highly correlated (average r = 0.78) between populations during 2000–2014.

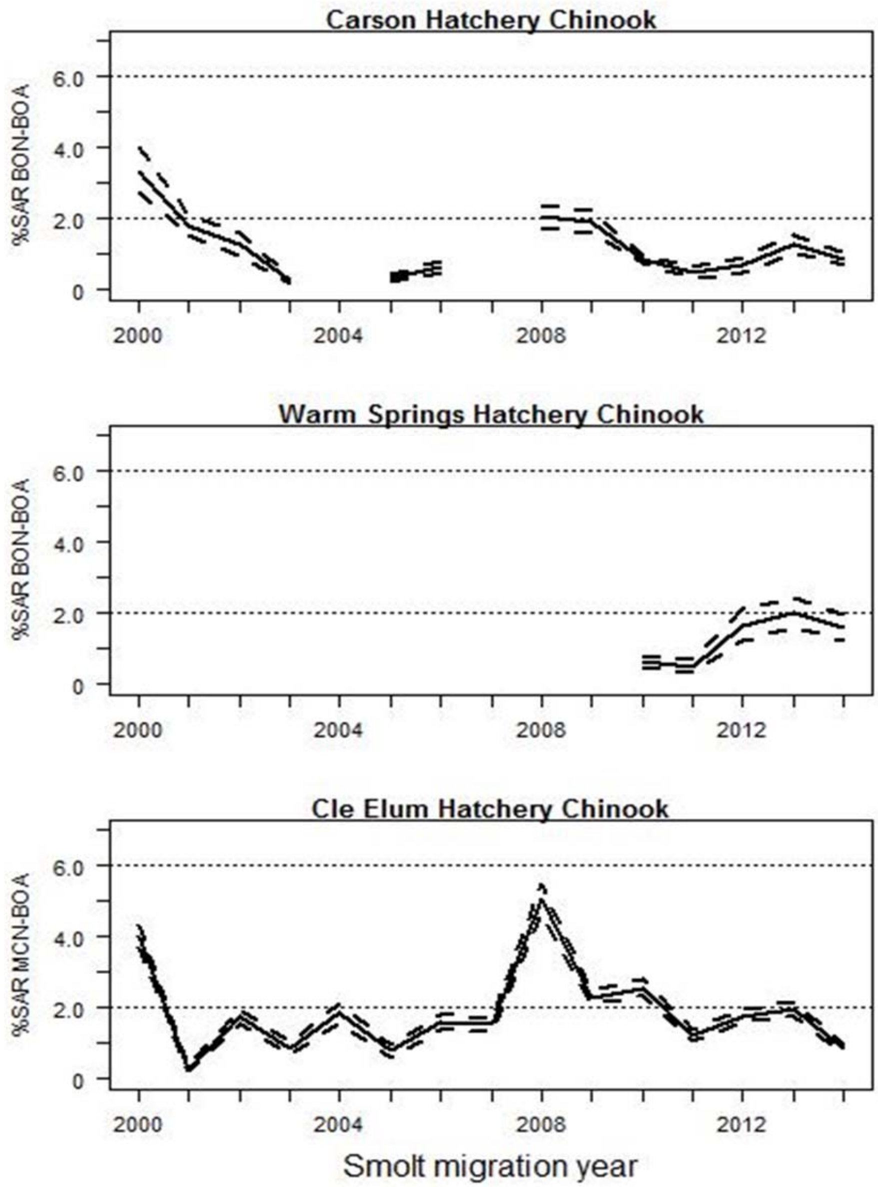


Figure 4.12. Bootstrapped SAR (including jacks) and upper and lower CI for hatchery spring Chinook in the mid-Columbia region for migration years 2000–2014. Smolts are estimated at upper dam; adults are enumerated at BOA. Migration year 2014 is complete through 2-salt returns only. SAR for Carson Hatchery not calculated for 2004 and 2007 because release to BON survival estimate > 1.0. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

The CSS estimated SARs and confidence intervals for mid-Columbia wild steelhead from the John Day River beginning with migration year 2004, from Trout Creek in the Deschutes River beginning with migration year 2006, and from the Yakima River beginning with migration year 2002 (Tables B.77–B.79; Figure 4.13). We have the 2004-2013 PIT-tagged wild steelhead from John Day River summarized in Table B.77. Nine out of ten years of JDA-BOA SAR estimates significantly exceeded the NPCC's minimum SAR objective of 2% (Figure 4.13); the

2011 SAR was the single exception. The PIT-tagged John Day River steelhead group represents the five wild populations of the John Day MPG: the North Fork, Middle Fork, South Fork, upper mainstem, and lower mainstem John Day rivers. However, fish in the lower mainstem John Day population from tributaries downstream of the ODFW juvenile seining site are not trapped and PIT tagged and that population is not fully represented. Deschutes River (Trout Creek) wild steelhead SARs (BON-to-BOA) significantly exceeded the NPCC's minimum SAR objective of 2% in the seven years of study, 2006-2012 (Table B.78; Figure 4.13). Yakima River wild steelhead SARs (MCN-to-MCA) significantly exceeded the NPCC's minimum SAR objective of 2% in eight out of 12 years (Table B.79; Figure 4.13); MCN-to-BOA SARs were 22% higher than MCN-to-MCA SARs. SAR confidence intervals for the Yakima wild steelhead population, in particular, were relatively wide due to limited sample size. Wild steelhead SARs from the mid-Columbia River populations exceeded by 2.4 fold, and correlated highly (average r = 0.67) with, wild steelhead SARs from the Snake River. Common among these populations (as well as Chinook PIT tag groups in other regions), SARs were high in 2008 and low in 2011.

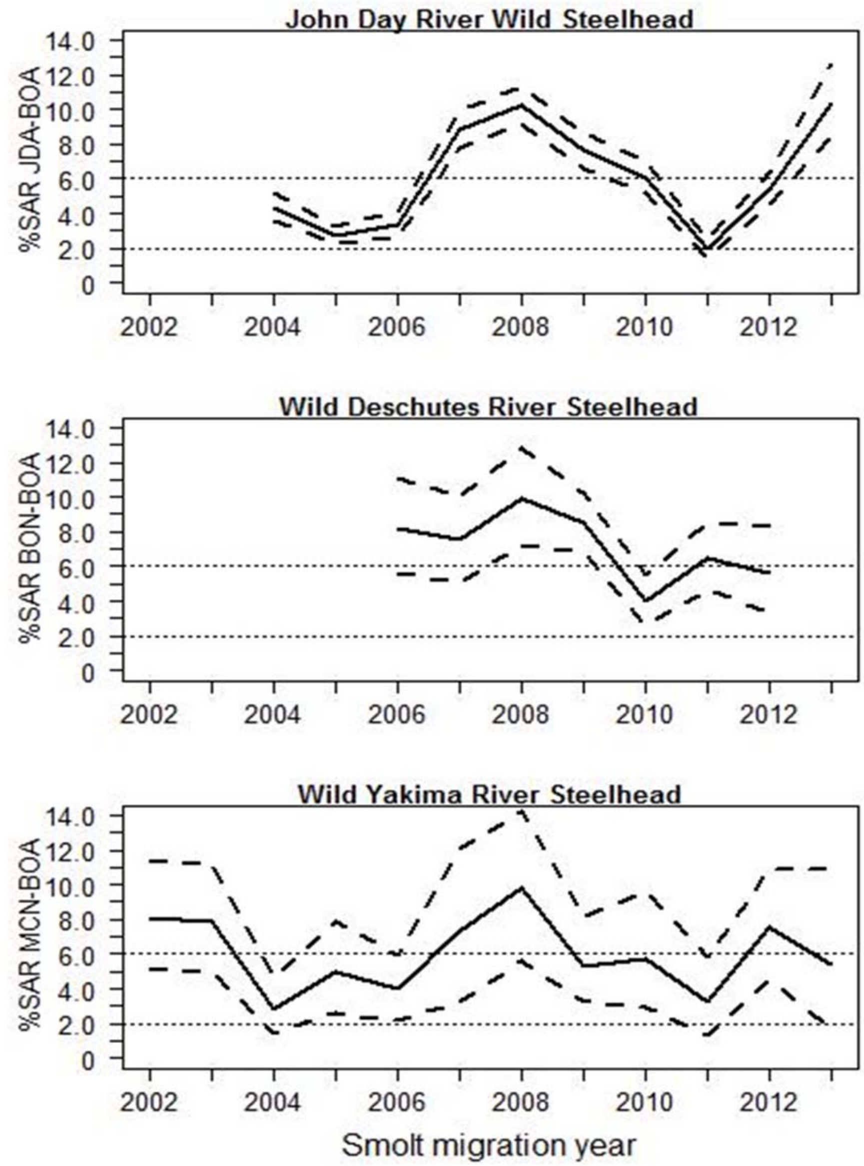


Figure 4.13. Bootstrapped SAR and upper and lower CI for wild steelhead from mid-Columbia region for migration years 2002–2013. Smolts are estimated at upper dam; adults are enumerated at BOA. Too few PIT-tagged smolts were released in the Deschutes River in 2013 for SAR estimate.The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

No PIT-tag SARs have been compiled for hatchery steelhead populations in the mid-Columbia region. There may be some potential for run reconstruction SARs for hatchery steelhead in the Deschutes and Umatilla subbasins.

Upper Columbia River Overall SARs

Raymond (1988) estimated pre-harvest SARs for upper Columbia River (above PRD) spring Chinook and steelhead, 1962–1984 smolt migration years, which may be useful for future analyses. These estimated SARs were somewhat lower than those for the Snake River during the 1960s for both species. Raymond's smolt indices for the upper Columbia were subject to several assumptions, however, creating greater uncertainty in the SAR estimates here than for the Snake River. Raymond explained that smolt indices were less available than for the Snake River because indexing of smolts at upper Columbia River dams was not ongoing except at Priest Rapids Dam between 1965 and 1967.

The estimated overall SARs (MCN to BOA, including jacks) for Upper Columbia River wild spring Chinook ranged from 0.54% to 3.26% during 2006–2014 (Wenatchee River—Table B84; Entiat and Methow rivers—Table B.85; Figure 4.14); SARs significantly exceeded 2% for both groups in 2008 and for Entiat/Methow in 2013. Overall SARs were also estimated for smolts further upstream from RRE to BOA in 2008–2014 for wild spring Chinook from the Entiat and Methow rivers (Table B.86; Figure 4.15). Wild spring Chinook SARs based on smolts at RRE were 58% (geometric mean of ratio) those based on smolts at MCN, illustrating the need to monitor SARs for the complete smolt migration path through the hydrosystem.

The estimated overall SARs (MCN to BOA, including jacks) for Upper Columbia River wild summer Chinook, tagged above Wells Dam, ranged from 1.17% to 4.14% during 2011–2013 (Table B.87). The estimated overall SARs (RRE to BOA) were 74% of those based on smolts at MCN and ranged from 0.84% to 2.81% (Table B.88).

The geometric mean SAR for Leavenworth hatchery spring Chinook was 0.61% during 2000-2014 (Table B.89; Figure 4.14). The overall MCN-BOA SARs of Upper Columbia wild and hatchery spring Chinook were highly correlated with wild and hatchery spring Chinook SARs from the mid-Columbia (average $r = 0.76$) and with wild and hatchery spring/summer Chinook SARs from the Snake River (average $r = 0.78$) during 2000–2014.

Overall SARs (MCN–BOA) for Upper Columbia River wild steelhead ranged from 1.31% to 6.66% during 2006–2013 (Table B.90; Figure 4.16). Overall SARs from RRE to BOA were also estimated in 2008–2013 for Upper Columbia River wild steelhead from the Entiat and Methow rivers (Table B.91; Figure 4.15). This represents a subgroup of the wild steelhead aggregate reported in Table B.90 (i.e., excludes Wenatchee River steelhead). Wild steelhead SARs based on smolts at RRE were 61% (geometric mean of ratio) those based on smolts at MCN in 2008–2012, again demonstrating the need to monitor SARs for the complete smolt migration path through the hydrosystem.

SARs (MCN–BOA) for Upper Columbia River hatchery steelhead ranged from 0.90% to 5.78% during 2003–2013 (Table B.92; Figure 4.16).

The estimated overall SAR (MCN–BOA) for Upper Columbia River wild sockeye was 2.82% in 2014; an estimate was not made for 2013 because the RRE-MCN juvenile survival estimate was unreliable that year (Table B.93). The estimated overall SAR (RRE–BOA) was 8.13% in 2013 and 2.05% in 2014 (Table B.93).

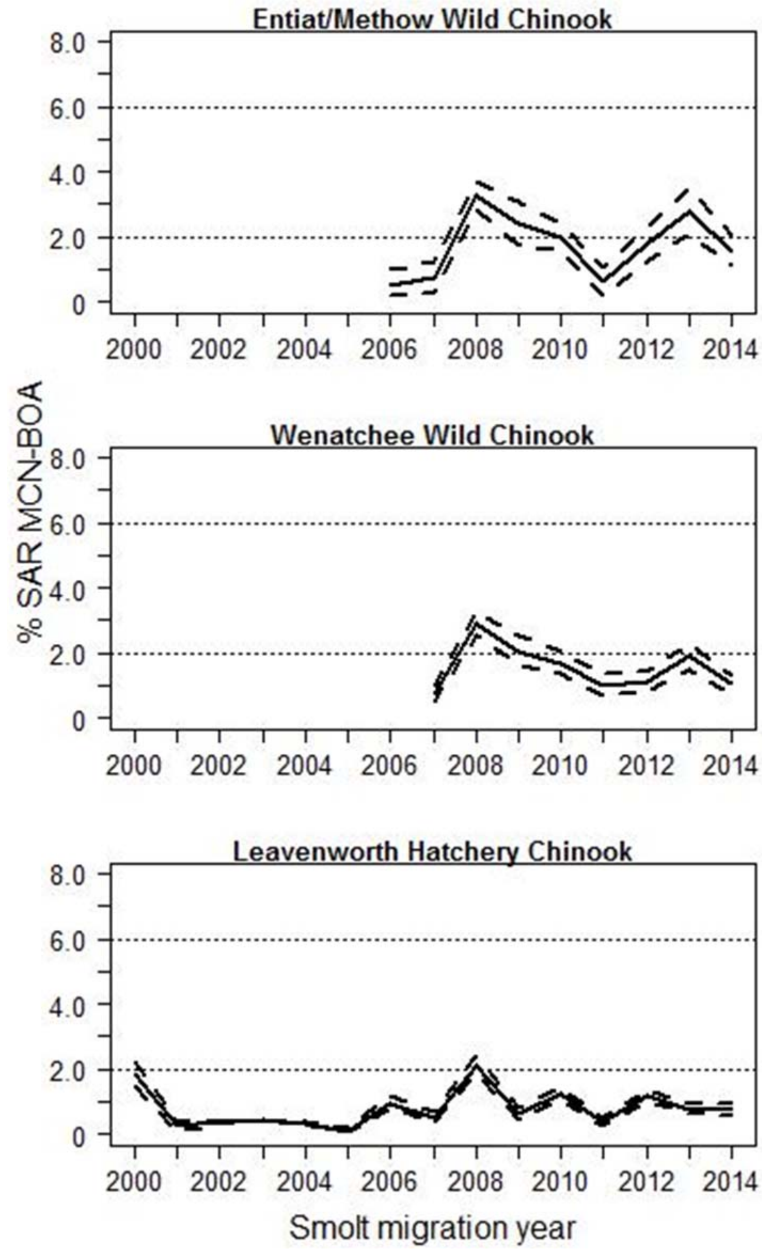


Figure 4.14. Bootstrapped SAR (MCN-to-BOA, including jacks) and upper and lower CI for Methow/Entiat River wild spring Chinook, Wenatchee River wild spring Chinook and Leavenworth hatchery spring Chinook from Upper Columbia region for migration years 2000–2014. Migration year 2014 is complete through 2-salt returns only. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

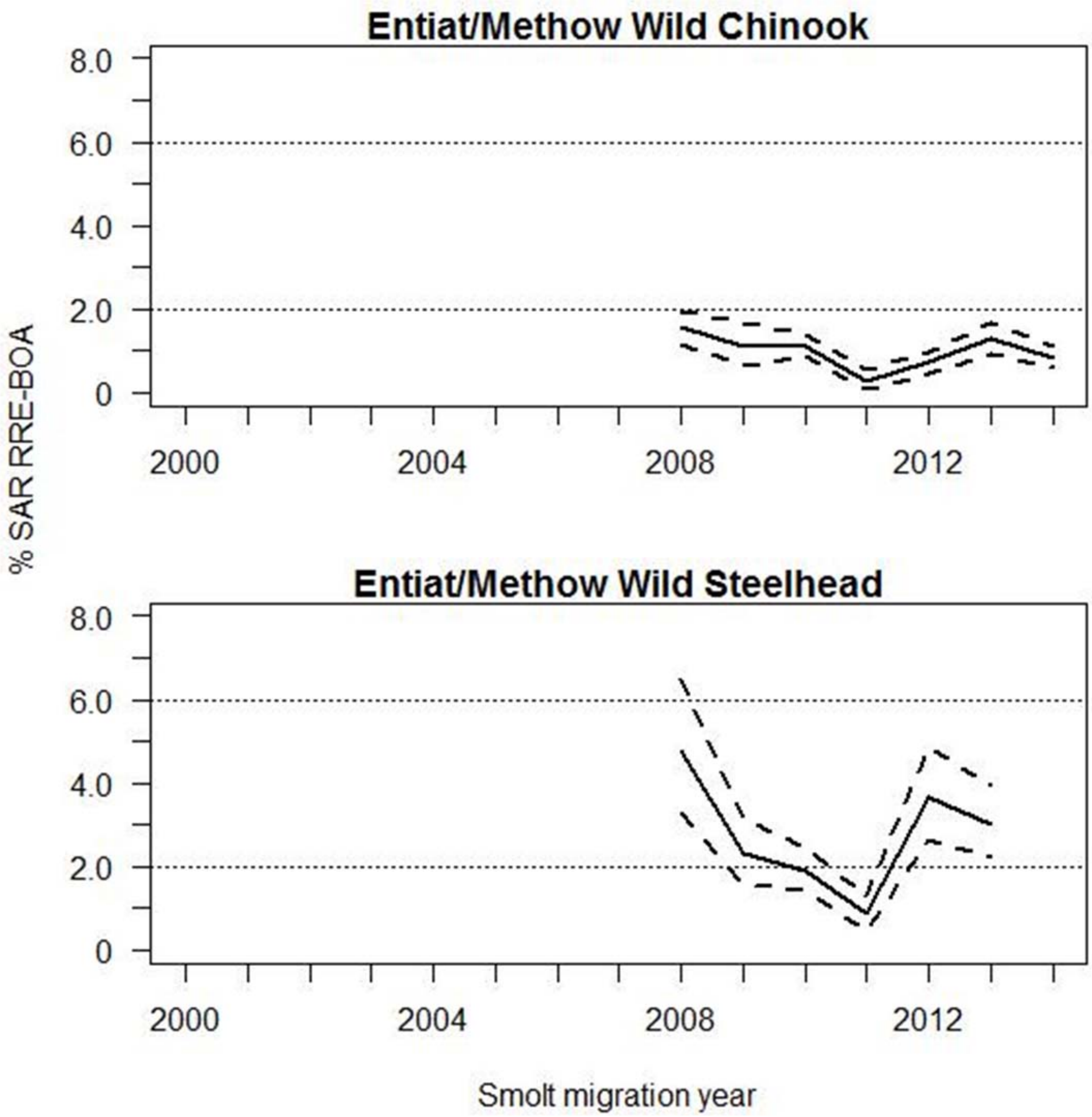


Figure 4.15. Bootstrapped SAR (RRE-to-BOA) and upper and lower CI for Methow/Entiat River wild Chinook and wild steelhead from Upper Columbia region through the 2014 and 2013 migration years, respectively. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

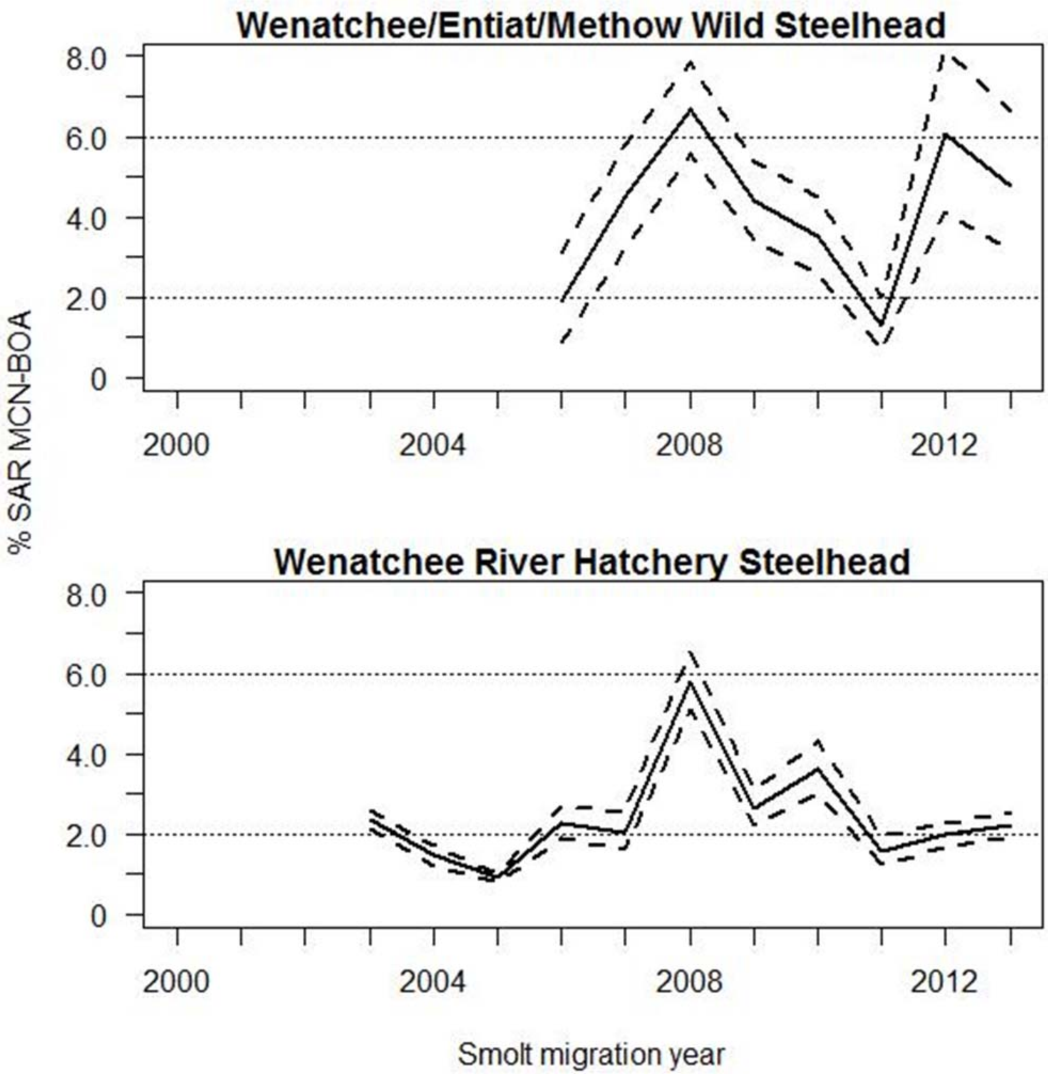
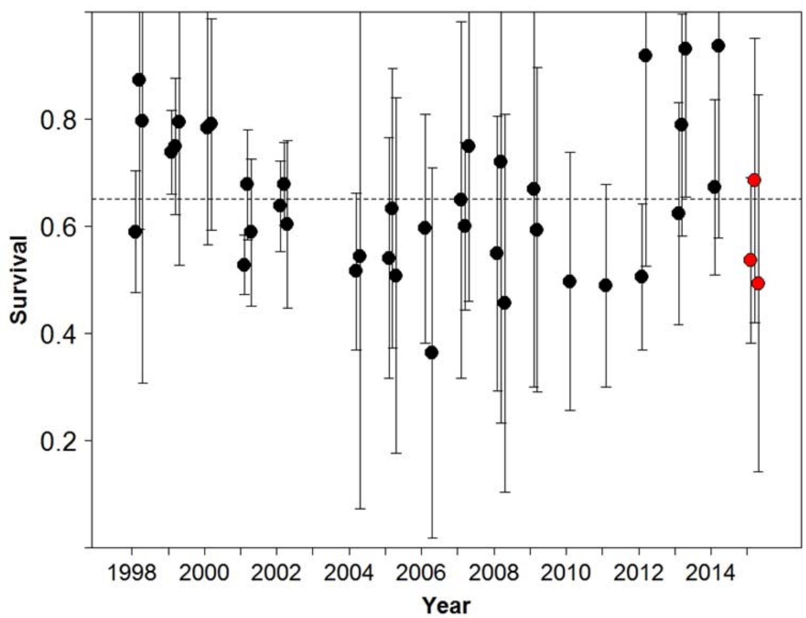


Figure 4.16. Bootstrapped SAR (MCN-to-BOA) and upper and lower CI for Methow/Entiat River wild steelhead and Wenatchee River hatchery steelhead from Upper Columbia region through the 2013 migration year. The hatchery steelhead group is a wild x wild cross released in the Wenatchee basin (reared at Chelan, East Bank, or Turtle Rock hatcheries depending on year). The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

Because the component of Upper Columbia SARs upstream of McNary Dam is missing for most populations and migration years due to insufficient smolt PIT tag detection capability, the CSS used smolts PIT-tagged at Rock Island Dam (RIS) by the SMP to estimate SARs further upriver closer to their entry into the mainstem migration corridor in the hydrosystem. The SMP estimates survival from RIS, downstream of the Wenatchee basin, to McNary Dam for run-at-large hatchery and wild steelhead and Chinook smolts captured, PIT-tagged, and released at RIS (FPC annual report 2015). Survival estimates through this 360-kilometer reach are estimated in 2-week periods across several migration years when sample size is available (Figure 4.17). The 2-week estimates are highly variable but consistently indicate that a large mortality occurs from RIS to MCN for the run-at-large juvenile spring Chinook and steelhead (geometric mean survival ~ 0.60). For the Wenatchee stocks, this implies that if estimating SARs similarly to

other CSS groups were possible, they would average about 60% of that indicated by the MCN to BOA SAR. For example, the geometric mean MCN to BOA SAR for Wenatchee hatchery steelhead (Table B.66) would change from 2.19% to 1.31%.



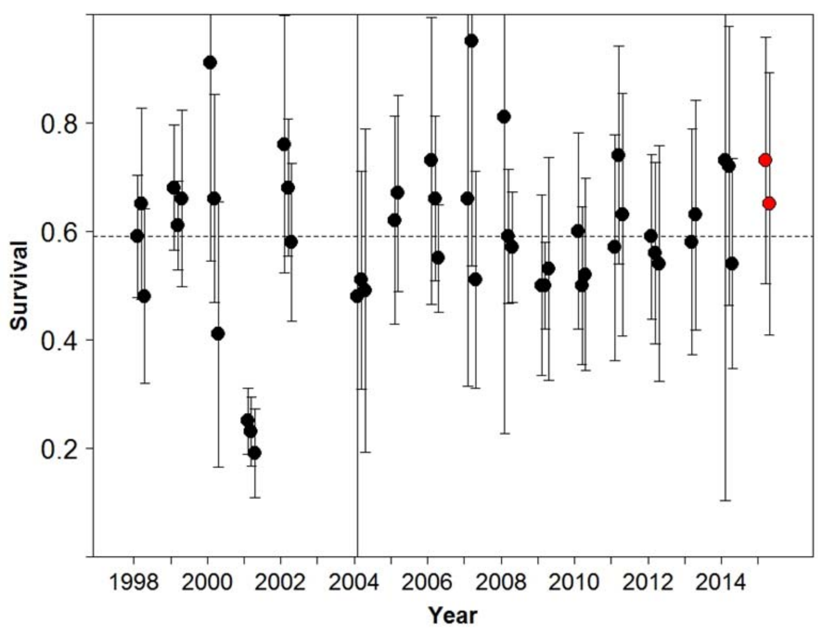


Figure 4.17. Spring out-migrants' juvenile survival from RIS to MCN. The top panel is hatchery + wild yearling spring Chinook and the bottom panel is hatchery + wild steelhead. These are 2-week CJS estimates for smolts captured, PIT-tagged, and released at RIS as part of the SMP project (FPC 2015 annual report). The confidence interval plotted is 95%. The geometric means (through 2014) noted by the horizontal dashed line were 0.61 and 0.59 for Chinook and steelhead respectively.

SARs from smolts tagged at RIS to adults at BOA are summarized in Tables B.94 to B.97 and Figure 4.18 for the SMP PIT tag groups of Upper Columbia wild and hatchery spring (yearling) Chinook, summer (subyearling) Chinook, steelhead and sockeye. The RIS to BOA SARs of the four Upper Columbia population groups were inter-correlated (average r = 0.52). The SARs of SMP spring Chinook and steelhead groups are 56% and 49% of those for tributary-tagged wild groups (Tables B.86, B.91, B.94 and B.96), likely because of the mixed hatchery/wild composition of the sample and because collection, handling, and tagging at the dam may introduce a negative SAR bias. However, the SMP groups provide a consistent, 15-year time series of survival rates that, except for Leavenworth hatchery spring Chinook, is otherwise lacking in this region.

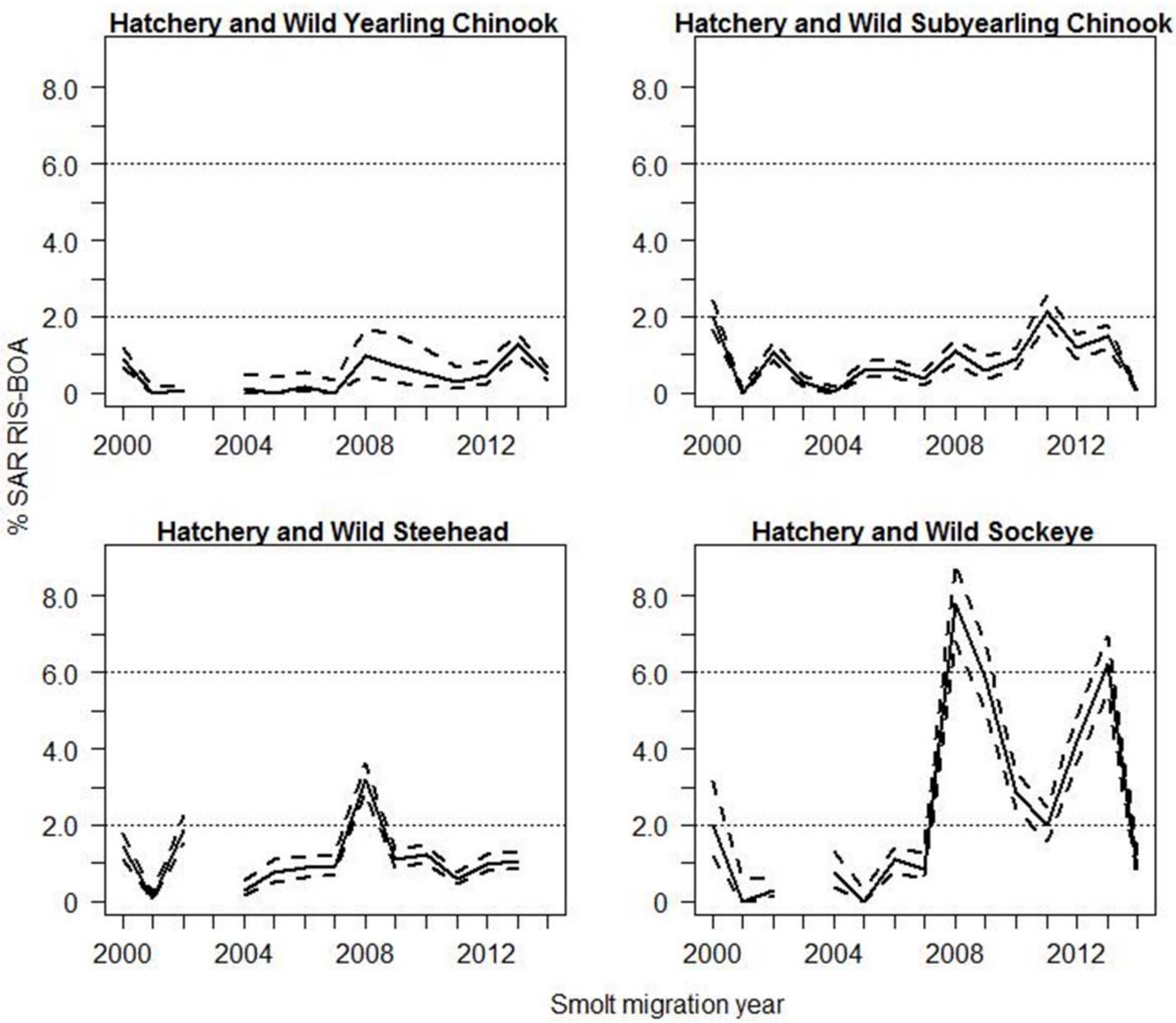


Figure 4.18. SAR (RIS-to-BOA) and upper and lower CI for Upper Columbia wild and hatchery Yearling Chinook , Subyearling Chinook, steelhead and sockeye tagged at Rock Island Dam for the Smolt Monitoring Program, 2000–2014. Smolts were tagged at upper dam; adults are enumerated at BOA. The NPCC (2014) 2%–6% SAR objective for listed wild populations is shown for reference.

Comparison of PIT-tag and Run Reconstruction SARs

The ISAB/ISRP (2007) review of the CSS Ten-Year Retrospective Report (Schaller et al. 2007), encouraged the CSS to investigate differences, and reasons for any differences, between SARs based on PIT-tags and those based on run reconstruction (RR) methods. Schaller et al. (2007) found that the NOAA RR SAR point estimates (Williams et al. 2005) were about 19% higher (geometric mean) than those produced by CSS using PIT-tags. It was unclear whether a bias existed in the RR SARs, PIT-tag SARs, or both, due, in part, to uncertainties and assumptions in both methods. Knudsen et al. (2009) reported that hatchery spring Chinook from the Yakima River that were coded-wire-tagged, elastomer marked, and ad-clipped returned at a 33% higher rate than fish that were PIT-tagged, coded-wire-tagged, elastomer marked, and ad-clipped. The Knudsen study illustrated the potential for PIT-tag effects, however, its applicability to other river reaches or populations of fish is unknown (Tuomikoski et al. 2009; DeHart 2009).

Snake River wild spring/summer Chinook SARs based on IDFG run reconstruction (Stiefel et al. 2015) were 41% greater (geometric mean of ratio) than those based on PIT tags, during migration years 1996–2012 (Figure 4.19). The RR and PIT-tag SARs were highly correlated (0.95), and both time series indicated SARs were well short of the NPCC (2014) 2%–6% SAR objectives across the majority of years.

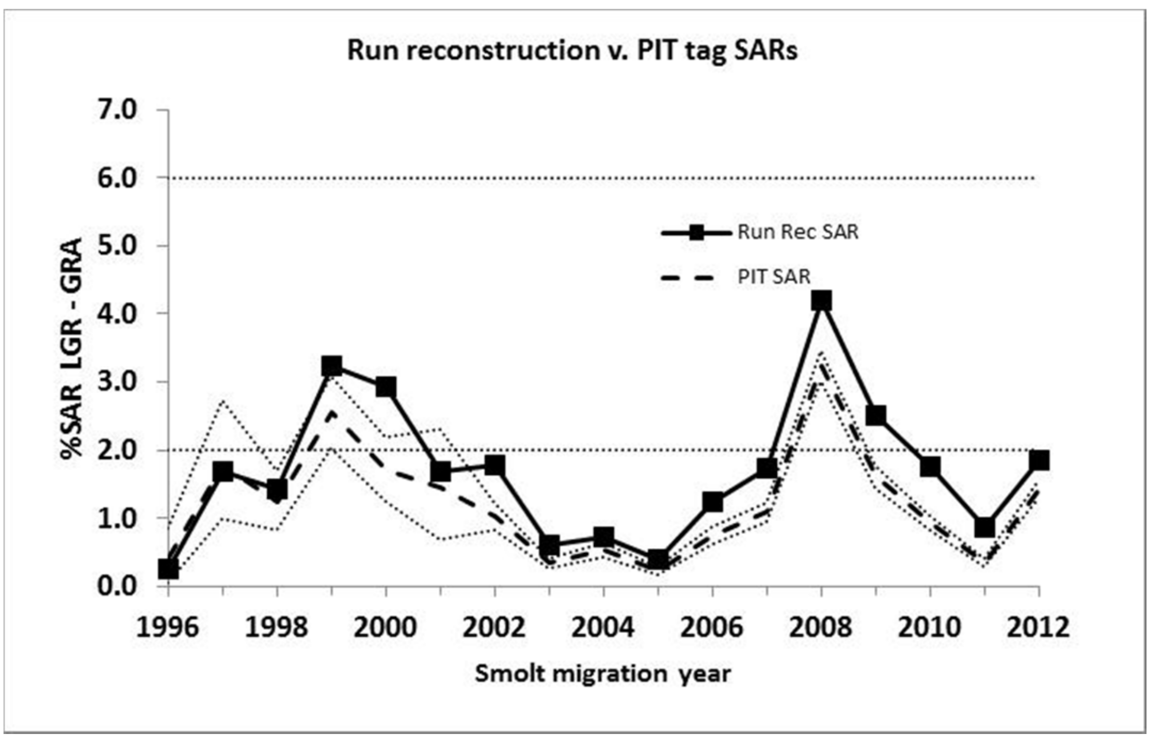


Figure 4.19. IDFG run reconstruction SARs (including jacks) compared to CSS PIT-tag SARs and 90% CI, Snake River wild spring/summer Chinook, migration years 1996–2012. NPCC (2014) 2%–6% SAR objectives for listed wild populations are shown for reference.

In the CSS 2009 annual report (Tuomikoski et al. 2009), we compared SARs and estimates of juveniles and associated variance used in the IDFG run reconstruction of Snake River wild spring/summer Chinook at Lower Granite Dam (Copeland et al. 2008) with CSS PIT-tag estimates. The difference between RR and PIT tag SARs did not appear to be predominantly due to differences in juvenile abundance estimation methods. Tuomikoski et al. (2009) concluded that estimates of juvenile population abundance derived in CSS, when using the SMP collection index, were similar to those reported by Copeland et al. (2008). Tuomikoski et al. (2009) also developed a bootstrap variance estimator to account for variation in daily detection probability estimates and collection samples for use with the RR methods.

In the CSS 2010 annual report (Tuomikoski et al. 2010), we examined SAR methodologies, and developed hypotheses for possible sources of bias in both RR and PIT tag SARs for Snake River wild spring/summer Chinook. We also identified ongoing and future studies and comparisons to examine this question further.

The following factors could potentially bias PIT-tag SARs: (1) non-representative tagging; (2) post-tagging mortality; (3) tag loss (shedding or damaged tags); (4) weighting schemes from different passage routes (before 2006); and (5) adult detection efficiency. Tuomikoski et al. (2010) concluded that factors 2 and 3 appeared most plausible (but un-quantified) for Snake River wild spring/summer Chinook PIT tag SARs.

For RR SARs, bias could result because: (1) wild smolt indices and wild adult indices may incorporate different proportions of adipose-intact hatchery fish; (2) window counts used in the RR are not corrected for fallback or counting period; (3) window counts use length criteria to separate jacks and adults; and (4) age composition estimation errors tend to inflate SARs. All factors appeared plausible for at least some past RR estimates; Tuomikoski et al. (2010) suggested a focus on RR adult data based on LGR adult trap sampling may be useful for future PIT tag and RR SAR comparisons.

There is potential for bias in both the CSS PIT tag and IDFG RR SAR estimates, although both provide useful, highly correlated estimates. To date, a definitive control group has been lacking to quantify the potential post-marking mortality or tag shedding bias in PIT tag SARs. Similarly, it is not yet possible to evaluate the extent of bias in RR SARs. CSS has identified several hypotheses that might help explain the observed differences in SARs between PIT tag and RR methods. Determining the extent and causes of bias ultimately will be important in the synthesis and interpretation of the different survival rate data sets (see CSS 2014 report, Chapter 6).

Ocean Survival Rates (S.oa and S.o1)

Estimated ocean survival rates (with recruits calculated at the Columbia River mouth), *S.oa*, for Snake River wild spring/summer Chinook during 1994–2013 ranged from 0.003 to 0.061 and the 20-year geometric mean was 0.019 (Table B.98). These recent *S.oa* rates for spring/summer Chinook were more than five-fold lower than the geometric mean of 0.099 for the 1964–1969 period (Figure 4.20). Similarly, *S.oa* for wild steelhead declined more than 6-fold from a geometric mean of 0.175 during 1964–1969 to 0.028 during 1997–2013 (Table B.99; Figure 4.20).

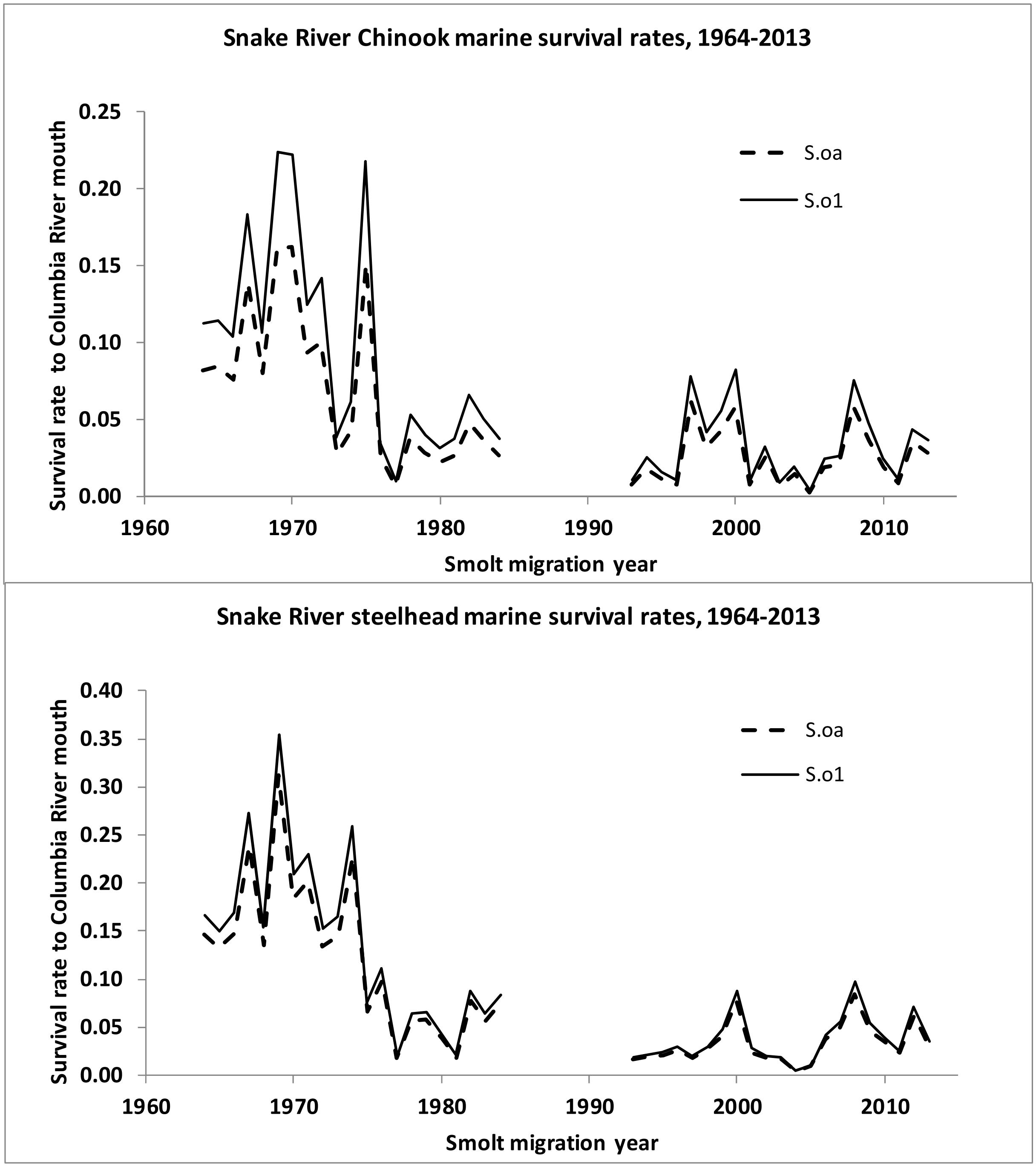


Figure 4.20 Marine survival rates for Snake River wild spring/summer Chinook and steelhead, 1964–2013.

Estimated first year ocean survival rates, *S.o1*, for Snake River wild spring/summer Chinook during 1994-2013 ranged from 0.004 in 2005 to 0.082 in 2000 and the 20-year geometric mean was 0.025 (Table B.98). Estimated *S.o1* for wild steelhead during 1997–2013 ranged from 0.005 in 2004 to 0.097 in 2008 and the 17-year geometric mean was 0.032 (Table B.99). Over the same 17-year period as shown for wild steelhead, the geometric mean of *S.o1* was 0.028 for Snake River wild spring/summer Chinook. In contrast, the geometric

mean of first year ocean survival during 1964–1969 was estimated to be 0.134 and 0.199 for Snake River spring/summer Chinook and steelhead, respectively (Petrosky and Schaller 2010; Tuomikoski et al. 2012).

To date, CSS has estimated *S.oa* and *S.o1* only for Snake River wild spring/summer Chinook and steelhead, but will explore estimating *S.oa* and *S.o1* for mid-Columbia and upper Columbia wild spring Chinook and steelhead in future reports as we develop the relevant time series of SARs and in-river survival rates. The *S.oa* and *S.o1* calculations are simplified for these regions without the impacts of juvenile collection and transportation from the FCRPS dams, although detection capability for juvenile outmigrants is more limited.

Discussion

In summary, it appears that neither Snake River wild spring/summer Chinook nor wild steelhead populations are consistently meeting the NPCC 2%–6% SAR objective. Geometric mean SARs (LGR-to-GRA) were 0.87% and 1.62% for PIT-tagged wild spring/summer Chinook and steelhead, respectively. In the 18 years since 1997, SARs have significantly exceeded the 2% minimum in only two years for Snake River wild Chinook and four years for wild steelhead. SARs of both species have been well short of the NPCC objective of an average 4% SAR.

Although Snake River hatchery spring/summer Chinook exhibited a generally more positive response to transportation and relatively lower levels of differential delayed mortality (higher *D*) than wild populations (Appendix A), annual SARs of Snake River wild and hatchery spring/summer Chinook were highly correlated across years. In view of this high correlation, continuing the CSS time series of hatchery SARs will be important to augment wild spring/summer Chinook SAR information in future years of low tag return numbers of wild adults and in the investigation of survival rate variation of wild populations. In addition, the time series provides valuable management information for the specific hatcheries and for management of FCRPS river operations.

Similar factors during the smolt migration and estuary and ocean life stages appear to influence survival rates of Snake River wild and hatchery spring/summer Chinook populations, based on our evaluation of trends in SARs for the wild and hatchery groupings. We also observed a high degree of synchrony in SARs of wild spring/summer Chinook at the MPG level. A high degree of synchrony among populations may pose additional risk to metapopulation persistence when abundance is low (McElhany et al. 2000; Isaak et al. 2003). There were survival rate differences among spring/summer Chinook hatcheries such as Dworshak NFH, which showed generally poorer SARs within years than Rapid River, McCall and Imnaha hatcheries; conversely, the McCall and Imnaha hatcheries typically had among the highest SARs within a year.

Reasons for the relative lack of correlation between Snake River wild and hatchery steelhead SARs during 1997–2013 are unknown, but appear to be related to the opportunistic nature of assembling aggregate hatchery steelhead groups from various monitoring programs prior to 2008. More representative tagging for Snake River steelhead hatcheries began in coordination with LSRCP and IPC in migration year 2008. Wild and hatchery steelhead SARs have tracked more closely ($r = 0.87$) in the six years since we improved hatchery group

representation. Future implementation of the CSS design and analysis for hatchery steelhead should allow for evaluation of any disparity among groups (e.g., among facilities or A-run vs. B-run) to help craft appropriate retrospective weightings for aggregate hatchery steelhead SARs. A moderate correlation between wild spring/summer Chinook and wild steelhead SARs is apparent.

Overall SARs of Snake River wild spring/summer Chinook and steelhead are the net effect of SARs for the different routes of in-river passage and juvenile transportation. None of the passage routes have resulted in SARs that met the NPCC SAR objectives for either species (Appendix A). The relative effectiveness of transportation has been observed to decline as in-river conditions and survival rates improve.

The CSS began a time series of SARs for Snake River hatchery sockeye in 2009. Sockeye SARs have varied by year and hatchery group (Sawtooth and Oxbow hatcheries). Sockeye production was phased out at Sawtooth Hatchery after migration year 2015, with production (and the CSS mark group) being shifted to Springfield Hatchery.

Mid-Columbia River wild spring Chinook populations, as represented by the John Day River and Yakima River aggregate groups, have experienced SARs generally within or close to the range of the NPCC 2%–6% SAR objective. The geometric mean SARs for John Day River and Yakima River wild spring Chinook were 3.9% and 2.4%, respectively, during 2000–2014. CSS has begun time series of wild steelhead SARs for the John Day, Deschutes and Yakima rivers, with most SARs meeting (or exceeding) the NPCC 2%–6% SAR objective.

Mid-Columbia River hatchery spring Chinook (Carson and Cle Elum) SARs have varied by year and hatchery during 2000–2014. SARs for Carson Hatchery were less than those for Cle Elum Hatchery; SARs for both hatcheries were consistently less than those for John Day and Yakima wild spring Chinook. Although differing in magnitude, SARs were highly correlated among wild and hatchery spring Chinook stocks within the mid-Columbia Region.

The CSS has begun to establish a time series of SARs (MCN-BOA) for Upper Columbia River wild spring Chinook and steelhead, with PIT-tagging in the Wenatchee, Entiat, and Methow rivers beginning in 2006 and 2007. Leavenworth Hatchery spring Chinook SARs were highly correlated with SARs of wild and hatchery spring and spring/summer Chinook stocks from both the mid-Columbia and Snake regions during 2000–2014. The MCN-BOA reach excludes much of the migration corridor for upper Columbia populations, which pass an additional three (Wenatchee River), four (Entiat River) or five (Methow River) PUD dams upstream of MCN. Consequently, SARs based on detections of PIT-tagged smolts at MCN are biased high. The CSS has begun to estimate SARs of wild spring Chinook and steelhead from populations upstream of Rocky Reach Dam beginning with the 2008 juvenile outmigration year, and with the 2013 juvenile migration year for wild summer Chinook and wild sockeye. SARs from spring Chinook and steelhead smolts at RRE were about 60% of those based on smolts at MCN for these populations and years. Increases in PIT tag detection capability in the Columbia River upstream of MCN will make regional monitoring of overall SARs more comparable to the SARs for salmon and steelhead populations in the Snake River and Mid-Columbia regions.

The high degree of inter-regional correlation in SARs of wild and hatchery spring and spring/summer Chinook populations indicates that common environmental factors are influencing survival rates from outmigration to the estuary and ocean environments. This "common year effect" between Snake River wild spring/summer Chinook and mid-Columbia

wild spring Chinook has been previously estimated from spawner-recruit patterns (e.g., Deriso et al. 2001; Schaller and Petrosky 2007; Schaller et al. 2014).

PIT tag SARs of Snake River wild spring/summer Chinook were highly correlated with IDFG RR SARs for the period 1996–2012, and SARs from both time series were well short of the NPCC 2%–6% SAR objective. The RR SARs were about 40% higher than PIT-tag SARs. We developed several hypotheses in the 2010 CSS report that might help explain the observed differences in SARs between PIT-tag and RR methods. There is potential for bias in both the CSS PIT-tag and IDFG RR SAR estimates, although both provide useful, highly correlated estimates. To date, a definitive RR control group has been lacking to quantify the potential bias from post-marking mortality or tag loss in PIT-tag SARs. Determining the extent and causes of bias in both types of estimates is a priority research topic, and ultimately will be important in the synthesis and interpretation of the different survival rate data sets.

Several studies should yield additional insight into the question of PIT-tag effects on SARs in the near future. The USFWS (in collaboration with the CSS oversight committee) is working towards implementing an independent basin-wide study of PIT-tag bias to evaluate and test the repeatability of Knudsen et al. (2009) results. Double tagging experiments are currently being implemented for Carson Hatchery (see Chapter 6 of 2014 CSS annual report).

CSS studies have found that the life-cycle survival, SAR and marine survival rates for Snake River spring/summer Chinook and steelhead were strongly related to both ocean conditions and seaward migration conditions through the FCRPS (Schaller et al. 2007; Petrosky and Schaller 2010; Haeseker et al. 2012; Hall and Marmorek 2013; Schaller et al. 2014). Lower survival rates for spring/summer Chinook were associated with warmer ocean conditions, reduced upwelling in the spring, and slower river velocity during the smolt migration or multiple passages through powerhouses at dams (Petrosky and Schaller 2010; Schaller et al. 2014). Similarly, lower survival rates for steelhead were associated with warmer ocean conditions, reduced upwelling in the spring, slower river velocity and warmer river temperatures (Petrosky and Schaller 2010). Parameters estimated in CSS, including in-river survival, transport proportions and *D*, allow for partitioning of the SARs to estimate ocean survival rates, *S.oa*, and first year ocean survival rates, *S.o1*. The NPCC (2009 and 2014) highlighted the need to identify the effects of ocean conditions on anadromous fish survival so that this information can be used to evaluate and adjust inland conservation and mitigation actions. The NPCC recognized that a better understanding of the conditions salmon face in the ocean could reveal factors that are most critical to survival, and thus which actions taken inland could provide the greatest benefit to improve the likelihood that Columbia River Basin salmon populations can be recovered in the face of varying ocean conditions (NPCC 2009 and 2014). The time series of SARs, *S.oa* and *S.o1* can then be used to evaluate ocean and smolt migration factors that may influence ocean survival of Snake River and upper Columbia salmon and steelhead as called for in the Fish and Wildlife Program (NPCC 2009 and 2014).

Additional comparisons of PIT-tag data within seasons suggest that shared environmental factors are influencing mortality rates of Snake River wild spring/summer Chinook and steelhead (Haeseker et al. 2012). Mortality rates in both species were positively correlated: (1) during freshwater outmigration as smolts through a series of hydropower dams and reservoirs; (2) during the period of post-hydrosystem, estuarine/marine residence through adult return; and (3) during the overall life-cycle from smolt outmigration through adult return, suggesting that shared environmental factors are influencing mortality rates of both species. In addition,

evidence of positive co-variation in mortality rates between the freshwater and subsequent marine-adult life stage for each species, suggests that factors affecting mortality in freshwater partially affect mortality during the marine-adult life stage (Haeseker et al. 2012). The percentage of river flow spilled and water transit time were important factors for characterizing variation in survival rates not only during freshwater outmigration, but also during estuarine/ marine residence (Haeseker et al. 2012); the Pacific Decadal Oscillation index was also important for characterizing variation in marine survival rates and SARs of both species. This work, along with the findings in Schaller et al. (2007), Petrosky and Schaller (2010) and Schaller et al. (2014), have illuminated a promising direction of inquiry for CSS work. We plan to continue evaluation of the correlation of SARs among the regions. In the 2013 CSS Workshop (Hall and Marmorek 2013), we used these retrospective models to evaluate which environmental and river management variables best explained the variation in survival rates for the various life stages (e.g., SAR, *S.oa*, *S.o1, and* S.r), and developed prospective models to evaluate expected responses to alternative spill management scenarios. This study direction is consistent with NPCC direction and past recommendations from the ISAB/ISRP. These tools hold promise for evaluating river operations with respect to NPCC objectives, and in guiding design for adaptive management experiments.

Conclusions

- Overall PIT-tag SARs for Snake River wild spring/summer Chinook and wild steelhead fell well short of the Northwest Power and Conservation Council (NPCC) SAR objectives of a 4% average for recovery and 2% minimum.
- PIT-tag SARs of Snake River hatchery spring/summer Chinook varied by hatchery and year, and were highly correlated with those of wild spring/summer Chinook. There was a general lack of correlation between Snake River hatchery and wild steelhead SARs.
- Overall SARs of Snake River wild spring/summer Chinook and steelhead are the net effect of SARs for the different routes of in-river passage and juvenile transportation. None of the passage routes have resulted in SARs that met the NPCC SAR objectives for either species. The relative effectiveness of transportation has been observed to decline as in-river conditions and survival rates improve.
- PIT-tag SARs for Mid-Columbia wild spring Chinook (John Day and Yakima rivers) and wild steelhead (John Day, Deschutes and Yakima rivers) generally fell within the 2%–6% range of the NPCC SAR objectives.
- Hatchery (Carson and Cle Elum) and wild spring Chinook SARs from the Mid-Columbia region were highly correlated; hatchery SARs were consistently lower in magnitude.

- PIT-tag SARs for Upper Columbia hatchery spring Chinook (Leavenworth) were highly correlated with wild and hatchery spring/summer and spring Chinook stocks from both the Snake and Mid-Columbia regions. Due to limited juvenile detection capability in the Columbia River mainstem upstream of MCN, most Upper Columbia SAR time series are presented as MCN-to-BOA and overstate life cycle survival by excluding mortality within the migration corridor upstream of MCN. The CSS has begun to estimate SARs beginning with smolts at Rocky Reach Dam to address this issue.
- SARs based on run reconstruction methods were greater than and highly correlated with, PIT-tag SARs of Snake River wild spring Chinook. Both time series indicate survival rates fell well short of the NPCC 2%–6% SAR objective. Potential for bias in SAR estimates exists in both the run reconstruction and PIT-tag methodologies. Determining the extent and cause of bias ultimately will be important in the synthesis and interpretation of the different survival rate data sets.
- Parameters estimated in CSS, including in-river survival, transport proportions and *D*, allow for partitioning of SARs to estimate ocean survival rates. The time series of SARs and ocean survival rates can be used to evaluate ocean environmental variables and smolt migration conditions within the FCRPS that may influence ocean survival of Snake River and upper Columbia salmon and steelhead as called for in the Fish and Wildlife Program (NPCC

CHAPTER 5
SARS AND PRODUCTIVITY

The CSS has been reporting smolt-to-adult survival rates (SARs) for wild and hatchery salmon and steelhead relative to the Northwest Power and Conservation Council's (NPCC 2003, 2009, 2014) 2%-6% SAR objectives (Chapter 4). Recent SARs have consistently fallen short of these objectives for wild population groups in the Snake and upper Columbia rivers, whereas recent SARs for most of the mid-Columbia wild population groups have fallen within this 2%-6% range. The NPCC's (2014) Columbia River Basin Fish and Wildlife Program contains several qualitative goal statements and quantitative objectives to prioritize the restoration efforts, including supporting tribal and non-tribal harvest, and achieving smolt-to-adult return rates in the 2%-6% range (average 4%; minimum 2%) for listed Snake River and upper Columbia salmon and steelhead. The Program also supports the ISAB's recommendation to evaluate the 2%-6% SAR objective to reflect the survival of populations needed to achieve recovery and harvest goals.

The genesis of the NPCC 2%–6% SAR objectives was from analyses conducted by the Plan for Analyzing and Testing Hypotheses (PATH), in support of the 2000 Biological Opinion of the Federal Columbia River Power System (FCRPS). Marmorek et al. (1998) found that median SARs of 4% were necessary to meet the NMFS interim 48-year recovery standard for Snake River spring/summer Chinook; meeting the interim 100-year survival standard required a median SAR of at least 2%. The NPCC (2009 and 2014) SAR objectives did not specify the points in the life cycle where Chinook smolt and adult numbers should be estimated. However, the original PATH analysis for Snake River spring/summer Chinook was based on SARs calculated as adult and jack returns to the uppermost dam (Marmorek et al. 1998). PATH analyses also did not identify specific SARs necessary for steelhead survival and recovery. However, before completion of the FCRPS, steelhead SARs were somewhat greater than those of spring/summer Chinook (Marmorek et al. 1998). The Interior Columbia River Technical Recovery Team (ICTRT 2007) developed biological recovery criteria based on the Viable Salmonid Population concepts (McElhany et al. 2000). Additional SAR objectives may be associated with the ICTRT recovery criteria for abundance and productivity when adopted or incorporated into a Recovery Plan, as well as with the objectives identified in Fish and Wildlife Program subbasin plans, and other State and Tribal fishery management plans. Broad-scale recovery goals, such as these, are higher than required for ESA delisting and typically include a provision for restoring sustainable fisheries of wild salmon and steelhead. The Independent Scientific Advisory Board (ISAB 2012) review of the 2012 CSS draft annual report also highlighted the NPCC SAR objectives as an important regional programmatic issue.

A SAR objective for persistence may need to account for adults returning to the spawning grounds, whereas broader objectives would also need to account for adults returning to various locations to meet harvest objectives (e.g., subbasin or Columbia River mouth). In the 2016 annual report, we continue to investigate the relation between SARs and population productivity using two approaches. The first approach is related to persistence objectives and summarizes the SAR levels of Snake River wild spring/summer Chinook and steelhead associated with population replacement at recent levels of abundance. The second approach incorporates stock-recruitment functions to investigate the association between pre-harvest SARs and historical

productivity levels relative to broad-scale recovery objectives of wild Snake River spring/summer Chinook and mid-Columbia spring Chinook.

Analyses in this Chapter support objectives of the Columbia River Basin Fish and Wildlife Program (NPCC 2014), encouraging a regional review of the NPCC SAR objectives relative the survival of populations needed to achieve salmon and steelhead recovery and harvest goals. New to the 2016 annual report are the comparisons of Snake River SARs and steelhead population productivity for Fish Creek (Clearwater Major Population Group (MPG)) and Rapid River (Salmon MPG), which complement those for Snake River spring/summer Chinook. The CSS plans continue to update and expand these analyses as Chinook and steelhead run reconstruction data are updated and become available.

Comparisons of Chinook and steelhead population productivity and SARs are conducted at the finest geographic scales possible, consistent with the ISAB (2013) review comments of the CSS draft 2013 annual report. Analyses in this Chapter are also complimentary to the Chapter 2 analysis for the Grande Ronde/Imnaha spring/summer Chinook MPG, adding data from populations and MPGs across the entire Snake River spring/summer Chinook ESU. Notably, analyses in this chapter include population data from the Middle Fork Salmon River MPG that is primarily in wilderness and has little potential for improvement to tributary habitat or survival during the egg-to-smolt life stage.

Methods

Recent SARs and Population Replacement

In the 2016 annual report, we continue our investigation of the relation between SARs and realized population productivity of Snake River spring/summer Chinook populations for brood years 1992–2008. Spring/summer Chinook populations used in this analysis are 17 Snake River populations across four MPGs used in Schaller et al. (2014). Populations (and MPGs) include: Bear Valley Creek, Marsh Creek, Sulphur Creek and Big Creek (Middle Fork Salmon); South Fork Salmon River Mainstem, East Fork South Fork Salmon River and Secesh River (South Fork Salmon); Lemhi River, East Fork Salmon River, Upper Salmon River and Valley Creek (Upper Salmon); and Wenaha River, Minam River, Lostine River, Catherine Creek, Upper Grande Ronde River and Imnaha River (Grande Ronde/Imnaha). (The 18th population, Big Sheep Creek (Imnaha), used in Schaller et al. (2014) was functionally extinct and not included in this summary). Snake River spring/summer Chinook run reconstruction data consisting of spawner and spawning-ground recruit estimates, were recently updated by ODFW, IDFG and NPT staff through 2013 adult returns (2008 brood year) and submitted to NOAA Fisheries for the 2016 ESA Status Review.

We defined the realized Chinook population productivity as ln((adult recruits to spawning grounds)/(adult spawners)) for brood years 1992–2008. Productivity in terms of spawning ground recruits (Rsg) is most applicable to evaluation of population persistence (e.g., ICTRT 2007) and spawning escapement objectives. We used the CSS estimates of LGR-GRA SARs (jacks excluded) for wild spring/summer Chinook for smolt migration years 1994–2010. We used aggregate wild SARs for smolt migration years 1994–2005, and MPG-specific SARs for 2006–2010 in this analysis. We selected SARs excluding jacks for this summary because that metric aligns most closely with the population productivity metric, which also excludes jacks on

the spawning grounds. We plotted population productivity against SARs for the 17 individual populations and for the four MPGs. We then summarized the population productivities by MPG and graphically compared distributions of observed productivity by SAR category: <1.0% SAR, 1.0 - 1.9% SAR, and $\geq$ 2.0% SAR. These graphical comparisons begin to illuminate the SARs needed for population abundance to stabilize or increase, given recent (1992–2008) wild adult abundance levels; however, it is primarily observational and does not attempt to account for density-dependent effects on recruitment at higher spawner abundances.

In this report, we also began to investigate the relation between SAR and realized population productivity of Snake River steelhead using data from Fish Creek (a major tributary of the Lochsa River Population, Clearwater River MPG) and Rapid River (a major tributary of the Lower Salmon Population, Salmon River MPG). Hatchery influence is minimized in both drainages by exclusion of any hatchery strays at the weirs (Copeland et al. 2015). Data from Fish Creek included brood years 1996-2009 and data from Rapid River included brood years 2003-2009. Steelhead from Fish Creek are classified as B-run; steelhead from Rapid River are classified as A-run. Steelhead run reconstruction data were obtained from Copeland et al. (2015) as updated by Stark et al. (2016) to include data collected in 2015.

We defined the realized steelhead population productivity as ln((recruits to spawning grounds)/(spawners)). Steelhead cohorts produce smolts ranging in age from one to five (or more) years old, in contrast to spring/summer Chinook, which primarily produce only yearling smolts (with a few exceptions). Therefore, to calculate SARs by brood year we weighted multiple years of SARs by the juvenile outmigrant age structure. We used CSS estimates of LGR-GRA SARs for wild A-run (Rapid River) or B-run (Fish Creek) steelhead for smolt migration years 2006-2012 (Tables B.38, B.39). Prior to smolt migration year 2006, we used SAR estimates for the wild aggregate steelhead (Table B.33). We used the age composition of spring migrants at rotary screw traps to index average smolt age composition from Copeland et al. (2015). For Fish Creek, age composition was 12.5% one year, 50.0% two year, 33.3% three year, and 4.2% four year. Average age composition for Rapid River steelhead was 9.1% one year, 25.8% two year, 49.5% three year, 14.5% four year, and 1.1% five year.

We plotted population productivity against brood year SARs for the Fish Creek and Rapid River steelhead populations. We then graphically compared distributions of observed productivity by brood year SAR category: <1.0% SAR, 1.0 - 1.9% SAR, and $\geq$ 2.0% SAR.

SARs and Historical Productivity

We have also begun to examine the relation of SARs to historical pre-harvest productivity, using the (density-dependent) stock-recruitment functions from Schaller et al. (2014). Schaller et al. defined spawners (S) as adult spawners and recruits (R) as pre-harvest recruits (adults and jacks) to the Columbia River mouth. Spawner-recruit (SR) relationships were developed for 18 populations of Snake River spring/summer Chinook from four MPGs for brood years 1950s–2004. Non-stationarity in migration and marine conditions was accounted for by using a period effect:

$$ln(R_{ij}/S_{ij}) = T_i + a - \beta(S_{ij} - \overline{S_{..}}) + \varepsilon_{ij}$$

where T_i is the class effect (period), a is the intercept, β is the slope, $\overline{S_{..}}$ is the average spawners

for all observations during both time periods, ε_{ij} is the normally distributed residual, i is the class (period), and j is the observation (brood year).

Schaller et al. (2014) classified SR data into two primary periods defined by FCRPS development and operations affecting the threatened Snake River populations. The first period, pre-1970 brood years, was before completion of the final two Snake River dams. The second period, post-1974 brood years (1975–2004), was characterized by completion of the full eight dam complex, collection and transportation of smolts around dams in barges and trucks, turbine screening programs, and other management actions to improve passage at the dams (Budy et al. 2002). The 1970–1974 period was excluded from fitting of the recruitment functions because it was a period of construction and of changing operations in the Snake River that caused extremely high levels of atmospheric gas supersaturation in high-flow years (Raymond 1979) before mass transportation of smolts had begun.

Schaller et al. (2014) also presented SR residuals for the period 1950s–2004 brood years, designated as survival rate indices (SRIs). They defined SRIs as the deviation of the observed ln(R/S) from the pre-1970 expected ln(R/S). The pre-1970 period represented a baseline before full development of the FCRPS, and prior to initiation of mass juvenile transportation.

Pre-harvest SARs (Columbia River returns) for Snake River aggregate wild Chinook are available beginning in 1964 (1962 brood year; Table B.72). Snake River average annual SRI estimates were regressed against the aggregate ln(SARs), and plotted by decade to examine temporal patterns of the association. In addition, we examined SRI and SAR patterns within the four Snake River MPGs. Average annual SRI estimates for each MPG were regressed against the aggregate ln(SARs) and plotted to examine spatial patterns across the Snake River ESU.

Schaller et al. (2014) similarly developed SR relationships for three populations of John Day River spring Chinook from a single MPG for brood years 1950s–2004 and estimated SRIs as defined above. SARs based on PIT tags for John Day River wild Chinook are available beginning in smolt migration year 2000 (1998 brood year) (Table B.70). The SRI estimates (SR residuals) were then regressed against the pre-harvest ln(SARs) for the John Day River populations for the seven years of overlap. Pre-harvest SARs for John Day spring Chinook were estimated by dividing the JDA-to-BOA SAR by the survival of adults returning through the lower river fisheries.

Results

Recent Chinook SARs and Population Replacement

Aggregate Snake River wild Chinook SARs (LGR-GRA, jacks excluded) during smolt migration years 1994–2010 (brood years 1992-2008) averaged 0.84% (geometric mean) and ranged from 0.22% to 2.74% (Table B.1). SARs were less than 1% during ten years, in the 1%-2% range during five years, and greater than 2% during only two of 17 years.

A strong association is evident between Rsg/S and SAR for Snake River Chinook populations. Generational declines in abundance (ln(Rsg/S) < 0) occurred in 116 out of 163 cases (71%) where SARs were less than 1%, and in only one out of 34 cases (3%) where SARs were

greater than 2% (Figure 5.1 upper panel). The patterns of association between Rsg/S and SAR were generally similar across the four MPGs (Figure 5.1, lower panel). Average population replacement for Grande Ronde/Imnaha and South Fork Salmon MPGs at recent abundances however, appears to require somewhat higher SARs than for Middle Fork Salmon and Upper Salmon MPGs.

SARs less than 1% consistently resulted in generational decreases in abundance ($\ln(Rsg/S) < 0$) in all four Chinook MPGs (Figure 5.2). Conversely, SARs greater than 2% resulted in generational increases in abundance in all four MPGs. Observed productivity was generally positive (median $\ln(Rsg/S) > 0$) when SARs were in the 1%–2% range; this result might be expected, because population abundance was typically very low and only a fraction of the Minimum Abundance Thresholds (MAT; Table 5.1) established for long-term population viability (ICTRT 2007). These graphical comparisons begin to illuminate the SARs needed for Snake River Chinook population abundance to stabilize or increase, given recent (brood years 1992–2008) abundance levels.

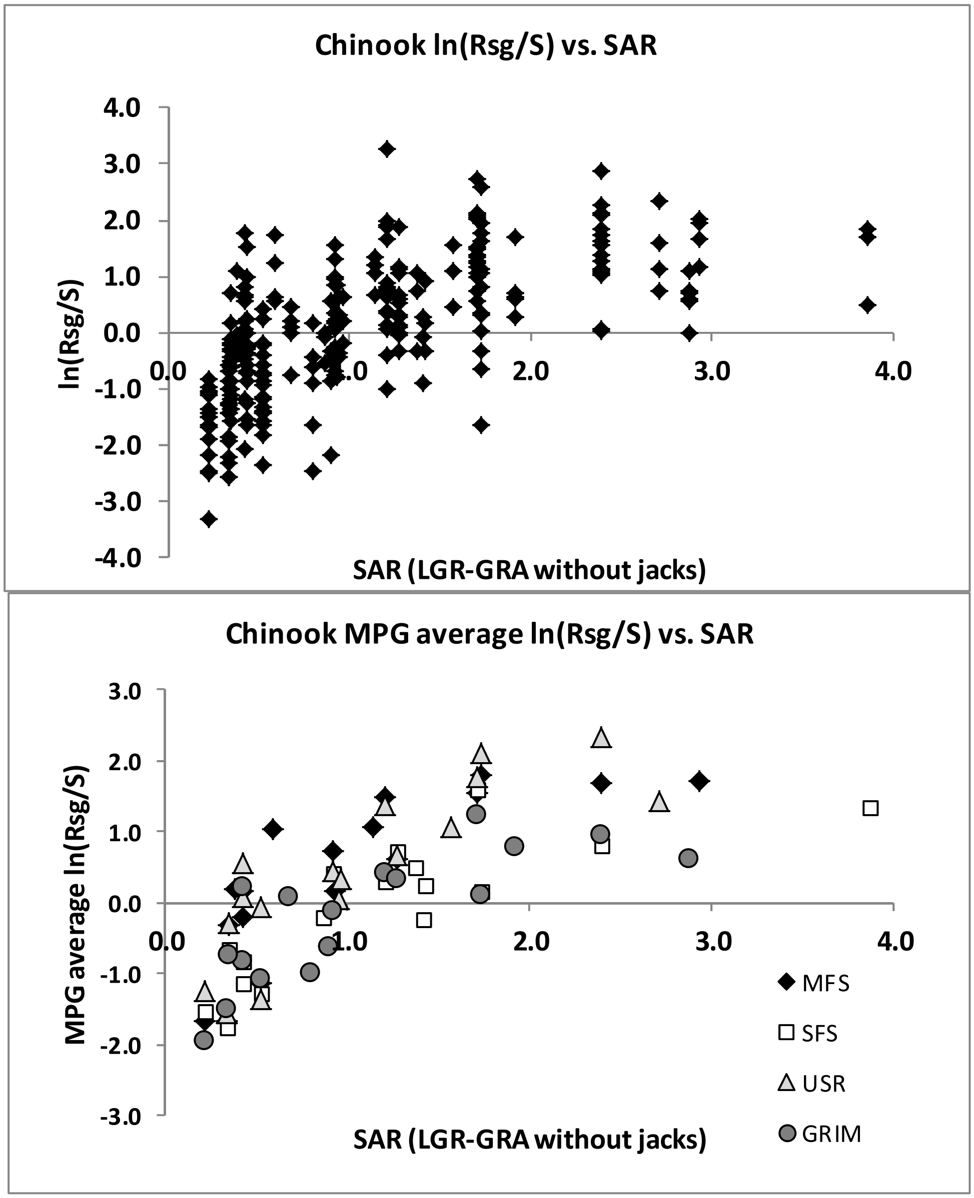


Figure 5.1. Association of spawning ground recruits/spawner, ln(Rsg/S), and SAR for 17 Snake River spring/summer Chinook populations (upper panel), and by Major Population Group (MPG) (lower panel), brood years 1992-2008. SARs represent LGR-GRA, excluding jacks (1994--2010 smolt migration years). MPGs are Middle Fork Salmon (MFS), South Fork Salmon (SFS), Upper Salmon (USR) and Grand Ronde/Imnaha (GRIM).

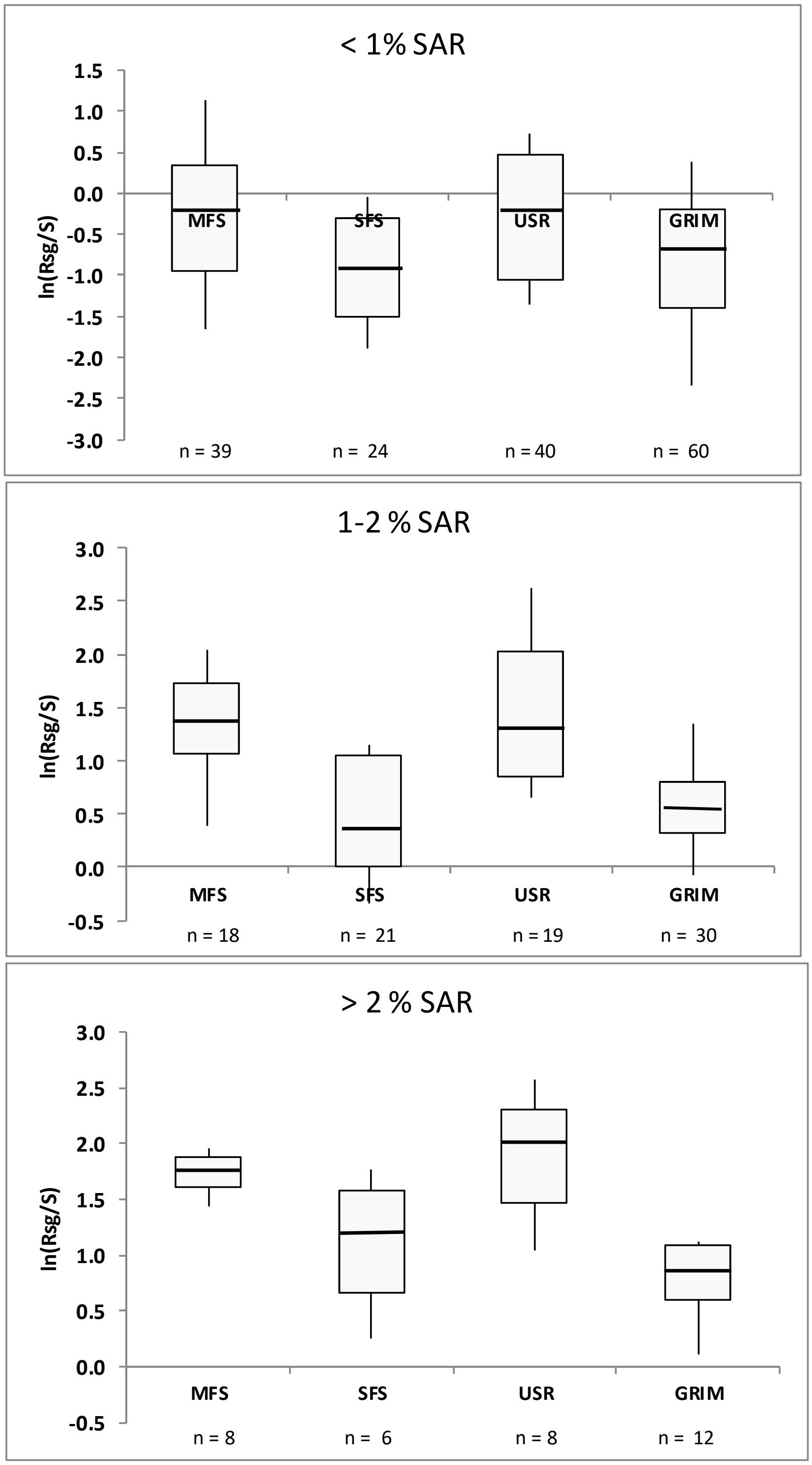


Figure 5.2. Snake River Chinook population productivity (ln(Rsg/S)) by MPG and SAR category, brood years 1992–2008. Boxes show 25th percentile, median and 75th percentile of ln(Rsg/S); whiskers show 10th and 90th percentiles of ln(Rsg/S). SARs represent LGR-GRA, excluding jacks (1994--2010 smolt migration years). MPGs are Middle Fork Salmon (MFS), South Fork Salmon (SFS), Upper Salmon (USR) and Grand Ronde/Imnaha (GRIM).

Table 5.1. Summary population abundance statistics, Snake River spring/summer Chinook populations, 1992–2008 brood years.

MPG, Population	Average total adult spawners	Range total adult spawners	Average hatchery fraction	ICTRT (2007) Minimum Abundance Threshold (MAT)	Average natural adult spawners as % MAT
Middle Fork Salmon (MFS)					
Bear Valley Creek	399	16 - 1315	0%	750	53%
Marsh Creek	202	0 - 872	0%	500	40%
Sulphur Creek	59	0 - 201	0%	500	12%
Big Creek	177	3 - 668	0%	1000	18%
South Fork Salmon (SFS)					
South Fork Mainstem	1173	203 - 2464	41%	1000	69%
East Fork South Fork	346	47 - 1067	22%	1000	27%
Secesh River	518	142 - 1400	4%	750	66%
Upper Salmon River (USR)					
Lemhi	118	9 - 691	0%	1000	12%
East Fork Salmon River	245	11 - 866	13%	1000	21%
Upper Salmon Mainstem	533	27 - 1741	28%	1000	38%
Valley Creek	82	0 - 288	0%	500	16%
Grande Ronde/Imnaha (GRIM)					
Catherine Creek	170	27 - 403	38%	1000	11%
Grande Ronde Upper Mainstem	133	4 - 532	32%	1000	9%
Lostine River	390	33 - 1081	35%	1000	25%
Minam River	355	54 - 657	12%	750	42%
Wenaha River	399	73 - 832	17%	750	44%
Imnaha River Mainstem	966	158 - 2736	56%	1000	43%

Recent Steelhead SARs and Population Replacement

The Fish Creek steelhead analysis was based on Rsg/S estimates for brood years 1996-2009; age 1-4 smolts from these brood years migrated during 1997-2013. SARs (LGR-GRA) from smolt migration years 1997-2013 averaged (geometric mean) 1.47% and ranged from 0.30% to 3.54% (Tables B.33 and B.39). Weighted brood year SARs for 1996-2009 averaged 1.64% and ranged from 0.87% to 2.61% (Table 5.2). Spawning ground recruits/spawner (Rsg/S) of Fish Creek steelhead ranged from 0.37 in 2002 to 10.25 in 1997 (Table 5.2).

The Rapid River steelhead analysis was based on Rsg/S estimates for brood years 2003-2009; age 1-5 smolts from these brood years migrated during 2003-2014 (approximately 1% migrated in 2014). SARs (LGR-GRA) from smolt migration years 2004-2013 averaged

(geometric mean) 1.83% and ranged from 0.80% to 3.30% (Tables B.33 and B.38). Weighted brood year SARs for 2003-2009 averaged 2.21% and ranged from 1.50% to 2.70% (Table 5.2). Spawning ground recruits/spawner (Rsg/S) of Rapid River steelhead ranged from 0.34 in 2008 to 2.13 in 2007 (Table 5.2).

Table 5.2. Estimates of brood year SAR and spawning ground recruits/spawner (Rsg/S) for Fish Creek and Rapid River steelhead populations. Brood years represented are 1996–2009 for Fish Creek and 2003-2009 for Rapid River. Brood year SARs represent LGR-GRA, (Fish Creek 1997--2013 smolt migration years; Rapid River 2004-2013 smolt migration years.

	Fish Creek		Rapid River	
Brood year	Brood year SAR	Rsg/S	Brood year SAR	Rsg/S
1996	1.35	2.95		
1997	2.45	10.25		
1998	2.60	3.45		
1999	2.35	2.65		
2000	1.94	3.45		
2001	1.37	0.89		
2002	0.93	0.37		
2003	0.87	0.78	1.50	0.84
2004	1.17	0.92	2.48	0.99
2005	2.07	3.03	2.69	1.69
2006	2.61	2.44	2.70	1.46
2007	1.82	1.41	2.23	2.13
2008	1.30	0.43	1.91	0.34
2009	1.56	0.79	2.24	0.35

An association is evident between Rsg/S and brood year SAR for steelhead from Fish Creek and Rapid River. Generational declines in abundance (Rsg/S < 1; ln(Rsg/S < 0)) occurred in nine out of 14 cases where brood year SARs were less than 2% (Table 5.2; Figure 5.3). Population replacement (ln(Rsg/S) = 0) for Rapid River steelhead at recent abundance appears to require higher SARs than for Fish Creek steelhead, although sample sizes are limited.

SARs less than 1% resulted in generational decreases in steelhead abundance (ln(Rsg/S) < 0) (Figure 5.4). Conversely, SARs greater than 2% resulted in generational increases in steelhead abundance. Observed productivity was generally negative (median ln(Rsg/S) < 0) when SARs were in the 1%–2% range. These graphical comparisons begin to illuminate the SARs needed for steelhead population abundance to stabilize or increase, given recent abundance levels.

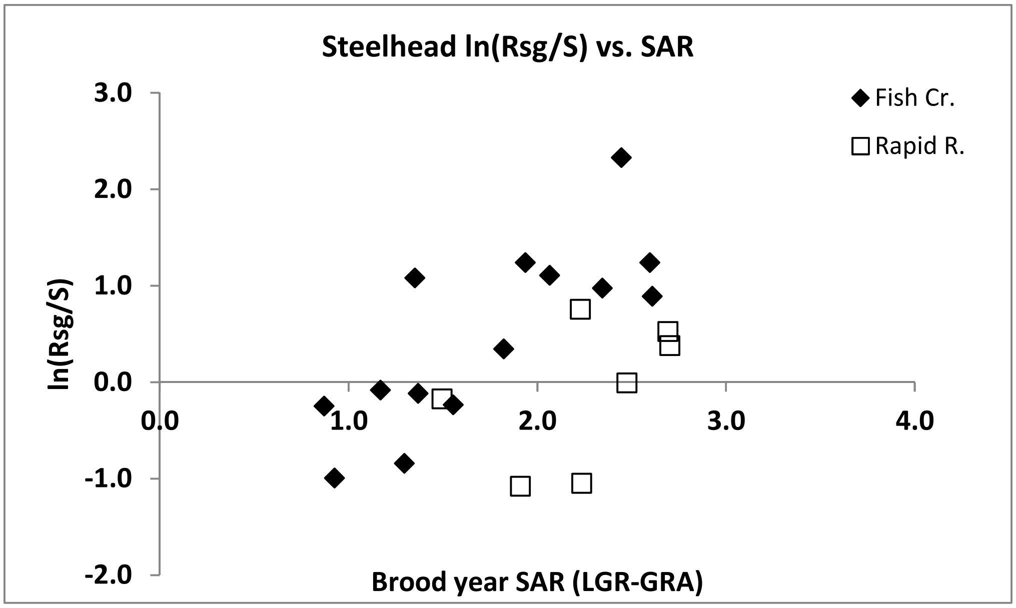


Figure 5. 3 Association of spawning ground recruits/spawner, ln(Rsg/S), and brood year SAR for Fish Creek and Rapid River steelhead. Brood years represented are 1996–2009 for Fish Creek and 2003-2009 for Rapid River. Brood year SARs represent LGR-GRA (Fish Creek 1997--2013 smolt migration years; Rapid River 2004-2013 smolt migration years).

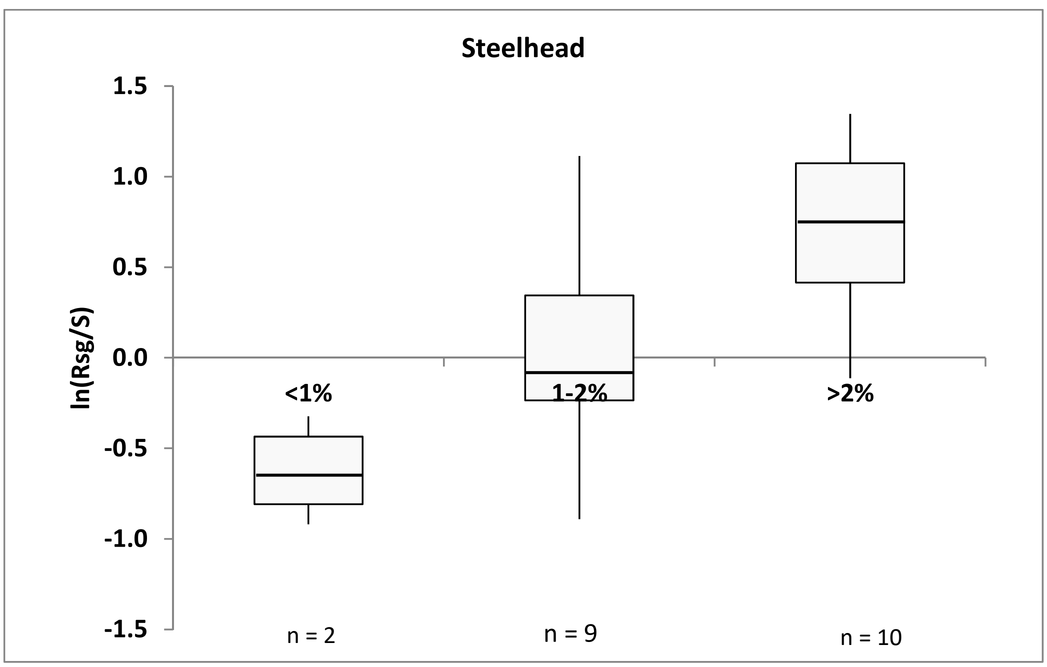


Figure 5.4 Snake River steelhead population productivity (ln(Rsg/S)) by brood year SAR category for Fish Creek and Rapid River. Brood years represented are 1996–2009 for Fish Creek and 2003-2009 for Rapid River. Boxes show 25th percentile, median and 75th percentile of ln(Rsg/S); whiskers show 10th and 90th percentiles of ln(Rsg/S). Brood year SARs represent LGR-GRA (Fish Creek 1997--2013 smolt migration years; Rapid River 2004-2013 smolt migration years).

SARs and Historical Productivity

Historical survival rate indices (SRIs) for Snake River spring/summer Chinook from Schaller et al. (2014) (Figure 5.5, upper panel) illustrate large declines in life cycle survival rates associated with development and completion of the FCRPS in the 1970s as well as with other environmental changes. SRIs averaged -2.1 (range, -4.3 to -0.6) for the 1975–2004 brood years, indicating that life cycle productivity declined to only about 12% ($e^{-2.1}$) of that during the pre-1970 base period.

A plot of the average SRI from 18 Snake River Chinook populations versus SARs to the Columbia River mouth is shown in Figure 5.6. SARs explained a large portion (79%) of the variability in recruitment during this time period (1964-2006 smolt migration years), after accounting for density dependence in life cycle survival rates. SARs in the 1960s (1964–1969 smolt migration years) ranged from 3.5% to 6.5%, while parental spawner levels resulted in pre-harvest recruitments within the expected range (by definition) for the base period. Both SARs and SRIs declined in the 1970s, and have remained depressed in subsequent decades into the 2000s. The relation between SAR and SRI appears very consistent across the decades. The prediction line indicates that a pre-harvest SAR of 2% is associated with 36% of base-period productivity; pre-harvest SARs of 4% and 6% are associated with 75% and 116% of base-period productivity, respectively (Figure 5.6). In general, the pattern of SARs and SRIs suggests that achieving pre-harvest SARs in the 4% to 6% range would be necessary to fully restore historical (pre-1970s) productivity for Snake River spring/summer Chinook.

The pattern of SRIs and SARs appears quite similar across the four MPGs of the Snake River spring/summer Chinook ESU (Figure 5.7). Historical levels of productivity (pre-1970) were associated with pre-harvest SARs in the range of 4% to 6% for all MPGs.

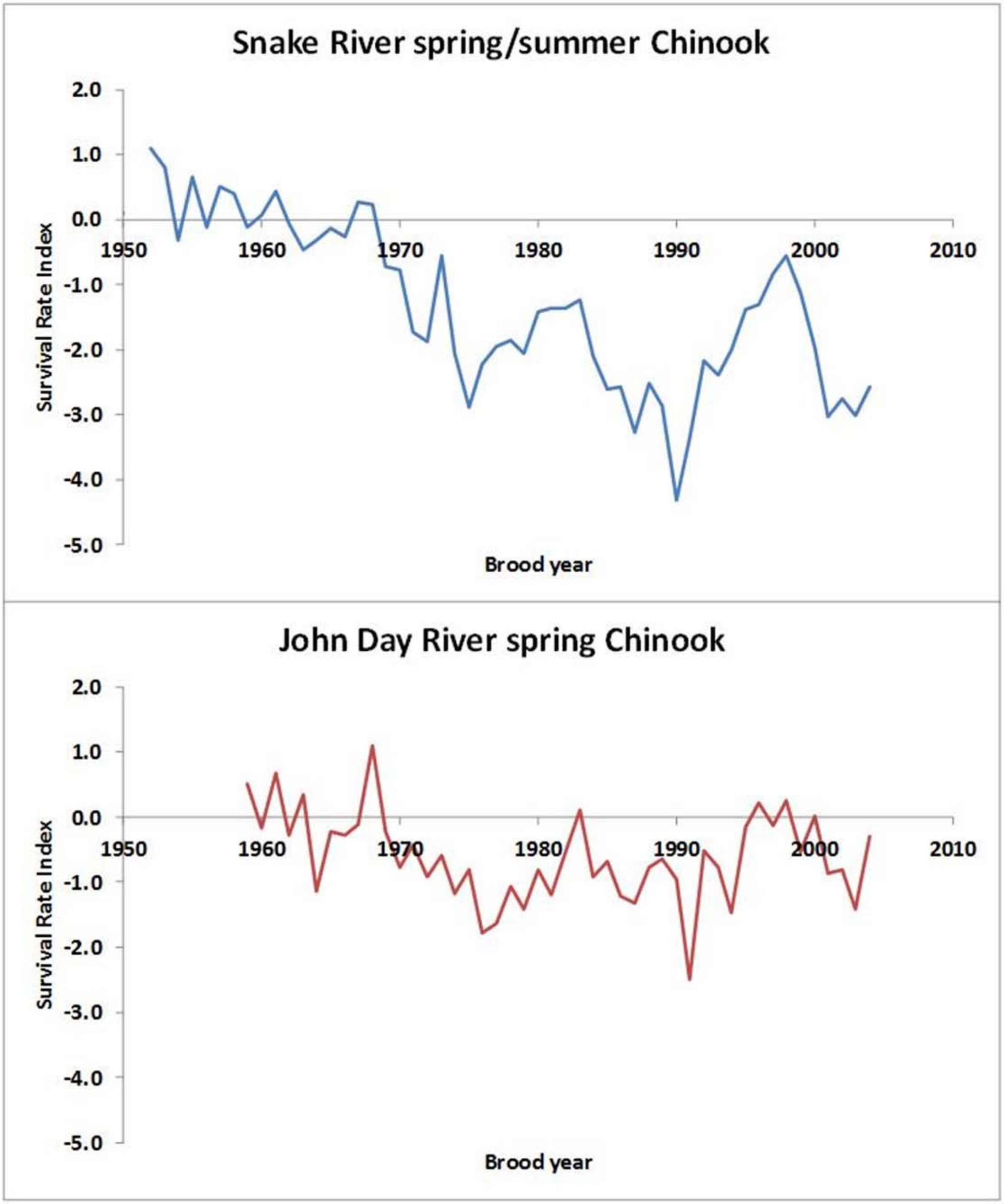


Figure 5.5 Survival rate indices for Snake River spring/summer Chinook (upper panel) and John Day River spring Chinook (lower panel), 1950s-2004 brood years (Schaller et al. 2014).

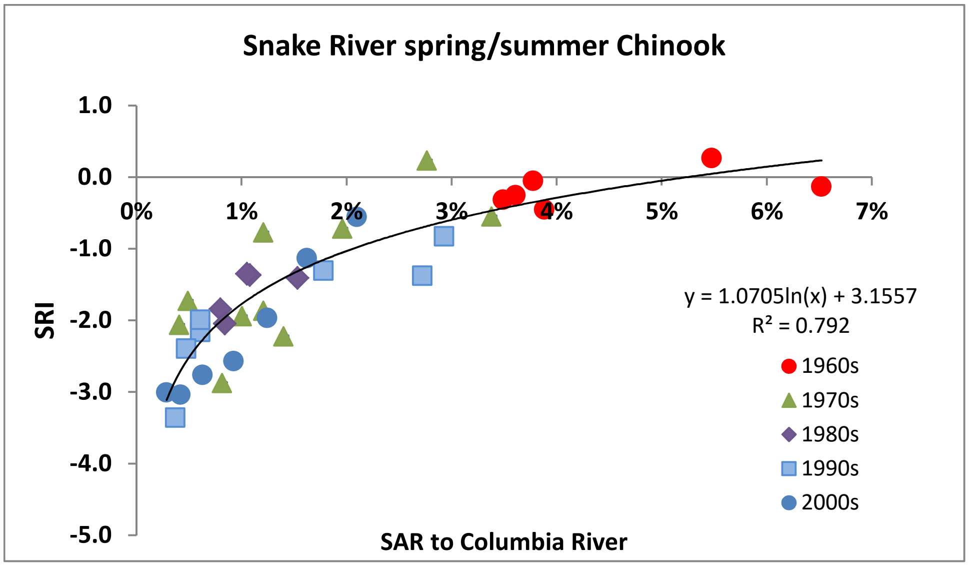


Figure 5.6 Comparison of survival rate indices (SRIs) and SARs of Snake River spring/summer Chinook, 1964-2006 smolt migration years. SRIs represent the annual average from 18 Snake River populations, where SRI = 0 is the average expected productivity for the pre-1970 brood years (Schaller et al. 2014). SARs to the Columbia River mouth are from Table B.98 and the 2012 CSS annual report (Tuomikoski et al. 2012). The prediction line is fitted through all years of data.

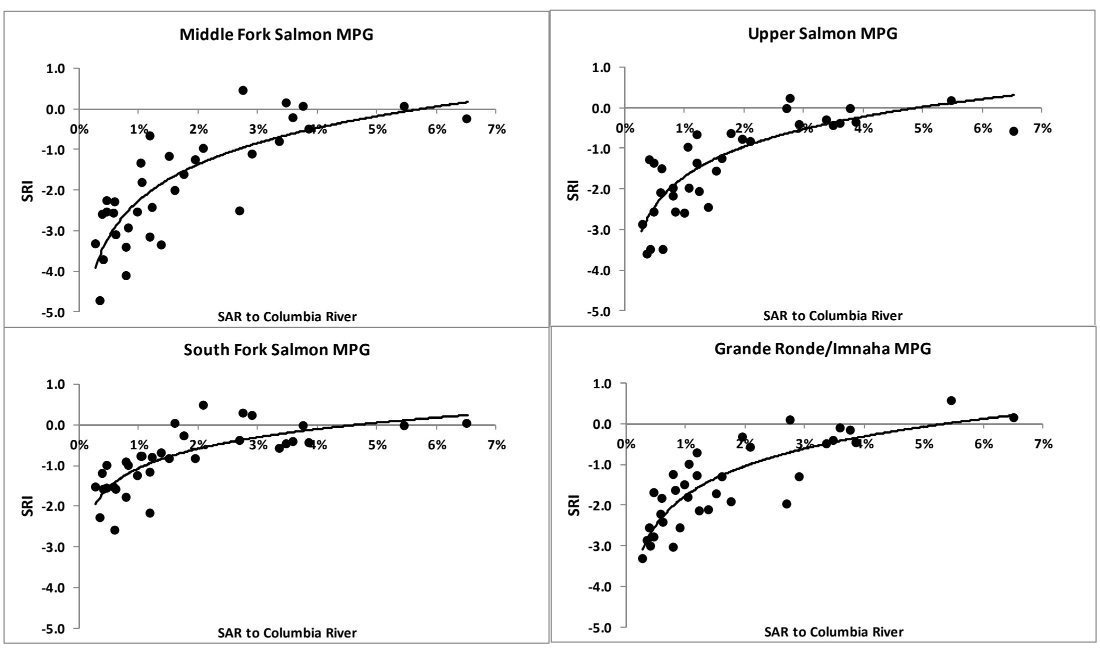


Figure 5.7 Comparison of survival rate indices (SRIs) and SARs for four MPGs of Snake River spring/summer Chinook, 1964-2006 smolt migration years. SRIs represent the annual average from populations within each MPG (Schaller et al. 2014). SARs to the Columbia River mouth are from Table B.98 and the 2012 CSS annual report (Tuomikoski et al. 2012). The prediction line is fitted through all observations.

Historical survival rate indices (SRIs) for John Day River spring Chinook from Schaller et al. (2014) (Figure 5.5, lower panel) illustrate declines in life cycle survival rates since the late 1960s. SRIs averaged -0.8 (range, -2.5 to 0.3) during the 1975–2004 brood years, indicating that life cycle productivity declined to about 44% of that during the pre-1970 base period.

Although we have fewer data points (n=7) for John Day River spring Chinook, the relation between SARs and SRIs appears generally similar to that in the Snake River. Historical (1950–60s) productivity for John Day spring Chinook appears to be associated with pre-harvest SARs in the 4%–7% range (Figure 5.8).

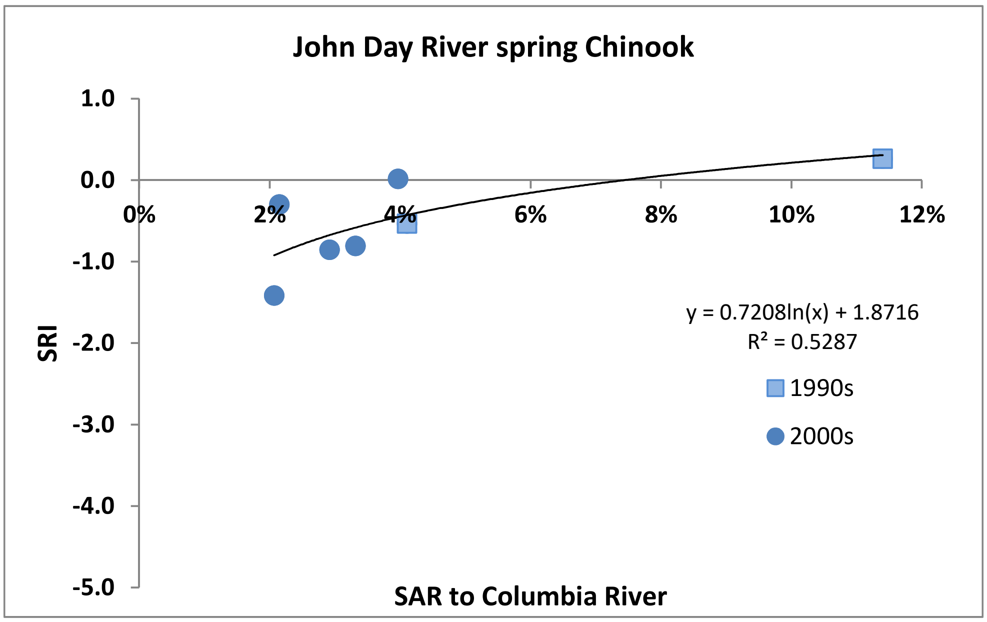


Figure 5.8. Comparison of survival rate indices (SRIs) and SARs of John Day River spring/summer Chinook, 1964-2006 smolt migration years. SRIs represent the annual average from three John Day River populations, where SRI = 0 is the average expected productivity for the pre-1970 brood years (Schaller et al. 2014).

The CSS is working to update the SAR vs. SRI analyses, incorporating SR data for additional brood years beyond 2004. Several steps will be needed for this update. As noted previously, IDFG, ODFW and NPT submitted in 2015 updated spawner and recruit estimates for Snake River spring/summer Chinook populations for the NOAA ESA Status Review update process. In addition, ODFW has recently updated spawner and recruit estimates for the John Day River through brood year 2009 (Bare et al. 2015). SR updates from both regions calculated recruits to spawning grounds, which need to be expanded to Columbia River recruits to examine historical patterns of productivity. In addition, some of the revised spawner estimates rely on different redd count expansions than used in the Schaller et al. (2014) analysis, which will necessitate refitting the SR models.

Discussion

The graphical summary of SARs and realized population productivity (spawning ground recruits) presented in this chapter begins to illuminate the SARs necessary for Snake River spring/summer Chinook population abundance to stabilize or increase, given the depressed wild abundance levels in recent years. It begins to address the ISAB (2012) review comments of the CSS draft 2012 annual report, as well as to support objectives of the amended Columbia River Basin Fish and Wildlife Program (NPCC 2014), encouraging a regional review of the NPCC SAR objectives. Additionally, it continues recent years' reporting of wild spring/summer Chinook SARs at finer geographic and MPG scales as observed in the ISAB (2013) review of the CSS draft 2013 annual report. This summary is also complimentary to the Chapter 2 analysis for the Grande Ronde/Imnaha MPG, adding data from populations and MPGs across the entire Snake River spring/summer Chinook ESU. Notably, the summary in this chapter includes population data from the Middle Fork Salmon River MPG that is primarily in wilderness and has little potential for improvement to tributary habitat or survival during the egg-to-smolt life stage.

The observations to date are relevant to and generally support the NPCC (2014) 2%–6% SAR objectives. We have observed major Chinook population declines associated with SARs (LGR-GRA) less than 1%, and increased life-cycle productivity for Snake River populations in the few years that SARs exceeded 2%. These observations of SARs and population increases or declines at recent abundances do not account for density-dependent nature of recruitment at higher abundance.

Unlike most Columbia River stream-type Chinook populations, steelhead smolts from the same brood year emigrate over several years. We began to explore the relationship of SARs to population productivity for two Snake River spawning tributaries: Fish Creek (Clearwater River MPG) and Rapid River (Salmon River MPG). To align population productivity (spawning ground recruits/spawner) with SARs, we calculated a weighted brood year SAR, based on smolt age composition. Similar to our observations for Snake River Chinook, we have observed steelhead population declines associated with brood year SARs (LGR-GRA) less than 1%, and increased life-cycle productivity for Snake River steelhead populations in the years that brood year SARs exceeded 2%.

We might expect more variation for steelhead populations in response to SARs due to their more complex life history. The response likely varies according to smolt age composition, with populations producing older smolts requiring relatively higher SARs to achieve population replacement, which is consistent with these results. In the limited data set presented here, Rapid River age composition is slightly older than Fish Creek age composition. Currently we have data for two populations but potential exists to expand this analysis in the future.

In the 2016 report we examine the relation of SAR to historical pre-harvest productivity using the (density-dependent) stock-recruitment functions from Schaller et al. (2014). Results indicate that pre-harvest SARs in the range of 4%-6% are associated with historical (pre-1970) levels of productivity for Snake River spring/summer Chinook. The relation between pre-harvest SARs and life-cycle productivity (spawner-recruit residuals) appears similar across Snake River spring/summer Chinook MPGs. Although we have fewer SAR estimates for John Day River spring Chinook, historical levels of productivity appear to be achieved with pre-harvest SARs in the range of 4%–7%. These observations, which account for density dependence, are also generally consistent with the NPCC (2014) 2%–6% SAR objectives.

Conclusions

- Major population declines of Snake River wild spring/summer Chinook were associated with SARs less than 1% and increased life-cycle productivity occurred when SARs exceeded 2%.
- Snake River wild steelhead population declines were associated with brood year SARs less than 1%, and increased life-cycle productivity occurred in the years that brood year SARs exceeded 2%.
- Pre-harvest SARs in the range of 4% to 6% are associated with historical levels of productivity for Snake River wild spring/summer Chinook. Although we have fewer SAR estimates for John Day River spring Chinook, historical levels of productivity appear to be achieved with pre-harvest SARs in the range of 4%-7%

CHAPTER 6
ESTIMATION OF SARS, TIRS AND *D* FOR SNAKE RIVER SUBYEARLING FALL CHINOOK

Introduction

During the review of the 2010 Comparative Survival Study (CSS) Annual Report, the CSS Oversight Committee received a request to include fall Chinook migration and smolt-to-adult return (SAR) data in future CSS reports. The addition of fall Chinook to the CSS monitoring analyses and data time series serves two purposes: to meet the objectives of the CSS study and to provide data and analyses to the Fall Chinook Planning Team. In 2007, the *U.S. v. Oregon* parties approved a consensus proposal entitled *Evaluating the Responses of Snake River and Columbia River basin fall Chinook Salmon to Dam Passage Strategies and Experiences*. The intent of the parties agreeing to the consensus proposal is for the salmon managers to work together with the U.S. Army Corps of Engineers (USACE) on collaborative analyses that include methods consistent with the CSS. The 2015 report was the fifth CSS report to include analyses of fall Chinook adult returns to the Snake River, both overall for the entire run and by study category, as is reported for spring/summer Chinook, steelhead, and sockeye. As such, the inclusion of fall Chinook in the CSS is a work in progress. The CSS Oversight Committee expects to refine tools and analyses for fall Chinook in future reports. Further, as information is available the CSS develops SAR estimates for other wild and hatchery fall Chinook groups in the Mid Columbia River (e.g., Columbia River Hanford Reach, Deschutes River, Spring Creek and Little White Salmon National Fish hatcheries).

The CSS, working with Nez Perce Tribe (NPT), helped fund PIT-tag marking of 40,400 subyearling fall Chinook in 2015 and over 50,000 tags in 2016. This effort was considered a pilot program to re-instate annual marking that had been discontinued after migration year 2012 due to the end of a USACE-funded transportation study. The joint effort by CSS and NPT will make available a limited number of PIT-tag marks on two release groups in the Snake River. As a pilot effort, its scope is limited, but will provide some level of information for an entire ESU that currently has no comprehensive marking program to evaluate the effects of transportation on adult return rates. Prior to providing PIT tags for the marking effort, the CSS developed a power analysis to determine an adequate mark group as well as proportions of fish to be pre-assigned to transport and in-river categories (McCann et al. 2015). Reach survivals (S_R) for these groups will be reported in next year's CSS annual report.

The inclusion of fall Chinook in the CSS follows the foundational objective of the CSS to establish a long-term dataset that measures the survival rate of annual generations of salmon and steelhead from the outmigration as smolts to their return to freshwater as adults to spawn (i.e., SAR or smolt-to-adult return rate). The primary objective for fall Chinook SAR estimation was to use the CSS methodology to estimate overall SARs and SARs by study category that have been used successfully with other salmonid species (see Chapter 4 and Appendix A for methods descriptions). These SAR estimates could then be used to evaluate the efficacy of transportation, particularly for cohorts of actively migrating subyearling Chinook. These cohorts would not include either a large portion of late season migrants or a high proportion of holdover detections.

Methods

Methods to estimate SARs have been described previously (McCann et al. 2015). Methods to calculate TIR and *D* have also been presented (see Chapter 4 and Appendix A).

Results

SAR Estimation

Data for the adults that escaped marine fisheries used in SAR estimation were updated through the end of 2015, so that returns through 5-salt are complete for 2010 and earlier migration years (4-salt adults for 2011, and 3-salt adults for 2012). The estimated SARs for both overall LGR to GRA and by study category are reported as well as transport/in-river ratios where adequate data were available for the Snake River groups. No update is available for wild Snake River fall Chinook.

In response to requests from fisheries managers as well as the ISAB, we included new groups of fish released in locations outside the Snake River to compare to those released above Lower Granite Dam. Included in this report are SAR estimates for wild subyearling fall Chinook marked at Hanford Reach in the Columbia River above McNary Dam. Fish released from Spring Creek National Fish Hatchery and Little White Salmon National Fish Hatchery are also included. For the Hanford releases, SARs were estimated from McNary Dam as juveniles to Bonneville Dam as adults, while for Spring Creek and Little White Salmon releases SAR estimates are from Bonneville Dam as juveniles back to Bonneville Dam as adults. We also estimated SARs for wild fall Chinook PIT tagged and released in the Deschutes River.

Patterns in Annual Overall SARs

Overall LGR-to-GRA SARs for Snake River subyearling fall Chinook have been low in the years we have analyzed (McCann et al. 2015). For hatchery fall Chinook releases, overall SARs excluding 1-salt (or jacks) ranged from 0.12% to 0.56% for releases in 2006, 0.0% to 0.3% in 2007 (McCann et al. 2015). SARs for migration years 2008 and 2011 tended to be highest, while SARs for migration year 2009 appeared similar to 2006. The addition of older adults for the 2011 juvenile migration increased the SAR as would be expected, but only slightly with the exception of the Grande Ronde River release. That group's SAR increased from 0.08 (McCann et al. 2015) to 0.30 after including the 4-salt returns (Table 6.1).

Return rates for migration year 2012 are presented in this report; while not complete these estimates are not likely to change significantly, given that only 4-salt and older adult returns remain for those groups (Table 6.2).

Table 6.1. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2011 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord-id)	Smolts arriving LGR	SAR without Jacks (Non-parametric CI 90% LL – 90% UL)	SAR with Jacks (Non-parametric CI 90% LL - 90% UL)
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	16,275	0.95 (0.82 - 1.08)	1.24 (1.09 - 1.38)
Cedar Flats, Cedar Flats, (BDA)	6,680	0.91 (0.73 - 1.11)	1.36 (1.14 - 1.60)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	16,949	0.96 (0.83 - 1.08)	1.35 (1.20 - 1.50)
Grande Ronde River, Irrigon Hatchery, (BDA)	9,233	0.30 (0.22 - 0.40)	0.44 (0.33 - 0.57)
Luke's Gulch, Luke's Gulch, (BDA)	6,595	0.80 (0.62 - 0.98)	1.08 (0.87 - 1.30)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	13,624	0.73 (0.61 - 0.86)	0.95 (0.81 - 1.09)
Snake River, Dworshak Hatchery, (DMM)	56,234	0.86 (0.80 - 0.93)	1.06 (0.98 - 1.13)
Snake River, Lyons Ferry Hatchery, (BDA)	6,491	0.92 (0.73 - 1.14)	1.26 (1.03 - 1.51)
Snake River, Irrigon Hatchery, (BDA)	10,509	0.34 (0.25 - 0.44)	0.44 (0.34 - 0.55)
Snake River, Oxbow Hatchery, (IPC)	5,251	0.42 (0.27 - 0.58)	0.61 (0.44 - 0.80)

Note: SARs are calculated with and without jacks.

Updating the 2012 SAR with additional returning adults did not appreciably change the pattern of SARs across migration years or release groups (Figure 6.1).

Table 6.2. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2012 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord-id)	Smolts arriving LGR	SAR without Jacks (Non-parametric CI 90% LL - 90% UL)	SAR with Jacks (Non-parametric CI 90% LL - 90% UL)
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	14,898	0.66 (0.56 - 0.78)	0.95 (0.82 - 1.09)
Cedar Flats, Cedar Flats, (BDA)	5,163	0.79 (0.59 - 1.02)	0.87 (0.65 - 1.11)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	15,919	0.65 (0.54 - 0.75)	0.81 (0.69 - 0.93)
Grande Ronde River, Irrigon Hatchery, (BDA)	8,059	0.51 (0.38 - 0.64)	0.68 (0.53 - 0.84)
Luke's Gulch, Luke's Gulch, (BDA)	6,328	0.44 (0.31 - 0.59)	0.52 (0.38 - 0.68)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	12,788	0.73 (0.61 - 0.87)	0.99 (0.85 - 1.14)
Snake River, Lyons Ferry Hatchery, (BDA)	5,547	0.41 (0.28 - 0.56)	0.49 (0.34 - 0.65)
Snake River, Irrigon Hatchery, (BDA)	12,770	0.67 (0.54 - 0.79)	0.85 (0.71 - 1.00)
Snake River, Oxbow Hatchery, (IPC)	5,046	0.40 (0.26 - 0.53)	0.59 (0.41 - 0.77)

Note: SARs are calculated with and without jacks.

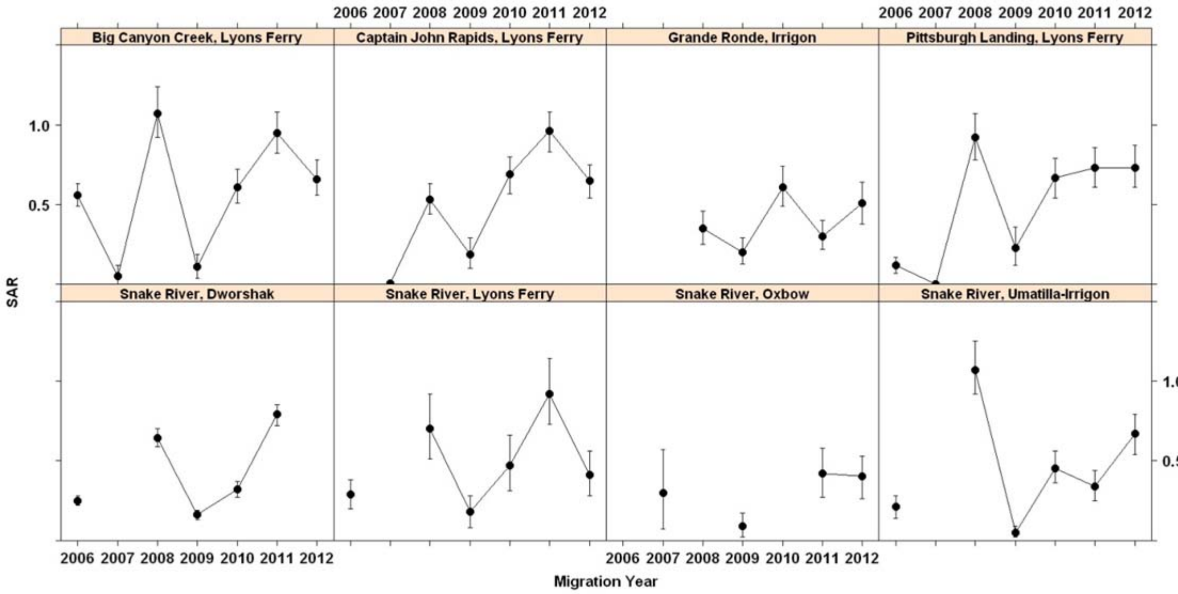


Figure 6.1 Patterns in overall SARs (LGR to GRA), excluding jacks, for subyearling Chinook PIT-tag release groups shown by release site and mark site for migration years 2006 to 2012. Only groups with 3 or more migration years of returns are included. Vertical bars represent 90% non-parametric CIs.

As requested by ISAB and consistent with other species reported in the CSS, SARs are reported for adults at Bonneville Dam in contrast to returns to Lower Granite Dam. Not surprisingly, SARs for nearly every group were higher when using Bonneville Dam adult observations compared to Lower Granite adults. When jacks were included, SARs in a few cases approached or exceeded 3% (McCann et al. 2015).

The highest 2011 LGR-to-BOA SAR was for Luke's Gulch release at 2.00, while the lowest LGR-to-BOA SAR (without jacks) was for the cohort released in the Grande Ronde River reared at Irrigon Hatchery with a SAR of 0.48 (Table 6.3). Overall SARS LGR-to-BOA for migration year 2012 were higher than 2009 but lower than those for 2010 and 2011 (McCann et al. 2015; Table 6.4). As stated previously the SARs for migration year 2012 include up to 3-salt adults.

The addition of older adults for the 2011 juvenile migration increased the SAR as would be expected, but only slightly with the exception of the Grande Ronde River release. That group's SAR increased from 0.16 (McCann et al. 2015) to 0.48 after including the 4-salt returns (Table 6.3). The Dworshak Hatchery SAR did not increase as no additional adults were detected (McCann et al. 2015; Table 6.3).

Return rates for migration year 2012 are presented in this report; while not complete these estimates are not likely to change significantly, given that only 4-salt and older adult returns remain for those groups (Table 6.4).

Table 6.3. Overall LGR-to-BOA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2011 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord-id)	Smolts arriving LGR	SAR without Jacks (Non-parametric CI 90% LL - 90% UL)	SAR with Jacks (Non-parametric CI 90% LL - 90% UL)
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	16,275	1.48 (1.32 - 1.64)	1.81 (1.63 - 1.99)
Cedar Flats, Cedar Flats, (BDA)	6,680	1.66 (1.39 - 1.94)	2.40 (2.07 - 2.73)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	16,949	1.49 (1.34 - 1.64)	1.96 (1.79 - 2.15)
Grande Ronde River, Irrigon Hatchery, (BDA)	9,233	0.48 (0.36 - 0.60)	0.62 (0.49 - 0.76)
Luke's Gulch, Luke's Gulch, (BDA)	6,595	2.00 (1.71 - 2.28)	2.47 (2.15 - 2.78)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	13,624	1.23 (1.06 - 1.38)	1.48 (1.30 - 1.65)
Snake River, Dworshak Hatchery, (DMM)	56,234	1.33 (1.25 - 1.41)	1.57 (1.48 - 1.66)
Snake River, Lyons Ferry Hatchery, (BDA)	6,491	1.46 (1.23 - 1.76)	1.82 (1.55 - 2.12)
Snake River, Irrigon Hatchery, (BDA)	10,509	0.64 (0.52 - 0.78)	0.76 (0.63 - 0.92)
Snake River, Oxbow Hatchery, (IPC)	5,251	0.74 (0.55 - 0.95)	1.07 (0.84 - 1.32)

Note: SARs are calculated with and without jacks.

Table 6.4. Overall LGR-to-BOA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2012 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord-id)	Smolts arriving LGR	SAR without Jacks (Non-parametric CI 90% LL - 90% UL)	SAR with Jacks (Non-parametric CI 90% LL - 90% UL)
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	14,898	0.98 (0.85 - 1.11)	1.37 (1.20 - 1.53)
Cedar Flats, Cedar Flats, (BDA)	5,163	1.14 (0.89 - 1.42)	1.28 (1.01 - 1.59)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	15,919	1.07 (0.93 - 1.20)	1.32 (1.16 - 1.47)
Grande Ronde River, Irrigon Hatchery, (BDA)	8,059	0.83 (0.66 - 1.01)	1.08 (0.88 - 1.28)
Luke's Gulch, Luke's Gulch, (BDA)	6,328	0.63 (0.47 - 0.80)	0.76 (0.58 - 0.95)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	12,788	1.08 (0.92 - 1.24)	1.47 (1.31 - 1.65)
Snake River, Lyons Ferry Hatchery, (BDA)	5,547	0.56 (0.40 - 0.73)	0.67 (0.49 - 0.86)
Snake River, Irrigon Hatchery, (BDA)	12,770	1.05 (0.90 - 1.21)	1.32 (1.15 - 1.51)
Snake River, Oxbow Hatchery, (IPC)	5,046	0.65 (0.48 - 0.83)	1.07 (0.84 - 1.31)

Note: SARs are calculated with and without jacks.

Updating the 2012 SAR with additional returning adults did not appreciably change the pattern of SARs across migration years or release groups (Figure 6.2).

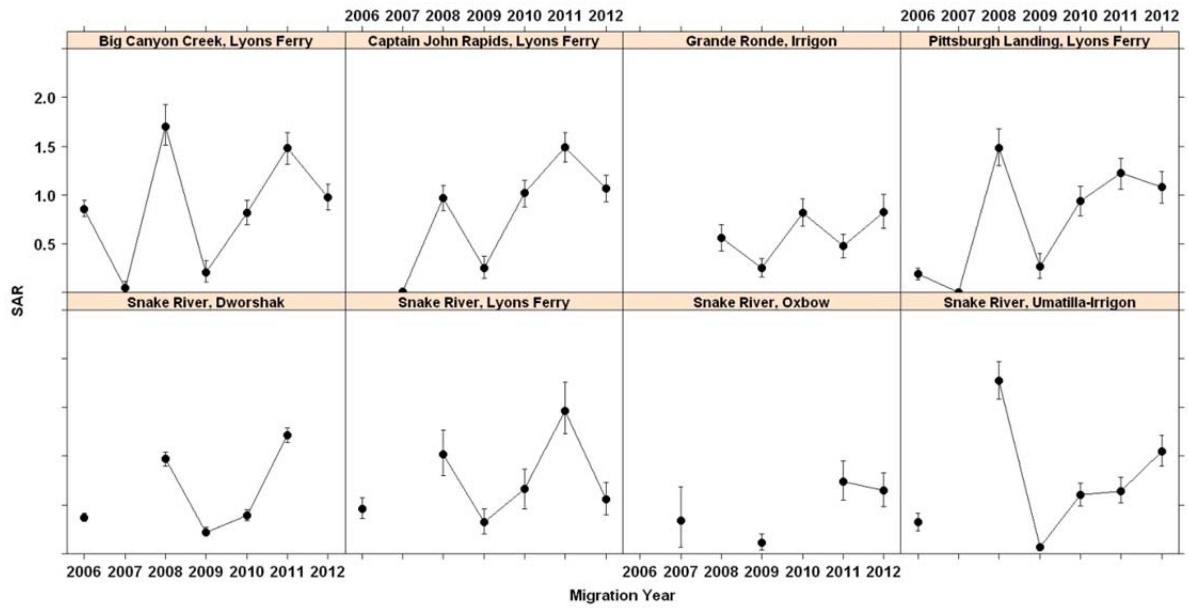


Figure 6.2. Patterns in overall SARs (LGR to BOA), excluding jacks, for subyearling Chinook PIT-tag release groups shown by release site and mark site for migration years 2006 to 2012. Only groups with 3 or more migration years of returns are included.

McNary Dam to Bonneville Dam SARs for Hanford Reach PIT-tag release groups were included for the first time in 2013 (Table 6.5). By comparison to Snake River releases, SARs for these cohorts ranged between 0.20% and 3.19% (excluding jacks). SAR estimates were similar or higher for Snake River wild Chinook for the same out-migration years, although estimates were too imprecise (resulting in wide overlapping confidence intervals) making the differences statistically insignificant.

SAR estimates for Spring Creek National Fish Hatchery were included for the first time in 2013 (Table 6.6). For those PIT-tag groups there were multiple releases in some years resulting in two to three SAR estimates depending upon the year. SARs are presented from Bonneville Dam as smolts to Bonneville Dam as adult returns as well as from release at the hatchery as smolts back to Bonneville Dam as adults. Marked releases were available for SAR estimation beginning in 2008. In many cases, the initial survival estimate from release to Bonneville Dam was greater than one causing the estimated smolt population arriving at Bonneville Dam to be higher than one. This in turn made SAR estimates lower than estimated SARs from release to Bonneville. Where those occurred, the SAR estimates were not included since they were considered biased. The overestimation of survival, particularly for these Spring Creek NFH release groups, may be caused by relatively high bypass mortality that has been observed in the Smolt Monitoring Program over the past several years (see the Fish Passage Center memo from 2012 that addressed powerhouse operation effects on subyearling Chinook survival at http://www.fpc.org/documents/memos/153-12.pdf). If bypass mortality is high, and since many of the detected fish pass through the bypass (as opposed to the corner collector) this would represent a violation of the mark-recapture survival model assumption of equal survival probability for detected and undetected fish.

Table 6.5. Overall MCN-to-BOA SARs for Columbia River (Hanford Reach) PIT-tagged wild subyearling fall Chinook, 2000 to 2013 (with 90% confidence intervals).

Juvenile migration year	Smolts arriving MCN	MCN-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)	MCN-to-BOA with Jacks (Non-parametric CI 90% LL - 90% UL)	Smolts released	REL-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)
2000	4,521	2.68 (2.27 - 3.11)	2.88 (2.45 - 3.32)	10,967	1.10 (0.93 - 1.28)
2001	3,642	0.68 (0.47 - 0.91)	0.71 (0.50 - 0.94)	9,973	0.25 (0.17 - 0.33)
2003	930	0.43 (0.11 - 0.82)	0.43 (0.11 - 0.82)	2,975	0.13 (0.03 - 0.27)
2004	1,000	0.20 (0.00 - 0.44)	0.20 (0.00 - 0.44)	2,989	0.07 (0.00 - 0.17)
2005	6,602	0.26 (0.15 - 0.37)	0.29 (0.18 - 0.40)	22,634	0.08 (0.04 - 0.11)
2007	7,790	0.35 (0.24 - 0.46)	0.45 (0.33 - 0.58)	21,007	0.13 (0.09 - 0.17)
2008	5,543	2.00 (1.62 - 2.39)	2.27 (1.88 - 2.71)	16,651	0.67 (0.56 - 0.77)
2009	4,614	0.72 (0.51 - 0.96)	0.89 (0.65 - 1.17)	13,728	0.24 (0.17 - 0.31)
2010	1,418	2.61 (1.88 - 3.40)	2.96 (2.15 - 3.88)	4,850	0.76 (0.56 - 0.97)
2011	4,045	3.19 (2.61 - 3.80)	3.44 (2.81 - 4.09)	10,337	1.25 (1.07 - 1.43)
2012	1,313	1.29 (0.80 - 1.87)	1.37 (0.84 - 2.00)	4,885	0.35 (0.23 - 0.49)
2013	1,416	0.64 (0.30 - 1.01)	0.99 (0.56 - 1.55)	4,185	0.22 (0.10 - 0.33)

Table 6.6. Overall BON-to-BOA SARs for Columbia River Spring Creek National Fish Hatchery PIT-tagged subyearling fall Chinook, 2008 to 2013 (with 90% confidence intervals).

Juvenile migration year	Month of release	Smolts arriving BON	BON-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)	BON-to-BOA with Jacks (Non-parametric CI 90% LL - 90% UL)	Smolts released	REL-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)
2008	March	5,877	0.34 (0.19 - 0.52)	0.43 (0.25 - 0.64)	7,477	0.27 (0.17 - 0.36)
2008	April	NA[A]	--	--	3,953	0.63 (0.43 - 0.83)
2008	May	NA[A]	--	--	2,677	0.52 (0.30 - 0.75)
2009	April	NA[A]	--	--	8,686	0.06 (0.02 - 0.10)
2009	May	NA[A]	--	--	5,950	0.22 (0.13 - 0.32)
2010	April	NA[A]	--	--	8,962	0.25 (0.16 - 0.33)
2010	May	5,908	0.20 (0.11 - 0.31)	0.24 (0.14 - 0.36)	5,971	0.20 (0.12 - 0.30)

2011	April	8,163	0.16 (0.09 - 0.25)	0.16 (0.09 - 0.25)	8,956	0.15 (0.08 - 0.21)
2011	May	NA[A]	--	--	5,983	0.23 (0.13 - 0.33)
2012	April	NA[A]	--	--	14,750	0.26 (0.20 - 0.34)
2013	April	8,078	0.56 (0.39 - 0.74)	0.68 (0.48 - 0.89)	8,964	0.50 (0.38 - 0.64)
2013	May	5,402	0.56 (0.37 = 0.75)	0.65 (0.45 - 0.87)	5,976	0.50 (0.35 - 0.65)

[A] Not calculated; release to BON survival estimate > 1.0.

Such a violation, lower survival for detected fish, could cause an underestimate of detection probability and an over-estimate of the population arriving at the dam—which is what has been observed for many of the release groups.

SAR estimates for Little White Salmon National Fish Hatchery were included for the first time in 2014 (Table 6.7). SARs are presented from Bonneville Dam as smolts to Bonneville Dam as adult returns. Marked releases were available for SAR estimation beginning in 2008. In contrast to Spring Creek releases, these groups had initial survival estimates below one in all years SARs were estimated. The Little White Salmon releases were done in late June or early July each year and fish were much larger at release.

Table 6.7. Overall BON-to-BOA SARs and REL-to-BOA SARs for Columbia River Little White Salmon National Fish Hatchery PIT-tagged subyearling fall Chinook, 2008 to 2013 (with 90% confidence intervals).

Juvenile migration year	Smolts arriving BON	BON-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)	BON-to-BOA with Jacks (Non-parametric CI 90% LL - 90% UL)	Smolts released	REL-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)
2008	14,393	1.74 (1.52 - 1.99)	1.85 (1.62 - 2.10)	24,886	1.01 (0.90 - 1.11)
2009	14,805	0.84 (0.70 - 1.00)	0.95 (0.80 - 1.12)	24,947	0.50 (0.43 - 0.57)
2010	15,140	2.69 (2.35 - 3.06)	2.75 (2.41 - 3.13)	24,951	1.63 (1.50 - 1.77)
2011	17, 626	3.30 (2.75 - 3.90)	3.38 (2.82 - 3.99)	24,638	2.36 (2.20 - 2.52)
2012	17, 502	0.58 (0.43 - 0.75)	0.62 (0.46 - 0.80)	24,953	0.41 (0.34 - 0.48)
2013	10,547	0.66 (0.52 - 0.82)	0.78 (0.62 - 0.95)	14,960	0.47 (0.38 - 0.56)

Note: BON-to-BOA SARs are calculated with and without jacks.

SAR estimates for Deschutes River wild fall Chinook were included for the first time in 2014 (Table 6.8). SARs are presented from Bonneville Dam as smolts to Bonneville Dam as adult returns as well as from release to Bonneville Dam as adults. Marked releases were available for SAR estimation beginning in 2011.

Table 6.8. Overall BON-to-BOA SARs and REL-to-BOA SARs for Deschutes River PIT-tagged wild subyearling fall Chinook from 2011 and 2013 (with 90% confidence intervals).

Juvenile migration year	Smolts arriving BON	BON-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)	BON-to-BOA with Jacks (Non-parametric CI 90% LL - 90% UL)	Smolts released	REL-to-BOA without Jacks (Non-parametric CI 90% LL - 90% UL)
2011	5,860	2.30 (1.48 - 3.22)	2.95 (1.91 - 4.09)	19,897	0.68 (0.58 - 0.77)
2012	6,696	0.70 (0.41 - 0.78)	0.91 (0.54 - 1.37)	20,798	0.23 (0.17 - 0.28)
2013	6,069	0.31 (0.17 - 0.47)	0.65 (0.39 - 0.95)	26,322	0.10 (0.07 - 0.14)

Note: BON-to-BOA SARs are calculated with and without jacks.

Estimates of SAR by Study Category

Presented here are the LGR-to-GRA SAR estimates by route of juvenile passage or study category for the migration years 2011 and 2012. These SARs represent portions of the run as a whole and the C_0 and transport SARs are components that make up TIR and *D*. Explanations of methods for calculating these component SARs can be found in Chapter 4 and Appendix A. While the C_1 SARs are reported, those SARs do not represent a significant portion of the non-PIT-tagged population, since transportation occurs throughout the migration of subyearling Chinook. This contrasts with yearling Chinook and steelhead from the Snake River, where transportation has been delayed in recent years, beginning in May at the collector sites.

Similar to the overall SARs, the SARs by juvenile passage route did not increase appreciably after with the inclusion of the additional returning adults, with the exception of the Grande Ronde group. For migration year 2011, up to 4-salt adult returns were included, so that SARs are not likely to change significantly with adult returns from 2016. The C_0 SAR of 1.45% for Luke's Gulch releases is highest and significantly higher than the transport SAR of 0.50 (Table 6.9). Nine of the ten point estimates for C_0 in-river versus transport groups were higher than the transport SARs for 2011. There were three cases when the in-river C_0 SAR was significantly higher than transport SAR and in no case were the transport SARs significantly higher than the C_0 in-river SARs.

Table 6.9. Estimated LGR-to-GRA SAR (%) by study category without jacks for PIT-tagged hatchery subyearling Chinook by release site, tag site and coordinator ID from 2011 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord_id)	$SAR(T_x)$ %		$SAR(C_0)$ %		$SAR(C_1)$ %	
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	0.90	(0.70 - 1.09)	0.92	(0.81 - 1.04)	1.21	(0.66 - 1.91)
Cedar Flats, Cedar Flats, (BDA)	0.57	(0.35 - 0.78)	1.07	(0.86 - 1.29)	1.05	(0.25 - 2.42)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	0.58	(0.41 - 0.76)	1.15	(1.01 - 1.28)	1.15	(0.67 - 1.66)
Grande Ronde River, Irrigon Hatchery, (BDA)	0.26	(0.12 - 0.42)	0.36	(0.27 - 0.47)	0.18	(0.00 - 0.58)
Luke's Gulch, Luke's Gulch, (BDA)	0.50	(0.30 - 0.72)	1.45	(1.21 - 1.72)	0.83	(0.00 - 2.16)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0.71	(0.50 - 0.94)	0.91	(0.78 - 1.03)	1.17	(0.61 - 1.79)
Snake River, Dworshak Hatchery, (DMM)	0.85	(0.75 - 0.96)	0.91	(0.84 - 0.97)	0.55	(0.32 - 0.81)
Snake River, Lyons Ferry Hatchery, (BDA)	0.76	(0.50 - 1.01)	1.10	(0.90 - 1.33)	0.76	(0.00 - 1.80)
Snake River, Irrigon Hatchery, (BDA)	0.24	(0.12 - 0.37)	0.44	(0.33 - 0.55)	0.17	(0.00 - 0.53)
Snake River, Oxbow Hatchery, (IPC)	0.47	(0.2 - 0.81)	0.47	(0.33 - 0.62)	0.00	(0.00 - 0.00)

SARs by study category for migration year 2012 LGR to GRA are presented in Table 6.10. Since adult returns include up to 3-salt adults, the data are considered preliminary. In all cases the C_0 in-river SAR point estimates were higher than the transport SARs. In three cases the C_0 in-river SARs were significantly higher than the transport SARs.

Table 6.10. Estimated LGR-to-GRA SAR (%) by study category without jacks for PIT-tagged hatchery subyearling Chinook by release site, tag site and coordinator ID from 2012 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord_id)	$SAR(T_x)$ %		$SAR(C_0)$ %		$SAR(C_1)$ %	
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	0.53	(0.38 - 0.70)	0.78	(0.67 - 0.89)	1.38	(0.00 - 7.69)
Cedar Flats, Cedar Flats, (BDA)	0.71	(0.38 - 1.09)	0..87	(0.69 - 1.08)	1.69	(0.00 - 6.25)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	0.46	(0.34 - 0.58)	0.80	(0.69 - 0.91)	0.00	(0.00 - 0.00)
Grande Ronde River, Irrigon Hatchery, (BDA)	0.41	(0.25 - 0.62)	0.60	(0.49 - 0.79)	0.00	(0.00 - 0.00)
Luke's Gulch, Luke's Gulch, (BDA)	0.28	(0.09 - 0.49)	0.53	(0.40 - 0.66)	0.00	(0.00 - 0.00)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0.59	(0.45 - 0.77)	0.81	(0.68 - 0.94)	1.14	(0.00 - 4.30)
Snake River, Lyons Ferry Hatchery, (BDA)	0.34	(0.15 - 0.59)	0.36	(0.25 - 0.48)	0.00	(0.00 - 0.00)
Snake River, Irrigon Hatchery, (BDA)	0.42	(0.27 - 0.57)	0.74	(0.63 - 0.86)	0.00	(0.00 - 0.00)
Snake River, Oxbow Hatchery, (IPC)	0.25	(0.11 - 0.41)	0.62	(0.43 - 0.82)	0.00	(0.00 - 0.00)

Figure 6.3 shows the patterns in SARs by study category for release groups with three or more return years available. In most cases SARs for transport and in-river groups followed similar patterns with the highest returns in 2008 and lowest returns in 2006 or 2007 (where available).

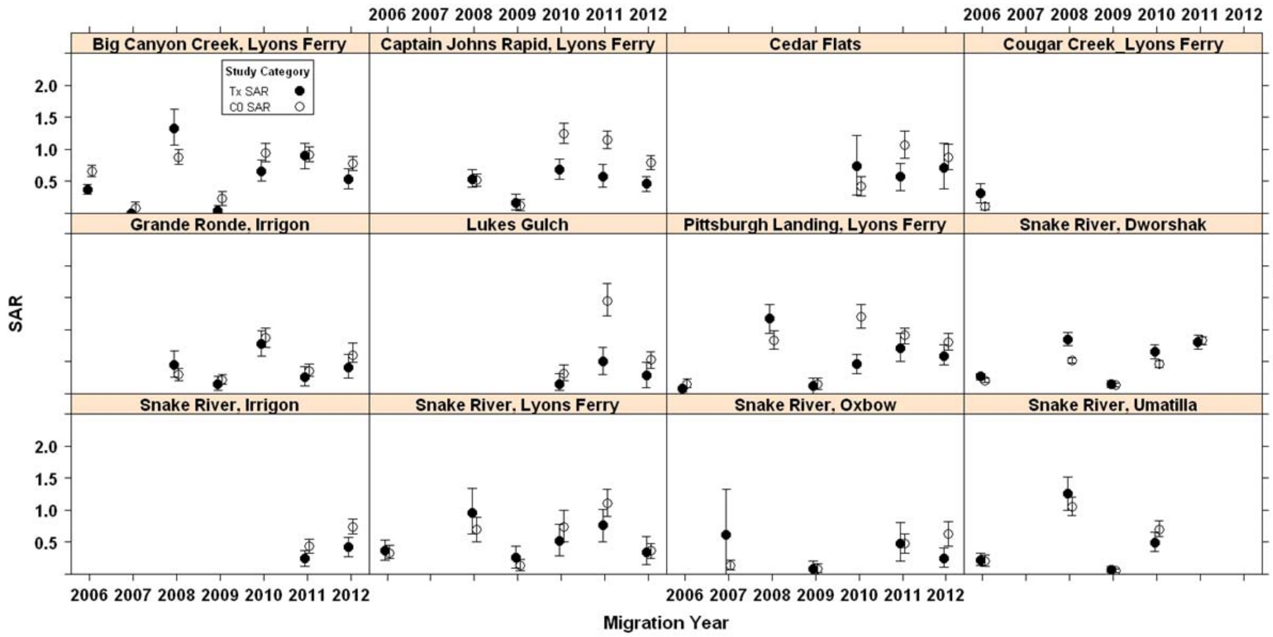


Figure 6.3. Patterns in SARs LGR-to-GRA by study category (excluding jacks), for transported and in-river PIT-tag groups of subyearling fall Chinook salmon released above Lower Granite Dam for the years 2006 to 2012. Error bars represent 90% non-parametric confidence intervals. Only groups with three or more migration years of returns are included.

Estimates of TIR and *D*

The estimates of transport/in-river SAR LGR to LGR ratios or TIR, and ratios of transport/in-river SARs post Bonneville Dam or *D*, are reported below using methods described in Chapter 4.

The estimates of TIR and *D* for migration year 2011 are reported in Table 6.11. Updating the 2011 estimates with the additional returning adults did not appreciably influence the estimates. The TIR for five release groups was significantly below one, indicating that the in-river SAR for the C_0 groups was significantly higher than that of the transport group. All but one of the release groups had TIRs less than one. The TIR for one of the PIT-tag release groups was above one but had confidence interval that overlapped one. The data for migration year 2011 are preliminary with adult returns expected from return year 2016. Estimates of *D* were all less than one for 2011, similar to what was seen in 2010 (McCann et al. 2015), and all but one were significantly less than one.

Table 6.11. Estimated TIR and *D* in LGR-to-GRA SAR (%) without jacks for PIT-tagged hatchery subyearling Chinook by release site, tag site and coordinator ID from 2011 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord-id)	TIR	*D*
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	0.98 (0.74 - 1.23)	**0.67** (0.47 - **0.92**)
Cedar Flats, Cedar Flats, (BDA)	**0.53** (0.32 - **0.79**)	**0.26** (0.16 - **0.41**)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	**0.51** (0.35 - **0.68**)	**0.40** (0.27 - **0.58**)
Grande Ronde River, Irrigon Hatchery, (BDA)	0.73 (0.32 – 1.25)	**0.43** (0.19 - **0.83**)
Luke's Gulch, Luke's Gulch, (BDA)	**0.35** (0.20 - **0.51**)	**0.20** (0.11 - **0.31**)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0.79 (0.54 - 1.09)	**0.58** (0.38 - **0.84**)
Snake River, Dworshak Hatchery, (DMM)	0.94 (0.81 - 1.09)	**0.40** (0.34 - **0.48**)
Snake River, Lyons Ferry Hatchery, (BDA)	**0.69** (0.43 - **0.98**)	**0.39** (0.23 - **0.59**)
Snake River, Irrigon Hatchery, (BDA)	**0.55** (0.27 - **0.93**)	**0.19** (0.09 - **0.34**)
Snake River, Oxbow Hatchery, (BDA)	1.01 (0.40 - 1.88)	0.82 (0.31 - 1.82)

Note: TIRs and *D* significantly different than one are bolded.

Estimates of TIR and *D* for migration year 2012 are reported in Table 6.12. Six release groups had TIR estimates that were significantly below one, indicating that the in-river SAR for the C_0 groups were significantly higher than that of the transport group. None of the TIRs for 2012 release groups were greater than one. The data for migration year 2012 are preliminary with adult returns expected from return years 2016 and 2017. Estimates of *D* were all less than one for 2012, similar to what was seen in 2010 (McCann et al. 2015) and 2011, and *D* was significantly less than one for seven of the nine groups.

Table 6.12. Estimated TIR and *D* in LGR-to-GRA SAR (%) without jacks for PIT-tagged hatchery subyearling Chinook by release site, tag site and coordinator ID from 2012 (with 90% confidence intervals).

Release Site, Tag Site, (PIT-tag coord-id)	**TIR**	***D***
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	**0.67** (0.48 - **0.92**)	**0.51** (0.36 - **0.73**)
Cedar Flats, Cedar Flats, (BDA)	0.81 (0.40 - 1.32)	0.59 (0.29 - 1.05)
Captain John Rapids, Lyons Ferry Hatchery, (BDA)	**0.58** (0.41 - **0.77**)	**0.44** (0.30 - **0.60**)
Grande Ronde River, Irrigon Hatchery, (BDA)	0.69 (0.39 - 1.03)	**0.44** (0.25 - **0.69**)
Luke's Gulch, Luke's Gulch, (BDA)	**0.53** (0.19 – **0.97**)	**0.34** (0.13 - **0.67**)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	**0.73** (0.52 – **0.97**)	**0.53** (0.37 – **0.74**)
Snake River, Lyons Ferry Hatchery, (BDA)	0.96 (0.43 – 1.84)	0.91 (0.40 - 1.88)
Snake River, Irrigon Hatchery, (BDA)	**0.56** (0.35 - **0.81**)	**0.49** (0.30 - **0.73**)
Snake River, Oxbow Hatchery, (BDA)	**0.41** (0.15 - **0.74**)	**0.36** (0.13 - **0.71**)

Note: TIRs and *D* significantly different than one are bolded.

Figure 6.4 shows the patterns in natural log TIRs for all cohorts where sufficient information was available to estimate TIRs. Overall, there were 48 TIRs that were estimated for the years 2006 to 2012 PIT-tag cohorts. Of the 48 estimated cohorts, 31 TIRs were above zero (on the natural log scale) and 17 below. However, only five TIRs were significantly above zero (90% confidence intervals did not overlap zero), indicating a significant benefit to transport, while 18 TIRs were significantly below zero indicating a significant benefit to in-river passage. The Big Canyon Creek release of production subyearling Chinook had significant TIRs for four years (confidence intervals not overlapping 0). For 25 cohorts TIRs were not significant.

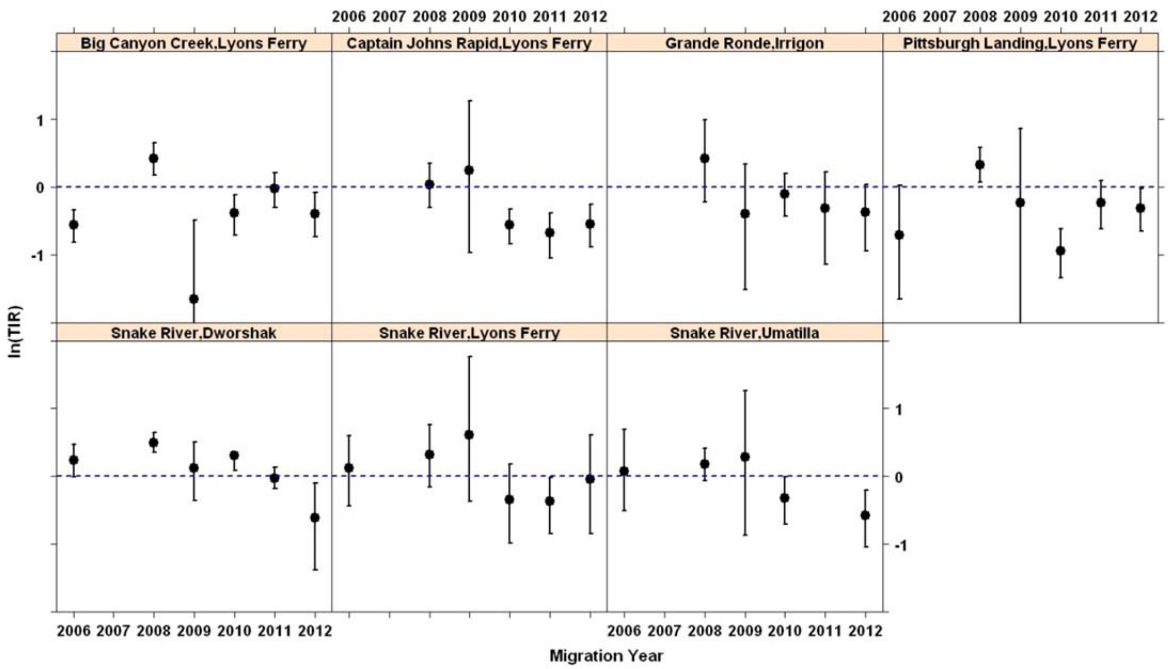


Figure 6.4. Patterns in TIRs LGR-to-GRA (excluding jacks), for transported and in-river PIT-tag groups of subyearling fall Chinook salmon released above Lower Granite Dam for the years 2006 to 2012. Confidence intervals overlapping one indicate non-significant TIRs. Dashed line at zero indicates equal SARs for transport and in-river study categories. TIRs were plotted on a natural log scale.

Figure 6.5 shows patterns in ln TIRs versus in-river survival for subyearling fall Chinook cohorts that had sufficient data available to estimate SARs by study category. Similar to the patterns seen in yearling Chinook and steelhead (presented in Figure A.19 in Appendix A), a trend of decreasing transport benefit with increasing reach survival is apparent. Wild Chinook and wild steelhead annual estimates of ln(TIR) versus juvenile reach survival were plotted in for comparison purposes. The prediction line in Figure 6.5 has a negative slope and was estimated to intersect the ln(TIR) line at 0 with 90% CI (-0.71,0.71) at about 0.42 reach survival. For fall Chinook the point at which the ln(TIR) crosses zero is at a lower reach survival than predicted for steelhead and Chinook. This illustrates that transportation benefited only the fall Chinook cohorts in our analysis when in-river survival was relatively low. TIRs were similar in range for yearling Chinook and steelhead to that of subyearling fall Chinook, when comparing only the years 2006 to 2012 (See Figure A.19 in Appendix A). In years prior to 2006, for yearling Chinook and steelhead, there were years when TIRs were quite high, especially when reach

survivals were lower than 0.4 (for steelhead especially). It should be pointed out that the hatchery subyearling Chinook TIR data presented in Figure 6.5 had multiple data points per year, and included only the years 2006 through 2012, in contrast to the wild steelhead and wild yearling Chinook data points that show only 1 annual TIR and begin with migration year 1994 for wild yearling Chinook and 1997 for wild steelhead.

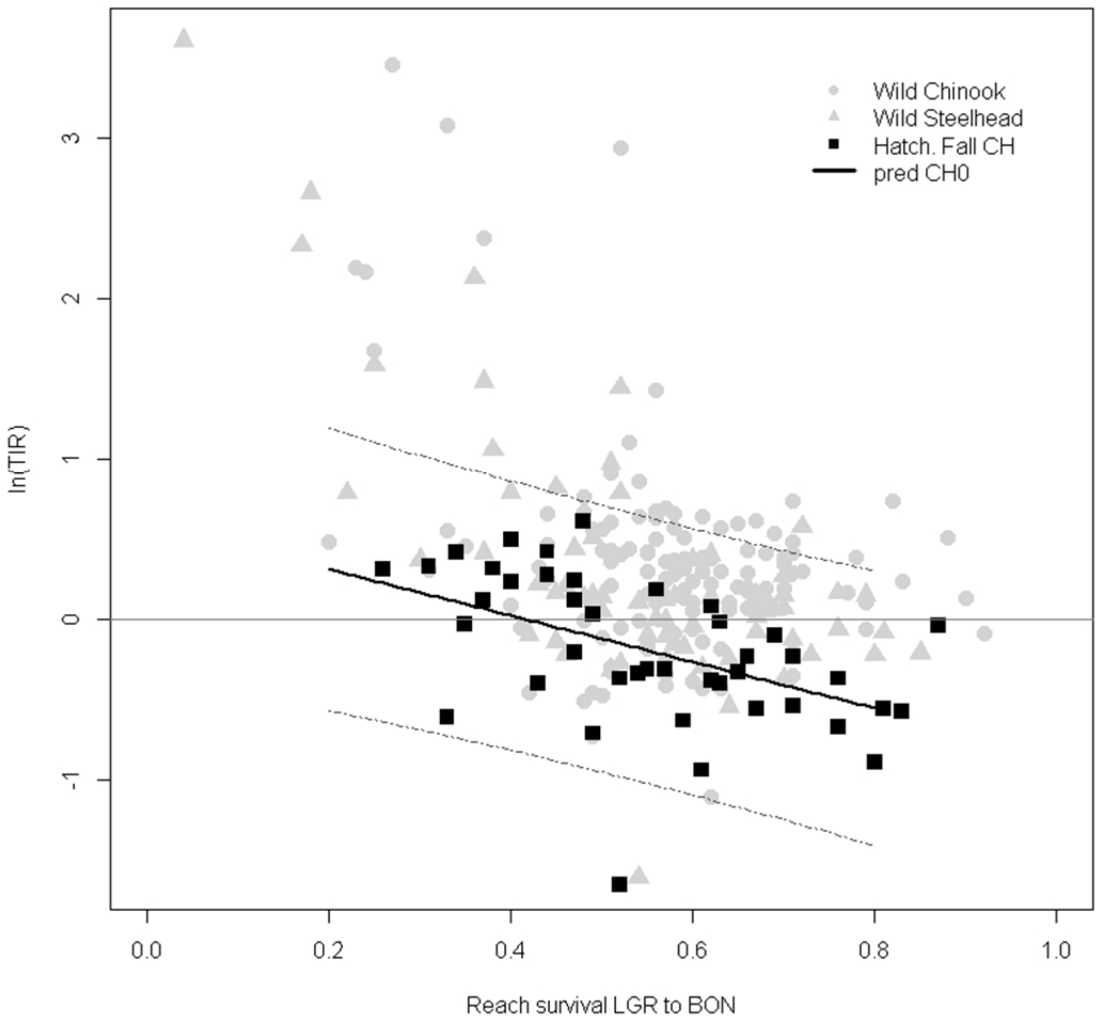


Figure 6.5. Log of Transport/in-river ratio of adult returns versus juvenile survival from LGR to BON for production releases of subyearling fall Chinook with regression line and 95% prediction intervals. All release groups from migration years 2006 to 2012, were included. Wild yearling Chinook and wild Steelhead annual TIR estimates were also plotted for comparison.

Conclusions

Updating the overall SARs with additional returning adults for the juvenile migration years 2011 and 2012 did not change observations reported by McCann et al. (2015).

Overall smolt-to-adult return rates to Lower Granite Dam (excluding jacks) for Snake River hatchery subyearling fall Chinook were low in three of the seven years we have analyzed. Fall Chinook overall SARs ranged from 0.12% to 0.56% for hatchery releases in 2006 and 0.0% to 0.3% in 2007. The highest SARs were observed for migration years 2008, and 2011, with SARs ranging between 0.30% and 1.07%. SARs for 2009 were relatively low as well, with SARs ranging between 0.05% and 0.23%. For the 2010 migration year, SARs were between the low returns from 2009 and the highest returns from 2008. SARs for 2010 ranged between 0.20% and 0.97%. For migration year 2012 SARs ranged between 0.40 and 0.79. Return data for migration year 2012 now includes 3-salt adults.

Eighteen of 48 study cohorts showed significant benefit to adult returns from migrating in-river as juveniles while five cohorts showed a significant transport benefit. Overall, 25 TIRs were not significantly different than one. In all, 31 of 48 adult return cohorts showed a benefit to in-river migration (ln TIRs less than 0) while 17 showed a transport benefit.

Estimated *D* values for subyearling Snake River fall Chinook were below 1, for nearly all groups in the years 2006 to 2012. That was similar to patterns seen in yearling Chinook and steelhead (hatchery and wild groups) in the same years. A longer time series for subyearling Chinook would be helpful to determine if *D* estimates would have been higher prior to 2005 (the beginning of court-ordered summer spill) similar to the pattern seen for hatchery and wild steelhead groups that had *D* values that were well above 1 for several years prior to 2006.

Based on TIRs of adult returns to LGR it appears that the juvenile smolt transportation program does not mitigate for the adverse impacts of the operation of the FCRPS on fall Chinook groups that we analyzed.

Transport benefit appears to be related to in-river survival from LGR to BON, similar to what has been demonstrated for yearling Chinook and steelhead, with transport benefit decreasing as in-river survival increases.

SAR estimates for wild subysearling Chinook marked in the Deschutes River were included for the first time in 2014. Marking of Deschutes River fall Chinook began in migration year 2011. Similarly, SAR estimates for Little White Salmon National Fish Hatchery were also provided for the first time in 2014.

CHAPTER 7
EFFECTS OF JUVENILE BYPASS SYSTEMS ON SMOLT TO ADULT RETURN RATES

Introduction

Juvenile collection and bypass systems are currently in place at seven of the eight Federal Columbia River Power System (FCRPS) dams on the lower Snake and Columbia rivers. These systems were designed to either collect juvenile salmonids for barge or truck transportation or divert juvenile salmonids away from turbine intakes and to return them back to the river downstream of the dam.

Studies of survival through juvenile collection/bypass systems at FCRPS dams have indicated relatively high estimates of "direct" passage survival from the face of the dam to the tailrace of the dam. Some of the earliest route-specific dam passage survival estimates using passive integrated transponder (PIT) tags (Prentice et al. 1990) indicated that survival through bypass systems were nearly as high through spillways (Muir et al. 2001a). Survival estimates through juvenile bypass systems are now routinely estimated as part of juvenile dam passage survival performance standards that evaluate the effectiveness of hydropower Reasonable and Prudent Alternative (RPA) actions specified in the NOAA Biological Opinion. The methodological approach for evaluating these performance standards incorporates survival through the juvenile bypass system, in addition to survival through spillway and turbine routes. However, this performance standard approach only examines short-term survival from the face of the dam to the tailrace, and ignores possible delayed effects (Budy et al. 2002) resulting from passage through specific routes.

Beyond short-term passage survival, several studies have documented other effects of juvenile bypass passage, including: migration delay (Beeman and Maule 2001, Muir et al. 2001b, Tuomikoski et al. 2010), delayed mortality (Budy et al. 2002, Schaller and Petrosky 2007, McMichael et al. 2010), and reduced smolt-to-adult survival rates (SARs) (Sandford and Smith 2002, Williams et al. 2005, Tuomikoski et al. 2010, Buchanan et al. 2011). If juvenile fish that migrate through bypass systems express any of these other effects, then juvenile bypass survival estimates, as encompassed in the "performance standards" approach may not be providing an accurate or complete assessment of the effects of FCRPS projects on salmon and steelhead populations. In addition, delayed mortality associated with juvenile bypass systems will negatively affect projected rebuilding of Endangered Species Act (ESA)-listed stocks if this effect is not considered in implementation of operations of FCRPS projects. A better understanding of the delayed effects of passage through bypass systems would assist hydrosystem and fishery managers to develop operations that would more accurately address the total impacts of project operations on life-cycle survival rates.

An analysis of bypass effects on SARs was first presented in Chapter 7 of the Comparative Survival Study 2010 Annual Report (Tuomikoski et al. 2010). In that analysis, passage through juvenile bypass systems was associated with subsequent reductions in SARs compared to juveniles that did not experience juvenile bypass systems based on data from juvenile migration years 2000-2008. These results provided evidence that bypass passage experiences were a form of hydrosystem-related delayed mortality (Budy et al. 2002). Since

2005, there have been a number of operational and configuration changes at the FCRPS dams such as changes in spill levels and the installation of spillway weirs. These changes may have influenced the effect of bypass passage experiences relative to fish that avoid bypass systems, primarily through spillway passage. In addition, the number of PIT-tagged hatchery steelhead dramatically increased in 2008, providing additional data to assess the effects of bypass passage experiences on SARs. Data from recent years provide an opportunity to assess whether bypass passage experiences continue to influence SARs under the recent operation and configuration of the FCRPS dams. The following analysis for hatchery and wild Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) uses data from juvenile migration years 2006-2013 and a similar analytical approach as Tuomikoski et al. (2010).

Methods

Data for this analysis consisted of hatchery and wild, spring/summer Chinook salmon and steelhead, PIT-tagged and released upstream of Lower Granite Dam during migration years 2006 - 2013. Detection histories at juvenile bypass systems with PIT-tag detection capabilities were determined. This included Lower Granite (GRJ), Little Goose (GOJ), Lower Monumental (LMJ), Ice Harbor (ICJ), McNary Dam (MCJ), John Day (JDJ), and Bonneville Dam (BON) dams. At BON, juvenile fish can be detected within the bypass system or within a surface flow outlet (i.e. the "corner collector").

Every individual included in this analysis was conditioned on being detected at Bonneville Dam as a juvenile during the expected year of migration and before July 1. Very low numbers of steelhead and Chinook smolts are observed migrating past Bonneville Dam after this date. Adult detection (including Chinook jacks) at Bonneville Dam (BOA) was used to provide estimates of SAR rates from BON to BOA (BON-BOA).

The data used in this analysis covers juvenile migration years 2006-2013 (Table 7.1). The hatchery datasets provided much larger sample sizes compared to those for wild smolts. For most migration years, Chinook sample sizes were larger than steelhead. SARs for migration year 2013 are based on

1-salt and 2-salt returns through return year 2015.

Table 7.1 Number of hatchery and wild Snake River spring/summer Chinook and steelhead detected at Bonneville Dam as juveniles, and the number of returning adults of those smolts, by migration year.

	Chinook				Steelhead			
	Hatchery		Wild		Hatchery		Wild	
	Smolts	Adults	Smolts	Adults	Smolts	Adults	Smolts	Adults
2006	7,249	95	1,092	17	874	24	325	5
2007	15,550	189	1,803	32	1,536	41	604	20
2008	6,726	256	1,326	76	10,785	626	682	49
2009	13,901	229	2,026	70	15,538	446	659	30
2010	29,190	469	4,199	54	27,132	933	1,557	53
2011	4,842	30	1,080	7	5,475	85	171	3
2012	14,003	213	1,618	40	5,576	168	348	12
2013	12,747	212	1,467	32	11,150	240	775	26
Total	104,208	1,693	14,611	328	78,066	2,563	5,121	198

In order to examine the effects of bypass systems on BON-BOA SARs, adult returns at Bonneville Dam for individual i of rear type r in year y were assumed to follow a Bernoulli distribution:

$$\text{Adult Return}_{i,r,y} \sim \text{Bernoulli}\left(\text{SAR}_{i,r,y}\right)$$

Logistic regression techniques were then used to fit variations of the general model:

$$\text{logit}\left(\text{SAR}_{i,r,y}\right) = f(\text{Year}_{i,y}, \text{Rear}_{i,r}, \text{Bypass Effects}_{i}),$$

where $Year_{i,y}$ is the juvenile outmigration year for individual smolt i in year y, $Rear_{i,r}$ is the rear-type (i.e., hatchery or wild), and $Bypass\ Effects_i$ measures the effects of upriver bypass experiences. Indicator variables were used to define bypass passage experiences for each individual fish, with a “1” indicating that an individual fish was detected in the bypass system at a particular dam and a “0” indicating that an individual fish was not detected in the bypass system. The vast majority of individuals that were not detected passed through the spillways, although a small proportion of these individuals passed through the turbines (McCann et al. 2015, Appendix J).

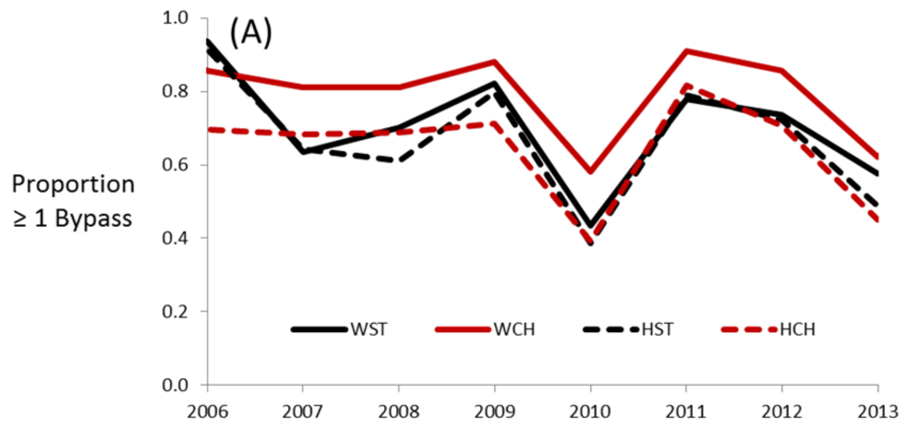
Similar to Tuomikoski et al. (2010), three different model formulations were used to characterize bypass effects (Table 7.2). These three model formulations represent three alternative hypotheses of whether the magnitude of bypass passage effects are similar or

different across dams. In the first formulation ("Total Bypass"), models 2 and 6 characterize the magnitude of bypass effects as being similar across dams. In these models, the cumulative values for the bypass variable ranges from zero (i.e., never bypassed, but detected at the Bonneville Dam) to six (i.e., bypassed at every dam upstream of Bonneville Dam with a bypass system). In the second formulation ("Snake Bypass + Columbia Bypass"), models 3 and 7 characterize the magnitude of bypass effects as being different for Snake River dams compared to Columbia River dams. In these models, the bypass variables include terms for the cumulative number of bypass encounters at Snake River dams separately from the cumulative number of bypass encounters at Columbia River dams (ranging from 0 to 4 and 0 to 2, respectively). In the third formulation ("Bypass Location"), models 4 and 8 characterize the magnitude of bypass effects as being different for each dam and separate estimates for the bypass effects are estimated for each individual dam. Finally, models 1 and 5 represent the hypothesis that there are no bypass passage effects. In addition to these model formulations characterizing the magnitude of the bypass effects, the models included two formulations of the differences between hatchery and wild rearing types across years. Models 1-4 represent the hypothesis that there is a consistent difference between hatchery and wild rearing types across years, while models 5-8 represent the hypothesis that the difference between hatchery and wild rearing types varies across years. All models assume that the SARs vary by year (Table 7.2).

Table 7.2. Description of the eight logistic regression models considered to examine the effects of bypass systems on BON-BOA SARs.

Model: Functional Form	Year by Rear Interaction	Bypass Effects	Bypass Location Effects
1: Year + Rear	No	No	No
2: Year + Rear + Total Bypass	No	Cumulative	No
3: Year + Rear + Snake Bypass + Columbia Bypass	No	Cumulative	Yes
4: Year + Rear + Bypass Location	No	Dam-specific	Yes
5: Year + Rear + Year x Rear	Yes	No	No
6: Year + Rear + Year x Rear + Total Bypass	Yes	Cumulative	No
7: Year + Rear + Year x Rear + Snake Bypass + Columbia Bypass	Yes	Cumulative	Yes
8: Year + Rear + Year x Rear + Bypass Location	Yes	Dam-specific	Yes

The proportion of smolts that experienced bypass events and the average number of bypass events upstream of Bonneville Dam varied across years (Figure 7.1). Lower proportions of smolts experiencing bypass events and lower numbers of bypass events occurred in 2010 and 2013, while higher proportions of bypass events and higher numbers of bypass events occurred in 2006, 2009, and 2011. Across years and species, 70% of the smolts detected at Bonneville Dam had at least one bypass experience at the upstream dams and smolts experienced an average of 1.2 bypass events.



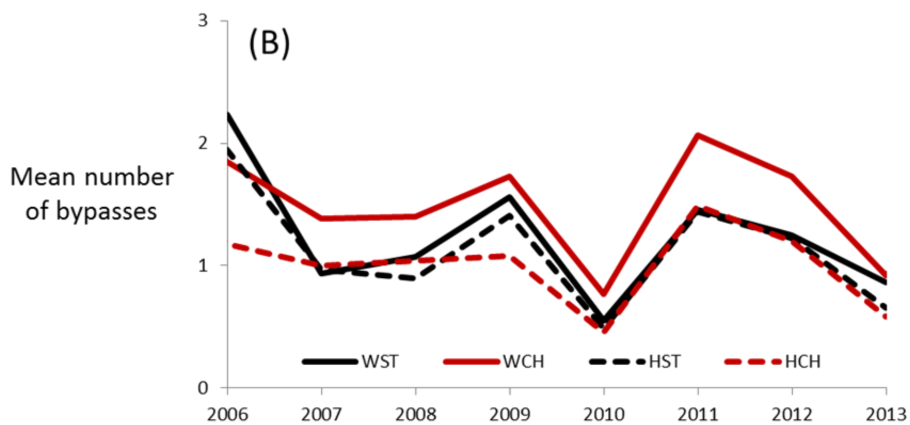


Figure 7.1. Proportion of smolts detected at Bonneville Dam that had at least one bypass event upstream (A) and the mean number of upstream bypass events (B) for wild steelhead (WST), hatchery steelhead (HST), wild Chinook salmon (WCH), and hatchery Chinook salmon (HCH).

Parameters estimates from the logistic regression models are reported on the logit scale, the scale of the predictor variables, but the interpretation of these parameters is provided on the odds ratio scale. The odds ratio, defined as the probability of an event occurring divided the probability of that event not occurring (i.e. the ratio of survival to adulthood to not surviving to adulthood), is obtained by exponentiation of the logistic regression parameters (Kutner et al. 2004, page 567). This interpretation is provided instead of one on the probability scale (*e.g.* SAR) due to the non-linear nature of the inverse logit function that does not result in simple interpretations of the effects of bypass encounters on SARs.

Parameter estimates of year and rearing effects are not reported for simplicity. These variables are included within the eight models to account year-to-year variability, and differences in survival for hatchery- and wild-origin smolts. This should result in more accurate and precise

estimates of bypass-related parameters. Because bypass related-related parameters are the primary focus of the models considered, the reporting of results is focused on these terms.

Multi-model inference techniques (Burnham and Anderson 2002) were used to report the results from the models described in Table 2. Akaike's Information Criterion corrected for small sample size (referred to as AIC for simplicity) was used to rank the models. Lower AIC values indicate better fitting and more parsimonious models. For each model, the difference in AIC to the best fitting model (ΔAIC) was calculated. This statistic was used to calculate the relative weight of the j^{th} model (w_j) in the candidate set as:

$$w_j = e^{-0.5\Delta\mathrm{AIC}_j} \Big/ \sum_j e^{-0.5\Delta\mathrm{AIC}_j}$$

The relative weights provide the weight of evidence of model *j* being the best model for the data, given that that one of the eight models is indeed the best model. Estimates of bypass-related parameters from the three models with the largest relative weight, or equivalently the smallest AIC, are reported.

Relative model weights were used to compute weighted average estimates of dam-specific bypass encounters. These estimates were computed by model-averaging bypass related parameters across all models, including those models where bypass effects were forced to be zero (i.e., models 1 and 5). For instance, the effect of encountering a juvenile bypass at Lower Granite Dam was estimated by taking the weighted average of the cumulative bypass parameter from models 2 and 6, the cumulative Snake River bypass parameter from models 3 and 7, and the Lower Granite bypass parameter from models 4 and 8.

The shrinkage estimator method (Burnham and Anderson 2002, p. 152) was used to compute weighted average estimates of parameters. In this case, shrinkage estimate of each parameter is averaged over all models and the weights are determined by the summed weights of these models. Standard errors based on the unconditional variance estimator (Burnham and Anderson 2002, p. 345, Burnham and Anderson 2004) are used to report standard errors and confidence intervals of weighted average estimates of parameters:

$$\mathrm{SE}\left(\hat{\bar{\theta}}\right) = \sqrt{\sum_j w_j \left[\mathrm{var}\left(\hat{\theta}_j\right) + (\hat{\theta}_j - \hat{\bar{\theta}})^2\right]}$$

where $\hat{\bar{\theta}}$ is the weighted average estimate and $\hat{\theta}_j$ is the parameter estimate from model *j*.

Results

Comparisons of AIC values and relative model weights indicated support for models with year by rear interaction terms for Chinook, but the additive year and rear terms demonstrated slightly better fits for steelhead compared to the year by rear interaction models for steelhead (Table 7.3). All of the top three models for Chinook, which accounted for approximately 99% of the model weights, included year by rear interaction terms. Conversely, models with additive year and rear terms for steelhead constituted 75% of the model weights while the year by rear interaction models constituted 25% of the model weights (Table 7.3).

Table 7.3. Model selection results for the eight models considered for steelhead and Chinook. Models are compared based AIC, ΔAIC and the corresponding model weight, w_j. The number of parameters in each model, *k,* is also provided. Model selection results from the top 3 models for each species are indicated in bold.

		Yearling Chinook salmon				Steelhead			
Model	Variables	k	AIC	Δ AIC	w_i	k	AIC	Δ AIC	w_i
1	Year + Rear	9	16,540.3	23.40	0.000	9	19,370.9	18.4	0.000
2	Year + Rear + Total Bypass	10	16,526.4	9.50	0.006	10	19,352.5	0.0	0.443
3	Year + Rear + Snake Bypass + Columbia Bypass	11	16,528.2	11.30	0.002	11	19,354.2	1.7	0.189
4	Year + Rear + Bypass Location	15	16,534.5	17.60	0.000	15	19,355.2	2.7	0.115
5	Year + Rear + Year x Rear	16	16,532.8	15.90	0.000	16	19,373.0	20.5	0.000
6	Year + Rear + Year x Rear + Total Bypass	17	16,516.9	0.00	0.676	17	19,354.7	2.2	0.147
7	Year + Rear + Year x Rear + Snake Bypass + Columbia Bypass	18	16,518.5	1.60	0.304	18	19,356.4	3.9	0.063
8	Year + Rear + Year x Rear + Bypass Location	22	16,524.9	8.00	0.012	22	19,357.2	4.7	0.042

The effect of models with and without year by rear interaction terms can be observed in the patterns of BON-BOA SARs shown in Figure 7.2. For Chinook, differences in SARs for hatchery and wild smolts varied from year to year with no differences in some years and large differences in other years indicating larger SARs for wild smolts. Due to the lack of interaction terms in the top steelhead models, the differences in SARs were more consistent from year to year always indicating higher SARs for wild compared to hatchery origin smolts. Although the models tended to favor year by rear-type interactions for Chinook salmon and additive year and rear-type effects for steelhead, the models indicated that the wild rear-type tended to have higher SARs than the hatchery rear-type for both species. From the model 2 results for both species, wild-reared Chinook salmon survived 52% better on average than hatchery-reared Chinook salmon and wild-reared steelhead survived 28% better on average than hatchery-reared steelhead.

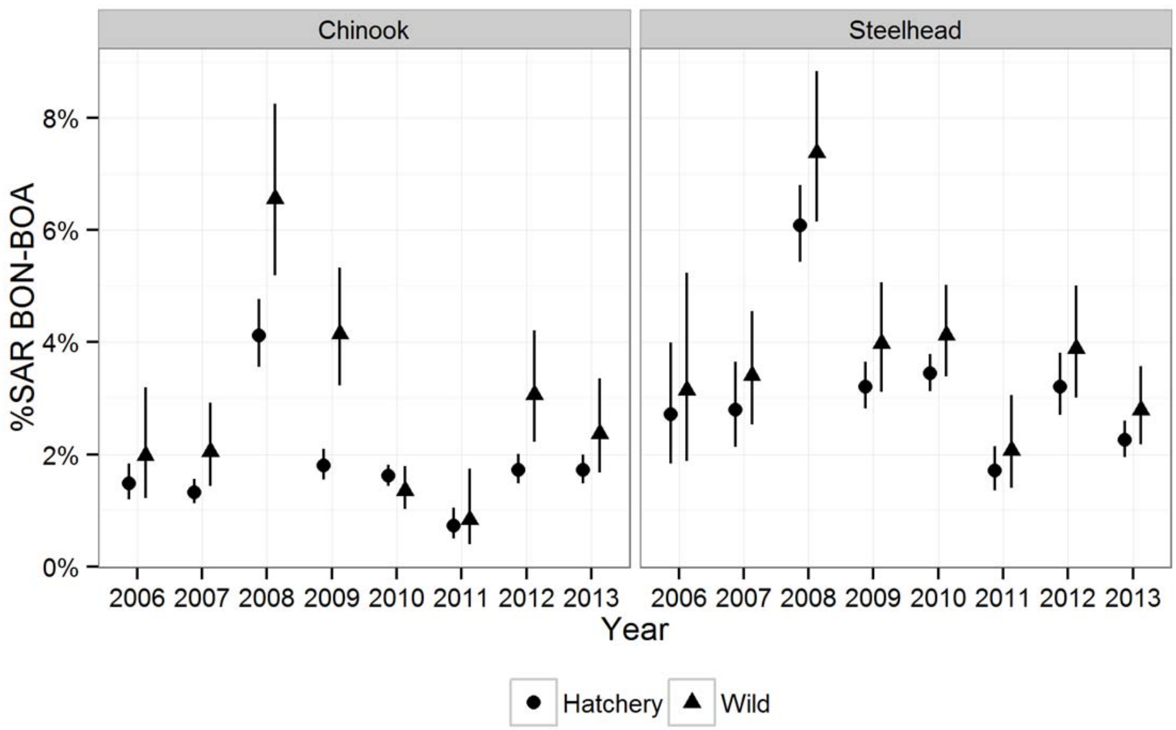


Figure 7.2. Weighted model averaged estimates of Bonneville to Bonneville (BON-BOA) SARs for hatchery and wild Chinook and steelhead with zero bypass encounters. Error bars represent 95% confidence intervals of the weighted average SAR estimates.

Year-to-year patterns in BON-BOA SARs were correlated between Chinook and steelhead (Figure 7.2). For both species, the highest SARs were observed for wild smolts in 2008 (approximately 6.6% and 7.4% for Chinook and steelhead respectively) and the lowest SARs were observed for hatchery smolts in 2011 (approximately 0.7% and 1.7% for Chinook and steelhead respectively). SARs in other years ranged from approximately 1.3% to 4.2% for Chinook, and from approximately 2.3% to 4.1% for steelhead.

All of the top 3 models for Chinook and steelhead included bypass effect terms and had substantially lower AIC values compared to models that did not include bypass effect terms (Table 7.3). For Chinook, the model that included a term for the cumulative number of bypass encounters without regard to location (model 6) had 68% of the relative weight, while the model that included terms for the cumulative number of Snake and Columbia rivers bypass encounters (model 7) had 30% of the relative weight (Table 7.3). The dam-specific bypass encounter model (model 8) only accounted for 1% of the total model weights. For steelhead, the model that accounted for cumulative bypass encounters without regard to location (model 2) also had the lowest AIC and accounted for 44% of the model weights. Like the model rankings for Chinook, the next best fitting model for steelhead (model 3) included terms for cumulative bypass encounters separately at Snake and Columbia dams.

For both Chinook and steelhead, the cumulative number of bypass encounters was estimated to reduce BON-BOA SARs (Table 7.4). For Chinook salmon, the cumulative number of bypass encounters (model 6) resulted in a 12.5% reduction in logit SARs. This translates to a 12% ($1 - e^{-0.125} = 0.12$) reduction in the odds of survival from BON to BOA for each bypass encounter. According to model 7, bypass encounters on the Snake River were more severe compared to the Columbia River. Cumulative bypass encounters on the Snake and Columbia Rivers (model 7) resulted in 14% and 10% reductions in logit SARs for Chinook salmon. For steelhead, cumulative (model 2), Snake and Columbia River (model 3) bypass encounters resulted in a 12%, 11%, and 14% reduction in logit SARs, respectively. These reductions in the logit SARs equate to 10-13% reductions in the odds of survival from BON to BOA.

Table 7.4. Estimates of bypass related parameters and standard errors (SE) from the three different model formulations that were used to characterize bypass effects. The model number denotes the model with the lowest AIC value for each bypass formulation.

	Yearling Chinook salmon			Steelhead		
	Model	Estimate	SE	Model	Estimate	SE
Total bypass	6	-0.125	0.030	2	-0.116	0.026
Snake bypass	7	-0.141	0.040	3	-0.106	0.032
Columbia bypass	7	-0.102	0.047	3	-0.139	0.050
LGR bypass	8	-0.163	0.078	4	-0.139	0.063
LGS bypass	8	-0.171	0.074	4	-0.159	0.055
LMN bypass	8	-0.137	0.088	4	0.063	0.071
IHR bypass	8	-0.045	0.100	4	-0.156	0.087
MCN bypass	8	-0.126	0.058	4	-0.116	0.068
JDA bypass	8	-0.061	0.075	4	-0.169	0.075

To account for model selection uncertainty as represented by the three alternative formulations of bypass effects, model-averaged estimates of dam-specific bypass encounters were calculated (Table 7.5). It is important to note that the Table 7.4 estimates are derived from individual models, whereas the Table 7.5 estimates are the model-averaged estimates from across all models. Because the weights associated with the dam-specific models were much less than the weights associated with the cumulative bypass models (Table 7.3), the weighted model average dam-specific estimates in Table 7.5 tend to converge towards the estimates derived from the cumulative bypass models. At all dams, logit SARs were 12-13% lower at each dam for Chinook smolts encountering juvenile bypass system compared to those fish that avoided the bypass system. These 12-13% differences imply that the odds of survival from BON to BOA decreased by 11-12% for each of the juvenile bypass systems between John Day and Lower Granite Dam. For steelhead, logit SARs were 9-13% lower at each dam, implying 8% to 12% reductions in the odds of survival from BON to BOA for each of the juvenile bypass systems between John Day and Lower Granite dams.

Table 7.5. Model averaged estimates and standard errors (SE) of location-specific bypass effects from the eight logistic regression models (Table 2) for yearling Chinook salmon and steelhead.

	Yearling Chinook		Steelhead	
	Estimate	SE	Estimate	SE
Lower Granite bypass	-0.130	0.035	-0.117	0.037
Little Goose bypass	-0.130	0.035	-0.120	0.038
Lower Monumental bypass	-0.130	0.035	-0.085	0.075
Ice Harbor bypass	-0.129	0.037	-0.119	0.046
McNary bypass	-0.118	0.038	-0.122	0.043
John Day bypass	-0.117	0.039	-0.130	0.048

Discussion

For both Chinook and steelhead, analyses presented in this chapter continued to demonstrate that juvenile bypass encounters were strongly associated with reductions in BON-BOA SARs, consistent with results reported in Tuomikoski et al. (2010). Models that accounted for cumulative bypass effects, without regard to location, ranked higher according to AIC than location-specific models. While encounters with particular juvenile bypasses may be more or less severe compared to other juvenile bypasses, this result suggests the effect of encountering juvenile bypass systems on BON-BOA SARs can be more parsimoniously explained by the cumulative number of encounters at all FCRPS dams. Hence, reducing exposure to any juvenile bypass system should result in increases in the odds of survival from BON to BOA.

The findings reported in this chapter have important implications for fishery managers tasked with recommending and developing hydrosystem operations intended to support recovery of ESA-listed salmon and steelhead stocks. RPA actions specified as performance standards in the NOAA Biological Opinion require action agencies to achieve an average dam passage survival rate of 96% for spring/summer Chinook salmon and steelhead at all FCRPS dams. This survival rate is defined from the face of the dam to a standardized reference point in the tailrace of the dam, and is determined by combining estimates of survival through all routes of passage. This study, however, has shown that encounters with one these routes of passage, the juvenile bypass system, results in reductions in BON-BOA SARs. Because of this finding, caution should be warranted when evaluating whether meeting performance standards for at dam passage survival accurately reflects the full impact of FCRPS project operations on ESA-listed salmon and steelhead and their recovery.

An additional finding implicit within the results of this study is that juvenile bypass systems may be one mechanism that results in hydrosystem-related delayed mortality, defined as mortality that takes place in the estuary and ocean that is related to prior hydrosystem experience during downstream migration (Budy et al. 2002). Every individual included in this analysis was known to survive to Bonneville Dam as a juvenile and encountered a varying number of juvenile bypass systems. The associations between cumulative and dam-specific bypass encounters and BON-BOA SARs, as reported in this study, provides evidence of hydrosystem-related delayed mortality. Because of this finding, the effects of juvenile bypass systems on survival should be evaluated using time frames capable of measuring both the direct and the delayed effects of passage through those routes, such as SAR rates.

Fisheries agencies in the Columbia River have dedicated substantial amount of resources towards understanding how different management actions will aid in the recovery of ESA-listed salmon and steelhead stocks. The findings reported here suggest that a greater focus on reducing bypass system encounters is one feasible action that managers could implement in order to improve smolt to adult return rates and help achieve recovery objectives. Reducing exposure to juvenile bypass systems could be achieved by increasing spill proportions (McCann et al. 2015, Appendix J).

Following release of the draft 2016 CSS Annual Report, comments from NOAA Fisheries suggested that Chapter 7 include a discussion of size selectivity and survival associated with juvenile bypass systems. In the following section, we discuss the studies that have been conducted, their results, and their limitations on inferring whether the juvenile bypass and collection systems are size-selective, and whether hypotheses on the combination of size-selectivity and size-dependent mortality can explain the patterns that have been observed in association with juvenile bypass and collection systems.

Bypass Selectivity and Survival

Introduction

In their comments on the Draft CSS 2016 Annual Report, NOAA suggested that the CSS Oversight Committee include a discussion of size selectivity of juvenile bypass collection systems at FCRPS projects in the Analyses of Bypass Effects chapter in the final report (Chapter 7). The NOAA comments refer to Zabel et al. (2005), Hostetter et al. (2015), and ISAB (2012-1) as the basis for the bypass size selectivity theory. Bypass size and condition selectivity has been theorized by some as the explanation for the documented lower smolt-to-adult return rates for juvenile fish that have been transported and juvenile fish that experience one or more powerhouse passages. The theory is based upon the premise that juvenile fish powerhouse collection and bypass systems select for smaller fish, and if size-selective mortality occurs, then lower SARs are expected to result. A critical assumption in this notion is that juvenile fish that pass through powerhouses have low SARs because they are small not because of the powerhouse bypass experience. The unstated assumption is that large fish would not have lower smolt-to-adult return rates as a result of powerhouse passage. The mechanisms involved in the juvenile powerhouse bypass experience should be taken into account to evaluate this concept. In the following discussion, the CSS Oversight Committee addresses the potential for, and the implications of, juvenile bypass system selectivity and the effects of potential bypass selectivity to management application of CSS monitoring data and analyses.

The CSS life cycle monitoring program collects and presents data and analyses that reflect the actual passage conditions and resulting effects on fish survival that occur as the result of the actual operation of the FCRPS. Multiple independent analyses and CSS analyses have concluded that fish that experience powerhouse passage have lower smolt-to-adult return rates than fish that pass over spillways. If bypass selectivity is actually occurring this represents a real impact of the development and operation of the FCRPS which is accurately reflected in the CSS results. Since wild stocks of salmon and steelhead are generally smaller than hatchery stocks, bypass selectivity if it occurs leads to the conclusion that the FCRPS has a disproportionally larger adverse impact on wild stocks of salmon and steelhead. It should be noted that bypass selectivity, if it occurs, does not affect the management application of CSS results because the CSS results are simply monitoring the effects of hydrosystem operations and configurations.

Juvenile Bypass Mechanisms

In order to weigh the premise that lower powerhouse passage SARs are the result of fish size or condition rather than the powerhouse passage experience, the actual mechanism of the power house passage and collection system must be understood. The function of a powerhouse juvenile collection/bypass system is to route fish entering the powerhouse through the powerhouse, avoiding turbines. Throughout this process, fish in the bypass collection system are moving through a system of channels, pipes and flumes with smaller and smaller amounts of water. In other words, fish passing through the bypass system are being dewatered as they are routed through the powerhouse. The McNary Dam bypass collection system is utilized as an example in the following discussion of the fish passage experience through the powerhouse bypass collection system.

A McNary turbine operating at the upper end of 1% of peak efficiency (at 75 feet of head) discharges approximately 12,350 cfs. A group of fish entering the project in this flow would be guided up the Extended Length Submersible Bar Screens (ESBS) into the gatewell, up the gatewell by the Vertical Barrier Screens (VBS), and discharged into the collection channel via three orifices (each discharging 14.3–16.7 cfs, under normal conditions). Upon initially entering the Juvenile Bypass at McNary, fish are separated from an average unit flow of 12,350 cfs into a 14.3–16.7 cfs orifice flow (three orifices per unit) which is routed into the juvenile collection channel. Only 0.4% of the original turbine unit flow discharges through the orifices into the collection channel, which equates to a 99.6% reduction in flow. According to the Operations and Maintenance Manual at McNary, total flow in the collection channel can range from a minimum of 406 cfs to a maximum of 728 cfs. However, under normal operating conditions, the juvenile collection channel flow typically ranges between 600 and 700 cfs depending on forebay elevation (with one orifice per gatewell open) (Carl Dugger, USACE, personal communication). At the downstream end of the collection channel there is a dewatering structure comprised of floor and side screens that separates the fish from a flow of 600–700 cfs in the collection channel to a flow of 30 cfs in the transportation flume. Therefore, approximately 95% of the collection channel water is removed before fish enter the transportation flume. Prior to the transportation flume, all fish moving through the juvenile bypass at McNary experience ESBS, VBS, gatewells, orifices, the collection channel, and the dewatering screens at the downstream end of the collection channel. As fish travel through the

transportation flume, flows continue at 30 cfs through a set of four PIT-tag detectors after which the transportation pipe either routes fish directly to the river (Primary Bypass) or through the sampling facilities (Secondary Bypass).

Considering the extensive dewatering screen mechanisms, hydraulics, potential for injury and disorientation that are likely to result in vulnerability to tailrace predation, it is difficult to accept the notion that the problem resulting in the documented lower SARs for this route of passage is fish size. The Smolt Monitoring Program records observation of fish injury in the juvenile bypass/collection system. These data provide evidence of trauma resulting from the bypass experience. Considering the mechanical operations and dewatering screen systems of even the best designed juvenile powerhouse bypass systems, attributing lower SARs for bypassed to fish size without consideration of the injury, disorientation, delay, and dewatering that is experienced is analogous to "blaming the victim". It is likely that these systems are directly responsible for lower SARs associated with the powerhouse passage route (Budy et al. 2002). Furthermore it is probable that fish of any size, large or small, would experience physiological stress and injury from exposure to these dewatering systems.

Historical Context of Bypass Effects and Review of Past Studies

Delayed and latent mortality was first documented in the PATH analytical process. Schaller et al. (1999) fitted spawner and recruit (SR) relationships for several Snake River spring/summer Chinook, mid-Columbia spring Chinook and upper Columbia spring Chinook populations and analyzed survival rate patterns before (1950s-1970 brood years) and after (1975-1990) FCRPS completion. Survival rates for Snake River populations (above 8 dams), and for upper Columbia populations (above 6-9 dams) declined at a significantly greater rate than for populations in the mid-Columbia (above 3 dams), coincident with FCRPS completion and operation. In addition, survival rates for the aggregate upriver spring Chinook run remained fairly stable from 1939-1970, then declined abruptly with FCRPS development. The empirical evidence pointed to the FCRPS as the primary factor affecting this differential mortality. Budy et al. (2002) summarized the weight of evidence supporting the delayed hydrosystem mortality hypothesis. Substantial evidence supported the existence of delayed mortality for Snake River Chinook salmon and steelhead and linked delayed mortality to hydrosystem experience. They summarized published literature on causes of stress and any resulting delayed mortality, indirect evidence from life cycle modeling, and direct evidence from fish-tagging experiments. The literature supplied numerous mechanisms that explain how the observed stressors of the hydrosystem could be cumulative and eventually lead to mortality at a later life stage. In post-development years in these analyses, 1975-1990, smolt transportation was maximized and no spill was provided at Lower Granite or Little Goose, which means that most of the downstream migrating salmon and steelhead experienced powerhouse passage. Therefore fish of all sizes would have passed through powerhouses, since spill for fish passage operations were not widely implemented during this period (1975-1990). These analyses showed that delayed mortality occurred due to hydrosystem passage. The historical data and analyses do not support the theory that bypass size selectivity is the probable cause of the documented delayed mortality and resulting lower SARs occurring to powerhouse passed fish.

In order to address the NOAA comments on the question of bypass selectivity, the references cited by NOAA were reviewed in addition to other analyses that address the question of bypass size selectivity. The overall conclusion of these reviews is that the available data and analyses do not support the hypothesis that bypass size selectivity is the cause for delayed mortality and lower SAR of powerhouse passed fish.

Zabel et al. (2004) examine the relationship of size of juvenile chinook salmon to survival within and among populations. In this study, juveniles of several populations Snake River tributaries were tagged in their freshwater rearing habitats and detected the following year during their downstream migration. The conclusion of these analyses was that fish length and condition at tagging were poor predictors of survival. The authors suggest that improvements in survival at one life stage may lead to improved survival in subsequent life stages. Although these researchers report that their analyses found a year and site effect, they did not analyze environmental variables such as flow, water temperature, seasonality (e.g., Julian day of release), or spill at hydroelectric projects and their subsequent effects on detection probability and survival which could be the basis of their observation of a year effect.

Zabel et al. (2005) presents an overview of capture/recapture models exploring the analytical potential to incorporate individual variability into population survival estimates Although Zabel et al. (2005) discusses evidence of bypass selectivity, the actual differences in size and the biological significance of that difference were not discussed. In addition, Zabel et al. (2005) did not find a consistent relationship between fish size and survival, but did conclude that the CJS population survival estimates are robust. Finally, Zabel et al. (2005) concludes that studies that include marking fish that are collected at dams (such as Hostetter et al. 2015) have the potential of not representing the overall migrating population. Although Zabel et al. (2005) focus on individual phenotypic traits and their effect on recapture probabilities, they did not include analyses of environmental variables such as flow or spill, which have been shown to have the greatest effect on recapture detection probabilities (McCann et al. 2015, Appendix J). This is particularly important since the years of study include 1998-2002.

Williams et al. (2005) includes discussion regarding the probability of detecting PIT-tagged fish versus length at tagging which is a reiteration and presentation of results from Zabel et al. (2005). Williams et al. (2005) carries the Zabel et al. (2005) conclusions further than the original analyses by proposing that the Zabel et al. (2005) analyses raise questions regarding the Budy et al. (2002) conclusions that passage through bypass systems results in delayed mortality. Williams et al. (2005) propose that the poor performance of transported fish is related to the size and condition of fish in the bypass system. The Williams et al.(2005) discussion suffers from the same shortcomings as Zabel et al. (2005), in that environmental variables such as flow and spill for fish passage were not considered in their analyses of detection probability or survival. Flow and spill have been shown to be the primary factors affecting detection probability and survival. The years of these analyses included high flow years and low flow years. Most notably, Williams et al. (2005) present data on juvenile survival and travel time for 2001 a low-flow, no-spill year. They do not discuss fish length in terms of detection probability in that year nor the high delayed mortality that was observed in in-river migrants in that year.

Based on the results of Zabel et al. (2005) and on NOAA's comments on the 2005 CSS Annual Report the CSS Oversight Committee included an analysis of bypass selectivity in its 2006 Annual Report (Chapter 9 of Berggren et al. (2006). The analysis focused on wild Chinook salmon, because this group exhibits the largest transport vs. in-river post-Bonneville differential delayed mortality difference. Using an AIC-based model-selection procedure, the level of empirical support for size–detection probability relationships at LGR, LGS, and LMN was evaluated using smolts tagged and released immediately upstream of Lower Granite pool as part of the CSS during migration years 1998-2006. Size–detection probability function parameters (i.e., the slope and intercept of fitted logistic functions) and their associated uncertainty for LGR, LGS, and LMN bypass/collection sites were estimated. Fork length at release between detected and undetected smolts, minus known removals made at upstream projects, through year and project-specific t-tests were compared. This analysis suggested that on average, size–detection probability relationships are likely of negligible importance for wild Chinook salmon study group comparisons currently made as part of the CSS.

McMichael et al. (2010) observed a similar pattern of delayed mortality associated with bypass passage in acoustic telemetry studies conducted at John Day Dam, particularly for steelhead. A 2009 study using acoustic telemetry data indicated that, among all passage routes, passage through the juvenile bypass system resulted in the highest direct survival estimates for yearling Chinook (0.975), steelhead (0.966), and subyearling Chinook (0.908) (Weiland et al., 2010). However, Michael et al.(2010), utilizing the same acoustic tagged fish, indicated that steelhead passing through the juvenile bypass system at John Day Dam had the lowest survival to the estuary (0.42-0.59, depending on the passage route at Bonneville Dam). Steelhead juveniles that passed John Day Dam through deep spill had estuary survival that ranged from 0.55 to 0.70 (depending on the passage route at Bonneville Dam). Passage through the TSW's at John Day Dam resulted in estuary survivals that ranged from 0.56 to 0.65 (depending on the passage route at Bonneville Dam). These results are notable because acoustic tagged fish are large by necessity of the size of the acoustic tag, indicating that large fish passing through a powerhouse system also incur the stress resulting in subsequent evidence of delayed mortality.

Buchanan, et al. (2011) analyzed PIT-tag data to identify the history of bypass system use by individual juvenile fish and compared the observed numbers of adults that returned with specific juvenile passage histories to the numbers of adults expected in the absence of any bypass effects. The authors found strong evidence that bypass events are associated with reduced adult return rates of Chinook salmon and steelhead smolts. In general, fish that migrated through the hydrosystem without detection in any bypass system had higher adult return rates. The authors found no consistent evidence that bypass systems were size selective for smaller fish. The authors also observed that the long lag time between fish being PIT-tagged at hatchery locations and subsequent detection events is problematic in attempting to assess bypass/collection size selectivity using these data.

The NOAA comments cite ISAB (2012-1) in regards to bypass size selectivity. In this memorandum, the ISAB reviews CSS bypass effects analyses and concludes that the available evidence demonstrates that fish bypass systems are associated with some degree of latent mortality and raised question about the potential causative factors. The ISAB however, did not consider the actual dewatering function or physical hydraulics of powerhouse collection/bypass systems.

In response to a request from the Fish Passage Advisory Committee, the Fish Passage Center provided a technical review of Hostetter et al. (2015) (DeHart 2016). This technical review was completed on February 16, 2016, was distributed to the regions Fish and Wildlife Management agencies and tribes and has been available to the public on the FPC website The FPC review concluded that, due to the significant methodological and analytical problems in this work, the findings do not have management application. The Hostetter et al (2015) study and conclusions are based on one year of data that was collected and represented a single season of environmental conditions. Only hatchery fish were marked and evaluated for this study. No data are presented to demonstrate that the daily mark groups were of consistent size over the time period. Thus, length may be confounded with other variables not included in this analysis that changed over the time period. Inferences about trait selectivity on detection probability at Lower Granite Dam cannot be made from this study since all the fish utilized in this study were tagged at this location.

Bypass Selectivity and Potential for Disproportionate Impact on Wild Fish

. In coordinated effort with the CSS, the Smolt Monitoring Program (SMP) has been tagging wild and hatchery spring/summer Chinook and steelhead juvenile out-migrants at three mainstem traps: the Snake River Trap (at Lewiston, ID), the Grande Ronde River Trap (about 2 km from the confluence with the Snake River), and the Salmon River Trap (near Whitebird, ID). In order to consiser the potential impacts of bypass selectivity on hatchery versus wild stocks, lengths of migrating wild and hatchery fish from these traps (2009-2016) were analyzed for comparisons. These revealed that wild fish are significantly smaller than hatchery fish (Figure 7.3 and 7.4) ($p<0.0001$ in all T-tests conducted). Among these three traps, the mean lengths of wild spring/summer Chinook were 14.4-29.6 mm less than hatchery spring/summer Chinook and mean lengths for wild steelhead were 34.6-50.7 mm less than hatchery steelhead. This leads to the conclusion that, if bypass selectivity actually occurs, as theorized by Williams et al.(2005), juvenile bypass/collection systems at FCRPS projects are having a disproportionally larger adverse impact on wild stocks of salmon and steelhead than on larger hatchery produced fish. Under the size-selectivity bypass and size-dependent mortality hypothesis, we would expect that wild fish would have lower post-Bonneville SARs because they are smaller. Contradicting this hypothesis earlier results presented in this chapter found that wild Chinook salmon and steelhead survived 52% and 28% better on average than their hatchery counterparts. These results are contrary to expectations under the size-selectivity bypass and size-dependent mortality hypothesis.

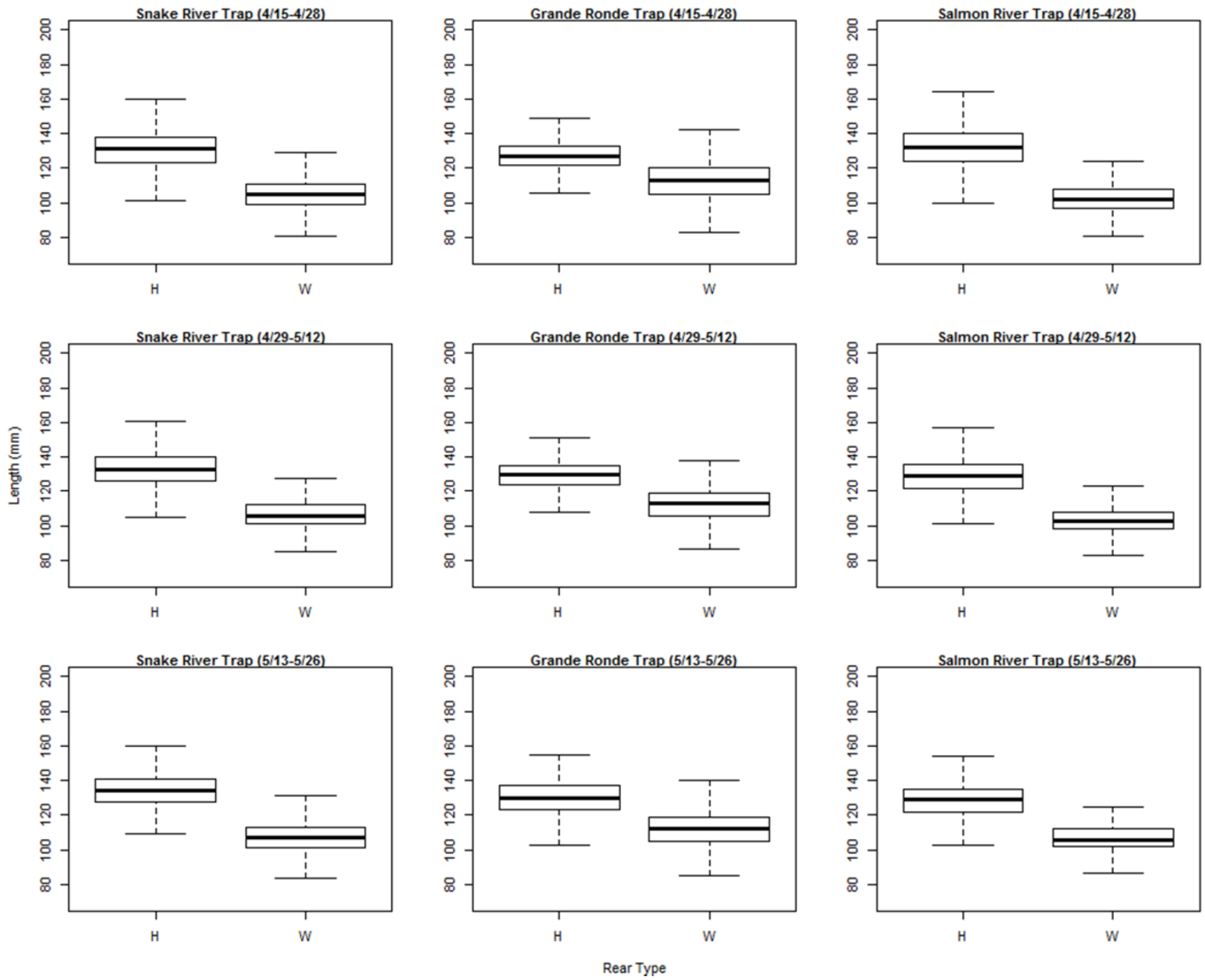


Figure 7.3. Box plots of juvenile hatchery (H) versus wild (W) spring/summer Chinook collected and tagged at the Snake River Trap, Grande Ronde River Trap, and Salmon River Trap between 2009 and 2016. To accommodate for seasonal changes in size, tagged fish were broken into three two-week blocks (Apr. 15-Apr 28, Apr. 29-May12, and May 13-May 26) for comparisons.

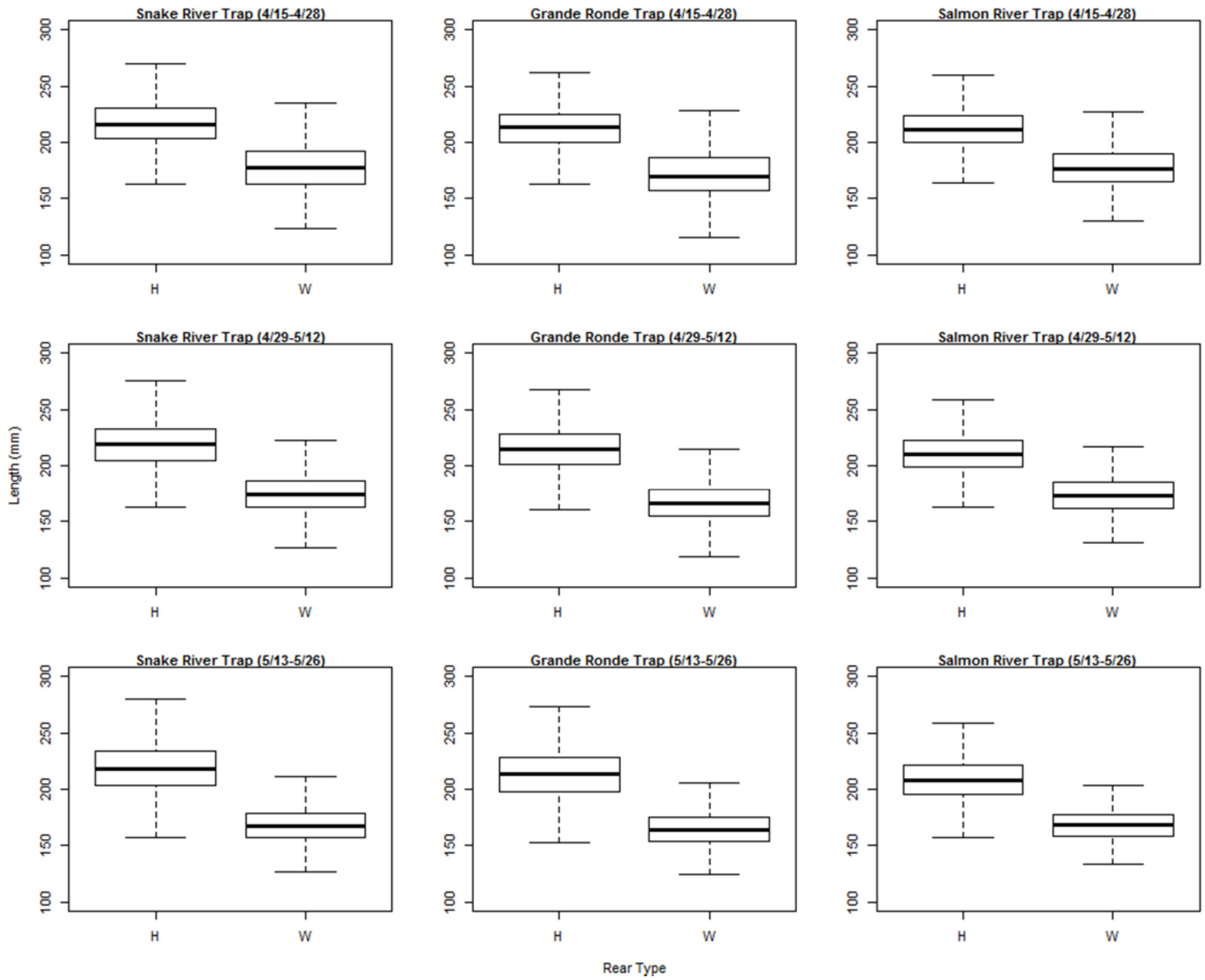


Figure 7.4. Box plots of juvenile hatchery (H) versus wild (W) steelhead collected and tagged at the Snake River Trap, Grande Ronde River Trap, and Salmon River Trap between 2009 and 2016. To accommodate for seasonal changes in size, tagged fish were broken into three two-week blocks (Apr. 15-Apr 28, Apr. 29-May12, and May 13-May 26) for comparisons.

Why Length at Marking is Not a Reliable Indicator of Length at Bypass/Collection

PIT tag marking of salmon and steelhead occurs many months in advance of the downstream migration. Time of marking of hatchery fish varies from November through March. In addition size at marking varies among hatcheries and among years. Finally, survival to Lower Granite is affected by many variables such as flow conditions, hatchery rearing conditions, and other factors. Fish length and mass has been shown to change as fish migrate downstream (Congelton 2003). Fish travel time and survival is affected by flow conditions and distance to the first bypass/collection site. These environmental factors could result in changing size distributions from the time of marking to detection in bypass collection systems.

The use of length at marking as a surrogate for length at dam passage is problematic. We compared length at marking at CSS hatcheries with length at recapture at downstream traps during active migration (Figure 7.5). We found that the correlation between length at tagging and recapture length was 0.74, indicating that only about 55% of the variability in recapture length was explained by length at tagging. This alone would suggest that there could be problems interpreting resultsfrom bypass selectivity studies that use length at marking as a surrogate for size at dam passage. Furthermore there appears to be a systematic bias in the data. When length at taggingdata were plotted aginst recapture lengthe, we found that the smaller the fish , the poorer the length at tagging fit the length at recapture(i.e. lengthe during active migration). (Figure 7.4)This is likely due to the fact that smaller fish are likely tagged earlier than larger fish and so spend a longer time in rearing. This is particularly troubling when analysis such as Williams et al.(2005), which is based on length at tagging data used as a surrogate for length at dam passage, emphasize the impacts to the smallest fish in the population,as these fish appear to have a length at marking that most poorly represents the length of the fish when they arrive at the dams.

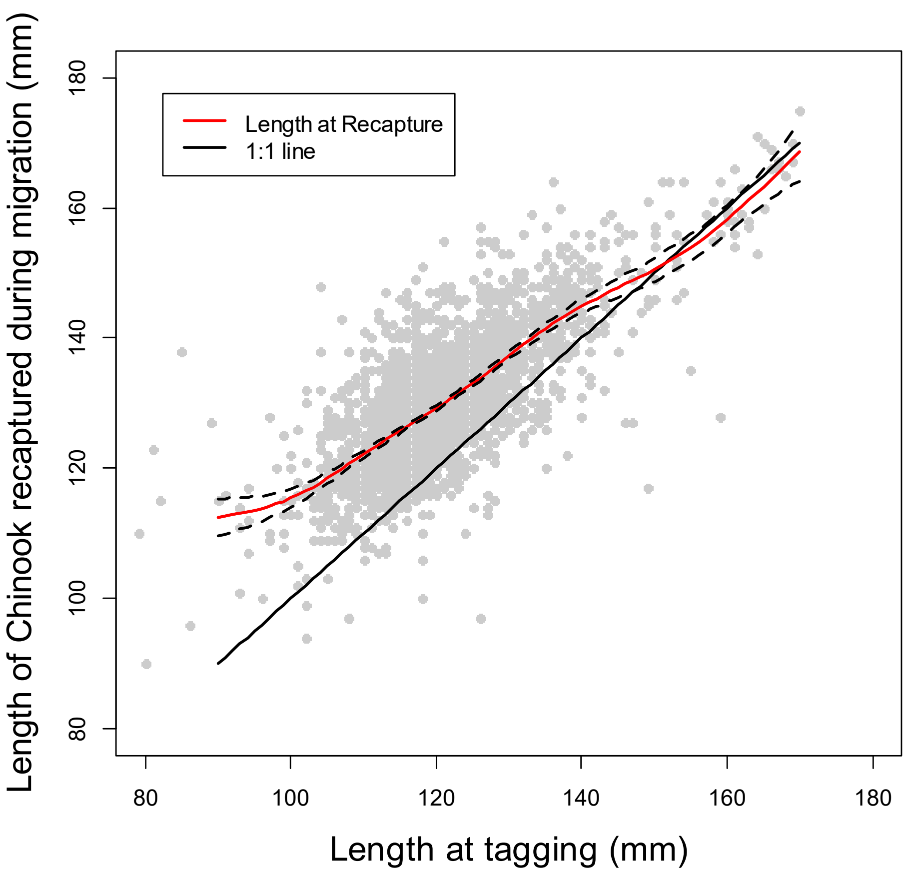


Figure 7.5. Length at tagging versus length at recapture for PIT-tagged CSS hatchery yearling Chinook tagged at Dworshak, Rapid River, Lookingglass and McCall hatcheries in the years 1995 to 2016. Recapture lengths were taken during down-stream migration at SMP traps on the Clearwater, Salmon , Grande Ronde, and Snake rivers. The figure shows a 1:1 line in black and a red spline curve to show how length at recapture differs from length at tagging.

Analyses of Bypass Selectivity

The following analyses explores the potential for bypass selectivity, investigating whether there is evidence of bypass selectivity at LGR, LGS, or LMN by comparinglength frequency distributions of wild spring/summer Chinook tagged at the Snake River Trap (at Lewiston, ID) to those that were detected at LGR, LGS, or LMN. If there was bypass selectivity, we would expect to see distributions of shorter length at LGR, LGS and LMN, compared to the lengths at tagging at the Snake River Trap. The Snake River Trap is located approximately 52 kilometers above Lower Granite Dam and collects and PIT-tags active migrants from March through May. Using two-sample Kolmogorov-Smirnov tests (Sokal and Rohlf, 1981) we compared frequency distributions of wild spring/summer Chinook tagged at the Snake River Trap to those that were detected at LGR, LGS, or LMN. These tests indicated that there was no statistical difference in the length frequency distributions of the tagged population versus those fish that were detected at LGR or LGS, but that there was a statistically significant difference between the tagged populations versus those fish that were detected at LMN (Table 7.6, Figures 7.6 and 7.7). However, this statistically significant difference in length distributions is unlikely to be of biological significance. For example, the magnitude of the difference in mean lengths between the tagged population and the fish detected at LMN was only 0.6 mm, which is less than the measurement error for this metric.

Table 7.6. Summary statistics and results of Kolomogorov-Smirnov Test to test for differences in length frequency distributions between wild spring/summer Chinook tagged at the Snake River Trap between 2009 and 2016 and those same fish that were detected at LGR, LGS, or LMN. Bold italics indicate a statistically significant difference in length distribution of detected fish compared to the tagged population (α = 0.05).

Group	Sample Size	Mean Length	Kolomogorov-Smirnov Test	
			D	p-value
Tagged at SNKTRP	17,491	105.6		
Detected at LGR	6,698	105.4	0.0167	0.1356
Detected at LGS	6,408	105.4	0.0143	0.2944
Detected at LMN	3,852	105.0	0.0399	***<0.001***

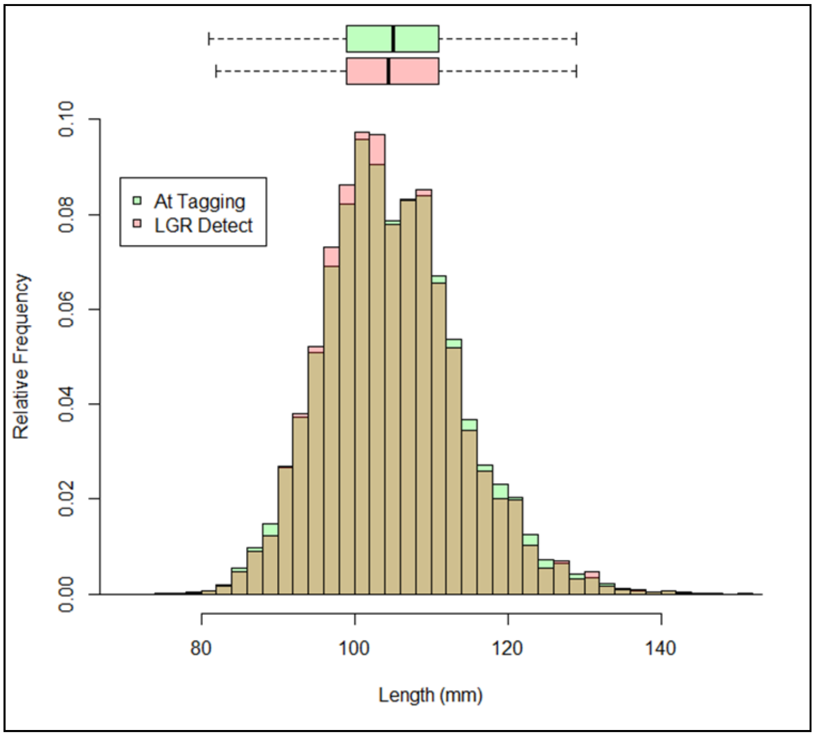


Figure 7.6. Length frequency distribution and box plot for wild spring/summer Chinook tagged at the Snake River Trap at time of tagging (At Tagging, green) compared to when the same fish were detected at Lower Granite Dam (LGR Detect, pink), 2009-2016.

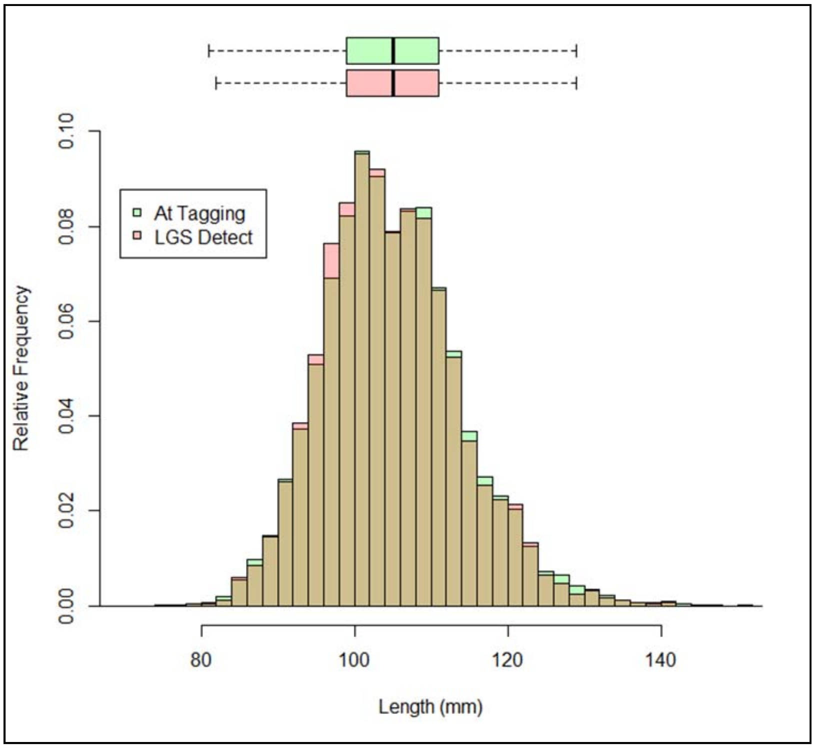


Figure 7.7. Length frequency distribution and box plot for wild spring/summer Chinook tagged at the Snake River Trap at time of tagging (At Tagging, green) compared to when the same fish were detected at Little Goose Dam (LGS Detect, pink), 2009-2016.

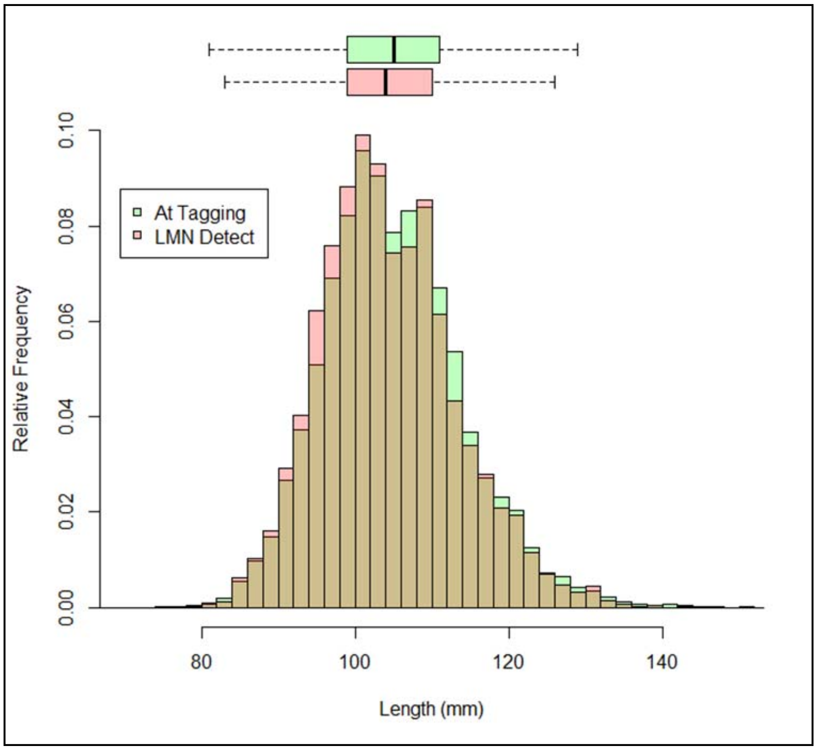


Figure 7.8. Length frequency distribution and box plot for wild spring/summer Chinook tagged at the Snake River Trap at time of tagging (At Tagging, green) compared to when the same fish were detected at Lower Monumental Dam (LMN Detect, pink), 2009-2016.

Conclusion

CSS analyses and various independent analyses show that juvenile salmon and steelhead that pass through powerhouses suffer significant delayed mortality in later life stages which results in lower smolt-to-adult return rates. Review of analyses of length at marking indicates that fish length at marking is not a good predictor of length at the time of bypass, particularly for hatchery fish. The available analyses of fish length and detection probability suffer from the same fundamental flaw, that they do not consider flow and spill environmental variables which have been shown to have the greatest impact on detection probability. As a result, available analyses indicate that length of fish passing through powerhouses is not a plausible explanation for the delayed mortality associated with powerhouse passage. Fish injury data from bypass sampling provides real evidence of the physical and hydraulic conditions in the bypass/collection dewatering systems. These data support the findings from the literature compiled in Budy et al. (2002) regarding fish injury, disease, disorientation, and cumulative stress leading to delayed mortality in later life stages. Analyses of wild and hatchery fish shows that in general wild fish are smaller than hatchery fish which, if bypass length selectivity occurs, would indicate that the present operation of the FCRPS is having a disproportionally greater impact on wild fish than hatchery fish.

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APPENDIX A

SURVIVALS (SR), SAR, TIR, AND D
FOR SNAKE RIVER HATCHERY AND WILD SPRING/SUMMER CHINOOK SALMON,
STEELHEAD, AND SOCKEYE

APPENDIX A

SURVIVALS (S_R), SAR BY STUDY CATEGORY, TIR, AND *D* FOR SNAKE RIVER HATCHERY AND WILD SPRING/SUMMER CHINOOK, STEELHEAD, SOCKEYE, AND FALL CHINOOK

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APPENDIX A

SURVIVALS (S_R), SAR BY STUDY CATEGORY, TIR, AND *D* FOR SNAKE RIVER HATCHERY AND WILD SPRING/SUMMER CHINOOK, STEELHEAD, SOCKEYE, AND FALL CHINOOK

Introduction

This appendix presents juvenile in-river survival (termed S_R) from LGR tailrace to BON tailrace for PIT-tagged Snake River wild and hatchery spring/summer Chinook, hatchery and wild subyearling fall Chinook, steelhead, and sockeye smolts analyzed in the CSS. Prior to the 2012 report, these juvenile survival data were presented in Chapter 2. In addition, this appendix presents smolt-to-adult survival (SAR) probability estimates (by study category) for Snake River PIT-tagged spring/summer Chinook, fall Chinook, summer steelhead, and sockeye smolts analyzed in the CSS. Prior to the 2012 report, the SARs, TIR, and *D* data were presented in Chapter 4. Parameters estimated in this appendix include (i) S_R (annual in-river survival from LGR tailrace to BON tailrace), (ii) annual SAR from LGR to GRA (LGR's adult ladder) by study category (transported smolts [T_0 or T_X beginning 2006], in-river migrants not detected at a Snake River transportation site [C_0], and in-river migrants with at least one detection at a Snake River transportation site [C_1]), (iii) TIR (ratio of SAR of transported and SAR of C_0 migrants), and (iv) *D* (ratio of post-Bonneville transported SAR and SAR of C_0 migrants). In-river survival (S_R) estimates are provided for PIT-tagged Snake River wild spring/summer Chinook (1994–2015), hatchery spring/summer Chinook (1997–2015), wild and hatchery steelhead (1997–2015), hatchery sockeye (2009–2015), and wild and hatchery subyearling fall Chinook (2006-2012). Annual SARs, TIR, and *D* values are estimated for PIT-tagged wild spring/summer Chinook (1994–2014), hatchery spring/summer Chinook (1997–2014), wild and hatchery steelhead (1997–2013), hatchery sockeye (2009–2014), and wild and hatchery subyearling fall Chinook (2006-2012). A primary focus of comparisons (SARs, TIR, and *D*) is between the transported and in-river smolt migrants.

The S_R, SAR, TIR, and *D* parameter estimates are presented in tables and figures within this appendix and are available from the FPC Web site (www.fpc.org). Data on the PIT-tag numbers by release site and PIT-tag returning adult age composition are also available from the FPC Web site and in Appendices C and F of this report, respectively. The data on the juvenile migrant reach survival probabilities (used to expand PIT-tag smolt counts in the three study categories to LGR equivalents for each migration year) and estimated numbers of smolts (and associated returning adults) in the CSS study categories are available only from the FPC Web site. These two series of data have become voluminous and difficult to present in report appendices, but are easily accessible from the FPC Web site in downloadable formats amenable to analyses by interested users. The FPC Web site is updated with these data after the final report is issued each November. These data are accessed from the FPC Web site homepage as follows:

(i) Click on "SURVIVAL & TRAVEL TIMES," then "JUVENILES" to access:

a. "CSS Number of Fish by Site" – provides PIT-tag numbers by release site for juvenile data above and smolt-to-adult data below.

b. "CSS Reach Survival Data" – provides survival rate estimates for individual reaches.

c. "CSS S_R, TIR, and D" – provides estimate S_R for LGR-to-BON reach survival rate.

(ii) Click on "SURVIVAL & TRAVEL TIMES," then "SMOLT-TO-ADULT" to access:

a. "CSS SARs by study category" – provides data for T_0 (or T_X), C_0, and C_1 by juvenile year and release.

b. "CSS Annual SARs for Zones in the Snake and Columbia Rivers" – provides annual overall SARs for all groups of Snake, Middle Columbia, and Upper Columbia Chinook, steelhead, and sockeye.

c. "CSS SR, TIR, and D" – provides estimated TIR and *D* by juvenile year and release.

d. "CSS Ten Year Report Results and Expectations" – allows user to query the results and expectations data presented in Appendix E of the CSS Ten Year Report.

e. "CSS Returning Adults Age Composition" – provides number of returning adults for PIT-tagged fish by juvenile year, release, and age.

f. "Number of Smolts and Returning Adults by Study Category" – provides data for T_0 (or T_X), C_0, and C_1 by juvenile year and release.

Methods

Estimation of juvenile in-river survival (S_R)

In this appendix, we define the hydrosystem as the overall reach between Lower Granite (LGR) and Bonneville (BON) dams. There are six dams between LGR and BON: Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), and The Dalles (TDA). We used Cormack-Jolly-Seber (CJS) methods to estimate survival probabilities through the two reaches based on detections at the dams and in a PIT-tag trawl (TWX) operating below BON (Cormack 1964, Jolly 1965, Seber 1965, Burnham et al. 1987).

The array of detection sites in the Snake and Columbia rivers is analogous to multiple recaptures of tagged individuals, allowing for standard multiple mark-recapture survival estimates over several reaches of the hydrosystem using the CJS method. This method was used to obtain estimates of survival and corresponding standard errors for up to six reaches between release site and tailrace of BON (survival estimates S_1 through S_6). An overall survival probability from LGR-to-BON, referred to as S_R is the product of the reach survival estimates. Estimates of individual reach survival (e.g., LGR-to-LGS) can exceed 100%; however, this is

often associated with an underestimate of survival in preceding or subsequent reaches. Therefore, when computing a multi-reach survival estimate, we allow individual reach survival estimates to exceed 100%. An estimate of S_R was considered unreliable when its point estimate exceeded 100% or its coefficient of variation exceeded 25%.

The number of inter-dam reaches for which an annual survival could be estimated was a function of the number of smolts in each release and the recovery effort available. When fewer than six individual reach survival estimates could be made, the product of the useable estimates was extrapolated to estimate S_R. Prior to 1998, PIT-tag detection capability at JDA and TWX was limited. Reliable survival estimates in those years were possible only to the tailrace of LMN or MCN. After 1998, reliable survival estimates to the tailrace of JDA were possible in most cases. Estimation of S_R with fewer than six individual independent estimates was calculated as follows: first, the product of the survival estimates over the longest reach possible was converted to survival per mile, and then this was expanded to the number of miles between LGR and BON. However, because survival per mile rates thus generated were generally lower for the Snake River (LGR to MCN) than for the Columbia River (MCN to BON), direct estimates of in-river survival over the longest reach possible were preferable. For all groups, we provide nonparametric bootstrap confidence intervals for the closed form CJS estimators of juvenile reach survival.

Estimation of smolt numbers in study categories

Comparisons between SARs for groups of smolts with different hydrosystem experiences are made from a common start and end point. Thus, LGR-to-GRA SARs were estimated for all groups of smolts including those not detected at LGR as juveniles. The population of PIT-tagged study fish arriving at LGR was partitioned into three pathways related to the route of subsequent passage through the hydrosystem. Fish were "destined" to (1) pass in-river through the Snake River collector dams in a non-bypass channel route (spillways or turbines), (2) pass in-river through the dam's bypass channel, or (3) pass in a truck or barge to below BON. These three routes of hydrosystem passage defined the study categories C_0, C_1 and T_0 (or T_X beginning 2006), respectively.

The Snake River basin fish used in SAR estimation were PIT-tagged and released in tributaries and mainstem locations upstream from LGR reservoir. Other investigators (Sanford and Smith 2002; Paulsen and Fisher 2005; Budy and Schaller 2007) have used detection information from smolts released both above LGR and at LGR for their estimates of SARs. Because all Snake River spring/summer Chinook, steelhead, and sockeye juveniles must pass through the LGR reservoir, we believe that smolts released upstream from LGR most closely reflect the impacts of the Lower Snake and Columbia River hydrosystem on the untagged run at large in-river migrating fish. The C_0 group may include only smolts released above LGR, since it is defined as those fish that remained in-river while migrating past the three Snake River collector dams undetected. Fish collected and marked at LGR do not have a similar experience.

Symbol Definitions

Symbols for Primary Statistics

R_1 = number of PIT-tagged fish released
X_{12} = number of smolts transported at LGR

X_{102} = number of first-detected smolts transported at LGS
X_{112} = number of LGR bypassed smolts transported at LGS
X_{1002} = number of first-detected smolts transported at LMN
X_{1102} = number of LGR bypassed smolts transported at LMN
X_{1012} = number of LGS bypassed smolts transported at LMN
X_{1112} = number of both LGR and LGS bypassed smolts transported at LMN
X_{1a2} = number of smolts transported at LGS where "a" codes to 1 if detected and 0 if undetected
X_{1aa2} = number of smolts transported at LMN where "a" codes to 1 if detected and 0 if undetected

m_{12} = number of fish first detected at LGR
m_{13} = number of fish first detected at LGS
m_{14} = number of fish first detected at LMN

d_2 = number of fish removed at LGR (includes all transported fish, site-specific mortalities, unknown disposition fish, and fish removed for use by other research studies)
d_3 = number of fish removed at LGS (includes all transported fish, site-specific mortalities, unknown disposition fish, and fish removed for use by other research studies)
d_4 = number of fish removed at LMN (includes all transported fish, site-specific mortalities, unknown disposition fish, and fish removed for use by other research studies)

$d_{5.0}$ = number of removals for C_0 type fish at MCN
$d_{6.0}$ = number of removals for C_0 type fish at JDA
$d_{7.0}$ = number of removals for C_0 type fish at BON

$d_{5.1}$ = number of removals for C_1 type fish at MCN
$d_{6.1}$ = number of removals for C_1 type fish at JDA
$d_{7.1}$ = number of removals for C_1 type fish at BON

Symbols for Primary Parameters

d_{C0} = Sum of site-specific removals at dams below LMN of fish not detected previously at a Snake River Dam estimated in LGR-equivalents.

Note: Pre-2003 uses fixed expansion rate of 50% survival probability for all removals below LMN. Beginning with migration year 2003, d_{C0} contains site-specific removals below that have been expanded by their corresponding estimated survival probability from LGR.

d_{C1} = Sum of site-specific removals at dams below LMN of fish previously detected at a Snake River Dam estimated in LGR-equivalents.

Note: Pre-2003 uses fixed expansion rate of 50% survival probability for all removals below LMN. Beginning with migration year 2003, d_{C1} contains site-specific removals below that have been expanded by their corresponding estimated survival probability from LGR.

S_1 = survival from hatchery release site to LGR tailrace
S_2 = survival from LGR tailrace to LGS tailrace
S_3 = survival from LGS tailrace to LMN tailrace
S_4 = survival from LMN tailrace to MCN tailrace
S_5 = survival from MCN tailrace to JDA tailrace
S_6 = survival from JDA tailrace to BON tailrace

P_2 = detection probability at LGR
P_3 = detection probability at LGS
P_4 = detection probability at LMN
P_5 = detection probability at MCN
P_6 = detection probability at JDA
P_7 = detection probability at BON

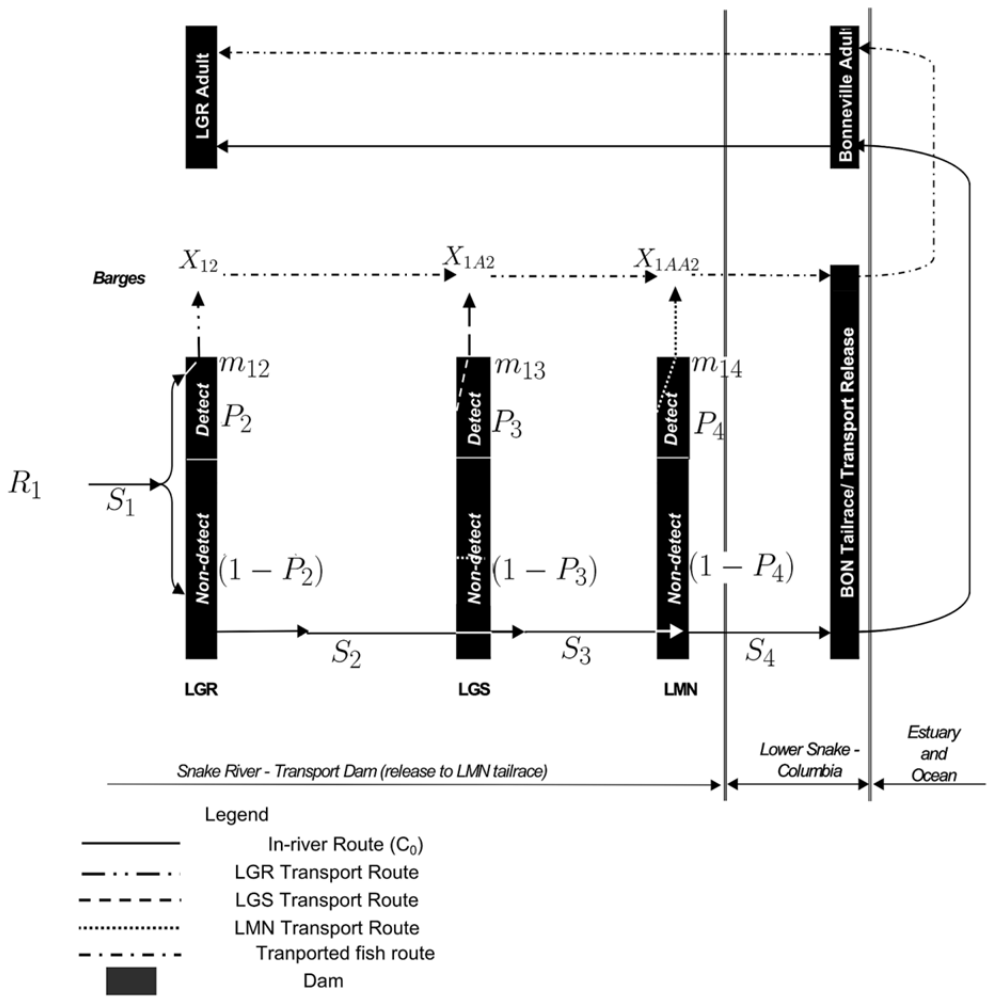


Figure A.1. Schematic of the Lower Snake and Columbia River system with focus on the three transport sites and estimation methods after migration year 2006. Locations for some primary statistics and parameters are shown.

Pre-2006 migration years

The PIT-tagged study groups should mimic the experience of the non-tagged fish that they represent. For migration years prior to 2006, only first-time detected tagged smolts at a dam are considered for inclusion in the transportation (T_0) group since non-tagged smolts were nearly always transported when they entered a bypass/collector facility (where PIT-tag detectors are in operation) at a Snake River dam. Prior to 2006, smolts that were returned to river at LGR, LGS, and LMN were primarily PIT-tagged study fish. Typically during these years, most of the transported smolts were from LGR with the remainders being transported from LGS and LMN. Because some smolts died while migrating in-river from LGR to either LGS or LMN, the actual numbers transported at LGS and LMN were divided by the survival estimates from LGR to each respective transportation site to produce LGR equivalents starting numbers. The combination of PIT-tagged fish first-time detected and transported from LGR, LGS, and LMN forms Category T_0. Using the definitions presented in the previous section, the formula for estimating the number of juvenile fish in Category T_0 is:

$$T_0 = X_{12} + \frac{X_{102}}{S_2} + \frac{X_{1002}}{S_2 * S_3} \quad [A.1]$$

The PIT-tagged smolts that passed all Snake River dams undetected (C_0) were the group most representative of the non-tagged smolts that migrated in-river during the years prior to 2006, since the C_0 group never entered collection facilities at collector dams. Detected PIT-tagged smolts were not representative because they do enter these facilities, and because non-tagged fish that entered a detection/collection facility were normally removed for transportation. The starting number of C_0 fish was also computed in LGR equivalents, and therefore required estimates of survival. To estimate the number of smolts that were not detected at any of the collector projects (C_0), the number of smolts first detected (transported and non-transported) at LGR, LGS, and LMN (in LGR equivalents) was subtracted from the total number of smolts estimated to arrive at LGR. The number of smolts arriving at LGR was estimated by multiplying the release to LGR survival probability (S_1) and release number (R_1) (or equivalently, dividing the number of smolts detected at LGR [m_{12}] by the CJS estimate of seasonal LGR detection probability p_2) specific for the smolt group of interest.

Smolts detected at MCN, JDA, and BON were not excluded from the C_0 group since fish entering the bypass facilities at these projects, both tagged and untagged, were generally returned to the river. However, any removal of fish at sites below LMN had to be taken into account. Using symbols defined in the previous section, the formula for estimating the number of juvenile fish in Category C_0 is:

$$C_0 = R * S_1 - \left(m_{12} + \frac{m_{13}}{S_2} + \frac{m_{14}}{S_2 * S_3}\right) - d_{C0} \quad [A.2]$$

where, for migration years 1994–2002,

$$d_{C0} = \left(\frac{d_{5.0} + d_{6.0} + d_{7.0}}{0.5}\right)$$

and beginning in 2003,

$$d_{C0} = \left(\frac{d_{5.0}}{S_2 * S_3 * S_4} + \frac{d_{6.0}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.0}}{S_2 * S_3 * S_4 * S_5 * S_6}\right)$$

The last group of interest was comprised of fish that were detected at one or more Snake River dams and remained in-river below LMN. These PIT-tagged fish formed Category C_1. Prior to 2006, the C_1 category existed primarily because a portion of the PIT-tagged smolts entering the detection/collection facility are returned to the river so reach survival estimates are possible. Although these fish do not mimic the general untagged population, they are of interest with regard to possible effects on subsequent survival of passing through Snake River dam bypass/collection systems, and in investigating non-transport operations. Using symbols defined in the previous section, the formula for estimating the number of juvenile fish in Category C_1 is:

$$C_1 = (m_{12} - d_2) + \left(\frac{(m_{13} - d_3)}{S_2}\right) + \left(\frac{(m_{14} - d_4)}{S_2 * S_3}\right) - d_{C1} \qquad \text{[A.3]}$$

where, for migration years 1994–2002,

$$d_{C1} = \left(\frac{(d_{5.1} + d_{6.1} + d_{7.1})}{0.5}\right)$$

and, beginning in 2003,

$$d_{C1} = \left(\frac{d_{5.1}}{S_2 * S_3 * S_4} + \frac{d_{6.1}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.1}}{S_2 * S_3 * S_4 * S_5 * S_6}\right)$$

A combination of exceptionally low in-river survival and no-spill hydrosystem operations maximized the transportation of smolts in 2001 and resulted in very few estimated Category C_0 migrants. Furthermore, the C_0 smolts that did exist passed mostly through turbines without the opportunity to pass via spill as in prior years. Obtaining a valid estimate of the number of PIT-tagged wild and hatchery steelhead in Category C_0 in 2001 was also problematic due to the apparently large amount of residualism that year (Berggren et al. 2005a). Most in-river steelhead migrants that returned as adults were actually detected as smolts in the lower river in 2002 (details are in the CSS 10-year Retrospective Analysis Report, Schaller et al. 2007). Returning adults of steelhead and Chinook that had no detections as juveniles were more likely to have either completed their smolt migration in 2002 or passed undetected into the raceways during a computer outage in mid-May at LGR than to have traversed the entire hydrosystem undetected in

2001. Because of the uncertainty in passage route and the timing of the undetected PIT-tagged migrants in 2001, the C_1 group was the only viable in-river group for estimation purposes. Due to these conditions in 2001, C_1 data were used instead of C_0 data in the computation of SAR, TIR, and *D* parameters (described below) and therefore are presented separately for comparison to other years in the multi-year geometric averages computed for S_R, TIR, and *D*.

The C_0 and C_1 groups were combined in two additional migration years. Spills were lower in migration years 2004 and 2005 than previous years at both LGR and LGS (excluding 2001), resulting in high collection efficiency at those two dams and a lower than usual percentage of PIT-tagged smolts estimated to pass the three collector dams on the Snake River undetected (C_0 migrants). In 2004, <6% of the LGR population of wild and hatchery Chinook PIT-tagged smolts were in Category C_0. Only 2.3% of the hatchery steelhead and 2.6% of the wild steelhead were in Category C_0. In 2005, 4.0% of the wild Chinook LGR population, 4.9%-7.9% of the five CSS hatchery Chinook groups, 1.8% of the hatchery steelhead, and 1.4% of the wild steelhead were in the C_0 category. When the estimated number of C_0 PIT-tagged smolts is extremely low, attempting to estimate SAR(C_0) is problematic since few or no adult returns will result in unreliable SAR estimates with large confidence intervals. Therefore, we combined the estimated C_0 and C_1 smolt numbers for PIT-tagged steelhead in 2004 and both Chinook and steelhead in 2005 in order to create a larger in-river group for estimating SARs, TIR, and *D*. This combined in-river group should adequately approximate the SAR of the smolts passing the three collector dams undetected for the following reason. Since smolts that pass the three collector dams undetected may do so through either spill or turbines, when the provision of spill is limited, as occurred in 2004 and 2005, there will be a higher proportion of undetected smolts utilizing the turbine route. With project passage survival ranked highest through spill and lowest through turbines, and intermediate through the bypass, the SARs of C_0 and C_1 smolts will likely be more similar in magnitude in low spill years such as 2004 and 2005, and therefore, using a combined in-river group for SAR, TIR and *D* estimation is justified.

Migration years 2006 and later

In 2006, the protocol for transportation operations was altered by delaying the start date of transportation at LGR, LGS, and LMN (dates shown in Appendix D). The goal of this change in protocol was to improve the overall SARs by allowing more early run-at-large migrants to out-migrate entirely in-river when, historically, transport SARs tended to be low (NOAA 2008). Additionally, spill percentages at the Snake River transportation projects during 2006–2015 were consistently higher than many previous years (see Figure 1.6).

Also in 2006, the CSS began randomly pre-assigning PIT-tagged wild and hatchery Chinook and wild steelhead smolts into monitor-mode (Group T) and return-to-river mode (Group R) operations. In this appendix, the total release, which is the combination of T and R groups, is designated as Group CRT. Group T follows the same fate as the run at large throughout the hydrosystem, while Group R followed a default return to river action at the transportation dams. With a delayed transportation initiation during these years, two new smolt experiences are developed. First, for the transportation study group, the combination of both first-time detected (T_0) and prior-detected transported smolts obtained from Group T represent the transported fish from the run at large (referred to as T_X). Additionally, the transported fish (T_X) exist only over a particular temporal window of the smolt out-migration. The portion of the run that this window includes depends on the intersection of the start date of transportation

and timing for the run at large from a particular study group (e.g., Dworshak hatchery Chinook, or wild Snake River steelhead). Second, the C_1 group (detected and returned to river) now represents the portion of the run at large that out-migrates before transportation started whereas in years before 2006, this group represented a very small portion of the actual run at large (see discussion of C_1 group in previous section). One advantage of the pre-assignment approach, when calculating an overall SAR, is that these relationships are automatically encapsulated and properly weighted within Group T since they "follow the fate" of the run at large. Pre-assignment of the PIT-tagged hatchery steelhead and hatchery sockeye did not begin until 2008 and 2009, respectively. Parameters may have suffixes of "t", "r", or "crt" for groups T, R, and CRT attached whenever necessary to avoid confusion about which group is being used to create the parameter estimate. Figure A.2 shows the relation between the transport (T_0 and T_X) and in-river (C_0 and C_1) study categories and the T, R, and CRT groups from which these categories originate.

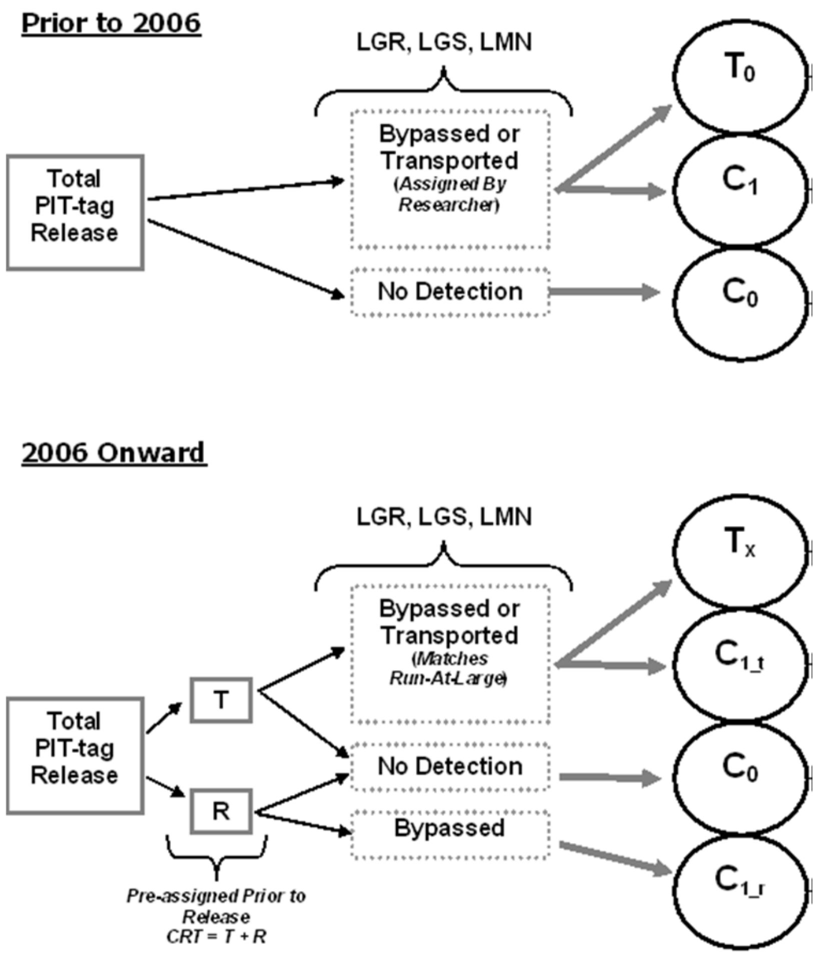


Figure A.2. Schematic depicting how the differently marked cohorts are used to translate into SARs for all years of the CSS relative to the passage of PIT-tagged smolts at the three Snake River collection/ transportation dams (LGR, LGS, and LMN). The upper flow chart covers years prior to pre-assignments and the lower flow chart covers years with pre-assignment of tags to Group T (monitor-mode) and Group R (bypass-mode). All CSS Snake River releases incorporate the pre-assignment approach starting in 2006 for hatchery and wild Chinook, 2008 for hatchery steelhead, and 2009 for hatchery sockeye.

The formula for estimating the number of juvenile smolts in Group T in Category T_X is:

$$T_{X\_t} = X_{12} + \frac{X_{1a2}}{S_2} + \frac{X_{1aa2}}{S_2 * S_3} \qquad \text{[A.4]}$$

where

$$a = 0 \; if \; undetected \; and \; 1 \; if \; detected \; at \; a \; dam \; prior \; to \; the \; transportation \; site$$

It is not necessary to limit our use to Group T fish when estimating C_0, since the pre-assignment affects only the passage routes of detected smolts. By using Group CRT, we have access to more PIT-tagged C_0 smolts and returning adults for computing the SAR(C_0) estimate. Since the reach survival probabilities and collection probabilities are computed using Group CRT, Equation A.2 may still be used for estimating number of juvenile smolts in Category C_0:

$$C_{0\_crt} = "see \; Equation \; A.2"$$

However, when estimating C_0 or C_1 smolt numbers in either Group T or Group R, expectation equations should be used. This is because the computation of C_0 and C_1 smolt numbers with the m-matrix statistics m_{12}, m_{13}, and m_{14} is sensitive to the estimated reach survival probabilities being used. Reach survival probabilities are estimated using Group CRT. Groups T and R are subsets of Group CRT. The magnitudes of m_{12}, m_{13}, and m_{14} relative to the release number R_1 may vary slightly across groups T and R due to sampling variability, resulting in shifts in the proportion of C_0 and C_1 smolts estimated for each of the two groups. This is not the case when E[C_0] and E[C_1] equations (shown below) are used, since the same set of reach survival probabilities and collection probabilities generated with Group CRT are passed to groups T and R for use in estimating key study parameters. Since the random pre-assignment action (bypass or transport) occurs after collection, the same collection probability should apply to both groups, and survival estimates should be applicable to either group while it is in-river. The reach survival probabilities Sj's and collection probabilities Pj's computed with Group CRT are passed to Groups T and R, while the parameters R_1, X_{12}, X_{1A2}, X_{1AA2}, and C_1 removals (d_1, d_2, d_3, d_4) and C_0 removals (d_0) are specific to the respective group.

Therefore, when estimating the proportion of Group T smolts by passage experience as in Appendix E or comparing SARs of C_1 smolts bypassed over the entire season (Group R) with C_0 smolts (Group CRT) as in the meta analysis of Chapter 7 in the 2010 CSS annual report (Tuomikoski et al., 2010), we use the following expectation formulas. We used the equation below to estimate the expected C_0 smolt numbers given the known removal of d_{C0} or E[C_0 | d_{C0}]. Because d_{C0} is often zero and for simplicity we refer to this value as E[C_0] hereafter. The equation is used similarly for both the T and CRT groups.

$$E[C_0] = R_1 * S_1 * (1 - P_2) * (1 - P_3) * (1 - P_4) - d_{C0} \qquad \text{[A.5]}$$

where

$$d_{C0} = \frac{d_{5.0}}{S_2 * S_3 * S_4} + \frac{d_{6.0}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.0}}{S_2 * S_3 * S_4 * S_5 * S_6}$$

Similarly the expected C_1 smolt numbers were estimated for either T or R group where known removals d_{C1}, d_2, d_3, and d_4 are constants. The expected value given known removals is $E[C_1 \mid d_{C1}]$ and is referred to as $E[C_1]$ hereafter. This estimate is obtained by first re-arranging terms in Equation A.3,

$$C_1 = m_{12} + \frac{m_{13}}{S_2} + \frac{m_{14}}{S_2 * S_3} - \left[d_2 + \frac{d_3}{S_2} + \frac{d_4}{S_2 * S_3} + d_{C1}\right]$$

where

$$d_{C1} = \frac{d_{5.1}}{S_2 * S_3 * S_4} + \frac{d_{6.1}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.1}}{S_2 * S_3 * S_4 * S_5 * S_6}$$

and substituting the following expectations for m_{12}, m_{13}, and m_{14}

$$E[m_{12}] = R_1 * S_1 * P_2$$

$$E[m_{13}] = R_1 * S_1 * (1 - P_2) * S_2 * P_3$$

$$E[m_{14}] = R_1 * S_1 * (1 - P_2) * S_2 * (1 - P_3) * S_3 * P_4$$

to yield:

$$E[C_1] = R_1 * S_1 * [P_2 + (1 - P_2) * P_3 + (1 - P_2) * (1 - P_3) * P_4] - \left[d_2 + \frac{d_3}{S_2} + \frac{d_4}{S_2 * S_3} + d_{C1}\right] \qquad \text{[A.6]}$$

Special considerations for migration year 2010

In some cases, the closed form estimators of the CJS model performed poorly during out-migration 2010. For example, survival estimates for the LGS to LMN reach were above 1.0 and detection probabilities were remarkably low. This was potentially due to increased bird predation at the bypass outfall of Lower Monumental Dam in 2010 (FPC 2011). CJS methodology assumes that detected and undetected fish survive to downstream projects at the same rate. For example, if fish detected at LMN had lower survival to downstream projects than undetected fish (e.g., high predation at the bypass outfall), then this CJS assumption has been

violated. This violation could result in an overestimate of the population at LMN and an under-estimate of the detection probability at LMN. Therefore, reach survival from LGS to LMN could be overestimated.

To correct for any subsequent potential biases associated in SARs, all survival estimates used in equations A.2, A.3 (using Group T fish), and A.4 were 'adjusted' to 100% whenever the point estimate or bootstrap estimate exceeded 100%. This adjustment is more logical than using survival estimates that exceeded 100% and the resulting estimates of SAR, TIR and *D* changed very little implying that these estimators are relatively insensitive to variation in the short reach smolt survival estimates. The estimate for C_1 SAR used equation A.3 instead of A.6 because of remarkably low detection probabilities at LMN that were probably a result of the above noted bias. To reflect the experience of the run at large, Group T fish were used in the C_1 SAR calculation. When survival estimates were limited to 100%, the resulting SARs had an absolute increase of no more than 0.02 for 2010 Snake River Chinook groups. This increase of 0.02 occurred for only one of the 2010 Snake River Chinook groups.

Estimation of SARs and Ratios of SARs for Study Categories

LGR is the primary upriver evaluation site for most objectives of the CSS. Adults detected at GRA (LGR's adult ladder) were assigned to a particular study category based on the study category they belonged to as a smolt (fish with no previous detections at any dam were automatically assigned to Category C_0). In the SAR estimation, the adult steelhead and sockeye count is the sum of the 1- to 3-ocean returns (mini-jacks returning in the same year as their smolt out-migration are excluded). The adult Chinook count is the sum of the 2- to 4-ocean returns. Chinook jacks and mini-jacks (1-ocean or less, precocious males) are excluded in the estimation of SARs by study category. In Chapter 4, wild and hatchery Chinook annual overall SAR estimates are presented both with and without jacks. However, mini-jacks are excluded in the estimates of annual overall SARs for wild and hatchery Chinook that are presented in Chapter 4.

SARs are calculated by study category with the adult tally in the numerator and estimated smolt numbers in the denominator. Prior to 2006 (2008 for hatchery steelhead) when there was no pre-assignment of CSS study fish to Groups T and R, the formulas are:

$$SAR(T_0) = \frac{\{AT_{LGR} + AT_{LGS} + AT_{LMN}\}}{T_0} \quad \text{[A.7]}$$

where

$$AT_{LGR} = adults\ at\ LGR\ that\ were\ transported\ as\ juveniles\ from\ LGR$$

$$AT_{LGS} = adults\ at\ LGR\ that\ were\ transported\ as\ juveniles\ from\ LGS$$

$$AT_{LMN} = adults\ at\ LGR\ that\ were\ transported\ as\ juveniles\ from\ LMN$$

$$SAR(C_0) = \frac{\{AC_0\}}{C_0} \quad \text{[A.8]}$$

where

$$AC_0 = adults\ at\ LGR\ with\ C_0\ smolt\ outmigration\ history$$

$$SAR(C_1) = \frac{\{AC_1\}}{C_1} \qquad [A.9]$$

where

$$AC_1 = adults\ at\ LGR\ with\ C_1\ smolt\ outmigration\ history$$

As stated previously, due to change in operations, transported smolts had different potential detection histories depending on if the migration year was before 2006 or not. The adult counts included in the transport SARs reflect these changes. Counts of returning adults (i.e., AT_{LGR}, AT_{LGS}, AT_{LMN}) from smolt migration years before 2006 include capture histories of X_{12}, X_{102}, or X_{1002} (sometimes referred to as "first-time detects"). Counts of adults with smolt migration years of 2006 and later include both first-time detected and previously detected fish. The abbreviated capture histories for the smolt out-migration experience of adults from the T_X group (using a '1' for a single release followed by a 1,0, or 2 to denote bypass, undetected, or transported at LGR, LGS, or LMN) would be 12, 102, 1002, 112, 1012, 1102, or 1112. Using the pre-assigned fish in Group T, the equation for SAR(T_X_t) is:

$$SAR\left(T_{X\_t}\right) = \frac{\{AT_{LGR\_t} + AT_{LGS\_t} + AT_{LMN\_t}\}}{T_{X\_t}} \qquad [A.10]$$

Using the total release, the formula for SAR(C_0_crt) is:

$$SAR\left(C_{0\_crt}\right) = \frac{\{AC_{0\_crt}\}}{C_{0\_crt}} \qquad [A.11]$$

Using the pre-assigned fish in Group T, the equations for SAR[EC_1_t] is:

$$SAR\left[EC_{1\_t}\right] = \frac{\{AC_{1\_t}\}}{E\left[C_{1\_t}\right]} \qquad [A.12]$$

The difference between SAR(T_0) (or SAR(T_X_t) beginning 2006) and SAR(C_0) is characterized as the ratio of these SARs and denoted as the TIR (transport: in-river ratio):

$$TIR = \frac{SAR(T_0)}{SAR(C_0)} \qquad [A.13]$$

The statistical test of whether SAR(T_0) (or SAR(T_{X_t}) beginning 2006) is significantly different than SAR(C_0) is conducted by evaluating whether TIR differs from one. We use the criteria that the non-parametric 90% confidence interval's lower limit of TIR (rounded to hundredths) must exceed 1.00 or its upper limit must be less than 1.00. This provides a statistical two-tailed ($\alpha = 0.10$) test of H_0 TIR = 1 versus H_A TIR ≠ 1. The upper and lower limit values of the 90% confidence interval for TIR (and any other parameter of interest) are obtained at the 50th and 951st rank order position from the 1,000 bootstrapped resampling of the PIT-tagged population of interest.

Estimation of *D*

The parameter used to evaluate the differential delayed effects of transportation in relation to in-river out-migrants is *D*. *D* is the ratio of SARs of transported smolts (SAR(T_0)) to in-river out-migrants (SAR(C_0)), but unlike TIR, the SAR is estimated from BON instead of from LGR. If the value of *D* is around 1, there is little or no differential mortality occurring between transported and in-river migrating smolts once they are both below BON. The estimate of *D* (substituting T_X for T_0 for migration years 2006 and later) is:

$$D = \frac{SAR_{BON-LGR}(T_0)}{SAR_{BON-LGR}(C_0)} \qquad [A.14]$$

The total number of smolts passing BON is not observed directly. However, *D* can be estimated by removing the portion of the LGR-to-GRA SAR that contains the LGR to BON juvenile hydrosystem survival. So, the parameters S_T and S_R were divided out of their respective LGR-to-GRA SAR values to estimate the $SAR_{BON\text{-}LGR}$ for each study group shown in Equation A.14. The resulting estimate of *D* (substituting T_X for T_0 for migration years 2006 and later) was calculated as:

$$D = \frac{\left(\frac{SAR(T_0)}{S_T}\right)}{\left(\frac{SAR(C_0)}{S_R}\right)} \qquad [A.15]$$

where S_R is the estimated in-river survival from LGR tailrace to BON tailrace and S_T is the assumed direct transportation survival probability (0.98) adjusted for in-river survival to the respective transportation sites for those fish transported from LGS or LMN.

In the denominator of *D* (in-river portion), the quotient is simply SAR(C_0)/S_R, where S_R is estimated using CJS estimates (expanded to the entire hydrosystem if necessary). Errors in estimates of S_R influenced the accuracy of *D* estimates: recall that when it was not possible to estimate S_R directly, an expansion based on a "per mile" survival probability obtained from an upstream reach (where survival could be directly estimated) was instead applied to the remaining downstream reach (see *Estimation of juvenile in-river survival (S_R)* above).

In the numerator of *D* (transportation portion), the quotient is SAR(T_0)/S_T, where S_T is a weighted harmonic mean estimate of the in-river survival probability between LGR tailrace and downstream Snake River transportation sites for the estimated project-specific proportion of the

transported run at large at these two downstream transportation sites. Calculation of S_T includes an estimate of survival to each transportation site, effectively putting S_T into LGR equivalents similar to SAR(T_0), with a fixed 98% survival probability for the fish once they were placed into the transportation vehicle (truck or barge). The S_T estimate for years prior to 2006 is:

$$S_T = (0.98) * \frac{(t_2 * t_3 * t_4)}{\left(t_2 + \frac{t_3}{S_2} + \frac{t_4}{S_2 * S_3}\right)} \qquad [A.16]$$

where t_j is the estimate of the fraction of PIT-tagged fish that would have been transported at each dam (e.g., t_2 = LGR, t_3 = LGS, and t_4 = LMN) if all PIT-tagged fish had been routed to transport at the same rate as the run at large (i.e., untagged fish).

Beginning in 2006 with pre-assignment to Group T for all PIT-tagged fish groups except hatchery steelhead, the values for t_j were obtained directly using Group T for the number of PIT-tagged smolts (X) with the following capture histories (shown in subscript): $t_2 = X_{12}$, $t_3 = X_{1A2}$, and $t_4 = X_{1AA2}$. Since the routing of the PIT-tagged hatchery steelhead was in the same proportion at each collector dam, the values for t_j were obtained directly with the total release for the above capture histories. Using this approach for all PIT-tagged groups properly accounted for the effect of the later start of transportation in years beginning in 2006. The S_T estimate for years 2006 and later is:

$$S_T = (0.98) \left[\frac{X_{12} + X_{1a2} + X_{1aa2}}{X_{12} + \frac{X_{1a2}}{S_2} + \frac{X_{1aa2}}{S_2 * S_3}} \right] \qquad [A.17]$$

The estimates of S_T have ranged between 0.88 and 0.98 for Chinook and steelhead across all the years evaluated.

A statistical test of whether D is significantly greater or less than 1 was conducted in the same manner as was done with TIR. We use the criteria that the non-parametric 90% confidence interval's lower limit of D (rounded to hundredths) must exceed 1.00 or its upper limit must be less than 1.00. This provides a statistical two-tailed ($\alpha = 0.10$) test of H_0 $D = 1$ versus H_A $D \neq 1$.

Results

Estimates of Annual Survival (S_R)

Presented here are the juvenile in-river survival estimates (S_R) for the Lower Granite Dam to Bonneville Dam reach for Snake River wild and hatchery spring/summer Chinook, wild and hatchery steelhead, hatchery sockeye, and wild and hatchery subyearling fall Chinook.

Wild and Hatchery Spring/Summer Chinook

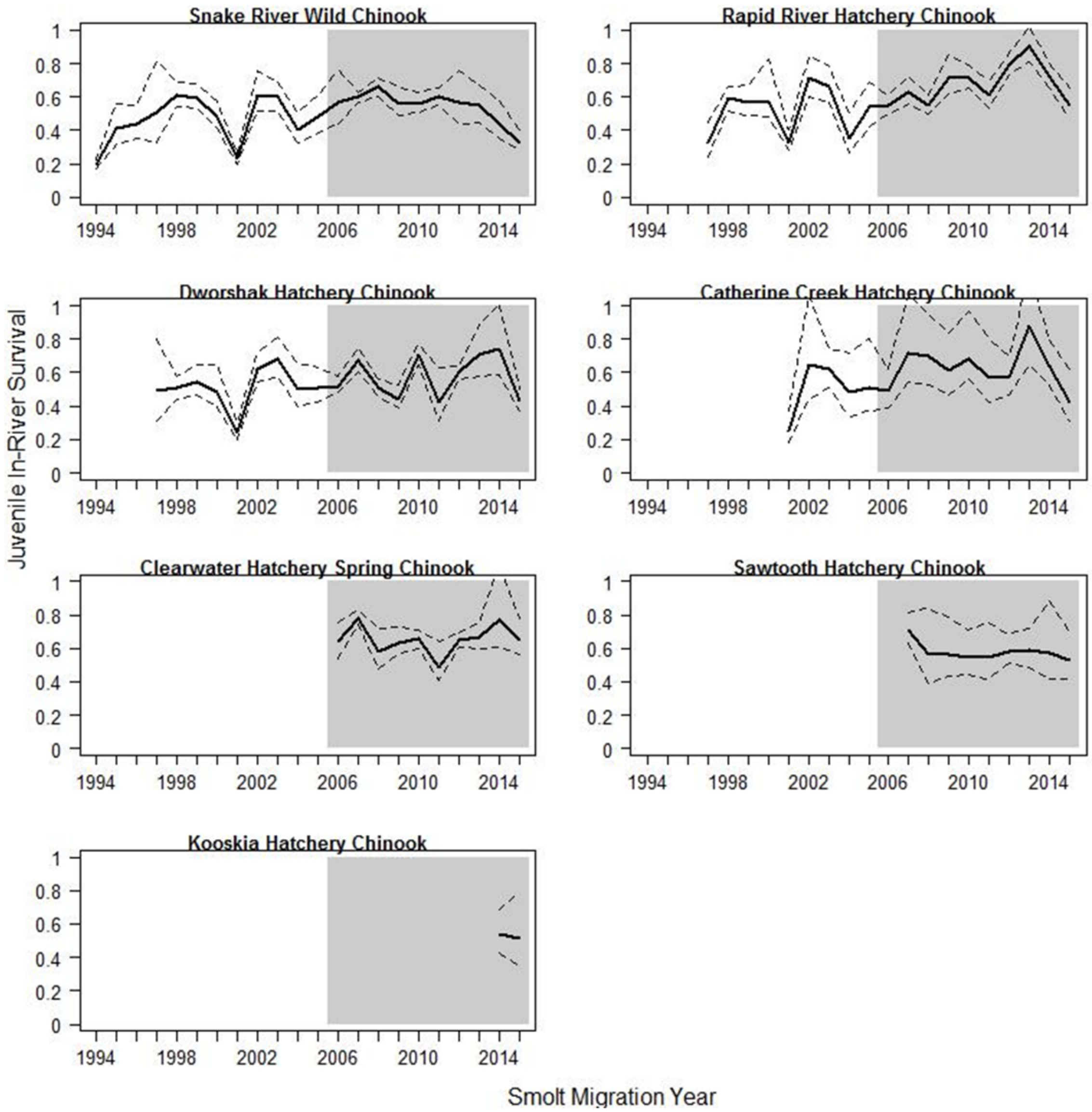


Figure A.3. Trend in juvenile in-river survival LGR to BON (S_R) for PIT-tagged Snake River wild spring/summer Chinook and hatchery spring Chinook in migration years 1994 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data are from Tables A.1 and A.2.

Table A.1. Estimated in-river survival LGR to BON (S_R) of PIT-tagged Snake River wild spring/summer Chinook and hatchery spring Chinook from Rapid River Hatchery, Dworshak NFH, and Catherine Creek AP for migration years 1994 through 2015 (with 90% confidence intervals). Migration years 2006 and later use reach survival probability estimates of combined T and R groups.

Migration Year	Aggregate Wild Chinook	Rapid River Hatchery	Dworshak NFH	Catherine Creek AP
1994	0.20[3] (0.17 - 0.22)			
1995	0.41[2] (0.32 - 0.56)			
1996	0.44[3] (0.35 - 0.55)			
1997	0.51[3] (0.33 - 0.82)	0.33[3] (0.24 - 0.45)	0.49[3] (0.31 - 0.80)	
1998	0.61[1] (0.54 - 0.69)	0.59[1] (0.52 - 0.66)	0.51[1] (0.44 - 0.58)	
1999	0.59 (0.53 - 0.68)	0.57 (0.49 - 0.67)	0.54 (0.47 - 0.65)	
2000	0.48 (0.41 - 0.58)	0.58 (0.48 - 0.83)	0.48 (0.40 - 0.65)	
2002	0.61 (0.52 - 0.76)	0.71 (0.60 - 0.84)	0.62 (0.54 - 0.72)	0.65 (0.44 - 1.06)
2003	0.60 (0.52 - 0.69)	0.66 (0.57 - 0.78)	0.68 (0.58 - 0.81)	0.62[1] (0.51 - 0.74)
2004	0.40 (0.33 - 0.51)	0.35 (0.27 - 0.51)	0.50 (0.40 - 0.66)	0.48[1] (0.34 - 0.72)
2005	0.48 (0.39 - 0.61)	0.54 (0.42 - 0.69)	0.51 (0.42 - 0.63)	0.51[1] (0.37 - 0.80)
2006	0.57 (0.44 - 0.77)	0.55[1] (0.50 - 0.61)	0.52[1] (0.48 - 0.58)	0.49[1] (0.39 - 0.62)
2007	0.60[1] (0.57 - 0.63)	0.63 (0.56 - 0.72)	0.67 (0.60 - 0.75)	0.72 (0.54 - 1.07)
2008	0.66[2] (0.60 - 0.71)	0.55[2] (0.50 - 0.61)	0.51[2] (0.46 - 0.56)	0.70[2] (0.53 - 0.95)
2009	0.56 (0.49 - 0.66)	0.71 (0.62 - 0.85)	0.44 (0.39 - 0.53)	0.61[1] (0.47 - 0.84)
2010	0.56 (0.51 - 0.63)	0.71 (0.65 - 0.79)	0.71 (0.65 - 0.77)	0.68 (0.56 - 0.88)
2011	0.60[1] (0.55 - 0.65)	0.61[1] (0.53 - 0.70)	0.42 (0.31 - 0.60)	0.57[2] (0.43 - 0.77)
2012	0.57 (0.44 - 0.78)	0.79[2] (0.73 - 0.86)	0.60[1] (0.56 - 0.64)	0.57[1] (0.47 - 0.70)
2013	0.55 (0.45 - 0.67)	0.90[2] (0.81 - 1.02)	0.71 (0.58 - 0.89)	0.88[2] (0.65 - 1.20)
2014	0.44 (0.35 - 0.58)	0.72[2] (0.65 - 0.80)	0.74 (0.59 - 1.01)	0.64[2] (0.53 - 0.79)
2015	0.33[1] (0.28 - 0.40)	0.55[1] (0.47 - 0.65)	0.43 (0.37 – 0.50)	0.42[2] (0.31 - 0.62)
Geomean	**0.50**	**0.60**	**0.55**	**0.60**
2001	0.23 (0.20 - 0.27)	0.33 (0.28 - 0.40)	0.24 (0.20 - 0.30)	0.25 (0.18 - 0.37)

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Table A.2. Estimated in-river survival LGR to BON (S_R) of PIT-tagged Snake River wild spring/summer Chinook and hatchery spring Chinook from Clearwater, Sawtooth Hatchery, and Kooskia hatcheries for migration years 1994 through 2015 (with 90% confidence intervals). Migration years 2006 and later use reach survival probability estimates of combined T and R groups.

Migration Year	Aggregate Wild Chinook	Clearwater Hatchery (Spring)	Sawtooth Hatchery	Kooskia Hatchery
1994	0.20[3] (0.17 - 0.22)			
1995	0.41[2] (0.32 - 0.56)			
1996	0.44[3] (0.35 - 0.55)			
1997	0.51[3] (0.33 - 0.82)			
1998	0.61[1] (0.54 - 0.69)			
1999	0.59 (0.53 - 0.68)			
2000	0.48 (0.41 - 0.58)			
2002	0.61 (0.52 - 0.76)			
2003	0.60 (0.52 - 0.69)			
2004	0.40 (0.33 - 0.51)			
2005	0.48 (0.39 - 0.61)			
2006	0.57 (0.44 - 0.77)	0.64[1] (0.54 - 0.75)		
2007	0.60[1] (0.57 - 0.63)	0.78[1] (0.74 - 0.83)	0.71[1] (0.63 - 0.81)	
2008	0.66[2] (0.60 - 0.71)	0.58[2] (0.48 - 0.72)	0.56[2] (0.39 - 0.84)	
2009	0.56 (0.49 - 0.66)	0.63 (0.56 - 0.73)	0.56[1] (0.43 - 0.79)	
2010	0.56 (0.51 - 0.62)	0.66 (0.60 - 0.71)	0.55 (0.44 - 0.71)	
2011	0.60[1] (0.55 - 0.65)	0.49 (0.41 - 0.63)	0.55[1] (0.41 - 0.76)	
2012	0.57 (0.44 - 0.78)	0.65[1] (0.62 - 0.70)	0.58[1] (0.51 - 0.68)	
2013	0.55 (0.45 - 0.67)	0.67[1] (0.60 - 0.75)	0.59[1] (0.49 - 0.72)	
2014	0.44 (0.35 - 0.58)	0.77 (0.61 – 1.10)	0.57 (0.42 - 0.88)	0.54 (0.43 – 0.69)
2015	0.33[1] (0.28- 0.40)	0.65 (0.56 - 0.78)	0.53 (0.42 - 0.70)	0.51 (0.35 – 0.79)
Geomean	**0.50**	**0.65**	**0.58**	**0.52**
2001	0.23 (0.20 - 0.27)			

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

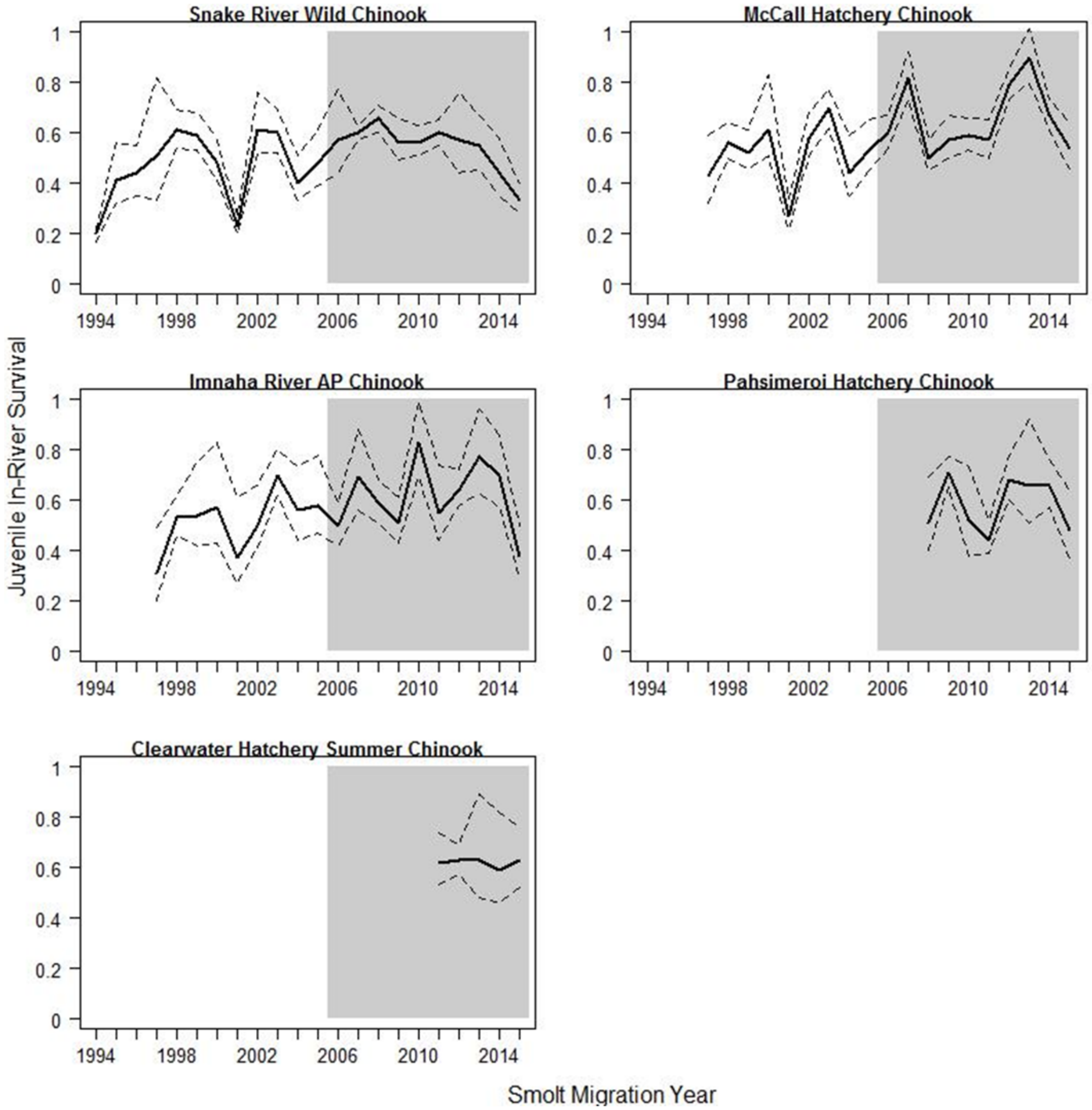


Figure A.4. Trend in juvenile in-river survival LGR to BON (S_R) for PIT-tagged Snake River wild spring/summer Chinook and hatchery summer Chinook in migration years 1994 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data for wild Chinook are from Table A.1 and hatchery summer Chinook are from Table A.3.

Table A.3. Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery summer Chinook from McCall Hatchery, Imnaha AP, Pahsimeroi Hatchery, and Clearwater Hatchery for migration years 1997 through 2015 (with 90% confidence intervals). Migration years 2006 and later use reach survival probability estimates of combined T and R groups.

Migration Year	McCall Hatchery	Imnaha AP	Pahsimeroi Hatchery	Clearwater Hatchery (Summer)
1997	0.43[3] (0.32 - 0.59)	0.31[3] (0.20 - 0.49)		
1998	0.56[1] (0.50 - 0.64)	0.53[1] (0.46 - 0.62)		
1999	0.52 (0.46 - 0.61)	0.54 (0.42 - 0.75)		
2000	0.61 (0.51 - 0.83)	0.57 (0.43 - 0.83)		
2002	0.58 (0.51 - 0.68)	0.50 (0.41 - 0.66)		
2003	0.70 (0.62 - 0.77)	0.70[1] (0.62 - 0.80)		
2004	0.44 (0.35 - 0.59)	0.56[1] (0.44 - 0.73)		
2005	0.53 (0.45 - 0.65)	0.58[1] (0.47 - 0.78)		
2006	0.60[1] (0.54 - 0.67)	0.50[1] (0.42 - 0.59)		
2007	0.82 (0.73 - 0.92)	0.69 (0.56 - 0.88)		
2008	0.50[2] (0.45 - 0.57)	0.59[2] (0.51 - 0.68)	0.51[2] (0.40 - 0.69)	
2009	0.57 (0.50 - 0.67)	0.51[1] (0.43 - 0.61)	0.71[2] (0.65 - 0.77)	
2010	0.59 (0.53 - 0.66)	0.83 (0.69 - 0.99)	0.52 (0.38 - 0.73)	
2011	0.57[2] (0.50 - 0.65)	0.55[1] (0.44 - 0.74)	0.44[1] (0.39 - 0.52)	0.62[1] (0.53 - 0.73)
2012	0.79[1] (0.73 - 0.85)	0.64[1] (0.58 - 0.72)	0.68[1] (0.60 - 0.77)	0.63[1] (0.57 - 0.69)
2013	0.90[2] (0.80 - 1.01)	0.77[1] (0.63 - 0.96)	0.66 (0.51 - 0.92)	0.63 (0.48 - 0.89)
2014	0.67[2] (0.61 - 0.73)	0.70[1] (0.57 - 0.86)	0.66[1] (0.57 - 0.76)	0.59 (0.46 - 0.82)
2015	0.54 (0.46 - 0.64)	0.38 (0.30 - 0.50)	0.48[2] (0.37 - 0.64)	0.63 (0.52 - 0.76)
Geomean	**0.60**	**0.57**	**0.57**	**0.62**
2001	0.27 (0.22 - 0.34)	0.37 (0.27 - 0.61)		

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Wild and Hatchery Steelhead

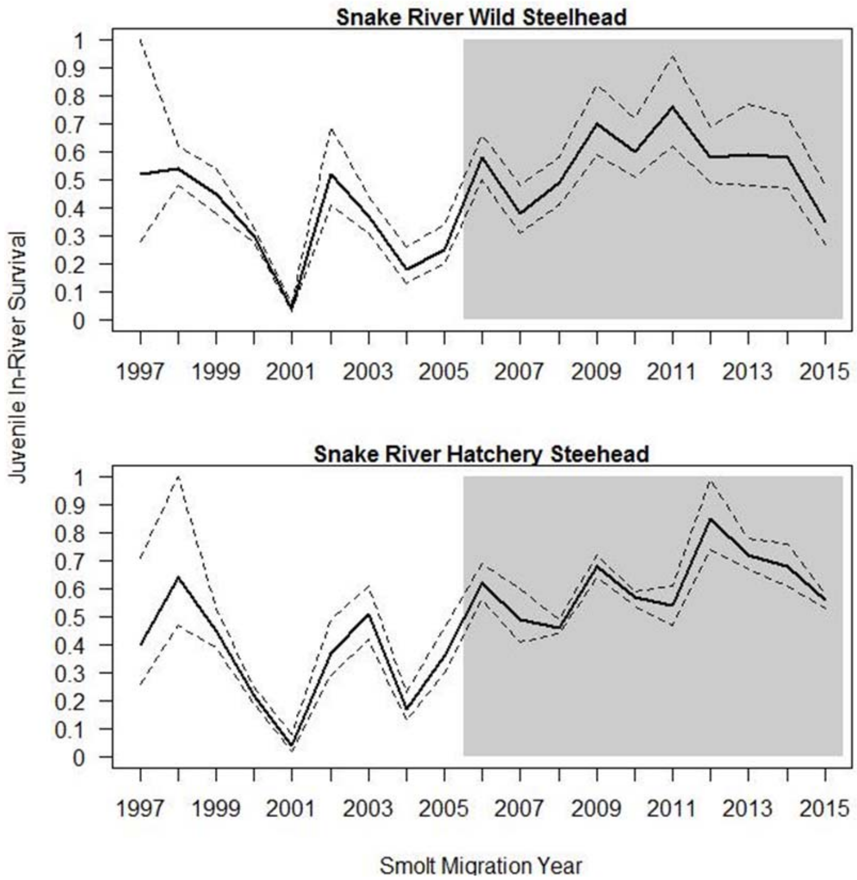


Figure A.5. Trend in juvenile in-river survival LGR to BON (S_R) for PIT-tagged Snake River aggregate wild and hatchery (aggregate) steelhead in migration years 1997 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data displayed in figure are from Table A.4.

Table A.4. Estimated in-river survival LGR to BON (S_R) of PIT-tagged aggregate wild and hatchery steelhead for migration years 1997 through 2015 (with 90% confidence intervals). Migration years 2006 and later use reach survival probability estimates of combined T and R groups.

Migration Year	Aggregate Wild Steelhead	Aggregate Hatchery Steelhead
1997	0.52[1] (0.28 - 1.00)	0.40[1] (0.26 - 0.71)
1998	0.54[1] (0.48 - 0.62)	0.64 (0.47 - 1.00)
1999	0.45 (0.38 - 0.54)	0.45 (0.39 - 0.53)
2000	0.30[1] (0.28 - 0.33)	0.22[1] (0.19 - 0.25)
2002	0.52 (0.41 - 0.69)	0.37 (0.29 - 0.49)
2003	0.37 (0.31 - 0.44)	0.51 (0.42 - 0.61)
2004	0.18[2] (0.13 - 0.26)	0.17[2] (0.13 - 0.23)
2005	0.25[1] (0.20 - 0.34)	0.36[1] (0.30 - 0.46)
2006	0.58[1] (0.50 - 0.66)	0.62[1] (0.56 - 0.69)
2007	0.38 (0.31 - 0.48)	0.49 (0.41 - 0.60)
2008	0.49[2] (0.41 - 0.58)	0.46[2] (0.44 - 0.49)
2009	0.70[1] (0.59 - 0.85)	0.68 (0.63 - 0.72)
2010	0.60 (0.51 - 0.72)	0.57 (0.54 - 0.59)
2011	0.76[2] (0.62 - 0.94)	0.54 (0.47 - 0.61)
2012	0.58[2] (0.49 - 0.69)	0.85 (0.74 - 0.99)
2013	0.59[1] (0.48 - 0.77)	0.72 (0.67 - 0.78)
2014	0.58[1] (0.47 - 0.73)	0.68 (0.61 - 0.76)
2015	0.35 (0.27 - 0.48)	0.56 (0.53 - 0.58)
Geomean	**0.46**	**0.48**
2001	0.04 (0.03 - 0.06)	0.04 (0.02 - 0.08)

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

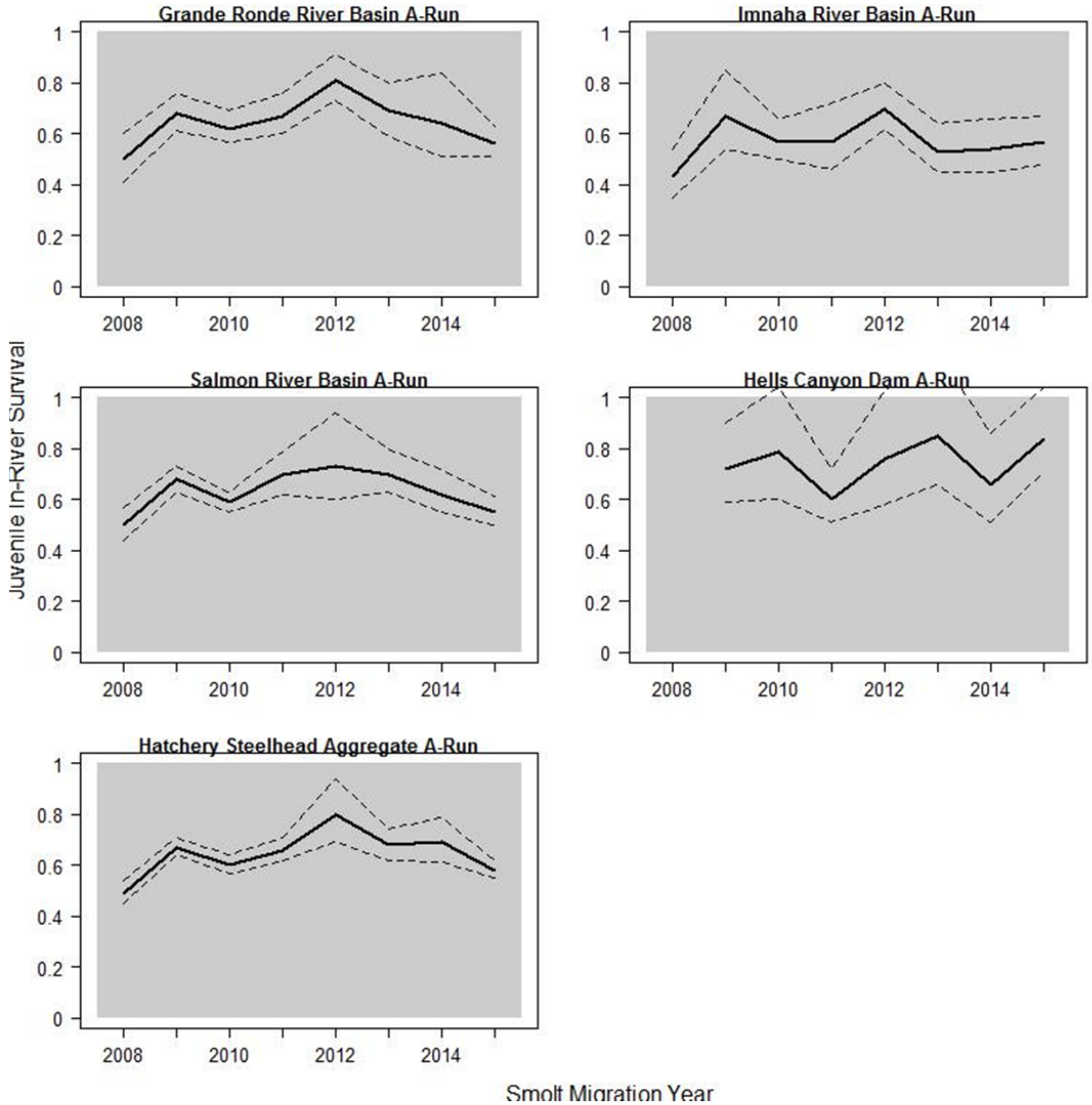


Figure A.6 Trend in juvenile in-river survival LGR to BON (S_R) for various groups of PIT-tagged Snake River A-Run hatchery steelhead in migration years 2008 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data displayed in figure are from Table A.5.

Table A.5. Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery A-Run steelhead for migration years 2008 through 2015 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups.

Migration Year	Grande Ronde R. A-run (Wallowa)	Imnaha R. A-run	Salmon R. A-run	Mainstem below HCD A-run	Combined A-run
2008	0.50[2] (0.41 - 0.60)	0.43[2] (0.35 - 0.54)	0.50[2] (0.44 - 0.57)		0.49[2] (0.45 - 0.54)
2009	0.68[2] (0.61 - 0.76)	0.67[2] (0.54 - 0.85)	0.68[2] (0.63 - 0.73)	0.72[2] (0.59 - 0.90)	0.67[2] (0.64 - 0.71)
2010	0.62 (0.56 - 0.69)	0.57 (0.50 - 0.66)	0.59 (0.55 - 0.63)	0.79[2] (0.60 - 1.04)	0.60 (0.57 - 0.64)
2011	0.67[2] (0.60 - 0.76)	0.57[2] (0.46 - 0.72)	0.70[2] (0.62 - 0.79)	0.60[2] (0.51 - 0.72)	0.66 (0.62 - 0.71)
2012	0.81[1] (0.73 - 0.91)	0.70[1] (0.62 - 0.80)	0.73 (0.60 - 0.94)	0.76[2] (0.58 - 1.03)	0.80 (0.69 - 0.94)
2013	0.69[1] (0.59 - 0.80)	0.53[1] (0.45 - 0.64)	0.70[1] (0.63 - 0.80)	0.85[1] (0.66 - 1.18)	0.68[1] (0.62 - 0.74)
2014	0.64 (0.51 - 0.84)	0.54[1] (0.45 - 0.66)	0.62 (0.55 - 0.72)	0.66 (0.51 - 0.86)	0.69 (0.61 - 0.79)
2015	0.56 (0.51 - 0.63)	0.57 (0.48 - 0.67)	0.55 (0.50 - 0.61)	0.84 (0.71 - 1.04)	0.58 (0.55 - 0.62)
Geomean	**0.64**	**0.57**	**0.63**	**0.74**	**0.64**

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

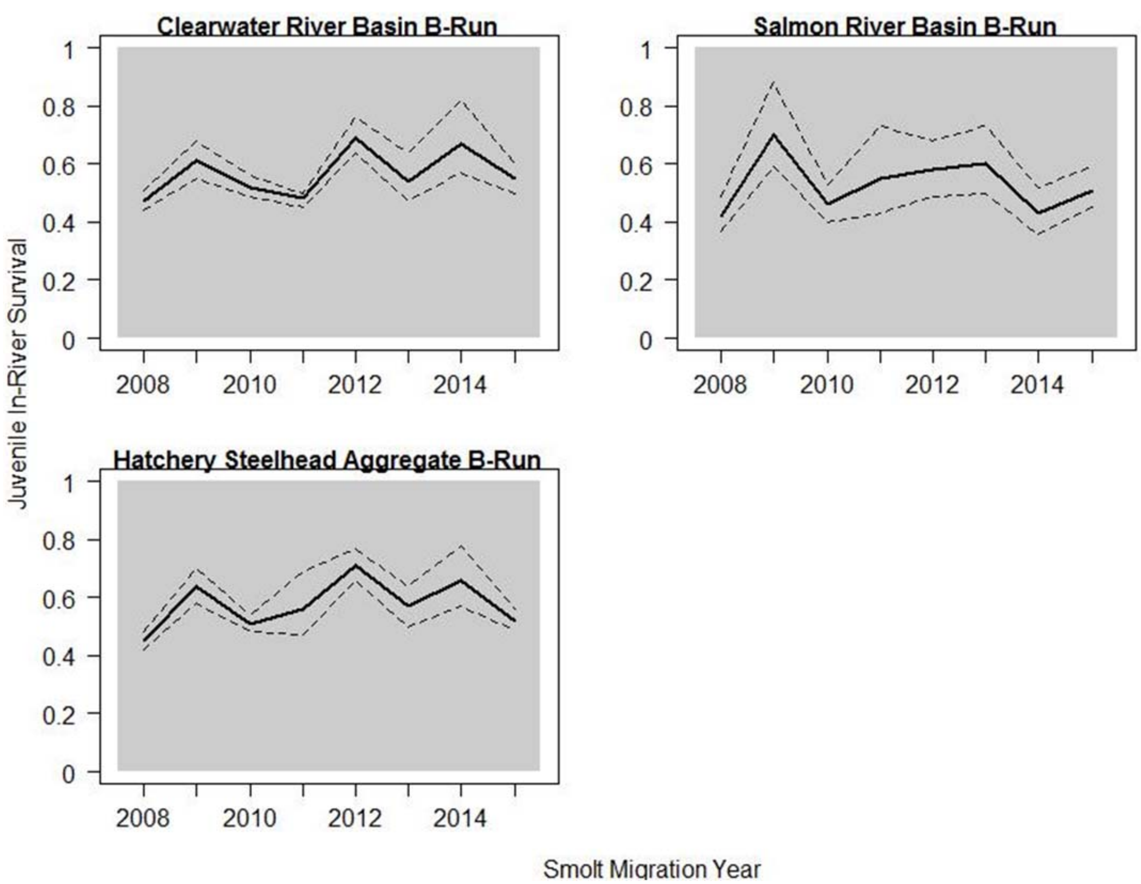


Figure A.7 Trend in juvenile in-river survival LGR to BON (S_R) for various groups of PIT-tagged Snake River B-Run hatchery steelhead in migration years 2008 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data displayed in figure are from Table A.6.

Table A.6. Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery B-Run steelhead for migration years 2008 through 2015 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups.

Migration Year	Clearwater R. B-run	Salmon R. B-run	Combined B-run
2008	0.47[2] (0.44 - 0.51)	0.42[2] (0.37 - 0.49)	0.45[2] (0.42 - 0.48)
2009	0.61 (0.55 - 0.68)	0.70 (0.59 - 0.88)	0.64 (0.58 - 0.70)
2010	0.52 (0.49 - 0.56)	0.46 (0.40 - 0.53)	0.51 (0.47 - 0.70)
2011	0.48[2] (0.46 - 0.50)	0.55[2] (0.43 - 0.73)	0.56 (0.47 - 0.69)
2012	0.69[1] (0.64 - 0.76)	0.58[1] (0.49 - 0.68)	0.71[1] (0.66 - 0.77)
2013	0.54 (0.47 - 0.64)	0.60[1] (0.50 - 0.73)	0.57 (0.50 - 0.64)
2014	0.67 (0.57 - 0.82)	0.43[1] (0.36 - 0.52)	0.66 (0.57 - 0.78)
2015	0.55 (0.50 - 0.60)	0.51 (0.45 - 0.59)	0.52 (0.49 - 0.56)
Geomean	**0.56**	**0.52**	**0.57**

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Hatchery Sockeye

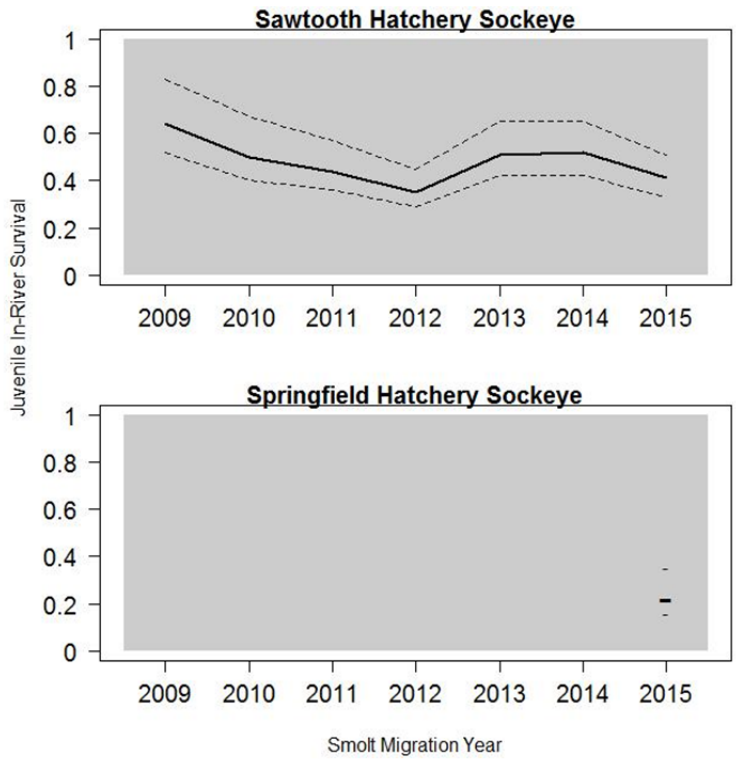


Figure A.8. Trend in in-river survival LGR to BON (S_R) of PIT-tagged Snake River hatchery sockeye from Sawtooth and Springfield hatcheries in migration years 2009 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data displayed in figure are from Table A.7. Due to small sample sizes, S_R for Oxbow Hatchery sockeye could not be estimated. Releases from Springfield Hatchery first began in 2015.

Table A.7. Estimated in-river survival LGR to BON (S_R) of PIT-tagged Snake River hatchery sockeye from Sawtooth and Springfield hatcheries for migration years 2009 through 2015 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups. Due to small sample sizes, S_R for the Oxbow Hatchery sockeye could not be estimated. Releases from Springfield Hatchery first began in 2015.

Migration Year	Sawtooth Hatchery	Springfield Hatchery
2009	0.64 (0.52 - 0.83)	
2010	0.50 (0.40 - 0.67)	
2011	0.44[1] (0.35 - 0.57)	
2012	0.35 (0.29 - 0.45)	
2013	0.51 (0.42 - 0.65)	
2014	0.52[1] (0.42 - 0.65)	
2015	0.41 (0.33 - 0.51)	0.22 (0.16 - 0.35)
Geomean	**0.47**	**0.22**

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Wild and Hatchery Subyearling Fall Chinook

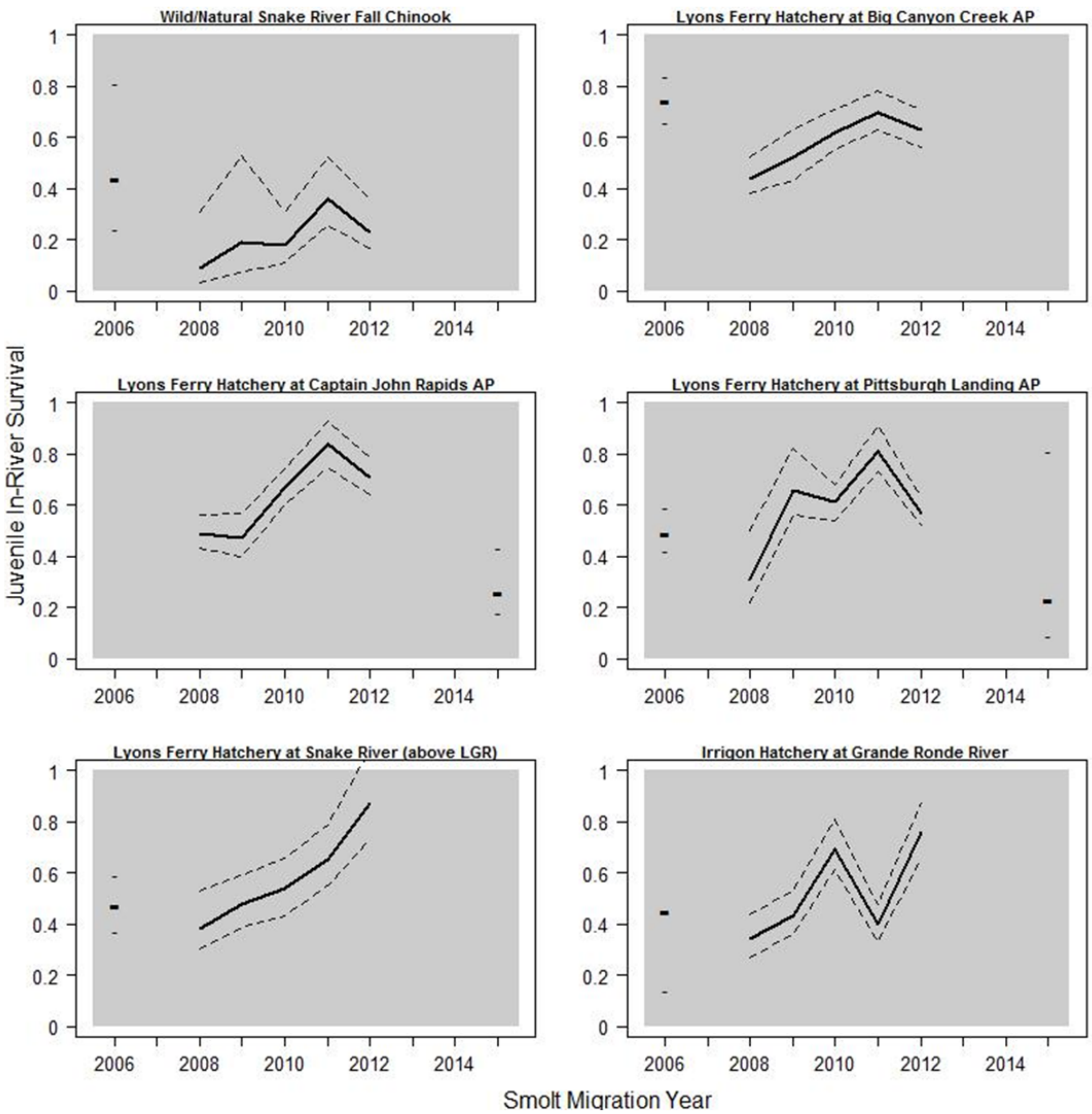


Figure A.9. Trend in in-river survival LGR to BON (S_R) for PIT-tagged Snake River wild/natural subyearling fall Chinook, Lyons Ferry Hatchery subyearling fall Chinook, and Irrigon Hatchery subyearling fall Chinook (released into the Grande Ronde River) in migration years 2006 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data for wild/natural and Lyons Ferry Hatchery fall Chinook are from Table A.8. Data for Irrigon Hatchery fall Chinook (released into the Grande Ronde River) are from Table A.9.

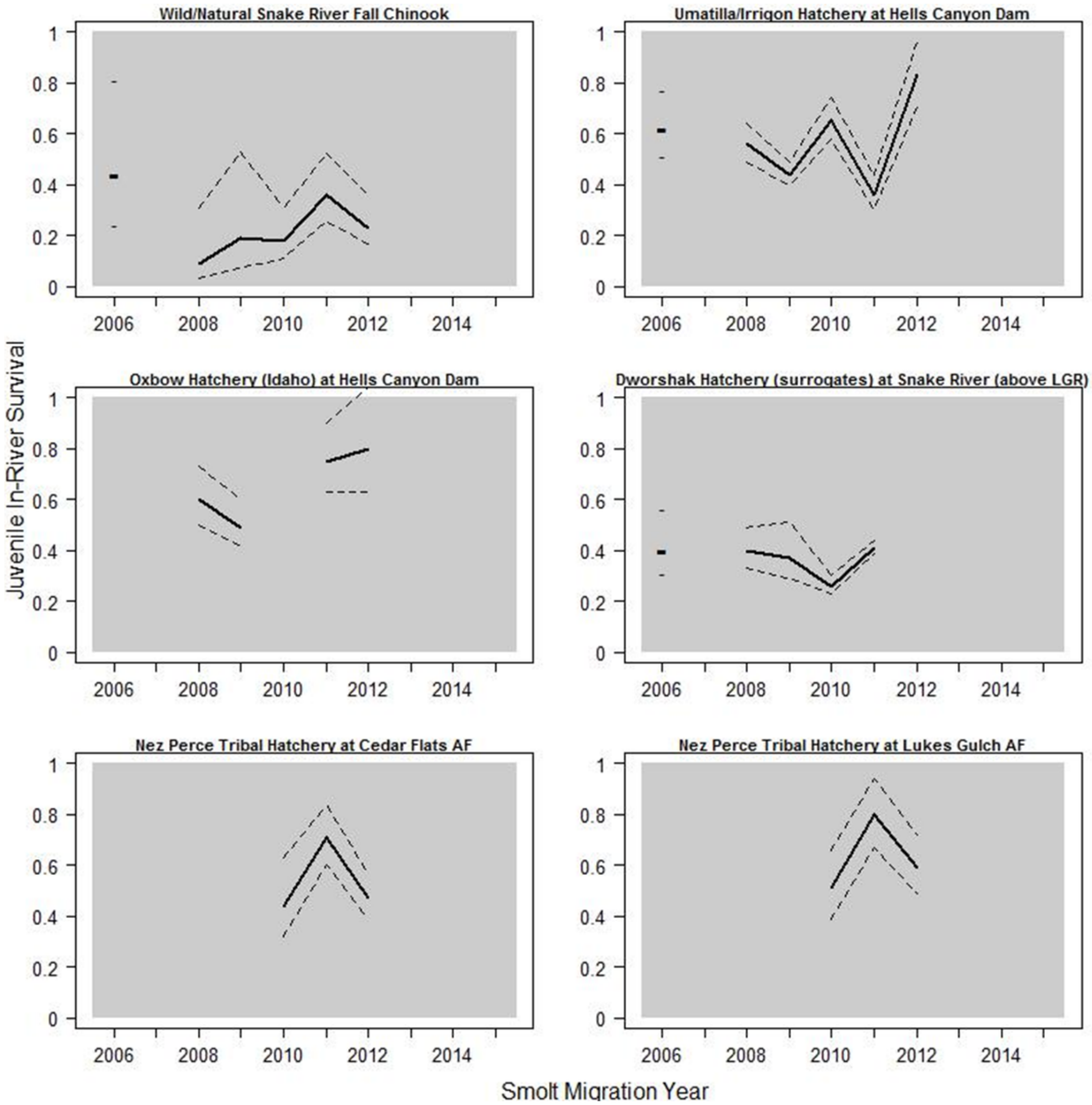


Figure A.10. Trend in in-river survival LGR to BON (S_R) for PIT-tagged Snake River wild/natural subyearling fall Chinook and Hatchery subyearling fall Chinook (various hatcheries and release sites) in migration years 2006 to 2015 (with 90% confidence intervals). Shaded area highlights the period of Court Order spill and later start of transportation. Data for wild/natural fall Chinook are from Table A.8. Data for hatchery fall Chinook (various hatcheries and release sites) are from Tables A.9 and A.10.

Table A.8. Estimated in-river survival LGR to BON (S_R) of PIT-tagged wild/natural subyearling fall Chinook and hatchery subyearling fall Chinook reared at Lyons Ferry Hatchery (LYFE) and released at Big Canyon Creek Acclimation Pond, Captain John Rapids Acclimation Pond, Pittsburg Landing Acclimation Pond or into the mainstem Snake River (above Lower Granite Dam) for migration years 2006 through 2012, and 2015 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups.

Migration Year	Wild/Natural fall Chinook	LYFE released at Big Canyon Creek AP	LYFE released at Captain John Rapids AP	LYFE released at Pittsburg Landing AP	LYFE released at Mainstem Snake River (above LGR)
2006	0.44[3] (0.24 – 0.81)	0.74 (0.66 – 0.84)		0.49[1] (0.42 – 0.59)	0.47[3] (0.37 – 0.59)
2007[A]	---	---	---	---	---
2008	0.09[2] (0.03 – 0.31)-	0.44[1] (0.38 – 0.52)	0.49[1] (0.43 – 0.56)	0.31[2] (0.22 – 0.50)	0.38[1] (0.30 – 0.53)
2009	0.19[2] (0.07 – 0.53)	0.52[1] (0.43 – 0.63)	0.47[1] (0.40 – 0.57)	0.66[1] (0.56 – 0.82)	0.48[1] (0.39 – 0.59)
2010	0.18[3] (0.11 – 0.31)	0.62[1] (0.55 – 0.71)	0.67[1] (0.60 – 0.74)	0.61[1] (0.54 – 0.68)	0.54[1] (0.43 – 0.66)
2011	0.36[3] (0.26 – 0.52)	0.70[3] (0.63 – 0.78)	0.84[3] (0.75 – 0.90)	0.81[3] (0.73 – 0.91)	0.65[3] (0.55 – 0.79)
2012	0.23[3] (0.17 – 0.36)	0.63[3] (0.56 – 0.71)	0.71[3] (0.64 – 0.79)	0.57[3] (0.52 – 0.63)	0.87[1] (0.73 – 1.08)
2015	---	---	0.26[1] (0.18 – 0.43)	0.23[3] (0.09 – 0.81)	---
Geomean	**0.22**	**0.60**	**0.54**	**0.491**	**0.53**

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

[A] S_R not reported for 2007 due to small sample sizes and lack of pre-assignments in that year.

Table A.9. Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery subyearling fall Chinook released in various locations throughout the Snake River (above Lower Granite Dam) including: the Grande Ronde River (reared at Irrigon Hatchery), below Hells Canyon Dam (reared at Umatilla or Irrigon Hatchery), below Hells Canyon Dam (reared at Oxbow Hatchery in Idaho), and the mainstem Snake River (reared at Dworshak National Fish Hatchery) (surrogates) for migration years 2006 through 2012 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups.

Migration Year	Irrigon Hatchery released into Grande Ronde River	Umatilla/Irrigon Hatchery released below Hells Canyon Dam	Oxbow Hatchery (Idaho) released below Hells Canyon Dam	Dworshak Hatchery (surrogates) released into Snake River
2006	0.45[2] (0.14 – 1.35)[A]	0.62[1] (0.51 – 0.77)	---	0.40[2] (0.31 – 0.56)
2007[B]	---	---	---	---
2008	0.34[1] (0.27 – 0.44)	0.56[1] (0.49 – 0.64)	0.60[1] (0.50 – 0.73)	0.40[2] (0.33 – 0.49)
2009	0.43[1] (0.36 – 0.53)	0.44[1] (0.40 – 0.49)	0.49[1] (0.42 – 0.60)	0.37[2] (0.29 – 0.51)
2010	0.69[1] (0.61 – 0.81)	0.65[1] (0.58 – 0.74)	---[C]	0.26[1] (0.23 – 0.30)
2011	0.40[3] (0.33 – 0.48)	0.36[3] (0.30 – 0.44)	0.75[3] (0.63 – 0.90)	0.41[3] (0.39 – 0.44)
2012	0.76[3] (0.66 – 0.87)	0.83[1] (0.71 – 0.96)	0.80[1] (0.63 – 1.04)	---[D]
Geomean	**0.49**	**0.56**	**0.65**	**0.36**

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

[A] 2006 release into Grande Ronde River were reared at Lyons Ferry Hatchery

[B] S_R not reported for 2007 due to small sample sizes and lack of pre-assignments in that year.

[C] No PIT-tags were released for this group in 2010.

[D] S_R not reported due to high estimates of holdover rates.

Table A.10. Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery subyearling fall Chinook reared at the Nez Perce Tribal Hatchery and released from Cedar Flats Acclimation Facility or Lukes Gulch Acclimation Facility for migration years 2010 through 2012 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups.

Migration Year	Cedar Flats Acclimation Facility	Lukes Gulch Acclimation Facility
2010	0.44[1] (0.32 – 0.63)	0.51[1] (0.39 – 0.66)
2011	0.71[3] (0.60 – 0.84)	0.80[3] (0.67 – 0.94)
2012	0.47[3] (0.39 – 0.57)	0.59[3] (0.49 – 0.72)
Geomean	**0.53**	**0.62**

[1 to 3] Number of reaches with a constant "per mile" survival probability expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Estimates of SAR by Study Category

Presented here are the LGR-to-GRA SAR estimates (without jacks for Chinook) by route of juvenile passage or study category. These SARs represent portions of the run as a whole, and the C_0 and transport SARs are components that make up TIR and *D*.

Wild and Hatchery Spring/Summer Chinook

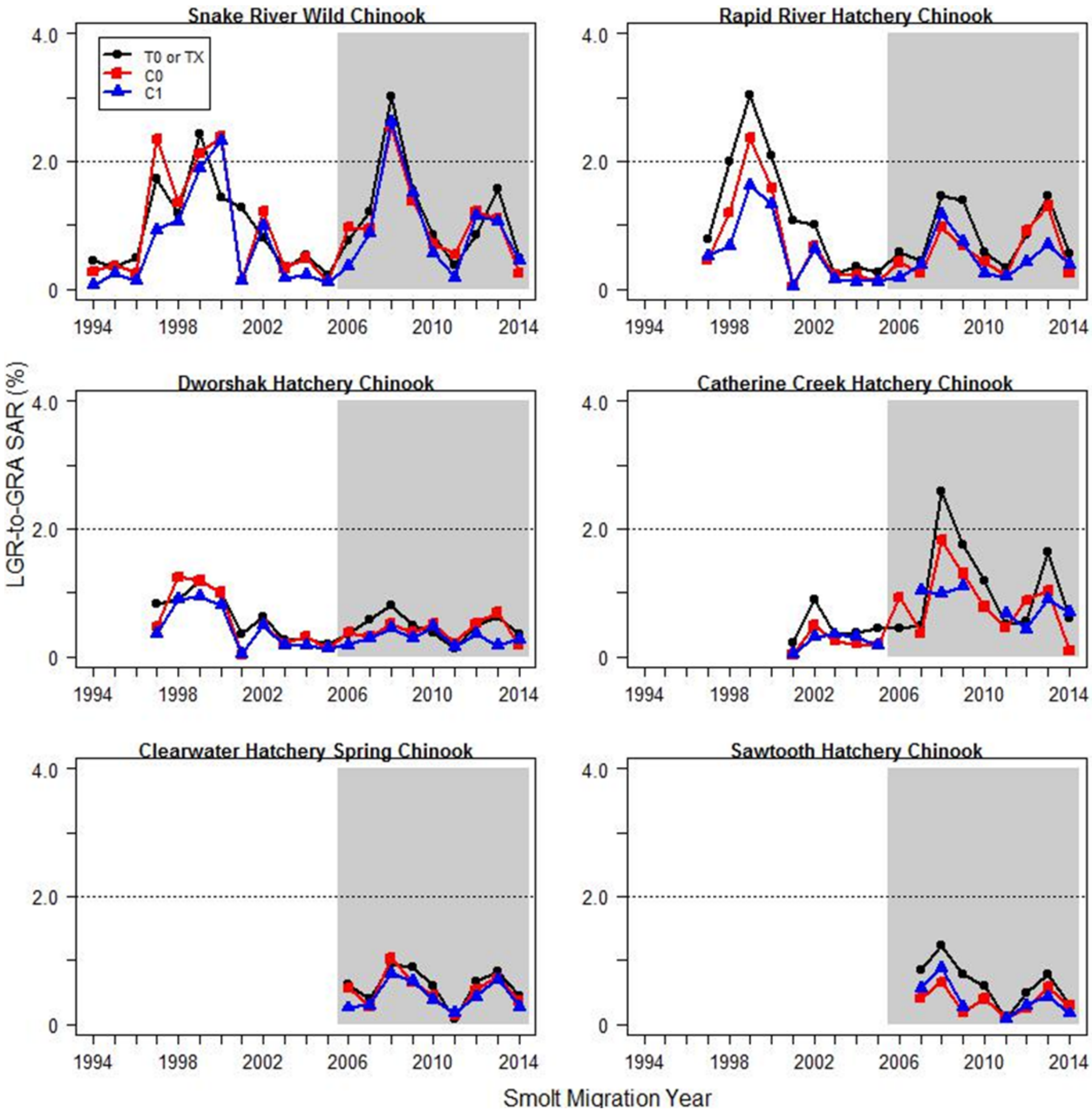


Figure A.11. Estimated LGR-to-GRA SAR (without jacks) for PIT-tagged wild Chinook aggregate and five CSS hatchery spring Chinook groups in transport (T_0 or T_X beginning 2006) and in-river (C_0 and C_1) study categories for migration years 1994 to 2014 (incomplete adult returns for 2014). Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2% SAR objective for listed wild populations is shown for reference. For 2001 and 2005, only 1 in-river SAR was calculated (see methods). Wild Chinook data from Table A.11; hatchery spring Chinook data from Tables A.12–A.16.

Table A.11. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged wild Chinook in annual aggregate for each study category from 1994 to 2014 (with 90% confidence intervals).

Migration Year	$SAR(T_0)$ %		$SAR(C_0)$ %		$SAR(C_1)$ %	
1994	0.45	(0.20 – 0.72)	0.28	(0.11 – 0.51)	0.07	(0.02 – 0.14)
1995	0.35	(0.17 – 0.57)	0.37	(0.18 – 0.57)	0.25	(0.18 – 0.32)
1996	0.50	(0.00 – 1.07)	0.26	(0.10 – 0.48)	0.13	(0.06 – 0.23)
1997	1.74	(0.44 – 3.27)	2.35	(1.45 – 3.36)	0.93	(0.60 – 1.32)
1998	1.18	(0.71 – 1.70)	1.36	(1.05 – 1.70)	1.07	(0.91 – 1.22)
1999	2.43	(1.85 – 3.07)	2.13	(1.78 – 2.50)	1.89	(1.76 – 2.04)
2000	1.43	(0.74 – 2.14)	2.39	(2.08 – 2.72)	2.33	(2.12 – 2.52)
2001	1.28	(0.54 – 2.14)	Assume = SAR(C1)		0.14	(0.10 – 0.18)
2002	0.80	(0.57 – 1.04)	1.22	(0.99 – 1.45)	0.99	(0.84 – 1.14)
2003	0.34	(0.24 – 0.45)	0.33	(0.23 – 0.43)	0.17	(0.12 – 0.23)
2004	0.53	(0.42 – 0.63)	0.49	(0.26 – 0.74)	0.22	(0.16 – 0.29)
2005	0.23	(0.17 – 0.29)	0.11 [A]	(0.07 – 0.15)		
Monitor Mode Years[B]	**$SAR(T_X)$_t %**		**$SAR(C_0)$_crt %**		**$SAR(EC_1)$_t %**	
2006	0.76	(0.60 – 0.90)	0.97	(0.71 – 1.26)	0.36	(0.18 – 0.56)
2007	1.20	(0.88 – 1.51)	0.94	(0.79 – 1.10)	0.88	(0.67 – 1.14)
2008	3.01	(2.70 – 3.30)	2.53	(2.23 – 2.87)	2.62	(2.22 – 3.04)
2009	1.54	(1.32 – 1.77)	1.39	(1.14 – 1.63)	1.50	(1.26 – 1.76)
2010	0.86	(0.71 – 1.00)	0.71	(0.62 – 0.81)	0.57	(0.26 – 0.91)
2011	0.38	(0.27 – 0.49)	0.55	(0.41 – 0.72)	0.19	(0.12 – 0.27)
2012	0.86	(0.64 – 1.11)	1.21	(1.00 – 1.42)	1.15	(1.00 – 1.32)
2013	1.57	(1.31 – 1.82)	1.10	(0.94 – 1.25)	1.07	(0.76 – 1.39)
2014[C]	0.48	(0.35 – 0.62)	0.26	(0.16 – 0.37)	0.45	(0.34 – 0.56)
21-yr avg.	**1.04**	**(0.76 – 1.32)**	**1.00**	**(0.70 – 1.30)**	**0.81**	**(0.52 – 1.10)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.12. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged spring Chinook from Rapid River Hatchery for each study category from 1997 to 2014 (with 90% confidence intervals).

Migration Year	$SAR(T_0)$ %		$SAR(C_0)$ %		$SAR(C_1)$ %	
1997	0.79	(0.57 – 1.01)	0.45	(0.31 – 0.63)	0.53	(0.39 – 0.68)
1998	2.00	(1.80 – 2.21)	1.20	(0.95 – 1.48)	0.67	(0.56 – 0.79)
1999	3.04	(2.78 – 3.31)	2.37	(2.07 – 2.68)	1.63	(1.46 – 1.79)
2000	2.10	(1.91 – 2.28)	1.59	(1.40 – 1.81)	1.33	(1.07 – 1.58)
2001	1.08	(0.96 – 1.21)	{Assume =$SAR(C_1)$}		0.05	(0.02 – 0.08)
2002	1.01	(0.86 – 1.16)	0.67	(0.55 – 0.79)	0.63	(0.53 – 0.74)
2003	0.25	(0.18 – 0.32)	0.23	(0.17 – 0.29)	0.15	(0.08 – 0.24)
2004	0.36	(0.29 – 0.43)	0.23	(0.11 – 0.39)	0.12	(0.07 – 0.16)
2005	0.27	(0.21 – 0.34)	0.12[A] (0.07 – 0.16)			
Monitor Mode Years[B]	**$SAR(T_X)$_t %**		**$SAR(C_0)$_crt %**		**$SAR(EC_1)$_t %**	
2006	0.57	(0.48– 0.66)	0.42	(0.30 – 0.54)	0.19	(0.05 – 0.35)
2007	0.45	(0.34 – 0.57)	0.25	(0.19 – 0.31)	0.38	(0.22 – 0.56)
2008	1.47	(1.32 – 1.62)	0.97	(0.82 – 1.13)	1.18	(0.90 – 1.48)
2009	1.40	(1.21 – 1.60)	0.68	(0.57 – 0.79)	0.74	(0.53 – 0.98)
2010	0.57	(0.43 – 0.74)	0.43	(0.37 – 0.50)	0.24	(0.00 – 0.74)
2011	0.33	(0.26 – 0.41)	0.23	(0.15 – 0.29)	0.20	(0.09 – 0.32)
2012	0.86	(0.73 – 1.01)	0.92	(0.79 – 1.06)	0.43	(0.28 – 0.58)
2013	1.45	(1.25 – 1.67)	1.30	(1.17 – 1.43)	0.70	(0.29 – 1.22)
2014[C]	0.56	(0.44 – 0.66)	0.26	(0.20 – 0.33)	0.39	(0.16 – 0.65)
18-yr avg.	**1.03**	**(0.71 – 1.35)**	**0.69**	**(0.43 – 0.95)**	**0.54**	**(0.35 – 0.73)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.13. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged spring Chinook from Dworshak Hatchery for each study category from 1997 to 2014 (with 90% confidence intervals).

Migration Year	SAR(T_0) %		SAR(C_0) %		SAR(C_1) %	
1997	0.83	(0.52 – 1.19)	0.47	(0.26 – 0.72)	0.36	(0.21 – 0.54)
1998	0.90	(0.77 – 1.02)	1.25	(1.08 – 1.42)	0.90	(0.77 – 1.04)
1999	1.18	(1.01 – 1.35)	1.19	(1.01 – 1.37)	0.95	(0.82 – 1.07)
2000	1.00	(0.88 – 1.12)	1.01	(0.87 – 1.16)	0.81	(0.62 – 1.02)
2001	0.36	(0.29 – 0.43)	{Assume =SAR(C_1)}		0.04	(0.02 – 0.07)
2002	0.62	(0.49 – 0.75)	0.50	(0.42 – 0.58)	0.50	(0.40 – 0.58)
2003	0.26	(0.19 – 0.33)	0.21	(0.16 – 0.27)	0.18	(0.10 – 0.27)
2004	0.28	(0.23 – 0.35)	0.32	(0.21 – 0.44)	0.18	(0.13 – 0.25)
2005	0.20	(0.16 – 0.26)	0.14[A]	(0.10 – 0.19)		
Monitor Mode Years[B]	**SAR(T_X)_t %**		**SAR(C_0)_crt %**		**SAR(EC_1)_t %**	
2006	0.36	(0.29 – 0.44)	0.38	(0.30 – 0.47)	0.19	(0.09 – 0.31)
2007	0.59	(0.35 – 0.86)	0.32	(0.27 – 0.38)	0.29	(0.19 – 0.40)
2008	0.80	(0.64 – 0.95)	0.52	(0.43 – 0.61)	0.45	(0.30 – 0.61)
2009	0.49	(0.37 – 0.61)	0.38	(0.30 – 0.46)	0.29	(0.17 – 0.43)
2010	0.37	(0.24 – 0.52)	0.52	(0.46 – 0.59)	0.47	(0.25 – 0.69)
2011	0.13	(0.07 – 0.20)	0.21	(0.15 – 0.28)	0.15	(0.09 – 0.23)
2012	0.50	(0.35 – 0.66)	0.53	(0.44 – 0.63)	0.36	(0.25 – 0.46)
2013	0.62	(0.46 – 0.80)	0.69	(0.61 – 0.78)	0.18	(0.07 – 0.32)
2014[C]	0.36	(0.27 – 0.45)	0.18	(0.14 – 0.23)	0.28	(0.13 – 0.45)
18-yr avg.	**0.55**	**(0.43 – 0.67)**	**0.49**	**(0.34 – 0.64)**	**0.37**	**(0.26 – 0.48)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.14. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged spring Chinook from Catherine Creek AP for each study category from 2001 to 2014 (with 90% confidence intervals).

Migration Year	$SAR(T_0)$ %	$SAR(C_0)$ %	$SAR(C_1)$ %
2001	0.23 (0.12 – 0.35)	{Assume =SAR(C1)}	0.04 (0.00 – 0.09)
2002	0.89 (0.59 – 1.20)	0.49 (0.28 – 0.74)	0.32 (0.18 – 0.50)
2003	0.36 (0.20 – 0.56)	0.25 (0.10 – 0.41)	0.35 (0.14 – 0.61)
2004	0.38 (0.21 – 0.57)	0.20 (0.00 – 0.60)	0.32 (0.11 – 0.54)
2005	0.44 (0.24 – 0.65)	0.18[A] (0.04 – 0.35)	
Monitor Mode Years[B]	**$SAR(T_X)$_t %**	**$SAR(C_0)$_crt %**	**$SAR(EC_1)$_t %**
2006[C]	0.45 (0.24 – 0.67)	0.93 (0.55 – 1.33)	---
2007	0.50 (0.27 – 0.76)	0.37 (0.20 – 0.55)	1.04 (0.25 – 2.40)
2008	2.58 (2.15 – 3.02)	1.83 (1.39 – 2.27)	0.99 (0.44 – 1.71)
2009	1.76 (1.37 – 2.17)	1.30 (0.96 – 1.67)	1.10 (0.40 – 2.08)
2010[C,D]	1.18 (0.77 – 1.63)	0.78 (0.58 – 0.98)	---
2011	0.52 (0.30 – 0.78)	0.45 (0.21 – 0.71)	0.67 (0.16 – 1.32)
2012	0.55 (0.27 – 0.90)	0.89 (0.55 – 1.29)	0.44 (0.11 – 0.81)
2013	1.63 (1.11 – 2.16)	1.03 (0.66 – 1.43)	0.90 (0.00 – 2.33)
2014[E]	0.60 (0.34 – 0.86)	0.10 (0.00 – 0.26)	0.70 (0.19 – 1.51)
14-yr avg.	**0.86 (0.52 – 1.20)**	**0.63 (0.37 – 0.89)**	**0.59 (0.39 – 0.79)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[C] C_1 SAR not estimable - small estimated juvenile population with zero returning adults.
[D] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[E] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.15. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged spring Chinook from Clearwater Hatchery for each study category from 2006 to 2014 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006	0.63 (0.53 – 0.74)	0.57 (0.43 – 0.70)	0.26 (0.09 – 0.47)
2007	0.41 (0.24 – 0.58)	0.28 (0.22 – 0.33)	0.30 (0.18 – 0.43)
2008	0.93 (0.76 – 1.11)	1.03 (0.85 – 1.22)	0.80 (0.53 – 1.08)
2009	0.89 (0.71 – 1.08)	0.66 (0.56 – 0.76)	0.67 (0.52 – 0.85)
2010[B]	0.60 (0.42 – 0.76)	0.45 (0.39 – 0.50)	0.39 (0.19 – 0.63)
2011	0.09 (0.04 – 0.15)	0.14 (0.09 – 0.19)	0.18 (0.12 – 0.24)
2012	0.67 (0.48 – 0.85)	0.55 (0.46 – 0.64)	0.44 (0.36 – 0.53)
2013	0.82 (0.61 – 1.03)	0.73 (0.66 – 0.82)	0.71 (0.51 – 0.92)
2014[C]	0.44 (0.32 – 0.58)	0.37 (0.29 – 0.45)	0.28 (0.18 – 0.38)
9-yr avg.	**0.61 (0.43 – 0.79)**	**0.53 (0.36 – 0.70)**	**0.45 (0.30 – 0.60)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.16. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged spring Chinook from Sawtooth Hatchery for each study category from 2007 to 2014 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2007	0.85 (0.61 – 1.12)	0.41 (0.26 – 0.59)	0.57 (0.14 – 1.11)
2008	1.23 (0.89 – 1.61)	0.66 (0.32 – 1.03)	0.89 (0.22 – 1.79)
2009	0.79 (0.48 – 1.13)	0.19 (0.09 – 0.32)	0.28 (0.00 – 0.64)
2010[B,C]	0.60 (0.35 – 0.89)	0.40 (0.27 – 0.54)	---
2011	0.09 (0.02 – 0.18)	0.11 (0.03 – 0.22)	0.09 (0.00 – 0.26)
2012	0.49 (0.29 – 0.72)	0.25 (0.11 – 0.42)	0.30 (0.07 – 0.58)
2013	0.79 (0.58 – 1.02)	0.58 (0.41 – 0.76)	0.44 (0.00 – 1.68)
2014[D]	0.31 (0.18 – 0.46)	0.29 (0.16 – 0.42)	0.17 (0.00 – 0.40)
8-yr avg.	**0.64 (0.39 – 0.89)**	**0.36 (0.22 – 0.50)**	**0.39 (0.17 – 0.61)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[C] C_1 SAR not estimable - small estimated juvenile population with zero returning adults.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.

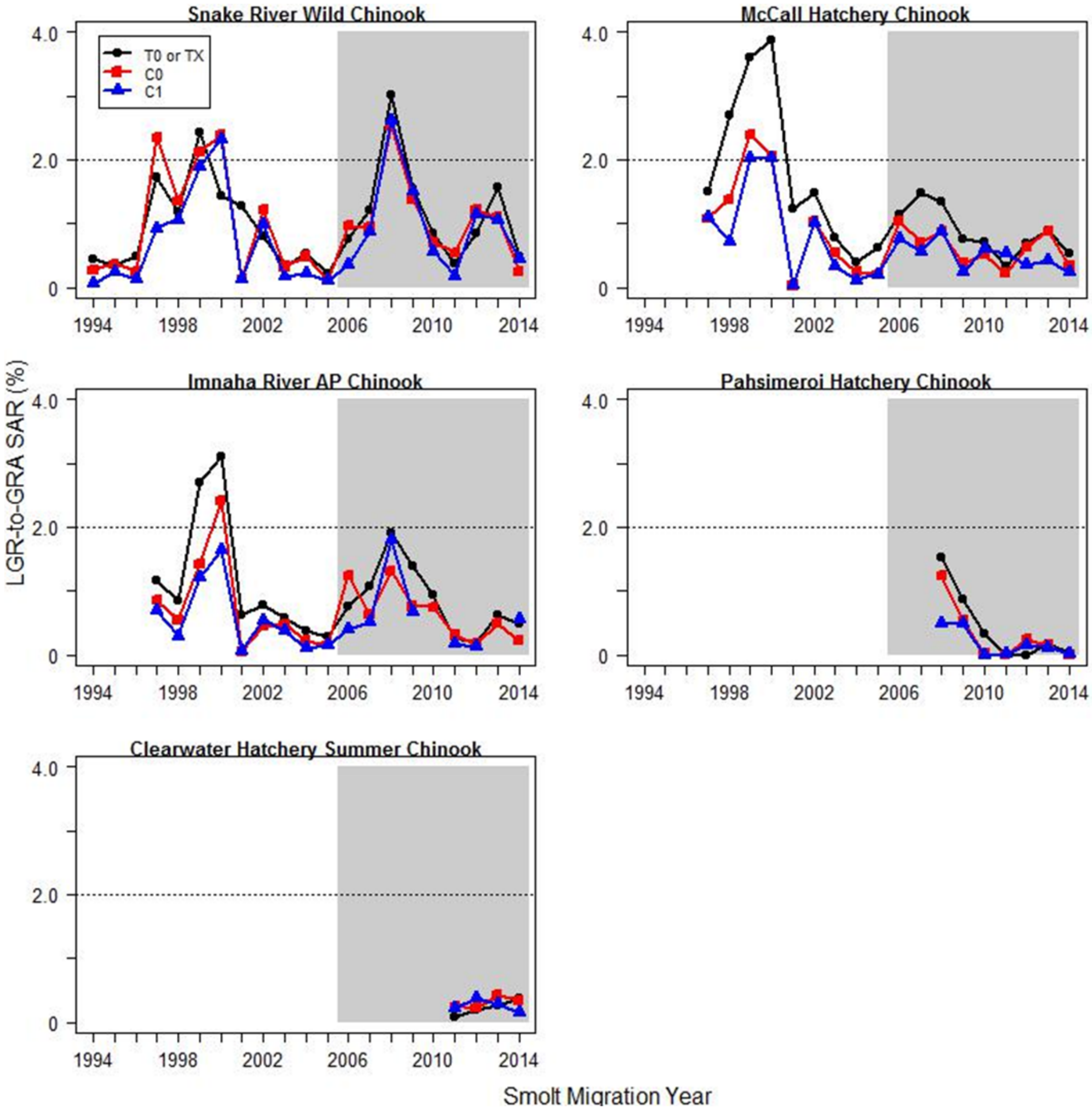


Figure A.12. Estimated LGR-to-GRA SAR (without jacks) for PIT-tagged wild Chinook aggregate and four CSS hatchery summer Chinook groups in transport (T_0 or T_X beginning 2006) and in-river (C_0 and C_1) study categories for migration years 1994 to 2014 (incomplete adult returns for 2014). Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2% SAR objective for listed wild populations is shown for reference. For 2001 and 2005, only 1 in-river SAR was calculated (see methods). Wild Chinook data from Table A.11; hatchery summer Chinook data from Tables A.17–A.20.

Table A.17. Estimated LGR-to-GRA SAR (%)(without jacks) for PIT-tagged summer Chinook from McCall Hatchery for each study category from 1997 to 2014 (with 90% confidence intervals).

Migration Year	SAR(T_0) %		SAR(C_0) %		SAR(C_1) %	
1997	1.51	(1.26 – 1.77)	1.09	(0.88 – 1.34)	1.10	(0.92 – 1.29)
1998	2.69	(2.44 – 2.96)	1.38	(1.05 – 1.69)	0.73	(0.62 – 0.87)
1999	3.59	(3.29 – 3.87)	2.40	(2.12 – 2.69)	2.03	(1.82 – 2.26)
2000	3.88	(3.60 – 4.18)	2.06	(1.84 – 2.29)	2.03	(1.68 – 2.38)
2001	1.24	(1.10 – 1.38)	{Assume =SAR(C1)}		0.04	(0.01 – 0.07)
2002	1.48	(1.27 – 1.70)	1.03	(0.87 – 1.20)	1.02	(0.89 – 1.18)
2003	0.79	(0.68 – 0.92)	0.54	(0.45 – 0.62)	0.34	(0.24 – 0.46)
2004	0.40	(0.34 – 0.48)	0.25	(0.09 – 0.44)	0.12	(0.07 – 0.16)
2005	0.62	(0.54 – 0.71)	0.20[A] (0.16 – 0.26)			
Monitor Mode Years[B]	**SAR(T_X)_t %**		**SAR(C_0)_crt %**		**SAR(EC_1)_t %**	
2006	1.15	(1.01 – 1.30)	1.04	(0.85 – 1.22)	0.77	(0.42 – 1.20)
2007	1.48	(1.20 – 1.75)	0.71	(0.60 – 0.82)	0.57	(0.32 – 0.86)
2008	1.35	(1.17 – 1.54)	0.88	(0.73 – 1.03)	0.89	(0.59 – 1.24)
2009	0.76	(0.60 – 0.94)	0.38	(0.30 – 0.47)	0.25	(0.09 – 0.43)
2010[C]	0.71	(0.54 – 0.91)	0.52	(0.44 – 0.61)	0.61	(0.00 – 1.43)
2011	0.33	(0.24 – 0.43)	0.23	(0.17 – 0.31)	0.54	(0.35 – 0.76)
2012	0.69	(0.52 – 0.86)	0.63	(0.51 – 0.76)	0.36	(0.24 – 0.50)
2013	0.89	(0.73 – 1.07)	0.89	(0.78 – 0.99)	0.42	(0.10 – 0.94)
2014[D]	0.54	(0.43 – 0.65)	0.33	(0.26 – 0.39)	0.24	(0.06 – 0.46)
18-yr avg.	**1.34**	**(0.90 – 1.78)**	**0.81**	**(0.54 – 1.08)**	**0.68**	**(0.44 – 0.92)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[C] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.18. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged summer Chinook from Imnaha River AP for each study category from 1997 to 2014 (with 90% confidence intervals).

Migration Year	$SAR(T_0)$ %	$SAR(C_0)$ %	$SAR(C_1)$ %
1997	1.16 (0.77 – 1.60)	0.86 (0.53 – 1.22)	0.69 (0.48 – 0.93)
1998	0.85 (0.65 – 1.09)	0.55 (0.28 – 0.83)	0.30 (0.20 – 0.42)
1999	2.69 (2.28 – 3.08)	1.43 (1.08 – 1.82)	1.22 (0.98 – 1.49)
2000	3.11 (2.77 – 3.44)	2.41 (2.01 – 2.83)	1.64 (1.22 – 2.08)
2001	0.62 (0.49 – 0.78)	{Assume =$SAR(C_1)$}	0.06 (0.01 – 0.11)
2002	0.79 (0.56 – 1.04)	0.45 (0.29 – 0.63)	0.55 (0.38 – 0.72)
2003	0.58 (0.40 – 0.75)	0.48 (0.34 – 0.62)	0.38 (0.20 – 0.59)
2004	0.38 (0.26 – 0.49)	0.23 (0.07 – 0.48)	0.11 (0.04 – 0.20)
2005	0.28 (0.18 – 0.40)	0.16[A] (0.08 – 0.26)	
Monitor Mode Years[B]	**$SAR(T_X)$_t %**	**$SAR(C_0)$_crt %**	**$SAR(EC_1)$_t %**
2006	0.77 (0.58 – 0.97)	1.25 (0.93 – 1.61)	0.40 (0.10 – 0.77)
2007	1.07 (0.73 – 1.43)	0.63 (0.48 – 0.79)	0.52 (0.28 – 0.80)
2008	1.92 (1.61 – 2.23)	1.32 (1.02 – 1.65)	1.80 (1.30 – 2.35)
2009	1.39 (1.10 – 1.67)	0.76 (0.57 – 0.97)	0.67 (0.33 – 1.07)
2010[C,D]	0.95 (0.65 – 1.27)	0.75 (0.61 – 0.91)	---
2011	0.26 (0.13 – 0.38)	0.31 (0.16 – 0.47)	0.18 (0.00 – 0.44)
2012	0.20 (0.07 – 0.33)	0.18 (0.10 – 0.30)	0.14 (0.05 – 0.25)
2013[D]	0.63 (0.40 – 0.86)	0.50 (0.38 – 0.63)	---
2014[E]	0.50 (0.35 – 0.66)	0.23 (0.13 – 0.34)	0.56 (0.14 – 1.12)
18-yr avg.	**1.01 (0.67 – 1.35)**	**0.70 (0.45 – 0.95)**	**0.59 (0.35 – 0.83)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[C] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[D] C_1 SAR not estimable - small estimated juvenile population with zero returning adults.
[E] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.19. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged summer Chinook from Pahsimeroi Hatchery for each study category from 2008 to 2014 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2008	1.53 (1.18 – 1.88)	1.24 (0.85 – 1.63)	0.49 (0.12 – 0.95)
2009	0.87 (0.19 – 1.58)	0.54 (0.36 – 0.73)	0.50 (0.31 – 0.71)
2010[B]	0.33 (0.08 – 0.64)	0.02 (0.00 – 0.05)	---
2011	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.02 (0.00 – 0.07)
2012[C]	---	0.24 (0.11 – 0.38)	0.16 (0.08 – 0.25)
2013	0.17 (0.00 – 0.36)	0.15 (0.08 – 0.22)	0.12 (0.00 – 0.28)
2014[D]	0.04 (0.00 – 0.12)	0.00 (0.00 – 0.00)	0.02 (0.00 – 0.07)
7-yr avg.	**0.49 (0.00[E] – 1.03)**	**0.31 (0.00[E] – 0.67)**	**0.22 (0.02 – 0.42)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[C] Transport SAR not estimable – small estimated juvenile population and zero returning adults.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.
[E] The lower limit of the 90% confidence interval is shown as 0.00 rather than the negative value resulting from the limited degree of freedom and lack of precision.

Table A.20. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged summer Chinook from Clearwater Hatchery for each study category from 2011 to 2014 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2011	0.08 (0.00 – 0.17)	0.26 (0.14 – 0.38)	0.22 (0.10 – 0.37)
2012	0.19 (0.06 – 0.39)	0.23 (0.12 – 0.35)	0.38 (0.25 – 0.52)
2013	0.27 (0.09 – 0.45)	0.43 (0.31 – 0.55)	0.29 (0.07 – 0.56)
2014[B]	0.37 (0.23 – 0.54)	0.35 (0.25 – 0.46)	0.16 (0.06 – 0.30)
4-yr avg.	**0.23 (0.06 – 0.40)**	**0.32 (0.20 – 0.44)**	**0.26 (0.13 – 0.39)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Wild and Hatchery Steelhead

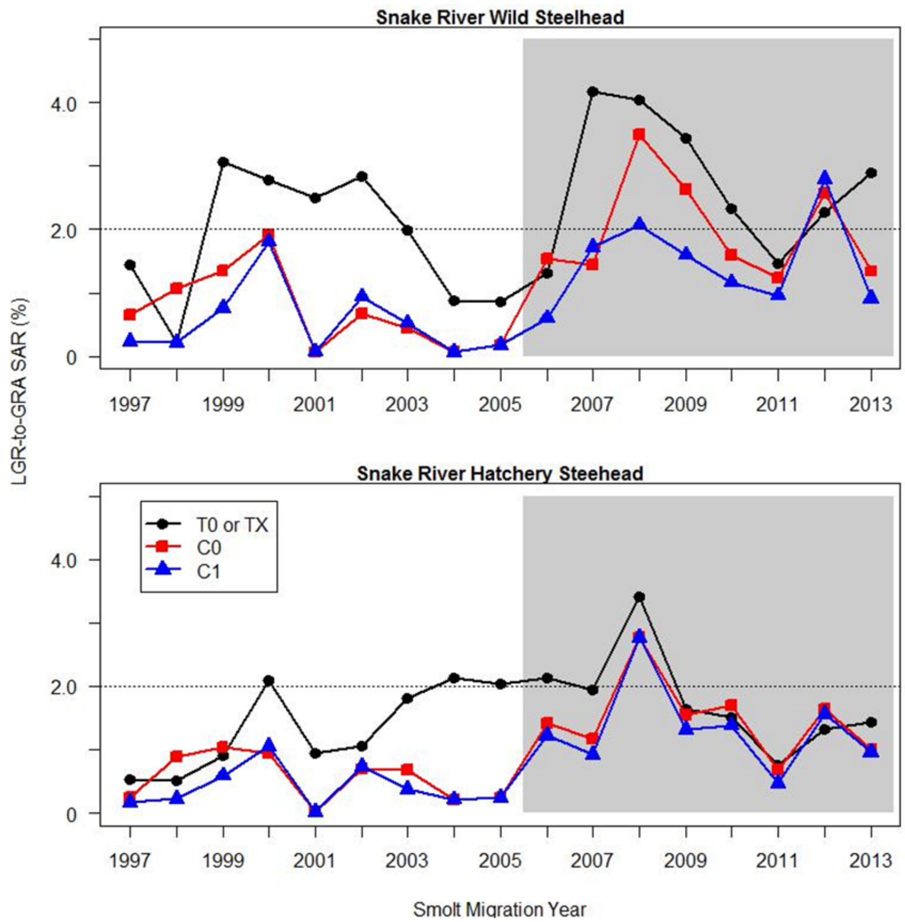


Figure A.13. Estimated LGR-to-GRA SAR for PIT-tagged wild and hatchery steelhead aggregate in transport (T_0 or T_X beginning 2008) and in-river (C_0 and C_1) study categories for migration years 1997 to 2013. Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2% SAR objective for listed wild populations is shown for reference. For 2001, 2004, and 2005, only 1 in-river SAR was calculated (see methods). Data for wild steelhead from Table A.21 and hatchery steelhead aggregate from Table A.22. SARs for wild steelhead (2006-2013) and hatchery steelhead aggregate (2008-2013) include all groups with pre-assignment in those years (see Tables A.21-A.30 for details).

Table A.21. Estimated LGR-to-GRA SAR (%) for PIT-tagged wild steelhead in annual aggregate for each study category from 1997 to 2013 (with 90% confidence intervals).

Migration Year	$SAR(T_0)$ %		$SAR(C_0)$ %		$SAR(C_1)$ %	
1997	1.45	(0.36 – 2.80)	0.66	(0.00 – 1.34)	0.23	(0.10 – 0.39)
1998	0.21	(0.00 – 0.63)	1.07	(0.51 – 1.73)	0.21	(0.12 – 0.33)
1999	3.07	(1.74 – 4.66)	1.35	(0.80 – 1.96)	0.76	(0.60 – 0.94)
2000	2.79	(1.55 – 4.11)	1.92	(1.40 – 2.49)	1.81	(1.59 – 2.03)
2001	2.49	(0.93 – 4.37)	{Assume $=SAR(C_1)$}		0.07	(0.03 – 0.10)
2002	2.84	(1.52 – 4.43)	0.67	(0.46 – 0.90)	0.94	(0.77 – 1.11)
2003	1.99	(1.52 – 2.51)	0.45	(0.27 – 0.66)	0.52	(0.37 – 0.66)
2004	0.87	(0.65 – 1.11)	0.06[A]	(0.02 – 0.11)		
2005	0.84	(0.63 – 1.07)	0.17[A]	(0.11 – 0.25)		
Monitor Mode Years[B]	**$SAR(T_X)$_t %**		**$SAR(C_0)$_crt %**		**$SAR(EC_1)$_t %**	
2006	1.31	(1.02 – 1.66)	1.54	(0.72 – 2.44)	0.60	(0.27 – 0.92)
2007	4.18	(3.60 – 4.83)	1.44	(1.12 – 1.79)	1.72	(1.17 – 2.33)
2008	4.05	(3.43 – 4.76)	3.49	(2.89 – 4.09)	2.07	(1.50 – 2.70)
2009	3.45	(2.88 – 4.01)	2.64	(2.07 – 3.31)	1.60	(1.15 – 2.08)
2010	2.33	(1.87 – 2.80)	1.60	(1.35 – 1.87)	1.17	(0.53 – 1.92)
2011	1.46	(1.07 – 1.87)	1.24	(0.84 – 1.70)	0.96	(0.55 – 1.43)
2012	2.27	(1.64 – 2.89)	2.57	(2.07 – 3.09)	2.80	(2.35 – 3.30)
2013[C]	2.89	(2.44 – 3.33)	1.34	(1.09 – 1.62)	0.91	(0.46 – 1.50)
17-yr avg.	**2.26**	**(1.77 – 2.75)**	**1.31**	**(0.89 – 1.73)**	**0.98**	**(0.63 – 1.33)**

[A] In-river SAR is combination of groups C_0 and C_1.

[B] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.

[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016 at GRA.

Table A.22. Estimated LGR-to-GRA SAR (%) for PIT-tagged hatchery steelhead in annual aggregate for each study category from 1997 to 2013 (with 90% confidence intervals).

MigrationYear	$SAR(T_0)$ %	$SAR(C_0)$ %	$SAR(C_1)$ %
1997	0.52 (0.24 – 0.81)	0.24 (0.09 – 0.39)	0.17 (0.12 – 0.22)
1998	0.51 (0.22 – 0.84)	0.89 (0.61 – 1.19)	0.22 (0.17 – 0.28)
1999	0.90 (0.51 – 1.33)	1.04 (0.79 – 1.31)	0.59 (0.51 – 0.69)
2000	2.10 (1.22 – 3.07)	0.95 (0.71 – 1.19)	1.05 (0.92 – 1.18)
2001	0.94 (0.24 – 1.78)	{Assume =$SAR(C_1)$}	0.016 (0.005 – 0.03)
2002	1.06 (0.32 – 2.11)	0.70 (0.54 – 0.88)	0.73 (0.61 – 0.85)
2003	1.81 (1.50 – 2.13)	0.68 (0.52 – 0.86)	0.37 (0.26 – 0.47)
2004	2.13 (1.17 – 3.27)	0.21[A] (0.15 – 0.26)	
2005	2.03 (1.28 – 2.83)	0.24[A] (0.18 – 0.30)	
2006[B]	2.14 (1.49 – 2.84)	1.42 (0.94 – 1.93)	1.23 (1.06 – 1.41)
2007[B]	1.94 (1.51 – 2.38)	1.17 (0.96 – 1.38)	0.92 (0.78 – 1.07)
Monitor Mode Years[C]	**$SAR(T_X)$_t %**	**$SAR(C_0)$_crt %**	**$SAR(EC_1)$_t %**
2008[D]	3.41 (3.25 – 3.56)	2.78 (2.63 – 2.92)	2.77 (2.57 – 2.97)
2009	1.65 (1.55 – 1.75)	1.55 (1.44 – 1.66)	1.32 (1.22 – 1.42)
2010	1.51 (1.41 – 1.63)	1.69 (1.61 – 1.76)	1.38 (1.16 – 1.62)
2011	0.75 (0.68 – 0.82)	0.68 (0.61 – 0.75)	0.47 (0.41 – 0.53)
2012	1.32 (1.21 – 1.43)	1.64 (1.53 – 1.75)	1.56 (1.46 – 1.67)
2013[E]	1.44 (1.33 – 1.54)	1.01 (0.95 – 1.08)	0.96 (0.82 – 1.11)
17-yr avg.	**1.58 (1.26 – 1.90)**	**1.01 (0.71 – 1.31)**	**0.85 (0.55 – 1.15)**

[A] In-river SAR is combination of groups C_0 and C_1.
[B] No pre-assignment for hatchery steelhead, so one group; transport SARs estimated with T_X smolts.
[C] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[D] SARs for 2008 hatchery steelhead aggregate includes all groups with pre-assignment (see Tables A.20–A.27 for details).
[E] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016 at GRA.

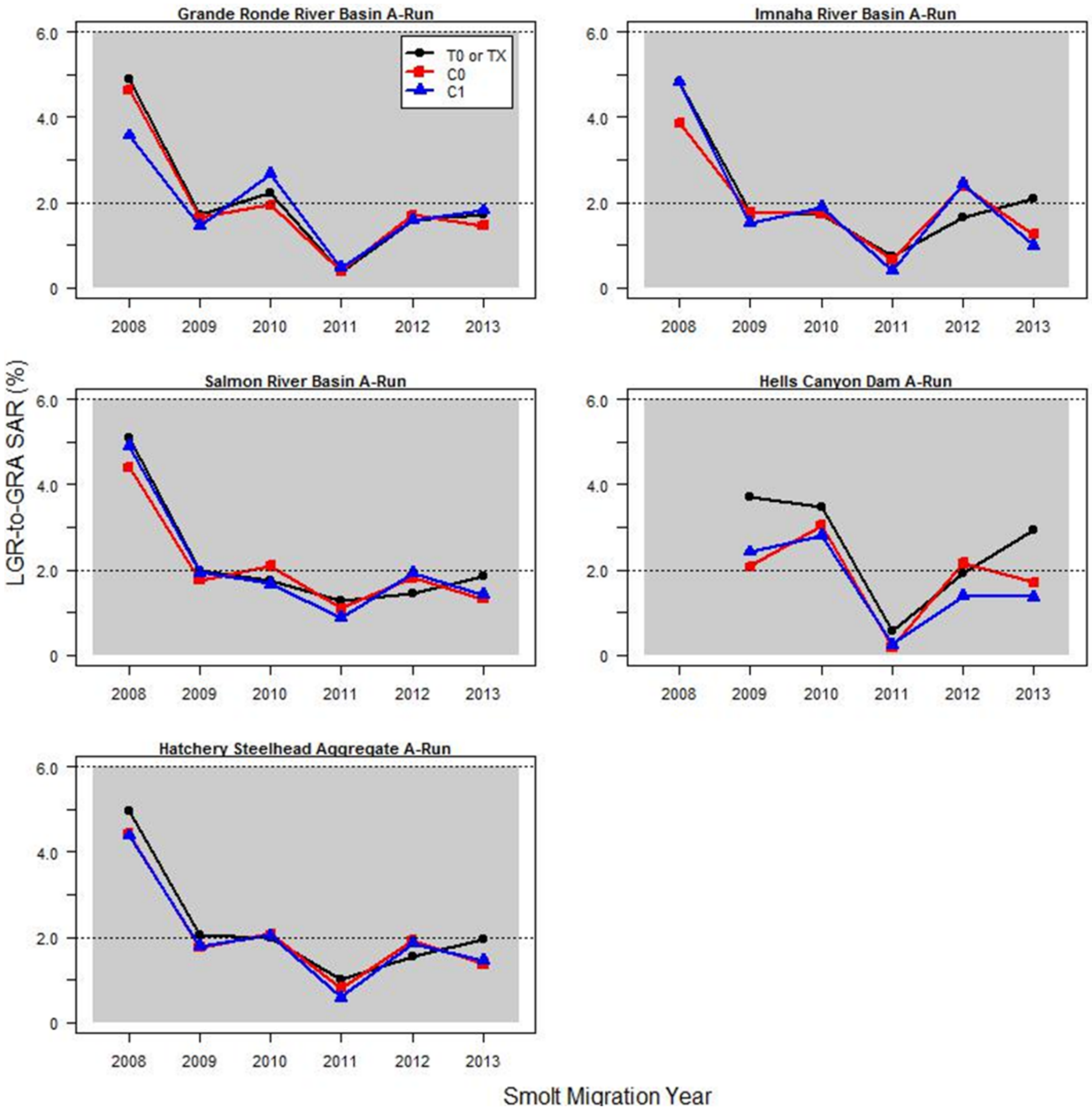


Figure A.14. Estimated LGR-to-GRA SAR (%) for individual groups of PIT-tagged A-run hatchery steelhead in transport (T_0 or T_X beginning 2008) and in-river (C_0 and C_1) study categories for migration years 2008 to 2013. Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference. Data for individual A-run hatchery steelhead groups are from Tables A.23–A.27. SARs include all groups with pre-assignment in those years (see Tables A.23–A.27 for details).

Table A.23. Estimated LGR-to-GRA SAR (%) for PIT-tagged Grande Ronde Basin (A-Run) hatchery steelhead, 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008[B]	4.89	(4.46 – 5.33)	4.65	(4.18 – 5.15)	3.57	(3.04 – 4.10)
2009	1.72	(1.47 – 2.00)	1.64	(1.37 – 1.91)	1.46	(1.15 – 1.80)
2010	2.22	(1.86 – 2.57)	1.94	(1.74 – 2.15)	2.67	(1.82 – 3.66)
2011	0.37	(0.23 – 0.53)	0.40	(0.29 – 0.52)	0.46	(0.32 – 0.61)
2012	1.58	(1.24 – 1.96)	1.71	(1.44 – 1.98)	1.58	(1.34 – 1.83)
2013[C]	1.71	(1.41 – 2.02)	1.45	(1.27 – 1.66)	1.81	(1.30 – 2.41)
6-yr avg.	**2.08**	**(0.72 – 3.44)**	**1.97**	**(0.69 – 3.25)**	**1.93**	**(0.96 – 2.90)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Not pre-assigned to T and R groups. Pre-2006 methods applied for this year (see *Pre-2006 Migration Years* in above Methods section for details).
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.24. Estimated LGR-to-GRA SAR (%) for PIT-tagged Imnaha Basin (A-Run) hatchery steelhead, 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008[B]	4.84	(4.35 – 5.31)	3.87	(3.35 – 4.42)	4.82	(4.07 – 5.61)
2009	1.78	(1.48 – 2.06)	1.75	(1.44 – 2.08)	1.51	(1.13 – 1.86)
2010	1.72	(1.41 – 2.04)	1.75	(1.52 – 1.98)	1.90	(1.10 – 2.94)
2011	0.75	(0.55 – 0.95)	0.66	(0.48 – 0.86)	0.39	(0.19 – 0.63)
2012	1.65	(1.32 – 1.99)	2.39	(1.97 – 2.81)	2.43	(2.01 – 2.86)
2013[C]	2.10	(1.77 – 2.44)	1.25	(1.03 – 1.50)	0.99	(0.49 – 1.57)
6-yr avg.	**2.14**	**(0.88 – 3.40)**	**1.95**	**(0.95 – 2.95)**	**2.01**	**(0.61 – 3.41)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Not pre-assigned to T and R groups. Pre-2006 methods applied for this year (see *Pre-2006 Migration Years* in above Methods section for details).
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.25. Estimated LGR-to-GRA SAR (%) for PIT-tagged Salmon River Basin (A-Run) hatchery steelhead, 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008	5.09	(4.73 – 5.49)	4.41	(4.01 – 4.78)	4.91	(4.25 – 5.60)
2009	2.00	(1.81 – 2.20)	1.76	(1.53 – 2.00)	1.94	(1.71 – 2.19)
2010	1.76	(1.56 – 1.97)	2.09	(1.93 – 2.25)	1.67	(1.14 – 2.25)
2011	1.28	(1.14 – 1.43)	1.10	(0.95 – 1.26)	0.87	(0.69 – 1.08)
2012	1.45	(1.26 – 1.64)	1.82	(1.62 – 2.02)	1.93	(1.72 – 2.14)
2013[B]	1.85	(1.65 – 2.06)	1.32	(1.18 – 1.44)	1.41	(1.01 – 1.82)
6-yr avg.	**2.24**	**(0.96 – 3.52)**	**2.08**	**(1.00 – 3.16)**	**2.12**	**(0.84 – 3.40)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.26. Estimated LGR-to-GRA SAR (%) for PIT-tagged Hells Canyon Dam (A-Run) hatchery steelhead, 2009 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2009	3.71	(3.04 – 4.27)	2.08	(1.46 – 2.71)	2.42	(1.64 – 3.30)
2010[B]	3.49	(2.77 – 4.22)	3.04	(2.54 – 3.60)	2.81	(0.50 – 8.04)
2011	0.56	(0.24 – 0.91)	0.19	(0.00 – 0.46)	0.25	(0.10 – 0.45)
2012	1.93	(1.15 – 2.77)	2.15	(1.49 – 2.90)	1.38	(0.92 – 1.80)
2013[C]	2.92	(2.16 – 3.79)	1.70	(1.30 – 2.11)	1.37	(0.49 – 2.61)
5-yr avg.	**2.52**	**(1.14 – 3.90)**	**1.83**	**(0.72 – 2.94)**	**1.65**	**(0.58 – 2.72)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.

[B] See Section: *Special Considerations for Migration Year 2010*.

[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.27. Estimated LGR-to-GRA SAR (%) for PIT-tagged hatchery steelhead (Aggregate A-Run), 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008	4.96	(4.71 – 5.22)	4.42	(4.14 – 4.70)	4.38	(3.98 – 4.79)
2009	2.04	(1.91 – 2.19)	1.76	(1.61 – 1.91)	1.79	(1.62 – 1.95)
2010	2.00	(1.84 – 2.14)	2.07	(1.96 – 2.19)	2.04	(1.67 – 2.49)
2011	0.99	(0.89 – 1.09)	0.81	(0.71 – 0.90)	0.59	(0.50 – 0.69)
2012	1.54	(1.40 – 1.70)	1.92	(1.78 – 2.06)	1.85	(1.71 – 2.00)
2013[B]	1.94	(1.80 – 2.10)	1.38	(1.29 – 1.48)	1.45	(1.20 – 1.74)
6-yr avg.	**2.25**	**(1.00 – 3.50)**	**2.20**	**(1.00 – 3.40)**	**2.13**	**(0.88 – 3.38)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.

[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

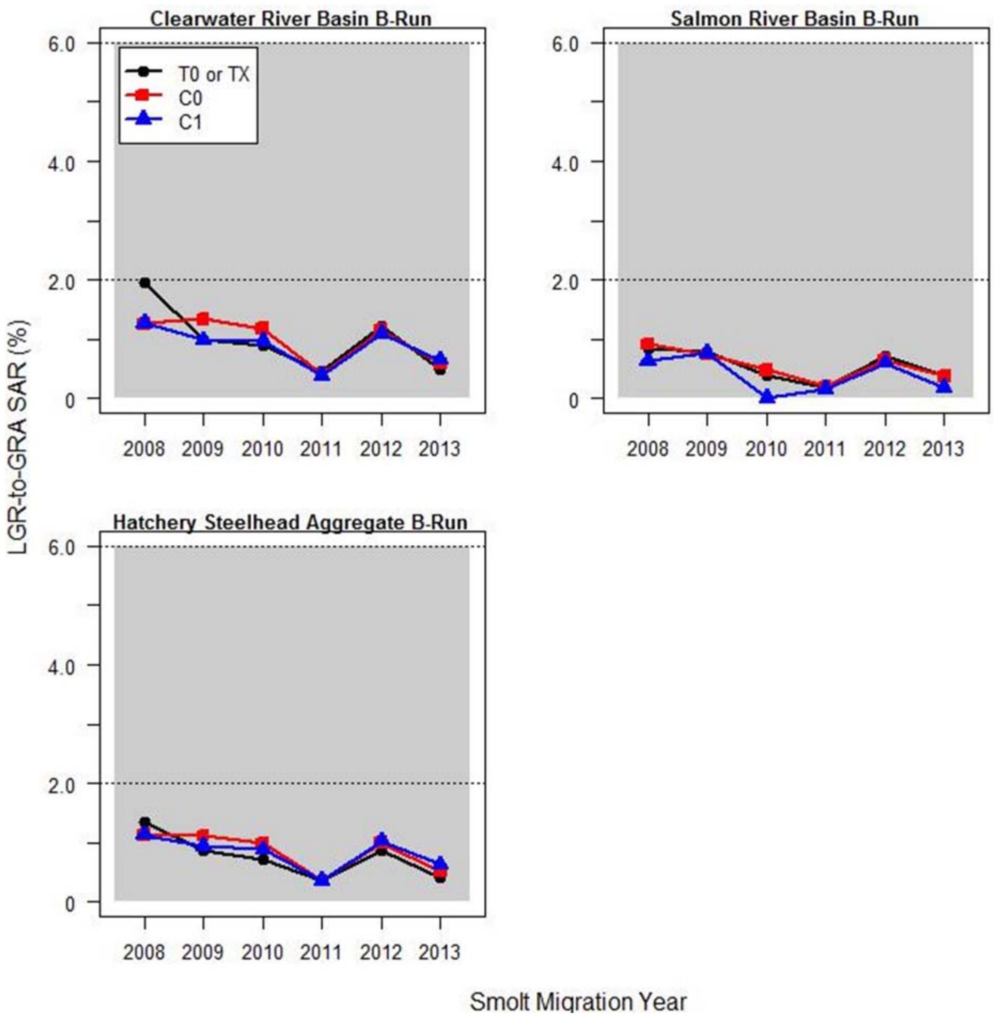


Figure A.15. Estimated LGR-to-GRA SAR (%) for individual groups of PIT-tagged B-run hatchery steelhead in transport (T_0 or T_X beginning 2008) and in-river (C_0 and C_1) study categories for migration years 2008 to 2013. Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference. Data for individual B-run hatchery steelhead groups are from Tables A.28–A.30. SARs include all groups with pre-assignment in those years (see Tables A.28–A.30 for details).

Table A.28. Estimated LGR-to-GRA SAR (%) for PIT-tagged Clearwater River Basin (B-Run) hatchery steelhead, 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008	1.96	(1.68 – 2.23)	1.26	(1.10 – 1.43)	1.28	(1.05 – 1.49)
2009	0.99	(0.79 – 1.20)	1.34	(1.12 – 1.57)	0.98	(0.86 – 1.11)
2010	0.90	(0.73 – 1.06)	1.18	(1.07 – 1.31)	0.97	(0.71 – 1.25)
2011	0.47	(0.36 – 0.60)	0.41	(0.31 – 0.53)	0.39	(0.32 – 0.47)
2012	1.21	(0.87 – 1.57)	1.15	(0.94 – 1.37)	1.09	(0.93 – 1.25)
2013[B]	0.48	(0.32 – 0.68)	0.59	(0.51 – 0.68)	0.65	(0.51 – 0.81)
6-yr avg.	**1.00**	**(0.50 – 1.50)**	**0.99**	**(0.64 – 1.34)**	**0.89**	**(0.60 – 1.18)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.

[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.29. Estimated LGR-to-GRA SAR (%) for PIT-tagged Salmon River Basin (B-Run) hatchery steelhead, 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008	0.84	(0.68 – 1.01)	0.92	(0.74 – 1.11)	0.63	(0.37 – 0.92)
2009	0.79	(0.64 – 0.95)	0.74	(0.54 – 0.94)	0.77	(0.55 – 1.02)
2010[B]	0.38	(0.25 – 0.54)	0.48	(0.36 – 0.60)		---
2011	0.18	(0.10 – 0.28)	0.20	(0.09 – 0.32)	0.16	(0.00 – 0.34)
2012	0.72	(0.56 – 0.91)	0.65	(0.45 – 0.86)	0.60	(0.30 – 0.97)
2013[C]	0.38	(0.26 – 0.50)	0.38	(0.28 – 0.49)	0.19	(0.00 – 0.62)
6-yr avg.	**0.55**	**(0.31 – 0.79)**	**0.56**	**(0.33 – 0.79)**	**0.47**	**(0.17 – 0.77)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.

[B] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.

[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.30. Estimated LGR-to-GRA SAR (%) for PIT-tagged hatchery steelhead (Aggregate B-Run), 2008 and 2013 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %		$SAR(C_0)$_crt %		$SAR(EC_1)$_t %	
2008	1.34	(1.20 – 1.49)	1.13	(1.02 – 1.26)	1.13	(0.95 – 1.32)
2009	0.87	(0.74 – 1.01)	1.12	(0.96 – 1.29)	0.94	(0.83 – 1.06)
2010	0.72	(0.60 – 0.84)	0.99	(0.90 – 1.09)	0.88	(0.67 – 1.10)
2011	0.36	(0.28 – 0.44)	0.36	(0.28 – 0.44)	0.37	(0.31 – 0.44)
2012	0.87	(0.72 – 1.03)	1.00	(0.84 – 1.16)	1.03	(0.89 – 1.17)
2013[B]	0.41	(0.32 – 0.51)	0.52	(0.45 – 0.58)	0.63	(0.49 – 0.78)
6-yr avg.	**0.76**	**(0.44 – 1.08)**	**0.85**	**(0.55 – 1.15)**	**0.83**	**(0.58 – 1.08)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.

[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Hatchery Sockeye

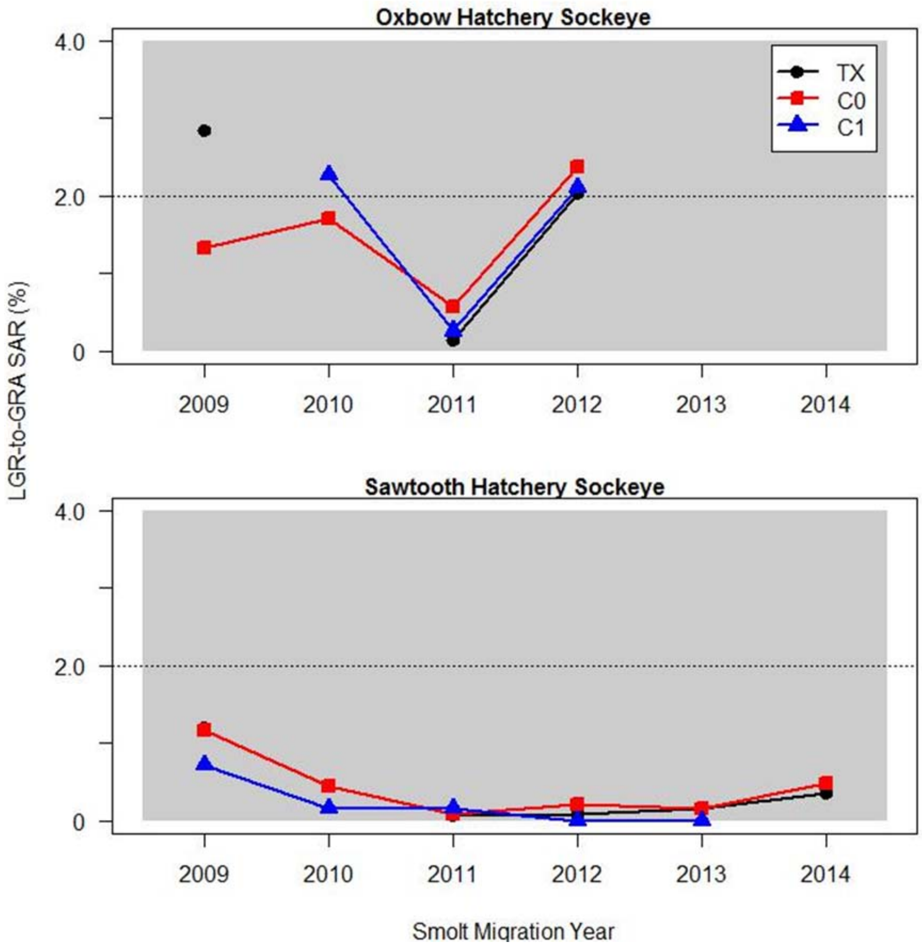


Figure A.16. Estimated LGR-to-GRA SAR for PIT-tagged hatchery sockeye groups in transport (T_X) and in-river (C_0 and C_1) study categories for migration years 2009 to 2014 (incomplete adult returns for 2014). Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2% SAR objective for listed wild populations is shown for reference. Hatchery sockeye data are from Tables A.31 and A.32.

Table A.31. Estimated LGR-to-GRA SAR (%) for PIT-tagged sockeye reared from Oxbow Hatchery for each study category from 2009 and 2012 (with 90% confidence intervals). Estimates beyond 2012 are not possible, due to decreased in PIT-tag release numbers.

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2009[B,C]	2.84 (1.89 – 3.64)	1.33 (0.89 – 1.86)	---
2010[D,E]	---	1.71 (1.18 – 2.29)	2.27 (1.03 – 3.71)
2011	0.14 (0.00 – 0.29)	0.58 (0.36 – 0.82)	0.26 (0.06 – 0.52)
2012	2.03 (1.41 – 2.70)	2.37 (1.88 – 2.92)	2.11 (0.00 – 11.11)
4-yr avg.	**1.67 (0.00 – 4.53)[F]**	**1.50 (0.48 – 2.52)**	**1.55 (0.00 – 3.86)[F]**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Used same methodology outlined in *Special Considerations for Migration Year 2010* (see page A-11) for 2009 Oxbow.
[C] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[D] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[E] Transport SAR not estimable – small estimated juvenile population and zero returning adults.
[F] Lower limit of 90% confidence interval shows as 0.00 rather than negative value resulting from limited degrees of freedom and lack of precision.

Table A.32. Estimated LGR-to-GRA SAR (%) for PIT-tagged sockeye reared from Sawtooth Hatchery for each study category from 2009 and 2014 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2009	1.21 (1.03 – 1.40)	1.16 (0.98 – 1.35)	0.72 (0.35 – 1.15)
2010[B]	---	0.45 (0.29 – 0.60)	0.16 (0.00 – 0.34)
2011	0.07 (0.03 – 0.13)	0.08 (0.04 – 0.12)	0.16 (0.09 – 0.24)
2012	0.08 (0.04 – 0.12)	0.21 (0.13 – 0.30)	0.00 (0.00 – 0.00)
2013	0.16 (0.10 – 0.23)	0.16 (0.10 – 0.22)	0.00 (0.00 – 0.00)
2014[C,D]	0.35 (0.23 – 0.48)	0.48 (0.39 – 0.58)	---
6-yr avg.	**0.38 (0.00[E] – 0.97)**	**0.41 (0.01 – 0.81)**	**0.21 (0.00[E] – 0.53)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Transport SAR not estimable – small estimated juvenile population and zero returning adults.
[C] Incomplete, 2-salt returns through Sept 16, 2016.
[D] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[E] The lower limit of 90% confidence limit is shown as 0.00 rather than the negative value resulting from limited degrees of freedom and lack of precision.

Wild and Hatchery Subyearling Fall Chinook

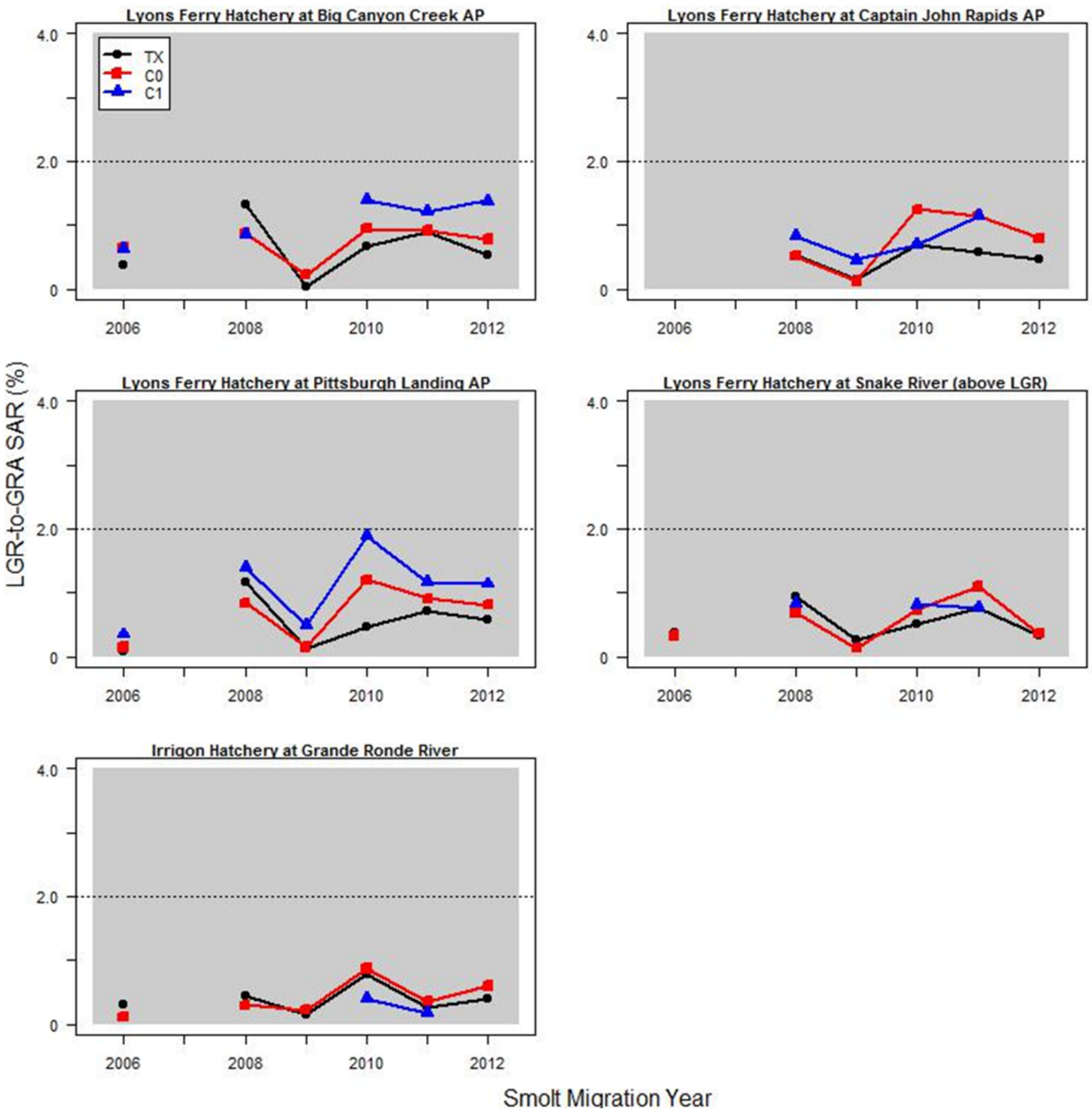


Figure A.17. Estimated LGR-to-GRA SAR for PIT-tagged Lyons Ferry and Irrigon hatchery subyearling fall Chinook in transport (T_X) and in-river (C_0 and C_1) study categories for migration years 2006 to 2012 (incomplete adult returns for 2012). Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2% SAR objective for listed wild populations is shown for reference. Data for above figures are from Tables A.34 through A.38.

Table A.33. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged wild/natural subyearling fall Chinook tagged and released into the mainstem Snake River (above Lower Granite Dam) for each study category from 2006 to 2009 (with 90% confidence intervals). Due to small sample sizes and no adult returns for some categories, estimates of SARs by study categories were not possible for migration years 2007-2012.

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006[B]	0.56 (0.00 – 1.73)	0.96 (0.34 – 1.69)	---

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.

Table A.34. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released from Big Canyon Creek Acclimation Pond (Clearwater River) for each study category from 2006 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006	0.37 (0.30 – 0.45)	0.66 (0.57 – 0.75)	0.64 (0.21 – 1.20)
2007[B]	---	---	---
2008	1.33 (1.07 – 1.63)	0.88 (0.76 - 1.00)	0.86 (0.00 – 1.98)
2009[C]	0.04 (0.00 – 0.13)	0.23 (0.13 – 0.34)	---
2010	0.66 (0.51 – 0.83)	0.95 (0.81 – 1.10)	1.40 (0.78 – 2.15)
2011	0.90 (0.70 – 1.09)	0.92 (0.81 – 1.04)	1.21 (0.66 – 1.91)
2012[D]	0.53 (0.38 – 0.70)	0.78 (0.67 – 0.89)	1.38 (0.00 – 7.69)
6-yr avg.	**0.64 (0.24 – 1.04)**	**0.74 (0.50 – 0.98)**	**1.09 (0.73 – 1.45)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[C] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[D] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.35. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released from Captain John Landing Acclimation Pond for each study category from 2007 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2007[B]	---	---	---
2008	0.50 (0.41 – 0.69)	0.52 (0.43 – 0.62)	0.83 (0.17 – 2.00)
2009	0.16 (0.06 – 0.30)	0.13 (0.05 – 0.22)	0.46 (0.00 – 1.50)
2010	0.69 (0.54 – 0.85)	1.25 (1.09 – 1.41)	0.70 (0.26 – 1.27)
2011	0.58 (0.41 – 0.76)	1.15 (1.01 – 1.28)	1.15 (0.67 – 1.66)
2012[C,D]	0.46 (0.34 – 0.58)	0.80 (0.69 – 0.91)	---
5-yr avg.	**0.64 (0.24 – 1.04)**	**0.74 (0.50 – 0.98)**	**0.79 (0.40 – 1.18)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[C] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[D] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.36. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released from Pittsburg Landing Acclimation Pond for each study category from 2006 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006	0.08 (0.03 – 0.12)	0.15 (0.09 – 0.23)	0.35 (0.00 – 0.81)
2007[B]	---	---	---
2008	1.17 (0.94 – 1.40)	0.84 (0.70 – 0.99)	1.40 (0.34 – 3.30)
2009	0.12 (0.00 – 0.25)	0.15 (0.07 – 0.25)	0.49 (0.00 – 1.62)
2010	0.46 (0.32 – 0.61)	1.20 (1.02 – 1.39)	1.89 (0.96 – 3.09)
2011	0.71 (0.50 – 0.94)	0.91 (0.78 – 1.03)	1.17 (0.61 – 1.79)
2012[C]	0.59 (0.45 – 0.77)	0.81 (0.68 – 0.94)	1.14 (0.00 – 4.30)
6-yr avg.	**0.52 (0.15 – 0.89)**	**0.68 (0.29 – 1.07)**	**1.07 (0.55 – 1.59)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.37. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released into the mainstem Snake River (above Lower Granite Dam) for each study category from 2006 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006[B]	0.37 (0.22 – 0.53)	0.33 (0.24 – 0.45)	---
2007[C]	---	---	---
2008	0.95 (0.62 – 1.34)	0.69 (0.50 – 0.88)	0.83 (0.00 – 3.53)
2009[B]	0.26 (0.09 – 0.44)	0.14 (0.05 – 0.23)	---
2010	0.52 (0.29 – 0.78)	0.73 (0.51 – 1.00)	0.82 (0.00 – 2.06)
2011	0.76 (0.50 – 1.01)	1.10 (0.90 – 1.33)	0.76 (0.00 – 1.80)
2012[B,D]	0.34 (0.15 – 0.59)	0.36 (0.25 – 0.48)	---
6-yr avg.	**0.53 (0.29 – 0.77)**	**0.56 (0.25 – 0.87)**	**0.80 (0.72 – 0.88)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] C_1 SAR not estimable – small estimated juvenile population and zero returning adult.
[C] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[D] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.38. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Irrigon Hatchery subyearling fall Chinook released into the Grande Ronde River for each study category from 2006 to 2012 (with 90% confidence intervals).

Migration Year[A]	SAR(T_X)_t %	SAR(C_0)_crt %	SAR(EC_1)_t %
2006[B,C]	0.31 (0.17 – 0.46)	0.11 (0.00 – 0.17)	---
2007[D]	---	---	---
2008[C]	0.45 (0.26 – 0.67)	0.30 (0.20 – 0.39)	---
2009[C]	0.15 (0.06 – 0.27)	0.23 (0.15 – 0.31)	---
2010	0.78 (0.59 – 0.98)	0.87 (0.72 – 1.03)	0.40 (0.00 – 0.98)
2011	0.26 (0.12 – 0.43)	0.36 (0.27 – 0.47)	0.18 (0.00 – 0.58)
2012[C,E]	0.41 (0.25 – 0.62)	0.60 (0.49 – 0.79)	---
6-yr avg.	**0.39 (0.19 – 0.59)**	**0.41 (0.16 – 0.66)**	**0.29 (0.00 – 1.27)[F]**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] 2006 release was reared at Lyons Ferry Hatchery
[C] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[D] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[E] Incomplete, 3-salt returns through Dec. 31, 2015.
[F] Lower limit of 90% confidence interval shown as 0.00 rather than negative value resulting from limited degrees of freedom and lack of precision.

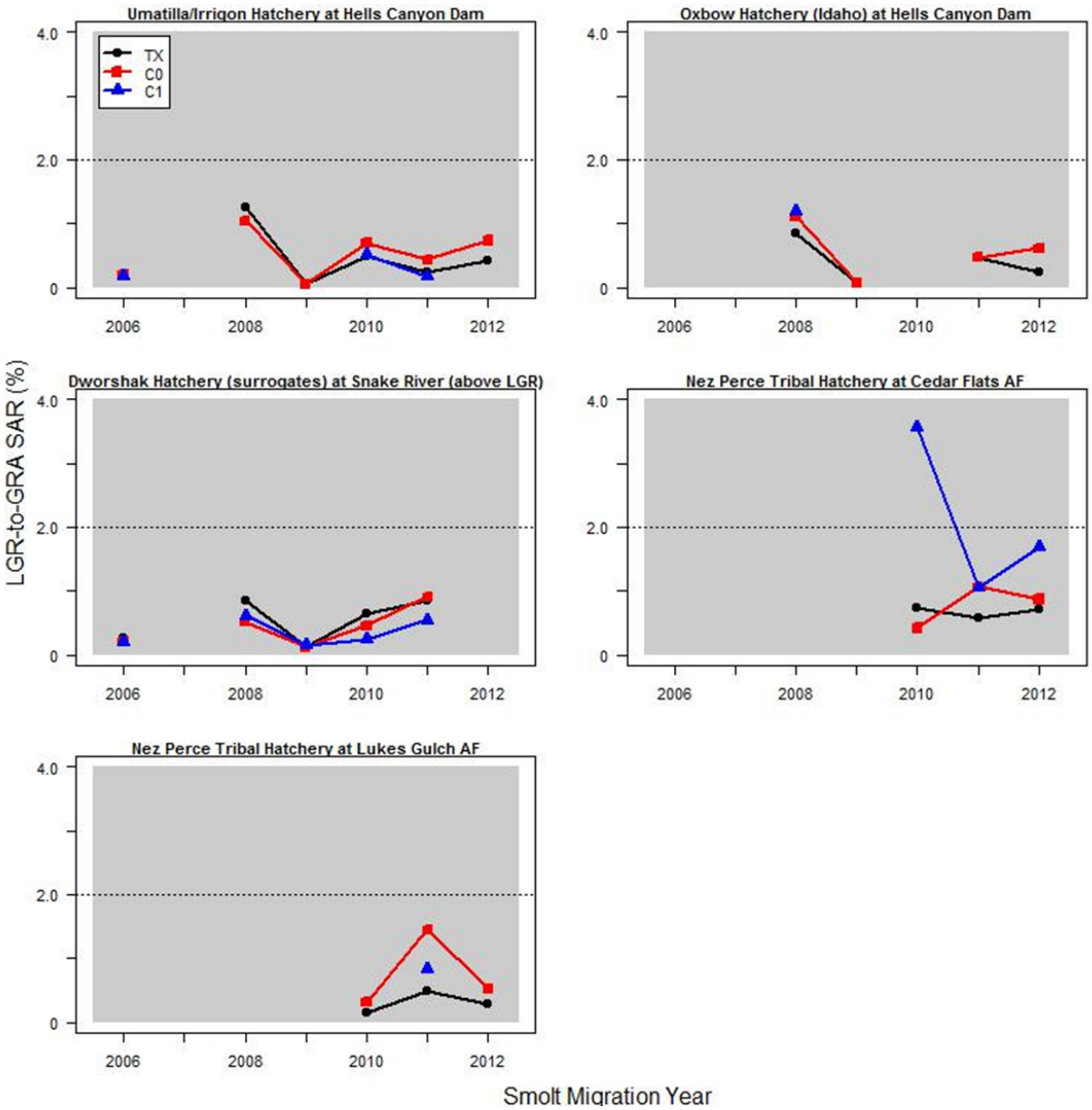


Figure A.18. Estimated LGR-to-GRA SAR for PIT-tagged subyearling fall Chinook (various hatcheries and release locations) in transport (T_X) and in-river (C_0 and C_1) study categories for migration years 2006 to 2012 (incomplete adult returns for 2012). Shaded area highlights the period of Court Order spill and later start of transportation. The NPCC (2014) 2% SAR objective for listed wild populations is shown for reference. Data for above figures are from Tables A.39 through A.43.

Table A.39. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Umatilla/Irrigon Hatchery subyearling fall Chinook released into the Snake River below Hells Canyon Dam for each study category from 2006 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006	0.22 (0.13 – 0.32)	0.20 (0.12 – 0.29)	0.18 (0.00 – 0.56)
2007[B]	---	---	---
2008[C]	1.25 (1.00 – 1.52)	1.05 (0.91 – 1.20)	---
2009[C]	0.07 (0.03 – 0.12)	0.05 (0.03 – 0.08)	---
2010	0.49 (0.35 – 0.65)	0.70 (0.58 – 0.83)	0.52 (0.25 – 0.87)
2011	0.24 (0.12 – 0.37)	0.44 (0.33 – 0.55)	0.17 (0.00 – 0.53)
2012[C,D]	0.42 (0.27 – 0.57)	0.74 (0.63 – 0.86)	---
6-yr avg.	**0.39 (0.19 – 0.59)**	**0.41 (0.16 – 0.66)**	**0.29 (0.00 – 0.70)**[E]

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[C] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[D] Incomplete, 3-salt returns through Dec. 31, 2015.
[E] Lower limit of 90% confidence interval shown as 0.00 rather than negative value resulting from limited degrees of freedom and lack of precision.

Table A.40. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Oxbow Hatchery (Idaho) subyearling fall Chinook released into the Snake River below Hells Canyon Dam for each study category from 2006 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2007[B]	---	---	---
2008	0.86 (0.58 – 1.16)	1.11 (0.86 – 1.36)	1.19 (0.29 – 2.42)
2009[C]	0.08 (0.00 – 0.20)	0.08 (0.02 – 0.16)	---
2010[D]	---	---	---
2011[C]	0.47 (0.20 – 0.81)	0.47 (0.33 – 0.62)	---
2012[C,E]	0.25 (0.11 – 0.41)	0.62 (0.43 – 0.82)	---
4-yr avg.	**0.27 (0.00 – 0.67)**[F]	**0.39 (0.00 – 0.97)**[F]	**---**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of SARs by study category were not possible.
[C] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[D] No PIT-tags were released for this group in 2010.
[E] Incomplete, 3-salt returns through Dec. 31, 2015.
[F] Lower limit of 90% confidence interval shown as 0.00 rather than negative value resulting from limited degrees of freedom and lack of precision.

Table A.41. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Dworshak Hatchery subyearling fall Chinook (surrogates) released into the mainstem Snake River (above Lower Granite Dam) for each study category from 2006 to 2011 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2006	0.27 (0.22 – 0.32)	0.21 (0.18 – 0.24)	0.20 (0.05 – 0.44)
2007[B]	---	---	---
2008	0.85 (0.75 – 0.95)	0.52 (0.47 – 0.56)	0.62 (0.29 – 1.07)
2009	0.14 (0.09 – 0.19)	0.13 (0.11 – 0.16)	0.16 (0.11 – 0.21)
2010	0.65 (0.54 – 0.77)	0.46 (0.41 – 0.52)	0.24 (0.06 – 0.46)
2011	0.85 (0.75 – 0.96)	0.91 (0.84 – 0.97)	0.55 (0.32 – 0.81)
2012[C]	---	---	---
5-yr avg.	**0.55 (0.20 – 0.90)**	**0.45 (0.12 – 0.78)**	**0.35 (0.12 – 0.58)**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] SARs not estimable due to high estimated holdover rates.

Table A.42. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Nez Perce Tribal Hatchery subyearling fall Chinook released from the Cedar Flats Acclimation Facility (Clearwater River) for each study category from 2010 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2010	0.74 (0.29 – 1.22)	0.42 (0.27 – 0.58)	3.57 (0.00 – 25.00)
2011	0.57 (0.35 – 0.78)	1.07 (0.86 – 1.29)	1.05 (0.25 – 2.42)
2012[B]	0.71 (0.38 – 1.09)	0.87 (0.69 – 1.08)	1.69 (0.00 – 6.25)
3-yr avg.	**0.67 (0.48 – 0.86)**	**0.79 (0.10 – 1.48)**	**2.1 (0.00 – 4.80)**[C]

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] Incomplete, 3-salt returns through Dec.31, 2015.
[C] Lower limit of 90% confidence interval shown as 0.00 rather than negative value resulting from limited degrees of freedom and lack of precision.

Table A.43. Estimated LGR-to-GRA SAR (%) (without jacks) for PIT-tagged Nez Perce Tribal Hatchery subyearling fall Chinook released from the Lukes Gulch Acclimation Facility (Clearwater River) for each study category from 2010 to 2012 (with 90% confidence intervals).

Migration Year[A]	$SAR(T_X)$_t %	$SAR(C_0)$_crt %	$SAR(EC_1)$_t %
2010[B]	0.15 (0.05– 0.31)	0.32 (0.20 – 0.45)	---
2011	0.50 (0.30 – 0.72)	1.45 (1.21 – 1.72)	0.83 (0.00 – 2.16)
2012[B,C]	0.28 (0.09 – 0.49)	0.53 (0.40 – 0.66)	---
3-yr avg.	**0.31 (0.00 – 0.86)**[D]	**0.77 (0.00 – 2.01)**[D]	**---**

[A] All monitor mode years, estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[B] C_1 SAR not estimable – small estimated juvenile population and zero returning adults.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.
[D] Lower limit of 90% confidence interval shows as 0.00 rather than negative value resulting from limited degrees of freedom and lack of precision.

Estimates of TIR and *D*

Presented here are the estimates of Transport:In-River SAR Ratios (TIR) and differential delayed effects of transportation (*D*) for Snake River spring/summer Chinook, steelhead, sockeye, and subyearling fall Chinook.

Wild and Hatchery Spring/Summer Chinook

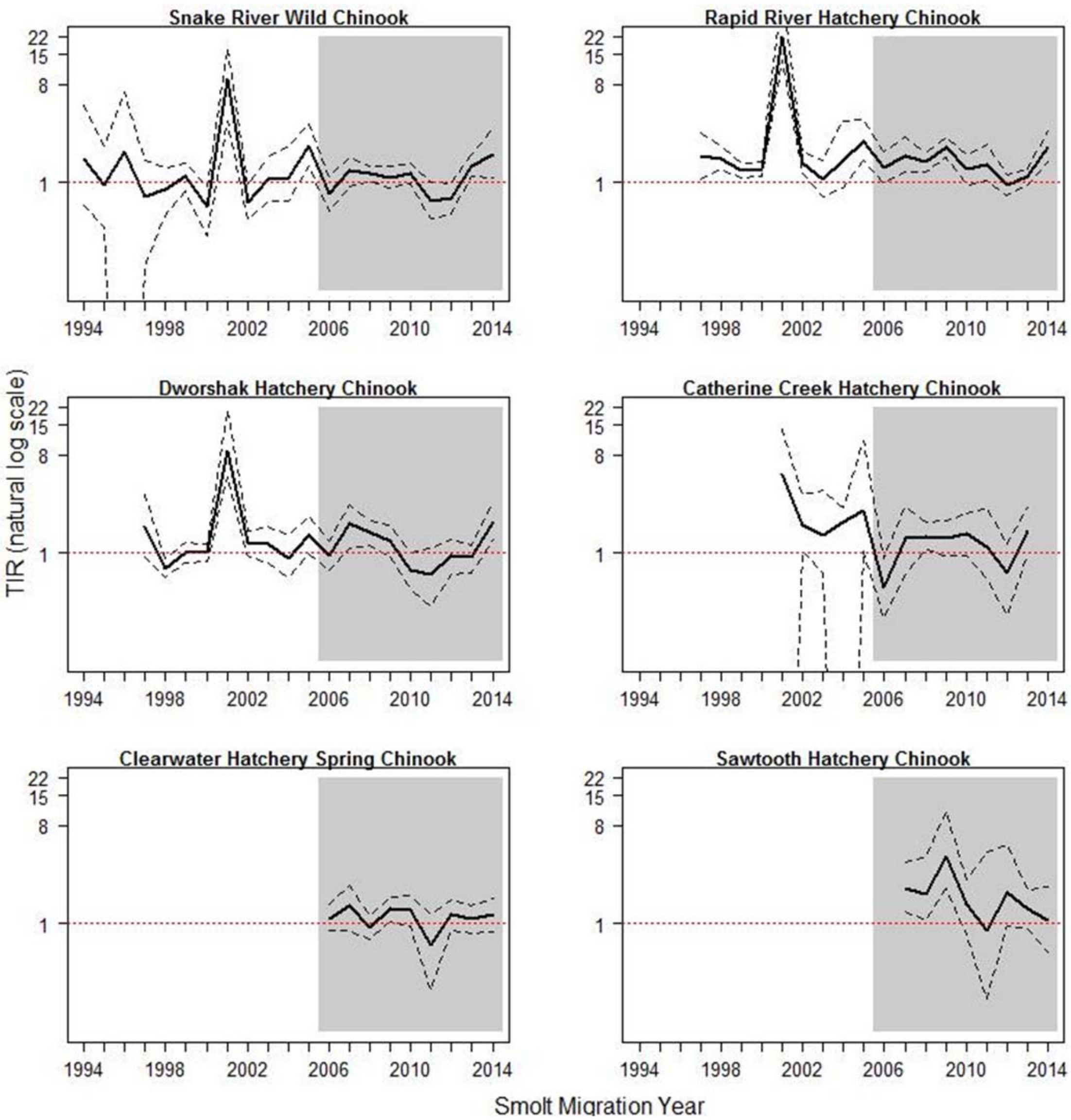


Figure A.19. Trend in TIR on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery spring Chinook for migration years 1994 to 2014 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. TIR calculation for 2001 and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Wild Chinook data are from Table A.44; hatchery spring Chinook data are from Tables A.45–A.49.

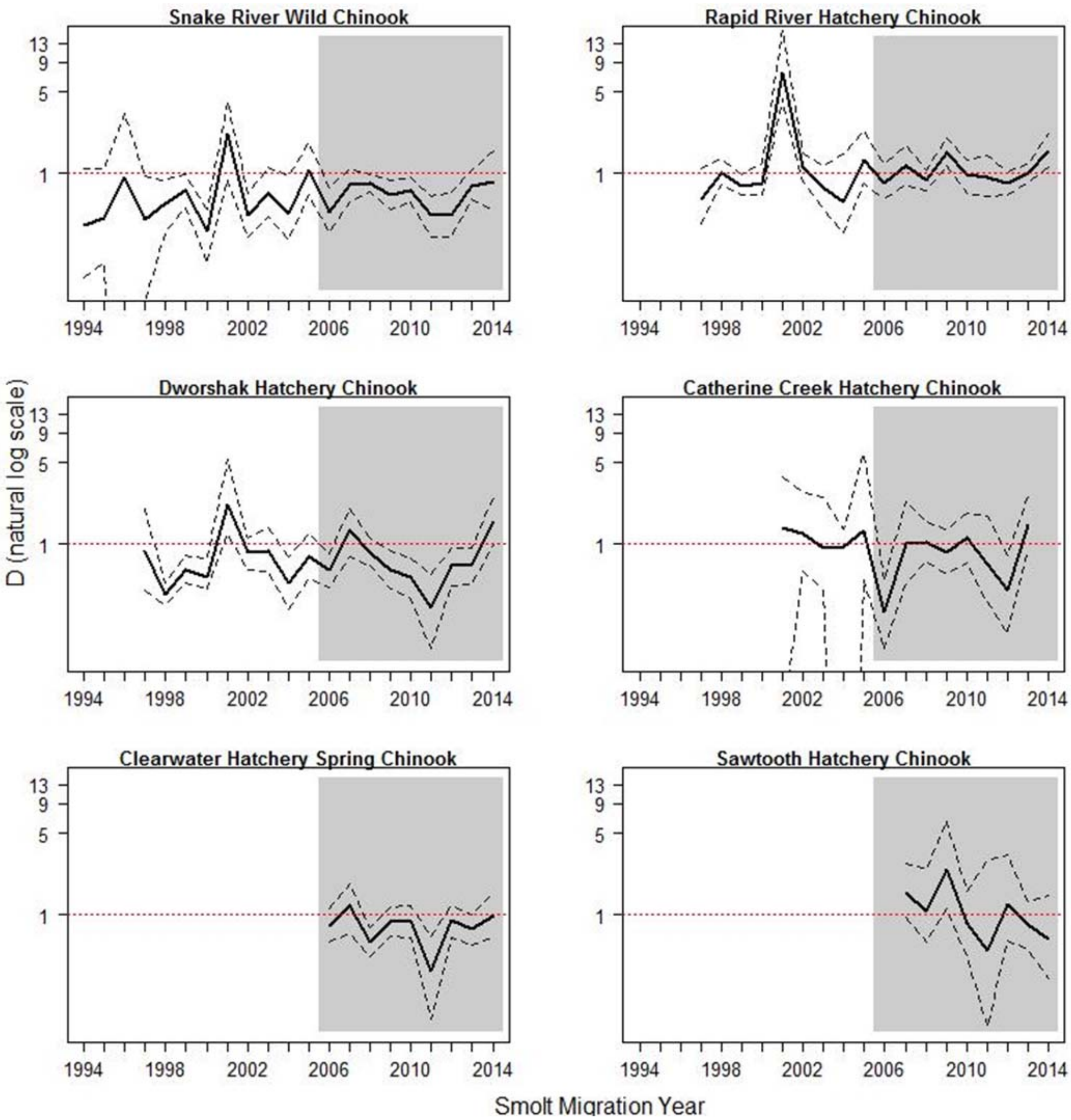


Figure A.20. Trend in *D* on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery spring Chinook in migration years 1994–2014 (with 90% confidence intervals). The red horizontal dotted line denotes a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. *D* calculation for 2001 and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Wild Chinook data are from Table A.44; hatchery spring Chinook data from Tables A.45–A.49.

Table A.44. Estimated TIR and *D* of PIT-tagged wild Chinook for migration years 1994 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1994	1.62	(0.62 – 5.05)	0.36	(0.13 – 1.09)
1995	0.95	(0.39 – 2.14)	0.42	(0.17 – 1.09)
1996	1.92	(0.00 – 6.80)	0.92	(0.00 – 3.24)
1997	0.74	(0.17 – 1.58)	0.40	(0.08 – ***0.95***)
1998	0.87	(0.50 – 1.35)	0.55	(0.31 – ***0.87***)
1999	1.14	(0.82 – 1.51)	0.72	(0.52 – ***0.98***)
2000	0.60	(0.32 – ***0.92***)	0.32	(0.17 – ***0.50***)
2001[A]	8.96	(**3.61** – 16.8)	2.16	(0.87 – 4.16)
2002	0.65	(0.45 – ***0.94***)	0.44	(0.29 – ***0.68***)
2003	1.05	(0.68 – 1.68)	0.68	(0.43 – 1.12)
2004	1.09	(0.68 – 2.19)	0.45	(0.27 – ***0.95***)
2005[B]	2.14	(**1.40** – 3.45)	1.07	(0.65 – 1.85)
Monitor Mode Years[C]				
2006	0.78	(0.54 – 1.14)	0.47	(0.31 – ***0.75***)
2007	1.27	(0.91 – 1.71)	0.80	(0.57 – 1.09)
2008	1.19	(**1.02** – 1.39)	0.82	(0.69 – ***0.97***)
2009	1.11	(0.89 – 1.41)	0.65	(0.50 – ***0.87***)
2010	1.21	(0.96 – 1.48)	0.72	(0.57 – ***0.92***)
2011	0.68	(0.46 – ***0.99***)	0.44	(0.29 – ***0.63***)
2012	0.71	(0.51 – ***0.98***)	0.44	(0.29 – ***0.69***)
2013	1.42	(**1.15** – 1.78)	0.79	(0.60 – 1.07)
2014[D]	1.82	(**1.11** – 3.14)	0.85	(0.49 – 1.54)
Geomean	1.19	(0.95 – 1.48)	0.62	(0.52 – ***0.73***)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.45. Estimated TIR and *D* of PIT-tagged Rapid River Hatchery spring Chinook for 1997 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1997	1.73	(**1.08** – 2.85)	0.61	(0.37 – 1.09)
1998	1.66	(**1.32** – 2.16)	1.01	(0.80 – 1.36)
1999	1.28	(**1.11** – 1.51)	0.79	(0.65 – ***0.99***)
2000	1.32	(**1.13** – 1.55)	0.82	(0.66 – 1.25)
2001[A]	21.70	(**13.3** – 54.1)	7.33	(**4.40** – 16.9)
2002	1.51	(**1.20** – 1.91)	1.14	(0.87 – 1.52)
2003	1.07	(0.73 – 1.58)	0.75	(0.50 – 1.15)
2004	1.57	(0.88 – 3.67)	0.57	(0.31 – 1.46)
2005[B]	2.36	(**1.59** – 3.79)	1.31	(0.83 – 2.30)
Monitor Mode Years[C]				
2006	1.35	(0.98 – 1.91)	0.83	(0.60 – 1.19)
2007	1.77	(**1.25** – 2.57)	1.18	(0.81 – 1.74)
2008	1.52	(**1.26** – 1.85)	0.87	(0.71 – 1.08)
2009	2.08	(**1.69** – 2.57)	1.51	(**1.17** – 2.00)
2010	1.33	(0.95 – 1.78)	0.97	(0.68 – 1.31)
2011	1.47	(**1.02** – 2.25)	0.93	(0.63 – 1.44)
2012	0.94	(0.75 – 1.17)	0.82	(0.65 – 1.04)
2013	1.12	(0.94 – 1.33)	1.00	(0.83 – 1.21)
2014[D]	2.11	(**1.56** – 2.93)	1.55	(**1.13** – 2.16)
Geomean	1.74	(**1.32** – 2.29)	1.06	(0.84 – 1.33)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.46. Estimated TIR and *D* of PIT-tagged Dworshak Hatchery spring Chinook for 1997 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1997	1.75	(0.92 – 3.46)	0.88	(0.40 – 2.01)
1998	0.72	(0.59 – ***0.88***)	0.37	(0.30 – ***0.47***)
1999	0.99	(0.81 – 1.24)	0.60	(0.47 – ***0.81***)
2000	0.99	(0.82 – 1.19)	0.53	(0.42 – ***0.75***)
2001[A]	8.76	(**5.04** – 20.4)	2.21	(**1.23** – 5.30)
2002	1.24	(0.93 – 1.61)	0.84	(0.61 – 1.12)
2003	1.21	(0.81 – 1.75)	0.88	(0.58 – 1.37)
2004	0.89	(0.59 – 1.43)	0.46	(0.28 – ***0.77***)
2005[B]	1.43	(0.97 – 2.17)	0.77	(0.51 – 1.22)
Monitor Mode Years[C]				
2006	0.95	(0.69 – 1.30)	0.60	(0.43 – ***0.83***)
2007	1.84	(**1.11** – 2.81)	1.31	(0.78 – 2.02)
2008	1.53	(**1.17** – 1.99)	0.86	(0.66 – 1.13)
2009	1.29	(0.92 – 1.80)	0.60	(0.42 – ***0.88***)
2010	0.70	(0.46 – 1.01)	0.52	(0.34 – ***0.75***)
2011	0.63	(0.32 – 1.09)	0.29	(0.13 – ***0.56***)
2012	0.94	(0.63 – 1.31)	0.65	(0.44 – ***0.93***)
2013	0.90	(0.65 – 1.17)	0.67	(0.45 – ***0.94***)
2014[D]	1.94	(**1.32** – 2.86)	1.54	(0.98 – 2.51)
Geomean	1.25	(0.98 – 1.59)	0.72	(0.58 – ***0.88***)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.47. Estimated TIR and *D* of PIT-tagged Catherine Creek AP spring Chinook for 2001 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
2001[A]	5.33	(0.00 – 13.6)	1.38	(0.03 – 3.79)
2002	1.81	(**1.02** – 3.43)	1.23	(0.59 – 2.79)
2003	1.45	(0.65 – 3.79)	0.94	(0.41 – 2.53)
2004	1.94	(0.00 – 2.57)	0.95	(0.00 – 1.33)
2005[B]	2.48	(**1.02** – 10.6)	1.32	(0.50 – 5.90)
Monitor Mode Years[C]				
2006	0.48	(0.25 – ***0.88***)	0.26	(0.13 – ***0.50***)
2007	1.35	(0.65 – 2.71)	1.02	(0.46 – 2.29)
2008	1.41	(**1.06** – 1.92)	1.05	(0.72 – 1.53)
2009	1.35	(0.94 – 1.95)	0.85	(0.55 – 1.35)
2010[D]	1.51	(0.94 – 2.32)	1.13	(0.70 – 1.86)
2011	1.15	(0.57 – 2.58)	0.68	(0.32 – 1.72)
2012	0.66	(0.27 – 1.21)	0.41	(0.17 – ***0.80***)
2013	1.58	(0.97 – 2.63)	1.48	(0.86 – 2.62)
2014[E,F]		---		---
Geomean	1.47	(**1.10** – 1.96)	0.89	(0.69 – 1.14)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[E] Incomplete, 2-salt returns through Sept. 16, 2016.
[F] Too few adults in Transport and/or C_0 group to estimate TIR and D.

Table A.48. Estimated TIR and *D* of PIT-tagged Clearwater Hatchery spring Chinook for 2006 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year[A]	TIR		*D*	
2006	1.11	(0.85 – 1.50)	0.80	(0.59 – 1.13)
2007	1.47	(0.86 – 1.24)	1.21	(0.70 – 1.85)
2008	0.91	(0.71 – 1.18)	0.59	(0.44 – ***0.78***)
2009	1.35	(**1.04** – 1.76)	0.88	(0.66 – 1.18)
2010[B]	1.33	(0.94 – 1.78)	0.90	(0.64 – 1.21)
2011	0.63	(0.24 – 1.22)	0.33	(0.13 – ***0.66***)
2012	1.22	(0.86 – 1.66)	0.90	(0.63 – 1.21)
2013	1.11	(0.80 – 1.44)	0.76	(0.55 – 1.01)
2014[C]	1.19	(0.83 – 1.70)	0.98	(0.64 – 1.56)
Geomean	1.12	(0.95 – 1.31)	0.77	(0.61 – ***0.98***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.49. Estimated TIR and *D* of PIT-tagged Sawtooth Hatchery spring Chinook for 2007 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year[A]	TIR		*D*	
2007	2.08	(**1.27** – 3.66)	1.56	(0.96 – 2.73)
2008	1.88	(**1.08** – 4.11)	1.08	(0.58 – 2.46)
2009	4.19	(**2.08** – 10.67)	2.42	(**1.13** – 6.33)
2010[B]	1.51	(0.78 – 2.56)	0.85	(0.44 – 1.58)
2011	0.85	(0.20 – 4.47)	0.49	(0.11 – 2.89)
2012	1.93	(0.94 – 5.22)	1.24	(0.60 – 3.31)
2013	1.36	(0.88 – 2.02)	0.82	(0.51 – 1.31)
2014[C]	1.08	(0.54 – 2.15)	0.62	(0.29 – 1.48)
Geomean	1.67	(**1.21** – 2.30)	1.01	(0.71 – 1.42)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

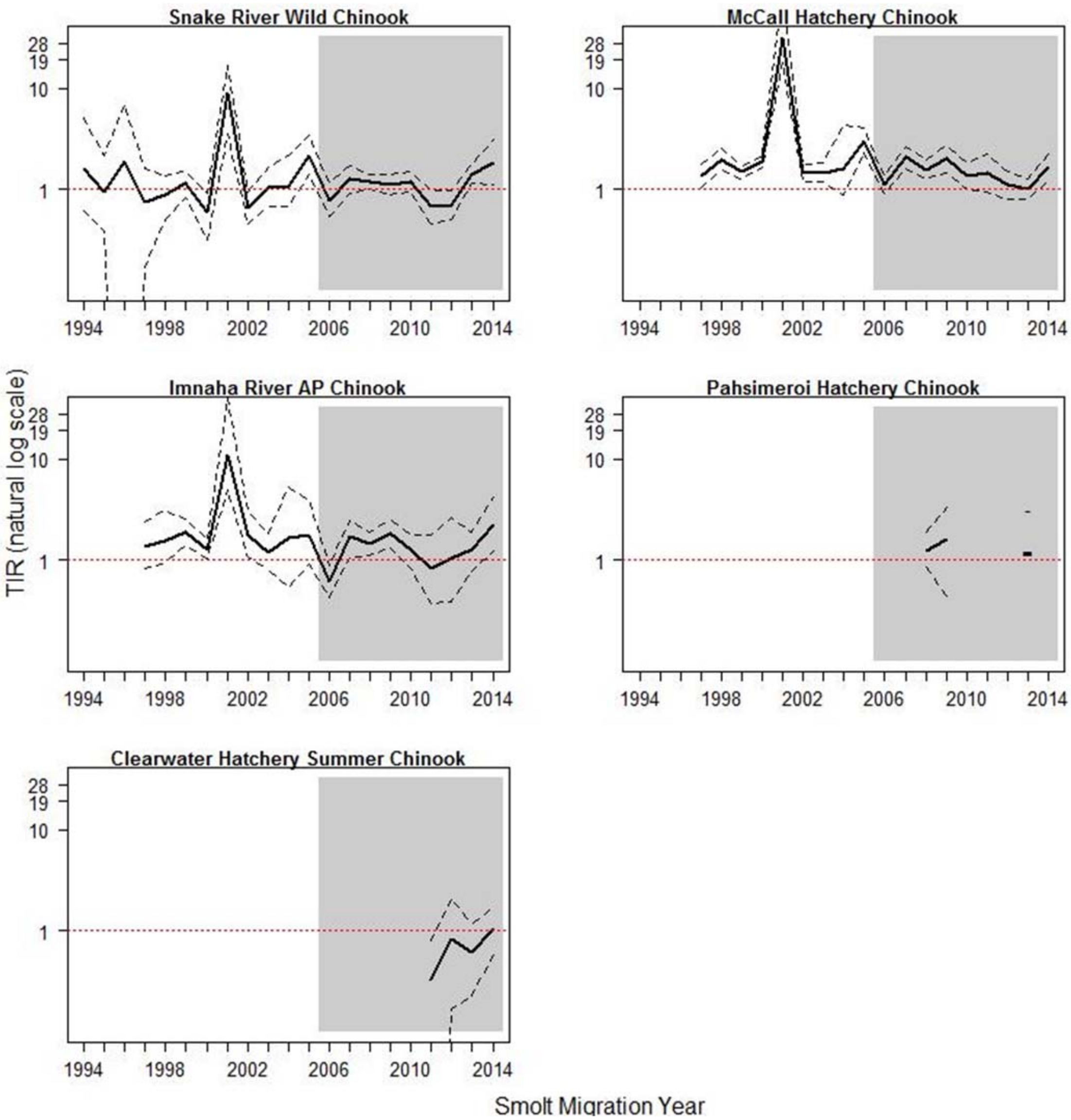


Figure A.21. Trend in TIR on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery summer Chinook for migration years 1994 to 2014 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. TIR calculation for 2001 and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Wild Chinook data are from Table A.44; hatchery summer Chinook data are from Tables A.50–A.53. TIR estimate for PAHH not possible in 2010–2012 and 2014, see footnote B in Table A.52.

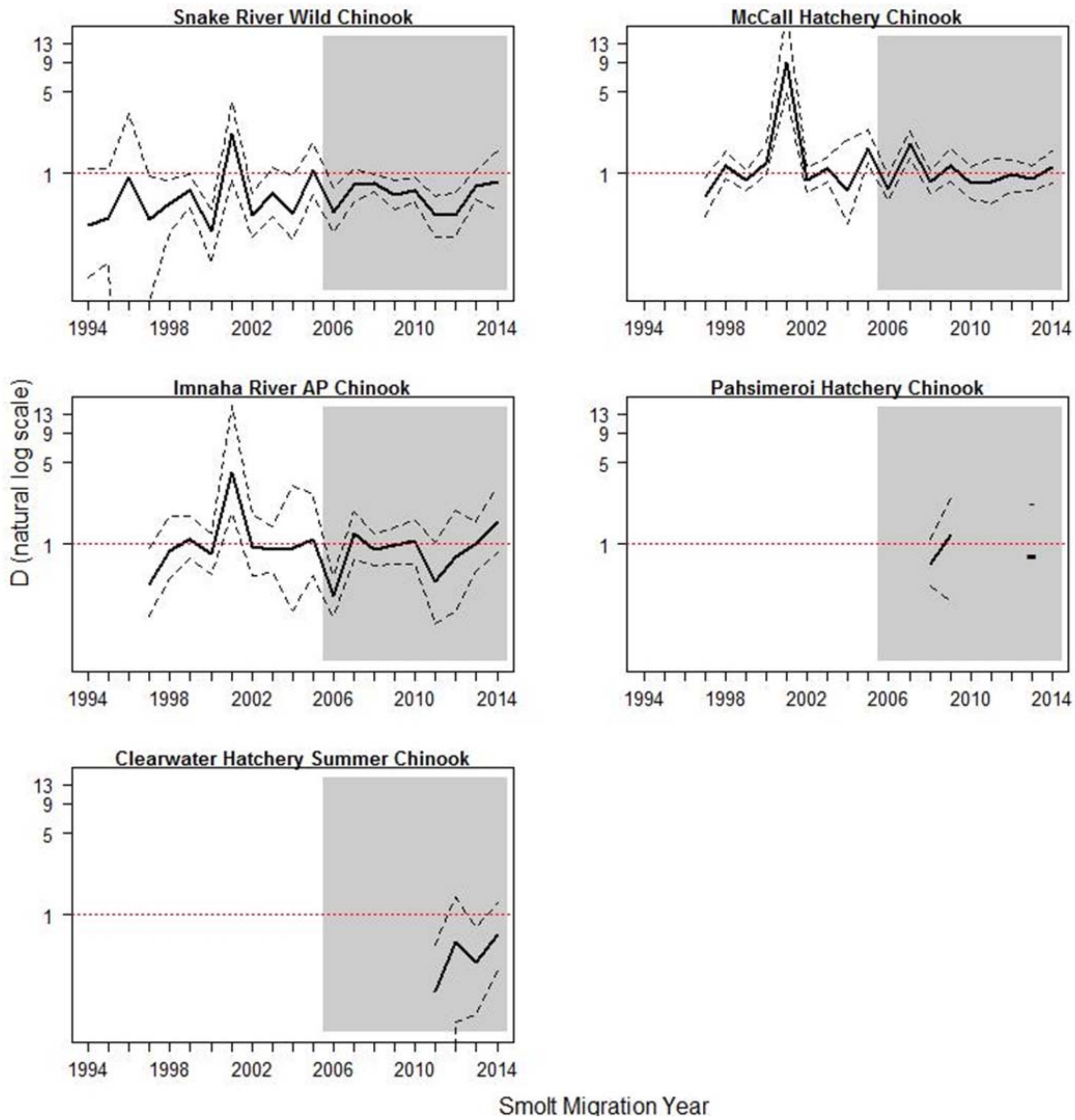


Figure A.22. Trend in *D* on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery summer Chinook in migration years 1994–2014 (with 90% confidence intervals). The red horizontal dotted line denotes a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. *D* calculation for 2001 and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Wild Chinook data are from Table A.44; hatchery summer Chinook data are from Tables A.50–A.53. *D* estimate for PAHH in 2010–2012 and 2014 not possible, see footnote D in Table A.52 above.

Table A.50. Estimated TIR, and *D* of PIT-tagged McCall Hatchery summer Chinook for 1997 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1997	1.38	(**1.06** – 1.80)	0.64	(0.43 – ***0.93***)
1998	1.96	(**1.54** – 2.56)	1.16	(0.89 – 1.54)
1999	1.49	(**1.29** – 1.73)	0.87	(0.72 – 1.07)
2000	1.89	(**1.67** – 2.15)	1.24	(0.98 – 1.81)
2001[A]	31.9	(**17.9** – 88.4)	8.95	(**4.87** – 24.1)
2002	1.44	(**1.18** – 1.79)	0.87	(0.68 – 1.14)
2003	1.47	(**1.18** – 1.83)	1.09	(0.85 – 1.37)
2004	1.59	(0.87 – 4.37)	0.72	(0.37 – 1.95)
2005[B]	3.02	(**2.32** – 4.12)	1.66	(**1.23** – 2.36)
Monitor Mode Years[C]				
2006	1.11	(0.90 – 1.38)	0.74	(0.59 – ***0.95***)
2007	2.09	(**1.63** – 2.65)	1.78	(**1.35** – 2.31)
2008	1.54	(**1.26** – 1.94)	0.84	(0.67 – 1.08)
2009	2.00	(**1.45** – 2.71)	1.17	(0.84 – 1.64)
2010[D]	1.37	(**1.01** – 1.84)	0.82	(0.60 – 1.13)
2011	1.43	(0.94 – 2.25)	0.84	(0.55 – 1.34)
2012	1.11	(0.79 – 1.48)	0.97	(0.69 – 1.32)
2013	1.01	(0.81 – 1.28)	0.90	(0.71 – 1.16)
2014[E]	1.65	(**1.22** – 2.21)	1.14	(0.82 – 1.55)
Geomean	1.85	(**1.36** – 2.52)	1.12	(0.88 – 1.42)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[E] Incomplete, 2-salt returns through Sept 16, 2016.

Table A.51. Estimated TIR and *D* of PIT-tagged Imnaha AP summer Chinook for 1997 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1997	1.36	(0.83 – 2.37)	0.45	(0.24 – ***0.92***)
1998	1.55	(0.93 – 3.15)	0.87	(0.51 – 1.72)
1999	1.89	(**1.40** – 2.51)	1.11	(0.75 – 1.72)
2000	1.29	(**1.06** – 1.58)	0.82	(0.56 – 1.25)
2001[A]	10.80	(**4.94** – 39.8)	4.15	(**1.83** – 15.3)
2002	1.75	(**1.07** – 3.03)	0.95	(0.54 – 1.78)
2003	1.21	(0.80 – 1.86)	0.91	(0.57 – 1.41)
2004	1.64	(0.54 – 5.32)	0.94	(0.27 – 3.14)
2005[B]	1.77	(0.91 – 3.93)	1.11	(0.54 – 2.69)
Monitor Mode Years[C]				
2006	0.62	(0.42 – ***0.89***)	0.36	(0.24 – ***0.54***)
2007	1.70	(**1.05** – 2.50)	1.22	(0.74 – 1.90)
2008	1.45	(**1.10** – 1.92)	0.89	(0.66 – 1.25)
2009	1.83	(**1.31** – 2.53)	0.97	(0.68 – 1.39)
2010[D]	1.27	(0.82 – 1.80)	1.07	(0.67 – 1.61)
2011	0.83	(0.37 – 1.76)	0.48	(0.21 – 1.03)
2012	1.06	(0.38 – 2.61)	0.78	(0.26 – 1.94)
2013	1.27	(0.77 – 1.90)	1.00	(0.58 – 1.56)
2014[E]	2.20	(**1.24** – 4.25)	1.55	(0.86 – 3.11)
Geomean	1.56	(**1.23** – 1.97)	0.94	(0.76 – 1.16)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] See Section: *Special Considerations for Migration Year 2010* on page A-11.
[E] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.52. Estimated TIR and *D* of PIT-tagged Pahsimeroi Hatchery summer Chinook for 2008 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year[A]	TIR		*D*	
2008	1.23	(0.85 – 1.90)	0.68	(0.44 – 1.09)
2009	1.62	(0.44 – 3.34)	1.20	(0.33 – 2.44)
2010[B]		---		---
2011[B]		---		---
2012[B]		---		---
2013	1.18	(0.00 – 3.09)	0.80	(0.00 – 2.26)
2014[B,C]		---		---
Geomean	1.33	(0.93 – 1.90)	0.87	(0.47 – 1.59)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Too few adults in Transport and/or C_0 study category to estimate TIR and *D*.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table A.53. Estimated TIR and *D* of PIT-tagged Clearwater Hatchery summer Chinook for 2011 and 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year[A]	TIR		*D*	
2011	0.33	(0.07 – ***0.80***)	0.22	(0.05 – ***0.56***)
2012	0.83	(0.17 – 2.08)	0.58	(0.12 – 1.44)
2013	0.62	(0.23 – 1.15)	0.39	(0.14 – ***0.79***)
2014 [B]	1.05	(0.58 – 1.73)	0.68	(0.34 – 1.28)
Geomean	0.65	(0.36 – 1.17)	0.43	(0.24 – ***0.78***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Wild and Hatchery Steelhead

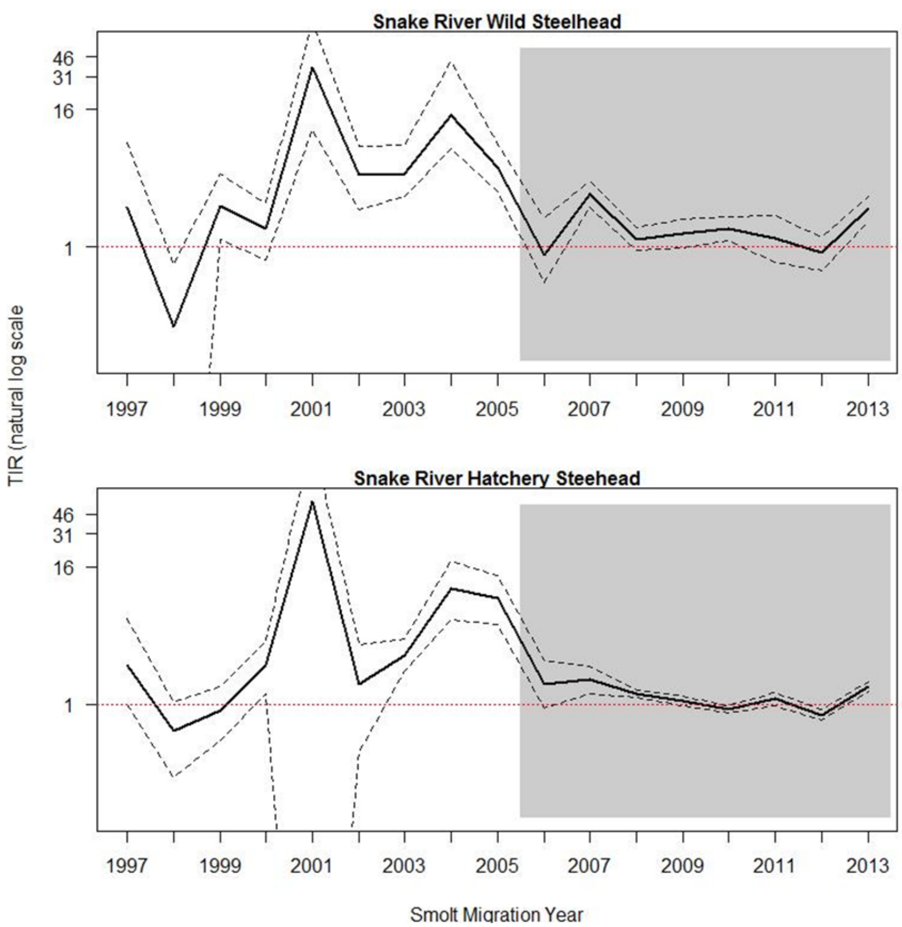


Figure A.23. Trend in TIR on the natural log scale for PIT-tagged Snake River wild (aggregate) and hatchery (aggregate) in migration years 1997 to 2013 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. TIR calculation for 2001, 2004, and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Data for wild steelhead (aggregate) are from Table A.54; hatchery (aggregate) steelhead data are from Table A.55.

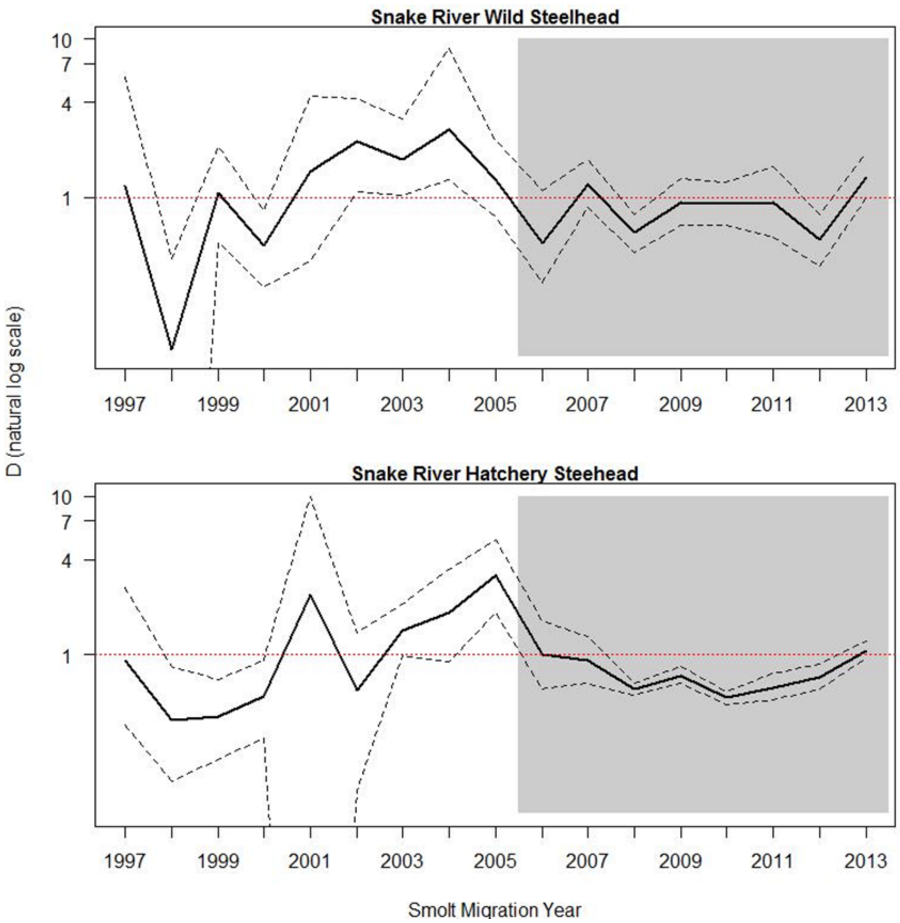


Figure A.24. Trend in *D* on the natural log scale for PIT-tagged Snake River wild (aggregate) and hatchery (aggregate) steelhead in migration years 1997–2013 (with 90% confidence intervals). The red horizontal dotted line corresponds to a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. *D* calculation for 2001, 2004, and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Data for wild steelhead (aggregate) are from Table A.54; hatchery (aggregate) steelhead data are from Table A.55.

Table A.54. Estimated TIR and *D* of PIT-tagged wild steelhead for migration years 1997 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1997	2.20	(0.00 – 8.16)	1.18	(0.00 – 5.74)
1998	0.20	(0.00 – ***0.70***)	0.11	(0.00 – ***0.41***)
1999	2.28	(**1.15** – 4.38)	1.07	(0.53 – 2.09)
2000	1.45	(0.77 – 2.40)	0.50	(0.27 – ***0.82***)
2001[A]	37.00	(**10.6** – 94.6)	1.46	(0.40 – 4.40)
2002	4.25	(**2.12** – 7.67)	2.24	(**1.09** – 4.25)
2003	4.41	(**2.74** – 7.73)	1.75	(**1.04** – 3.16)
2004[B]	14.30	(**7.19** – 42.10)	2.69	(**1.29** – 8.78)
2005[B]	4.88	(**3.01** – 7.98)	1.30	(0.76 – 2.30)
Monitor Mode Years[C]				
2006	0.85	(0.49 – 1.80)	0.52	(0.29 – 1.11)
2007	2.89	(**2.21** – 3.80)	1.20	(0.87 – 1.74)
2008	1.16	(0.93 – 1.49)	0.60	(0.45 – ***0.79***)
2009	1.31	(0.99 – 1.75)	0.94	(0.67 – 1.32)
2010	1.45	(**1.12** – 1.85)	0.92	(0.67 – 1.26)
2011	1.18	(0.74 – 1.86)	0.93	(0.56 – 1.56)
2012	0.88	(0.62 – 1.22)	0.54	(0.37 – ***0.78***)
2013[D]	2.15	(**1.67** – 2.79)	1.35	(1.00 – 1.93)
Geomean	2.23	(**1.36** – 3.67)	0.93	(0.68 – 1.27)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[D] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.55. Estimated TIR, and *D* of PIT-tagged hatchery (aggregate) steelhead for migration years 1997 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. After 2005, transport operations initiated on a delayed start date compared to previous years.

Migration Year	TIR		*D*	
1997	2.21	(0.99 – 5.66)	0.92	(0.36 – 2.67)
1998	0.58	(0.23 – 1.05)	0.39	(0.16 – ***0.85***)
1999	0.87	(0.48 – 1.41)	0.41	(0.22 – ***0.70***)
2000	2.20	(**1.22** – 3.58)	0.55	(0.30 – ***0.93***)
2001[A]	59.70	(0.00 – 215.6)	2.40	(0.00 – 10.0)
2002	1.51	(0.38 – 3.33)	0.60	(0.14 – 1.38)
2003	2.65	(**1.93** – 3.71)	1.43	(0.99 – 2.10)
2004[B]	10.30	(**5.43** – 17.9)	1.85	(0.91 – 3.46)
2005[B]	8.44	(**5.04** – 13.4)	3.19	(**1.86** – 5.37)
2006[C]	1.50	(0.93 – 2.42)	1.01	(0.61 – 1.63)
2007[C]	1.66	(**1.22** – 2.16)	0.92	(0.66 – 1.30)
Monitor Mode Years[D]				
2008[E]	1.23	(**1.15** – 1.31)	0.61	(0.56 – ***0.66***)
2009	1.06	(0.97 – 1.17)	0.74	(0.66 – ***0.84***)
2010	0.90	(0.83 – ***0.97***)	0.54	(0.49 – ***0.59***)
2011	1.11	(0.97 – 1.27)	0.62	(0.52 – ***0.76***)
2012	0.80	(0.73 – ***0.90***)	0.72	(0.61 – ***0.88***)
2013[F]	1.42	(**1.29** – 1.56)	1.07	(0.95 – 1.22)
Geomean	2.04	(**1.25** – 3.33)	0.88	(0.68 – 1.13)

[A] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[C] No pre-assignment for hatchery steelhead, so one group; transport SARs estimated with T_X smolts.
[D] Estimated SARs for T_X and C_1 with Group T (reflects later start of transportation), and C_0 with combined Group CRT.
[E] TIR and D estimates for 2008 hatchery steelhead aggregate includes all groups with pre-assignment (see Tables A.23–A.26 and A.28-A.29 for details).
[F] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

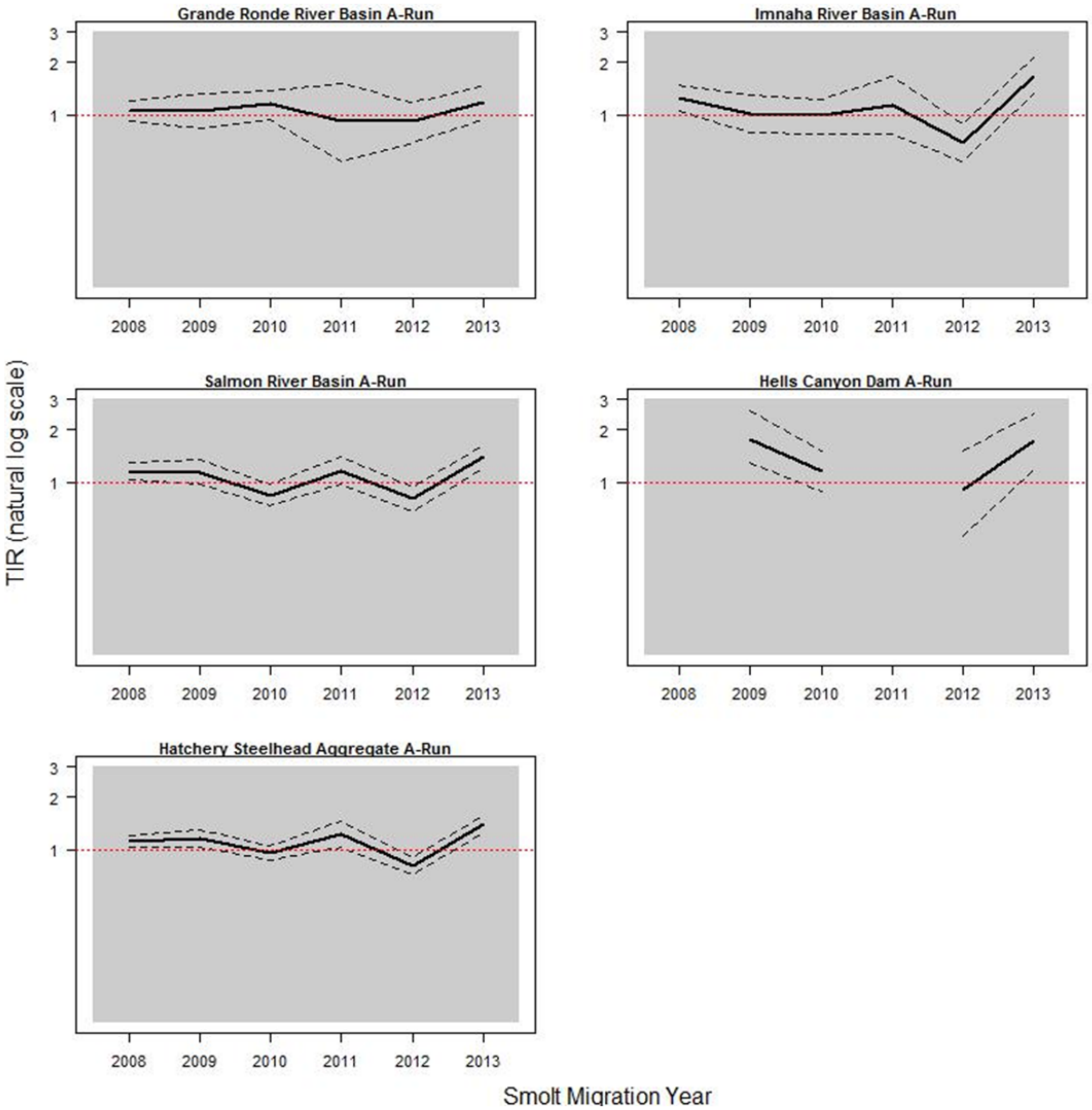


Figure A.25. Trend in TIR on the natural log scale for PIT-tagged Snake River A-run hatchery steelhead in migration years 2008 to 2013 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for hatchery A-run steelhead are from Tables A.56–60.

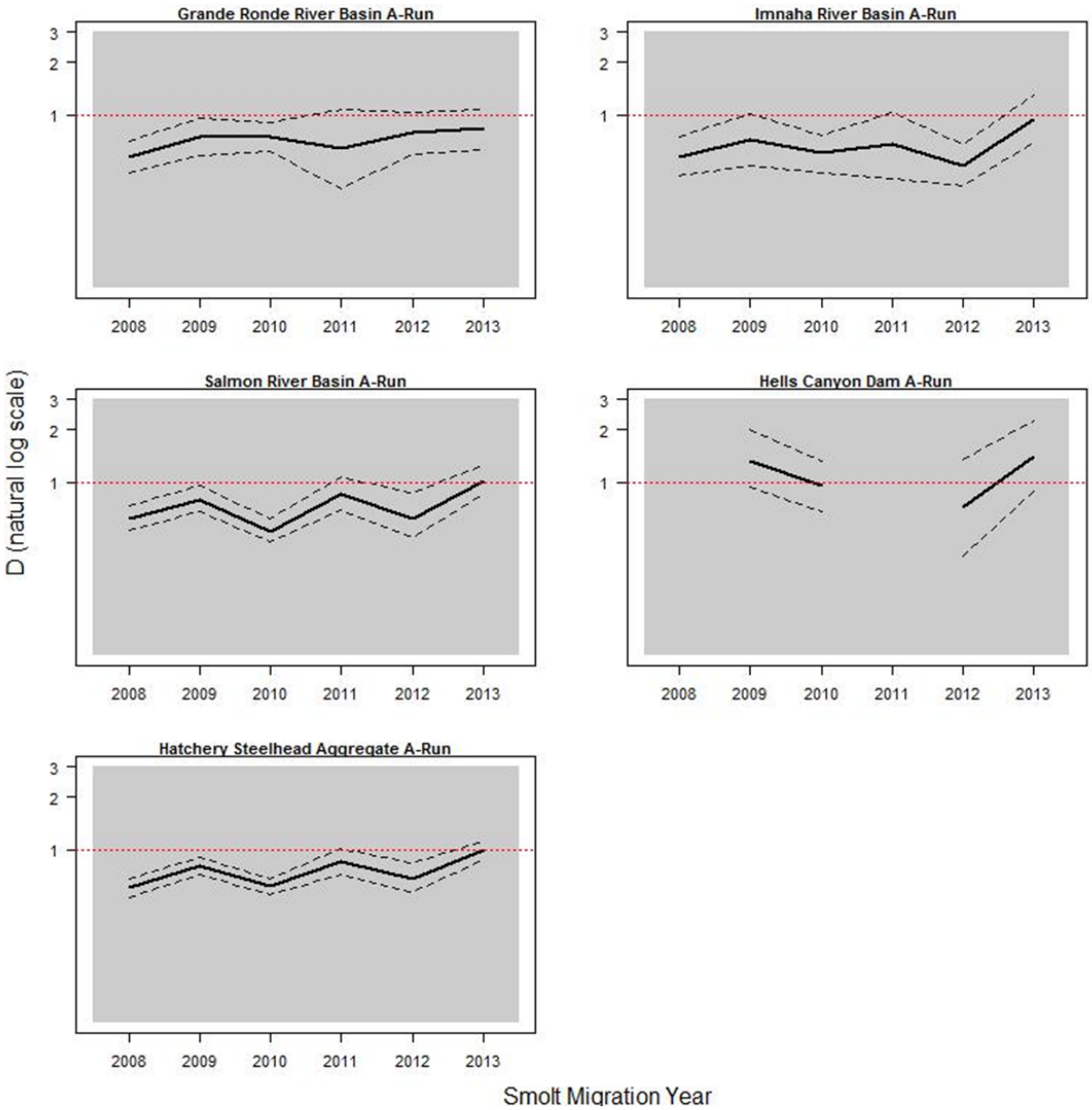


Figure A.26. Trend in *D* on the natural log scale for PIT-tagged Snake River A-run hatchery steelhead in migration years 2008 to 2013 (with 90% confidence intervals). The red horizontal dotted line denotes a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for hatchery A-run steelhead are from Tables A.56–60.

Table A.56. Estimated TIR, and *D* of PIT-tagged Grande Ronde Basin (A-Run) hatchery steelhead for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2008[B]	1.05	(0.92 – 1.20)	0.57	(0.46 – ***0.70***)
2009	1.05	(0.83 – 1.33)	0.74	(0.58 – ***0.95***)
2010	1.15	(0.94 – 1.37)	0.75	(0.61 – ***0.91***)
2011	0.92	(0.54 – 1.50)	0.64	(0.37 – 1.08)
2012	0.92	(0.69 – 1.19)	0.79	(0.59 – 1.03)
2013[C]	1.18	(0.93 – 1.45)	0.83	(0.63 – 1.08)
Geomean	1.04	(0.95 – 1.13)	0.71	(0.63 – ***0.80***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Not pre-assigned to T and R groups. Pre-2006 methods applied for these groups (see *Pre-2006 Migration Years* in the Methods section above for details).
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.57. Estimated TIR, and *D* of PIT-tagged Imnaha River Basin (A-Run) hatchery steelhead for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2008[B]	1.25	(**1.06** – 1.47)	0.57	(0.44 – ***0.75***)
2009	1.02	(0.79 – 1.29)	0.71	(0.51 – 1.01)
2010	0.99	(0.78 – 1.23)	0.60	(0.46 – ***0.76***)
2011	1.13	(0.77 – 1.66)	0.67	(0.43 – 1.03)
2012	0.69	(0.54 – ***0.88***)	0.51	(0.39 – ***0.67***)
2013[C]	1.68	(**1.31** – 2.15)	0.94	(0.69 – 1.29)
Geomean	1.09	(0.85 – 1.38)	0.65	(0.55 – ***0.78***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Not pre-assigned to T and R groups. Pre-2006 methods applied for these groups (see *Pre-2006 Migration Years* in the Methods section above for details).
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.58. Estimated TIR, and *D* of PIT-tagged Salmon River Basin (A-Run) hatchery steelhead for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2008	1.15	(**1.04** – 1.29)	0.62	(0.53 – ***0.73***)
2009	1.14	(0.97 – 1.35)	0.79	(0.67 – ***0.95***)
2010	0.84	(0.73 – ***0.97***)	0.52	(0.45 – ***0.61***)
2011	1.16	(0.98 – 1.40)	0.85	(0.69 – 1.08)
2012	0.80	(0.67 – ***0.94***)	0.62	(0.48 – ***0.86***)
2013[B]	1.40	(**1.21** – 1.62)	1.02	(0.85 – 1.24)
Geomean	1.06	(0.89 – 1.27)	0.72	(0.59 – ***0.88***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.59. Estimated TIR, and *D* of PIT-tagged Hells Canyon Dam (A-Run) hatchery steelhead for migration years 2009 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2009	1.78	(**1.29** – 2.58)	1.33	(0.93 – 2.03)
2010[B]	1.16	(0.88 – 1.51)	0.96	(0.68 – 1.33)
2011[C]		---		---
2012	0.90	(0.49 – 1.52)	0.71	(0.37 – 1.34)
2013[D]	1.72	(**1.19** – 2.49)	1.39	(0.88 – 2.25)
Geomean	1.34	(0.91 – 1.97)	1.06	(0.73 – 1.53)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] See section: *Special Considerations for Migration Year 2010*.
[C] Too few adults in C_0 group to estimate TIR and *D*.
[D] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.60. Estimated TIR, and *D* of PIT-tagged hatchery steelhead (Aggregate A-Run) for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2008	1.12	(**1.04** – 1.21)	0.60	(0.53 – ***0.68***)
2009	1.16	(**1.04** – 1.29)	0.81	(0.72 – ***0.90***)
2010	0.96	(0.87 – 1.05)	0.61	(0.55 – ***0.67***)
2011	1.23	(**1.04** – 1.45)	0.85	(0.71 – 1.01)
2012	0.80	(0.71 – ***0.91***)	0.68	(0.57 – ***0.83***)
2013[B]	1.41	(**1.26** – 1.56)	0.99	(0.87 – 1.12)
Geomean	1.10	(0.93 – 1.29)	0.74	(0.63 – ***0.88***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

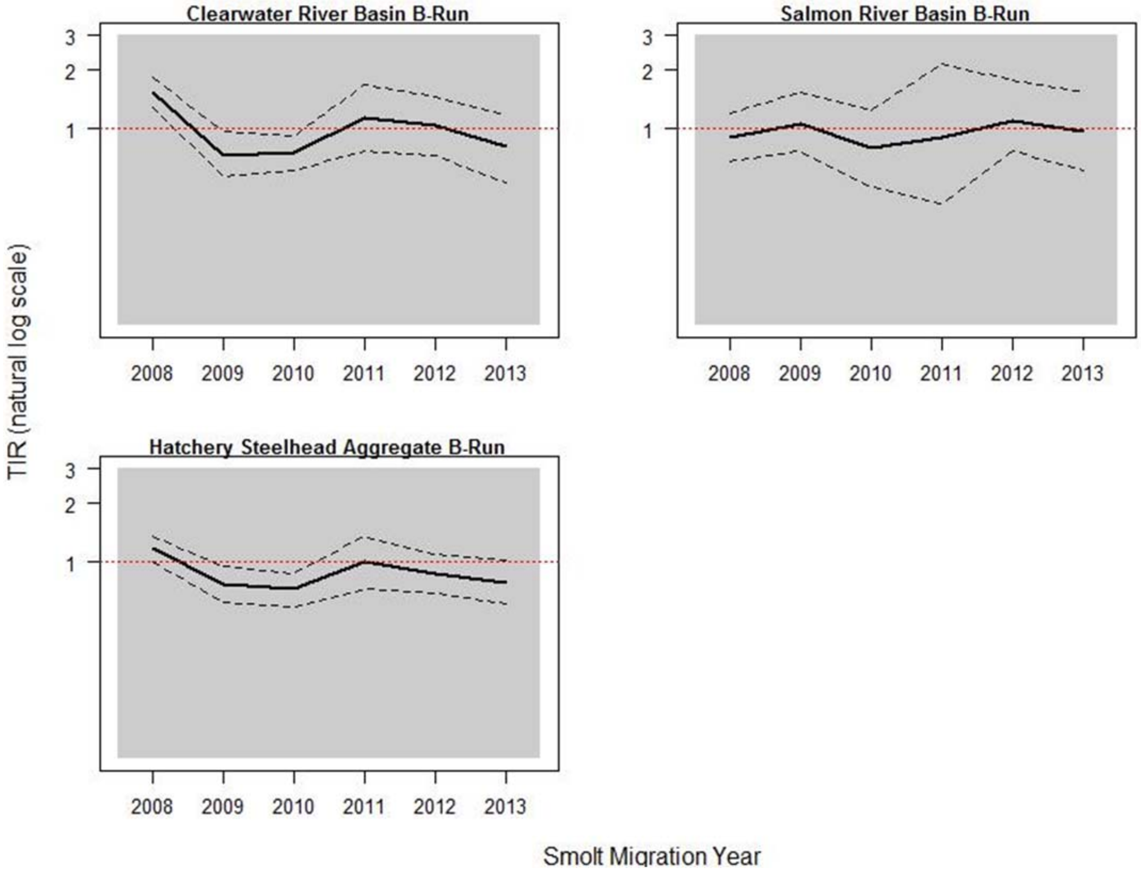


Figure A.27. Trend in TIR on the natural log scale for PIT-tagged Snake River B-run hatchery steelhead in migration years 2008 to 2013 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for hatchery B-run steelhead are from Tables A.61–63.

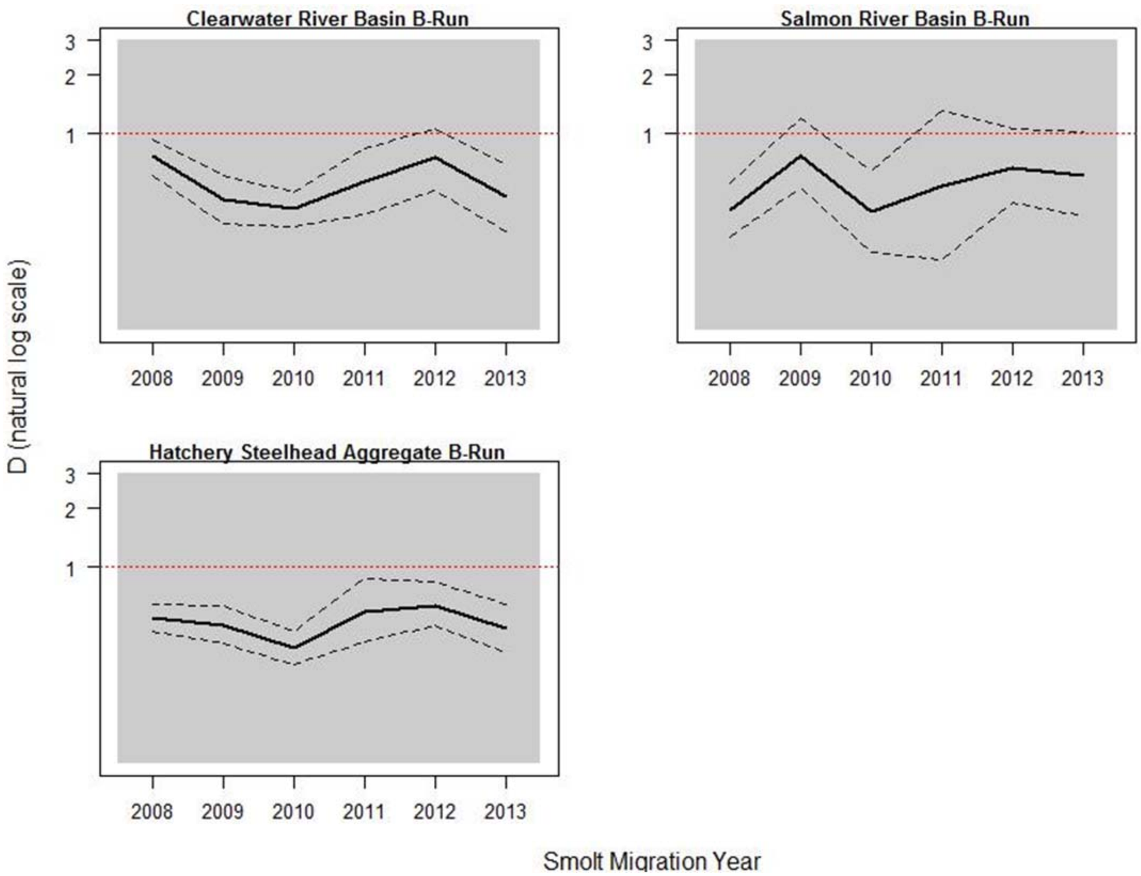


Figure A.28. Trend in *D* on the natural log scale for PIT-tagged Snake River B-run hatchery steelhead in migration years 2008 to 2013 (with 90% confidence intervals). The red horizontal dotted line denotes a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for hatchery B-run steelhead are from Tables A.61–63.

Table A.61. Estimated TIR, and *D* of PIT-tagged Clearwater River Basin (B-Run) hatchery steelhead for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2008	1.55 (**1.28** – 1.85)	0.77 (0.61 – ***0.94***)
2009	0.74 (0.57 – ***0.97***)	0.46 (0.35 – ***0.62***)
2010	0.76 (0.61 – ***0.92***)	0.42 (0.34 – ***0.51***)
2011	1.14 (0.78 – 1.69)	0.57 (0.39 – ***0.84***)
2012	1.05 (0.73 – 1.46)	0.76 (0.52 – 1.07)
2013[B]	0.82 (0.53 – 1.19)	0.48 (0.32 – ***0.71***)
Geomean	0.97 (0.77 – 1.24)	0.56 (0.45 – ***0.69***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.62. Estimated TIR, and *D* of PIT-tagged Salmon River Basin (B-Run) hatchery steelhead for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2008	0.91	(0.68 – 1.20)	0.41	(0.30 – ***0.56***)
2009	1.07	(0.78 – 1.54)	0.78	(0.53 – 1.20)
2010	0.80	(0.51 – 1.25)	0.40	(0.25 – ***0.65***)
2011	0.91	(0.42 – 2.17)	0.54	(0.23 – 1.31)
2012	1.11	(0.77 – 1.76)	0.67	(0.45 – 1.07)
2013[B]	0.98	(0.62 – 1.53)	0.62	(0.38 – 1.02)
Geomean	0.96	(0.87 – 1.06)	0.55	(0.44 – ***0.69***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept. 16, 2016, at GRA.

Table A.63. Estimated TIR, and *D* of PIT-tagged hatchery steelhead (Aggregate B-Run) for migration years 2008 to 2013 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR		*D*	
2008	1.18	(**1.01** – 1.37)	0.55	(0.47 – ***0.65***)
2009	0.78	(0.63 – ***0.95***)	0.51	(0.41 – ***0.64***)
2010	0.73	(0.59 – ***0.87***)	0.39	(0.32 – ***0.47***)
2011	1.00	(0.73 – 1.36)	0.59	(0.42 – ***0.88***)
2012	0.87	(0.69 – 1.11)	0.64	(0.51 – ***0.84***)
2013[B]	0.79	(0.61 – 1.02)	0.49	(0.37 – ***0.65***)
Geomean	0.88	(0.76 – 1.02)	0.52	(0.46 – ***0.60***)

[A] TIR and *D* use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after Sept 16, 2016, at GRA.

Hatchery Sockeye

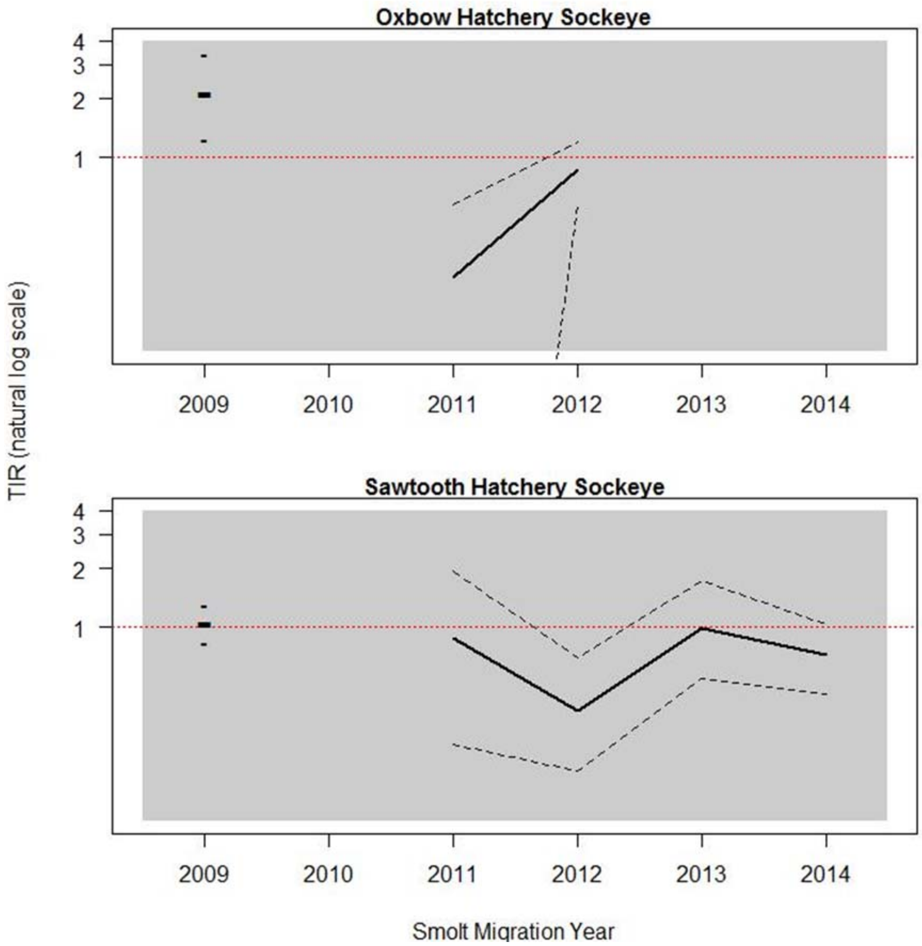


Figure A.29. Trend in TIR on the natural log scale for PIT-tagged Snake River hatchery sockeye in migration years 2009 to 2014 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for hatchery sockeye are from Tables A.64 and A.65.

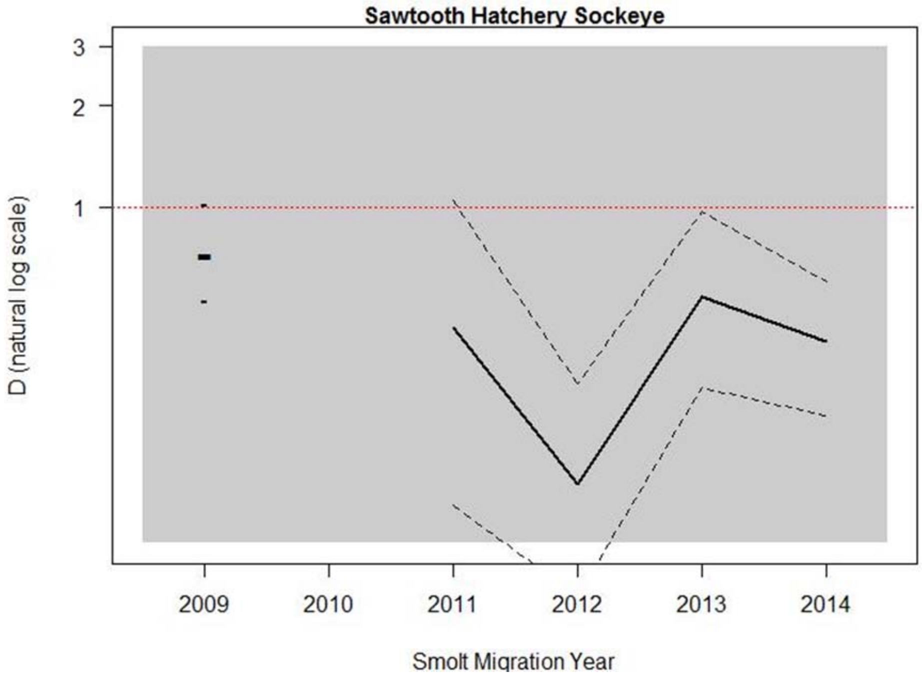


Figure A.30. Trend in *D* on the natural log scale for PIT-tagged Sawtooth Hatchery sockeye in migration years 2009-2014 (with 90% confidence intervals). The red horizontal dotted line corresponds to a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for hatchery sockeye are from Table A.65. Estimates of *D* were not possible for Oxbow Hatchery sockeye, see footnote B in Table A.64.

Table A.64. Estimated TIR and *D* of PIT-tagged hatchery sockeye reared at Oxbow Hatchery for migration years 2009 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	***D***[B]
2009[C]	2.13 (**1.23** – 3.37)	---
2010[D]	---	---
2011	0.24 (0.00 – ***0.57***)	---
2012	0.86 (0.57 – 1.21)	---
Geomean	0.76 (0.12 – 4.83)	---

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] Due to small sample sizes, could not estimate *D* for this group.
[C] Used same methodology outlined in *Special Considerations for Migration Year 2010* on Page A-11 for 2009 out-migrants.
[D] Too few adults in Transport group to estimate TIR.

Table A.65. Estimated TIR and *D* of PIT-tagged hatchery sockeye reared at Sawtooth Hatchery for migration years 2009 to 2014 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2009	1.04 (0.83 – 1.30)	0.72 (0.53 – 1.02)
2010[B]	---	---
2011	0.88 (0.25 – 1.94)	0.44 (0.13 – 1.05)
2012	0.37 (0.18 – ***0.69***)	0.15 (0.07 – ***0.30***)
2013	0.99 (0.54 – 1.73)	0.54 (0.29 – ***0.97***)
2014[C]	0.72 (0.45 – 1.04)	0.40 (0.24 – ***0.60***)
Geomean	0.75 (0.50 – 1.12)	0.40 (0.23 – ***0.70***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] Too few adults in Transport category to estimate TIR and *D*.
[C] Incomplete. 2-salt returns through Sept. 16, 2016.

Wild and Hatchery Subyearling Fall Chinook

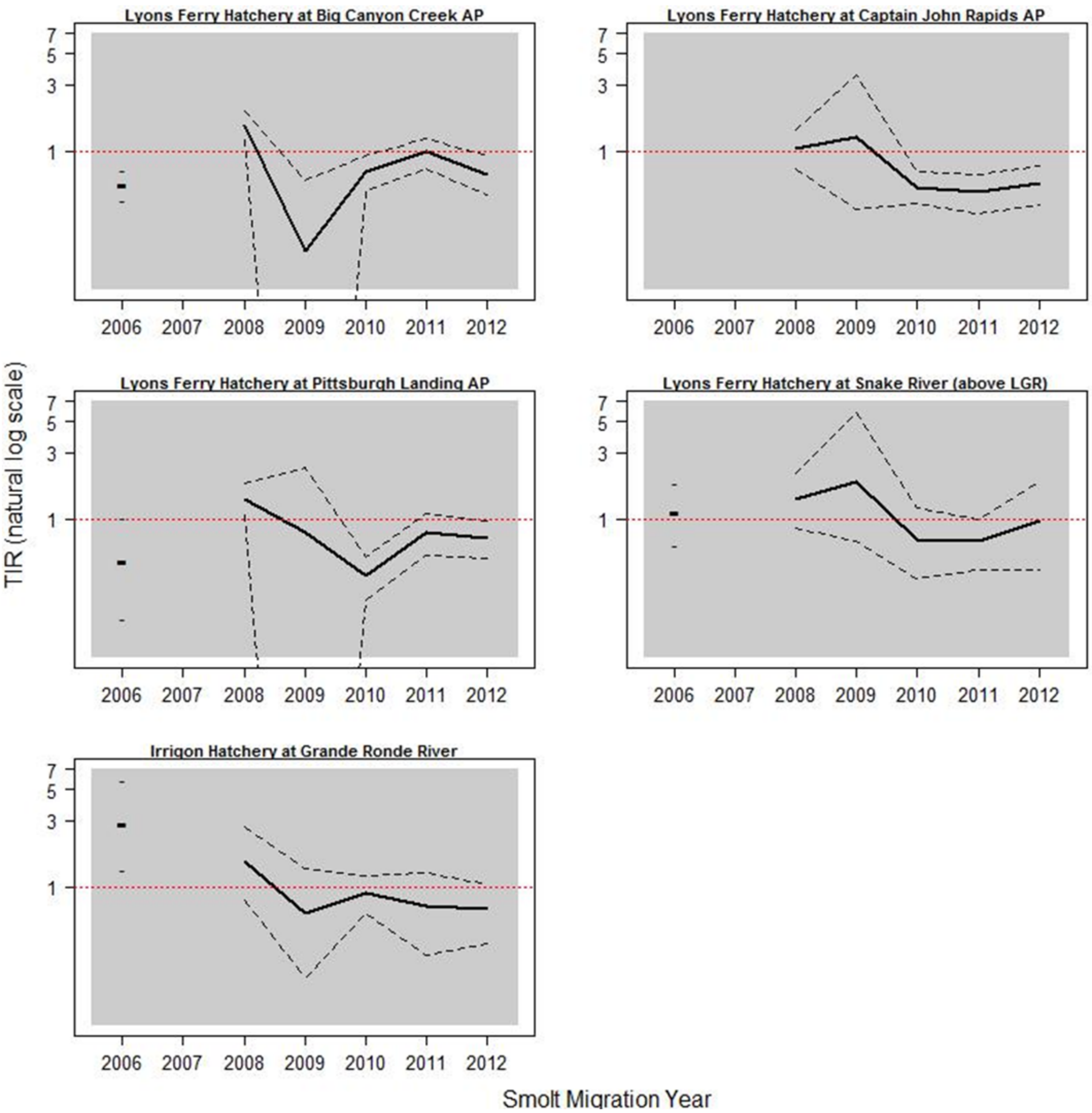


Figure A.31. Trend in TIR on the natural log scale for PIT-tagged Lyons Ferry and Irrigon hatchery subyearling fall Chinook in migration years 2006-2012 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for Lyons Ferry and Irrigon hatchery subyearling fall Chinook are from Tables A.67-A.71.

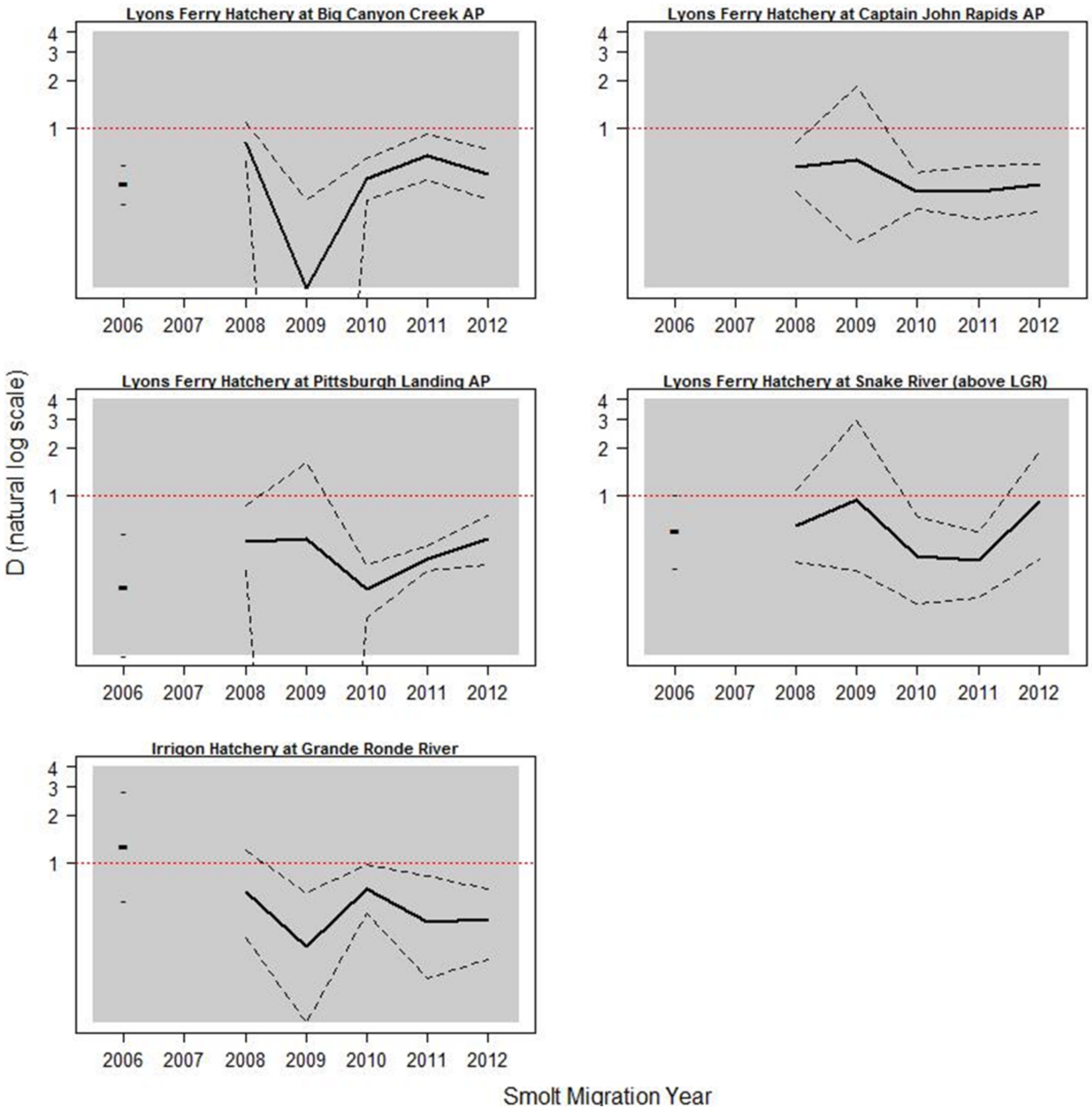


Figure A.32 Trend in *D* on the natural log scale for PIT-tagged Lyons Ferry and Irrigon hatchery subyearling fall Chinook in migration years 2006-2012 (with 90% confidence intervals). The red horizontal dotted line corresponds to a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for Lyons Ferry and Irrigon hatchery subyearling fall Chinook are from Tables A.67-A.71.

Table A.66. Estimated TIR and *D* of PIT-tagged wild/natural subyearling fall Chinook tagged and released in the mainstem Snake River (above Lower Granite Dam) in 2006 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics. Due to small sample sizes, estimates of TIR and *D* were not possible for migration years 2007-2012.

Migration Year[A]	TIR	*D*
2006	0.59 (0.00 – 2.52)	0.31 (0.00 – 1.36)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.

Table A.67. Estimated TIR and *D* of PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released from Big Canyon Creek Acclimation Pond (Clearwater River) from migration year 2006 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2006	0.57 (0.44 – ***0.72***)	0.45 (0.34 – ***0.60***)
2007[B]	---	---
2008	1.52 (**1.19** – 1.92)	0.81 (0.62 – 1.08)
2009	0.19 (0.00 – ***0.61***)	0.10 (0.00 – ***0.35***)
2010	0.70 (0.52 – ***0.92***)	0.48 (0.35 – ***0.65***)
2011	0.98 (0.74 – 1.23)	0.67 (0.47 – ***0.92***)
2012[C]	0.67 (0.48 – ***0.92***)	0.51 (0.36 – ***0.73***)
Geomean	0.65 (0.37 – 1.15)	0.43 (0.23 – ***0.80***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.68. Estimated TIR and *D* of PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released from Captain John Rapids Acclimation Pond from migration year 2007 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2007[B]	---	---
2008	1.03 (0.74 – 1.42)	0.57 (0.40 – 0.***81***)
2009	1.27 (0.38 – 3.56)	0.63 (0.19 – 1.82)
2010	0.55 (0.42 – ***0.70***)	0.40 (0.31 – ***0.52***)
2011	0.51 (0.35 – ***0.68***)	0.40 (0.27 – ***0.58***)
2012[C]	0.58 (0.41 – ***0.77***)	0.44 (0.30 – ***0.60***)
Geomean	0.73 (0.49 – 1.09)	0.48 (0.39 – ***0.59***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.69. Estimated TIR and *D* of PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released from Pittsburg Landing Acclimation Pond from migration year 2006 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2006	0.49 (0.19 – 1.02)	0.27 (0.10 – ***0.58***)
2007[B]	---	---
2008	1.39 (**1.07** – 1.79)	0.51 (0.34 – ***0.86***)
2009	0.79 (0.00 – 2.36)	0.53 (0.00 – 1.60)
2010	0.39 (0.26 – ***0.53***)	0.26 (0.17 – ***0.37***)
2011	0.79 (0.54 – 1.09)	0.40 (0.34 – ***0.48***)
2012[C]	0.73 (0.52 – ***0.97***)	0.53 (0.37 – ***0.74***)
Geomean	0.70 (0.49 – 1.01)	0.40 (0.30 – ***0.52***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.70. Estimated TIR and *D* of PIT-tagged Lyons Ferry Hatchery subyearling fall Chinook released into the mainstem Snake River (above Lower Granite Dam) from migration year 2006 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2006	1.12 (0.64 – 1.82)	0.61 (0.35 – 1.01)
2007[B]	---	---
2008	1.37 (0.85 – 2.13)	0.65 (0.38 – 1.08)
2009	1.84 (0.69 – 5.82)	0.94 (0.34 – 2.93)
2010	0.71 (0.37 – 1.19)	0.42 (0.21 – ***0.74***)
2011	0.69 (0.43 – ***0.98***)	0.39 (0.23 – ***0.59***)
2012[C]	0.96 (0.43 – 1.84)	0.91 (0.40 – 1.88)
Geomean	1.05 (0.77 – 1.43)	0.62 (0.46 – ***0.84***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.71. Estimated TIR and *D* of PIT-tagged Irrigon Hatchery subyearling fall Chinook released into the Grande Ronde River from migration year 2006 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2006[B]	2.81 (**1.33** – 5.79)	1.28 (0.58 – 2.80)
2007[C]	---	---
2008	1.51 (0.80 – 2.69)	0.66 (0.34 – 1.21)
2009	0.64 (0.22 – 1.34)	0.30 (0.10 – ***0.65***)
2010	0.89 (0.65 – 1.20)	0.69 (0.48 – ***0.98***)
2011	0.73 (0.32 – 1.25)	0.43 (0.19 – ***0.83***)
2012[D]	0.69 (0.39 – 1.03)	0.44 (0.25 – ***0.69***)
Geomean	1.03 (0.64 – 1.66)	0.57 (0.37 – ***0.86***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] 2006 release was reared at Lyons Ferry Hatchery
[C] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[D] Incomplete, 3-salt returns through Dec. 31, 2015.

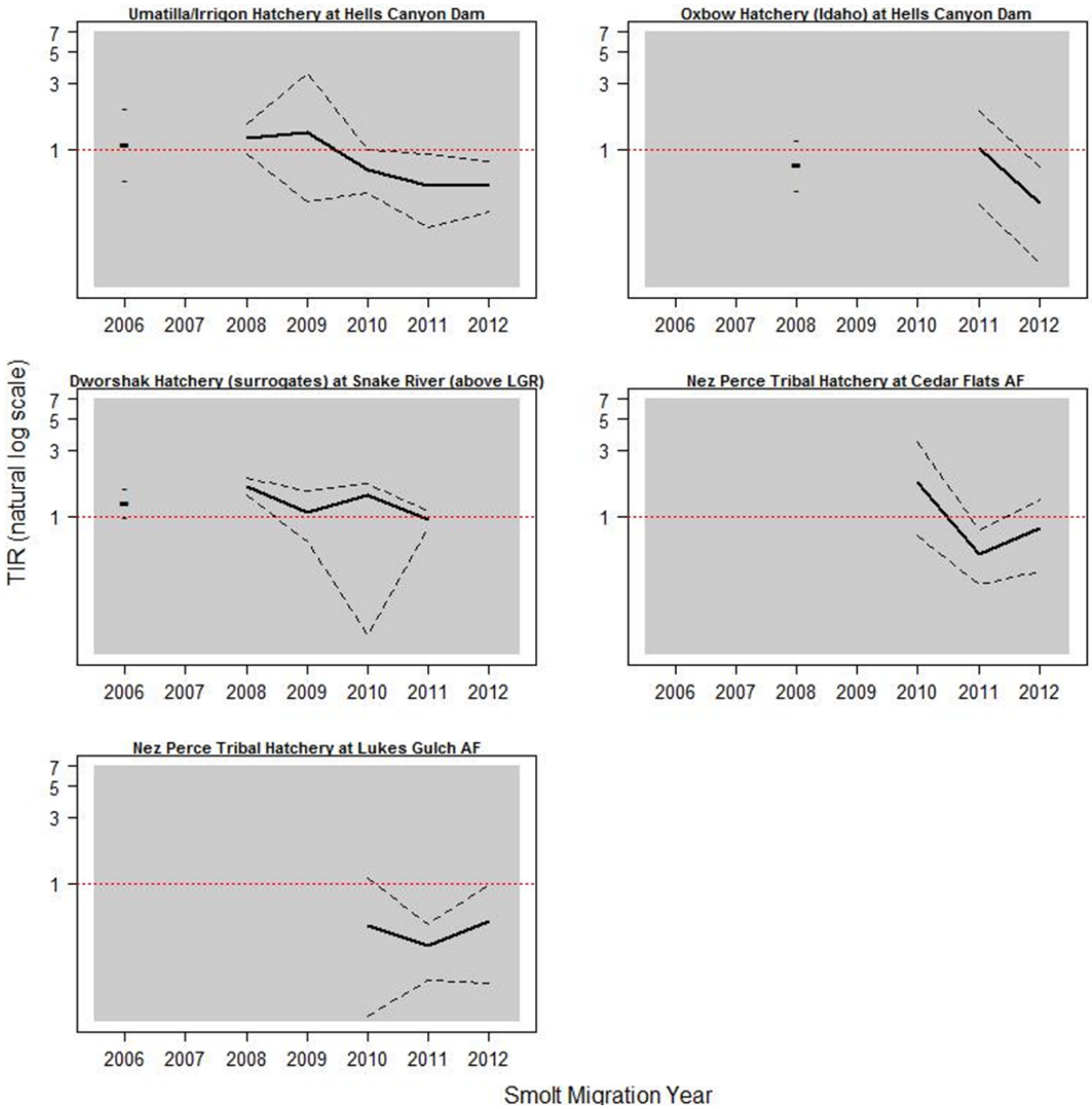


Figure A.33. Trend in TIR on the natural log scale for PIT-tagged subyearling fall Chinook (various hatcheries and release locations) in migration years 2006-2012 (with 90% confidence intervals). The red horizontal dotted line denotes a TIR value of 1 (in-river and transport SARs equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for above figure are from Tables A.72-A.76.

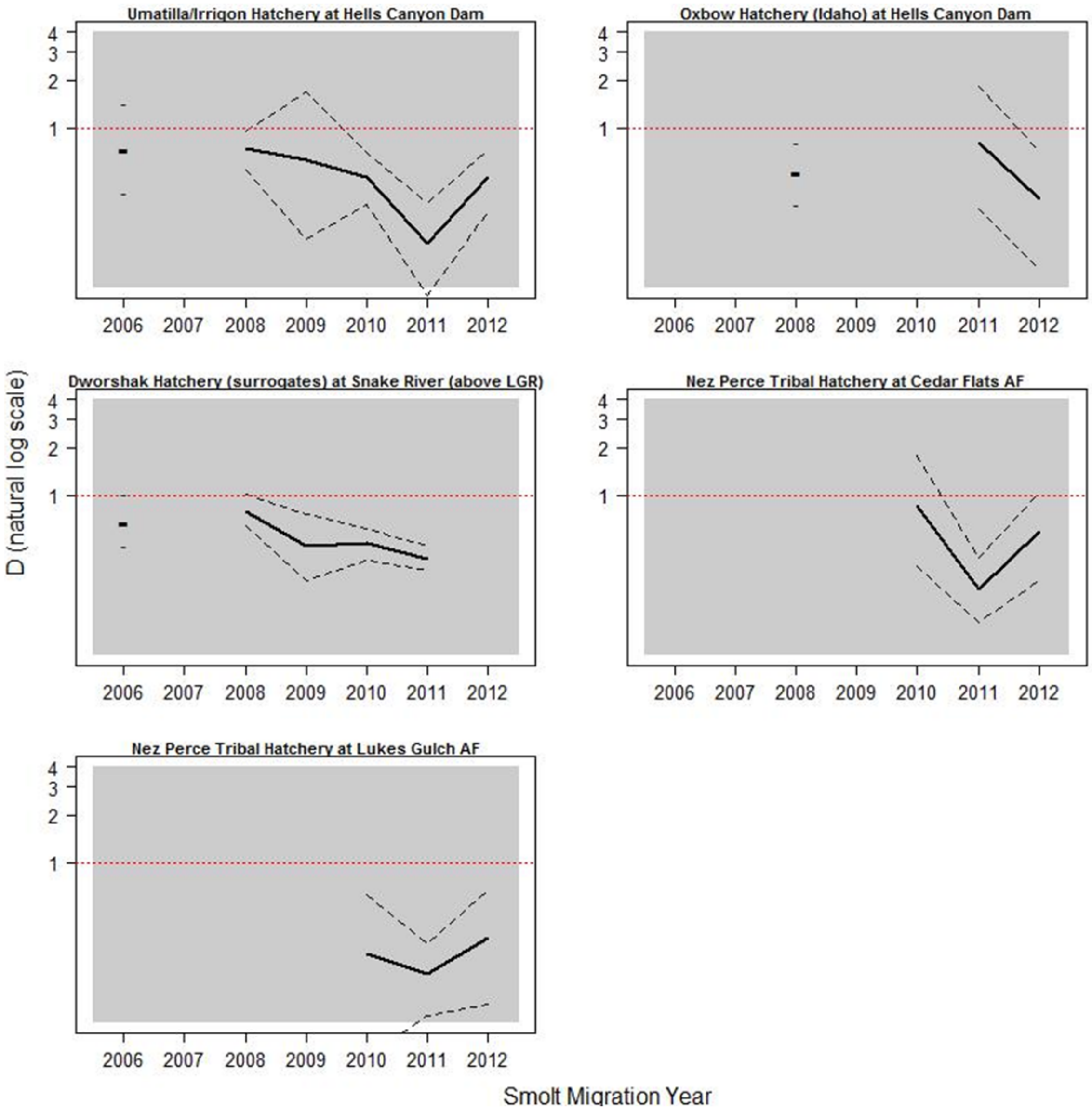


Figure A.34 Trend in *D* on the natural log scale for PIT-tagged subyearling fall Chinook (various hatcheries and release locations) in migration years 2006-2012 (with 90% confidence intervals). The red horizontal dotted line corresponds to a *D* value of 1 (in-river and transport post-BON survivals are equal). Shaded area highlights the period of Court Order spill and later start of transportation. Data for above figure are from Tables A.72-A.76.

Table A.72. Estimated TIR and *D* of PIT-tagged Umatilla/Irrigon Hatchery subyearling fall Chinook released into the Snake River below Hells Canyon Dam from migration year 2006 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2006	1.08 (0.60 – 2.00)	0.73 (0.39 – 1.43)
2007[B]	---	---
2008	1.20 (0.93 – 1.51)	0.74 (0.55 – ***0.96***)
2009	1.32 (0.42 – 3.53)	0.63 (0.20 – 1.69)
2010	0.70 (0.48 – ***0.98***)	0.49 (0.33 – ***0.70***)
2011	0.55 (0.27 – ***0.93***)	0.19 (0.09 – ***0.34***)
2012[C]	0.56 (0.35 – ***0.81***)	0.49 (0.30 – ***0.73***)
Geomean	0.85 (0.61 – 1.17)	0.50 (0.33 – ***0.76***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[C] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.73. Estimated TIR and *D* of PIT-tagged Oxbow Hatchery (Idaho) subyearling fall Chinook released into the Snake River below Hells Canyon Dam from migration year 2007 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2007[B]	---	---
2008	0.78 (0.50 – 1.16)	0.52 (0.33 – ***0.81***)
2009[C]	---	---
2010[D]	---	---
2011	1.01 (0.40 – 1.88)	0.82 (0.31 – 1.82)
2012[C]	0.41 (0.15 – ***0.74***)	0.36 (0.13 – ***0.71***)
Geomean	0.69 (0.31 – 1.50)	0.54 (0.27 – 1.07)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] All PIT-tagged fish were routed in-river. Therefore, estimates of TIR and *D* were not possible.
[C] Too few adults in Transport and/or C_0 category to estimate TIR and D.
[D] No PIT-tags were released in 2010.
[E] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.74. Estimated TIR and *D* of PIT-tagged Dworshak Hatchery subyearling fall Chinook (surrogates) released into the mainstem Snake River (above Lower Granite Dam) from migration year 2006 to 2011 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2006	1.26 (0.99 – 1.59)	0.67 (0.48 – 1.02)
2007[B]	---	---
2008	1.64 (**1.42** – 1.90)	0.80 (0.64 – 1.03)
2009	1.06 (0.66 – 1.54)	0.48 (0.29 – ***0.77***)
2010	1.41 (0.14 – 1.70)	0.50 (0.39 – ***0.62***)
2011	0.94 (0.81 – 1.09)	0.40 (0.34 – ***0.48***)
2012[C]	---	---
Geomean	1.24 (1.00 – 1.53)	0.55 (0.42 – ***0.72***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] Due to low broodstock, no PIT-tags were released for this group in 2007.
[C] TIR and D not estimable due to high estimated holdover rates.

Table A.75. Estimated TIR and *D* of PIT-tagged Nez Perce Tribal Hatchery subyearling fall Chinook released from Cedar Flats Acclimation Facility (Clearwater River) from migration year 2010 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2010	1.76 (0.73 – 3.43)	0.87 (0.36 – 1.78)
2011	0.53 (0.32 – ***0.79***)	0.26 (0.16 – ***0.41***)
2012[B]	0.81 (0.40 – 1.32)	0.59 (0.29 – 1.05)
Geomean	0.91 (0.33 – 2.54)	0.51 (0.18 – 1.45)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete, 3-salt returns through Dec. 31, 2015.

Table A.76. Estimated TIR and *D* of PIT-tagged Nez Perce Tribal Hatchery subyearling fall Chinook released from Lukes Gulch Acclimation Facility (Clearwater River) from migration year 2010 to 2012 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migration Year[A]	TIR	*D*
2010	0.49 (0.11 – 1.08)	0.27 (0.06 – ***0.63***)
2011	0.35 (0.20 – ***0.51***)	0.20 (0.11 – ***0.31***)
2012[B]	0.53 (0.19 – ***0.97***)	0.34 (0.13 – ***0.67***)
Geomean	0.45 (0.31 – ***0.65***)	0.26 (0.17 – ***0.41***)

[A] TIR and *D* use SAR T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete, 3-salt returns through Dec. 31, 2015.

APPENDIX B

SUPPORTING TABLES TO CHAPTER 4 — OVERALL SARS

APPENDIX B

ANNUAL OVERALL SARS
(SUPPORTING TABLES TO CHAPTERS 4 AND 6)

Snake River wild spring/summer Chinook

Table B.1. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Wild Chinook, 1994 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
1994	15,260	0.43	0.22	0.66	0.47	0.24	0.70
1995	20,206	0.35	0.20	0.52	0.35	0.19	0.52
1996	7,868	0.42	0.06	0.84	0.43	0.06	0.85
1997	2,898	1.73	0.97	2.68	1.78	0.99	2.73
1998	17,363	1.21	0.82	1.64	1.25	0.84	1.70
1999	33,662	2.39	1.89	2.94	2.55	2.03	3.09
2000	25,053	1.71	1.22	2.24	1.72	1.25	2.20
2001	22,415	1.27	0.54	2.11	1.45	0.70	2.32
2002	23,356	0.92	0.75	1.10	1.04	0.83	1.24
2003	31,093	0.34	0.26	0.41	0.34	0.26	0.42
2004	32,546	0.52	0.43	0.63	0.54	0.44	0.64
2005	35,216	0.22	0.17	0.28	0.24	0.18	0.30
2006	15,274	0.70	0.58	0.81	0.75	0.63	0.87
2007	14,919	0.98	0.85	1.11	1.09	0.95	1.23
2008	18,599	2.74	2.53	2.95	3.24	3.02	3.45
2009	18,781	1.45	1.31	1.60	1.61	1.45	1.76
2010	26,624	0.74	0.66	0.83	0.93	0.83	1.04
2011	23,304	0.33	0.27	0.39	0.36	0.30	0.42
2012	21,576	1.10	0.99	1.22	1.43	1.31	1.57
2013	18,867	1.21	1.08	1.36	1.37	1.22	1.53
2014[B]	21,417	0.42	0.35	0.49	0.47	0.39	0.55
Geometric mean		0.80			0.87		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.2. Overall LGR-to-BOA SARs for Snake River Basin (above LGR) Wild Chinook, 2000 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	25,053	2.60	1.95	3.28	2.69	2.01	3.39
2001	22,415	1.81	0.90	2.89	1.99	1.10	2.99
2002	23,356	1.14	0.94	1.35	1.29	1.07	1.52
2003	31,093	0.34	0.26	0.42	0.34	0.27	0.42
2004	32,546	0.68	0.56	0.80	0.69	0.58	0.80
2005	35,216	0.29	0.23	0.36	0.30	0.24	0.37
2006	15,274	0.84	0.73	0.98	0.90	0.77	1.03
2007	14,919	1.16	1.01	1.31	1.27	1.12	1.43
2008	18,599	3.56	3.33	3.79	4.13	3.90	4.37
2009	18,781	1.93	1.76	2.09	2.09	1.90	2.26
2010	26,624	0.92	0.82	1.02	1.16	1.05	1.28
2011	23,304	0.42	0.35	0.49	0.45	0.38	0.52
2012	21,576	1.48	1.35	1.62	1.84	1.69	2.00
2013	18,867	1.56	1.41	1.72	1.71	1.55	1.88
2014[B]	21,417	0.48	0.40	0.56	0.56	0.48	0.64
Geometric mean		1.00			1.10		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.3. Overall LGR-to-GRA SARs for Clearwater River Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	1,778	0.28	0.11	0.52	0.34	0.11	0.57
2007	574	0.87	0.19	1.54	0.87	0.33	1.64
2008	1,152	1.39	0.84	2.08	1.56	1.00	2.19
2009	1,076	1.02	0.49	1.59	1.02	0.54	1.59
2010	5,694	0.76	0.57	0.96	0.76	0.57	0.95
2011	1,432	0.35	0.14	0.63	0.35	0.14	0.63
2012	1,301	0.69	0.32	1.07	0.69	0.32	1.07
2013	1,075	0.37	0.09	0.67	0.37	0.09	0.67
2014[B]	819	0.24	0.00	0.61	0.24	0.00	0.61
Geometric mean		0.56			0.58		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.4. Overall LGR-to-BOA SARs for Clearwater River Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	1,778	0.39	0.17	0.66	0.45	0.18	0.73
2007	574	1.04	0.38	1.77	1.04	0.36	1.81
2008	1,152	1.74	1.09	2.48	1.91	1.25	2.60
2009	1,076	1.39	0.84	1.97	1.39	0.81	2.07
2010	5,694	1.05	0.85	1.30	1.07	0.86	1.34
2011	1,432	0.49	0.21	0.83	0.49	0.21	0.83
2012	1,301	0.69	0.31	1.11	0.69	0.31	1.11
2013	1,075	0.74	0.36	1.21	0.74	0.36	1.21
2014[B]	819	0.37	0.00	0.74	0.37	0.00	0.74
Geometric mean		0.77			0.79		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.5. Overall LGR-to-GRA SARs for Grande Ronde Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	3,469	0.89	0.65	1.18	0.95	0.68	1.24
2007	2,672	1.16	0.80	1.51	1.38	0.99	1.77
2008	2,382	2.94	2.41	3.56	3.32	2.74	3.94
2009	2,781	2.16	1.69	2.65	2.30	1.87	2.77
2010	3,743	0.53	0.35	0.75	0.64	0.44	0.86
2011	3,262	0.43	0.24	0.62	0.43	0.24	0.62
2012	3,094	1.45	1.09	1.84	1.65	1.26	2.05
2013	3,238	1.51	1.16	1.90	1.76	1.37	2.19
2014[B]	2,325	1.46	1.10	1.90	1.55	1.16	1.99
Geometric mean		1.19			1.32		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.6. Overall LGR-to-BOA SARs for Grande Ronde Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	3,469	1.07	0.80	1.36	1.12	0.82	1.42
2007	2,672	1.50	1.11	1.89	1.72	1.31	2.16
2008	2,382	3.82	3.16	4.51	4.20	3.52	4.88
2009	2,781	2.77	2.25	3.32	2.84	2.30	3.40
2010	3,743	0.80	0.56	1.04	0.94	0.68	1.20
2011	3,262	0.49	0.30	0.70	0.49	0.30	0.70
2012	3,094	2.00	1.58	2.45	2.20	1.74	2.64
2013	3,238	1.91	1.50	2.35	2.16	1.73	2.63
2014[B]	2,325	1.55	1.16	1.98	1.68	1.27	2.12
Geometric mean		1.50			1.64		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.7. Overall LGR-to-GRA SARs for Imnaha River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	714	0.70	0.27	1.27	0.70	0.14	1.28
2007	4,111	0.63	0.42	0.84	0.78	0.58	1.02
2008	4,050	2.81	2.36	3.28	3.53	3.07	4.05
2009	3,160	1.68	1.33	2.08	1.90	1.50	2.30
2010	4,094	0.83	0.60	1.07	1.10	0.81	1.38
2011	2,413	0.33	0.16	0.64	0.37	0.20	0.59
2012	2,389	0.80	0.51	1.10	1.00	0.68	1.36
2013	2,980	1.21	0.89	1.55	1.44	1.08	1.82
2014[B]	3,398	0.35	0.21	0.53	0.41	0.24	0.59
Geometric mean		0.83			0.99		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.8. Overall LGR-to-BOA SARs for Imnaha River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	714	0.70	0.26	1.24	0.84	0.29	1.43
2007	4,111	0.71	0.49	0.93	0.88	0.64	1.12
2008	4,050	3.88	3.38	4.38	4.72	4.15	5.32
2009	3,160	2.44	2.00	2.89	2.66	2.17	3.14
2010	4,094	0.93	0.68	1.18	1.27	0.98	1.57
2011	2,413	0.41	0.21	0.63	0.50	0.29	0.75
2012	2,389	1.13	0.78	1.48	1.51	1.11	1.92
2013	2,980	1.48	1.15	1.86	1.71	1.34	2.14
2014[B]	3,398	0.41	0.24	0.60	0.53	0.33	0.74
Geometric mean		1.02			1.26		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.9. Overall LGR-to-GRA SARs for South Fork Salmon River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	1,276	0.86	0.47	1.32	0.86	0.44	1.32
2007	2,113	1.42	0.99	1.90	1.47	1.01	1.92
2008	1,632	3.86	3.07	4.69	4.72	3.80	5.62
2009	1,891	1.38	0.95	1.83	1.53	1.09	2.02
2010	1,488	1.41	0.92	1.98	1.61	1.09	2.18
2011	1,100	0.27	0.00	0.54	0.27	0.00	0.54
2012	887	1.01	0.53	1.68	1.01	0.53	1.68
2013	611	0.82	0.30	1.50	0.82	0.30	1.50
2014[B]	515	0.58	0.00	1.19	0.58	0.00	1.49
Geometric mean		1.02			1.07		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.10. Overall LGR-to-BOA SARs for South Fork Salmon River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	1,276	0.94	0.54	1.41	0.94	0.52	1.38
2007	2,113	1.61	1.16	2.10	1.66	1.24	2.13
2008	1,632	4.78	3.90	5.65	5.76	4.78	6.82
2009	1,891	1.85	1.35	2.36	2.01	1.48	2.58
2010	1,488	1.55	1.03	2.10	1.88	1.33	2.51
2011	1,100	0.27	0.00	0.54	0.27	0.00	0.54
2012	887	1.24	0.66	1.97	1.24	0.66	1.97
2013	611	1.31	0.58	2.19	1.31	0.58	2.19
2014[B]	515	0.58	0.00	1.19	0.58	0.00	1.19
Geometric mean		1.20			1.27		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.11. Overall LGR-to-GRA SARs for Middle Fork Salmon River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	260	0.38	0.00	1.16	0.38	0.00	1.14
2007	341	0.59	0.00	1.35	0.59	0.00	1.32
2008	3,035	2.93	2.41	3.47	3.46	2.90	4.06
2009	2,636	1.14	0.81	1.48	1.56	1.17	1.96
2010	2,889	0.93	0.66	1.24	1.59	1.22	2.03
2011	3,176	0.35	0.19	0.53	0.44	0.25	0.64
2012	2,515	0.91	0.61	1.25	1.59	1.21	2.02
2013	2,265	1.46	1.03	1.87	1.55	1.09	1.98
2014[B]	3,045	0.36	0.19	0.55	0.43	0.23	0.64
Geometric mean		0.79			0.99		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.12. Overall LGR-to-BOA SARs for Middle Fork Salmon River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	260	0.38	0.00	1.15	0.38	0.00	1.15
2007	341	1.17	0.29	2.23	1.17	0.29	2.15
2008	3,035	3.49	2.93	4.12	4.09	3.50	4.72
2009	2,636	1.56	1.17	1.97	1.97	1.56	2.45
2010	2,889	1.11	0.82	1.46	1.83	1.44	2.30
2011	3,176	0.41	0.25	0.59	0.50	0.31	0.72
2012	2,515	1.35	0.99	1.74	2.03	1.58	2.52
2013	2,265	1.81	1.37	2.27	1.90	1.44	2.36
2014[B]	3,045	0.43	0.23	0.64	0.53	0.32	0.75
Geometric mean		1.02			1.24		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.13. Overall LGR-to-GRA SARs for Upper Salmon River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	2,885	0.52	0.31	0.75	0.55	0.34	0.78
2007	1,968	0.97	0.61	1.36	0.97	0.63	1.37
2008	1,623	2.71	2.01	3.41	2.83	2.12	3.60
2009	2,102	1.57	1.15	2.05	1.62	1.17	2.10
2010	3,604	0.94	0.66	1.23	1.08	0.79	1.39
2011	4,801	0.35	0.21	0.52	0.35	0.21	0.52
2012	3,792	1.53	1.22	1.89	1.98	1.62	2.36
2013	3,436	1.19	0.89	1.50	1.25	0.94	1.57
2014[B]	3,484	0.32	0.17	0.48	0.34	0.18	0.52
Geometric mean		0.91			0.97		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.14. Overall LGR-to-BOA SARs for Upper Salmon River Basin Wild Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	2,885	0.66	0.42	0.93	0.69	0.45	0.96
2007	1,968	1.02	0.65	1.43	1.02	0.67	1.43
2008	1,623	3.88	3.06	4.74	4.07	3.26	4.92
2009	2,102	1.95	1.46	2.48	2.00	1.48	2.53
2010	3,604	1.11	0.80	1.43	1.28	0.96	1.60
2011	4,801	0.46	0.31	0.62	0.46	0.31	0.62
2012	3,792	1.87	1.52	2.27	2.32	1.92	2.75
2013	3,436	1.63	1.27	1.99	1.69	1.33	2.03
2014[B]	3,484	0.34	0.18	0.51	0.37	0.20	0.55
Geometric mean		1.12			1.19		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Snake River hatchery spring and summer Chinook

Table B.15. Overall LGR-to-GRA SARs for Dworshak hatchery spring Chinook, 1997–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
1997	8,175	0.62	0.44	0.81	0.63	0.46	0.84
1998	40,218	1.00	0.89	1.11	1.14	1.04	1.25
1999	40,804	1.18	1.05	1.32	1.22	1.08	1.36
2000	39,412	1.00	0.92	1.10	1.01	0.92	1.12
2001	41,251	0.36	0.29	0.43	0.42	0.35	0.49
2002	45,233	0.57	0.48	0.65	0.72	0.63	0.81
2003	38,612	0.24	0.19	0.29	0.25	0.20	0.30
2004	45,505	0.29	0.23	0.34	0.29	0.23	0.34
2005	43,042	0.19	0.15	0.24	0.20	0.16	0.25
2006	29,511	0.35	0.29	0.42	0.46	0.40	0.52
2007	28,511	0.36	0.31	0.42	0.46	0.40	0.53
2008	25,643	0.57	0.50	0.65	0.85	0.75	0.95
2009	24,778	0.38	0.32	0.45	0.43	0.37	0.50
2010	32,204	0.47	0.41	0.53	0.80	0.72	0.89
2011	26,267	0.17	0.13	0.22	0.19	0.15	0.24
2012	26,750	0.47	0.41	0.55	0.67	0.59	0.76
2013	29,108	0.59	0.52	0.67	0.72	0.63	0.81
2014[B]	29,739	0.25	0.20	0.30	0.28	0.23	0.33
Geometric mean		0.43			0.51		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.16. Overall LGR-to-BOA SARs for Dworshak hatchery spring Chinook, 2000–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	39,412	1.51	1.40	1.63	1.52	1.40	1.64
2001	41,251	0.43	0.36	0.50	0.50	0.42	0.58
2002	45,233	0.73	0.64	0.82	0.85	0.75	0.96
2003	38,612	0.30	0.24	0.35	0.31	0.26	0.36
2004	45,505	0.53	0.46	0.61	0.53	0.46	0.60
2005	43,042	0.29	0.23	0.34	0.29	0.24	0.35
2006	29,511	0.56	0.49	0.64	0.68	0.61	0.76
2007	28,511	0.49	0.42	0.56	0.62	0.54	0.70
2008	25,643	1.01	0.90	1.11	1.33	1.21	1.45
2009	24,778	0.53	0.45	0.61	0.59	0.51	0.66
2010	32,204	0.70	0.62	0.77	1.15	1.04	1.25
2011	26,267	0.24	0.19	0.29	0.26	0.20	0.31
2012	26,750	0.66	0.58	0.75	0.89	0.80	0.99
2013	29,108	0.85	0.75	0.94	1.01	0.91	1.11
2014[B]	29,739	0.36	0.30	0.42	0.39	0.33	0.45
Geometric mean		0.54			0.63		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.17. Overall LGR-to-GRA SARs for Rapid River hatchery spring Chinook, 1997–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
1997	15,765	0.65	0.52	0.79	0.65	0.52	0.78
1998	32,148	1.88	1.71	2.07	1.98	1.80	2.18
1999	35,895	2.91	2.69	3.13	3.04	2.82	3.25
2000	35,194	1.94	1.79	2.08	1.96	1.82	2.10
2001	38,026	1.06	0.94	1.18	1.16	1.04	1.29
2002	41,471	0.90	0.79	1.01	1.07	0.95	1.19
2003	37,911	0.24	0.19	0.29	0.31	0.26	0.37
2004	36,178	0.34	0.28	0.41	0.36	0.29	0.42
2005	38,231	0.25	0.20	0.31	0.27	0.22	0.33
2006	26,349	0.50	0.43	0.58	0.60	0.52	0.68
2007	25,798	0.34	0.28	0.40	0.47	0.40	0.53
2008	29,071	1.30	1.19	1.41	1.96	1.82	2.10
2009	26,304	1.03	0.92	1.14	1.17	1.07	1.28
2010	28,623	0.48	0.41	0.55	0.78	0.69	0.87
2011	27,821	0.28	0.23	0.33	0.31	0.26	0.36
2012	26,887	0.83	0.74	0.92	1.02	0.92	1.12
2013[B]	26,839	1.30	1.18	1.42	1.54	1.41	1.67
2014[B]	27,415	0.42	0.35	0.48	0.49	0.42	0.56
Geometric mean		0.71			0.83		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.18. Overall LGR-to-BOA SARs for Rapid River hatchery spring Chinook, 2000–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	35,194	2.60	2.43	2.75	2.62	2.45	2.78
2001	38,026	1.35	1.22	1.49	1.45	1.30	1.59
2002	41,471	1.02	0.91	1.14	1.21	1.09	1.34
2003	37,911	0.32	0.27	0.38	0.40	0.34	0.46
2004	36,178	0.43	0.36	0.50	0.44	0.38	0.52
2005	38,231	0.31	0.26	0.37	0.33	0.27	0.40
2006	26,349	0.74	0.66	0.83	0.85	0.76	0.95
2007	25,798	0.48	0.41	0.56	0.62	0.54	0.70
2008	29,071	1.82	1.69	1.95	2.55	2.39	2.69
2009	26,304	1.44	1.32	1.57	1.57	1.44	1.69
2010	28,623	0.74	0.65	0.84	1.12	1.01	1.23
2011	27,821	0.35	0.29	0.41	0.38	0.33	0.44
2012	26,887	1.13	1.02	1.24	1.33	1.22	1.44
2013	26,839	1.52	1.39	1.65	1.78	1.65	1.93
2014[B]	27,415	0.54	0.46	0.61	0.61	0.53	0.69
Geometric mean		0.80			0.93		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.19. Overall LGR-to-GRA SARs for Catherine Creek hatchery spring Chinook, 2001–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2001	10,885	0.22	0.12	0.34	0.26	0.15	0.40
2002	8,435	0.77	0.56	1.00	1.00	0.76	1.28
2003	7,202	0.31	0.20	0.43	0.40	0.25	0.54
2004	5,348	0.36	0.20	0.54	0.40	0.22	0.58
2005	4,848	0.40	0.22	0.60	0.48	0.27	0.68
2006	4,289	0.49	0.32	0.69	0.61	0.41	0.81
2007	4,695	0.43	0.27	0.59	0.83	0.61	1.06
2008	6,605	2.13	1.83	2.44	2.95	2.60	3.32
2009	5,381	1.54	1.26	1.83	1.80	1.50	2.10
2010	6,329	0.88	0.68	1.10	1.55	1.24	1.85
2011	4,366	0.48	0.32	0.65	0.50	0.33	0.69
2012	3,615	0.69	0.46	0.91	0.94	0.67	1.22
2013	3,209	1.37	1.01	1.76	1.87	1.47	2.30
2014[B]	3,834	0.44	0.26	0.62	0.63	0.41	0.82
Geometric mean		0.61			0.80		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.20. Overall LGR-to-BOA SARs for Catherine Creek hatchery spring Chinook, 2001–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2001	10,885	0.36	0.23	0.51	0.42	0.27	0.59
2002	8,435	1.00	0.76	1.25	1.23	0.97	1.51
2003	7,202	0.33	0.21	0.48	0.42	0.27	0.57
2004	5,348	0.44	0.25	0.64	0.48	0.30	0.69
2005	4,848	0.51	0.31	0.73	0.58	0.37	0.82
2006	4,289	0.79	0.58	1.03	0.91	0.66	1.15
2007	4,695	0.60	0.41	0.79	1.04	0.80	1.29
2008	6,605	2.72	2.38	3.07	3.69	3.28	4.10
2009	5,381	2.10	1.77	2.41	2.40	2.03	2.75
2010	6,329	1.20	0.97	1.43	1.96	1.65	2.33
2011	4,366	0.64	0.44	0.84	0.66	0.46	0.87
2012	3,615	0.94	0.69	1.21	1.22	0.93	1.54
2013	3,209	1.65	1.27	2.06	2.18	1.76	2.64
2014[B]	3,834	0.60	0.40	0.80	0.83	0.58	1.06
Geometric mean		0.81			1.03		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.21. Overall LGR-to-GRA SARs for McCall[A] hatchery summer Chinook, 1997–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[B]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
1997	22,381	1.31	1.15	1.46	1.41	1.25	1.58
1998	27,812	2.50	2.28	2.73	3.07	2.80	3.32
1999	31,571	3.26	3.02	3.49	3.73	3.48	4.02
2000	31,825	3.12	2.92	3.33	3.63	3.41	3.84
2001	36,784	1.20	1.07	1.34	1.54	1.39	1.70
2002	32,599	1.34	1.18	1.49	1.82	1.64	2.00
2003	43,144	0.68	0.60	0.76	1.00	0.91	1.09
2004	40,150	0.39	0.33	0.46	0.47	0.40	0.55
2005	43,229	0.57	0.50	0.64	0.61	0.54	0.69
2006	21,794	1.06	0.95	1.18	1.27	1.15	1.41
2007	19,082	0.90	0.78	1.01	1.43	1.28	1.59
2008	21,044	1.14	1.02	1.26	2.37	2.19	2.56
2009	18,495	0.52	0.44	0.61	0.83	0.72	0.94
2010	20,552	0.58	0.49	0.67	1.06	0.93	1.18
2011	22,876	0.31	0.25	0.38	0.37	0.31	0.44
2012	20,541	0.59	0.51	0.68	1.13	1.01	1.26
2013	23,998	0.89	0.79	0.99	1.43	1.30	1.55
2014[C]	25,957	0.41	0.34	0.47	0.69	0.60	0.77
Geometric mean		0.91			1.27		

[A] SAR estimates are based on unweighted methodology, as outlined in Chapter 4.
[B] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.22. Overall LGR-to-BOA SARs for McCall[A] hatchery summer Chinook, 2000–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[B]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	31,825	3.61	3.39	3.83	4.00	3.78	4.23
2001	36,784	1.43	1.28	1.59	1.72	1.56	1.87
2002	32,599	1.66	1.48	1.85	2.05	1.84	2.24
2003	43,144	0.76	0.68	0.85	1.06	0.97	1.15
2004	40,150	0.52	0.44	0.61	0.62	0.54	0.71
2005	43,229	0.67	0.59	0.76	0.73	0.65	0.82
2006	21,794	1.29	1.15	1.42	1.52	1.39	1.67
2007	19,082	1.10	0.97	1.23	1.67	1.53	1.82
2008	21,044	1.55	1.40	1.70	3.07	2.87	3.27
2009	18,495	0.94	0.82	1.05	1.25	1.11	1.38
2010	20,552	0.73	0.63	0.84	1.32	1.19	1.47
2011	22,876	0.41	0.34	0.48	0.48	0.40	0.56
2012	20,541	0.99	0.87	1.11	1.64	1.50	1.79
2013	23,998	1.69	1.55	1.82	2.34	2.17	2.50
2014[C]	25,957	0.57	0.50	0.65	1.04	0.93	1.15
Geometric mean		1.02			1.41		

[A] SAR estimates are based on unweighted methodology, as outlined in Chapter 4.
[B] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.23. Overall LGR-to-GRA SARs for Imnaha hatchery summer Chinook, 1997–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
1997	8,254	0.98	0.76	1.23	1.35	1.10	1.64
1998	13,577	0.80	0.63	1.00	1.46	1.20	1.73
1999	13,244	2.41	2.09	2.74	3.20	2.82	3.57
2000	14,267	2.89	2.63	3.16	3.99	3.66	4.31
2001	15,650	0.61	0.48	0.77	0.97	0.80	1.17
2002	13,962	0.68	0.52	0.85	1.02	0.83	1.23
2003	14,948	0.53	0.42	0.65	1.26	1.08	1.43
2004	12,867	0.36	0.25	0.46	0.45	0.33	0.58
2005	11,172	0.27	0.17	0.37	0.32	0.23	0.43
2006	8,753	0.80	0.64	0.96	1.12	0.95	1.30
2007	9,596	0.67	0.53	0.80	1.39	1.18	1.57
2008	10,148	1.76	1.55	1.97	4.47	4.13	4.83
2009	9,734	1.04	0.85	1.21	1.84	1.63	2.07
2010	9,907	0.78	0.62	0.94	1.45	1.24	1.67
2011	8,351	0.24	0.15	0.33	0.43	0.32	0.56
2012	10,021	0.18	0.11	0.25	0.59	0.46	0.72
2013	10,360	0.52	0.40	0.64	1.54	1.33	1.76
2014[B]	9,761	0.41	0.31	0.52	0.69	0.56	0.83
Geometric mean		0.67			1.19		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.24. Overall LGR-to-BOA SARs for Imnaha hatchery summer Chinook, 2000–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	14,267	3.46	3.16	3.78	4.48	4.14	4.84
2001	15,650	0.77	0.62	0.94	1.12	0.95	1.31
2002	13,962	0.89	0.70	1.09	1.19	0.98	1.41
2003	14,948	0.67	0.54	0.80	1.25	1.08	1.43
2004	12,867	0.57	0.44	0.72	0.68	0.54	0.83
2005	11,172	0.35	0.24	0.46	0.43	0.31	0.55
2006	8,753	0.99	0.83	1.18	1.41	1.21	1.62
2007	9,596	0.85	0.72	1.02	1.64	1.43	1.87
2008	10,148	2.48	2.22	2.76	5.55	5.16	5.94
2009	9,734	1.66	1.44	1.88	2.58	2.30	2.84
2010	9,907	0.94	0.78	1.12	1.82	1.59	2.06
2011	8,351	0.38	0.28	0.50	0.62	0.48	0.77
2012	10,021	0.39	0.29	0.49	0.92	0.76	1.09
2013	10,360	1.20	1.00	1.38	2.43	2.14	2.72
2014[B]	9,761	0.50	0.39	0.63	0.95	0.80	1.12
Geometric mean		0.85			1.41		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.25. Overall LGR-to-GRA SARs for Clearwater Hatchery spring Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	25,964	0.57	0.49	0.65	0.67	0.58	0.75
2007	29,961	0.30	0.25	0.35	0.40	0.34	0.46
2008	19,336	0.97	0.85	1.10	1.31	1.17	1.45
2009	28,743	0.71	0.63	0.80	0.87	0.78	0.96
2010	37,579	0.48	0.42	0.54	0.71	0.63	0.79
2011	31,107	0.15	0.12	0.18	0.16	0.13	0.20
2012	33,279	0.51	0.44	0.57	0.69	0.61	0.77
2013	30,442	0.73	0.65	0.81	0.86	0.78	0.95
2014[B]	24,949	0.35	0.30	0.42	0.44	0.38	0.51
Geometric mean		0.47			0.59		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.26. Overall LGR-to-BOA SARs for Clearwater Hatchery spring Chinook, 2006–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	25,964	0.88	0.79	0.98	1.00	0.90	1.11
2007	29,961	0.43	0.36	0.49	0.54	0.47	0.61
2008	19,336	1.36	1.22	1.51	1.76	1.60	1.94
2009	28,743	1.03	0.93	1.13	1.20	1.09	1.31
2010	37,579	0.65	0.58	0.73	0.93	0.84	1.03
2011	31,107	0.22	0.17	0.26	0.23	0.19	0.28
2012	33,279	0.69	0.61	0.76	0.90	0.81	0.98
2013	30,442	0.88	0.79	0.97	1.04	0.95	1.14
2014[B]	29,949	0.48	0.41	0.55	0.58	0.51	0.67
Geometric mean		0.66			0.80		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.27. Overall LGR-to-GRA SARs for Sawtooth Hatchery spring Chinook, 2007–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2007	7,761	0.63	0.50	0.79	1.08	0.88	1.28
2008	4,514	1.00	0.75	1.25	1.77	1.45	2.14
2009	4,916	0.39	0.25	0.54	0.57	0.39	0.76
2010	6,631	0.45	0.32	0.60	0.78	0.61	0.97
2011	7,446	0.08	0.03	0.13	0.13	0.07	0.20
2012	6,300	0.40	0.27	0.54	0.57	0.43	0.74
2013	8,520	0.69	0.54	0.85	0.77	0.61	0.95
2014[B]	8,618	0.32	0.23	0.42	0.72	0.57	0.86
Geometric mean		0.41			0.66		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.28. Overall LGR-to-BOA SARs for Sawtooth Hatchery spring Chinook, 2007–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2007	7,761	0.72	0.55	0.89	1.20	0.99	1.42
2008	4,514	1.20	0.93	1.49	2.15	1.78	2.53
2009	4,916	0.43	0.27	0.58	0.61	0.44	0.82
2010	6,631	0.54	0.40	0.71	1.01	0.80	1.22
2011	7,446	0.12	0.05	0.19	0.17	0.09	0.26
2012	6,300	0.54	0.40	0.70	0.76	0.59	0.95
2013	8,520	1.01	0.83	1.19	1.12	0.93	1.31
2014[B]	8,618	0.42	0.30	0.53	0.94	0.77	1.12
Geometric mean		0.52			0.83		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.29. **Overall LGR-to-GRA SARs for Pahsimeroi Hatchery summer Chinook, 2008–2014. SARs are calculated with and without jacks.**

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2008	5,963	1.26	1.02	1.49	2.11	1.80	2.44
2009	6,892	0.55	0.40	0.70	0.73	0.57	0.89
2010	5,729	0.09	0.03	0.16	0.19	0.10	0.30
2011	7,375	0.01	0.00	0.04	0.01	0.00	0.04
2012	8,692	0.16	0.09	0.23	0.26	0.18	0.36
2013	9,056	0.15	0.09	0.22	0.28	0.18	0.37
2014[B]	11,933	0.02	0.00	0.04	0.02	0.00	0.04
Geometric mean		0.12			0.18		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.30. **Overall LGR-to-BOA SARs for Pahsimeroi Hatchery summer Chinook, 2008–2014. SARs are calculated with and without jacks.**

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2008	5,963	1.66	1.39	1.98	2.70	2.33	3.07
2009	6,892	0.91	0.73	1.11	1.07	0.87	1.28
2010	5,729	0.10	0.04	0.18	0.23	0.13	0.34
2011	7,375	0.01	0.00	0.04	0.01	0.00	0.04
2012	8,692	0.22	0.14	0.31	0.37	0.27	0.48
2013	9,056	0.28	0.19	0.37	0.43	0.31	0.56
2014[B]	11,933	0.02	0.00	0.04	0.02	0.00	0.04
Geometric mean		0.16			0.22		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.31. Overall LGR-to-GRA SARs for Clearwater Hatchery summer Chinook, 2011–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2011	9,359	0.18	0.12	0.26	0.25	0.17	0.33
2012	10,191	0.30	0.22	0.40	0.55	0.44	0.67
2013	9,918	0.32	0.22	0.41	0.45	0.34	0.56
2014[B]	13,119	0.30	0.22	0.38	0.43	0.34	0.52
Geometric mean		0.27			0.40		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.32. Overall LGR-to-BOA SARs for Clearwater Hatchery summer Chinook, 2011–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2011	9,359	0.24	0.16	0.32	0.30	0.22	0.40
2012	10,191	0.48	0.37	0.60	0.78	0.63	0.92
2013	9,918	0.83	0.68	0.98	1.03	0.85	1.20
2014[B]	13,119	0.50	0.40	0.61	0.75	0.63	0.88
Geometric mean		0.47			0.65		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Snake River wild Steelhead

Table B.33. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Basin (above LGR) Wild Steelhead, 1997–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
1997	3,830	1.16	0.39	2.11	--	--	--
1998	7,109	0.30	0.07	0.68	--	--	--
1999	8,820	2.84	1.67	4.24	--	--	--
2000	13,609	2.66	1.59	3.79	2.99	1.88	4.17
2001	12,929	2.47	0.93	4.33	3.95	1.87	6.17
2002	13,378	2.14	1.24	3.21	2.60	1.47	3.82
2003	12,926	1.57	1.22	1.94	1.86	1.47	2.25
2004	13,263	0.85	0.63	1.08	1.31	1.03	1.58
2005	15,124	0.80	0.59	1.00	1.01	0.79	1.23
2006	5,431	1.14	0.91	1.40	1.92	1.59	2.21
2007	7,083	2.57	2.26	2.90	3.30	2.92	3.67
2008	5,730	3.21	2.82	3.62	4.38	3.91	4.84
2009	5,976	2.46	2.13	2.77	3.56	3.17	3.98
2010	8,313	1.71	1.46	1.95	2.37	2.08	2.68
2011	4,932	1.26	1.01	1.53	1.85	1.53	2.17
2012	6,890	2.54	2.23	2.88	3.40	3.04	3.76
2013	8,422	1.99	1.74	2.26	2.70	2.40	3.00
Geometric mean (97-13)		1.62	Geometric mean (00-13)		2.46		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release through 2005 and Group T tags beginning in 2006.

Table B.34. Overall LGR-to-GRA and LGR-to-BOA SARs for Clearwater Basin Wild Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	2,747	0.80	0.52	1.09	1.24	0.89	1.61
2007	2,249	1.16	0.80	1.53	1.51	1.06	1.95
2008	3,546	2.79	2.35	3.29	3.95	3.41	4.53
2009	1,747	1.72	1.20	2.25	2.29	1.68	2.90
2010	3,566	1.46	1.13	1.81	1.91	1.51	2.30
2011	1,838	1.03	0.64	1.45	1.14	0.72	1.59
2012	2,937	2.76	2.25	3.31	3.40	2.82	3.99
2013	3,042	2.33	1.87	2.81	2.70	2.19	3.21
Geometric mean		1.60			2.07		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.35. Overall LGR-to-GRA and LGR-to-BOA SARs for Grande Ronde Basin Wild Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	553	1.63	0.86	2.59	3.61	2.39	5.05
2007	432	4.39	2.76	6.28	4.86	3.11	7.00
2008	357	3.36	1.78	5.00	5.60	3.61	7.94
2009	342	2.34	1.08	3.80	4.39	2.61	6.40
2010	489	2.87	1.65	4.34	4.09	2.55	5.87
2011	640	1.87	1.05	2.81	3.28	2.13	4.46
2012	533	3.57	2.27	5.06	4.13	2.71	5.79
2013	654	2.45	1.50	3.49	3.82	2.65	5.19
Geometric mean		2.68			4.17		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.36. Overall LGR-to-GRA and LGR-to-BOA SARs for Imnaha Basin Wild Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	1,701	1.23	0.78	1.69	2.23	1.69	2.84
2007	3,581	3.10	2.62	3.62	4.13	3.60	4.71
2008	2,064	5.17	1.79	9.16	5.57	2.14	9.59
2009	2,228	3.64	3.00	4.32	5.07	4.30	5.89
2010	2,209	1.90	1.45	2.39	2.67	2.12	3.24
2011	945	1.06	0.53	1.70	1.69	1.04	2.45
2012	1,588	2.33	1.71	2.95	3.78	3.00	4.53
2013	2,758	1.96	1.52	2.40	2.97	2.44	3.56
Geometric mean		2.25			3.27		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.37. Overall LGR-to-GRA and LGR-to-BOA SARs for Salmon Basin Wild Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	630	1.59	0.80	2.47	1.91	1.08	2.88
2007	828	3.14	2.07	4.29	3.74	2.66	4.99
2008	1,385	5.20	4.12	6.33	6.50	5.22	7.70
2009	1,450	1.93	1.38	2.56	3.10	2.33	3.91
2010	1,927	1.76	1.22	2.40	2.59	1.90	3.39
2011	1,471	1.36	0.88	1.89	2.18	1.58	2.90
2012	1,374	2.69	1.97	3.44	3.57	2.78	4.43
2013	1,226	1.55	0.98	2.20	2.37	1.63	3.20
Geometric mean		2.17			3.02		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.38. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Basin (above LGR) Wild A-run Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	2,382	1.43	1.02	1.83	2.65	2.10	3.16
2007	4,491	3.30	2.87	3.76	4.27	3.76	4.81
2008	1,635	2.57	1.90	3.22	3.79	3.07	4.61
2009	3,572	2.88	2.40	3.35	4.23	3.66	4.83
2010	4,675	2.05	1.69	2.43	2.91	2.48	3.36
2011	2,989	1.41	1.07	1.78	2.17	1.74	2.60
2012	3,226	2.73	2.28	3.21	3.78	3.24	4.33
2013	4,696	2.30	1.94	2.69	3.19	2.73	3.63
Geometric mean		2.24			3.29		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.39. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Basin (above LGR) Wild B-run Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	3,049	0.92	0.65	1.22	1.34	1.02	1.72
2007	1,872	1.39	0.93	1.85	1.76	1.24	2.32
2008	3,559	3.54	3.03	4.10	4.69	4.08	5.32
2009	2,393	1.84	1.39	2.28	2.59	2.08	3.16
2010	2,788	1.26	0.91	1.65	1.69	1.28	2.14
2011	1,905	1.00	0.62	1.40	1.31	0.92	1.76
2012	3,293	2.46	2.02	2.91	3.16	2.68	3.67
2013	2,496	1.88	1.46	2.38	2.40	1.89	2.98
Geometric mean		1.62			2.17		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Snake River hatchery Steelhead

Table B.40. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Basin (above LGR) Hatchery Steelhead (all groups combined), 1997–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
1997	24,710	0.39	0.23	0.57	--	--	--
1998	23,507	0.56	0.31	0.85	--	--	--
1999	27,193	0.92	0.59	1.28	--	--	--
2000	24,565	1.89	1.16	2.68	2.28	1.46	3.08
2001	20,877	0.92	0.24	1.74	1.38	0.52	2.31
2002	20,681	0.95	0.40	1.72	0.98	0.29	1.71
2003	21,400	1.46	1.24	1.68	1.82	1.57	2.08
2004	17,082	2.08	1.14	3.19	2.28	1.24	3.45
2005	19,640	1.83	1.17	2.55	2.95	2.07	3.87
2006	13,473	1.96	1.32	2.62	2.71	1.98	3.52
2007	21,828	1.64	1.37	1.92	2.34	2.00	2.66
2008	89,884	3.09	3.00	3.19	4.46	4.34	4.59
2009	103,947	1.49	1.43	1.56	2.14	2.07	2.21
2010	109,158	1.60	1.53	1.67	2.30	2.22	2.38
2011	105,914	0.64	0.60	0.68	0.96	0.91	1.01
2012	91,741	1.52	1.46	1.59	2.21	2.13	2.30
2013	102,604	1.16	1.10	1.22	1.58	1.51	1.64
Geometric mean (97-13)		1.26	Geometric mean (00-13)		2.01		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2007 and Group T tags beginning in 2008.

Table B.41. Overall LGR-to-GRA and LGR-to-BOA SARs for Grande Ronde River Basin (A-Run) Hatchery Steelhead, 2008–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2008	16,858	4.54	4.23	4.85	6.75	6.37	7.15
2009	15,279	1.62	1.44	1.79	2.45	2.23	2.68
2010	16,205	2.05	1.86	2.25	3.17	2.92	3.43
2011	15,236	0.43	0.35	0.53	0.71	0.61	0.83
2012	15,408	1.65	1.47	1.82	2.57	2.35	2.78
2013	15,031	1.56	1.39	1.73	2.32	2.10	2.54
Geometric mean		1.60			2.46		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.42. Overall LGR-to-GRA and LGR-to-BOA SARs for Imnaha River Basin (A-Run) Hatchery Steelhead, 2008–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2008	12,468	4.50	4.15	4.83	6.70	6.26	7.12
2009	11,286	1.72	1.50	1.91	2.63	2.38	2.89
2010	11,873	1.69	1.50	1.91	2.43	2.19	2.68
2011	10,532	0.64	0.50	0.76	0.94	0.78	1.10
2012	10,440	2.16	1.92	2.39	3.16	2.87	3.45
2013	11,106	1.70	1.49	1.94	2.51	2.25	2.79
Geometric mean		1.77			2.61		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.43. Overall LGR-to-GRA and LGR-to-BOA SARs for Hells Canyon Dam (A-Run) Hatchery Steelhead, 2009–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA %SAR Estimate	LGR-to-GRA Non-parametric CI 90% LL	LGR-to-GRA Non-parametric CI 90% UL	LGR-to-BOA %SAR Estimate	LGR-to-BOA Non-parametric CI 90% LL	LGR-to-BOA Non-parametric CI 90% UL
2009	4,536	3.04	2.60	3.46	4.76	4.23	5.28
2010	5,289	3.16	2.69	3.60	4.63	4.04	5.17
2011	4,015	0.35	0.20	0.52	0.55	0.36	0.75
2012	3,605	1.78	1.38	2.13	2.69	2.25	3.12
2013	3,769	2.15	1.78	2.58	2.71	2.28	3.21
Geometric mean		1.67			2.45		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.44. Overall LGR-to-GRA and LGR-to-BOA SARs for Salmon River Basin (A-Run) Hatchery Steelhead, 2008–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA %SAR Estimate	LGR-to-GRA Non-parametric CI 90% LL	LGR-to-GRA Non-parametric CI 90% UL	LGR-to-BOA %SAR Estimate	LGR-to-BOA Non-parametric CI 90% LL	LGR-to-BOA Non-parametric CI 90% UL
2008[B]	19,133	4.78	4.51	5.07	6.45	6.13	6.78
2009	29,321	1.91	1.78	2.04	2.52	2.37	2.67
2010	34,240	1.99	1.85	2.14	2.75	2.60	2.92
2011	31,923	1.13	1.04	1.23	1.68	1.56	1.80
2012	31,756	1.74	1.62	1.87	2.55	2.40	2.70
2013	30,124	1.58	1.47	1.70	2.10	1.97	2.26
Geometric mean		1.96			2.72		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] Excludes 1,200 released from Niagara Springs due to low number and exclusive return to river at transportation sites.

Table B.45. Overall LGR-to-GRA and LGR-to-BOA SARs for Salmon River Basin (B-Run) Hatchery Steelhead, 2008–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2008	16,673	0.83	0.71	0.95	1.28	1.14	1.43
2009	15,706	0.75	0.64	0.86	1.12	0.98	1.26
2010	11,808	0.43	0.34	0.54	0.59	0.48	0.71
2011	11,152	0.19	0.12	0.26	0.39	0.30	0.49
2012	11,194	0.69	0.57	0.82	0.96	0.82	1.11
2013	14,021	0.39	0.30	0.47	0.47	0.38	0.57
Geometric mean		0.49			0.73		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Table B.46. Overall LGR-to-GRA and LGR-to-BOA SARs for Clearwater River Basin (B-Run) Hatchery Steelhead, 2008–2013.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2008	24,718	1.46	1.33	1.58	2.17	2.01	2.33
2009	28,455	1.04	0.93	1.14	1.48	1.37	1.60
2010	29,993	1.05	0.96	1.15	1.51	1.39	1.63
2011	34,771	0.41	0.35	0.46	0.59	0.52	0.66
2012	19,900	1.12	1.01	1.24	1.45	1.31	1.59
2013	27,692	0.57	0.50	0.65	0.69	0.60	0.77
Geometric mean		0.86			1.19		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.

Snake River hatchery Sockeye

Table B.47. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Hatchery Sockeye, 2009–2014.

Hatchery-Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA			LGR-to-BOA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
SAWT-2009	17,224	1.15	1.02	1.29	1.81	1.65	1.98
SAWT-2010[B]	----	---	---	---	---	---	---
SAWT-2011	26,238	0.10	0.06	0.13	0.19	0.14	0.23
SAWT-2012	21,420	0.12	0.08	0.15	0.29	0.23	0.35
SAWT-2013	19,224	0.15	0.11	0.20	2.72	2.51	2.93
SAWT-2014[C]	18,444	0.42	0.34	0.50	0.67	0.57	0.78
Geometric mean		0.24			0.71		
OXBH-2009	2,214	2.03	1.52	2.56	2.98	2.30	3.72
OXBH-2010[B]	---	---	---	---	---	---	---
OXBH-2011	5,442	0.39	0.25	0.54	1.21	0.97	1.47
OXBH-2012	4,857	2.26	1.81	2.75	4.10	3.41	4.85
Geometric mean			1.21		2.46		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using Group T tags.
[B] All PIT tagged sockeye were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Snake River wild subyearling fall Chinook

Table B.48. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) wild/natural subyearling fall Chinook, 2006 to 2011. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	363	0.28	0.00	0.85	0.28	0.00	0.84
2007[B]	---	---	---	---	---	---	---
2008	302	0.99	0.29	2.14	1.66	0.63	2.90
2009	499	0.60	0.17	1.27	0.80	0.20	1.54
2010[C]	---	---	---	---	---	---	---
2011	1,467	0.68	0.36	1.06	0.95	0.55	1.39
Geometric mean		0.80			0.87		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] SAR not possible due to low sample size.
[C] SAR not reported due to high estimated holdover rates.

Table B.49. Overall LGR-to-BOA SARs for Snake River Basin (above LGR) wild/natural subyearling fall Chinook, 2006 to 2011. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	363	0.83	0.24	1.75	0.83	0.00	1.70
2007[B]	---	---	---	---	---	---	---
2008	302	1.99	0.70	3.40	2.98	1.40	4.72
2009	499	1.20	0.40	2.15	1.40	0.62	2.46
2010[C]	---	---	---	---	---	---	---
2011	1,467	0.89	0.52	1.33	1.16	0.74	1.66
Geometric mean		1.15			1.42		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] SAR not possible due to low sample size.
[C] SAR not reported due to high estimated holdover rates.

Snake River hatchery subyearling fall Chinook

Table B.50. Overall LGR-to-GRA SARs for Lyons Ferry Hatchery subyearling fall Chinook released at Big Canyon Creek Acclimation Pond (Clearwater River), 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	32,030	0.54	0.47	0.61	0.89	0.80	0.98
2007[B]	---	---	---	---	---	---	---
2008	12,280	1.07	0.92	1.24	1.86	1.64	2.08
2009	5,239	0.11	0.04	0.19	0.19	0.10	0.29
2010	14,021	0.80	0.68	0.92	1.03	0.89	1.16
2011	16,275	0.95	0.82	1.08	1.24	1.09	1.38
2012[C]	14,898	0.66	0.56	0.78	0.95	0.82	1.09
Geometric mean		0.56			0.85		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.51. Overall LGR-to-BOA SARs for Lyons Ferry Hatchery subyearling fall Chinook released at Big Canyon Creek Acclimation Pond (Clearwater River), 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	32,030	0.85	0.76	0.94	1.25	1.15	1.36
2007[B]	---	---	---	---	---	---	---
2008	12,280	1.70	1.51	1.93	2.70	2.41	2.99
2009	5,239	0.21	0.11	0.33	0.29	0.17	0.42
2010	14,021	1.17	1.02	1.32	1.45	1.29	1.63
2011	16,275	1.48	1.32	1.64	1.81	1.63	1.99
2012[C]	14,898	0.98	0.85	1.11	1.37	1.20	1.53
Geometric mean		0.90			1.23		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.52. Overall LGR-to-GRA SARs for Lyons Ferry Hatchery subyearling fall Chinook released at Captain John Rapids Acclimation Pond, 2007 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2007[B]	---	---	---	---	---	---	---
2008	15,205	0.53	0.44	0.63	1.05	0.90	1.19
2009	5,889	0.19	0.10	0.29	0.37	0.25	0.51
2010	14,865	0.97	0.84	1.10	1.51	1.34	1.68
2011	16,949	0.96	0.83	1.08	1.35	1.20	1.50
2012[C]	15,919	0.65	0.54	0.75	0.81	0.69	0.93
Geometric mean		0.57			0.92		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.53. Overall LGR-to-BOA SARs for Lyons Ferry Hatchery subyearling fall Chinook released at Captain John Rapids Acclimation Pond, 2007 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2007[B]	---	---	---	---	---	---	---
2008	15,205	0.97	0.84	1.10	0.61	1.46	1.79
2009	5,889	0.25	0.15	0.37	0.46	0.32	0.60
2010	14,865	1.67	1.49	1.85	2.30	2.09	2.51
2011	16,949	1.49	1.34	1.64	1.96	1.79	2.15
2012[C]	15,919	1.07	0.93	1.20	1.32	1.16	1.47
Geometric mean		0.92			1.35		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.54. Overall LGR-to-GRA SARs for Lyons Ferry Hatchery subyearling fall Chinook released at Pittsburg Landing Acclimation Pond, 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	14,894	0.12	0.07	0.17	0.24	0.17	0.31
2007[B]	---	---	---	---	---	---	---
2008	11,464	0.92	0.78	1.07	1.79	1.58	2.00
2009	4,786	0.23	0.12	0.36	0.36	0.23	0.51
2010	10,772	0.83	0.69	0.98	1.23	1.06	1.42
2011	13,624	0.73	0.61	0.86	0.95	0.81	1.09
2012[C]	12,788	0.73	0.61	0.87	0.99	0.85	1.14
Geometric mean		0.47			0.75		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.55. Overall LGR-to-BOA SARs for Lyons Ferry Hatchery subyearling fall Chinook released at Pittsburg Landing Acclimation Pond, 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	14,894	0.19	0.13	0.25	0.34	0.25	0.42
2007[B]	---	---	---	---	---	---	---
2008	11,464	1.48	0.13	1.68	2.52	2.26	2.78
2009	4,786	0.27	0.15	0.40	0.42	0.27	0.58
2010	10,772	1.42	1.24	1.61	1.91	1.69	2.14
2011	13,624	1.23	1.06	1.38	1.48	1.30	1.65
2012[B]	12,788	1.08	0.92	1.24	1.47	1.31	1.65
Geometric mean		0.72			1.07		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.56. Overall LGR-to-GRA SARs for Lyons Ferry Hatchery subyearling fall Chinook released into the mainstem Snake River (above LGR), 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	11,083	0.29	0.20	0.38	0.42	0.32	0.53
2007[B]	---	---	---	---	---	---	---
2008	5,693	0.70	0.51	0.92	1.18	0.91	1.45
2009	5,078	0.18	0.08	0.28	0.35	0.23	0.50
2010	4,248	0.64	0.44	0.88	0.94	0.71	1.11
2011	6,491	0.92	0.73	1.14	1.26	1.03	1.51
2012[C]	5,547	0.41	0.28	0.56	0.49	0.34	0.65
Geometric mean		0.45			0.68		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.57. Overall LGR-to-BOA SARs for Lyons Ferry Hatchery subyearling fall Chinook released into the mainstem Snake River (above LGR), 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	11,083	0.46	0.36	0.57	0.63	0.51	0.77
2007[B]	---	---	---	---	---	---	---
2008	5,693	1.02	0.80	1.27	1.67	1.37	1.98
2009	5,078	0.32	0.20	0.46	0.49	0.33	0.66
2010	4,248	1.13	0.88	1.42	1.48	1.20	1.82
2011	6,491	1.46	1.23	1.76	1.82	1.55	2.12
2012[C]	5,547	0.56	0.40	0.73	0.67	0.49	0.86
Geometric mean		0.72			0.99		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.58. Overall LGR-to-GRA SARs for Irrigon Hatchery subyearling fall Chinook released into the Grande Ronde River, 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006[B]	11,143	0.21	0.14	0.29	0.31	0.22	0.40
2007[C]	---	---	---	---	---	---	---
2008	7,987	0.35	0.25	0.46	0.68	0.53	0.84
2009	8,795	0.20	0.13	0.29	0.28	0.20	0.39
2010	11,009	0.79	0.66	0.94	0.95	0.81	1.11
2011	9,233	0.30	0.22	0.40	0.44	0.33	0.57
2012[D]	8,059	0.51	0.38	0.64	0.68	0.63	0.84
Geometric mean		0.35			0.51		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] 2006 release was reared at Lyons Ferry Hatchery
[C] Due to low broodstock, no PIT-tags were released in this group in 2007.
[D] Incomplete, 3-salt returns through December 31, 2015.

Table B.59. Overall LGR-to-BOA SARs for Irrigon Hatchery subyearling fall Chinook released into the Grande Ronde River, 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006[B]	11,143	0.28	0.19	0.36	0.43	0.32	0.56
2007[C]	---						
2008	7,987	0.56	0.43	0.70	0.94	0.75	1.13
2009	8,795	0.25	0.17	0.34	0.34	0.24	0.45
2010	11,009	1.32	1.15	1.50	1.54	1.34	1.73
2011	9,233	0.48	0.36	0.60	0.62	0.49	0.76
2012[D]	8,059	0.83	0.66	1.01	1.08	0.88	1.28
Geometric mean		0.52			0.72		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] 2006 release was reared at Lyons Ferry Hatchery
[C] Due to low broodstock, no PIT-tags were released in this group in 2007.
[D] Incomplete, 3-salt returns through December 31, 2015.

Table B.60. Overall LGR-to-GRA SARs for Umatilla/Irrigon Hatchery subyearling fall Chinook released into the Snake River below Hells Canyon Dam, 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006	11,930	0.21	0.14	0.28	0.31	0.23	0.39
2007[B]	---	---	---	---	---	---	---
2008	12,201	1.07	0.92	1.25	2.29	2.06	2.51
2009	15,156	0.05	0.02	0.09	0.15	0.09	0.20
2010	13,428	0.62	0.50	0.73	0.84	0.71	0.97
2011	10,509	0.34	0.25	0.44	0.44	0.34	0.55
2012[C]	12,770	0.67	0.54	0.79	0.85	0.71	1.00
Geometric mean		0.34			0.57		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.61. Overall LGR-to-BOA SARs for Umatilla/Irrigon Hatchery subyearling fall Chinook released into the Snake River below Hells Canyon Dam, 2006 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	11,930	0.32	0.23	0.41	0.45	0.36	0.56
2007[B]	---	---	---	---	---	---	---
2008	12,201	1.17	1.58	1.97	3.32	3.02	3.60
2009	15,156	0.07	0.03	0.10	0.16	0.11	0.22
2010	13,428	0.94	0.80	1.08	1.21	1.06	1.37
2011	10,509	0.64	0.52	0.78	0.76	0.63	0.92
2012[C]	12,770	1.05	0.90	1.21	1.32	1.15	1.51
Geometric mean		0.54			0.81		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.62. Overall LGR-to-GRA SARs for Oxbow Hatchery (Idaho) subyearling fall Chinook released into the Snake River below Hells Canyon Dam, 2007 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2007[B]	---	---	---	---	---	---	---
2008	5,577	0.90	0.70	1.12	2.22	1.91	2.56
2009	4,569	0.09	0.02	0.17	0.31	0.17	0.45
2010	---	---	---	---	---	---	---
2011	5,251	0.42	0.27	0.58	0.61	0.44	0.80
2012[C]	5,046	0.40	0.26	0.53	0.59	0.41	0.77
Geometric mean		0.34			0.71		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.63. Overall LGR-to-BOA SARs for Oxbow Hatchery (Idaho) subyearling fall Chinook released into the Snake River below Hells Canyon Dam, 2007 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2007[B]	---	---	---	---	---	---	---
2008	5,577	1.51	1.24	1.79	3.03	2.67	3.43
2009	4,569	0.11	0.04	0.20	0.33	0.20	0.47
2010	---	---	---	---	---	---	---
2011	5,251	0.74	0.55	0.95	1.07	0.84	1.32
2012[C]	5,046	0.65	0.48	0.83	1.07	0.84	1.31
Geometric mean		0.53			1.03		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] All PIT-tagged fish were routed in-river. There were very few incidentally transported PIT-tagged fish for both groups, therefore, estimate of overall SAR (LGR-to-GRA and LGR-to-BOA) was not possible.
[C] Incomplete, 3-salt returns through December 31, 2015.

Table B.64. Overall LGR-to-GRA SARs for Dworshak Hatchery subyearling fall Chinook (surrogates) released into the mainstem Snake River (above Lower Granite Dam), 2006 to 2011. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	63,844	0.25	0.22	0.28	0.36	0.32	0.40
2007[B]	---	---	---	---	---	---	---
2008	62,103	0.64	0.59	0.70	1.09	1.02	1.16
2009	85,076	0.15	0.13	0.17	0.22	0.19	0.25
2010	44,215	0.52	0.46	0.58	0.83	0.74	0.90
2011	56,234	0.86	0.80	0.93	1.06	0.98	1.13
2012[C]	---	---	---	---	---	---	---
Geometric mean		0.40			0.60		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] SAR not reported due to high estimated holdover rates.

Table B.65. Overall LGR-to-BOA SARs for Dworshak Hatchery subyearling fall Chinook (surrogates) released into the mainstem Snake River (above Lower Granite Dam), 2006 to 2011. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2006	63,844	0.37	0.33	0.41	0.49	0.44	0.54
2007[B]	---	---	---	---	---	---	---
2008	62,103	0.97	0.90	1.04	1.51	1.42	1.60
2009	85,076	0.21	0.18	0.23	0.29	0.26	0.32
2010	44,215	0.74	0.66	0.81	1.07	0.98	1.17
2011	56,234	1.33	1.25	1.41	1.57	1.48	1.66
2012	---	---	---	---	---	---	---
Geometric mean		0.59			0.82		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Due to low broodstock, no PIT-tags were released in this group in 2007.
[C] SAR not reported due to high estimated holdover rates.

Table B.66. Overall LGR-to-GRA SARs for Nez Perce Tribal Hatchery subyearling fall Chinook released from Cedar Flats Acclimation Facility (Clearwater River), 2010 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2010	2,850	0.56	0.34	0.78	0.63	0.40	0.87
2011	6,680	0.91	0.73	1.11	1.36	1.14	1.60
2012[B]	5,163	0.79	0.59	1.02	0.87	0.65	1.11
Geometric mean		0.74			0.91		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 3-salt returns through December 31, 2015.

Table B.67. Overall LGR-to-BOA SARs for Nez Perce Tribal Hatchery subyearling fall Chinook released from Cedar Flats Acclimation Facility (Clearwater River), 2010 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2010	2,850	0.95	0.66	1.25	1.05	0.75	1.36
2011	6,680	1.66	1.39	1.94	2.40	2.07	2.73
2012[B]	5,163	1.14	0.89	1.42	1.28	1.01	1.59
Geometric mean		1.22			1.48		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 3-salt returns through December 31, 2015.

Table B.68. Overall LGR-to-GRA SARs for Nez Perce Tribal Hatchery subyearling fall Chinook released from Lukes Gulch Acclimation Facility (Clearwater River), 2010 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-GRA without Jacks			LGR-to-GRA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2010	4,436	0.20	0.11	0.32	0.54	0.39	0.71
2011	6,595	0.80	0.62	0.98	1.08	0.87	1.30
2012[B]	6,328	0.44	0.31	0.59	0.52	0.38	0.68
Geometric mean		0.41			0.67		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 3-salt returns through December 31, 2015.

Table B.69. Overall LGR-to-BOA SARs for Nez Perce Tribal Hatchery subyearling fall Chinook released from Lukes Gulch Acclimation Facility (Clearwater River), 2010 to 2012. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR[A]	LGR-to-BOA without Jacks			LGR-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2010	4,436	0.47	0.31	0.64	0.88	0.65	1.11
2011	6,595	2.00	1.71	2.28	2.47	2.15	2.78
2012[B]	6,328	0.63	0.47	0.80	0.76	0.58	0.95
Geometric mean		0.84			1.18		

[A] Estimated population of tagged study fish alive to LGR tailrace (includes fish detected at the dam and those estimated to pass undetected) using total tag release in years through 2005 and Group T tags beginning in 2006.
[B] Incomplete, 3-salt returns through December 31, 2015.

Middle Columbia wild spring Chinook

Table B.70. Overall JDA-to-BOA SARs for John Day River Basin Wild Chinook, 2000 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving JDA[A]	JDA-to-BOA without Jacks			JDA-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	1,310	10.91	9.32	12.55	11.14	9.51	12.77
2001	2,743	3.86	3.25	4.50	4.12	3.48	4.76
2002	2,513	3.78	3.13	4.52	3.98	3.29	4.75
2003	4,388	2.80	2.38	3.26	2.92	2.49	3.39
2004	2,805	3.14	2.46	3.88	3.32	2.60	4.07
2005	3,817	1.86	1.51	2.22	2.07	1.71	2.47
2006	2,237	2.06	1.55	2.59	2.15	1.63	2.70
2007	2,726	4.33	3.65	5.00	5.06	4.33	5.76
2008	2,973	5.48	4.69	6.27	6.22	5.36	7.08
2009	3,219	6.77	5.95	7.63	7.11	6.25	8.03
2010	3,095	3.55	2.99	4.14	4.85	4.18	5.49
2011	2,569	0.90	0.59	1.24	0.93	0.63	1.28
2012	2,528	3.40	2.70	4.20	4.27	3.49	5.15
2013	1,151	4.08	3.06	5.18	5.12	3.93	6.39
2014[B]	991	3.23	2.20	4.51	3.53	2.40	4.90
Geometric mean		3.46			3.85		

[A] Estimated population of tagged study fish alive to JDA tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.71. Overall MCN-to-BOA SARs for Yakima River Basin Wild Chinook, 2000 to 2014. SARs are calculated with and without jacks. No PIT-tagged smolts released in 2010 or 2014.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks			MCN-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	2,581	6.90	6.10	7.73	7.48	6.67	8.38
2001	521	1.54	0.73	2.52	1.92	0.98	3.04
2002	2,130	2.25	1.73	2.82	2.30	1.77	2.86
2003	2,143	2.47	1.91	3.04	2.89	2.27	3.55
2004	1,297	3.70	2.87	4.62	3.78	2.95	4.70
2005	519	1.35	0.57	2.20	1.35	0.57	2.20
2006	565	1.59	0.76	2.65	1.77	0.85	2.78
2007	362	1.93	0.86	3.26	1.93	0.86	3.26
2008	512	6.84	4.93	8.96	9.19	6.85	11.73
2009	990	4.95	3.78	6.21	5.56	4.33	6.88
2010	0	--	--	--	--	--	--
2011	411	0.97	0.24	1.79	0.97	0.24	1.79
2012	826	2.79	1.85	3.85	3.27	2.19	4.45
2013	704	1.42	0.75	2.25	1.56	0.83	2.44
2014	0	--	--	--	--	--	--
Geometric mean		2.46			2.71		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

Table B.72. Overall MCN-to-MCA SARs for Yakima River Basin Wild Chinook, 2002 to 2014. SARs are calculated with and without jacks. No PIT-tagged smolts released in 2010 or 2014.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-MCA without Jacks			MCN-to-MCA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2002	2,130	2.16	1.67	2.71	2.21	1.70	2.76
2003	2,143	2.52	1.94	3.09	2.89	2.28	3.52
2004	1,297	3.47	2.67	4.38	3.62	2.83	4.54
2005	519	1.35	0.57	2.20	1.35	0.57	2.20
2006	565	1.42	0.57	2.32	1.59	0.72	2.51
2007	362	1.93	0.85	3.25	1.93	0.85	3.25
2008	512	5.67	3.98	7.61	8.01	5.91	10.38
2009	990	4.14	3.15	5.29	4.65	3.59	5.82
2010	0	--	--	--	--	--	--
2011	411	0.73	0.00	1.47	0.73	0.00	1.47
2012	826	2.79	1.84	3.82	3.27	2.23	4.43
2013	704	1.56	0.86	2.41	1.71	0.94	2.61
2014	0	--	--	--	--	--	--
Geometric mean		2.18			2.39		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

Middle Columbia hatchery spring Chinook

Table B.73. Overall BON-to-BOA SARs for Carson Hatchery Chinook, 2000–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving BON [A]	BON-to-BOA without Jacks			BON-to-BOA with Jacks			Smolts released	REL-to-BOA without Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	12,945	3.30	2.71	3.91	3.34	2.75	4.00	14,992	2.85	2.62	3.07
2001	12,506	1.78	1.50	2.05	1.81	1.51	2.09	14,978	1.49	1.32	1.65
2002	12,349	1.22	0.94	1.54	1.26	0.95	1.57	14,983	1.01	0.88	1.14
2003	12,709	0.27	0.19	0.36	0.27	0.19	0.36	14,983	0.23	0.17	0.29
2004	NA [B]	--	--	--	--	--	--	14,973	0.62	0.51	0.73
2005	14,053	0.32	0.23	0.42	0.33	0.23	0.43	14,958	0.30	0.23	0.37
2006	10,509	0.60	0.45	0.77	0.63	0.48	0.79	14,971	0.42	0.33	0.51
2007	NA [B]	--	--	--	--	--	--	14,943	0.54	0.43	0.63
2008	12,250	1.80	1.51	2.11	2.05	1.72	2.37	14,884	1.48	1.32	1.65
2009	11,595	1.84	1.54	2.17	1.91	1.60	2.23	14,975	1.42	1.32	1.63
2010	11,056	0.75	0.64	0.86	0.86	0.73	0.98	14,947	0.75	0.64	0.86
2011	10,873	0.46	0.33	0.63	0.48	0.35	0.66	14,953	0.33	0.26	0.42
2012	13,070	0.61	0.44	0.82	0.67	0.48	0.89	14,941	0.54	0.44	0.64
2013	13,006	1.21	0.96	1.47	1.28	1.02	1.55	14,907	1.05	0.92	1.19
2014 [C]	10,895	0.76	0.59	0.95	0.84	0.67	1.05	14,906	0.56	0.46	0.66
geometric mean		0.90			0.95				0.72		

[A] Estimated population of tagged study fish alive to BON tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Not calculated; release to BON survival estimate > 1.0
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.74. Overall BON-to-BOA SARs for Warm Springs Hatchery Chinook (Deschutes River), 2007–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving BON [A]	BON-to-BOA without Jacks			BON-to-BOA with Jacks			Smolts released	REL-to-BOA without Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2007 [B]	--	--	--	--	--	--	--	19,698	0.30	0.24	0.38
2008 [B]	--	--	--	--	--	--	--	19,936	0.84	0.73	0.94
2009 [B]	--	--	--	--	--	--	--	19,924	0.65	0.56	0.74
2010	8,361	0.37	0.26	0.48	0.63	0.47	0.79	14,907	0.21	0.15	0.27
2011	6,164	0.45	0.29	0.65	0.49	0.31	0.69	14,924	0.19	0.13	0.25
2012	7,802	1.26	0.92	1.63	1.64	1.23	2.10	14,806	0.66	0.56	0.77
2013	10,595	1.65	1.30	2.03	2.00	1.61	2.45	14,877	1.18	1.04	1.32
2014 [C]	9,537	1.36	1.04	1.69	1.58	1.22	1.95	14,818	0.88	0.75	0.99
geometric mean		0.86			1.10				0.51		

[A] Estimated population of tagged study fish alive to BON tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Chinook smolts are released in fall and spring and form two different cohorts. Cannot distinguish between fall and spring PIT tag releases. Estimated juvenile population at BON not possible.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.75. Overall MCN-to-BOA SARs for Cle Elum Hatchery Chinook, 2000-2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks			MCN-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	14,416	3.65	3.35	3.96	3.99	3.67	4.31
2001	9,269	0.28	0.19	0.38	0.29	0.20	0.39
2002	11,753	1.37	1.20	1.55	1.73	1.54	1.93
2003	11,978	0.59	0.48	0.71	0.86	0.72	1.01
2004	7,982	1.54	1.30	1.78	1.85	1.59	2.10
2005	5,792	0.66	0.49	0.83	0.78	0.59	0.98
2006	10,283	1.24	1.06	1.41	1.59	1.40	1.80
2007	12,661	1.01	0.86	1.16	1.51	1.33	1.68
2008	11,686	3.17	2.86	3.46	5.06	4.64	5.47
2009	15,382	1.82	1.65	1.99	2.29	2.10	2.49
2010	12,473	1.52	1.33	1.71	2.53	2.30	2.79
2011	11,866	0.94	0.79	1.09	1.21	1.04	1.38
2012	15,719	1.22	1.07	1.37	1.76	1.57	1.96
2013	13,269	1.38	1.20	1.56	1.95	1.74	2.16
2014[B]	12,895	0.58	0.47	0.70	0.84	0.70	0.97
Geometric mean		1.15			1.53		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.76. Overall MCN-to-MCA SARs for Cle Elum Hatchery Chinook, 2002–2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-MCA without Jacks			MCN-to-MCA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2002	11,753	1.39	1.21	1.57	1.77	1.58	1.98
2003	11,978	0.63	0.52	0.76	0.94	0.80	1.09
2004	7,983	1.34	1.13	1.57	1.64	1.41	1.88
2005	5,792	0.59	0.43	0.76	0.73	0.54	0.92
2006	12,661	1.10	0.93	1.27	1.47	1.27	1.67
2007	12,661	0.86	0.72	1.00	1.32	1.16	1.49
2008	11,686	2.79	2.51	3.06	4.64	4.27	5.01
2009	15,382	1.57	1.40	1.73	2.03	1.84	2.22
2010	12,473	1.40	1.22	1.58	2.31	2.07	2.55
2011	11,866	0.87	0.73	1.00	1.12	0.96	1.28
2012	15,719	1.07	0.93	1.22	1.57	1.40	1.76
2013	13,269	1.33	1.15	1.50	1.87	1.66	2.07
2014[B]	12,895	0.49	0.39	0.60	0.73	0.60	0.85
Geometric mean		1.07			1.50		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Middle Columbia wild Steelhead

Table B.77. Overall JDA-to-BOA SARs for John Day River Basin Wild Steelhead, 2004–2013.

Juvenile migration year	Smolts arriving JDA[A]	JDA-to-BOA		
		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL
2004	2,530	4.35	3.60	5.18
2005	3,571	2.77	2.31	3.28
2006	1,910	3.35	2.65	4.07
2007	2,874	8.80	7.73	9.89
2008	3,069	10.23	9.19	11.31
2009	2,556	7.67	6.63	8.65
2010	2,190	6.08	5.18	7.04
2011	2,252	1.95	1.46	2.51
2012	3,202	5.43	4.56	6.34
2013	1,483	10.38	8.39	12.62
Geometric mean		5.33		

[A] Estimated population of tagged study fish alive to JDA tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

Table B.78. Overall BON-to-BOA SARs for Deschutes River Basin (Trout Creek) Wild Steelhead, 2006–2013.

Juvenile migration year	Smolts arriving BON[A]	BON-to-BOA		
		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL
2006	815	8.22	5.57	11.06
2007	942	7.54	5.07	9.98
2008	1,277	9.95	7.20	12.79
2009	1,830	8.47	6.84	10.21
2010	806	3.97	2.59	5.46
2011	1,704	6.45	4.68	8.49
2012	1,940	5.67	3.31	8.31
2013[B]	---	---	---	---
Geometric mean		6.92		

[A] Estimated population of tagged study fish alive to BON tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

[B] Too few PIT-tags released to obtain reliable estimate of smolts arriving at BON. Therefore, estimate of BON-to-BOA SAR was not possible.

Table B.79. Overall MCN-to-BOA and MCN-to-MCA SARs for Yakima River Basin Wild Steelhead, 2002–2013.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA			MCN-to-MCA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2002	357	8.12	5.24	11.37	6.16	3.72	8.83
2003	293	7.85	4.93	11.19	6.49	4.05	9.29
2004	387	2.84	1.46	4.67	2.58	1.26	4.29
2005	263	4.94	2.56	7.90	4.56	2.29	7.36
2006	397	4.03	2.20	5.98	3.27	1.70	4.97
2007	219	7.30	3.29	12.06	6.39	2.87	10.55
2008	215	9.79	5.67	14.26	8.85	4.93	13.24
2009	360	5.27	3.26	8.20	4.72	2.79	7.28
2010	331	5.74	2.91	9.56	4.53	2.13	7.71
2011	213	3.28	1.32	5.82	2.34	0.88	4.57
2012	381	7.60	4.52	10.87	5.24	2.99	7.91
2013	240	5.42	1.60	10.85	4.17	1.18	8.78
Geometric mean		5.65			4.62		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

Middle Columbia wild subyearling fall Chinook

Table B.80. Overall MCN-to-BOA and Rel-to-BOA SARs for Hanford Reach subyearling wild fall Chinook, 2000-2013. SARs are calculates with and without jacks.

Juvenile migration year	Smolts arriving MCN [A]	MCN-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	MCN-to-BOA with Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	Smolts released	REL-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	4,521	2.68	2.27	3.11	2.88	2.45	3.32	10,967	1.10	0.93	1.28
2001	3,642	0.68	0.47	0.91	0.71	0.50	0.94	9,973	0.25	0.17	0.33
2002	--	--	--	--	--	--	--	--	--	--	--
2003	820	0.43	0.11	0.82	0.43	0.11	0.82	2,975	0.13	0.03	0.27
2004	1,000	0.20	0.00	0.44	0.20	0.00	0.44	2,989	0.07	0.00	0.17
2005	6,602	0.26	0.15	0.37	0.29	0.18	0.40	22,634	0.08	0.04	0.11
2006	--	--	--	--	--	--	--	--	--	--	--
2007	7,790	0.35	0.24	0.46	0.45	0.33	0.58	21,007	0.13	0.09	0.17
2008	5,543	2.00	1.62	2.39	2.27	1.88	2.71	16,651	0.67	0.56	0.77
2009	4,614	0.72	0.51	0.96	0.89	0.65	1.17	13,728	0.24	0.17	0.31
2010	1,418	2.61	1.88	3.40	2.96	2.15	3.88	4,850	0.76	0.56	0.97
2011	4,045	3.19	2.61	3.80	3.44	2.81	4.09	10,337	1.25	1.07	1.43
2012[B]	1,313	1.29	0.80	1.87	1.37	0.84	2.00	4,885	0.35	0.23	0.49
2013[C]	1,416	0.64	0.30	1.01	0.99	0.56	1.55	4,185	0.22	0.10	0.33
geometric mean		0.85			0.96				0.29		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 3-salt returns through December 31, 2015.
[C] Incomplete, 2-salt returns through December 31, 2015.

Table B.81. Overall BON-to-BOA and Rel-to-BOA SARs for Deschutes River subyearling wild fall Chinook, 2011-2013. SARs are calculates with and without jacks.

Juvenile migration year	Smolts arriving BON [A]	BON-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	BON-to-BOA with Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	Smolts released	REL-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2011	5,860	2.30	1.48	3.22	2.95	1.91	4.09	9,897	0.68	0.58	0.77
2012[B]	6,696	0.70	0.41	0.78	0.91	0.54	1.37	20,798	0.23	0.17	0.28
2013[C]	6,069	0.31	0.17	0.47	0.65	0.39	0.95	26,322	0.10	0.07	0.14
geometric mean		0.79			1.20				0.25		

[A] Estimated population of tagged study fish alive to BON tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 3-salt returns through December 31, 2015.
[C] Incomplete, 2-salt returns through December 31, 2015.

Middle Columbia hatchery subyearling fall Chinook

Table B.82. Overall BON-to-BOA and Rel-to-BOA SARs for Spring Creek Hatchery subyearling fall Chinook, 2008-2013. SARs are calculates with and without jacks.

Juvenile migration year	Month of Release	Smolts arriving BON [A]	BON-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	90% UL	BON-to-BOA with Jacks %SAR Estimate	Non-parametric CI 90% LL	90% UL	Smolts released	REL-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	90% UL
2008	March	5,877	0.34	0.19	0.52	0.43	0.25	0.64	7,477	0.27	0.17	0.36
2008[B]	April	---	---	---	---	---	---	---	3,853	0.63	0.43	0.83
2009[B]	April	---	---	---	---	---	---	---	8,686	0.06	0.02	0.10
2010[B]	April	---	---	---	---	---	---	---	8,962	0.25	0.16	0.33
2011	April	8,163	0.16	0.09	0.25	0.16	0.09	0.25	8,956	0.15	0.08	0.21
2012[B,C]	April	---	---	---	---	---	---	---	8,772	0.28	0.19	0.39
2013[D,E]	April	8,178	0.56	0.39	0.74	0.68	0.48	0.89	8,964	0.50	0.38	0.64
geometric mean (Apr)			0.30			0.33				0.24		
2008[B]	May	---	---	---	---	---	---	---	2,677	0.52	0.30	0.75
2009[B]	May	---	---	---	---	---	---	---	5,950	0.22	0.13	0.32
2010	May	5,908	0.20	0.11	0.31	0.24	0.14	0.36	5,971	0.20	0.12	0.30
2011[B]	May	---	---	---	---	---	---	---	5,983	0.23	0.13	0.33
2012[B,C,D]	May	---	---	---	---	---	---	---	5,978	0.23	0.13	0.35
2013[E]	May	5,402	0.56	0.37	0.75	0.65	0.45	0.87	5,976	0.50	0.35	0.65
geometric mean (May)			0.33			0.39				0.29		

[A] Estimated population of tagged study fish alive to BON tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] BON-to-BOA SAR not calculated, release to BON survival > 1.0.
[C] Incomplete, 3-salt returns through December 31, 2015.
[D] May release was rescheduled for April 30th due to high flows in the Columbia River
[E] Incomplete, 2-salt returns through December 31, 2015.

Table B.83. Overall BON-to-BOA and Rel-to-BOA SARs for Little White Salmon Hatchery subyearling fall Chinook, 2008-2013. SARs are calculates with and without jacks.

Juvenile migration year	Smolts arriving BON [A]	BON-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	90% UL	BON-to-BOA with Jacks %SAR Estimate	Non-parametric CI 90% LL	90% UL	Smolts released	REL-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	90% UL
2008	14,393	1.74	1.52	1.99	1.85	1.62	2.10	24,886	1.01	0.90	1.11
2009	14,805	0.84	0.70	1.00	0.95	0.80	1.12	24,947	0.50	0.43	0.57
2010	15,140	2.69	2.35	3.06	2.75	2.41	3.13	24,951	1.63	1.50	1.77
2011	17,626	3.30	2.75	3.90	3.38	2.82	3.99	24,638	2.36	2.20	2.52
2012[B]	17,502	0.58	0.43	0.75	0.62	0.46	0.80	24,953	0.41	0.34	0.48
2013[C]	10,547	0.66	0.52	0.82	0.78	0.62	0.95	14,960	0.47	0.38	0.56
geometric mean		1.31			1.41				0.85		

[A] Estimated population of tagged study fish alive to BON tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 3-salt returns through December 31, 2015.
[C] Incomplete, 2-salt returns through December 31, 2015.

Upper Columbia wild Chinook

Table B.84. Overall MCN-to-BOA SARs for Upper Columbia Wild Chinook (Wenatchee River), 2007 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA (without jacks)			MCN-to-BOA (with jacks)		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2007	3,019	0.76	0.54	1.02	0.76	0.54	1.02
2008	5,747	2.75	2.40	3.14	2.89	2.51	3.30
2009	3,329	1.98	1.57	2.44	2.07	1.63	2.55
2010	4,833	1.37	1.08	1.66	1.70	1.37	2.03
2011	2,854	0.95	0.64	1.30	1.02	0.70	1.39
2012	3,779	0.95	0.68	1.24	1.14	0.84	1.46
2013	3,004	1.86	1.39	2.25	1.93	1.48	2.32
2014[B]	3,957	0.83	0.59	1.07	1.04	0.77	1.30
Geometric mean		1.29			1.44		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.85. Overall MCN-to-BOA SARs for Upper Columbia Wild Chinook (Entiat and Methow Rivers), 2006 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA (without jacks)			MCN-to-BOA (with jacks)		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006[B]	927	0.43	0.11	0.81	0.54	0.20	0.98
2007	804	0.75	0.26	1.27	0.75	0.26	1.27
2008	4,901	2.94	2.51	3.38	3.26	2.82	3.73
2009	1,625	2.22	1.58	2.87	2.40	1.72	3.06
2010	3,244	1.85	1.45	2.28	1.97	1.57	2.42
2011	972	0.41	0.10	0.79	0.62	0.22	1.09
2012	2,035	1.23	0.83	1.64	1.77	1.27	2.28
2013	1,857	2.21	1.61	2.85	2.80	2.11	3.53
2014[C]	2,450	1.43	1.01	1.84	1.55	1.11	2.02
Geometric mean		1.22			1.46		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] 2006 is Entiat River only.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.86. Overall RRE-to-BOA SARs for Upper Columbia Wild Chinook (Entiat and Methow Rivers)[A], 2008 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving RRE[B]	RRE-to-BOA (without jacks)			RRE-to-BOA (with jacks)		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2008[C]	9,309	1.55	1.17	1.94	1.72	1.30	2.15
2009[C]	3,253	1.11	0.64	1.65	1.20	0.69	1.76
2010_	5,292	1.13	0.89	1.39	1.21	0.97	1.47
2011	1,361	0.29	0.07	0.55	0.44	0.15	0.79
2012	3,494	0.72	0.47	0.97	1.03	0.75	1.33
2013	3,123	1.31	0.94	1.68	1.66	1.25	2.08
2014[D]	4,253	0.82	0.59	1.09	0.89	0.64	1.17
Geometric mean		0.89			1.08		

[A] The Entiat/Methow wild Chinook aggregate is the same group as used for the MCN-to-BOA reach. SARs are calculated as number of adults at BOA divided by estimated number of smolts at Rocky Reach Dam.
[B] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[C] Uses recaptures at Rocky Reach Dam. After 2009, both the new juvenile detector and recaptures at Rocky Reach Dam are used.
[D] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.87. Overall MCN-to-BOA SARs for Upper Columbia Wild Summer Chinook (Okanogan River or Columbia Mainstem above Wells Dam), 2011 to 2013. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA (without jacks)			MCN-to-BOA (with jacks)		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2011	4,062	4.01	3.38	4.67	4.14	3.47	4.77
2012	5,913	1.03	0.79	1.30	1.17	0.91	1.46
2013[B]	6,931	1.27	0.97	1.59	1.37	1.06	1.70
Geometric mean		1.74			1.88		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 3-salt returns through Sept. 16, 2016.

Table B.88. Overall RRE-to-BOA SARs for Upper Columbia Wild Summer Chinook (Okanogan River or Columbia Mainstem above Wells Dam)[A], 2011 to 2013. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving RRE[B]	RRE-to-BOA (without jacks)			RRE-to-BOA (with jacks)		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2011	5,978	2.73	2.34	3.14	2.81	2.43	3.21
2012	8,246	0.74	0.57	0.92	0.84	0.66	1.02
2013[C]	8,206	1.07	0.87	1.28	1.16	0.94	1.37
Geometric mean		1.29			1.40		

[A] This is the same group as used for the MCN-to-BOA reach. SARs are calculated as number of adults at BOA divided by estimated number of smolts at Rocky Reach Dam.
[B] CJS estimation of S1 uses both the juvenile detector and recaptures at Rocky Reach Dam, as well as PIT-tags on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[C] Incomplete, 3-salt returns through Sept. 16, 2016.

Upper Columbia hatchery Chinook

Table B.89. Overall MCN-to-BOA SARs for Leavenworth Hatchery Chinook, 2000 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks			MCN-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL		90% LL	90% UL
2000	4,337	1.84	1.48	2.22	1.87	1.49	2.24
2001	3,823	0.24	0.11	0.37	0.24	0.11	0.37
2002	179,051	0.36	0.34	0.38	0.38	0.35	0.40
2003	153,755	0.42	0.40	0.45	0.45	0.42	0.48
2004	105,788	0.34	0.31	0.37	0.34	0.31	0.38
2005	7,888	0.09	0.04	0.15	0.11	0.06	0.18
2006	8,214	0.89	0.72	1.06	0.97	0.80	1.16
2007	8,820	0.46	0.34	0.58	0.53	0.40	0.67
2008	9,186	1.89	1.64	2.17	2.11	1.84	2.40
2009	6,964	0.59	0.44	0.75	0.65	0.48	0.81
2010	9,810	0.82	0.67	0.98	1.23	1.05	1.43
2011	6,563	0.35	0.24	0.48	0.38	0.26	0.52
2012	9,006	1.05	0.87	1.24	1.19	0.99	1.39
2013	9,267	0.69	0.55	0.85	0.77	0.62	0.94
2014[B]	8,665	0.59	0.45	0.73	0.75	0.59	0.91
Geometric mean		0.55			0.61		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Upper Columbia wild Steelhead

Table B.90. Overall MCN-to-BOA SARs for Upper Columbia Wild Steelhead (Wenatchee, Entiat, and Methow Rivers), 2006 to 2013.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006[B]	472	1.91	0.86	3.09
2007	891	4.49	3.19	5.81
2008	2,268	6.66	5.55	7.82
2009	1,636	4.40	3.45	5.39
2010	1,481	3.51	2.61	4.50
2011	993	1.31	0.70	2.01
2012	740	6.08	4.13	8.15
2013	924	4.76	3.16	6.64
Geometric mean		3.68		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] 2006 is Entiat River only, all other years are Entiat, Methow, and Wenatchee combined.

Table B.91. Overall RRE-to-BOA SARs for Upper Columbia Wild Steelhead (Entiat and Methow Rivers)[A], 2008–2013.

Juvenile migration year	Smolts arriving RRE[B]	RRE-to-BOA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2008[C]	2,664	4.77	3.31	6.47
2009[C]	2,695	2.30	1.57	3.17
2010	2,143	1.91	1.44	2.44
2011	1,382	0.87	0.45	1.29
2012	986	3.65	2.62	4.85
2013	1,464	3.01	2.20	3.95
Geometric mean		2.42		

[A] The Entiat/Methow wild steelhead aggregate is a subgroup of that used for the MCN-to-BOA reach (excludes Wenatchee). SARs are calculated as number of adults at BOA divided by estimated number of smolts at Rocky Reach Dam.
[B] CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[C] Uses recaptures at Rocky Reach Dam. After 2009, both the new juvenile detector and recaptures at Rocky Reach Dam are used.

Upper Columbia hatchery Steelhead

Table B.92. Overall MCN-to-BOA SARs for Upper Columbia Hatchery Steelhead released into the Wenatchee River Basin (Eastbank and Chelan Hatcheries), 2003–2013.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA		
		%SAR Estimate	Non-parametric CI	
			90% LL	90% UL
2003	13,366	2.35	2.12	2.58
2004	9,183	1.46	1.22	1.69
2005	14,720	0.90	0.77	1.03
2006	4,058	2.29	1.90	2.70
2007	3,514	2.05	1.61	2.56
2008	4,673	5.78	5.11	6.52
2009	4,589	2.66	2.23	3.12
2010	4,383	3.63	3.02	4.31
2011	5,520	1.59	1.27	1.94
2012	8,463	1.97	1.68	2.26
2013	8,520	2.23	1.93	2.55
Geometric mean		2.19		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

Upper Columbia wild Sockeye

Table B.93. Overall MCN-to-BOA and RRE-to-BOA SARs for Okanogan River Wild Sockeye, 2013–2014.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA			Smolts arriving RRE[B]	RRE-to-BOA		
		%SAR Estimate	Non-parametric CI			%SAR Estimate	Non-parametric CI	
			90% LL	90% UL			90% LL	90% UL
2013[C]	--	--	--	--	1,993	8.13	6.96	9.45
2014[D]	2,126	2.82	2.14	3.54	2,930	2.05	1.61	2.52

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] CJS estimation of S1 uses both the detector and recaptures at Rocky Reach Dam, as well as PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[C] Juvenile survival estimate for RRE-MCN reach was greater than 100%, resulting in an overestimate of the juvenile population at MCN. Therefore, $SAR_{MCN\text{-}to\text{-}BOA}$ was not estimated for this year.
[D] Incomplete, 2-salt returns through Sept. 16, 2016

Upper Columbia wild and hatchery Chinook, Steelhead, and Sockeye Tagged at Rock Island Dam

Table B.94. Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery Yearling Chinook tagged at Rock Island Dam, 2000 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA (without jacks)			RIS-to-BOA (with jacks)		
		%SAR Estimate	Exact Binomial CI		%SAR Estimate	Exact Binomial CI	
			90% LL	90% UL		90% LL	90% UL
2000	3,989	0.90	0.67	1.19	0.90	0.67	1.19
2001	1,837	0.00	0.00	0.16	0.00	0.00	0.16
2002	3,987	0.05	0.01	0.16	0.08	0.02	0.19
2003[B]	--	--	--	--	--	--	--
2004	910	0.11	0.01	0.52	0.11	0.01	0.52
2005	723	0.00	0.00	0.41	0.00	0.00	0.41
2006	1,127	0.18	0.03	0.56	0.18	0.03	0.56
2007	859	0.00	0.00	0.35	0.00	0.00	0.35
2008	843	0.47	0.16	1.08	0.95	0.47	1.71
2009	688	0.73	0.29	1.52	0.73	0.29	1.52
2010	799	0.50	0.17	1.14	0.50	0.17	1.14
2011	1,338	0.15	0.03	0.47	0.30	0.10	0.68
2012	1,702	0.24	0.08	0.54	0.47	0.23	0.85
2013	5,220	1.11	0.86	1.34	1.28	1.02	1.53
2014[C]	4,834	0.29	0.18	0.45	0.48	0.33	0.67
Geometric mean		--			--		
Arithmetic mean		0.34			0.43		

[A] Tagged as part of Smolt Monitoring Program. SARs are calculated as number of adults at BOA divided by number of smolts marked and released at Rock Island Dam. Confidence intervals are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).
[B] No data in 2003 due to bypass inoperable during spring outmigration
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.95. Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery subyearling Chinook tagged at Rock Island Dam, 2000 to 2014. SARs are calculated with and without jacks.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA (without jacks)			RIS-to-BOA (with jacks)		
		%SAR Estimate	Exact Binomial CI 90% LL	Exact Binomial CI 90% UL	%SAR Estimate	Exact Binomial CI 90% LL	Exact Binomial CI 90% UL
2000	4,073	1.94	1.60	2.33	2.01	1.66	2.41
2001	4,484	0.00	0.00	0.07	0.00	0.00	0.07
2002	4,800	1.00	0.78	1.27	1.06	0.83	1.34
2003	4,338	0.28	0.16	0.45	0.28	0.16	0.45
2004	3,183	0.03	0.00	0.15	0.03	0.00	0.15
2005	3,547	0.54	0.35	0.79	0.59	0.40	0.85
2006	4,208	0.57	0.39	0.80	0.62	0.43	0.86
2007	3,596	0.31	0.17	0.51	0.36	0.21	0.57
2008	3,678	1.06	0.80	1.38	1.09	0.82	1.41
2009	1,889	0.58	0.33	0.96	0.58	0.33	0.96
2010	3,625	0.85	0.62	1.15	0.88	0.64	1.18
2011	4,387	2.10	1.75	2.49	2.14	1.80	2.54
2012	3,656	1.12	0.85	1.45	1.18	0.90	1.51
2013	4,021	1.27	0.99	1.57	1.47	1.17	1.79
2014[B]	4,688	0.04	0.00	0.11	0.06	0.02	0.13
Geometric mean		--			--		
Arithmetic mean		0.78			0.82		

[A] Tagged as part of Smolt Monitoring Program. SARs are calculated as number of adults at BOA divided by number of smolts marked and released at Rock Island Dam. Confidence intervals are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).
[B] Incomplete, 2-salt returns through Sept. 16, 2016.

Table B.96. Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery Steelhead tagged at Rock Island Dam, 2000 to 2013.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA		
		%SAR Estimate	Exact Binomial CI	
			90% LL	90% UL
2000	3,946	1.42	1.12	1.77
2001	4,027	0.07	0.02	0.19
2002	3,996	1.88	1.54	2.27
2003[B]	--	--	--	--
2004	2,627	0.30	0.15	0.55
2005	2,850	0.77	0.52	1.10
2006	3,181	0.88	0.63	1.20
2007	3,551	0.90	0.66	1.21
2008	6,052	3.21	2.84	3.60
2009	5,304	1.09	0.87	1.36
2010	6,630	1.22	1.01	1.47
2011	7,226	0.58	0.44	0.75
2012	5,943	0.99	0.79	1.23
2013	5,255	1.07	0.84	1.33
Geometric mean		0.84		
Arithmetic mean		1.11		

[A] Tagged as part of Smolt Monitoring Program. SARs are calculated as number of adults at BOA divided by number of smolts marked and released at Rock Island Dam. Confidence intervals are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).
[B] No data in 2003 due to bypass inoperable during spring outmigration.

Table B.97. Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery Sockeye tagged at Rock Island Dam, 2000 to 2014.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA		
		%SAR Estimate	Exact Binomial CI	
			90% LL	90% UL
2000	656	1.98	1.18	3.13
2001	491	0.00	0.00	0.61
2002	2,091	0.29	0.13	0.57
2003[B]	--	--	--	--
2004	1,083	0.74	0.37	1.33
2005	888	0.00	0.00	0.34
2006	3,600	1.08	0.82	1.41
2007	2,097	0.86	0.56	1.27
2008	1,910	7.80	6.81	8.89
2009	2,059	5.88	5.05	6.80
2010	3,527	2.86	2.42	3.37
2011	2,977	1.98	1.58	2.46
2012	3,231	4.18	3.61	4.80
2013	2,674	6.21	5.46	6.96
2014[C]	3,059	0.85	0.60	1.18
Geometric mean		---		
Arithmetic mean		2.48		

[A] Tagged as part of Smolt Monitoring Program. SARs are calculated as number of adults at BOA divided by number of smolts marked and released at Rock Island Dam. Confidence intervals are Clopper-Pearson binomial confidence intervals (Clopper and Pearson 1934).
[B] No data in 2003 due to bypass inoperable during spring outmigration.
[C] Incomplete, 2-salt returns through Sept. 16, 2016.

First Year Estuary and Ocean Survival Rates

Table B.98. Estimation of first year estuary and ocean survival rates, So1, for Snake River wild spring/summer Chinook 1994–2013 based on CSS parameter estimates for SAR, in-river survival, proportion transported and *D*.

Migration year	In-river survival (S_R)	Proportion transported (pT)	D	System survival	CSS SAR (LGR-LGR)	SAR (LGR - Col. R. mouth)	S.oa (LGR)	S.oa (Col. R.)	S.o1
1994	0.20	0.86	0.36	0.33	0.45%	0.61%	0.014	0.018	0.025
1995	0.41	0.81	0.42	0.41	0.36%	0.47%	0.009	0.012	0.016
1996	0.44	0.71	0.92	0.77	0.42%	0.61%	0.005	0.008	0.011
1997	0.51	0.57	0.40	0.44	1.82%	2.72%	0.041	0.061	0.078
1998	0.61	0.82	0.55	0.55	1.32%	1.78%	0.024	0.032	0.042
1999	0.59	0.86	0.72	0.69	2.48%	2.93%	0.036	0.042	0.055
2000	0.48	0.71	0.32	0.36	1.74%	2.10%	0.048	0.058	0.082
2001	0.23	0.99	2.16	2.10	1.33%	1.62%	0.006	0.008	0.010
2002	0.61	0.71	0.44	0.48	1.02%	1.24%	0.021	0.026	0.033
2003	0.60	0.69	0.68	0.65	0.35%	0.42%	0.005	0.007	0.009
2004	0.40	0.93	0.45	0.44	0.53%	0.63%	0.012	0.014	0.019
2005	0.48	0.93	1.07	1.01	0.23%	0.29%	0.002	0.003	0.004
2006	0.57	0.66	0.47	0.50	0.75%	0.92%	0.015	0.019	0.024
2007	0.60	0.21	0.80	0.64	1.09%	1.30%	0.017	0.020	0.026
2008	0.66	0.46	0.82	0.73	3.24%	4.26%	0.045	0.059	0.076
2009	0.56	0.42	0.65	0.59	1.61%	2.16%	0.027	0.036	0.048
2010	0.56	0.40	0.72	0.62	0.93%	1.20%	0.015	0.019	0.024
2011	0.60	0.35	0.42	0.53	0.36%	0.47%	0.007	0.009	0.011
2012	0.57	0.21	0.44	0.54	1.43%	1.90%	0.026	0.035	0.043
2013	0.55	0.35	0.79	0.63	1.30%	1.77%	0.021	0.028	0.037
geometric mean	0.492	0.576	0.607	0.592	0.90%	1.15%	0.015	0.019	0.025

Table B.99. Estimation of first year estuary and ocean survival rates, So1, for Snake River wild steelhead 1997–2013 based on CSS parameter estimates for SAR, in-river survival, proportion transported and *D*.

Migration year	In-river survival (S_R)	Proportion transported (pT)	D	System survival	CSS SAR (LGR-LGR)	SAR (LGR - Col. R. mouth)	S.oa (LGR)	S.oa (Col. R.)	S.o1
1997	0.52	0.72	1.18	0.98	1.16%	1.70%	0.013	0.017	0.020
1998	0.54	0.89	0.11	0.15	0.30%	0.43%	0.021	0.028	0.030
1999	0.45	0.87	1.07	0.97	2.84%	3.92%	0.031	0.040	0.047
2000	0.30	0.85	0.50	0.46	2.66%	3.56%	0.061	0.077	0.087
2001	0.04	0.99	1.46	1.42	2.47%	3.28%	0.018	0.023	0.028
2002	0.52	0.68	2.24	1.65	2.14%	2.90%	0.014	0.018	0.020
2003	0.37	0.72	1.75	1.34	1.57%	2.18%	0.013	0.016	0.019
2004	0.18	0.97	2.69	2.57	0.85%	1.19%	0.004	0.005	0.005
2005	0.27	0.93	1.30	1.20	0.78%	1.08%	0.007	0.009	0.011
2006	0.58	0.65	0.52	0.53	1.14%	1.98%	0.021	0.037	0.042
2007	0.38	0.40	1.20	0.70	2.57%	3.43%	0.037	0.049	0.055
2008	0.49	0.41	0.60	0.53	3.21%	4.48%	0.061	0.085	0.097
2009	0.70	0.45	0.94	0.80	2.44%	3.67%	0.031	0.046	0.054
2010	0.60	0.35	0.93	0.71	1.70%	2.44%	0.024	0.034	0.039
2011	0.76	0.48	0.93	0.83	1.26%	1.92%	0.015	0.023	0.026
2012	0.58	0.23	0.53	0.57	2.54%	3.55%	0.045	0.062	0.071
2013	0.56	0.46	1.35	0.91	1.99%	2.81%	0.022	0.030	0.035
geometric mean	0.397	0.600	0.932	0.816	1.62%	2.30%	0.021	0.028	0.032

APPENDIX C

SOURCE OF PIT-TAGGED FISH

APPENDIX C

SOURCE OF PIT-TAGGED FISH

Snake River Wild Spring/Summer Chinook

Table C.1. Number of PIT-tagged wild Snake River spring/summer Chinook parr/smolts from tributaries above Lower Granite Dam (plus Snake River trap) used in the CSS analyses for migration years 1994 to 2015.

Migr Year	Total PIT tags	Clearwater River (Rkm 224)	Snake River Trap[A] (Rkm 225)	Grande Ronde River (Rkm 271)	Salmon River (Rkm 303)	Imnaha River (Rkm 308)
1994	49,660	8,292	1,423	8,829	27,725	3,391
1995	74,642	17,606	1,948	12,330	40,610	2,148
1996	21,524	2,246	913	7,079	7,017	4,269
1997	9,781	671	None	3,870	3,543	1,697
1998	33,836	4,681	921	8,644	11,179	8,411
1999	81,493	13,695	3,051	11,240	43,323	10,184
2000	67,841	9,921	1,526	7,706	39,609	9,079
2001	47,775	3,745	29	6,354	23,107	14,540
2002	67,286	14,060	1,077	9,715	36,051	6,428
2003	102,978	15,108	383	14,065	60,251	13,171
2004	99,710	17,204	541	12,103	56,131	13,731
2005	111,152	23,897	318	9,243	67,829	9,865
2006	52,978	8,663	2,639	10,457	30,094	1,125
2007	52,496	3,041	373	9,267	28,561	11,254
2008	55,839	5,049	1,576	8,316	30,058	10,840
2009	55,565	5,305	3,807	7,848	29,824	8,781
2010	87,304	17,299	849	11,724	40,367	17,065
2011	77,438	6,384	4,965	9,776	47,662	8,651
2012	82,382	7,360	3,943	12,282	49,174	9,623
2013	78,929	6,312	285	11,221	50,240	10,871
2014	75,248	4,633	1,963	10,690	47,377	10,585
2015	61,209	6,382	102	7,833	36,827	10,065
Average percent of total		**13.1%**	**2.4%**	**16.7%**	**53.4%**	**14.5%**

[A] Snake River trap at Lewiston, ID, collects fish originating in Salmon, Imnaha, and Grande Ronde rivers.

Snake River Hatchery Spring/Summer Chinook

Table C.2. Rapid River Hatchery spring Chinook PIT-tagged and released in Salmon River basin specifically for CSS, 1997 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
1997	85,838	20.5	100[A]	40,451	0.4712
1998	896,170	20.3	117	48,336	0.0539
1999	2,847,283	17.9	120	47,812	0.0168
2000	2,462,354	19.2	119	47,747	0.0194
2001	736,601	18.8	118	55,085	0.0748
2002	2,669,476	19.8	122	54,908	0.0206
2003	2,330,557	18.8	119	54,763	0.0235
2004	2,762,058	24.5	(none taken)	51,969	0.0188
2005	2,761,430	19.1	124	51,975	0.0188
2006	2,530,528	19.3	129	51,874	0.0205
2007	2,498,246	20.0	117	51,759	0.0207
2008	2,493,719	16.7	125	51,689	0.0207
2009	2,503,711	20.0	(none taken)	51,725	0.0207
2010	2,492,454	17.9	(none taken)	51,909	0.0208
2011	2,483,181	18.4	(none taken)	51,730	0.0208
2012	2,498,197	16.4	(none taken)	51,938	0.0208
2013	2,497,668	15.8	(none taken)	51,898	0.0208
2014	2,498,847	19.4	(none taken)	51,670	0.0207
2015	2,498,974	15.6	(none taken)	51,931	0.0208

[A] Tagged in fall 5 months before release; otherwise tagged in winter/spring 1–3 months before release.

Table C.3. Dworshak Hatchery spring Chinook PIT-tagged and released in Clearwater River basin specifically for CSS, 1997 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
1997	53,078	12.7	118	14,080	0.2653
1998	973,400	20.9	121	47,703	0.0490
1999	1,044,511	21.0	116	47,845	0.0458
2000	1,017,873	24.0	112	47,743	0.0469
2001	333,120	19.7	121	55,139	0.1655
2002	1,000,561	20.1	119	54,725	0.0547
2003	1,033,982	21.4	120	54,708	0.0529
2004	1,078,923	20.2	113	51,616	0.0478
2005	1,072,359	19.2	112	51,819	0.0483
2006	1,007,738	20.0	108	51,900	0.0515
2007	963,211	17.7	114	51,649	0.0536
2008	939,000	23.5	105	49,384	0.0526
2009	1,014,748	21.2	113	50,829	0.0501
2010	1,109,195	16.8	125	51,415	0.0464
2011	1,078,250	21.1	115	51,753	0.0480
2012	1,044,080	19.9	113	51,885	0.0497
2013	1,377,508	22.6	110	51,800	0.0376
2014	2,040,460	25.0	103	51,761	0.0254
2015	1,549,263	21.6	111	41,774	0.0270

[A] Tagged in winter/spring 1–3 months before release.

Table C.4. McCall Hatchery summer Chinook PIT-tagged and released in Salmon River basin specifically for CSS, 1997 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
1997	238,647	17.1	128	52,652	0.2206
1998	393,872	17.5	126	47,340	0.1202
1999	1,143,083	23.9	117	47,985	0.0420
2000	1,039,930	23.3	117	47,705	0.0459
2001	1,076,846	19.4	129	55,124	0.0512
2002	1,022,550	23.0	122	54,734	0.0535
2003	1,053,660	21.1	121	74,317	0.0705
2004	1,088,810	20.9	(none taken)	71,363	0.0655
2005	1,047,530	20.9	121	71,725	0.0685
2006	1,096,130	18.1	126	51,894	0.0473
2007	1,087,170	19.1	122	51,726	0.0476
2008	1,060,540	19.5	129	51,678	0.0487
2009	1,106,700	21.3	(none taken)	51,495	0.0465
2010	1,037,600	20.9	(none taken)	51,786	0.0499
2011	1,069,028	18.5	(none taken)	51,878	0.0485
2012	1,121,809	19.0	(none taken)	51,917	0.0463
2013	1,074,850	17.1	(none taken)	51,901	0.0483
2014	1,047,886	18.6	(none taken)	51,896	0.0495
2015	1,122,286	17.6	(none taken)	51,906	0.0463

[A] Tagged in winter/spring 1–3 months before release.

Table C.5. Imnaha Hatchery summer Chinook PIT-tagged and released in Imnaha River basin specifically for CSS, 1997 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
1997	50,911	17.0	122[A]	13,378	0.2628
1998	93,108	21.1	122[A]	19,825	0.2129
1999	184,725	18.5	117	19,939	0.1079
2000	179,797	19.1	113	20,819	0.1158
2001	123,014	16.0	121	20,922	0.1701
2002	303,737	14.1	121	20,920	0.0689
2003	268,426	16.3	123	20,904	0.0779
2004	398,469	26.1	98	20,910	0.0525
2005	435,186	24.5	105	20,917	0.0481
2006	320,752	27.1	105	20,623	0.0643
2007	432,530	21.6	107	20,885	0.0483
2008	348,910	20.3	116	20,760	0.0595
2009	293,802	20.0	110	20,863	0.0888
2010	390,064	20.0	112	20,603	0.0528
2011	252,588	19.1	104	20,757	0.0822
2012	469,810	22.2	112	20,819	0.0443
2013	390,604	20.0	110	20,896	0.0535
2014	346,702	22.1	108	20,779	0.0599
2015	331,703	21.8	104	20,871	0.0629

[A] Tagged in winter/spring 1–3 months before release; otherwise tagged in fall 5–7 months before release.

Table C.6. Catherine Creek Hatchery spring Chinook PIT-tagged and released in Grande Ronde River basin specifically for CSS, 2001 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2001	136,833	19.7	117	20,915	0.1529
2002	180,343	18.6	115	20,796	0.1153
2003	105,292	12.8	123	20,628	0.1959
2004	162,614	23.2	109	20,994	0.1291
2005	189,580	25.1	106	20,839	0.1099
2006	68,820	22.7	102	20,958	0.3045
2007	71,268	26.9	102	20,817	0.2921
2008	116,882	17.9	112	20,717	0.1772
2009	138,843	22.7	107	20,840	0.1501
2010	144,353	19.7	102	20,310	0.1407
2011	155,475	24.9	99	20,838	0.1340
2012	161,374	19.4	113	20,641	0.1279
2013	134,519	22.3	106	20,816	0.1547
2014	138,370	22.8	110	20,772	0.1501
2015	14,6310	23.2	102	20,854	0.1425

[A] Tagged in fall 5–7 months before release.

Table C.7. Clearwater Hatchery spring Chinook PIT-tagged and released in Clearwater River basin in participation with the CSS, 2007 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2007	1,670,006	15.6	133[A]	44,900	0.0269
2008	1,666,315	16.8	(none taken)	37,595	0.0226
2009	2,145,480	16.8	(none taken)	68,649	0.0320
2010	2,251,033	15.3	(none taken)	72,707	0.0323
2011	2,234,031	16.2	(none taken)	68,327	0.0306
2012	2,180,789	16.6	(none taken)	65,393	0.0300
2013	2,203,720	19.0	(none taken)	68,048	0.0309
2014	2,401,813	18.2	(none taken)	68,290	0.0284
2015	2,153,215	15.6	(none taken)	43,916	0.0204

[A] Tagged in winter 3 weeks to 2 months before release.

Table C.8. Clearwater Hatchery summer Chinook PIT-tagged and released in Clearwater River basin in participation with the CSS, 2011 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)[A]	PIT Tags Released	PIT-Tag Proportion
2011	204,061	15.4	(none taken)	25,488	0.1249
2012	206,317	17.8	(none taken)	25,482	0.1235
2013	208,447	20.0	(none taken)	25,450	0.1221
2014	492,243	16.0	(none taken)	25,469	0.0517
2015	528,410	15.6	(none taken)	14,925	0.0282

[A] Tagged in winter 3 weeks to 2 months before release.

Table C.9. Sawtooth Hatchery spring Chinook PIT-tagged and released in Salmon River basin in participation with the CSS, 2008 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2008	174,132	19.1	(none taken)	14,925	0.0857
2009	274,644	14.0	(none taken)	18,671	0.0680
2010	1,455,933	22.0	(none taken)	21,283	0.0146
2011	1,735,179	23.7	(none taken)	21,333	0.0123
2012	1,456,221	27.6	(none taken)	19,041	0.0131
2013	786,864	23.3	(none taken)	21,282	0.0270
2014	1,739,906	18.0	(none taken)	18,969	0.0109
2015	1,729,449	18.2	(none taken)	21,357	0.0123

[A] Tagged in winter 1–2 months before release.

Table C.10. Pahsimeroi Hatchery summer Chinook PIT-tagged and released in Salmon River basin in participation with the CSS, 2009 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2009	870,842	11.3	(none taken)	18,750	0.0215
2010	1,169,701	22.0	(none taken)	21,375	0.0183
2011	1,030,028	14.0	(none taken)	21,131	0.0205
2012	1,027,580	14.4	(none taken)	21,374	0.0208
2013	1,005,873	14.0	(none taken)	21,390	0.0213
2014	969,829	12.8	(none taken)	21,367	0.0220
2015	828,209	11.2	(none taken(	21,369	0.0258

[A] Tagged in winter 1–2 months before release.

Table C.11. Kooskia Hatchery spring Chinook PIT-tagged and released in Clearwater River basin in participation with the CSS, 2014 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2014	628,007	32.0	100	12,252	0.0195
2015	661,441	24.4	(none taken)	7,967	0.0120

[A] Tagged in winter 1–2 months before release.

Snake River Wild Steelhead

Table C.12. Number of PIT-tagged wild steelhead smolts from tributaries above Lower Granite Dam (plus Snake River trap) used in the CSS analyses for migration years 1997 to 2015.

Migr Year	Total PIT Tags	Clearwater River (Rkm 224)	Snake River Trap[A,B] (Rkm 225)	Asotin Creek Trap (Rkm 234)	Grande Ronde River (Rkm 271)	Salmon River (Rkm 303)	Imnaha River (Rkm 308)
1997	7,703	5,518	68	0	248	1,158	711
1998	10,512	4,131	1,032	0	887	1,683	2,779
1999	15,763	5,095	886	0	1,628	5,569	2,585
2000	24,254	8,688	1,211	0	3,618	6,245	4,492
2001	24,487	8,845	867	0	3,370	7,844	3,561
2002	25,183	10,206	2,368	0	3,353	6,136	3,120
2003	24,005	5,764	1,197	0	4,257	6,818	5,969
2004	25,154	7,642	1,922	0	2,977	7,100	5,513
2005	25,000	8,391	1,349	1,400	3,771	5,652	4,437
2006	16,579	8,301	4	0	1,950	4,090	2,234
2007	17,857	5,001	1	0	2,170	4,112	6,573
2008	16,228	7,249	11	0	1,048	5,648	2,272
2009	16,625	4,066	4	0	1,494	5,951	5,110
2010	18,529	6,259	0	0	1,826	5,617	4,827
2011	12,706	3,753	14	0	2,434	4,205	2,300
2012	18,809	6,985	427	0	2,224	4,498	4,675
2013	19,499	6,606	1,002	0	2,303	3,437	6,151
2014	25,346	5,116	1,155	3,229	2,916	5,855	7,075
2015	36,073	9,897	992	1,724	6,154	11,133	6,173
Average percent of total		**35.3%**	**3.6%**	**1.2%**	**12.1%**	**26.6%**	**21.2%**

[A] Snake River trap at Lewiston, ID, collects fish originating in Grande Ronde, Salmon, and Imnaha rivers; wild steelhead at this trap are not part of pre-assigned smolts in 2006 to 2011 — the few tags shown on wild steelhead were originally planned for use on wild Chinook tagging.
[B] Pre-assignments of wild steelhead from Snake River Trap at Lewiston, ID, began in 2012.

Snake River Hatchery Steelhead

Table C.13. Number of PIT-tagged hatchery steelhead smolts from tributaries above Lower Granite Dam (plus Snake River trap) used in the CSS analyses for migration years 1997 to 2007.

Migr Year	Total PIT-Tags[A]	Clearwater River (Rkm 224)	Snake River Trap[B] (Rkm 225)	Grande Ronde River (Rkm 271)	Salmon River (Rkm 303)	Imnaha River (Rkm 308)
1997	35,409	12,872	725	6,039	9,394	6,379
1998	30,625	8,451	4,209	4,904	8,457	4,604
1999	36,667	11,486	3,925	5,316	9,132	6,808
2000	31,735	8,488	3,290	5,348	8,173	6,436
2001	28,812	9,155	3,126	4,677	7,859	3,995
2002	26,279	7,819	4,722	3,888	7,011	2,839
2003	26,083	4,912	4,171	3,113	7,764	6,123
2004	19,674	3,400	4,841	2,263	4,072	5,098
2005	23,463	7,228	3,354	2,395	3,684	6,802
2006	15,963	4,545	2,146	4,397	3,208	1,667
2007	26,323	3,893	2,545	8,979	8,820	2,086
Average percent of total		**26.7%**	**13.1%**	**17.3%**	**25.3%**	**17.6%**

[A] Total includes PIT-tagged hatchery steelhead released below Hells Canyon Dam ranging between 57 and 301 tags per year, and averaging 0.9% of total across the 11 years.
[B] Snake River trap at Lewiston, ID, collects fish released in Grande Ronde, Salmon, and Imnaha rivers, and below Hells Canyon Dam.

Table C.14. Number of PIT-tagged hatchery B-run steelhead smolts released into the Clearwater River and subsequently used in the CSS analyses for migration years 2008–2015.

Migration Year	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2008	CLWH	819,264	4.6	(none taken)	20,018	0.0244
	DWOR	2,254,407	5.8	175	27,276	0.0121
2009	CLWH	835,636	4.7	(none taken)	21,191	0.0254
	DWOR	1,798,874	6.5	185	28,306	0.0157
2010	CLWH	854,960	4.5	(none taken)	23,589	0.0276
	DWOR	1,234,563	6.0	165	28,394	0.0230
2011	CLWH	1,117,487	5.1	(none taken)	33,787	0.0302
	DWOR	2,265,405	7.1	168	30,187	0.0133
2012	CLWH	730,036	4.5	(none taken)	9,498	0.0130
	DWOR	2,595,828	6.2	161.5	30,082	0.0116
2013	CLWH	957,801	7.4	(none taken)	26,531	0.0277
	DWOR	2,160,790	6.5	154	30,200	0.0140
2014	CLWH	848,715	4.6	(none taken)	18,078	0.0213
	DWOR	2,228,021	7.1	175	30,698	0.0138
2015	CLWH	927,613	5.2	(none taken)	18,078	0.0195
	DWOR	2,480,746	5.9	165	31,297	0.0126

[A] Hatchery at which steelhead were PIT-tagged: CLWH – Clearwater H; DWOR – Dworshak NFH.

Table C.15. Number of PIT-tagged hatchery A-run steelhead smolts released into the Grande Ronde River and subsequently used in the CSS analyses for migration years 2008–2015.

Migration Year	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2008	IRRI	803,847	4.4	134	16,465	0.0205
	LYFE	175,961	4.6	(none taken)	4,000	0.0227
2009	IRRI	652,424	3.8	187	22,233	0.0341
	LYFE	170,232	4.7	(none taken)	5,974	0.0351
2010	IRRI	617,514	3.9	157	23,083	0.0374
	LYFE	163,197	4.2	(none taken)	5,985	0.0367
2011	IRRI	826,879	4.1	148	22,182	0.0268
	LYFE	197,839	4.8	(none taken)	5,967	0.0302
2012	IRRI	842,753	4.2	156	22,379	0.0266
	LYFE	176,902	4.8	(none taken)	5,978	0.0338
2013	IRRI	822,601	4.6	140	21,875	0.0266
	LYFE	205,913	4.7	(none taken)	5,991	0.0291
2014	IRRI	831,978	4.3	137	22,224	0.0267
	LYFE	209,000	5.1	(none taken)	6,000	0.0287
2015	IRRI	684,104	4.3	137	21,925	0.0320
	LYFE	206,735	5.0	(none taken)	5,981	0.0289

[A] Hatchery at which steelhead were PIT-tagged: Irrigon H – IRRI; Lyons Ferry H – LYFE.

Table C.16. Number of PIT-tagged hatchery A-run steelhead smolts released into the Imnaha River and subsequently used in the CSS analyses for migration years 2008–2015.

Migration Year	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2008	IRRI	274,865	4.8	136	14,877	0.0541
2009	IRRI	187,401	4.5	179	20,838	0.1112
2010	IRRI	215,467	4.5	147	21,680	0.1006
2011	IRRI	158,027	4.3	155	21,887	0.1385
2012	IRRI	212,220	5.0	150	21,943	0.1034
2013	IRRI	235,446	4.9	136	21,882	0.0929
2014	IRRI	239,614	4.7	137	21,897	0.0914
2015	IRRI	247,642	4.6	138	14,877	0.0602

[A] Hatchery at which steelhead were PIT-tagged: Irrigon H – IRRI.

Table C.17. Number of PIT-tagged hatchery A-run steelhead smolts released into the Salmon River and subsequently used in the CSS analyses for migration years 2008–2015.

Migration Year	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2008[B]	MAVA	868,273	4.6	(none taken)	13,170	0.0152
	HAGE	1,208,489	4.1	(none taken)	18,116	0.0150
2009	MAVA	880,384	4.8	(none taken)	16,781	0.0191
	HAGE	1,249,216	4.4	(none taken)	16,573	0.0133
	NISP	1,248,101	3.9	(none taken)	17,064	0.0137
2010	MAVA	640,513	4.8	(none taken)	11,142	0.0174
	HAGE	1,411,833	4.4	(none taken)	27,929	0.0198
	NISP	1,260,127	4.0	(none taken)	19,866	0.0158
2011	MAVA	656,743	5.2	(none taken)	11,545	0.0176
	HAGE	1,321,547	3.8	(none taken)	27,999	0.0212
	NISP	1,243,070	5.7	(none taken)	19,742	0.0159
2012	MAVA	593,384	4.5	(none taken)	11,676	0.0197
	HAGE	1,401,863	4.5	(none taken)	28,563	0.0204
	NISP	1,311,729	5.1	(none taken)	19,674	0.0150
2013	MAVA	500,986	4.6	(none taken)	8,180	0.0163
	HAGE	1,339,869	4.3	(none taken)	31,238	0.0233
	NISP	1,233,572	6.1	(none taken)	19,134	0.0155
2014	MAVA	480,529	4.6	(none taken)	7,886	0.0164
	HAGE	1,334,177	4.6	(none taken)	16,981	0.0127
	NISP	1,259,859	4.3	(none taken)	14,053	0.0112
2015	MAVA	881,310	4.5	(none taken)	17,089	0.0194
	HAGE	1,532,012	4.7	(none taken)	7,884	0.0051
	NISP	1,293,411	4.5	(none taken)	14,033	0.0108

[A] Hatchery at which steelhead were PIT-tagged: Magic Valley H – MAVA; Hagerman NFH – HAGE; Niagara Springs H – NISP.
[B] Niagara Springs H (NISP) is not included this year since release of 1,200 PIT-tagged smolts (none in monitor-mode) is not on scale with the magnitude of PIT-tagging at other hatcheries being analyzed.

Table C.18. Number of PIT-tagged hatchery B-run steelhead smolts released into the Salmon River and subsequently used in the CSS analyses for migration years 2008–2015.

Migration Year	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2008	MAVA	752,644	4.7	(none taken)	21,302	0.0283
	HAGE	179,034	4.7	(none taken)	11,330	0.0633
2009	MAVA	771,813	4.8	(none taken)	20,615	0.0267
	HAGE	171,094	4.6	(none taken)	8,344	0.0488
2010	MAVA	959,262	5.0	(none taken)	21,596	0.0225
2011	MAVA	902,866	5.1	(none taken)	20,709	0.0229
2012	MAVA	968,221	4.7	(none taken)	21,232	0.0219
2013	MAVA	1,062,884	4.4	(none taken)	29,286	0.0276
2014	MAVA	1,069,717	4.4	(none taken)	26,838	0.0251
2015	MAVA	700,650	4.5	(none taken)	26,819	0.0383

[A] Hatchery at which steelhead were PIT-tagged: Magic Valley H – MAVA; Hagerman NFH – HAGE.

Table C.19. Number of PIT-tagged hatchery A-run steelhead smolts released into the Snake River (just below Hells Canyon Dam) and subsequently used in the CSS analyses for migration years 2009–2015.

Migration Year	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2009	NISP	526,743	4.6	(none taken)	7,381	0.0140
2010	NISP	529,667	4.7	(none taken)	8,253	0.0156
2011	NISP	538,580	8.2	(none taken)	8,227	0.0153
2012	NISP	526,966	6.9	(none taken)	8,249	0.0157
2013	NISP	571,865	7.2	(none taken)	9,074	0.0159
2014	NISP	576,080	5.1	(none taken)	8,571	0.0149
2015	NISP	572,077	4.9	(none taken)	8,553	0.0150

[A] Hatchery at which steelhead were PIT-tagged: Niagara Springs H – NISP.

Snake River Hatchery Sockeye

Table C.20. Hatchery sockeye from Sawtooth, Oxbow (Oregon), and Springfield hatcheries[A] PIT-tagged and released in Salmon River, 2009–2015.

Migration Year	Rearing Hatchery[A]	Hatchery Release	Fish# / lb	Median Length at Tagging[B] (mm)	PIT Tags Released	PIT-Tag Proportion
2009	SAWT	99,374	30.6	101	52,551	0.5288
	OXBH	73,681	10.2	147	10,891	0.1478
2010	SAWT	99,392	28.1	106	51,684	0.5200
	OXBH	79,886	10.7	140	11,945	0.1453
2011	SAWT	136,287	54.8	84	51,672	0.3791
	OXBH	54,766	9.6	146	9,975	0.1821
2012	SAWT	80,912	50.6	96	51,710	0.6391
	OXBH[C]	85,741	8.9	147	9,971	0.1163
2013	SAWT	175,578	18.8	(none taken)	50,062	0.2851
2014	SAWT	173,992	24.9	(none taken)	49,879	0.2867
2015	SAWT	134,660	18.9	(none taken)	49,772	0.3696
	SPRF	211,205	10.0	(none taken)	49,307	0.2335

[A] Hatchery at which sockeye were reared and PIT-tagged: Sawtooth – SAWT, Oxbow (Oregon) – OXBH, Springfield – SPRF.
[B] Tagged in winter ~2-4 months before release.
[C] Oxbow Hatchery sockeye were eliminated in CSS analyses after 2012 due to low PIT-tag release numbers.

Snake River Wild Subyearling Fall Chinook

Table C.21. Number of PIT-tagged Snake River Basin (above LGR) wild/natural subyearling fall Chinook used in the CSS analyses for migration years 2006 to 2011.

Migration Year	Total PIT Tags
2006	2,153
2007	---
2008	6,739
2009	6,867
2010	---
2011	3,244

Snake River Hatchery Subyearling Fall Chinook

Table C.22. Lyons Ferry Hatchery subyearling fall Chinook (released at Big Canyon Creek Acclimation Pond) that were used in the CSS analyses for migration years 2006 to 2012.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2006	504,706	57.0	83	55,835	0.1106
2007	---	---	---	---	---
2008	520,035	55.0	74	32,307	0.0621
2009	474,868	62.5	79	13,759	0.0290
2010	511,236	52.3	72	38,160	0.0746
2011	509,146	51.0	74	40,694	0.0799
2012	511,629	47.0	78	41,040	0.0802

[A] Tagged in spring 1-2 months before release.

Table C.23. Lyons Ferry Hatchery subyearling fall Chinook (released at Captain John Rapids Acclimation Pond) that were used in the CSS analyses for migration years 2008 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2008	512,745	65.0	69	39,512	0.0771
2009	524,910	57.0	80	11,391	0.0217
2010	528,777	47.0	74	37,822	0.0715
2011	516,480	45.3	74	40,764	0.0789
2012	505,728	47.0	75	41,038	0.0811
2013	---	---	---	---	---
2014	---	---	---	---	---
2015	538,379	49.6	(none taken)	22,058	0.0410

[A] Tagged in spring 1-2 months before release.

Table C.24. Lyons Ferry Hatchery subyearling fall Chinook (released at Pittsburgh Landing Acclimation Pond) that were used in the CSS analyses for migration years 2006 to 2015.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2006[B]	397,085	50.0	80	24,396	0.0614
2007	---	---	---	---	---
2008	403,432	60.0	69	31,834	0.0789
2009	415,991	59.3	75	13,761	0.0331
2010	405,041	50.5	71	30,676	0.0757
2011	413,284	49.0	73	32,643	0.0790
2012	402,400	46.5	73	32,858	0.0817
2013	---	---	---	---	---
2014	---	---	---	---	---
2015	398,010	60.6	(none taken)	22,099	0.0555

[A] Tagged in spring 1-2 months before release.
[B] Fish reared and tagged at Umatilla Hatchery in 2006

Table C.25. Lyons Ferry Hatchery subyearling fall Chinook (released into the mainstem Snake River above LGR) that were used in the CSS analyses for migration years 2006 to 2012.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2006	211,508	50.0	76	22,865	0.1081
2007	---	---	---	---	---
2008	230,401	59.6	72	12,577	0.0546
2009	200,744	46.5	75	10,239	0.0510
2010	203,162	58.0	70	11,861	0.0584
2011	202,300	49.0	69	16,353	0.0808
2012	199,300	54.0	71	16,312	0.0818

[A] Tagged in spring 1-2 months before release.

Table C.26. Hatchery subyearling fall Chinook (released into the Grande Ronde River) that were used in the CSS analyses for migration years 2006 to 2012.

Migration Year	Rearing Hatchery[A]	Hatchery Release	Fish# / lb	Median Length at Tagging[B] (mm)	PIT Tags Released	PIT-Tag Proportion
2006	LYFE	409,165	50.6	71	25,349	0.0620
2007	---	---	---	---	---	---
2008	IRRI	303,270	47.0	76	22,261	0.0734
2009	IRRI	441,050	67.1	72	24,262	0.0550
2010	IRRI	386,840	42.2	82	30,277	0.0783
2011	IRRI	399,500	80.9	76	32,231	0.0807
2012	IRRI	384,000	48.0	84	32,416	0.0844

[A] Hatchery at which sockeye were reared and PIT-tagged: Lyons Ferry – LYFE, Irrigon – IRRI.
[B] Tagged in spring 1-2 months before release.

Table C.27. Irrigon/Umatilla hatchery subyearling fall Chinook (released below Hells Canyon Dam) that were used in the CSS analyses for migration years 2006 to 2012.

Migration Year	Rearing Hatchery[A]	Hatchery Release	Fish# / lb	Median Length at Tagging[B] (mm)	PIT Tags Released	PIT-Tag Proportion
2006	UMAH	332,165	58.0	80	21,534	0.0648
2007	---	---	---	---	---	---
2008	UMAH	770,350	44.0	82	33,224	0.0431
2009	UMAH	803,485	60.6	77	55,488	0.0691
2010	UMAH	685,735	46.4	81	49,813	0.0726
2011	IRRI	638,900	81.0	72	36,687	0.0574
2012	IRRI	800,400	46.0	83	36,926	0.0461

[A] Hatchery at which sockeye were reared and PIT-tagged: Umatilla – UMAH, Irrigon – IRRI.
[B] Tagged in spring 1-2 months before release.

Table C.28. Oxbow Hatchery (Idaho) subyearling fall Chinook (released below Hells Canyon Dam) that were used in the CSS analyses for migration years 2008 to 2012.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2008	192,471	51.4	(none taken)	15,469	0.0804
2009	202,839	54.8	(none taken)	14,844	0.0732
2010	---	---	---	---	---
2011	194,809	48.2	(none taken)	14,831	0.0761
2012	202,281	47.9	(none taken)	14,910	0.0737

[A] Tagged in spring 1-2 months before release.

Table C.29. Dworshak Hatchery subyearling fall Chinook (surrogates) (released into the mainstem Snake River above LGR) that were used in the CSS analyses for migration years 2006 to 2011.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2006	229,097	114.5	73	229,033	0.9997
2007	---	---	---	---	---
2008	202,369	N/A	78	201,723	0.9968
2009	237,741	N/A	70	237,667	0.9997
2010	195,492	N/A	68	193,985	0.9923
2011	200,754	N/A	76	185,760	0.9253

[A] Tagged within 1 day of release.

Table C.30. Nez Perce Tribal Hatchery subyearling fall Chinook (released from Cedar Flats Acclimation Facility) that were used in the CSS analyses for migration years 2010 to 2012.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2010	188,411	48.3	87	14,143	0.0751
2011	205,556	54.5	93	16,345	0.0795
2012	199,450	51.7	92	16,519	0.0828

[A] Tagged in May, ~2 weeks to 1 month before release.

Table C.31. Nez Perce Tribal Hatchery subyearling fall Chinook (released from Lukes Gulch Acclimation Facility) that were used in the CSS analyses for migration years 2010 to 2012.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2010	198,969	44.4	86	16,317	0.0820
2011	207,482	50.2	89	16,391	0.0790
2012	198,856	49.6	89	16,377	0.0824

[A] Tagged in May, ~3 weeks to 1 month before release.

Middle Columbia Wild Spring Chinook

Table C.32. Number of PIT-tagged wild Chinook parr/smolts from tributaries in the Mid-Columbia River used in the CSS analyses for migration years 2006 to 2014.

Migration Year	Total PIT-tags	Yakima River (Rkm 539)	John Day River (Rkm 351)
2000	8,034	6,183	1,851
2001	6,060	2,179	3,881
2002	12,706	8,707	3,999
2003	13,925	7,803	6,122
2004	8,303	3,931	4,372
2005	7,070	1,733	5,337
2006	5,090	2,333	2,757
2007	4,663	1,200	3,463
2008	5,603	1,675	3,928
2009	8,749	3,795	4,954
2010	5,291	0	5,291
2011	6,291	6,183	4,501
2012	8,799	2,595	6,204
2013	7,519	2,473	5,046
2014	3,129	0	3,129
Average percent of total		**36.3%**	**63.7%**

Middle Columbia Hatchery Spring Chinook

Table C.33. Carson NFH spring Chinook PIT-tagged and released in the Wind River, 2000 to 2014.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2000	1,430,022	15.6	116	14,992	0.0105
2001	1,608,684	14.9	108	14,978	0.0093
2002	1,449,361	15.6	116	14,983	0.0103
2003	1,673,255	17.1	111	14,983	0.0090
2004	1,417,986	17.3	111	14,973	0.0106
2005	1,470,134	14.5	120	14,958	0.0102
2006	1,209,384	17.3	112	14,971	0.0124
2007	1,158,425	17.2	109	14,943	0.0129
2008	1,336,741	16.5	103	14,884	0.0111
2009	1,216,198	16.9	108	14,975	0.0123
2010	1,278,492	16.8	108	14,947	0.0117
2011	1,058,771	33.8	104	14,953	0.0141
2012	1,126,579	18.0	102	14,941	0.0133
2013	1,125,192	17.9	103	14,907	0.0132
2014	1,127,012	18.1	105	14,906	0.0132

[A] Tagged in fall and winter, approximately 3–5 months before release.

Table C.34. Warm Springs NFH spring Chinook PIT-tagged and released in the Deschutes River basin, 2007 to 2014.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
2007[A]	520,000	25.0	100	19,698	0.0379
2008[A]	376,000	11.0	103	19,937	0.0530
2009[A]	580,897	29.8	101	19,926	0.0343
2010[B]	705,241	22.0	107	14,907	0.0211
2011[B]	537,280	30.9	108	14,924	0.0278
2012[B]	480,945	29.1	102	14,806	0.0308
2013[B]	783,546	23.9	105	14,877	0.0190
2014[B]	726,942	24.0	108	14,818	0.0204

[A] Tagged in fall, approximately 4–5 months before release.
[B] Tagged in winter, approximately 2 months before release.

Table C.35. Cle Elum Hatchery spring Chinook PIT-tagged and released in the Yakima River basin, 2000 to 2014.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2000	589,683	19.1	102	38,467	0.0652
2001	758,789	15.0	112	39,799	0.0525
2002	834,285	22.6	112	39,419	0.0472
2003	370,236	18.0	110	39,985	0.1080
2004	836,904	28.3	103	40,015	0.0478
2005	824,692	25.0	101	39,997	0.0485
2006	785,448	N/A	95	39,987	0.0509
2007	860,002	N/A	108	40,006	0.0465
2008	642,977	26.3	109	40,001	0.0622
2009	771,265	20.3	108	40,011	0.0519
2010	851,313	30.0	106	39,999	0.0470
2011	832,941	27.7	111	40,001	0.0480
2012	794,781	29.0	107	40,003	0.0503
2013	769,182	N/A	108	39,998	0.0520
2014	802,716	N/A	110	39,997	0.0498

[A] Tagged in fall, approximately 4–5 months before release.

Middle Columbia Wild Steelhead

Table C.36. Number of PIT-tagged wild steelhead smolts from tributaries in the Mid-Columbia River used in the CSS analyses for migration years 2002 to 2013.

Migration Year	Total PIT Tags	Yakima River (Rkm 539)	John Day River (Rkm 351)	Deschutes River (Rkm 328)
2002	1,337	1,337	0	0
2003	904	904	0	0
2004	5,708	1,473	4,235	0
2005	7,336	1,965	5,371	0
2006	5,501	954	3,163	1,384
2007	6,565	810	4,146	1,609
2008	7,079	1,389	3,975	1,715
2009	7,938	1,352	3,844	2,742
2010	6,561	1,341	3,931	1,289
2011	8,291	1,380	2,774	4,137
2012	10,177	2,685	4,624	2,868
2013	5,931	1,302	4,629	0
Average percent of total		**33.7%**	**49.1%**	**17.2%**

Middle Columbia Wild Subyearling Fall Chinook

Table C.37. Number of PIT-tagged wild subyearling fall Chinook from the Hanford Reach or Deschutes River that were used in the CSS analyses for migration years 2000 to 2013.

Migration Year	Total PIT Tags	Deschutes River (Rkm 328)	Hanford Reach
2000	10,967	0	10,967
2001	9,973	0	9,973
2002	0	0	0
2003	2,975	0	2,975
2004	2,989	0	2,989
2005	22,634	0	22,634
2006	0	0	0
2007	21,007	0	21,007
2008	16,651	0	16,651
2009	13,728	0	13,728
2010	4,850	0	4,850
2011	30,234	19,897	10,337
2012	25,683	20,798	4,885
2013	30,507	26,322	4,185
Average percent of total (2011-2013)		**77.7%**	**22.3%**

Middle Columbia Hatchery Subyearling Fall Chinook

Table C.38. Spring Creek NFH subyearling fall Chinook PIT-tagged and released, 2008 to 2013.

Migration Year	Release Month	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2008	March	7,416,056	143.8	68	7,477	0.0010
2008	April	3,990,744	90.8	75	3,853	0.0010
2009	April	6,479,326	114.9	69	8,686	0.0013
2010	April	6,200,507	111.8	72	8,962	0.0014
2011	April	6,229,093	110.6	71	8,956	0.0014
2012	April	6,271,782	90.8	65	8,772	0.0014
2013	April	6,441,575	101.0	67	8,964	0.0014
2008	May	3,492,789	N/A	75	2,677	0.0008
2009	May	4,773,958	90.0	77	5,950	0.0012
2010	May	4,550,054	76.3	77	5,910	0.0013
2011	May	4,632,199	89.6	74	5,983	0.0013
2012	May[B]	4,806,922	99.5	71	5,978	0.0012
2013	May	4,801,111	79.2	73	5,976	0.0012

[A] March release was tagged within 2-3 days of release, April releases were tagged within 1-2 weeks of release, and May releases were tagged approximately 1 month before release.
[B] May release was rescheduled for April 30th due to high flows in the Columbia River.

Table C.39. Little White Salmon NFH subyearling fall Chinook PIT-tagged and released, 2008 to 2013.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging[A] (mm)	PIT Tags Released	PIT-Tag Proportion
2008	2,001,759	96.0	67	24,886	0.012
2009	2,616,601	80.6	72	24,947	0.010
2010	2,053,707	87.2	70	24,951	0.012
2011	2,006,949	90.2	69	24,638	0.012
2012	1,995,627	86.4	64	24,953	0.013
2013	1,924,546	64.3	72	14,960	0.008

[A] Tagged in summer, approximately 1 week to 1 month before release.

Upper Columbia Wild Chinook

Table C.40. Number of PIT-tagged wild Chinook parr/smolts from tributaries above Rock Island Dam used in the CSS analyses for migration years 2006 to 2014.

Migration Year	Total PIT-tags	Wenatchee River (Rkm 754)	Entiat River (Rkm 778)	Methow River (Rkm 843)	Okanogan R. or Col. R. above Wells Dam (Rkm 858)
2006	1,895	0	1,895	0	0
2007	16,177	13,434	1,538	1,205	0
2008	29,193	16,350	9,541	3,302	0
2009	18,114	14,605	2,256	1,253	0
2010	28,229	17,962	8,326	1,941	0
2011	27,663	10,581	2,916	946	13,220
2012	37,595	14,427	5,974	1,918	15,276
2013	41,210	14,426	6,866	2,065	17,853
2014	27,429	18,797	6,693	1,939	N/A
Average percent of total (through 2013)		**49.4%**	**28.4%**	**5.8%**	**16.5%**

Upper Columbia Hatchery Spring Chinook

Table C.41. Leavenworth NFH spring Chinook PIT-tagged and released in Wenatchee River basin, 2000 to 2014.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2000[A]	1,680,904	18.2	116	7,387	0.0044
2001[B]	1,630,089	16.8	114	7,600	0.0047
2002[C]	1,554,362	22.4	114	317,271	0.2041
2003[B]	1,288,893	16.2	116	240,558	0.1866
2004[B]	1,422,100	25.7	119	216,600	0.1523
2005[D]	1,476,046	18.4	120	14,825	0.0100
2006[D]	1,005,505	19.0	118	14,700	0.0146
2007[D]	1,177,568	20.0	121	14,969	0.0127
2008[B]	1,539,668	18.0	111	15,968	0.0104
2009[B]	1,685,038	18.3	105	14,919	0.0089
2010[B]	1,284,653	16.1	116	14,948	0.0116
2011[B]	1,189,442	18.0	117	14,875	0.0125
2012[B]	1,186,622	17.9	117	14,901	0.0126
2013[B]	1,289,293	17.5	111	14,951	0.0116
2014[B]	1,239,025	18.5	116	14977	0.0121

[A] Tagged in winter, approximately 3 months before release.
[B] Tagged in fall, approximately 5 months before release.
[C] 16% tagged in fall (~4–5 months before release) and 84% tagged in spring (~1–2 months before release).
[D] Tagged in spring, approximately 1 month before release.

Upper Columbia Wild Steelhead

Table C.42. Number of PIT-tagged wild steelhead smolts from tributaries above Rock Island Dam used in the CSS analyses for migration years 2006 to 2013.

Migration Year	Total PIT Tags	Wenatchee River (Rkm 754)	Entiat River (Rkm 778)	Methow River (Rkm 843)
2006	1,032	0	1,032	0
2007	2,332	828	870	634
2008	4,535	823	2,904	808
2009	4,297	732	2,517	1,048
2010	3,655	780	2,106	769
2011	2,125	475	1,150	500
2012	2,135	663	1,227	245
2013	6,295	3,481	2,010	804
Average percent of total		**25.1%**	**57.6%**	**17.3%**

Upper Columbia Hatchery Steelhead

Table C.43. Eastbank Hatchery Complex steelhead PIT-tagged and released in Wenatchee River basin, 2003 to 2013.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT-Tag Proportion
2003[A]	156,145	7.6	95	33,145	0.2123
2004[B]	65,408	6.2	114	29,909	0.4573
2005[C]	100,519	5.8	93	34,815	0.3464
2006[D]	157,313	6.1	170	9,678	0.0615
2007[D]	100,499	6.8	72	8,022	0.0798
2008[D]	144,831	6.9	(none taken)	8,848	0.0611
2009[D]	153,783	7.4	93	9,405	0.0612
2010[E]	222,093	6.4	121	9,926	0.0447
2011[F]	172,363	6.4	125	9,894	0.0574
2012[G]	163,729	11.6	102	30,019	0.1833
2013[G]	223,480	9.6	85	25,129	0.01124

Tag sites: CHEL = Chelan PUD Hatchery, EBNK = Eastbank Hatchery, TURO = Turtle Rock Hatchery
[A] 36% were tagged in the fall (6 months before release) and 64% were tagged in spring (1 month before release).
[B] 32% were tagged in the fall (6 months before release) and 68% were tagged in spring (1 month before release).
[C] 10% tagged in the fall (8 months before release) and 90% tagged in spring (<1 month before release).
[D] Tagged in spring (<1 month before release).
[E] 3% tagged in the fall (7 Months before release) and 97% were tagged in spring (<1 months before release).
[F] 4% tagged in the fall (7 Months before release) and 96% were tagged in spring (<1 months before release).
[G] 100% tagged in the fall (7 Months before release).

Upper Columbia Wild Sockeye

Table C.44. Number of PIT-tagged Okanogan River Basin wild sockeye smolts used in the CSS analyses for migration years 2013 to 2014.

Migration Year	Total PIT Tags	Skaha Dam or Just Below (Rkm 858.177)	Osoyoos Lake Narrows Bridge (Rkm 858.135)	Osoyoos Lake (Rkm 858.130)
2013	4,018	1,178	2,783	57
2014	5,055	1,348	3,707	0
Average percent of total		**28.0%**	**71.3%**	**0.7%**

Upper Columbia Wild and Hatchery Yearling Chinook, Subyearling Chinook, Steelhead, and Sockeye Tagged at Rock Island Dam

Table C.45. Number of PIT-tagged wild and hatchery yearling Chinook, subyearling Chinook, and sockeye smolts (2000–2014) and steelhead smolts (2000–2013) tagged at Rock Island Dam used in the CSS analyses.

Migration Year	Yearling Chinook	Subyearling Chinook	Steelhead	Sockeye
2000	3,989	4,073	3,946	656
2001	1,837	4,484	4,027	491
2002	3,987	4,800	3,996	2,090
2003	0	4,338	0	0
2004	910	3,183	2,627	1,083
2005	723	3,547	2,850	887
2006	1,127	4,208	3,181	3,600
2007	859	3,596	3,551	2,082
2008	843	3,678	6,052	1,910
2009	688	1,889	5,304	2,059
2010	799	3,625	6,629	3,527
2011	1,338	4,387	7,224	2,977
2012	1,702	3,656	5,943	3,231
2013	5,220	4,021	5,255	2,674
2014	4,834	4,690		3,059

APPENDIX D

DAM-SPECIFIC TRANSPORTATION OF SARs

Appendix D
Dam-Specific Transportation SARs
(Adult returns to Lower Granite Dam without jacks)

Table D.1 Estimated dam-specific transportation SARs (%) of the PIT-tagged wild Chinook aggregate for juvenile migration years 1994 to 2014 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	SAR(TLGR) (CI%)	Adult #	SAR(TLGS) %	SAR(TLGS) (CI%)	Adult #	SAR(TLMN) %	SAR(TLMN) (CI%)	Adult #
1994	0.67	(0.28 – 1.12)	7	0.52	(0.00 – 1.11)	2	NA		None
1995	0.41	(0.18 – 0.68)	7	0.28	(0.00 – 0.84)	1	NA		None
1996	0.37	(0.00 – 1.10)	1	1.18	(0.00 – 3.41)	1	NA		None
1997	1.08	(0.00 – 2.37)	2	6.67	(0.00 – 14.8)	2	NA		None
1998	1.34	(0.72 – 2.01)	11	0.84	(0.00 – 1.66)	3	1.27	(0.00 – 3.53)	1
1999	2.53	(1.82 – 3.28)	28	2.82	(1.49 – 4.47)	9	2.09	(0.72 – 3.58)	6
2000	1.22	(0.31 – 2.27)	4	2.46	(0.87 – 4.29)	6	1.07	(0.00 – 2.38)	2
2001	1.33	(0.46 – 2.23)	6	1.39	(0.00 – 4.11)	1	NA		None
2002	0.61	(0.30 – 0.95)	10	1.08	(0.70 – 1.53)	20	0.60	(0.00 – 1.79)	1
2003	0.31	(0.19 – 0.45)	16	0.51	(0.28 – 0.75)	13	0.17	(0.00 – 0.50)	1
2004	0.55	(0.42 – 0.67)	49	0.46	(0.25 – 0.68)	13	0.72	(0.25 – 1.24)	6
2005	0.22	(0.16 – 0.29)	27	0.31	(0.16 – 0.48)	10	NA		None
2006	0.72	(0.49 – 0.96)	28	0.72	(0.51 – 0.93)	31	1.24	(0.78 – 1.77)	17
2007	1.23	(0.82 – 1.65)	26	1.44	(0.68 – 2.21)	9	0.89	(0.26 – 1.81)	3
2008	3.39	(2.99 – 3.80)	175	2.62	(2.11 – 3.14)	67	2.47	(1.55 – 3.45)	16
2009	1.80	(1.45 – 2.15)	69	1.34	(1.00 – 1.69)	40	1.48	(0.80 – 2.24)	11
2010	0.90	(0.70 – 1.11)	54	0.88	(0.62 – 1.18)	29	0.91	(0.44 – 1.45)	8
2011	0.35	(0.21 – 0.49)	15	0.43	(0.22 – 0.66)	10	0.48	(0.16 – 0.81)	6
2012	0.88	(0.56 – 1.23)	17	0.95	(0.58 – 1.33)	16	0.88	(0.34 – 1.60)	5
2013	1.73	(1.37 – 2.08)	60	1.44	(1.04 – 1.87)	33	1.16	(0.59 – 1.77)	10
2014 [A]	0.71	(0.46 – 0.96)	23	0.32	(0.16 – 0.53)	8	0.32	(0.08 – 0.59)	4

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.2 Estimated dam-specific transportation SAR percentages of PIT-tagged Rapid River hatchery spring Chinook for juvenile migration years 1997 to 2014 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
1997	0.80	(0.58 – 1.02)	33	NA		None	2.63	(0.00 – 7.89)	1
1998	2.12	(1.89 – 2.35)	239	1.18	(0.75 – 1.72)	16	1.02	(0.00 – 2.29)	2
1999	3.20	(2.89 – 3.52)	236	3.22	(2.79 – 3.64)	152	1.03	(0.31 – 2.13)	3
2000	2.34	(2.10 – 2.58)	243	1.89	(1.52 – 2.30)	79	2.23	(1.43 – 3.06)	27
2001	1.18	(1.04 – 1.33)	182	0.74	(0.49 – 1.00)	21	0.69	(0.17 – 1.29)	4
2002	1.14	(0.91 – 1.39)	61	0.94	(0.72 – 1.17)	50	1.05	(0.37 – 1.74)	6
2003	0.32	(0.23 – 0.43)	27	0.13	(0.05 – 0.23)	5	0.17	(0.00 – 0.53)	1
2004	0.39	(0.31 – 0.48)	53	0.30	(0.17 – 0.42)	16	0.18	(0.00 – 0.54)	1
2005	0.26	(0.19 – 0.33)	41	0.35	(0.22 – 0.51)	14	NA		None
2006	0.67	(0.53 – 0.83)	53	0.54	(0.39 – 0.70)	34	0.63	(0.38 – 0.89)	17
2007	0.58	(0.44 – 0.76)	35	0.20	(0.00 – 0.41)	3	0.17	(0.00 – 0.41)	2
2008	1.54	(1.34 – 1.73)	167	1.44	(1.18 – 1.71)	75	1.12	(0.54 – 1.80)	8
2009	1.52	(1.29 – 1.77)	106	1.21	(0.89 – 1.52)	41	1.25	(0.71 – 1.86)	14
2010	0.56	(0.37 – 0.79)	20	0.65	(0.38 – 0.95)	14	0.42	(0.00 – 0.87)	3
2011	0.38	(0.26 – 0.49)	27	0.32	(0.18 – 0.45)	14	0.27	(0.09 – 0.45)	6
2012	0.95	(0.74 – 1.17)	48	0.94	(0.70 – 1.21)	35	0.87	(0.52 – 1.23)	15
2013	1.68	(1.40 – 1.99)	93	1.04	(0.76 – 1.35)	34	1.27	(0.85 – 1.72)	25
2014 [A]	0.66	(0.49 – 0.82)	41	0.49	(0.33 – 0.68)	21	0.39	(0.18 – 0.63)	9

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.3 Estimated dam-specific transportation SAR percentages of PIT-tagged Dworshak hatchery spring Chinook for juvenile migration years 1997 to 2014 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
1997	0.86	(0.54 – 1.23)	16	NA		None	NA		None
1998	0.99	(0.85 – 1.14)	110	0.62	(0.41 – 0.85)	22	NA		None
1999	1.26	(1.01 – 1.53)	62	1.29	(0.99 – 1.59)	49	0.83	(0.21 – 1.62)	4
2000	1.18	(1.01 – 1.37)	116	1.08	(0.83 – 1.32)	53	0.69	(0.40 – 1.03)	14
2001	0.36	(0.29 – 0.44)	60	0.44	(0.27 – 0.60)	18	0.16	(0.00 – 0.47)	1
2002	0.64	(0.44 – 0.83)	26	0.74	(0.54 – 0.96)	32	0.27	(0.00 – 0.60)	2
2003	0.28	(0.18 – 0.39)	20	0.28	(0.16 – 0.41)	12	0.18	(0.00 – 0.38)	2
2004	0.17	(0.12 – 0.24)	22	0.45	(0.34 – 0.58)	37	0.36	(0.00 – 0.81)	2
2005	0.21	(0.16 – 0.29)	32	0.20	(0.11 – 0.31)	11	NA		None
2006	0.39	(0.24 – 0.56)	16	0.41	(0.28 – 0.56)	25	0.52	(0.31 – 0.75)	15
2007	0.63	(0.32 – 0.99)	9	0.66	(0.21 – 1.33)	3	0.51	(0.00 – 1.20)	2
2008	0.48	(0.28 – 0.68)	17	1.04	(0.78 – 1.31)	39	1.84	(1.03 – 2.72)	13
2009	0.76	(0.55 – 0.99)	32	0.67	(0.44 – 0.94)	21	0.76	(0.32 – 1.28)	7
2010	0.30	(0.17 – 0.44)	13	0.43	(0.15 – 0.73)	6	1.80	(0.00 – 3.78)	3
2011	0.14	(0.06 – 0.26)	5	0.14	(0.06 – 0.26)	5	0.13	(0.00 – 0.32)	2
2012	0.56	(0.24 – 0.96)	7	0.58	(0.34 – 0.89)	14	0.56	(0.19 – 0.96)	6
2013	0.54	(0.34 – 0.76)	17	0.59	(0.32 – 0.87)	13	1.10	(0.56 – 1.69)	10
2014 [A]	0.34	(0.21 – 0.50)	15	0.45	(0.28 – 0.62)	19	0.29	(0.13 – 0.50)	7

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.4 Estimated dam-specific transportation SAR percentages of PIT-tagged Catherine Creek hatchery spring Chinook for juvenile migration years 2001 to 2014 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2001	0.33	(0.18 – 0.50)	11	NA		None	NA		None
2002	1.09	(0.66 – 1.53)	16	0.72	(0.29 – 1.18)	8	NA		None
2003	0.32	(0.12 – 0.57)	5	0.57	(0.14 – 1.06)	4	NA		None
2004	0.29	(0.10 – 0.48)	6	0.57	(0.14 – 1.04)	4	1.37	(0.00 – 4.17)	1
2005	0.32	(0.11 – 0.53)	6	0.95	(0.36 – 1.72)	5	NA		None
2006	0.26	(0.08 – 0.53)	3	0.54	(0.19 – 0.95)	6	0.89	(0.22 – 1.69)	4
2007	0.51	(0.22 – 0.84)	7	0.20	(0.00 – 0.61)	1	1.08	(0.00 – 2.22)	3
2008	2.52	(1.92 – 3.11)	48	3.07	(2.33 – 3.82)	47	2.03	(0.93 – 3.35)	7
2009	1.61	(1.10 – 2.12)	26	1.99	(1.29 – 2.67)	21	1.86	(0.63 – 3.31)	6
2010	1.02	(0.52 – 1.57)	10	1.82	(1.01 – 2.79)	11	0.52	(0.00 – 1.51)	1
2011	0.25	(0.00 – 0.50)	3	0.99	(0.43 – 1.59)	7	0.57	(0.00 – 1.33)	2
2012	0.43	(0.00 – 1.01)	2	0.17	(0.00 – 0.52)	1	2.08	(0.79 – 3.73)	5
2013	2.13	(1.33 – 2.94)	19	0.83	(0.21 – 1.54)	4	1.88	(0.47 – 3.57)	4
2014 [A]	0.63	(0.22 – 1.03)	6	0.70	(0.27 – 1.24)	5	0.31	(0.00 – 0.90)	1

[A] Return to GRA incomplete with 2-salts through 9/16/2016

Table D.5 Estimated dam-specific transportation SAR percentages of PIT-tagged Clearwater hatchery spring Chinook for juvenile migration years 2006 to 2014 (with 90% confidence intervals). Transported smolts include both first-time and prior detected fish from Group T.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2006	0.70	(0.53 – 0.89)	43	0.69	(0.53 – 0.86)	39	0.73	(0.47 – 1.00)	20
2007	0.47	(0.26 – 0.71)	11	0.28	(0.00 – 0.60)	2	0.37	(0.00 – 0.80)	2
2008	1.12	(0.80 – 1.42)	37	0.95	(0.67 – 1.23)	33	0.93	(0.50 – 1.47)	9
2009	0.82	(0.57 – 1.07)	31	1.10	(0.76 – 1.44)	27	0.69	(0.26 – 1.28)	5
2010	0.48	(0.30 – 0.66)	19	0.98	(0.57 – 1.44)	12	0.60	(0.00 – 1.76)	1
2011	0.03	(0.00 – 0.09)	1	0.14	(0.04 – 0.27)	4	0.15	(0.00 – 0.36)	2
2012	0.77	(0.44 – 1.16)	12	0.64	(0.38 – 0.92)	15	0.97	(0.47 – 1.56)	8
2013	0.82	(0.53 – 1.11)	22	0.81	(0.47 – 1.20)	12	0.89	(0.34 – 1.58)	5
2014 [A]	0.32	(0.11 – 0.54)	7	0.71	(0.41 – 1.03)	16	0.32	(0.11 – 0.54)	6

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.6 Estimated dam-specific transportation SAR percentages of PIT-tagged Sawtooth hatchery spring Chinook for juvenile migration years 2007 to 2014 (with 90% confidence intervals). Transported smolts include both first-time and prior detected fish from Group T.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2007	0.91	(0.60 – 1.25)	20	0.42	(0.13 – 0.85)	3	1.46	(0.61 – 2.41)	7
2008	1.08	(0.64 – 1.55)	15	1.37	(0.82 – 1.99)	15	1.80	(0.00 – 3.59)	3
2009	0.88	(0.44 – 1.38)	10	0.63	(0.16 – 1.16)	4	0.71	(0.00 – 2.14)	1
2010	0.64	(0.31 – 1.05)	8	0.70	(0.27 – 1.23)	5	NA		None

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2011	0.09	(0.00 – 0.18)	2	0.072	(0.00 – 0.22)	1	0.16	(0.00 – 0.49)	1
2012	0.37	(0.09 – 0.74)	4	0.61	(0.29 – 0.95)	8	0.68	(0.20 – 1.40)	3
2013	0.46	(0.23 – 0.72)	10	0.60	(0.27 – 0.96)	9	0.16	(0.00 – 0.48)	1
2014 [A]	0.27	(0.11 – 0.48)	5	0.30	(0.08 – 0.59)	4	0.39	(0.00 – 0.79)	3

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.7 Estimated dam-specific transportation SAR percentages of PIT-tagged McCall hatchery summer Chinook for juvenile migration years 1997 to 2014 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
1997	1.49	(1.21 – 1.76)	87	2.86	(0.85 – 5.83)	3	3.23	(0.00 – 9.52)	1
1998	2.93	(2.65 – 3.22)	263	1.00	(0.46 – 1.62)	9	0.64	(0.00 – 1.88)	1
1999	4.36	(3.88 – 4.83)	206	3.23	(2.82 – 3.65)	161	4.93	(2.26 – 7.58)	10
2000	4.54	(4.18 – 4.94)	386	3.26	(2.69 – 3.83)	92	2.45	(1.61 – 3.36)	19
2001	1.41	(1.23 – 1.58)	184	0.76	(0.49 – 1.05)	20	0.40	(0.00 – 0.91)	2
2002	1.63	(1.31 – 1.95)	70	1.43	(1.14 – 1.74)	59	1.00	(0.00 – 2.21)	2
2003	0.82	(0.66 – 0.98)	68	0.85	(0.62 – 1.10)	36	0.81	(0.34 – 1.31)	7
2004	0.43	(0.35 – 0.51)	70	0.36	(0.21 – 0.53)	14	NA		None
2005	0.67	(0.59 – 0.77)	116	0.53	(0.36 – 0.72)	24	0.02	(0.00 – 0.07)	1
2006	1.35	(1.12 – 1.59)	80	0.98	(0.75 – 1.23)	46	1.60	(1.14 – 2.03)	37
2007	1.58	(1.23 – 1.94)	55	1.35	(0.77 – 2.00)	12	1.30	(0.64 – 1.96)	10
2008	1.36	(1.11 – 1.62)	76	1.39	(1.11 – 1.70)	55	2.17	(1.35 – 3.06)	17
2009	0.86	(0.62 – 1.12)	34	0.64	(0.41 – 0.92)	17	0.71	(0.25 – 1.19)	6
2010	0.84	(0.60 – 1.11)	29	0.54	(0.27 – 0.84)	10	0.51	(0.00 – 1.21)	2
2011	0.30	(0.18 – 0.44)	13	0.43	(0.26 – 0.62)	15	0.27	(0.10 – 0.48)	5
2012	0.60	(0.35 – 0.89)	12	0.77	(0.50 – 1.05)	22	0.96	(0.48 – 1.45)	12
2013	0.79	(0.57 – 1.02)	33	0.95	(0.68 – 1.25)	28	0.90	(0.50 – 1.31)	13
2014 [A]	0.70	(0.51 – 0.87)	38	0.41	(0.25 – 0.59)	15	0.38	(0.18 – 0.62)	8

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.8 Estimated dam-specific transportation SAR percentages of PIT-tagged Imnaha hatchery summer Chinook for juvenile migration years 1997 to 2014 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
1997	1.21	(0.84 – 1.66)	25	NA		None	NA		None
1998	0.92	(0.69 – 1.18)	37	0.66	(0.17 – 1.22)	4	NA		None
1999	3.43	(2.82 – 4.08)	74	2.31	(1.80 – 2.86)	53	2.63	(0.00 – 5.31)	3
2000	3.99	(3.50 – 4.48)	154	2.48	(1.91 – 3.09)	45	2.26	(1.18 – 3.36)	12
2001	0.73	(0.56 – 0.92)	42	0.37	(0.13 – 0.64)	6	NA		None
2002	0.74	(0.38 – 1.12)	12	0.82	(0.51 – 1.19)	16	1.55	(0.00 – 2.97)	3
2003	0.58	(0.36 – 0.81)	18	0.64	(0.32 – 0.99)	10	0.67	(0.00 – 1.58)	2
2004	0.34	(0.21 – 0.48)	16	0.42	(0.20 – 0.68)	8	1.23	(0.00 – 2.91)	2
2005	0.34	(0.20 – 0.48)	15	0.15	(0.00 – 0.36)	2	NA		None
2006	0.83	(0.47 – 1.22)	16	0.81	(0.54 – 1.11)	19	1.22	(0.61 – 1.90)	10
2007	1.32	(0.89 – 1.77)	22	0.39	(0.00 – 1.17)	1	NA		None
2008	1.72	(1.35 – 2.10)	57	2.55	(1.94 – 3.22)	44	1.37	(0.35 – 2.59)	4

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2009	1.40	(1.05 – 1.75)	40	1.68	(1.15 – 2.25)	25	0.65	(0.20 – 1.32)	3
2010	1.46	(0.94 – 1.99)	21	0.33	(0.00 – 0.67)	3	0.36	(0.00 – 1.10)	1
2011	0.13	(0.04 – 0.27)	3	0.38	(0.18 – 0.64)	6	0.39	(0.00 – 0.79)	3
2012	0.39	(0.00 – 0.77)	3	0.15	(0.00 – 0.37)	2	0.16	(0.00 – 0.48)	1
2013	0.83	(0.48 – 1.22)	14	0.40	(0.16 – 0.74)	5	0.56	(0.00 – 1.13)	3
2014[A]	0.51	(0.28 – 0.75)	13	0.53	(0.27 – 0.80)	5	0.35	(0.11 – 0.69)	3

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.9 Estimated dam-specific transportation SAR percentages of PIT-tagged Pahsimeroi hatchery summer Chinook for juvenile migration years 2008 to 2014 (with 90% confidence intervals). Transported smolts include both first-time and prior detected fish from Group T beginning 2008.

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2008	1.31	(0.89 – 1.74)	26	2.34	(1.60 – 3.18)	22	0.83	(0.00 – 2.40)	1
2009	1.47	(0.32 – 2.66)	5	0.00	(0.00 – 0.00)	0	0.00	(0.00 – 0.00)	0
2010	0.25	(0.00 – 0.54)	2	0.61	(0.00 – 1.34)	2	0.00	(0.00 – 0.00)	0
2011[A]	NA		None	NA		None	NA		None
2012[A]	NA		None	NA		None	NA		None
2013	0.30	(0.00 – 0.73)	2	NA		None	NA		None
2014[B]	NA		None	NA		None	0.14	(0.00 – 0.41)	1

[A] No transported smolts returned as adults for Pahsimeroi 2011 or 2012.
[B] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.10 Estimated dam-specific transportation SAR percentages of PIT-tagged Clearwater hatchery summer Chinook for juvenile migration years 2011 to 2014 (with 90% confidence intervals).

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2011	0.07	(0.00 – 0.20)	1	0.16	(0.00 – 0.32)	2	NA		None
2012	0.20	(0.00 – 0.59)	1	0.29	(0.00 – 0.67)	2	NA		None
2013	NA		None	0.62	(0.24 – 1.13)	5	0.38	(0.00 – 1.12)	1
2014[A]	0.42	(0.16 – 0.74)	5	0.50	(0.22 – 0.82)	7	0.20	(0.00 – 0.42)	2

[A] Return to GRA incomplete with 2-salts through 9/16/2016

Table D.11 Estimated dam-specific transportation SAR percentages of PIT-tagged wild steelhead in the annual aggregate groups for 1997 to 2013 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from Group T beginning 2006.

Migr Year	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adults #
1997	1.87	(0.47 – 3.59)	4	NA		None	NA		None
1998	0.34	(0.00 – 1.00)	1	NA		None	NA		None
1999	2.69	(0.98 – 4.65)	6	4.44	(1.12 – 8.43)	4	2.99	(0.00 – 7.04)	2
2000	3.50	(1.51 – 5.64)	7	3.37	(0.00 – 6.86)	3	2.73	(0.74 – 5.36)	3
2001	3.09	(1.16 – 5.59)	5	NA		None	NA		None
2002	3.91	(1.55 – 6.82)	5	1.61	(0.00 – 4.92)	1	2.22	(0.65 – 4.41)	3
2003	1.73	(1.15 – 2.40)	21	2.75	(1.71 – 3.85)	18	2.20	(0.84 – 4.07)	5

Migr Year	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adults #
2004	0.91	(0.66 – 1.19)	31	0.87	(0.37 – 1.40)	7	0.63	(0.00 – 1.90)	1
2005	0.97	(0.71 – 1.25)	34	0.62	(0.27 – 1.01)	7	NA		None
2006	1.23	(0.82 – 1.75)	19	1.56	(1.03 – 2.13)	22	1.16	(0.45 – 2.08)	5
2007	4.25	(3.45 – 5.10)	70	4.85	(3.56 – 6.19)	35	4.66	(2.87 – 6.94)	13
2008	3.88	(3.07 – 4.74)	58	5.09	(3.76 – 6.54)	34	2.44	(0.00 – 5.26)	2
2009	3.06	(2.31 – 3.81)	44	4.93	(3.78 – 6.11)	45	1.25	(0.31 – 2.43)	4
2010	2.38	(1.76 – 3.00)	39	2.64	(1.82 – 3.55)	25	1.67	(0.00 – 3.51)	3
2011	1.61	(1.02 – 2.31)	19	1.56	(0.85 – 2.34)	11	0.96	(0.24 – 1.72)	4
2012	1.46	(0.83 – 2.17)	1	3.70	(2.42 – 5.12)	19	2.46	(0.93 – 4.35)	5
2013 [A]	2.79	(2.17 – 3.46)	48	2.98	(2.25 – 3.72)	44	3.67	(2.41 – 5.02)	22

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.12 Estimated dam-specific transportation SAR percentages of PIT-tagged hatchery steelhead in the annual aggregate groups for 1997 to 2013 (with 90% confidence intervals). Transported smolts include only first-time detected fish from total PIT-tag release through 2005 and both first-time and prior detected fish from total PIT-tag release beginning 2006 (pre-assignment to Group T does not begin until 2008 for hatchery steelhead).

Migr Year	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
1997	0.59	(0.27 – 0.96)	9	NA		None	NA		None
1998	0.63	(0.24 – 1.13)	5	0.28	(0.00 – 0.84)	1	0.64	(0.00 – 1.91)	1
1999	1.03	(0.50 – 1.69)	8	1.37	(0.34 – 2.57)	4	NA		None
2000	3.01	(1.74 – 4.56)	14	1.37	(0.00 – 3.90)	1	1.09	(0.00 – 3.09)	1
2001	1.21	(0.30 – 2.32)	4	NA		None	NA		None
2002	2.42	(0.70 – 4.93)	3	NA		None	NA		None
2003	1.98	(1.49 – 2.49)	41	2.12	(1.51 – 2.76)	32	1.21	(0.59 – 1.86)	10
2004	1.70	(0.58 – 2.83)	6	4.60	(1.28 – 8.54)	4	NA		None
2005	2.37	(1.43 – 3.43)	15	1.03	(0.00 – 2.29)	2	2.86	(0.00 – 8.82)	1
2006	1.65	(0.63 – 3.02)	5	2.58	(1.51 – 3.82)	13	2.37	(1.02 – 4.07)	7
2007	1.88	(1.22 – 2.59)	19	2.63	(1.78 – 3.51)	25	1.97	(1.13 – 3.02)	12
2008	3.12	(2.90 – 3.33)	577	3.97	(3.73 – 4.22)	640	3.99	(3.31 – 4.66)	92
2009	1.61	(1.48 – 1.74)	377	1.74	(1.55 – 1.93)	224	1.73	(1.47 – 2.00)	113
2010	1.37	(1.24 – 1.50)	275	1.82	(1.63 – 2.01)	254	1.83	(1.39 – 2.29)	46
2011	0.79	(0.69 – 0.90)	152	0.89	(0.75 – 1.03)	108	0.57	(0.44 – 0.72)	48
2012	1.33	(1.17 – 1.49)	179	1.30	(1.10 – 1.51)	116	1.59	(1.29 – 1.86)	83
2013 [A]	1.44	(1.27 – 1.62)	199	1.50	(1.34 – 1.67)	232	1.52	(1.27 – 1.77)	92

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.13 Estimated dam-specific transportation SAR percentages of PIT-tagged Clearwater–B hatchery steelhead for 2008 to 2013 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead.

Hatchery Group	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2008	1.82	(1.49 – 2.17)	77	2.32	(1.85 – 2.79)	63	1.96	(0.85 – 3.19)	7
2009	0.93	(0.68 – 1.17)	35	1.03	(0.63 – 1.54)	15	1.23	(0.66 – 1.91)	11
2010	0.74	(0.56 – 0.93)	45	1.22	(0.86 – 1.63)	30	2.08	(1.00 – 3.37)	8
2011	0.47	(0.31 – 0.65)	20	0.73	(0.46 – 1.02)	19	0.17	(0.05 – 0.35)	3
2012	0.77	(0.43 – 1.15)	11	1.42	(0.81 – 2.19)	12	2.27	(1.21 – 3.48)	11
2013 [A]	0.70	(0.40 – 1.06)	12	0.49	(0.24 – 0.80)	8	NA		None

A Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.14 Estimated dam-specific transportation SAR percentages of PIT-tagged Grande Ronde–A hatchery steelhead for 2008 to 2013 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead.

Hatchery	SAR(TLGR)		Adult	SAR(TLGS)		Adult	SAR(TLMN)		Adult
Group	%	CI %	#	%	(CI%)	#	%	(CI%)	#
2008	5.16	(4.51 – 5.88)	163	5.34	(4.70 – 6.06)	153	5.19	(3.25 – 7.14)	18
2009	1.73	(1.39 – 2.11)	61	1.78	(1.32 – 2.28)	38	1.69	(1.06 – 2.43)	19
2010	1.83	(1.42 – 2.26)	49	2.52	(1.92 – 3.10)	48	4.32	(2.73 – 6.12)	16
2011	0.38	(0.16 – 0.65)	7	0.34	(0.13 – 0.62)	5	0.40	(0.10 – 0.78)	4
2012	1.53	(1.08 – 2.05)	26	1.93	(1.30 – 2.65)	22	1.47	(0.77 – 2.22)	12
2013 A	1.60	(1.15 – 2.15)	30	1.67	(1.23 – 2.11)	35	2.09	(1.40 – 2.82)	20

A Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.15 Estimated dam-specific transportation SAR percentages of PIT-tagged Imnaha–A hatchery steelhead for 2008 to 2013 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead.

Hatchery	SAR(TLGR)		Adult	SAR(TLGS)		Adult	SAR(TLMN)		Adult
Group	%	CI %	#	%	(CI%)	#	%	(CI%)	#
2008	4.18	(3.51 – 4.87)	107	5.94	(5.18 – 6.75)	150	5.06	(3.43 – 6.76)	22
2009	1.72	(1.32 – 2.13)	50	1.65	(1.65 – 2.17)	27	2.31	(1.53 – 3.14)	22
2010	1.49	(1.10 – 1.91)	36	2.19	(1.64 – 2.76)	40	1.71	(0.60 – 2.91)	6
2011	0.67	(0.40 – 0.94)	17	0.99	(0.57 – 1.45)	14	0.69	(0.29 – 1.15)	7
2012	2.04	(1.51 – 2.59)	38	1.53	(1.05 – 2.10)	21	1.31	(0.71 – 1.94)	11
2013 A	2.24	(1.77 – 2.80)	51	2.19	(1.68 – 2.71)	50	2.06	(1.30 – 2.88)	20

A Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.16 Estimated dam-specific transportation SAR percentages of PIT-tagged Salmon–A hatchery steelhead for 2008 to 2013 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead.

Hatchery	SAR(TLGR)		Adult	SAR(TLGS)		Adult	SAR(TLMN)		Adult
Group	%	CI %	#	%	(CI%)	#	%	(CI%)	#
2008	4.74	(4.21 – 5.31)	193	5.91	(5.32 – 6.55)	238	6.33	(4.66 – 8.08)	40
2009	2.00	(1.75 – 2.29)	147	1.98	(1.64 – 2.36)	82	2.20	(1.67 – 2.74)	44
2010	1.80	(1.52 – 2.10)	105	1.98	(1.66 – 2.33)	96	1.22	(0.67 – 1.88)	11
2011	1.38	(1.16 – 1.63)	100	1.43	(1.16 – 1.16)	64	1.01	(0.71 – 1.28)	32
2012	1.47	(1.20 – 1.74)	70	1.30	(0.96 – 1.67)	43	2.01	(1.48 – 2.59)	37
2013A	1.73	(1.42 – 2.05)	84	1.94	(1.63 – 2.26)	106	2.03	(1.53 – 2.53)	43

A Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.17 Estimated dam-specific transportation SAR percentages of PIT-tagged Salmon–B hatchery steelhead for 2008 to 2013 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead.

Hatchery	SAR(TLGR)		Adult	SAR(TLGS)		Adult	SAR(TLMN)		Adult
Group	%	CI %	#	%	(CI%)	#	%	(CI%)	#
2008	0.82	(0.61 – 1.06)	37	0.90	(0.64 – 1.15)	36	0.96	(0.36 – 1.71)	5

Hatchery Group	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2009	0.76	(0.55 – 0.97)	34	1.04	(0.75 – 1.37)	28	0.41	(0.16 – 0.74)	5
2010	0.33	(0.14 – 0.56)	7	0.51	(0.28 – 0.78)	11	0.33	(0.00 – 0.97)	1
2011	0.29	(0.14 – 0.48)	8	0.16	(0.05 – 0.33)	3	NA		None
2012	0.74	(0.51 – 0.99)	25	0.65	(0.35 – 9.05)	13	0.93	(0.47 – 1.44)	10
2013 [A]	0.28	(0.12 – 0.45)	7	0.53	(0.33 – 0.75)	18	0.23	(0.00 – 0.47)	3

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.18 Estimated dam-specific transportation SAR percentages of PIT-tagged Hells Canyon–A hatchery steelhead for 2009 to 2013 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead.

Hatchery Group	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2009	0.04	(0.03 – 0.05)	50	0.04	(0.03 – 0.05)	34	0.03	(0.02 – 0.05)	12
2010	0.05	(0.04 – 0.07)	52	0.60	(0.04 – 0.08)	45	0.03	(0.01 – 0.06)	7
2011	0.30	(0.00 – 0.74)	2	0.92	(0.00 – 1.83)	3	0.87	(0.00 – 1.90)	2
2012	2.43	(1.12 – 3.87)	9	1.79	(0.63 – 3.30)	5	1.23	(0.00 – 2.84)	2
2013[A]	2.55	(1.58 – 3.73)	15	2.75	(1.65 – 3.98)	15	3.16	(1.16 – 5.46)	6

[A] Return to GRA incomplete with 2-salts through 9/16/2016.

Table D.19 Estimated dam-specific transportation SAR percentages of PIT-tagged Sawtooth hatchery sockeye for 2009 to 2014 (with 90% confidence intervals).

Hatchery Group	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2009	1.80	(1.44 – 2.19)	69	0.62	(0.40 – 0.84)	22	1.48	(1.02 – 1.93)	30
2010[A]	NA		None	NA		None	NA		None
2011	0.13	(0.04 – 0.26)	3	0.22	(0.00 – 0.64)	1	0.03	(0.00 – 0.09)	1
2012	0.14	(0.07 – 0.22)	8	0.04	(0.00 – 0.09)	2	0.05	(0.00 – 0.15)	1
2013	0.23	(0.14 – 0.34)	8	0.04	(0.00 – 0.11)	1	NA		None
2014[B]	0.46	(0.27 – 0.67)	13	0.17	(0.00 – 0.36)	2	0.35	(0.12 – 0.59)	6

[A] Only 38 PIT-tagged Sawtooth Hatchery sockeye estimated in transport category with no adult returns.
[B] Return to GRA incomplete with 2-salts through 9/16/2016

Table D.20 Estimated dam-specific transportation SAR percentages of PIT-tagged Oxbow hatchery sockeye for 2009 to 2012 (with 90% confidence intervals).

Hatchery Group	SAR(TLGR) %	CI %	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
2009	3.29	(1.83 – 4.70)	13	2.09	(0.71 – 3.47)	6	3.16	(1.14 – 5.29)	6
2010[A]	NA		None	NA		None	NA		None
2011	0.12	(0.00 – 0.35)	1	NA		None	NA		None
2012	3.49	(2.27 – 4.67)	21	1.09	(0.42 – 1.98)	5	1.38	(0.00 – 2.93)	3

[A] Due to small sample sizes and other issues with 2010 (see Appendix A, Special considerations for 2010), estimates of dam-specific transportation SAR percentages were not possible.

APPENDIX E

ESTIMATED PROPORTIONS OF SMOLTS EXPERIENCING TX, C0, and C1 PASSAGE ROUTES

Appendix E
Estimated proportion of smolts experiencing T_X, C_0, and C_1 passage routes

The random pre-assignment of part of a release of PIT-tagged fish to monitor-mode (Group T) allows direct estimation of the proportion of smolts experiencing T_X, C_0, and C_1 passage routes for the CSS PIT-tag groups in recent years. Pre-assigning of the CSS PIT-tag wild and hatchery Chinook and wild steelhead groups began with the 2006 smolt migration season. Pre-assignments did not begin until 2008 for PIT-tagged hatchery steelhead. Group T reflects the untagged fish passage experience under a given year's fish passage management scenario.

Methods

In years prior to 2006, when marks were not pre-assigned to passage groups, the estimated number of smolts in each study category was adjusted to a projection of what that number could be if the proportion of smolts in each study category was the same as the run at large. This was done by utilizing the COE transportation and bypass numbers at LGR, LGS, and LMN, which are collected at the level of species and rearing type (the latter to a lesser degree of accuracy). These seasonal proportions were applied to the PIT-tagged smolts transported for a given group of interest at each dam and summed in LGR-equivalents to provide a projection of T_0* smolts transported for that particular group. The projection of C_1* bypassed was simply the remainder of ($T_0 + C_0 – T_0$*) smolts. These projections are presented in Chapter 7 (Tables 7.7, 7.8, 7.13, and 7.14 for PIT-tagged wild Chinook, hatchery Chinook by individual hatchery, wild steelhead, and hatchery steelhead, respectively) of the CSS 2009 Annual Report (Tuomikoski et al. 2009).

In years 2006 and later, the proportion of T_X, C_0, and C_1 smolts are computed directly from Group T for each corresponding CSS PIT-tag group. The reach survival rates (S_j) and collection probabilities (P_j) are computed with the total release (combined Group T smolts and the return-to-river Group R smolts) and passed to Group T, while the parameters R_1, X_{12}, X_{1A2}, X_{1AA2}, and C_1 removals (d_1, d_2, d_3, d_4) and C_0 removals (d_0) are specific to Group T. The equations for estimating the T_X, C_0, and C_1 smolt numbers in Group T are given in Chapter 4. In order for the proportion of Group T smolts being routed to T_X, C_0, and C_1 to reflect those in-river migrants estimated alive to the tailrace of LMN expanded to LGR-equivalents, any removals below LMN need to be added back into the C_0 and C_1 estimates. The following equations are therefore used to estimate the number of PIT-tagged smolts in Group T for each of the three passage history experience categories:

$$T_X = X_{12} + X_{1A2} / S_2 + X_{1AA2} / (S_2 \bullet S_3) \quad \text{[E.1]}$$

$$C_0^* = E(C_0) + d_0 = R_1 \bullet S_1 \bullet (1-P_2) \bullet (1-P_3) \bullet (1-P_4) \quad \text{[E.2]}$$

$$C_1^* = E(C_1) + d_1 = R_1 \bullet S_1 \bullet [P_2 + (1-P_2) \bullet P3 + (1-P_2) \bullet (1-P_3) \bullet P4] - [(d_2 + d_3/S_2 + d_4/(S_2 \bullet S_3))] \quad \text{[E.3]}$$

and

$$P[T_X] = T_X / (T_X + C_0^* + C_1^*) \qquad [E.4]$$

$$P[C_0^*] = C_0^* / (T_X + C_0^* + C_1^*) \qquad [E.5]$$

$$P[C_1^*] = C_1^* / (T_X + C_0^* + C_1^*) \qquad [E.6]$$

Results

Beginning in 2006 there was a major shift in the transportation operations within the FCRPS. The start of transportation was delayed at the three Snake River collector dams due to research findings suggesting that fish transported too early in the migration season have lower survival than if they were allowed to migrate in-river. In years prior to 2006, transportation of the run as a whole commenced as soon as the Snake River collection facilities became operational each year, which was around March 25 at LGR and April 1 at LGS and LMN. For years 2006 to 2014, the start of collecting fish for transportation has been delayed to:

Year	Lower Granite Dam (LGR)	Little Goose Dam (LGS)	Lower Monumental Dam (LMN)
2006	April 20	April 24	April 28
2007	May 1	May 8	May 11
2008	May 1	May 9	May 12
2009	May 1	May 5	May 8
2010	April 25	May 2	May 5
2011	May 1	May 5	May 8
2012	May 1	May 4	May 6
2013	May 1	May 3	May 7
2014	May 1	May 1	May 1
2015	May 1	May 1	May 1

In years prior to 2006, the start time of transportation encompassed most of the emigrating groups of CSS marked fish. With the change to a later start of transportation beginning in 2006, there is now a portion of the population that migrates entirely in-river through the hydrosystem before transportation begins. This reduces the proportion of the smolt population being transported in a given year as seen in Tables E.1 through E.5, particularly in 2007 through 2009 with the later start of transportation compared to 2006. Despite the slightly earlier start date for transportation in 2010, the estimates for proportion transported in 2010 were generally low. This is likely due to the later migration timing of juveniles in this year, as well as the higher spill proportions at Lower Granite and Lower Monumental dams. The outmigration of PIT-tagged Dworshak NFH and Clearwater Hatchery spring Chinook tend to commence earlier than the other four CSS PIT-tag hatchery Chinook groups and have consistently had the lowest proportion transported in all ten years (range 7.0%–52.2% for DWOR and 12.3%–66.3% for CLWH). The other CSS hatchery Chinook groups had fairly similar proportions transported within any given year, with the highest proportions occurring in 2006 (range 65.3%–70.5%) and lowest proportions in 2010 (range 18.6%–32.5%). The PIT-tagged wild Chinook aggregate also had the highest proportion transported in 2006 (66.4%), but its lowest proportion transported estimate came in 2015 (15.5%). The PIT-tagged wild steelhead aggregate likewise had the

highest proportion transported in 2006 (64.9%), while the lowest proportion transported was in 2015 (20.2%). The estimates of proportion transported are consistent among the different groups and among the three years where pre-assignments have been carried out under the CSS. In general, the proportion transported for the hatchery steelhead groups has been in the 30% to 50% range, with a few exceptions for particular groups. Finally, estimates of proportion transported for sockeye juveniles were in the range of 43.9% - 65.9%, with the exception of 2015, when proportion transported was 12.4%. With the later start of transportation in 2007 to 2015 (the first half of May), the goal of reaching a 50% spread-the-risk transport versus in-river migration appears to be more attainable now than was possible in earlier years for both wild Chinook and wild steelhead stocks. However, as was seen in 2010, this is still affected by the migration timing of juveniles.

Table E.1 Migration year 2006 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook and wild steelhead groups experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
RAPH	0.705	0.697	0.713	0.213	0.209	0.218	0.082	0.074	0.090
DWOR	0.522	0.515	0.530	0.319	0.314	0.325	0.158	0.151	0.166
CATH	0.680	0.654	0.706	0.256	0.241	0.269	0.064	0.040	0.090
CLWH	0.625	0.614	0.636	0.299	0.290	0.308	0.076	0.066	0.085
MCCA	0.653	0.643	0.663	0.275	0.269	0.281	0.072	0.062	0.081
IMNA	0.669	0.654	0.685	0.215	0.206	0.223	0.116	0.101	0.131
WCh	0.664	0.652	0.676	0.151	0.147	0.156	0.184	0.173	0.197
WSt	0.649	0.631	0.667	0.072	0.067	0.077	0.280	0.262	0.298

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP. **Wild Chinook** aggregate is WCh and **wild steelhead** aggregate is WSt.

Table E.2 Migration year 2007 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook and wild steelhead groups experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
RAPH	0.347	0.341	0.354	0.519	0.513	0.525	0.134	0.126	0.141
DWOR	0.083	0.081	0.086	0.687	0.682	0.692	0.230	0.225	0.235
CATH	0.473	0.452	0.494	0.465	0.451	0.479	0.062	0.042	0.081
CLWH	0.123	0.119	0.127	0.686	0.680	0.692	0.191	0.185	0.197
SAWT	0.454	0.436	0.471	0.456	0.442	0.471	0.090	0.075	0.106
MCCA	0.274	0.267	0.281	0.616	0.610	0.623	0.110	0.102	0.117
IMNA	0.225	0.216	0.234	0.552	0.543	0.561	0.223	0.212	0.234
WCh	0.213	0.207	0.220	0.490	0.483	0.496	0.297	0.289	0.306
WSt	0.401	0.385	0.416	0.385	0.373	0.399	0.214	0.198	0.229

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP. **Wild Chinook** aggregate is WCh and **wild steelhead** aggregate is WSt.

Table E.3 Migration year 2008 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook and wild steelhead groups experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
				Chinook					
RAPH	0.585	0.578	0.593	0.281	0.275	0.286	0.134	0.127	0.141
DWOR	0.338	0.331	0.345	0.470	0.463	0.478	0.192	0.184	0.199
CATH	0.600	0.579	0.619	0.293	0.281	0.306	0.107	0.088	0.125
CLWH	0.438	0.426	0.449	0.414	0.403	0.425	0.148	0.139	0.158
SAWT	0.594	0.563	0.621	0.307	0.286	0.329	0.100	0.075	0.124
MCCA	0.521	0.511	0.531	0.361	0.353	0.368	0.118	0.109	0.127
IMNA	0.541	0.528	0.552	0.283	0.275	0.292	0.176	0.164	0.188
PAHH	0.539	0.517	0.561	0.323	0.306	0.340	0.138	0.119	0.159
WCh	0.462	0.453	0.470	0.290	0.284	0.295	0.249	0.239	0.258
				Steelhead					
GRN-A[2]	0.416	0.407	0.424	0.383	0.372	0.395	0.201	0.196	0.206
IMN-A[2]	0.436	0.425	0.445	0.348	0.335	0.364	0.216	0.210	0.222
SAL-A	0.485	0.476	0.493	0.350	0.343	0.358	0.165	0.157	0.174
CLWR-B	0.304	0.299	0.311	0.385	0.378	0.390	0.311	0.304	0.318
SAL-B	0.557	0.547	0.567	0.301	0.292	0.309	0.143	0.133	0.152
WSt	0.405	0.390	0.420	0.317	0.306	0.328	0.278	0.262	0.294

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt.

[2] Used method of estimating $Pr(T_X)$, $Pr(C_0)$, and $Pr(C_1)$ for groups without pre-assignment (see Chapter 2 of the CSS 2009 Annual Report (Tuomikoski et al. 2009) for methods).

Table E.4 Migration year 2009 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
Chinook									
RAPH	0.437	0.430	0.443	0.404	0.398	0.410	0.159	0.152	0.167
DWOR	0.341	0.334	0.348	0.478	0.472	0.485	0.181	0.174	0.188
CATH	0.562	0.542	0.581	0.353	0.340	0.366	0.085	0.067	0.103
CLWH	0.245	0.240	0.251	0.486	0.480	0.492	0.269	0.262	0.275
SAWT	0.388	0.372	0.405	0.469	0.455	0.483	0.143	0.125	0.161
MCCA	0.404	0.395	0.413	0.468	0.460	0.475	0.128	0.119	0.137
IMNA	0.504	0.491	0.517	0.373	0.364	0.384	0.123	0.110	0.135
PAHH	0.084	0.078	0.089	0.394	0.384	0.403	0.523	0.512	0.535
WCh	0.416	0.408	0.425	0.225	0.221	0.229	0.359	0.350	0.367
Steelhead									
GRN-A	0.450	0.442	0.460	0.290	0.283	0.296	0.260	0.251	0.269
HCD-A	0.571	0.556	0.588	0.219	0.209	0.230	0.209	0.194	0.225
IMN-A	0.493	0.483	0.503	0.248	0.241	0.256	0.259	0.248	0.269
SAL-A	0.466	0.460	0.472	0.223	0.219	0.227	0.311	0.305	0.317
CLWR-B	0.218	0.213	0.222	0.179	0.175	0.182	0.604	0.599	0.609
SAL-B	0.539	0.531	0.548	0.214	0.208	0.220	0.247	0.238	0.255
WSt	0.453	0.439	0.468	0.190	0.183	0.198	0.357	0.341	0.371
Sockeye[2]									
SAWT	0.582	0.568	0.595	0.346	0.337	0.355	0.073	0.062	0.083

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: OXBOW=Oxbow H; SAWT=Sawtooth H.

[2] Due to smalls sample sizes, proportions of Oxbow Hatchery sockeye through different passage routes cannot be calculated for migration years 2009–2011.

Table E.5 Migration year 2010 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
				Chinook					
RAPH	0.226	0.218	0.234	0.760	0.753	0.767	0.015	0.009	0.020
DWOR	0.186	0.180	0.192	0.727	0.721	0.733	0.086	0.081	0.092
CATH	0.293	0.274	0.312	0.697	0.680	0.714	0.010	-0.004	0.024
CLWH	0.143	0.138	0.148	0.794	0.788	0.800	0.063	0.059	0.068
SAWT	0.325	0.308	0.345	0.659	0.642	0.676	0.015	0.001	0.031
MCCA	0.279	0.269	0.289	0.705	0.695	0.714	0.016	0.009	0.023
IMNA	0.260	0.246	0.275	0.726	0.713	0.740	0.013	0.003	0.023
PAHH	0.210	0.193	0.228	0.696	0.679	0.715	0.094	0.078	0.108
WCh	0.399	0.391	0.407	0.542	0.535	0.549	0.059	0.051	0.066
				Steelhead					
GRN-A	0.314	0.305	0.324	0.618	0.609	0.628	0.068	0.059	0.075
HCD-A	0.353	0.335	0.372	0.616	0.599	0.633	0.032	0.018	0.047
IMN-A	0.401	0.389	0.413	0.537	0.525	0.550	0.062	0.051	0.073
SAL-A	0.352	0.345	0.360	0.597	0.590	0.604	0.051	0.045	0.057
CLWR-B	0.309	0.302	0.316	0.540	0.534	0.548	0.151	0.144	0.157
SAL-B	0.421	0.407	0.436	0.542	0.528	0.554	0.037	0.026	0.049
WSt	0.347	0.333	0.361	0.561	0.548	0.575	0.093	0.080	0.105
				Sockeye[2]					
SAWT[3]	--	--	--	--	--	--	--	--	--

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: OXBOW=Oxbow H; SAWT=Sawtooth H.

[2] Due to smalls sample sizes, proportions of Oxbow Hatchery sockeye through different passage routes cannot be calculated for migration years 2009–2011.

[3] Due to small sample sizes, proportions of Sawtooth Hatchery sockeye through different passage routes cannot be calculated for migration year 2010.

Table E.6 Migration year 2011 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
Chinook									
RAPH	0.508	0.501	0.515	0.329	0.323	0.335	0.163	0.155	0.170
DWOR	0.345	0.338	0.351	0.360	0.355	0.366	0.296	0.288	0.303
CATH	0.536	0.513	0.559	0.327	0.311	0.343	0.137	0.116	0.159
CLWH (sp)	0.252	0.247	0.257	0.349	0.344	0.353	0.399	0.393	0.405
CLWH (su)	0.381	0.370	0.393	0.323	0.314	0.331	0.296	0.284	0.308
SAWT	0.581	0.566	0.598	0.263	0.252	0.274	0.156	0.140	0.172
MCCA	0.433	0.425	0.441	0.397	0.389	0.405	0.171	0.163	0.179
IMNA	0.563	0.548	0.579	0.305	0.293	0.317	0.132	0.117	0.146
PAHH	0.206	0.196	0.215	0.243	0.236	0.251	0.551	0.540	0.562
WCh	0.352	0.345	0.359	0.204	0.200	0.208	0.444	0.436	0.451
Steelhead									
GRN-A	0.288	0.281	0.295	0.327	0.321	0.334	0.385	0.376	0.393
HCD-A	0.312	0.299	0.326	0.186	0.177	0.196	0.502	0.487	0.517
IMN-A	0.491	0.480	0.502	0.312	0.302	0.321	0.197	0.185	0.209
SAL-A	0.494	0.486	0.501	0.297	0.291	0.302	0.209	0.203	0.217
CLWR-B	0.257	0.252	0.261	0.183	0.179	0.186	0.561	0.556	0.566
SAL-B	0.515	0.504	0.525	0.312	0.304	0.320	0.173	0.163	0.184
WSt	0.476	0.459	0.492	0.248	0.237	0.258	0.277	0.258	0.293
Sockeye[2]									
SAWT	0.439	0.431	0.447	0.403	0.394	0.413	0.158	0.155	0.160

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: OXBOW=Oxbow H; SAWT=Sawtooth H.

[2] Due to smalls sample sizes, proportions of Oxbow Hatchery sockeye through different passage routes cannot be calculated for migration years 2009–2011.

Table E.7 Migration year 2012 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
Chinook									
RAPH	0.423	0.415	0.429	0.388	0.382	0.394	0.190	0.181	0.197
DWOR	0.202	0.197	0.207	0.434	0.428	0.440	0.364	0.357	0.371
CATH	0.463	0.444	0.482	0.335	0.323	0.349	0.202	0.182	0.221
CLWH (sp)	0.158	0.154	0.162	0.380	0.375	0.385	0.462	0.456	0.468
CLWH (su)	0.155	0.148	0.161	0.327	0.319	0.335	0.519	0.509	0.528
SAWT	0.488	0.472	0.506	0.301	0.291	0.312	0.210	0.193	0.227
MCCA	0.323	0.316	0.330	0.395	0.389	0.401	0.282	0.274	0.290
IMNA	0.305	0.296	0.315	0.338	0.330	0.347	0.356	0.346	0.367
PAHH	0.023	0.021	0.026	0.273	0.266	0.280	0.703	0.670	0.711
WCh	0.205	0.200	0.210	0.220	0.216	0.224	0.575	0.269	0.581
Steelhead									
GRN-A	0.247	0.241	0.254	0.279	0.273	0.286	0.473	0.465	0.481
HCD-A	0.230	0.217	0.243	0.205	0.194	0.216	0.565	0.550	0.581
IMN-A	0.407	0.396	0.417	0.270	0.262	0.279	0.323	0.312	0.334
SAL-A	0.326	0.321	0.331	0.293	0.288	0.298	0.381	0.375	0.388
CLWR-B	0.142	0.138	0.146	0.254	0.249	0.254	0.604	0.598	0.611
SAL-B	0.595	0.582	0.608	0.257	0.248	0.266	0.148	0.136	0.160
WSt	0.230	0.221	0.238	0.258	0.251	0.259	0.512	0.500	0.523
Sockeye									
OXBOW[2]	0.294	0.266	0.324	0.686	0.657	0.714	0.020	0.003	0.035
SAWT	0.672	0.6591	0.685	0.278	0.271	0.286	0.050	0.039	0.061

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: OXBOW=Oxbow H; SAWT=Sawtooth H.

[2] 2012 was the last year of sockeye releases from Oxbow Hatchery.

Table E.8 Migration year 2013 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
Chinook									
RAPH	0.390	0.382	0.399	0.567	0.559	0.575	0.043	0.036	0.050
DWOR	0.220	0.214	0.226	0.682	0.675	0.689	0.098	0.092	0.104
CATH	0.518	0.488	0.546	0.413	0.391	0.435	0.070	0.044	0.098
CLWH (sp)	0.157	0.152	0.161	0.685	0.679	0.692	0.158	0.153	0.164
CLWH (su)	0.228	0.219	0.238	0.633	0.622	0.645	0.139	0.128	0.150
SAWT	0.506	0.487	0.523	0.463	0.448	0.478	0.031	0.017	0.045
MCCA	0.345	0.336	0.354	0.618	0.610	0.628	0.037	0.029	0.044
IMNA	0.337	0.322	0.351	0.614	0.600	0.627	0.048	0.038	0.059
PAHH	0.127	0.121	0.135	0.683	0.672	0.694	0.190	0.179	0.201
WCh	0.349	0.341	0.357	0.470	0.462	0.477	0.181	0.172	0.189
Steelhead									
GRN-A	0.331	0.321	0.342	0.551	0.540	0.562	0.118	0.108	0.127
HCD-A	0.328	0.308	0.348	0.565	0.544	0.586	0.108	0.090	0.124
IMN-A	0.519	0.505	0.534	0.399	0.387	0.411	0.082	0.071	0.094
SAL-A	0.418	0.410	0.426	0.499	0.491	0.507	0.082	0.076	0.089
CLWR-B	0.150	0.145	0.154	0.555	0.547	0.562	0.296	0.289	0.303
SAL-B	0.533	0.518	0.548	0.430	0.417	0.443	0.037	0.025	0.047
WSt	0.469	0.454	0.483	0.401	0.389	0.415	0.130	0.118	0.143
Sockeye									
SAWT	0.524	0.510	0.538	0.410	0.399	0.422	0.066	0.057	0.076

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: SAWT=Sawtooth H.

Table E.9 Migration year 2014 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish source[1]	Transportation			Passage w/o detection			Bypass passage		
	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
Chinook									
RAPH	0.471	0.462	0.480	0.463	0.455	0.471	0.066	0.089	0.073
DWOR	0.387	0.379	0.395	0.505	0.798	0.512	0.108	0.102	0.115
CATH	0.524	0.499	0.551	0.363	0.348	0.381	0.113	0.091	0.134
CLWH (sp)	0.267	0.261	0.273	0.442	0.436	0.448	0.291	0.285	0.298
CLWH (su)	0.291	0.282	0.300	0.476	0.467	0.485	0.233	0.223	0.243
SAWT	0.457	0.442	0.471	0.408	0.397	0.420	0.135	0.122	0.148
MCCA	0.440	0.431	0.448	0.495	0.487	0.502	0.065	0.058	0.072
IMNA	0.541	0.525	0.556	0.384	0.373	0.398	0.074	0.062	0.087
PAHH	0.219	0.211	0.227	0.434	0.425	0.442	0.348	0.338	0.357
WCh	0.341	0.333	0.378	0.202	0.198	0.206	0.457	0.450	0.465

				Steelhead					
GRN-A	0.333	0.322	0.344	0.487	0.476	0.497	0.180	0.172	0.188
HCD-A	0.394	0.379	0.411	0.348	0.332	0.362	0.258	0.242	0.274
IMN-A	0.543	0.529	0.556	0.363	0.351	0.375	0.094	0.082	0.104
SAL-A	0.369	0.361	0.377	0.460	0.452	0.468	0.171	0.164	0.178
CLWR-B	0.247	0.241	0.253	0.438	0.432	0.444	0.315	0.309	0.321
SAL-B	0.581	0.569	0.595	0.375	0.363	0.386	0.044	0.034	0.054
WSt	0.550	0.534	0.565	0.313	0.302	0.325	0.137	0.122	0.152
				Sockeye					
SAWT	0.659	0.647	0.673	0.013	0.005	0.022	0.327	0.314	0.340

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: SAWT=Sawtooth H.

Table E.10 Migration year 2015 estimated proportion of PIT-tagged smolts in CSS wild and hatchery Chinook, wild and hatchery steelhead groups, and hatchery sockeye experiencing passage through transportation, bypass, or without detection at the Snake River transportation sites (based on PIT-tagged fish in the monitor-mode (TWS) group). (Non-parametric 90% confidence intervals are shown.)

Fish	Transportation			Passage w/o detection			Bypass passage		
source[1]	$Pr(T_X)$	LL	UL	$Pr(C_0)$	LL	UL	$Pr(C_1)$	LL	UL
				Chinook					
RAPH	0.188	0.180	0.196	0.783	0.775	0.792	0.028	0.023	0.033
DWOR	0.073	0.069	0.077	0.777	0.769	0.784	0.150	0.144	0.156
CATH	0.024	0.022	0.026	0.663	0.655	0.672	0.312	0.305	0.321
CLWH (sp)	0.663	0.655	0.672	0.312	0.305	0.321	0.024	0.022	0.026
CLWH (su)	0.016	0.014	0.018	0.813	0.803	0.821	0.171	0.163	0.180
SAWT	0.191	0.177	0.206	0.778	0.764	0.794	0.030	0.021	0.039
MCCA	0.058	0.052	0.064	0.824	0.812	0.835	0.119	0.109	0.128
IMNA	0.269	0.253	0.285	0.698	0.682	0.714	0.033	0.022	0.044
PAHH	0.824	0.812	0.835	0.119	0.110	0.128	0.058	0.052	0.064
WCh	0.155	0.148	0.163	0.667	0.657	0.677	0.178	0.169	0.186
				Steelhead					
GRN-A	0.146	0.138	0.154	0.786	0.776	0.796	0.068	0.061	0.075
HCD-A	0.131	0.118	0.144	0.795	0.777	0.811	0.074	0.062	0.0873
IMN-A	0.187	0.175	0.200	0.768	0.754	0.780	0.045	0.035	0.055
SAL-A	0.135	0.128	0.142	0.798	0.789	0.806	0.067	0.062	0.073
CLWR-B	0.078	0.074	0.081	0.763	0.756	0.770	0.160	0.154	0.165
SAL-B	0.214	0.201	0.228	0.769	0.756	0.781	0.017	0.009	0.025
WSt	0.202	0.177	0.228	0.718	0.690	0.746	0.080	0.061	0.099
				Sockeye					
SAWT	0.124	0.111	0.137	0.874	0.862	0.886	0.002	0.00	0.008

[1] **Hatchery spring Chinook**: RAPH=Rapid River H; DWOR =Dworshak H; CATH=Catherine Creek AP; CLWH=Clearwater H; SAWT=Sawtooth H. **Hatchery summer Chinook**: MCCA=McCall H; IMNA=Imnaha AP; PAHH=Pahsimeroi H. **Wild Chinook** aggregate is WCh. **Hatchery steelhead**: GRN-A=Grand Ronde (Wallowa) A; HCD-A=Mainstem below HCD; IMN-A=Imnaha R. A; SAL-A=Salmon R. A; CLWR-B=Clearwater R. B; SAL-B=Salmon R. B. **Wild steelhead** aggregate is WSt. **Hatchery sockeye**: SAWT=Sawtooth H.

There are several benefits of having Group T for estimating these three passage experience proportions. The previous constraint of limiting transportation to first-time detects

has been eliminated in creating the T_X group, and so fish bypassed at an upstream dam are now included if transported at a downstream dam. Delaying the start of transportation does not add any complication to the estimation process. Since Group T follows the monitor-mode operations at the transportation sites, it best reflects the untagged population of transported and bypassed smolts at those sites. Therefore, there is no need to adjust the PIT-tag data using proportions of collected run-at-large smolts transported and bypassed at the dams, which is available only at the species and rearing type level, to individual PIT-tagged hatchery groups that may have different passage timing history.

APPENDIX F

RETURNING AGE COMPOSITION OF ADULTS

Appendix F
Returning Age Composition of Adults

Snake River wild and hatchery Chinook returning age composition

Table F.1 Age composition of returning PIT-tagged WILD SNAKE RIVR SP/SU CHINOOK adults and jacks detected at Lower Granite Dam that were PIT-tagged during the 10-month period from July 25 to May 20 from smolt migration years 1994 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1994	1	11	11	4.3	47.8	47.8
1995	1	38	20	1.7	64.4	33.9
1996	0	11	5	0.0	68.8	31.3
1997	2	33	5	5.0	82.5	12.5
1998	17	148	46	8.1	70.1	21.8
1999	25	517	144	3.6	75.4	21.0
2000	9	259	312(1[C])	1.5	44.6	53.9[C]
2001	2	30	15	4.3	63.8	31.9
2002	26	197	38	10.0	75.5	14.6
2003	3	61	24	3.4	69.3	27.3
2004	3	83	41(1[C])	2.3	64.8	32.8[C]
2005	4	38	24	6.1	57.6	36.4
2006[A]	12	124	36	7.0	72.1	20.9
2007[A]	22	178	28	9.6	78.1	12.3
2008[A]	133	675	205	13.1	66.6	20.2
2009[A]	50	357	145	9.1	64.7	26.3
2010[A]	98	321	123	18.1	59.2	22.7
2011[A]	29	210	28	10.9	78.6	10.5
2012[A]	109	371	43	20.8	70.9	8.2
2013[A]	44	261	75	11.6	68.7	19.7
2014[A, B]	18	133	NA	11.9	88.1	--
	Average (1994–2013)			10.7	71.0	18.4

[A] Smolt migration year 2006–2014 data are from combined T and R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.
[C] One 4-salt return is included in the 3-salt calculation.

Table F.2 Age composition of returning PIT-tagged DWORSHAK NFH SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1997	1	36	6	2.3	83.7	14.0
1998	51	372	23	11.4	83.4	5.2
1999	14	393	44	3.1	87.1	9.8
2000	3	180	197	0.8	47.4	51.8
2001	14	79	10	13.6	76.7	9.7
2002	52	222	8	18.4	78.7	2.8
2003	5	73	12	5.6	81.1	13.3
2004	1	84	26	0.9	75.7	23.4
2005	2	53	20	2.7	70.7	26.7
2006[A]	42	133	4	23.5	74.3	2.2
2007[A]	40	139	5	21.7	75.5	2.7
2008[A]	87	189	17	29.7	64.5	5.8
2009[A]	16	122	14	10.5	80.2	9.2
2010[A]	150	220	12	39.3	57.6	3.1
2011[A]	11	55	4	15.1	78.6	5.7
2012[A]	72	174	6	28.6	69.0	2.4
2013[A]	44	248	20	14.1	79.5	6.4
2014[A, B]	13	107	NA	10.8	89.2	--
Average (1997–2013)				15.9	72.9	11.2

[A] Smolt migration year 2006–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.3 Age composition of returning PIT-tagged RAPID RIVER HATCHERY SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1997	2	86	7	2.1	90.5	7.4
1998	32	390	23	7.2	87.6	5.2
1999	43	787	31	5.0	91.4	3.6
2000	8	371	256	1.3	58.4	40.3
2001	21	206	13	8.8	85.8	5.4
2002	60	298	5	16.5	82.1	1.4
2003	20	75	8	19.4	72.8	7.8
2004	4	67	27	4.1	68.4	27.6
2005	6	61	16	7.2	73.5	19.3
2006[A]	41	166	11	18.8	76.1	5.0
2007[A]	48	111	1	30.0	69.4	0.6
2008[A]	252	462	31	33.8	62.0	4.2
2009[A]	44	334	25	10.9	82.9	6.2
2010[A]	118	173	9	39.3	57.7	3.0
2011[A]	12	95	5	10.7	84.8	4.5
2012[A]	75	275	14	20.6	75.5	3.8
2013[A]	86	445	32	15.2	79.0	5.7
2014[A, B]	23	141	NA	14.0	86.0	--
Average (1997–2013)				15.1	76.1	8.9

[A] Smolt migration year 2006–2013 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.4 Age composition of returning PIT-tagged CATHERINE CREEK HATCHERY SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2001 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2001	2	13	0	13.3	86.7	0.0
2002	11	45	1	19.3	78.9	1.8
2003	5	22	0	18.5	81.5	0.0
2004	2	17	1	10.0	85.0	5.0
2005	3	15	0	16.7	83.3	0.0
2006[A]	10	36	0	21.7	78.3	0.0
2007[A]	26	32	0	44.8	55.2	0.0
2008[A]	71	185	6	27.1	70.6	2.3
2009[A]	17	113	3	12.8	85.0	2.3
2010[A]	59	71	3	44.3	53.4	2.3
2011[A]	4	26	1	12.9	83.9	3.2
2012[A]	18	37	1	32.1	66.1	1.8
2013[A]	20	59	1	25.0	73.8	1.3
2014[A, B]	7	19	NA	26.9	73.1	--
	Average (2001–2013)			26.5	71.7	1.8

[A] Smolt migration year 2006–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.5 Age composition of returning PIT-tagged MCCALL HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1997	21	263	11	7.1	89.2	3.7
1998	108	394	37	20.0	73.1	6.9
1999	119	722	113	12.5	75.7	11.8
2000	144	635	239(1[C])	14.1	62.3	23.6[C]
2001	62	200	23	21.8	70.2	8.1
2002	116	347	18	24.1	72.1	3.7
2003	129	222	27	34.1	58.7	7.1
2004	25	91	20	18.4	66.9	14.7
2005	16	155	29	8.0	77.5	14.5
2006[A]	67	301	25	17.0	76.6	6.4
2007[A]	145	228	2	38.7	60.8	0.5
2008[A]	361	285	28	53.6	42.3	4.2
2009[A]	72	124	9	35.1	60.5	4.4
2010[A]	137	145	14	46.3	49.0	4.7
2011[A]	24	96	6	19.0	76.2	4.8
2012[A]	160	158	7	49.2	48.6	2.2
2013[A]	189	265	35	38.7	54.2	7.2
2014[A, B]	112	138	NA	44.8	55.2	--
	Average (1997–2013)			27.3	66.8	5.8

[A] Smolt migration year 2006–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.
[C] One 4-salt return is included in the 3-salt calculation.

Table F.6 Age composition of returning PIT-tagged IMNAHA HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1997	24	63	7	25.5	67.0	7.4
1998	54	69	2	43.2	55.2	1.6
1999	81	226	12	25.4	70.8	3.8
2000	149	289	79	28.8	55.9	15.3
2001	30	49	4	36.1	59.0	4.8
2002	46	81	2	35.7	62.8	1.6
2003	93	71	2	56.0	42.8	1.2
2004	9	33	2	20.5	75.0	4.5
2005	5	24	1	16.7	80.0	3.3
2006[A]	39	89	13	27.7	63.1	9.2
2007[A]	91	89	4	49.5	48.4	2.2
2008[A]	359	225	15	59.9	37.6	2.5
2009[A]	97	123	8	42.5	54.0	3.5
2010[A]	96	103	6	46.8	50.2	2.9
2011[A]	20	32	0	38.5	61.5	0.0
2012[A]	54	27	1	65.9	32.9	1.2
2013[A]	87	39	2	68.0	30.5	1.6
2014[A, B]	19	34	NA	35.8	64.2	--
	Average (1997–2013)			42.7	52.2	5.1

[A] Smolt migration year 2006–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.7 Age composition of returning PIT-tagged CLEARWATER HATCHERY SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2006 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2006[A]	25	152	11	13.3	80.9	5.9
2007[A]	41	93	2	30.1	68.4	1.5
2008[A]	74	178	23	26.9	64.7	8.4
2009[A]	49	251	18	15.4	78.9	5.7
2010[A]	119	235	10	32.7	64.6	2.8
2011[A]	9	66	4	11.4	88.5	5.1
2012[A]	94	234	6	28.1	70.1	1.8
2013[A]	64	306	9	16.9	80.7	2.4
2014[A, B]	32	128	NA	20.0	80.0	--
	Average (2006–2013)			22.9	73.1	4.0

[A] Smolt migration year 2006–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.8 Age composition of returning PIT-tagged CLEARWATER HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2011 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2011[A]	7	23	1	22.6	74.2	3.2
2012[A]	38	39	2	48.1	49.4	2.5
2013[A]	22	51	5	28.2	65.4	6.4
2014[A, B]	30	62	NA	32.6	67.4	--
Average (2011–2013)				35.6	60.1	4.3

[A] Smolt migration year 2011–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.9 Age composition of returning PIT-tagged SAWTOOTH HATCHERY SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2007 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2007[A]	37	48	2	42.5	55.2	2.3
2008[A]	36	45	4	42.4	52.9	4.7
2009[A]	11	19	0	36.7	63.3	0.0
2010[A]	30	39	4	41.1	53.4	5.5
2011[A]	5	15	1	23.8	71.4	4.8
2012[A]	14	30	1	31.1	66.7	2.2
2013[A]	13	62	13	14.8	70.5	14.8
2014[A, B]	42	34	NA	55.3	44.7	--
Average (2007–2013)				34.0	60.1	5.8

[A] Smolt migration year 2007–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.10 Age composition of returning PIT-tagged PAHSIMEROI HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2008 to 2014.

Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	55	71	13	39.6	51.1	9.4
2009[A]	14	49	0	22.2	77.8	0.0
2010[A]	7	5	0	58.3	41.7	0.0
2011[A]	0	2	0	0.0	100.0	0.0
2012[A]	14	23	0	37.8	62.2	0.0
2013[A]	15	17	3	42.9	48.6	8.6
2014[A, B]	0	2	NA	0.0	100.0	--
Average (2008–2013)				36.5	58.0	5.6

[A] Smolt migration year 2008–2014 data are from combined T & R groups.
[B] Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Snake River wild and hatchery steelhead returning age composition

Table F.11 Age composition of returning PIT-tagged WILD SNAKE RIVER STEELHEAD adults detected at Lower Granite Dam that were PIT-tagged meeting a minimum length threshold during the 12-month period from July 1 to June 30 for smolt migration years 1997 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1997	4	10	0	28.6	71.4	0.0
1998	16	8	0	66.7	33.3	0.0
1999	33	49	2	39.3	58.3	2.4
2000	132	131	3	49.6	49.2	1.1
2001	5	14	2	23.8	66.7	9.5
2002	59	60	1	49.2	50.0	0.8
2003	37	63	0	37.0	63.0	0.0
2004	26	21	0	55.3	44.7	0.0
2005	17	42	1	28.3	70.0	1.7
2006[A]	37	42	1	46.3	52.5	1.3
2007[A]	115	107	1	51.6	48.0	0.4
2008[A]	236	254	6	47.6	51.2	1.2
2009[A]	100	192	4	33.8	64.9	1.4
2010[A]	155	193	6	40.0	55.3	1.7
2011[A]	41	56	3	41.0	56.0	3.0
2012[A]	121	147	11	43.4	52.7	3.9
2013 [A, B]	73	157	16	29.7	63.8	6.5
	Average (1997–2012)			44.2	54.2	1.6

[A] Smolt migration year 2006–2013 data are from combined T & R groups.
[B] Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Table F.12 Age composition of returning PIT-tagged HATCHERY SNAKE RIVER STEELHEAD adults detected at Lower Granite Dam from smolt migration years 1997 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
1997	34	15	0	69.4	30.6	0.0
1998	45	32	0	58.4	41.6	0.0
1999	85	96	1	46.7	52.7	0.5
2000	178	89	1	66.4	33.2	0.4
2001	3	8	0	27.3	72.7	0.0
2002	99	49	1	66.4	32.9	0.7
2003	90	77	0	53.9	46.1	0.0
2004	21	24	0	46.7	53.3	0.0
2005	41	26	0	61.2	38.8	0.0
2006[A]	102	77	0	57.0	43.0	0.0
2007[A]	163	87	0	65.2	34.8	0.0
2008[A]	2352	964	18	70.6	28.9	0.5
2009[A]	1217	955	10	55.8	43.8	0.5
2010[A]	155	193	3	44.2	55.0	0.8
2011[A]	534	363	31	57.5	39.1	3.3
2012[A]	974	914	33	50.7	47.6	1.7
2013 [A, B]	911	684	13	56.7	42.5	0.8
	Average (1997–2012)			60.0	39.1	1.0

[A] Smolt migration year 2006–2013 data are from combined T & R groups.

B Incomplete adult returns through 9/16/2016 at GRA; not included in average.

Table F.13 Age composition of returning PIT-tagged GRANDE RONDE A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	615	145	2	80.7	19.0	0.3
2009[A]	240	122	0	66.3	33.7	0.0
2010[A]	275	185	0	59.8	40.2	0.0
2011[A]	55	41	2	56.1	41.8	2.0
2012[A]	197	157	6	54.7	43.6	1.7
2013 [A, B]	196	142	1	57.8	41.9	0.3
Average (2008–2012)				67.7	31.8	0.5

A Smolt migration year 2008–2013 data are from combined T & R groups.
B Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Table F.14 Age composition of returning PIT-tagged IMNAHA A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	497	64	0	88.6	11.4	0.0
2009[A]	222	50	0	81.6	18.4	0.0
2010[A]	235	55	0	81.0	19.0	0.0
2011[A]	56	34	1	61.5	37.4	1.1
2012[A]	194	125	2	60.4	38.9	0.6
2013 [A, B]	155	90	5	62.0	36.0	2.0
Average (2008–2012)				78.4	21.4	0.2

A Smolt migration year 2008–2013 data are from combined T & R groups.
B Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Table F.15 Age composition of returning PIT-tagged HELLS CANYON A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	11	3	0	78.6	21.4	0.0
2009[A]	108	70	1	60.3	39.1	0.6
2010[A]	147	87	0	62.8	37.1	0.0
2011[A]	6	8	0	42.9	57.1	0.0
2012[A]	36	46	1	43.4	55.4	1.2
2013 [A, B]	71	36	0	66.4	33.6	0.0
Average (2008–2012)				58.8	40.8	0.4

A Smolt migration year 2008–2013 data are from combined T & R groups.
B Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Table F.16 Age composition of returning PIT-tagged SALMON A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	1136	155	1	87.9	12.0	0.1
2009[A]	606	166	0	78.5	21.5	0.0
2010[A]	745	207	0	78.3	21.7	0.0
2011[A]	393	108	6	77.5	21.3	1.2
2012[A]	525	247	3	67.7	31.9	0.4
2013 [A, B]	444	168	3	72.2	27.3	0.5
Average (2008–2012)				79.2	20.5	0.2

[A] Smolt migration year 2008–2013 data are from combined T & R groups.
[B] Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Table F.17 Age composition of returning PIT-tagged SALMON B HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	86	177	2	32.5	66.8	0.8
2009[A]	25	137	2	15.2	83.5	1.2
2010[A]	102	53	1	65.4	34.0	0.6
2011[A]	60	25	3	68.2	28.4	3.4
2012[A]	61	87	4	40.1	57.2	2.6
2013 [A, B]	71	43	1	61.7	37.4	0.9
Average (2008–2012)				40.5	58.1	1.5

[A] Smolt migration year 2008–2013 data are from combined T & R groups.
[B] Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Table F.18 Age composition of returning PIT-tagged CLEARWATER B HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008[A]	44	441	14	8.8	88.4	2.8
2009[A]	28	391	7	6.6	91.8	1.6
2010[A]	72	361	2	16.6	83.0	0.4
2011[A]	18	153	20	9.4	80.1	10.5
2012[A]	46	262	12	14.4	81.9	3.8
2013 [A, B]	32	185	4	14.5	83.7	1.8
Average (2008–2012)				11.1	85.9	2.9

[A] Smolt migration year 2008–2013 data are from combined T & R groups.
[B] Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Snake River hatchery sockeye returning age composition

Table F.19 Age composition of returning PIT-tagged OXBOW HATCHERY SOCKEYE adults detected at Lower Granite Dam from smolt migration years 2009 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2009[A]	11	43	0	20.4	49.6	0.0
2010[A]	19	25	0	43.2	56.8	0.0
2011[A]	4	26	0	13.3	86.7	0.0
2012[A]	30	124	0	19.5	80.5	0.0
	Average (2009–2012)			22.7	77.3	0.0

[A] Smolt migration year 2009–2012 data are from combined T & R groups.

Table F.20 Age composition of returning PIT-tagged SAWTOOTH HATCHERY SOCKEYE adults detected at Lower Granite Dam from smolt migration years 2009 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2009[A]	0	265	10	0.0	96.4	3.6
2010[A]	2	24	1	7.4	88.9	3.7
2011[A]	0	32	3	0.0	91.4	8.6
2012[A]	0	33	0	0.0	100.0	0.0
2013[A]	23	22	2	48.9	46.8	4.3
2014 [A, B]	0	114	NA	0.0	100.0	0.0
	Average (2009–2013)			6.0	90.2	3.8

[A] Smolt migration year 2009–2014 data are from combined T & R groups.
[B] Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at GRA; not included in average.

Snake River wild and hatchery subyearling fall Chinook

Table F.21 Age composition of returning PIT-tagged wild/natural subyearling fall Chinook adults and jacks detected at Lower Granite Dam from smolt migration years 2006 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2006	0	4	8	0	0.0	33.3	66.7	0.0
2007 [A]	--	--	--	--	--	--	--	--
2008	10	21	25	5	16.4	34.4	41.0	8.2
2009	5	6	5	1	29.4	35.3	29.4	5.9
2010	2	17	8	0	7.4	63.0	29.6	0.0
2011	0	13	8	2	0.0	56.5	34.8	8.7
2012	10	10	11	0	32.3	32.3	35.5	0.0
Average (2006–2012)					15.8	41.5	38.0	4.7

[A] No smolts were tagged in 2007.

Table F.22 Age composition of returning PIT-tagged HATCHERY LYONS FERRY SUBYEARLING CHINOOK released at Big Canyon Creek Acclimation Pond adults and jacks detected at Bonneville Dam from smolt migration years 2006 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2006	172	180	73	3	40.2	42.1	17.1	0.7
2007 [A]	--	--	--	--	--	--	--	--
2008	280	232	69	4	47.9	39.7	11.8	0.7
2009	10	10	8	0	35.7	35.7	28.6	0.0
2010	86	192	62	1	25.2	56.3	18.2	0.3
2011	128	198	107	9	29.0	44.8	24.2	2.0
2012	108	132	95	0	32.2	39.4	28.4	0.0
Average (2006–2012)					36.3	43.7	19.2	0.8

[A] No smolts were tagged in 2007.

Table F.23 Age composition of returning PIT-tagged HATCHERY LYONS FERRY SUBYEARLING CHINOOK released at Captain John Rapids Acclimation Pond adults and jacks detected at Bonneville Dam from smolt migration years 2008 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	166	177	42	1	43.0	45.9	10.9	0.3
2009	16	12	2	0	53.3	40.0	6.7	0.0
2010	169	247	93	7	32.8	47.9	18.0	1.4
2011	155	281	109	10	27.9	50.6	19.6	1.8
2012	65	155	93	0	20.8	49.5	29.7	0.0
Average (2008–2012)					31.7	48.4	18.8	1.0

Table F.24 Age composition of returning PIT-tagged HATCHERY LYONS FERRY SUBYEARLING CHINOOK released at Pittsburg Landing Acclimation Pond adults and jacks detected at Bonneville Dam from smolt migration years 2008 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	189	187	40	4	45.0	44.5	9.2	1.0
2009	10	12	3	0	40.0	48.0	12.0	0.0
2010	94	164	53	3	29.9	52.2	16.9	1.0
2011	89	162	80	5	26.5	48.2	23.8	1.5
2012	69	120	77	0	25.9	45.1	28.9	0.0
Average (2008–2012)					33.1	47.4	18.6	0.9

Table F.25 Age composition of returning PIT-tagged HATCHERY LYONS FERRY SUBYEARLING CHINOOK released into the mainstem Snake River adults and jacks detected at Bonneville Dam from smolt migration years 2006 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2006	27	45	12	1	31.8	52.9	14.1	1.2
2007 [A]	--	--	--	--	--	--	--	--
2008	43	56	10	0	39.4	54.4	9.2	0.0
2009	12	14	2	0	42.9	50.0	7.1	0.0
2010	34	54	16	0	32.7	51.9	15.4	0.0
2011	49	91	40	3	26.8	49.7	21.9	1.6
2012	15	31	12	0	25.9	53.4	20.7	0.0
Average (2006–2012)					31.7	51.3	16.2	0.7

[A] No smolts were tagged in 2007.

Table F.26 Age composition of returning PIT-tagged IRRIGON HATCHERY SUBYEARLING CHINOOK released into the Grande Ronde River adults and jacks detected at Bonneville Dam from smolt migration years 2008 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	49	36	13	1	49.5	36.4	13.1	1.0
2009	19	22	11	1	35.8	41.5	20.8	1.9
2010	41	144	41	2	18.0	63.2	18.0	0.9
2011	28	48	21	3	28.0	48.0	21.0	3.0
2012	67	85	66	0	30.7	39.0	30.3	0.0
Average (2008–2012)					29.2	48.0	21.8	1.0

Table F.27 Age composition of returning PIT-tagged UMATILLE/IRRIGON HATCHERY SUBYEARLING CHINOOK released into the Snake River adults and jacks detected at Bonneville Dam from smolt migration years 2006 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2006	23	28	5	0	41.1	50.0	8.9	0.0
2007 [A]	--	--	--	--	--	--	--	--
2008	296	232	44	2	51.6	40.4	7.7	0.3
2009	27	15	6	0	56.3	31.3	12.5	0.0
2010	65	115	47	3	28.3	50.0	20.4	1.3
2011	28	64	16	6	24.6	56.1	14.0	5.3
2012	75	110	71	0	29.3	43.0	27.7	0.0
Average (2006–2012)					40.2	43.9	15.1	0.9

[A] No smolts were tagged in 2007.

Table F.28 Age composition of returning PIT-tagged OXBOW HATCHERY SUBYEARLING CHINOOK released into the Snake River adults and jacks detected at Bonneville Dam from smolt migration years 2008 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	171	122	21	0	54.5	38.9	6.7	0.0
2009	14	10	0	0	58.3	41.7	0.0	0.0
2010 [A]	--	--	--	--	--	--	--	--
2011	24	38	18	2	29.3	46.3	22.0	2.4
2012	23	33	29	0	27.1	38.8	34.1	0.0
Average (2008–2012)					45.9	40.2	13.5	0.4

[A] No smolts were tagged in 2010.

Table F.29 Age composition of returning PIT-tagged DWORSHAK HATCHERY SUBYEARLING CHINOOK released into the Snake River adults and jacks detected at Bonneville Dam from smolt migration years 2006 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2006	146	184	100	9	33.3	41.9	22.8	2.1
2007 [A]	--	--	--	--	--	--	--	--
2008	539	503	203	28	42.3	39.5	15.9	2.2
2009	64	81	42	1	34.0	43.1	22.3	0.5
2010	269	281	143	16	37.9	39.6	20.2	2.3
2011	209	549	324	69	18.2	47.7	28.1	6.0
2012	88	106	0	0	45.4	54.6	0.0	0.0
Average (2006–2012)					33.3	43.2	20.3	3.2

[A] No smolts were tagged in 2007.

Table F.30 Age composition of returning PIT-tagged NEZ PERCE TRIBAL HATCHERY SUBYEARLING CHINOOK released from Cedar Flats Acclimation Facility adults and jacks detected at Bonneville Dam from smolt migration years 2008 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	26	16	14	0	46.4	28.6	25.0	0.0
2009	13	14	5	0	40.6	43.8	15.6	0.0
2010	13	25	9	1	27.1	52.1	18.8	2.1
2011	55	86	51	6	27.8	43.4	25.8	3.0
2012	9	47	42	0	9.2	48.0	42.9	0.0
Average (2008–2012)					26.9	43.5	28.0	1.6

Table F.31 Age composition of returning PIT-tagged NEZ PERCE TRIBAL HATCHERY SUBYEARLING CHINOOK released from Lukes Gulch Acclimation Facility adults and jacks detected at Bonneville Dam from smolt migration years 2008 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	39	30	18	2	43.8	33.7	20.2	2.2
2009	1	10	6	0	5.9	58.8	35.3	0.0
2010	25	26	4	1	44.6	46.4	7.1	1.8
2011	46	116	49	4	21.4	54.0	22.8	1.9
2012	11	30	34	0	14.7	40.0	45.3	0.0
Average (2008–2012)					27.0	46.9	24.6	1.5

Middle Columbia wild and hatchery yearling Chinook

Table F.32 Age composition of returning PIT-tagged WILD JOHN DAY RIVER SP CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	3	112	31	2.1	76.7	21.2
2001	7	90	15(1[A])	6.2	79.6	14.2[A]
2002	5	86	9	5.0	86.0	9.0
2003	5	110	13	3.9	85.9	10.2
2004	5	68	20	5.4	73.1	21.5
2005	8	61	10	10.1	77.2	12.7
2006	2	34	12	4.2	70.8	25.0
2007	20	114	4	14.5	82.6	2.9
2008	22	147	16	11.9	79.5	8.7
2009	11	209	9	4.8	97.3	3.9
2010	40	96	14	26.7	64.0	9.3
2011	1	21	2	4.2	87.5	8.3
2012	22	82	4	20.4	75.9	3.7
2013	12	47	0	22.3	79.7	100.0
2014 [B]	3	32	NA	8.6	91.4	0.0
Average (2000–2013)				10.3	80.6	9.1

[A] One 4-salt return is included in the 3-salt calculation.
[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.33 Age composition of returning PIT-tagged YAKIMA WILD CHINOOK adults detected at Bonneville Dam from smolt migration years 2000 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	15	164	14	7.8	95.0	7.3
2001	2	8	0	20.0	80.0	0.0
2002	1	47	1	2.0	95.9	2.0
2003	9	50	3	14.5	80.6	4.8
2004	1	44	4	2.0	89.8	8.2
2005	0	6	1	0.0	85.7	14.3
2006	1	8	1	10.0	80.0	10.0
2007	0	7	0	0.0	100.0	0.0
2008	12	33	2	25.5	70.2	4.3
2009	6	47	2	10.9	85.5	3.6
2010[A]	--	--	--	--	--	--
2011	0	3	1	0.0	75.0	25.0
2012	4	22	1	14.8	81.5	3.7
2013	1	9	1	9.1	81.8	9.1
2014 [B]	--	--	--	--	--	--
	Average (2000–2013)			9.8	84.4	5.8

[A] No Wild Chinook tagged in 2010 or 2014.

Table F.34 Age composition of returning PIT-tagged CARSON NFH SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	5	302	124(1[A])	1.2	69.9	28.9[A]
2001	3	205	18	1.3	90.7	8.0
2002	5	148	3	3.2	94.9	1.9
2003	0	32	2	0.0	94.1	5.9
2004	4	79	14	4.1	81.4	14.4
2005	1	37	8	2.2	80.4	17.4
2006	3	63	0	4.5	95.5	0.0
2007	12	80	4	12.5	83.3	4.2
2008	30	205	16	12.0	81.7	6.4
2009	8	196	17	3.6	88.7	7.7
2010	16	108	4	12.5	84.4	3.1
2011	2	48	2	3.8	92.3	3.8
2012	7	77	3	8.0	88.5	3.4
2013	9	147	10	5.4	88.6	6.0
2014 [B]	9	83	NA	9.8	90.2	--
	Average (2000–2013)			5.4	89.3	5.2

[A] One 4-salt return is included in the 3-salt calculation.
[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.35 Age composition of returning PIT-tagged WARM SPRINGS HATCHERY SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2007 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2007	12	58	2	16.7	80.6	2.8
2008	46	158	9	21.6	74.2	4.2
2009	11	126	3	7.9	90.0	2.1
2010	22	30	1	41.5	65.6	1.9
2011	2	27	1	6.7	90.0	3.3
2012	30	97	1	23.4	75.8	0.8
2013	37	173	2	17.5	81.6	0.9
2014 [A]	21	131	NA	13.8	86.2	--
	Average (2007–2013)			18.9	78.9	2.2

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.36 Age composition of returning PIT-tagged CLE ELUM HATCHERY SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	49	478	48	8.5	83.1	8.3
2001	1	25	1	3.7	92.6	3.7
2002	42	159	2	20.7	78.3	1.0
2003	32	71	0	31.1	68.9	0.0
2004	25	119	4	16.9	80.4	2.7
2005	7	37	1	15.6	82.2	2.2
2006	37	123	4	22.6	75.0	2.4
2007	63	126	2	33.0	66.0	1.0
2008	221	354	15	37.5	60.0	2.5
2009	73	277	3	20.9	78.5	0.9
2010	127	186	3	40.2	58.9	1.0
2011	32	108	3	22.4	75.5	2.1
2012	85	187	5	30.7	67.5	1.8
2013	76	181	2	29.3	69.9	0.8
2014 [A]	33	75	NA	30.6	69.4	--
	Average (2000–2013)			25.6	71.6	2.7

Note: Total pit-tag returns from Cle Elum Hatchery's Clark Flat (Rkm 270), Jack Creek (Rkm 284), and Easton (Rkm 325) acclimation pond releases in Yakima River.

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Middle Columbia wild and hatchery steelhead

Table F.37 Age composition of returning PIT-tagged WILD JOHN DAY RIVER STEELHEAD adults detected at Bonneville Dam that were PIT-tagged meeting a minimum length threshold during the 12-month period from July 1 to June 30 for each smolt migration year between 2006 and 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2006	42	22	0	65.6	34.4	0.0
2007	185	68	0	73.1	26.9	0.0
2008	215	99	0	68.5	31.5	0.0
2009	106	89	1	54.1	45.4	0.5
2010	127	66	1	65.5	34.0	0.5
2011	28	16	0	63.6	36.4	0.0

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2012	113	60	1	64.9	53.1	0.6
2013 [A]	82	72	0	53.2	87.8	0.0
Average (2006–2012)				65.9	33.9	0.2

[A] Incomplete adult returns until 3-salt returns (if any) after 9/16/2016 at BOA; not included in average.

Table F.38 Age composition of returning PIT-tagged DESCHUTES WILD STEELHEAD adults detected at Bonneville Dam from smolt migration years 2006 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2006	38	29	0	56.7	43.3	0.0
2007	38	33	0	53.6	46.5	0.0
2008	83	44	0	65.4	34.6	0.0
2009	69	86	0	44.5	55.5	0.0
2010	18	14	0	56.3	43.7	0.0
2011	42	68	0	38.2	61.8	0.0
2012	66	43	0	60.6	39.4	0.0
2013 [A]	3	7	0	30.0	70.0	0.0
Average (2006–2012)				51.8	47.2	0.0

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.39 Age composition of returning PIT-tagged YAKIMA WILD STEELHEAD adults detected at Bonneville Dam from smolt migration years 2002 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2002	24	5	0	82.8	17.2	0.0
2003	17	6	0	73.9	26.1	0.0
2004	9	1	0	90.0	10.0	0.0
2005	10	3	0	76.9	23.1	0.0
2006	15	1	0	93.8	6.2	0.0
2007	13	3	0	81.3	18.7	0.0
2008	17	4	0	81.0	19.3	0.0
2009	10	9	0	52.6	47.4	0.0
2010	15	4	0	78.9	21.1	0.0
2011	4	3	0	57.1	42.9	0.0
2012	16	13	0	55.2	44.8	0.0
2013 [A]	7	6	NA	53.8	46.2	--
Average (2002–2012)				74.3	25.7	0.0

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Middle Columbia wild and hatchery subyearling fall Chinook

Table F.40 Age composition of returning PIT-tagged Hanford Reach wild subyearling Chinook detected at Bonneville Dam from smolt migration years 2009 to 2012.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2009	8	4	19	10	19.5	9.8	46.3	24.4
2010	5	10	22	6	11.6	23.3	51.2	14.0
2011	10	29	54	46	7.2	20.9	38.8	33.1
2012	1	3	14	0	5.6	16.7	77.8	0.0
Average (2009–2012)					10.0	19.1	45.2	25.7

Table F.41 Age composition of returning PIT-tagged Deschutes River wild subyearling Chinook detected at Bonneville Dam from smolt migration years 2011 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2011	38	53	60	22	22.0	30.6	34.7	12.7
2012	14	21	26	0	23.0	34.4	42.6	0.0
2013[A]	28	26	0	0	51.9	48.1	0.0	0.0
Average (2011–2013)					27.8	34.7	29.9	7.6

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.42 Age composition of returning PIT-tagged Spring Creek hatchery subyearling Chinook detected at Bonneville Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2008	17	58	1	22.4	76.3	1.3
2009	10	18	0	35.7	64.3	0.0
2010	8	34	4	17.4	73.9	8.7
2011	0	22	5	0.0	81.5	18.5
2012	7	39	0	15.2	84.8	0.0
2013[A]	15	75	0	16.7	83.3	0.0
Average (2008–2013)				18.2	78.6	3.2

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.43 Age composition of returning PIT-tagged Little White Salmon Hatchery subyearling Chinook detected at Bonneville Dam from smolt migration years 2008 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2008	15	76	126	49	5.6	28.6	47.4	18.4
2009	15	34	64	28	10.6	24.1	45.4	19.9
2010	10	72	256	79	2.4	17.3	61.4	18.9
2011	13	170	262	149	2.2	28.6	44.1	25.1
2012	7	19	82	0	6.5	17.6	75.9	0.0
2013[A]	12	70	0	0	14.6	85.4	0.0	0.0
Average (2008–2013)					4.5	27.4	49.1	19.0

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Upper Columbia wild and hatchery yearling Chinook

Table F.44 Age composition of returning PIT-tagged WENATCHEE WILD CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2007 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2007	0	20	2(1[A])	0.0	90.9	9.1[A]
2008	8	95	63	4.8	57.2	38.0
2009	3	55	11	4.4	79.7	15.9
2010	16	58	8	19.5	70.7	9.8
2011	2	19	8	69.0	65.5	27.6
2012	7	33	3	16.3	76.7	7.0
2013	2	45	11	3.4	77.6	19.0
2014 [B]	8	33	NA	19.5	80.5	--
	Average (2007–2013)			8.1	69.6	22.3

[A] One 4-salt return is included in the 3-salt calculation.
[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.45 Age composition of returning PIT-tagged ENTIAT and METHOW WILD CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2006 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2006	1	4	0	20.0	80.0	0.0
2007	0	6	0	0.0	100.0	0.0
2008	16	96	47	10.1	60.4	29.6
2009	3	31	5	7.7	79.5	12.8
2010	4	42	18	6.3	65.6	18.1
2011	2	3	1	33.3	50.0	16.7
2012	11	22	3	30.6	61.1	8.3
2013	11	34	7	21.2	65.4	13.5
2014 [A]	3	35	NA	7.9	92.1	--
	Average (2006–2013)			13.1	64.9	22.1

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.46 Age composition of returning PIT-tagged Upper Columbia wild summer Chinook (Okanogan River or Columbia Mainstem above Wells Dam) adults and jacks detected at Bonneville Dam from smolt migration years 2011 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2011	5	34	85	44	3.0	20.2	50.6	26.2
2012	8	3	38	20	11.6	4.3	55.1	29.0
2013 [A]	7	33	55	NA	7.4	34.7	57.9	--
	Average (2011–2012)				5.5	15.6	27.0	27.9

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.47 Age composition of returning PIT-tagged LEAVENWORTH NFH SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	1	44	36	1.2	54.3	44.4
2001	0	8	1	0.0	88.9	11.1
2002	29	613	33(1[A])	4.3	90.7	5.0[A]
2003	36	560	93	5.2	81.3	13.5
2004	8	300	56	2.2	82.4	15.4
2005	2	5	2	22.2	55.6	22.2
2006	7	66	7	8.8	82.5	8.8
2007	6	40	1	12.8	85.1	2.1
2008	20	159	15	10.3	82.0	7.7
2009	4	32	9	8.9	71.1	20.0
2010	41	74	6	33.9	61.1	5.0
2011	2	20	3	8.0	80.0	12.0
2012	12	91	4	11.2	85.0	3.7
2013	7	56	7	10.0	80.0	10.0
2014 [B]	14	51	NA	21.5	78.5	--
	Average (2000–2013)			7.0	83.3	9.7

[A] One 4-salt return is included in the 3-salt calculation.
[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Upper Columbia wild and hatchery steelhead

Table F.48 Age composition of returning PIT-tagged WENATCHEE, ENTIAT, and METHOW WILD STEELHEAD adults detected at Bonneville Dam from smolt migration years 2006 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2006	5	4	0	55.6	44.4	0.0
2007	11	29	0	27.5	72.5	0.0
2008	86	65	0	57.0	43.1	0.0
2009	32	40	0	44.4	56.6	0.0
2010	28	24	0	53.9	46.1	0.0
2011	8	5	0	61.5	38.5	0.0
2012	26	18	1	57.8	40.0	2.2
2013 [A]	22	21	1	50.0	47.7	2.3
	Average (2006–2012)			51.3	48.4	0.3

[A] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.49 Age composition of returning PIT-tagged WENATCHEE HATCHERY STEELHEAD adults detected at Bonneville Dam from smolt migration years 2003 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2003	167	146	1	53.2	46.5	0.3
2004	42	91	1	31.3	67.9	0.8
2005	95	37	0	72.0	28.0	0.0
2006	45	48	0	48.4	51.6	0.0
2007	19	53	0	26.4	73.6	0.0
2008	127	143	0	47.0	53.0	0.0
2009	44	76	2	63.1	62.3	1.6

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2010	91	68	0	57.2	42.8	0.0
2011	33	55	0	37.5	62.5	0.0
2012	60	105	2	35.9	62.9	1.2 [A]
2013 [B]	74	115	1	38.9	60.5	0.5
Average (2003–2012)				46.6	53.0	0.4

[A] One 4-salt return is included in the 3-salt calculation.

[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Upper Columbia wild sockeye

Table F.50 Age composition of returning PIT-tagged Okanogan River wild sockeye adults detected at Bonneville Dam from smolt migration years 2013 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2013	59	99	4	36.4	61.1	2.5
2014 [A]	3	57	NA	5.0	95.0	0.0

[A] Incomplete adult returns through 9/16/2016 at BOA.

Upper Columbia wild and hatchery Chinook, steelhead, and sockeye tagged at Rock Island Dam

Table F.51 Age composition of returning PIT-tagged WILD AND HATCHERY YEARLING CHINOOK ROCK ISLAND adults detected at Bonneville Dam from smolt migration years 2000 to 2014.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	0	16	20	0.0	44.4	55.6
2001[A]	0	0	0	0.0	0.0	0.0
2002	1	0	2	33.3	0.0	66.7
2003[B]	--	--	--	--	--	--
2004	0	1	0	0.0	100.0	0.0
2005[A]	0	0	0	0.0	0.0	0.0
2006	0	1	1	0.0	50.0	50.0
2007[A]	0	0	0	0.0	0.0	0.0
2008	4	4	0	50.0	50.0	0.0
2009	0	2	3	0.0	40.0	60.0
2010	0	3	1	0.0	75.0	25.0
2011	2	1	1	50.0	25.0	25.0
2012	4	3	1	50.0	37.5	12.5
2013	9	37	21	13.4	55.2	31.3
2014 [C]	9	14	NA	39.1	60.9	--
Average (2003–2013)				14.5	49.3	36.2

[A] No adult returns in 2001, 2005, or 2007.
[B] No Chinook tagged in 2003.
[C] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.52 Age composition of returning wild and hatchery subyearling Chinook PIT-tagged at Rock Island detected at Bonneville Dam from smolt migration years 2000 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Age 4,5-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt	Percent 4-Salt
2000	3	10	26	43	3.7	12.2	31.7	52.4
2001	0	0	0	0	--	--	--	--
2002	3	3	23	22	5.9	5.9	45.1	43.1
2003	0	3	4	5	0.0	25.0	33.3	41.7
2004	0	0	1	0	0.0	0.0	100.0	0.0
2005	2	2	13	4	9.5	9.5	61.9	19.0
2006	2	2	16	6	7.7	7.7	61.5	23.1
2007	2	1	8	2	15.4	7.7	61.5	15.4
2008	1	4	26	9	2.5	10.0	65.0	22.5
2009	0	4	4	3	0.0	36.4	36.4	27.3
2010	1	7	17	7	3.1	21.9	53.1	21.9
2011	2	19	49	22	2.2	20.7	53.3	23.9
2012	2	2	30	9	4.7	4.7	69.8	20.9
2013 [A]	8	20	31	NA	13.6	33.9	52.5	--
Average (2000–2012)					4.2	13.4	31.1	32.2

[A] No Steelhead tagged in 2003.
[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.53 Age composition of returning PIT-tagged WILD AND HATCHERY STEELHEAD ROCK ISLAND adults detected at Bonneville Dam from smolt migration years 2000 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	25	31	0	44.6	55.4	0.0
2001	0	3	0	0.0	100.0	0.0
2002	45	30	0	60.0	40.0	0.0
2003[A]	--	--	--	--	--	--
2004	2	6	0	25.0	75.0	0.0
2005	15	7	0	68.2	31.8	0.0
2006	15	13	0	53.6	46.4	0.0
2007	16	15	1	50.0	46.9	3.1
2008	135	58	1	69.9	29.9	0.5
2009	33	25	0	56.9	43.1	0.0
2010	43	38	0	53.1	46.9	0.0
2011	23	19	0	54.8	45.2	0.0
2012	33	25	1	55.9	42.4	1.7
2013 [B]	29	27	0	51.8	48.2	0.0
Average (2000–2012)				58.5	41.0	0.5

[A] No Steelhead tagged in 2003.
[B] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

Table F.54 Age composition of returning wild and hatchery Sockeye PIT-tagged at Rock Island detected at Bonneville Dam from smolt migration years 2003 to 2013.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
2000	1	11	1	7.7	84.6	7.7
2001[A]	0	0	0	0.0	0.0	0.0
2002	0	6	0	0.0	100.0	0.0
2003[B]	--	--	--	--	--	--
2004	0	8	0	0.0	100.0	0.0
2005[A]	0	0	0	0.0	0.0	0.0
2006	1	36	2	2.6	92.3	5.1
2007	2	13	3	11.1	72.2	16.7
2008	18	121	10	12.1	81.2	6.7
2009	6	104	11	5.0	86.0	9.1
2010	7	92	2	6.9	91.1	2.0
2011	4	52	3	6.8	88.1	5.1
2012	12	109	14	8.9	80.4	10.4
2013	43	113	10	25.9	68.1	6.0
2014 [C]	1	25	NA	3.8	96.2	--
Average (2000–2013)				11.5	81.6	6.9

[A] No adult returns in 2001 or 2005.
[B] No Sockeye tagged in 2003.
[C] Incomplete adult returns through 9/16/2016 at BOA; not included in average.

APPENDIX G

SNAKE RIVER ADULT SUCCESS RATES FOR TRANSPORTED AND IN-RIVER OUTMIGRANTS FOR THE RUN AS A WHOLE

Appendix G
Snake River Adult Success Rates for Transported and In-river Out-migrants and for the Run as a Whole

Quantifying the efficacy of transportation is one of the foundational goals of the Comparative Survival Study (CSS). The estimation of smolt-to-adult survival rates (SARs) from smolts at Lower Granite Dam (LGR) to adults at LGR is an element of CSS full life-cycle monitoring and is addressed in detail in Appendix A. The CSS PIT-tag data allow for evaluation of the relative upstream passage success of adults between Bonneville Dam (BON) and LGR from transport and in-river groups to further partition the LGR-LGR SARs and assess the extent to which transportation may contribute to straying or poor upstream passage conversion. The capability of estimating the relative adult passage success between BON and LGR became possible in 2002 because adult PIT-tag detection devices were completed in all of the adult ladders at BON. This appendix presents the adult success rate for transported and in-river out-migrating smolts and additionally, because it is of interest to managers, adult success estimated for the run as a whole within one adult return year.

Given that estimates of TIR and *D* both rely on SARs based on adult detections at LGR, these values include both an ocean mortality component and one occurring during upstream migration (i.e., between BON and LGR) in the year of adult return. The adult success rates presented for two out-migration types, transport and in-river, are manifest in the last portion of the smolt-to-adult life cycle from LGR to LGR. The adult success ratio presented in this appendix is estimated for each out-migration year and is analogous to the last component of differential survival measured in both TIR and *D* with one difference. Because there are few PIT-tagged adults, the adult success rates combine the C_1 and C_0 groups whereas TIR and *D* use only the C_0 group to represent in-river out-migrants (see Appendix A for definitions of TIR, *D*, C_0, and C_1). The 2005 and 2006 CSS reports (Berggren et al. 2005b and 2006), contained an analysis/comparison of the inter-dam 'drop out' rates of hatchery and wild Chinook salmon. Annual CSS reports since 2008 have reported adult success rate estimates, the complement of dropout rates, and used these estimates to partition *D* into ocean and BON_{adult} to LGR_{adult} differential survival. This appendix updates the analyses from the 2016 report and includes migration years 2000–2015 for CSS Snake River groups.

The CSS was requested to add the adult success rate by return year to the 2010 report by IDFG and ODFW because it is of interest to managers. These estimates differ from those for each out-migration type in two key respects. They are applicable for the run as a whole and are aligned with each adult return year. Conversely, the adult success rates by out-migration type are aligned with the year of the smolt out-migration and are not applicable to the run as a whole. The estimates for Snake River wild Chinook are included in this appendix and one migration year is added to the time-series. Along the same lines of interest, Snake River wild steelhead success rate estimates for the run as a whole are presented here.

Methods

Adult passage success by migration year

Adult success rates by migration year and ocean survival were estimated for Snake River CSS groups from migration year 2000 to 2015. Data on the number of PIT-tagged adults passing various dams within the FCRPS were used to estimate a success rate for returning adults from BON to LGR. Using data collected at PIT-tag interrogation systems on adult fishways, this quantity was directly estimated and compared between the transport (T_X or T_0) and in-river (C_0 and C_1) study categories in the CSS. During years with a delayed initiation of transportation (after 2005) the transport group was expanded to include fish transported with a previous detection upstream (T_X). This is a logical fit with the delayed transport protocol in these years and follows the CSS study design.

Hatchery and wild Chinook and steelhead marked with PIT tags as juvenile fish in the Snake River basin were monitored at mainstem dams on their downstream migration; after spending one to three years in the ocean, the survivors were detected as they passed upstream as adults through the hydrosystem. PIT-tag detection systems have now been installed in the fish ladders at BON, TDA, MCN, ICH, LMN, LGS and LGR and allowed the tracking of PIT-tagged adults as they passed from lower Columbia River projects to upstream Snake River projects. The adult fish traverse about 286 river miles and encounter eight dams from BON to LGR. Once fish negotiate BON, they pass through tribal fisheries (between BON and MCN) and a sport fishery in both the Columbia and Snake rivers. The detections of adults decrease at upriver sites as a result of the combination of straying, harvest mortality, and passage mortality. Another source of losses is fallbacks since adults may pass BON, later fallback below BON, and do not subsequently re-ascend.

The adult success rate is the proportion of returning PIT-tagged adults that passed BON and were detected at LGR. This calculation requires an estimate of the number of PIT-tagged adults passing BON in the fish ladders. Jacks were excluded from the Chinook success rate so that this analysis is aligned with *D* and *TIR* that both exclude jacks. Jack Chinook typically have a higher success rate than 2-salt and 3-salt Chinook (Berggren et al. 2006; Table 46). Beginning with return year 2002 the capability to detect nearly all PIT-tagged adult fish passing the three ladders at BON was in place. Although the BON detection efficiency is very high it is less than 100%. This may be for a variety of reasons: (1) adults potentially could swim over the weir crests and not pass through the orifices where the detection equipment is installed; (2) adults pass in the navigational locks; (3) adults pass during potential PIT tag antennae outages.

Efficiency at Bonneville Dam was calculated using the Manly-Parr method (Pollock and Alpizar-Jara 2005). This approach conditions on upstream detections of adults and expresses the proportion of those detected upstream that were also detected at BON as an adult. While this estimate of BON detection efficiency is based on those fish surviving to upstream sites, it is not built on an assumption of 100% survival. Rather, estimating detection efficiency in this way only assumes that survival and detection probability are equivalent for all individuals (i.e., detected and undetected fish survive at a similar rate); the number of fish actually detected at upstream sites (i.e., 'sampled') will thus vary as a function of survival, but the estimate of detection efficiency will not. To maximize the sample and the precision for these estimates BON efficiency was calculated using the pooled transported and in-river adults. Detectability of adults

at BON has been shown to be similar regardless of previous juvenile history (Tuomikoski et al. 2011) and this approach allowed for use of the maximum number of detections. The pooled efficiency parameter was then used to expand the number of BON adult detections in the adult success rate. The adult success rate was calculated as:

$$Adult.success.rate = \frac{LGR_{count}}{\left(BON_{count} \div BON_{efficiency}\right)} \qquad [G.1]$$

which can be re-arranged as:

$$Adult.success.rate = \frac{LGR_{count}}{BON_{count}} \times BON_{efficiency} \qquad [G.2]$$

These calculations were performed for each group of interest. First efficiency was calculated at BON by aggregating adult detections from the transported and in-river study groups. Then, adult success rates were calculated for adults with in-river and transportation juvenile histories separately. Because the C_1 and C_0 in-river groups had a much smaller sample size than the T_X group, and few adults returned overall, the C_0 and C_1 were combined into group (C_X). Differences exist in the C_0 and C_1 SARs (see Appendix A of this report) and some of this may be expressed during the return adult migration through the FCRPS. However, comparing their pooled adult success with adults that were transported as juveniles, still allows for testing of how differing juvenile out-migration histories (i.e., transported and not transported) affect the adult return migration. Finally, the $BON_{efficiency}$ was used to correct the adult success rate for the T_X and the C_X subset from a particular migration year, species and release group (e.g., Dworshak Hatchery Chinook that out-migrated in 2007). The use of the efficiency parameter to expand BON detected adults only applies for group estimates of success. When comparing the two group rates in a fraction (e.g., $Success_{(Tx\ or\ T0)}/Success_{Cx}$), the efficiency parameter, existing in the numerator and denominator, cancels out.

The calculations of confidence intervals for all success, efficiency, success ratios, and efficiency comparisons (i.e., transported vs. in-river) in this appendix were performed in a similar fashion to those in Appendix A but using computer program R (R Development Core Team 2010). The non-parametric bootstrapping approach of Efron and Tibshirani (1993) was employed. First the point estimates were calculated from the population, and then the data were re-sampled with replacement to create 1,000 simulated populations. Specifically, a data set of individual fish released for each group of interest (e.g., 2001 Rapid River spring Chinook) was assembled. Each data set was composed of a study category identifier—C_0, C_1, or transported—and history of adult detections at BON, MCN, ICH, and LGR. All individuals from the group of interest were included in the data set even if there were zero adult detections at any site. Each data set was randomly resampled with replacement 1,000 times and the ordered 50th and 951st members for each iterative calculation were selected to express lower and upper 90% confidence intervals for that metric within each group of interest. This was done for each of the groups shown in Tables G.1 and G.2.

Adult passage success by adult return year

Success rates by adult return year are also of interest to managers in assessing the effects of hydrosystem actions and the results of fishing pressure for specific calendar years. The CSS study data are designed to apply to a broad scope of management questions, including hydropower operations, hatchery evaluations, and habitat evaluations. In the process of filling this need, the adult success by return year for wild Snake River Chinook in the return years 2003–2014 without confidence intervals is presented in this report (Table G3).

To calculate the success rate by return year, since several migration years may compose one return year, first age specific success rate within a calendar year was calculated for adult ages 1-salt, 2-salt and 3-salt for steelhead and ages 2-salt and 3-salt for Chinook. Age 4-salts were not included because only two returns of PIT-tagged Snake River wild Chinook occurred from 2003–2014 and these composed 0.15% and 0.67% of the return from the migration years when they occurred. To preclude the use of efficiency at BON, only those adults detected at BON were used as the denominator of the success rate. Of these, the proportion that is later seen at LGR was the numerator of the success rate. Each success rate estimate then resolves to a proportion of counts.

One advantage of the current CSS protocol of randomly pre-assigning is that study groups are properly weighted to represent the run-at-large from each annual out-migration. The pre-assigned T group fish (monitor mode) are a group of PIT tags that matches the run at large in their disposition at LGR, LGS and LMN (see Chapter 1 and Appendix A for more discussion of pre-assignment) and allows for the relatively simple calculation below (equation G.3) because the incorporated counts of adults at BON and LGR are only those adults from the T group. These PIT-tagged fish followed the run-at-large during the juvenile out-migration and are properly weighted in all three study groups: C_1, C_0, and transported. One assumption used in this approach is that tagging rates (PIT-tagged smolt per un-tagged smolt) are similar across migration years because each migration year is weighted equally. This seems a reasonable assumption given the consistent effort to tag wild fish for those groups utilized in the CSS. Future reports will include estimates for hatchery groups where the tagging rate is known (see Appendix A) but this is also consistent across years for most groups. In order to calculate estimates for years with adults that were not pre-assigned to follow the run-at-large, additional adjustments were necessary.

$$\textbf{Adult Success by ReturnYear} = \frac{\sum LGR_{2-salt} + LGR_{3-salt}}{\sum BON_{2-salt} + BON_{3-salt}} \qquad [G.3]$$

Calendar years prior to 2009 include returning adults from out-migrating smolts that were not pre-assigned to follow the run-at-large. Prior to 2006, relatively few untagged fish were returned to river during the spring out-migration. However in order to estimate in-river survivals, researchers routed more PIT-tags to return-to-river than would proportionally represent unmarked in-river smolts. In these cases, the PIT-tags across the three study categories (C_1, C_0, and transported) weighted in proportion with the run-at-large, changes in each out-migration year. We used the metrics that describe these migration year differences from the bootstrap program outputs presented in Chapter 4 and those available on the FPC website

(www.fpc.org; see Appendix A for instructions on website use) to create a weighting factor. For example, first the weighting factors used for 3-salts (2005 out-migration) for the 2008 calendar year were calculated as:

$$
\begin{aligned}
NT_{3-salt} &= Pop \times Transport\ SAR \times PROP(3-salt) \times PROP(Transport) \\
NC0_{3-salt} &= Pop \times C0\ SAR \times PROP(3-salt) \times PROP(C_0) \\
NC1_{3-salt} &= Pop \times C1\ SAR \times PROP(3-salt) \times PROP(C_1) \\
&and, \\
WT_{3-salt} &= \frac{NT_{3-salt}}{\sum all\ N's}\ ,\ WC0_{3-salt} = \frac{NC0_{3-salt}}{\sum all\ N's}\ ,\ WC1_{3-salt} = \frac{NC1_{3-salt}}{\sum all\ N's} \\
&where, \\
Pop &= Estimated\ smolt\ population\ at\ LGR \\
Transport\ SAR &= Transport\ SAR\ from\ LGR_{SMOLT}\ to\ BON_{ADULT} \\
C0\ SAR &= C_0\ SAR\ from\ LGR_{SMOLT}\ to\ BON_{ADULT} \\
C1\ SAR &= C_1\ SAR\ from\ LGR_{SMOLT}\ to\ BON_{ADULT} \\
PROP(3\text{-}salt) &= Overall\ proportion\ of\ \mathbf{3}\text{-}salt's \\
PROP(Transport) &= Run-at-large\ population\ proportion\ of\ transported \\
PROP(C_1) &= Run-at-large\ population\ proportion\ of\ C_0 \\
PROP(C_0) &= Run-at-large\ population\ proportion\ of\ C_1
\end{aligned}
\qquad [G.4]
$$

The above weighting factors were similarly calculated for 2-salts from the 2006 out-migration. Adult success was then calculated for each study category within each age. When incorporating the above weighting factors, the overall adult success for the 2008 adult return year was:

$$
\begin{aligned}
\textbf{Adult Success by Return Year} = &\left\{\frac{\sum LGR_{2-salt\_transported}}{\sum BON_{2-salt\_transported}} \times WT_{2-salt}\right\} + \left\{\frac{\sum LGR_{3-salt\_transported}}{\sum BON_{3-salt\_transported}} \times WT_{3-salt}\right\} + \\
&\left\{\frac{\sum LGR_{2-salt\_C1}}{\sum BON_{2-salt\_C1}} \times WC1_{2-salt}\right\} + \left\{\frac{\sum LGR_{3-salt\_C1}}{\sum BON_{3-salt\_C1}} \times WC1_{3-salt}\right\} + \\
&\left\{\frac{\sum LGR_{2-salt\_C0}}{\sum BON_{2-salt\_C0}} \times WC0_{2-salt}\right\} + \left\{\frac{\sum LGR_{3-salt\_C0}}{\sum BON_{3-salt\_C0}} \times WC0_{3-salt}\right\}
\end{aligned}
\qquad [G.5]
$$

The calculations in years both with and without pre-assignment assume that the proportion of 1-salts (for steelhead only), 2-salts and 3-salts is the same across all study categories (C_1, C_0, and transported) from a single migration year. This assumption seems reasonable from comparisons of age at return across study categories (Chapter 5; Tuomikoski 2010).

Results

Table G.1 – Counts of adults at LGR and BON for all Snake River CSS groups for the juvenile out-migration years 2000–2013. Total adults are shown for fish with two different routes of passage as emigrating juveniles (transported [T_0 before 2006, T_X thereafter] and in-river groups [C_X]). The BON efficiency used for success rates is calculated from the pooled ($T_X + C_X$) groups to make use of the most detections. The BON totals shown were adults detected and expanded by efficiency (∑(BON adult detects) ÷ [BON efficiency]).

Rear-type/Species/ Migration Year[A]	LGR-T_X	BON-T_X	LGR-C_X	BON-C_X	BON Efficiency ($T_X + C_X$)
2000					
HCH-CATH	N/A	N/A	N/A	N/A	N/A
HCH-DWOR	183	295	176	228	97.1%
HCH-IMNA	211	262	143	155	99.2%
HCH-MCCA	497	583	361	400	98.4%
HCH-RAPH	349	491	246	291	97.1%
WCH	12	21	547	640	98.1%
HST	14	17	239	220	72.0%
WST	13	15	228	224	81.8%
		Geom (ST)	76.8%	Geom (CH)	98.0%
2001					
HCH-CATH	11	18	2	3	100.0%
HCH-DWOR	79	96	7	8	100.0%
HCH-IMNA	48	61	5	8	100.0%
HCH-MCCA	206	246	9	10	96.4%
HCH-RAPH	207	265	10	14	98.7%
WCH	7	10	30	33	97.4%
HST	4	6	5	7	90.9%
WST	5	8	11	16	100.0%
		Geom (ST)	95.3%	Geom (CH)	98.7%
2002					
HCH-CATH	24	33	22	21	92.0%
HCH-DWOR	60	80	169	193	97.1%
HCH-IMNA	31	41	49	60	100.0%
HCH-MCCA	131	164	232	281	97.6%
HCH-RAPH	117	132	185	210	94.0%
WCH	31	41	201	223	96.6%
HST	3	3	145	167	96.1%
WST	9	11	109	126	98.3%
		Geom (ST)	97.2%	Geom (CH)	96.2%
2003					
HCH-CATH	9	10	13	14	90.9%
HCH-DWOR	34	44	50	57	93.3%
HCH-IMNA	30	39	43	51	97.6%
HCH-MCCA	111	124	137	154	95.4%
HCH-RAPH	33	52	50	52	91.7%
WCH	30	29	51	55	92.8%
HST	83	105	81	99	97.6%
WST	44	53	52	57	96.0%
		Geom (ST)	96.8%	Geom (CH)	93.6%
2004					
HCH-CATH	11	14	7	7	94.4%
HCH-DWOR	61	121	46	66	97.0%
HCH-IMNA	26	41	8	12	97.5%
HCH-MCCA	84	113	25	41	99.2%
HCH-RAPH	70	88	23	25	95.9%
WCH	68	88	48	59	96.1%
HST	10	9	33	39	95.6%

Rear-type/Species/ Migration Year[A]	LGR-T_X	BON-T_X	LGR-C_X	BON-C_X	BON Efficiency (T_X + C_X)
WST	39	60	5	7	97.9%
		Geom (ST)	96.7%	Geom (CH)	96.7%
2005					
HCH-CATH	11	14	4	4	87.5%
HCH-DWOR	43	65	30	35	96.4%
HCH-IMNA	17	23	8	8	100.0%
HCH-MCCA	141	168	41	49	99.0%
HCH-RAPH	55	69	20	23	92.5%
WCH	37	48	20	28	98.4%
HST	18	29	43	56	96.9%
WST	41	52	17	17	93.9%
		Geom (ST)	95.4%	Geom (CH)	95.5%
2006					
HCH-CATH	13	25	23	34	100.0%
HCH-CLWH	102	154	61	94	98.8%
HCH-DWOR	57	93	80	131	99.3%
HCH-IMNA	46	62	55	66	99.1%
HCH-MCCA	173	200	153	186	99.1%
HCH-RAPH	107	150	69	102	96.2%
WCH	80	92	79	101	99.4%
HST	25	35	154	192	99.5%
WST	48	82	32	46	98.9%
		Geom (ST)	99.2%	Geom (CH)	98.8%
2007					
HCH-CATH	12	15	20	22	90.9%
HCH-CLWH	15	23	80	112	98.1%
HCH-DWOR	16	27	127	172	98.0%
HCH-IMNA	23	27	70	90	100.0%
HCH-MCCA	78	93	152	187	99.2%
HCH-RAPH	41	64	71	95	94.4%
HCH-SAWT	30	35	20	22	92.6%
WCH	39	47	167	197	99.5%
HST	56	84	194	238	99.2%
WST	125	165	98	123	98.7%
		Geom (ST)	99.0%	Geom (CH)	96.5%
2008					
HCH-CATH	103	128	88	116	99.0%
HCH-CLWH	80	120	119	158	98.2%
HCH-DWOR	69	125	137	227	100.0%
HCH-IMNA	107	151	131	177	99.6%
HCH-MCCA	150	209	162	214	97.9%
HCH-PAHH	49	69	35	40	100.0%
HCH-RAPH	250	363	243	329	97.9%
HCH-SAWT	33	40	16	18	100.0%
WCH	259	349	436	542	98.5%
HST-GRN-A run	334	554	427	575	99.3%
HST-IMN-A run	279	461	281	379	99.7%
HST-SAL-A run	481	707	811	994	99.6%
HST-CLW-B run	151	240	348	473	99.3%
HST-SAL-B run	79	143	115	145	98.7%
WST	101	153	227	272	99.7%
		Geom (ST)	99.4%	Geom (CH)	99.0%
2009					
HCH-CATH	57	79	59	73	97.6%
HCH-CLWH	63	99	206	278	98.0%
HCH-DWOR	41	60	95	121	96.1%

Rear-type/Species/ Migration Year[A]	LGR-T_X	BON-T_X	LGR-C_X	BON-C_X	BON Efficiency (T_X + C_X)
HCH-IMNA	68	107	63	104	99.3%
HCH-MCCA	57	94	76	138	97.9%
HCH-PAHH	5	9	48	77	100.0%
HCH-RAPH	162	221	196	274	97.4%
HCH-SAWT	15	16	8	8	91.3%
WCH	123	164	295	405	98.6%
HST-GRN-A run	121	207	241	313	98.5%
HST-HCD-A run	98	162	81	110	98.6%
HST-IMN-A run	101	168	171	235	98.4%
HST-SAL-A run	275	391	496	624	99.3%
HST-CLW-B run	63	107	363	499	99.4%
HST-SAL-B run	70	112	101	129	99.0%
WST	95	143	124	164	99.6%
HSK-OXBH	21	32	22	36	100.0%
HSK-SAWT	124	188	151	245	98.6%
Geom (SK)	99.3%	Geom (ST)	99.0%	Geom (CH)	97.3%
2010					
HCH-CATH	22	28	52	76	97.5%
HCH-CLWH	32	52	213	268	95.5%
HCH-DWOR	22	46	210	275	95.7%
HCH-IMNA	25	32	84	101	98.2%
HCH-MCCA	41	51	118	155	98.8%
HCH-PAHH	4	4	1	2	100.0%
HCH-RAPH	37	57	145	215	94.5%
HCH-SAWT	13	16	30	35	97.7%
WCH	92	126	212	247	99.4%
HST-GRN-A run	113	219	346	473	98.6%
HST-HCD-A run	66	104	168	231	98.5%
HST-IMN-A run	83	129	207	260	98.4%
HST-SAL-A run	214	341	739	936	98.5%
HST-CLW-B run	83	144	351	468	98.7%
HST-SAL-B run	20	30	51	64	98.8%
WST	68	102	152	181	98.3%
HSK-OXBH[B]	0	0	25	46	100.0%
HSK-SAWT[B]	0	1	25	47	96.4%
Geom (SK)	98.2%	Geom (ST)	98.5%	Geom (CH)	97.5%
2011					
HCH-CATH	12	19	15	16	99.0%
HCH-CLWH	8	19	62	83	98.6%
HCH-DWOR	12	25	47	59	99.6%
HCH-IMNA	12	20	20	26	97.5%
HCH-MCCA	33	46	69	80	95.5%
HCH-PAHH	0	0	2	2	95.7%
HCH-RAPH	47	61	53	59	98.2%
HCH-SAWT	4	5	12	13	98.8%
WCH	32	41	94	117	100.0%
HST-GRN-A run	17	38	80	113	94.5%
HST-HCD-A run	7	11	7	13	97.7%
HST-IMN-A run	39	65	52	71	100.0%
HST-SAL-A run	199	329	304	380	96.4%
HST-CLW-B run	44	76	146	202	98.6%
HST-SAL-B run	11	29	16	21	98.5%
WST	34	53	48	67	98.4%
HSK-OXBH	44	76	146	202	98.5%
HSK-SAWT	11	29	16	21	98.7%
Geom (SK)	98.6%	Geom (ST)	97.7%	Geom (CH)	98.1%

Rear-type/Species/ Migration Year[A]	LGR-T_X	BON-T_X	LGR-C_X	BON-C_X	BON Efficiency (T_X + C_X)
2012					
HCH-CATH	8	11	30	40	99.4%
HCH-CLWH	36	53	204	265	98.3%
HCH-CLWH_SU	3	6	38	58	100.0%
HCH-DWOR	27	38	153	210	96.1%
HCH-IMNA	6	17	22	38	100.0%
HCH-MCCA	46	76	119	195	98.4%
HCH-PAHH					
HCH-RAPH	100	136	189	257	100.0%
HCH-SAWT	15	18	16	22	100.0%
WCH	40	49	308	417	99.0%
HST-GRN-A run	62	117	292	429	94.4%
HST-HCD-A run	16	25	67	96	97.8%
HST-IMN-A run	71	114	242	341	100.0%
HST-SAL-A run	154	255	610	839	98.5%
HST-CLW-B run	34	50	274	337	98.5%
HST-SAL-B run	48	71	49	63	99.1%
WST	48	65	220	290	94.4%
HSK-OXBH	15	18	16	22	100.0%
HSK-SAWT	26	64	98	149	99.1%
Geom (SK)	99.6%	Geom (ST)	97.5%	Geom (CH)	99.0%
2013					
HCH-CATH	27	32	32	39	100.0%
HCH-CLWH	38	56	268	297	94.9%
HCH-CLWH_SU	6	30	45	80	99.2%
HCH-DWOR	36	74	212	254	97.8%
HCH-IMNA	12	29	27	69	98.4%
HCH-MCCA	62	149	203	357	96.7%
HCH-PAHH					
HCH-RAPH	144	173	301	339	
HCH-SAWT	24	34	38	57	99.7%
WCH	70	96	191	245	100.0%
HST-GRN-A run	76	141	233	348	98.5%
HST-HCD-A run	35	51	68	87	100.0%
HST-IMN-A run	113	182	126	181	99.5%
HST-SAL-A run	222	324	376	505	100.0%
HST-CLW-B run	13	31	180	234	99.4%
HST-SAL-B run	17	36	38	50	99.5%
WST	88	162	116	164	99.1%
HSK-OXBH	24	34	38	57	97.3%
HSK-SAWT					
Geom(SK)	97.3%	Geom(ST)	99.5%	Geom (CH)	98.3%
2014					
HCH_CATH	12	15	7	15	95.8%
HCH_CLWH	30	40	98	126	95.3%
HCH_CLWH_SU	13	25	48	68	96.5%
HCH_DWOR	42	55	65	96	100.0%
HCH_IMNA	17	23	17	20	98.8%
HCH_MCCA	62	93	75	103	100.0%
HCH_PAHH	1	1	1	1	96.4%
HCH_RAPH	71	81	69	108	93.6%
HCH_SAWT	12	17	22	32	98.3%
WCH	38	44	113	135	97.8%
HST-GRN-A run	57	144	168	349	97.4%
HST-HCD-A run	13	62	17	57	99.6%
HST-IMN-A run	97	188	122	203	99.1%

Rear-type/Species/ Migration Year[A]	LGR-T_X	BON-T_X	LGR-C_X	BON-C_X	BON Efficiency (T_X + C_X)
HST-SAL-A run	81	168	211	350	100.0%
HST-CLW-B run	18	25	50	71	98.8%
HST-SAL-B run	14	28	14	20	96.3%
WST	57	120	64	113	100.0%
HSK_SAWT	21	48	92	119	98.9%
Geom(SK)	98.9%	Geom(ST)	98.7%	Geom (CH)	97.2%

[A] Rear-type and species shown are: hatchery Chinook (HCH), wild Chinook (WCH), hatchery steelhead (HST), wild steelhead (WST), and hatchery sockeye (HSK).

Hatcheries are: Catherine Creek AP (CATH), Clearwater (CLWH), Dworshak (DWOR), Imnaha AP (IMNA), McCall (MCCA), Pahsimeroi (PAHH), Rapid River (RAPH), Sawtooth (SAWT), and Oxbow (OXBH).

Hatchery steelhead basin and run-types are: Grande Ronde A run (GRN A run), Hells Canyon Dam A run (HCD A run), Imnaha A run (IMN A run), Salmon A run (SAL A run), Clearwater B run (CLW B run), and Salmon B run (SAL B run).

[B] No transport treatment in 2010; therefore estimation was not reliable.

Table G.2. Adult success rates for all CSS groups for the juvenile out-migration years 2000-2012. Adult success rate for the transported (T_0 before 2006, T_X thereafter) and in-river groups (C_X), and the success rate differential of those rates are each shown with their 90% confidence interval. The success ratio is shown in the right column; where in bold type, the two groups were significantly different at α = 0.10.

Mig. Year	Rear-type/ Species[A]	Hatchery Group[A]	Success T_0	Success C_X	Success ratio T_0/C_X
2000	HCH	DWOR	0.60 (0.55 – 0.65)	0.75 (0.70 - 0.80)	0.80 (0.72 - 0.89)
	HCH	IMNA	0.80 (0.76 – 0.84)	0.92 (0.87 - 0.95)	0.87 (0.81 - 0.93)
	HCH	MCCA	0.84 (0.81 – 0.86)	0.89 (0.86 - 0.92)	0.94 (0.91 - 0.99)
	HCH	RAPH	0.69 (0.65 – 0.72)	0.82 (0.78 - 0.86)	0.84 (0.79 - 0.90)
	WCH		0.56 (0.37 – 0.73)	0.84 (0.81 - 0.86)	0.67 (0.45 - 0.87)
	HST		0.59 (0.39 – 0.87)	0.78 (0.74 - 0.83)	0.76 (0.49 - 1.11)
	WST		0.71 (0.49 – 1.00)	0.83 (0.79 - 0.87)	0.85 (0.58 - 1.21)
2001	HCH	CATH	0.61 (0.41 – 0.80)	0.67 (0.14 - 0.98)[B]	NSD[B]
	HCH	DWOR	0.82 (0.76 – 0.89)	0.88 (0.67 - 1.00)	0.94 (0.78 - 1.29)
	HCH	IMNA	0.79 (0.70 – 0.87)	0.63 (0.33 - 1.00)	1.26 (0.81 - 2.48)
	HCH	MCCA	0.81 (0.76 – 0.85)	0.87 (0.69 - 0.98)	0.93 (0.80 - 1.17)
	HCH	RAPH	0.77 (0.73 – 0.81)	0.70 (0.50 - 0.90)	1.09 (0.85 - 1.54)
	WCH		0.68 (0.42 – 0.93)	0.89 (0.78 - 0.97)	0.77 (0.47 - 1.07)
	HST		0.61 (0.28 – 0.93)	0.65 (0.33 - 0.92)	0.93 (0.44 - 2.00)
	WST		0.63 (0.33 – 0.91)	0.69 (0.50 - 0.88)	0.91 (0.44 - 1.54)
2002	HCH	CATH	0.67 (0.53 – 0.82)	0.96 (0.86 - 1.08)	0.69 (0.52 - 0.89)
	HCH	DWOR	0.73 (0.64 – 0.82)	0.85 (0.81 - 0.89)	0.86 (0.74 - 0.97)
	HCH	IMNA	0.76 (0.65 – 0.86)	0.82 (0.73 - 0.89)	0.93 (0.77 - 1.10)
	HCH	MCCA	0.78 (0.73 – 0.83)	0.81 (0.77 - 0.85)	0.97 (0.89 - 1.06)
	HCH	RAPH	0.83 (0.77 – 0.89)	0.83 (0.78 - 0.87)	1.01 (0.92 - 1.10)
	WCH		0.73 (0.61 – 0.85)	0.87 (0.83 - 0.91)	0.84 (0.70 - 0.98)
	HST		0.96 (0.93 – 0.99)	0.83 (0.78 - 0.88)	1.15 (1.09 - 1.28)
	WST		0.80 (0.53 – 1.10)	0.85 (0.79 - 0.90)	0.95 (0.61 - 1.31)
2003	HCH	CATH	0.82 (0.57 – 1.05)	0.84 (0.66 - 1.01)	0.97 (0.63 - 1.43)
	HCH	DWOR	0.72 (0.60 – 0.85)	0.82 (0.73 - 0.90)	0.88 (0.72 - 1.09)
	HCH	IMNA	0.75 (0.62 – 0.86)	0.82 (0.73 - 0.91)	0.91 (0.74 - 1.09)
	HCH	MCCA	0.85 (0.80 – 0.91)	0.85 (0.80 - 0.90)	1.01 (0.91 - 1.10)
	HCH	RAPH	0.58 (0.47 – 0.70)	0.88 (0.79 - 0.97)	0.66 (0.52 - 0.82)
	WCH		0.96 (0.88 – 1.05)	0.86 (0.77 - 0.94)	1.12 (0.97 - 1.29)
	HST		0.77 (0.70 – 0.84)	0.80 (0.73 - 0.86)	0.97 (0.86 - 1.09)
	WST		0.80 (0.70 – 0.89)	0.88 (0.80 - 0.95)	0.91 (0.77 - 1.05)
2004	HCH	CATH	0.74 (0.55 – 0.93)	0.94 (0.67 - 1.25)	0.79 (0.50 - 1.22)
	HCH	DWOR	0.49 (0.42 – 0.56)	0.68 (0.58 - 0.77)	0.72 (0.59 - 0.89)

Mig. Year	Rear-type/ Species[A]	Hatchery Group[A]	Success T_0	Success C_X	Success ratio T_0/C_X
	HCH	IMNA	0.62 (0.49 - 0.74)	0.65 (0.42 - 0.88)	0.95 (0.65 - 1.53)
	HCH	MCCA	0.74 (0.67 - 0.81)	0.60 (0.48 - 0.74)	1.22 (0.99 - 1.56)
	HCH	RAPH	0.76 (0.69 - 0.84)	0.88 (0.75 - 1.02)	0.86 (0.72 - 1.06)
	WCH		0.74 (0.67 - 0.82)	0.78 (0.69 - 0.87)	0.95 (0.81 - 1.12)
	HST		1.06 (0.82 - 1.42)	0.81 (0.70 - 0.90)	1.31 (0.96 - 1.86)
	WST		0.64 (0.53 - 0.74)	0.70 (0.38 - 1.00)	0.91 (0.62 - 1.77)
2005	HCH	CATH	0.69 (0.45 - 0.89)	0.88 (0.42 - 1.83)	0.79 (0.31 - 1.86)
	HCH	DWOR	0.64 (0.54 - 0.74)	0.83 (0.71 - 0.93)	0.77 (0.63 - 0.96)
	HCH	IMNA	0.74 (0.59 - 0.89)	1.00 (1.00 - 1.00)	0.74 (0.59 - 0.89)
	HCH	MCCA	0.83 (0.78 - 0.88)	0.83 (0.74 - 0.91)	1.00 (0.90 - 1.15)
	HCH	RAPH	0.74 (0.65 - 0.82)	0.80 (0.66 - 0.94)	0.92 (0.74 - 1.14)
	WCH		0.76 (0.65 - 0.86)	0.70 (0.54 - 0.84)	1.08 (0.85 - 1.44)
	HST		0.60 (0.45 - 0.75)	0.74 (0.65 - 0.84)	0.81 (0.59 - 1.05)
	WST		0.74 (0.63 - 0.84)	0.94 (0.74 - 1.18)	0.79 (0.58 - 1.05)
2006	HCH	CATH	0.52 (0.36 - 0.71)	0.68 (0.55 - 0.81)	0.77 (0.51 - 1.13)
	HCH	CLWH	0.65 (0.59 - 0.72)	0.64 (0.55 - 0.72)	1.02 (0.87 - 1.22)
	HCH	DWOR	0.61 (0.53 - 0.70)	0.61 (0.53 - 0.68)	1.00 (0.84 - 1.21)
	HCH	IMNA	0.74 (0.64 - 0.82)	0.83 (0.75 - 0.90)	0.89 (0.77 - 1.04)
	HCH	MCCA	0.86 (0.82 - 0.90)	0.82 (0.77 - 0.86)	1.05 (0.98 - 1.14)
2006	HCH	RAPH	0.69 (0.62 - 0.75)	0.65 (0.57 - 0.73)	1.05 (0.91 - 1.24)
	WCH		0.86 (0.81 - 0.92)	0.78 (0.70 - 0.84)	1.11 (1.00 - 1.25)
	HST		0.71 (0.59 - 0.84)	0.80 (0.75 - 0.84)	0.89 (0.73 - 1.06)
	WST		0.58 (0.49 - 0.67)	0.69 (0.57 - 0.80)	0.84 (0.66 - 1.07)
2007	HCH	CATH	0.73 (0.54 - 0.89)	0.83 (0.67 - 0.97)	0.88 (0.63 - 1.19)
	HCH	CLWH	0.64 (0.45 - 0.82)	0.70 (0.63 - 0.78)	0.91 (0.64 - 1.19)
	HCH	DWOR	0.58 (0.41 - 0.73)	0.72 (0.67 - 0.78)	0.80 (0.56 - 1.01)
	HCH	IMNA	0.85 (0.73 - 0.96)	0.78 (0.71 - 0.85)	1.10 (0.92 - 1.28)
	HCH	MCCA	0.83 (0.77 - 0.90)	0.81 (0.76 - 0.85)	1.03 (0.93 - 1.14)
	HCH	RAPH	0.60 (0.51 - 0.70)	0.71 (0.62 - 0.78)	0.86 (0.69 - 1.06)
	HCH	SAWT	0.79 (0.68 - 0.91)	0.84 (0.71 - 0.96)	0.94 (0.76 - 1.19)
	WCH		0.83 (0.73 - 0.91)	0.84 (0.80 - 0.89)	0.98 (0.86 - 1.10)
	HST		0.66 (0.58 - 0.74)	0.81 (0.77 - 0.85)	0.82 (0.70 - 0.94)
	WST		0.75 (0.69 - 0.80)	0.79 (0.73 - 0.84)	0.95 (0.85 - 1.07)
2008	HCH	CATH	0.80 (0.74 - 0.85)	0.75 (0.68 - 0.82)	1.06 (0.95 - 1.19)
	HCH	CLWH	0.65 (0.58 - 0.73)	0.74 (0.68 - 0.80)	0.89 (0.77 - 1.02)
	HCH	DWOR	0.55 (0.48 - 0.62)	0.60 (0.55 - 0.66)	0.91 (0.77 - 1.06)
	HCH	IMNA	0.71 (0.64 - 0.76)	0.74 (0.68 - 0.79)	0.96 (0.84 - 1.08)
	HCH	MCCA	0.70 (0.65 - 0.76)	0.74 (0.69 - 0.79)	0.95 (0.86 - 1.05)
	HCH	PAHH	0.71 (0.62 - 0.80)	0.88 (0.79 - 0.96)	0.81 (0.68 - 0.95)
	HCH	RAPH	0.67 (0.63 - 0.71)	0.72 (0.68 - 0.77)	0.93 (0.86 - 1.01)
	HCH	SAWT	0.83 (0.71 - 0.92)	0.89 (0.76 - 1.00)	0.93 (0.77 - 1.13)
	WCH		0.73 (0.69 - 0.77)	0.79 (0.77 - 0.82)	0.92 (0.86 - 0.98)
	HST	GRN A Run	0.60 (0.56 - 0.63)	0.74 (0.71 - 0.77)	0.81 (0.76 - 0.87)
	HST	IMN A Run	0.60 (0.57 - 0.64)	0.74 (0.70 - 0.78)	0.82 (0.75 - 0.88)
	HST	SAL A Run	0.68 (0.65 - 0.71)	0.81 (0.79 - 0.83)	0.83 (0.79 - 0.88)
	HST	CLW B Run	0.62 (0.57 - 0.68)	0.73 (0.69 - 0.77)	0.86 (0.78 - 0.94)
	HST	SAL B Run	0.55 (0.48 - 0.62)	0.78 (0.73 - 0.84)	0.70 (0.60 - 0.81)
	WST		0.66 (0.59 - 0.72)	0.83 (0.80 - 0.87)	0.79 (0.71 - 0.87)
2009	HCH	CATH	0.70 (0.62 - 0.79)	0.79 (0.70 - 0.87)	0.89 (0.76 - 1.05)
	HCH	CLWH	0.62 (0.54 - 0.70)	0.73 (0.68 - 0.77)	0.86 (0.74 - 0.98)
	HCH	DWOR	0.66 (0.55 - 0.76)	0.75 (0.69 - 0.82)	0.87 (0.71 - 1.03)
	HCH	IMNA	0.63 (0.56 - 0.71)	0.60 (0.52 - 0.68)	1.05 (0.88 - 1.26)
	HCH	MCCA	0.59 (0.51 - 0.68)	0.54 (0.47 - 0.61)	1.10 (0.90 - 1.33)
	HCH	PAHH	0.56 (0.25 - 0.85)	0.62 (0.53 - 0.72)	0.89 (0.43 - 1.40)
	HCH	RAPH	0.71 (0.66 - 0.77)	0.70 (0.65 - 0.74)	1.02 (0.93 - 1.13)
	HCH	SAWT	0.86 (0.71 - 1.00)	0.91 (0.68 - 1.19)	0.94 (0.65 - 1.33)

Mig. Year	Rear-type/ Species[A]	Hatchery Group[A]	Success T_0	Success C_X	Success ratio T_0/C_X
	WCH		0.74 (0.68 – 0.80)	0.72 (0.68 - 0.76)	1.03 (0.93 - 1.13)
	HST	GRN A Run	0.58 (0.52 – 0.63)	0.76 (0.72 - 0.80)	0.76 (0.68 - 0.85)
	HST	HCD A Run	0.60 (0.53 – 0.65)	0.73 (0.65 - 0.80)	0.82 (0.71 - 0.95)
	HST	IMN A Run	0.59 (0.53 – 0.65)	0.72 (0.66 - 0.76)	0.83 (0.73 - 0.94)
	HST	SAL A Run	0.70 (0.66 – 0.74)	0.79 (0.76 - 0.82)	0.88 (0.83 - 0.94)
	HST	CLW B Run	0.58 (0.51 – 0.66)	0.72 (0.69 - 0.76)	0.81 (0.70 - 0.93)
	HST	SAL B Run	0.62 (0.54 – 0.70)	0.77 (0.71 - 0.84)	0.80 (0.69 - 0.92)
	WST		0.66 (0.60 – 0.73)	0.75 (0.70 - 0.80)	0.88 (0.78 - 1.00)
	HSK	OXHB	0.66 (0.52 – 0.79)	0.61 (0.47 - 0.74)	1.07 (0.77 - 1.44)
	HSK	SAWT	0.65 (0.59 – 0.71)	0.61 (0.56 - 0.66)	1.07 (0.96 - 1.21)
2010	HCH	CATH	0.77 (0.64 – 0.89)	0.67 (0.58 - 0.76)	1.15 (0.92 - 1.43)
	HCH	CLWH	0.59 (0.47 – 0.71)	0.76 (0.72 - 0.80)	0.77 (0.62 - 0.95)
	HCH	DWOR	0.46 (0.34 – 0.58)	0.73 (0.68 - 0.78)	0.63 (0.46 - 0.80)
	HCH	IMNA	0.77 (0.64 – 0.89)	0.82 (0.75 - 0.88)	0.94 (0.76 - 1.12)
	HCH	MCCA	0.79 (0.69 – 0.89)	0.75 (0.70 - 0.81)	1.06 (0.90 - 1.21)
	HCH	PAHH	1.00 (0.47 – 1.00)[B]	0.50 (0.03 - 0.97)[B]	NSD[B]
	HCH	RAPH	0.61 (0.51 – 0.72)	0.64 (0.59 - 0.69)	0.96 (0.79 - 1.16)
	HCH	SAWT	0.79 (0.63 – 0.96)	0.84 (0.73 - 0.94)	0.95 (0.74 - 1.19)
	WCH		0.73 (0.66 – 0.79)	0.85 (0.82 - 0.89)	NSD[B]
2010	HST	GRN A Run	0.51 (0.46 – 0.57)	0.72 (0.69 - 0.76)	0.71 (0.63 - 0.79)
	HST	HCD A Run	0.62 (0.55 – 0.70)	0.72 (0.66 - 0.76)	0.87 (0.75 - 1.00)
	HST	IMN A Run	0.63 (0.56 – 0.71)	0.78 (0.74 - 0.82)	0.81 (0.71 - 0.91)
	HST	SAL A Run	0.62 (0.58 – 0.66)	0.78 (0.76 - 0.80)	0.79 (0.74 - 0.86)
	HST	CLW B Run	0.57 (0.49 – 0.64)	0.74 (0.71 - 0.77)	0.77 (0.67 - 0.87)
	HST	SAL B Run	0.66 (0.52 – 0.80)	0.79 (0.70 - 0.87)	0.84 (0.65 - 1.04)
	WST		0.66 (0.58 – 0.74)	0.83 (0.78 - 0.87)	0.79 (0.69 - 0.90)
	HSK	OXHB	N/A[C]	0.54 (0.42 - 0.67)	N/A[C]
	HSK	SAWT	N/A[C]	0.51 (0.39 - 0.63)	N/A[C]
2011	HCH	CATH	0.63 (0.44 – 0.81)	0.94 (0.83 - 1.00)	0.67 (0.46 - 0.88)
	HCH	CLWH	0.40 (0.22 – 0.62)	0.72 (0.63 - 0.80)	0.56 (0.31 - 0.90)
	HCH	DWOR	0.47 (0.31 – 0.65)	0.78 (0.69 - 0.87)	0.60 (0.39 - 0.84)
	HCH	IMNA	0.60 (0.42 – 0.78)	0.77 (0.63 - 0.92)	0.78 (0.53 - 1.10)
	HCH	MCCA	0.72 (0.61 – 0.83)	0.86 (0.79 - 0.92)	0.83 (0.69 - 0.99)
	HCH	PAHH	N/A[D]	1.00 (0.22 - 1.00)	N/A[D]
	HCH	RAPH	0.76 (0.67 – 0.85)	0.89 (0.82 - 0.95)	0.86 (0.74 - 0.98)
	HCH	SAWT	0.76 (0.46 – 1.00)	0.87 (0.67 - 1.03)	0.87 (0.50 - 1.30)
	WCH		0.77 (0.65 – 0.88)	0.79 (0.73 - 0.85)	0.97 (0.80 - 1.15)
	HST	GRN A Run	0.44 (0.32 – 0.58)	0.70 (0.63 - 0.77)	0.63 (0.45 - 0.83)
	HST	HCD A Run	0.60 (0.33 – 0.88)	0.51 (0.29 - 0.75)	1.18 (0.58 - 2.40)
	HST	IMN A Run	0.60 (0.50 – 0.70)	0.73 (0.65 - 0.81)	0.82 (0.65 - 1.00)
	HST	SAL A Run	0.60 (0.55 – 0.64)	0.79 (0.76 - 0.83)	0.76 (0.69 - 0.82)
	HST	CLW B Run	0.58 (0.47 – 0.67)	0.72 (0.67 - 0.77)	0.80 (0.66 - 0.95)
	HST	SAL B Run	0.38 (0.23 – 0.53)	0.76 (0.59 - 0.92)	0.50 (0.30 - 0.77)
	WST		0.64 (0.52 – 0.75)	0.72 (0.62 - 0.81)	0.90 (0.71 - 1.11)
	HSK	OXHB	0.08 (0.00 – 0.18)	0.50 (0.39 - 0.62)	0.15 (0.00 - 0.37)
	HSK	SAWT	0.29 (0.12 – 0.50)	0.57 (0.44 - 0.68)	0.52 (0.21 - 0.93)
2012	HCH	CATH	0.69 (0.42 – 0.98)	0.71 (0.59 - 0.83)	0.97 (0.59 - 1.47)
	HCH	CLWH	0.67 (0.56 – 0.77)	0.76 (0.72 - 0.81)	0.88 (0.73 - 1.02)
	HCH	DWOR	0.70 (0.57 – 0.83)	0.72 (0.66 - 0.76)	0.98 (0.79 - 1.17)
	HCH	IMNA	0.34 (0.16 – 0.56)	0.56 (0.43 - 0.69)	0.61 (0.28 - 1.08)
	HCH	MCCA	0.60 (0.50 – 0.70)	0.60 (0.54 - 0.66)	0.99 (0.82 - 1.19)
	HCH	PAHH	N/A[D]	N/A[D]	N/A[D]
	HCH	RAPH	0.73 (0.67 – 0.79)	0.73 (0.69 - 0.78)	1.00 (0.90 - 1.10)
	HCH	SAWT	0.83 (0.67 – 0.96)	0.73 (0.56 - 0.88)	1.15 (0.87 - 1.55)
	WCH		0.83 (0.74 – 0.92)	0.76 (0.73 - 0.79)	1.10 (0.97 - 1.23)
	HST	GRN A Run	0.53 (0.46 – 0.60)	0.68 (0.64 - 0.71)	0.78 (0.66 - 0.90)

Mig. Year	Rear-type/ Species[A]	Hatchery Group[A]	Success T_0	Success C_X	Success ratio T_0/C_X
	HST	HCD A Run	0.64 (0.46 - 0.79)	0.70 (0.62 - 0.77)	0.92 (0.66 - 1.17)
	HST	IMN A Run	0.62 (0.54 - 0.70)	0.71 (0.67 - 0.74)	0.88 (0.76 - 1.01)
	HST	SAL A Run	0.60 (0.55 - 0.65)	0.72 (0.70 - 0.75)	0.83 (0.76 - 0.91)
	HST	CLW B Run	0.67 (0.56 - 0.78)	0.81 (0.77 - 0.84)	0.84 (0.69 - 0.97)
	HST	SAL B Run	0.66 (0.56 - 0.74)	0.77 (0.67 - 0.87)	0.85 (0.69 - 1.02)
	WST		0.73 (0.63 - 0.82)	0.75 (0.71 - 0.80)	0.97 (0.83 - 1.10)
	HSK	OXHB	0.36 (0.28 - 0.44)	0.65 (0.59 - 0.70)	0.56 (0.42 - 0.70)
	HSK	SAWT	0.24 (0.14 - 0.36)	0.71 (0.59 - 0.84)	0.34 (0.20 - 0.54)
2013	HCH	CATH	0.82 (0.69 - 0.93)	0.80 (0.69 - 0.90)	1.02 (0.83 - 1.24)
	HCH	CLWH	0.64 (0.54 - 0.75)	0.86 (0.83 - 0.89)	0.75 (0.62 - 0.89)
	HCH	CLWH_SU	0.19 (0.08 - 0.31)	0.56 (0.47 - 0.65)	0.34 (0.14 - 0.56)
	HCH	DWOR	0.47 (0.38 - 0.56)	0.81 (0.77 - 0.85)	0.58 (0.47 - 0.70)
	HCH	IMNA	0.43 (0.28 - 0.59)	0.40 (0.30 - 0.50)	1.08 (0.67 - 1.59)
	HCH	MCCA	0.44 (0.38 - 0.50)	0.58 (0.54 - 0.62)	0.76 (0.64 - 0.88)
	HCH	PAHH	N/A[D]	N/A[D]	N/A[D]
	HCH	RAPH	0.79 (0.74 - 0.84)	0.85 (0.82 - 0.88)	0.93 (0.86 - 1.00)
	HCH	SAWT	0.71 (0.59 - 0.82)	0.63 (0.52 - 0.74)	1.12 (0.88 - 1.42)
	HSK	SAWT	0.04 (0.03 - 0.06)	0.10 (0.07 - 0.13)	0.43 (0.26 - 0.69)
	HST	GRN A Run	0.60 (0.53 - 0.66)	0.72 (0.68 - 0.76)	0.83 (0.73 - 0.93)
2013	HST	HCD A Run	0.71 (0.59 - 0.81)	0.78 (0.71 - 0.86)	0.90 (0.74 - 1.07)
	HST	IMN A Run	0.67 (0.61 - 0.73)	0.70 (0.65 - 0.76)	0.95 (0.85 - 1.06)
	HST	SAL A Run	0.72 (0.68 - 0.76)	0.74 (0.71 - 0.78)	0.97 (0.90 - 1.04)
	HST	CLW B Run	0.66 (0.52 - 0.80)	0.85 (0.81 - 0.89)	0.77 (0.60 - 0.94)
	HST	SAL B Run	0.77 (0.65 - 0.89)	0.93 (0.88 - 0.98)	0.83 (0.68 - 0.98)
	WCH		0.75 (0.68 - 0.81)	0.77 (0.73 - 0.81)	0.97 (0.88 - 1.08)
	WST		0.72 (0.66 - 0.78)	0.75 (0.70 - 0.80)	0.95 (0.86 - 1.07)
2014	HCH	CATH	0.80 (0.60 - 0.95)	0.47 (0.25 - 0.67)	1.71 (1.07 - 3.33)
	HCH	CLWH	0.73 (0.62 - 0.84)	0.76 (0.70 - 0.82)	0.96 (0.80 - 1.14)
	HCH	CLWH_SU	0.51 (0.35 - 0.69)	0.70 (0.60 - 0.78)	0.74 (0.50 - 1.02)
	HCH	DWOR	0.76 (0.67 - 0.86)	0.68 (0.59 - 0.76)	1.13 (0.96 - 1.35)
	HCH	IMNA	0.74 (0.58 - 0.88)	0.85 (0.70 - 0.95)	0.87 (0.67 - 1.13)
	HCH	MCCA	0.66 (0.58 - 0.74)	0.72 (0.64 - 0.79)	0.92 (0.78 - 1.09)
	HCH	PAHH	N/A[D]	N/A[D]	N/A[D]
	HCH	RAPH	0.86 (0.80 - 0.93)	0.63 (0.55 - 0.71)	1.37 (1.21 - 1.60)
	HCH	SAWT	0.71 (0.53 - 0.88)	0.69 (0.54 - 0.82)	1.03 (0.72 - 1.40)
	HSK	SAWT	0.44 (0.32 - 0.57)	0.77 (0.71 - 0.83)	0.57 (0.41 - 0.74)
	HST	GRN A Run	0.39 (0.32 - 0.46)	0.48 (0.43 - 0.52)	0.82 (0.67 - 0.98)
	HST	HCD A Run	0.21 (0.13 - 0.30)	0.30 (0.20 - 0.40)	0.70 (0.39 - 1.21)
	HST	IMN A Run	0.51 (0.45 - 0.57)	0.60 (0.54 - 0.65)	0.86 (0.74 - 0.99)
	HST	SAL A Run	0.47 (0.41 - 0.54)	0.59 (0.55 - 0.63)	0.80 (0.69 - 0.93)
	HST	CLW B Run	0.72 (0.58 - 0.86)	0.70 (0.61 - 0.79)	1.02 (0.79 - 1.30)
	HST	SAL B Run	0.48 (0.33 - 0.64)	0.68 (0.50 - 0.84)	0.71 (0.46 - 1.07)
	WCH		0.86 (0.77 - 0.94)	0.83 (0.78 - 0.89)	1.03 (0.91 - 1.15)
	WST		0.48 (0.40 - 0.55)	0.57 (0.49 - 0.64)	0.84 (0.68 - 1.03)

[A] Rear-type and species shown are: hatchery Chinook (HCH), wild Chinook (WCH), hatchery steelhead (HST), wild steelhead (WST), and hatchery sockeye (HSK).

Hatcheries are: Catherine Creek AP (CATH), Clearwater (CLWH), Dworshak (DWOR), Imnaha AP (IMNA), McCall (MCCA), Pahsimeroi (PAHH), Rapid River (RAPH), Sawtooth (SAWT), and Oxbow (OXBH).

Hatchery steelhead basin and run-types are: Grande Ronde A run (GRN A run), Hells Canyon Dam A run (HCD A run), Imnaha A run (IMN A run), Salmon A run (SAL A run), Clearwater B run (CLW B run), and Salmon B run (SAL B run).

[B] Sample size was too small to effectively bootstrap (sample sizes shown in Table G.1). Exact binomial confidence interval (90 %) shown and overlap of confidence intervals for each group was used to test for NSD (no significant difference) or SD (significant difference).

[C] No transport treatment in 2010; therefore, estimation was not possible.

[D] No adults returned from transport category; therefore, estimation was not possible.

Table G.3. Adult success rates for Snake River run wild spring/summer Chinook and wild steelhead by adult return year. Wild Chinook estimates include 2-salt and 3-salt adults as available. Wild steelhead estimates include 1-salt, 2-salt, and 3-salt adults as available.

Adult Return Year	Snake River Wild Chinook	Snake River wild steelhead
2002	0.668	0.600
2003	0.636	0.670
2004	0.874	0.556
2005	0.846	0.659
2006	0.822	0.804
2007	0.763	0.561
2008	0.803	0.737
2009	0.827	0.739
2010	0.814	0.712
2011	0.664	0.703
2012	0.811	0.696
2013	0.807	0.707
2014	0.732	0.756
2015	0.727	N/A

APPENDIX H

DEVELOPMENT OF A WEIGHTED BOOTSTRAP FOR UNEQUALLY REPRESENTED HATCHERY PIT-TAG GROUPS

APPENDIX H

DEVELOPMENT OF A WEIGHTED BOOTSTRAP FOR UNEQUALLY REPRESENTED HATCHERY PIT-TAG GROUPS

Introduction

The Comparative Survival Study (CSS) relies upon bootstrap resampling to develop confidence intervals for various metrics related to PIT-tag groups of interest. The bootstrap method is a comprehensive approach, which allows confidence intervals to be computed for all of the parameters of interest without requiring assumptions about the form of distribution of the parameter (Berggren et. al. 2002, Chapter 4). Nonparametric 90% confidence intervals are computed around all estimated parameters, including annual SARs. The nonparametric bootstrapping approach of Efron and Tibshirani (1993) is used where first, the point estimate is calculated from the sample for each population, and then the data are resampled, via the naïve bootstrap resampling procedure (random resampling with replacement). This approach assumes that the PIT-tag marking is representative of the intended population being marked. Part of the CSS marking efforts are to mark hatchery and wild populations as evenly among available sub-populations as possible so that estimates of SARs and other parameters are meaningful and representative of the population.

In recent years CSS marking at a few hatcheries has caused concern because tags have been split equally between two different production groups within a single hatchery, but the total production for each of these groups is known to be unequal. This has necessitated some means to account for the unequal representation of these production groups within the CSS tagging program.

In response to the non-representative marking of PIT-tag groups, the CSS has developed an alternative bootstrap protocol that weights data sets so that bootstrap resampling reflects the proportions of the overall hatchery production. The need for a weighted resampling methodology arose when two different hatchery management practices were applied to subsets of a CSS release population. In 2012, McCall Hatchery implemented an integrated brood stock program (in addition to the existing segregated broodstock program) for summer Chinook salmon. Two different combinations of adult spawners were used for broodstock where the integrated broodstock included hatchery x wild adults (natural origin) and the segregated broodstock paired hatchery x hatchery origin adults. The hatchery wished to evaluate the efficacy of both brood stock programs. For example, a total of 51,912 juvenile Chinook salmon were PIT-tagged at the hatchery as part of the CSS study in migration year 2012. Nearly equal numbers of integrated (25,962) and segregated (25,950) progeny were marked with PIT-tags (see Table Z.1). The CSS required the full complement of tags for analyses of SARs based on previous power analyses and, thus, combined the release groups for SAR analysis. However, of the

1,028,353 juvenile Chinook released, only 23% (241,265) were integrated progeny while nearly 77% (787,088) were segregated progeny. Similar production and marking proportions occurred in migration year 2013 (Table H.1).

Thus, any analyses that combined both PIT-tag sub-groups would equally weight each one based on the numbers of PIT-tags released. Such an analysis would not represent the true proportions of the release population and hence would be biased (i.e. the integrated progeny group would be overrepresented). The CSS sought to correct for this bias by developing a bootstrap resampling method that re-weighted the sample based on the relative proportions of the PIT-tag fish in the two study groups within the release population.

Table H.1. Summary of PIT-tag marking and release numbers for integrated and segregated Chinook groups at McCall Hatchery in 2012 and 2013.

	Migration year	Release	Proportion of Release	PIT-tagged	Proportion of tags
Integrated	2012	241,265	0.23	25,962	0.50
Segregated	2012	787,088	0.77	25,950	0.50
Integrated	2013	253,849	0.24	25,950	0.50
Segregated	2013	821,001	0.76	25,951	0.50

Recently, bootstrap resampling methods have been developed by researchers to account for similar situations to that described for McCall Hatchery, where the proportions of subgroups within the sampled population do not reflect the ratios of those same subgroups in the overall population of inference. Nahorniak et al. (2015) used an inverse weighted bootstrap resampling protocol to weight bootstrap samples similar to the weight of the original sampling of the population. Bootstrap samples were weighted by the inverse of the relative frequency that the original populations were sampled in order to adjust the estimated values within the bootstrap. The average bootstrap outcomes were used to estimate the true parameter values. Goodwin and Mishra (2003) used a weighted resampling design in which resampling weights were assigned to individual farms based on the number of farms those sampled farms represented from the region of interest.

Methods

Simulation of Weighted Bootstrap Methodology

Similar to Goodwin and Mishra (2003), our approach assigned weights to individual PIT-tags based on the number of fish in the release group that were represented by those tags, essentially determining the number of fish represented by each tag. Based on the ratio of tags to fish in each group, individual tags were assigned a probability based upon which group they were from. For example, for migration year 2012, PIT-tags representing the integrated group were assigned a weight of

0.0000090368 (0.23/25,962) while PIT-tags representing the segregated population were given weights of 0.0000294947.

A cumulative weight field was used to facilitate rapid data selection using a half step algorithm that reduced the number of evaluations to find the appropriate tag. The algorithm reduced the number of evaluations from n/2 using a simple forward search, where each cumulative weight value had to be evaluated in order from 1 to n. The forward search approach resulted in, on average, half the records being evaluated to find the correct cumulative value relative to the random number chosen for each random draw. The half step algorithm reduced the number of evaluations per random draw to;

$$\frac{n}{2^x} \leq 1, \qquad [H.1]$$

where x is the minimum number that makes the above statement true. The number x in Equation H.1 then represents the maximum number of cumulative values needed to be evaluated to find the appropriate random value and thus the correct tag. For migration year 2012, x = 16, such that at maximum 16 cumulative values had to be evaluated to arrive at the correct random number.

In each weighted bootstrap sample (MY 2012), 51,912 tags were drawn from the original pool of tags, using the weighting procedure described above. Summary data were calculated from the weighted samples. The sampling procedure was repeated 1,000 times to provide 1,000 weighted bootstrap resamples. From the 1,000 bootstrap resamples, the mean summary statistics were used to estimate the weighted parameters, while the 50th and 951st records were used to determine the non-parametric 90% confidence intervals. The bootstrap average estimate was found to compare quite closely to likelihood based point estimates of SARs even when few adult returns were available (Berggren et. al. 2002).

A simulation was done to prove the concept of the weighting procedure described above. Because computing time was significant, despite the use of the half step algorithm, a simulated population of 5,000 PIT-tags was used. The weighted resampling protocol was evaluated based on the number of PIT-tags that were drawn from each study group from the simulated population. Since the underlying premise was to mimic the McCall Hatchery situation, 2,500 tags were assigned to represent each group (0.50 in each Group A and Group B) while the underlying population was simulated to be 25% Group A and 75% Group B. Thus, the target number of tags to be drawn for each weighted bootstrap, would be 1,250 from Group A (i.e., Integrated group) and 3,750 from Group B (i.e, Segrated group). For each weighted resampling iteration:

1. 5,000 tags were drawn, and this process was repeated 1,000 times to form a full bootstrap sample.
2. From the 1,000 bootstrap iteratios the average number of tags drawn from each group was calculated. That number was averaged to determine how well the weighting procedure performed.

3. The calculated average from all 1,000 bootstrap iteratios was then compared to the target number of tags (5,000*0.25 or 1,250 targeted for Group A (i.e., Integrated) and 5,000*0.75 or 3,750 tags targeted for Group B (i.e., Segregated).
4. Steps 1-3 were then repeated 100 times to complete the simulation. The distribution of this average number of tags representing each group was then examined.

Weighted Bootstrap for McCall Hatchery Data

Once the weighted bootstrap resampling procedure was evaluated and deemed to be working properly, four different bootstrap runs were evaluated to determine the performance of the weighted bootstrap results. For this evaluation, we estimated annual LGR-to-BOA SARs (with jacks) for migration years 2012 and 2013 for each of the four bootstrap runs. We did not include migration year 2014 in this evaluation because returns from this year are not yet complete. We estimated LGR-to-BOA SARs (with jacks) for comparison between bootstrap runs because these returns should show the greatest contrast between the four runs.

A naïve resampling bootstrap was carried out using the aggregated PIT-tag population (combining both integrated and segregated groups), referred to as $MCCA_{agg}$ (1). This is the bootstrap methodology currently used for most CSS PIT-tag groups. In addition, naïve bootstrap resampling was done separately for the integrated $MCCA_{int}$ (2) and segregated $MCCA_{seg}$ (3) groups. Finally, the weighted bootstrap resampling method described above was estimated for the combined tag groups $MCCA_{wgt}$ (4) with the identical tags used in the aggregated bootstrap ($MCCA_{agg}$).

Results

Results of the Weighted Bootstrap Simulation

The weighted bootstrap resampling protocol resulted in a range of the total number of tags being selected from each of the simulated groups, A and B. For Group A the goal was to sample 1,250 tags on average. The number of tags selected in each bootstrap run varied from about 1,150 to just over 1,350 Group A tags (Figure H.1). The data appear normally distributed, with a mean near the target value of 1,250 and tails symmetrical above and below that value. This outcome confirmed that the weighted random draw appeared to work as designed.

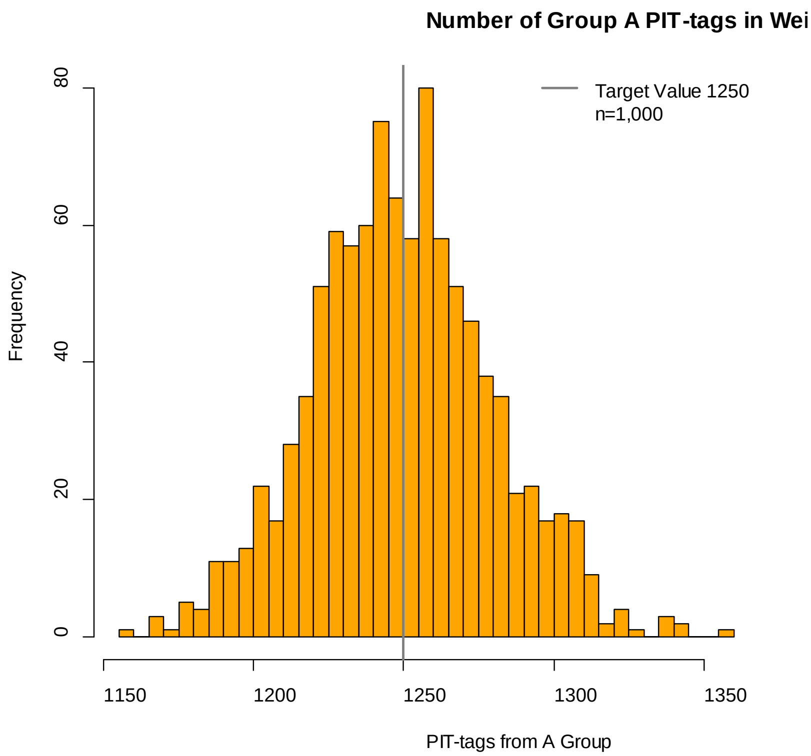


Figure H.1. Histogram of the number of Group A tags selected in a single bootstrap simulation (each simulation was 1,000 weighted resamples of the simulated population of 5,000 tags). The target value was 1,250 tags to be select from Group A (indicated in the figure by the grey vertical line).

While the results from a single boostrap run indicated that the weighted random draw appeared to work as designed (as depicted in Figure H.1), it was necessary to confirm that many bootstrap runs would also yield the same results, thus the simulation component of this exercise. Over the entire 100 bootstrap runs, the average number of tags drawn from Group A was 1,249.6, with a minimum greater than 1,248.4 and a maximum less than 1,52.5 (Figure H.2). These results show that the weighted resamples were distributed closely around the target of 1,250 for Group A, with a very small range of means around the value. Based on these results the methodology developed for resampling was considered successful.

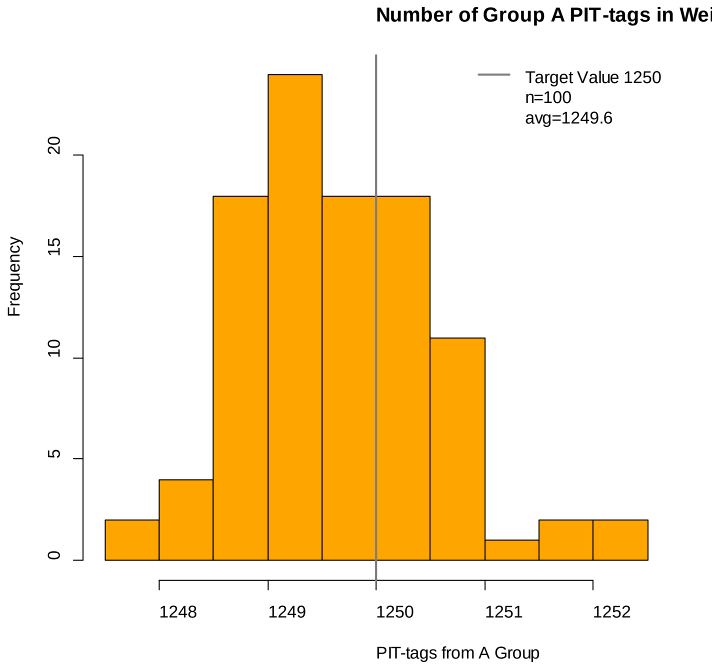


Figure H.2. Histogram of the average number of tags selected from Group A in each of 100 bootstrap simulations (each simulation was 1,000 weighted resamples of the simulated population of 5,000 tags). The target value was 1,250 tags to be select from Group A (indicated in the figure by the grey vertical line).

Results of Weighted Bootstrap of McCall Hatchery Data

The estimates of the weighted bootstrap applied to the McCall summer Chinook releases from 2012 and 2013 were compared to the naïve bootstrap approach that was reported for these groups in the CSS Annual Report (see Chapter 4 and Appendix B). When run separately, the two different hatchery release groups, the integrated ($MCCA_{int}$) and segregated ($MCCA_{seg}$) groups, had different LGR-to-BOA SARs (Table H.2). For migration year 2012, these two groups were not significantly different, based on overlapping confidence intervals. However, SAR estimates for the two groups ($MCCA_{int}$ vs. $MCCA_{seg}$) in migration year 2013 were significantly different. In both migration years, the SAR estimates for the $MCCA_{agg}$ and $MCCA_{wgt}$ groups were intermediate between the $MCCA_{int}$ and $MCCA_{seg}$ groups

Table H.2. Comparison of LGR-to-BOA SARs (with jacks) from four different bootstrap runs; see text for explanation.

Bootstrap Run	Migr_yr	SAR	np_90cill	np_90ciul	BS resampling method
Aggregate ($MCCA_{agg}$)	2012	1.64	1.50	1.79	Naïve
Integrated ($MCCA_{int}$)	2012	1.71	1.49	1.92	Naïve
Segregated ($MCCA_{seg}$)	2012	1.44	1.24	1.65	Naïve
Weighted ($MCCA_{wgt}$)	2012	1.56	1.41	1.71	Weighted
Aggregate ($MCCA_{agg}$)	2013[1]	2.21[1]	2.04	2.38	Naïve
Integrated ($MCCA_{int}$)	2013[1]	2.49[1]	2.25	2.75	Naïve
Segregated $MCCA_{seg}$)	2013[1]	1.90[1]	1.69	2.12	Naïve
Weighted ($MCCA_{wgt}$)	2013[1]	2.05[1]	1.89	2.23	Weighted

[1] The estimate presented here represent data update through 2015 and would therefore will not match SARs reported in Appendix A of the report which were updated through June of 2016.

The SAR estimate for the $MCCA_{agg}$ group could be considered a simple mean of the two subgroup SARs, since both groups are equally represented in the PIT-tag population, while the SAR for the $MCCA_{wgt}$ group could be compared to a weighted mean of two subgroup SARs (Table H.3). Weighted means in Table H.3 were based on the relative proportions of the overall hatchery release in each of the two release groups. For both migration years, the SARs for the MCCAagg group is higher than the $MCCA_{wgt}$ group, reflecting the relatively greater contribution of the integrated group to the $MCCA_{agg}$ group, while the SAR for the $MCCA_{wgt}$ group reflects that only about 25% of the release population was from integrated group so that the SAR is more heavily weighted toward the segregated group. For migration year 2013, the SAR for the $MCCA_{wgt}$ group compares closely to the weighted mean, while the SAR for the $MCCA_{agg}$ group compares more closely to the arithmetic mean.

Table H.3. Bootstrap estimated LGR-to-BOA SARs (with jacks), by method (naïve and weighted), compared to a calculated arithmetic mean and weighted mean SAR of the $MCCA_{int}$ and $MCCA_{seg}$ groups. Weighted mean was based on the proportion of the release in each group.

	SARs (by group and resampling method)					
Migr. Year	$MCCA_{AGG}$ Naive	$MCCA_{WGT}$ Weighted	$MCCA_{SEG}$ Naive	$MCCA_{INT}$ Naive	Arithmetic Mean	Weighted Mean
2012	1.64	1.56	1.44	1.71	1.58	1.50
2013	2.21[1]	2.05[1]	1.90[1]	2.49[1]	2.20	2.04

[1] The estimate presented here represent data update through 2015 and would therefore will not match SARs reported in Appendix A of the report which were updated through June of 2016.

Discussion

The use of a weighted bootstrap sampling procedure appears to have successfully accounted for the unequal representation of PIT-tags in the hatchery release population marked at McCall Hatchery. The weighted resampling methodology was successful for randomly drawing tags from the total pool in a ratio that represented the expected proportions. The weighted SARs used in this analysis were estimated average values for

the 1,000 bootstrap iteratios. Other methods of calculating this weighted value could be explored including median or 50th percentile value. However, the relatively simple approach presented here is appealing in that it is parsimonious and similar in most aspects to the existing methodology.

Similar ratios of the two groups described in the example above were evaluated, but intuitively it seems that the ratios chosen should not matter. However, we did not evaluate the performance of the methodology with other ratios or with more than two sub-populations. Those are likely areas for future exploration. While the method was developed for a single hatchery with two sub-populations, it is anticipated that the method could be applied to other situations where several sub-populations of known size are represented unequally by PIT-tags.

This analysis represents a work in progress and will continue to be developed and refined over years. The method presented here met our goal of maintaining a consistent approach to estimating confidence intervals using the bootstrap. Many of the calculations and assumptions required to develop likelihood estimates of variance remain intractable for the complex analyses used in CSS, so that a boostrap method seems the best approach available.

References

Berggren, T., H. Franzoni, L. Basham, P. Wilson, H. Schaller, C. Petrosky, E. Weber, R. Boyce and N. Bouwes. 2002. Comparative Survival Study (CSS) of PIT tagged spring/summer chinook. 2002 Annual Report, Migration Years 1997 – 2000, Mark/Recapture Activities and Bootstrap Analysis. BPA Contract #19960200. Available at http://www.fpc.org/

Efron, B. and R.J. Tibshirani. 1993. An introduction to the bootstrap. Chapman & Hall, NY

Goodwin, B.K. and Mishra, A.K., 2004. Farming efficiency and the determinants of multiple job holding by farm operators. *American Journal of Agricultural Economics*, *86*(3), pp.722-729.

Nahorniak, M., Larsen, D.P., Volk, C. and Jordan, C.E., 2015. Using Inverse Probability Bootstrap Sampling to Eliminate Sample Induced Bias in Model Based Analysis of Unequal Probability Samples. *PloS one*, *10*(6), p.e0131765.

APPENDIX I

COMPARATIVE SURVIVAL STUDY ANNUAL MEETING

This appendix contains the material presented at the Comparative Survival Study annual meeting held on April 20, 2016, at the Ambridge Event Center in Portland, Oregon. The presentations from that meeting are collected in this appendix in the same order as they were presented. The agenda from that meeting is shown below and is followed by a list of attendees.
This meeting has been a yearly event with summaries from the meeting presented in CSS annual reports. A question/answer session was held at the end of the presentations and is contained in this appendix. Below is a link to the presentations.

http://www.fpc.org/documents/CSS/Presentations_2016_CSS.pdf

It can also be found in a compact version in the following pages of this appendix.

2016 CSS Annual Meeting

List of Attendees

Names are taken from the written sign-in sheet from the event. All efforts have been made ot accurately transcribe those names and organizations

Name	Org
Al Giorgi	BioAnalysts, Inc.
Alec Maule	USGS
Alison Colotelo	PNNL
Andrew Derguin	USACE
Bob Heinith	CRITFC
Bob Lessard	CRITFC
Brandon Chockley	Fish Passage Center
Brian Bissell	USACE
Carl Schwarz	Simon Fraser University
Casey Baldwin	Colville Tribe
Charles Morrill	WDFW
Charlie Petrosky	IDFG
Christine Golightly	CRITFC
Colin Chapman	ODFW
Curt Dotson	Grant County PUD
Curt Knudsen	Oncorh Consulting
Dan Feil	USACE
Dave Statler	Nez Perce Tribe
David Heller	
David Howe	WDFW
David Swank	USFWS
Denny Rohr	DRA
Devin Olsen	Nez Perce Tribe
Doug Olson	USFWS
Doug Taki	Shoshone Bannock Tribes
Ed Bowles	ODFW
Eric Tinus	ODFW
Erick VanDyke	ODFW
Erik Merrill	NW Power & Conservation Council
Erin Cooper	Fish Passage Center
Fred Heutte	NWEC and Save Our Wild Salmon
Gulia Good Stefani	NRDC
Howard Schaller	USFWS
Jason Sweet	BPA
Jay Hesse	Nez Perce Tribe
Jeff Fryer	CRITFC
Jim Brick	ODFW
Jim Byrne	WDFW
Jim Heffernan	CRITFC
Joe Miller	Anchor QEA
Jon Hess	CRITFC
Julie Harris	USFWS
Karl Weist	NW Power & Conservation Council
Kurt Tardy	Shoshone Bannock Tribes
Lisa Harlan	WDFW
Laura Berg	Energy NewsData
Makary Hutson	BPA
Margaret Filardo	Fish Passage Center
Mark Bagdovitz	USFWS
Matt Falcy	ODFW
Maureen Hess	CRITFC
Megan Begay	YN
Michele DeHart	Fish Passage Center
Mike Langeslay	USACE
Mike Matylewich	CRITFC
Nancy Leonard	NW Power & Conservation Council
Olaf Paul Langness	WDFW
Patrick J Keniry	ODFW
Paul Kline	IDFG
Paul LeBaron	Fish Passage Center
Paul Wagner	NOAA
Paula Calvert	OR DEQ
Peter Hassemer	IDFG
Quinn Payton	Real Time Research
Robin Ehlke	WDFW
Roger Dick Jr	YN
Roy Elicker	USFWS
Scott Carlon	NOAA
Steve Haeseker	USFWS
Steve Schroder	ISRP/ISAB
Steve Smith	
Stuart Ellis	CRITFC
Tim Copeland	IDFG
Tom Berggren	
Tim Iverson	YN
Tom Kahler	Douglas County PUD
Tom Lorz	CRITFC
Tom Rien	ODFW
Tom Skiles	CRITFC
Tommy Garrison	Fish Passage Center
Tony Grover	NPCC
Trevor Conder	NOAA
Tucker Jones	ODFW

Comparative Survival Study Annual Meeting

April 20, 2016
8:30 AM to 1:00 PM

The Ambridge Event Center
1333 NE Martin Luther King Blvd.
Portland, Oregon 97232

- We ask that you please hold your questions until after the last presentation. There is time allotted after the talks for extended discussions and questions.
- Each presentation will have slide numbers for referencing back to.
- After each presentation, a 5-minute period is provided for clarifying questions if needed.

Agenda

Time	Topic	Presenter
8:30	Introduction to the Comparative Survival Study	Brandon Chockley
8:50	Juvenile survival, travel time, and the in-river environment	Steve Haeseker
9:15	PITPH (Powerhouse passage rate derived from PIT-tag data)	Steve Haeseker
9:30	SAR Patterns: Snake and Mid-Columbia	Charlie Petrosky
9:55	SARs and Juvenile Metrics of Upper Columbia Stocks	Robin Ehlke
10:15	Break	
10:30	Snake River Subyearling Fall Chinook	Tommy Garrison
10:45	Life-cycle modeling: Population recovery of Snake River Chinook	Bob Lessard
11:10	SARs and productivity	Charlie Petrosky
11:30	Questions / Discussion	

The meeting is expected to end at approximately 1:00 PM. However, the room is available for an extra hour for additional questions if needed.

Introduction to the Comparative Survival Study

Jerry McCann

Presented by: Brandon R. Chockley

CSS Annual Meeting April 20, 2016

Background

- **Initiated in 1996 by states, tribes & USFWS to estimate survival rates at various life stages**
  - Designed to assess hydro-system operations on state, tribal, and federal fish hatcheries and LSRCP
  - **PATH –** "can transportation . . . compensate for the effect of the hydro-system?"
  - NPCC has established the need to collect annual migration characteristics including survival
  - NOAA biological opinions require research, monitoring and evaluation
- **Developed as a management-oriented large scale monitoring program**
  - Observational study
  - Aligned with basin wide monitoring needs (RME)

Background

- **GOALS**
  1. **Quantify the efficacy of transportation**
     - Develop a more representative control group
  2. **Compare survival rates within and across species**
  3. **Establish long term data set**
  4. **Accomplish these goals in a collaborative and transparent manner**

Background

- **CSS data are derived from PIT tags**
  - **Tagged specifically for CSS**
  - **Cooperative marking between CSS and other research studies**
    - **reduce costs/handling, eliminate duplication**
  - **Groups marked for other studies**

Background

- **Collaborative scientific process was implemented for study design and to perform analyses**

- **CSS project independently reviewed and modified a number of times**
  - **Draft report typically posted – Aug 31st**
  - **ISAB, ISRP and other entities**

History of ISAB/ISRP Reviews of CSS

1997 – **ISAB** First review

1998 – **ISAB**

Extend to other species & life history types (Steelhead)

Improve estimation of SAR confidence intervals

2002 – **ISRP**

Further improvements in estimation methods

History of ISAB/ISRP Reviews of CSS

2003 – **ISAB** Report: *Review of Flow Augmentation: Update and Clarification*

“understanding of the relation between reach survival, instantaneous mortality, migration speed, and flow”

2006 – **ISAB** *Review of 2005 CSS Report*

1) “finer scale analyses of the relationships between survival and specific operational actions or environmental features”
2) Develop a ten year summary report

History of ISAB/ISRP Reviews of CSS

2007 – **ISAB/ISRP** *Review CSS "10-year" report*

1) continue coordination (cost savings/avoid redundancy)
2) Evaluate if PIT tag SARs are less than run reconstruction SARs

2009 – **ISAB** *Tagging Report*

Compare CSS SARs with Run Reconstruction SARs

2011 – USFWS initiated PIT-tag study at Carson NFH to investigate possible bias in PIT-tag SARs

>2009 **ISAB** *annually reviews CSS reports*

The CSS is a joint project of the state & tribal fishery managers and the USFWS

DESIGN

- WDFW, CRITFC, USFWS, ODFW, IDFG

IMPLEMENTATION AND TAGGING

- FPC: Logistics, coordination
- PTAGIS: Raw Data; FPC: Reports, Estimates

DATA PREPARATION & ANALYSIS

- CSS Oversight Committee
- Fish Passage Center

REGIONAL REVIEW

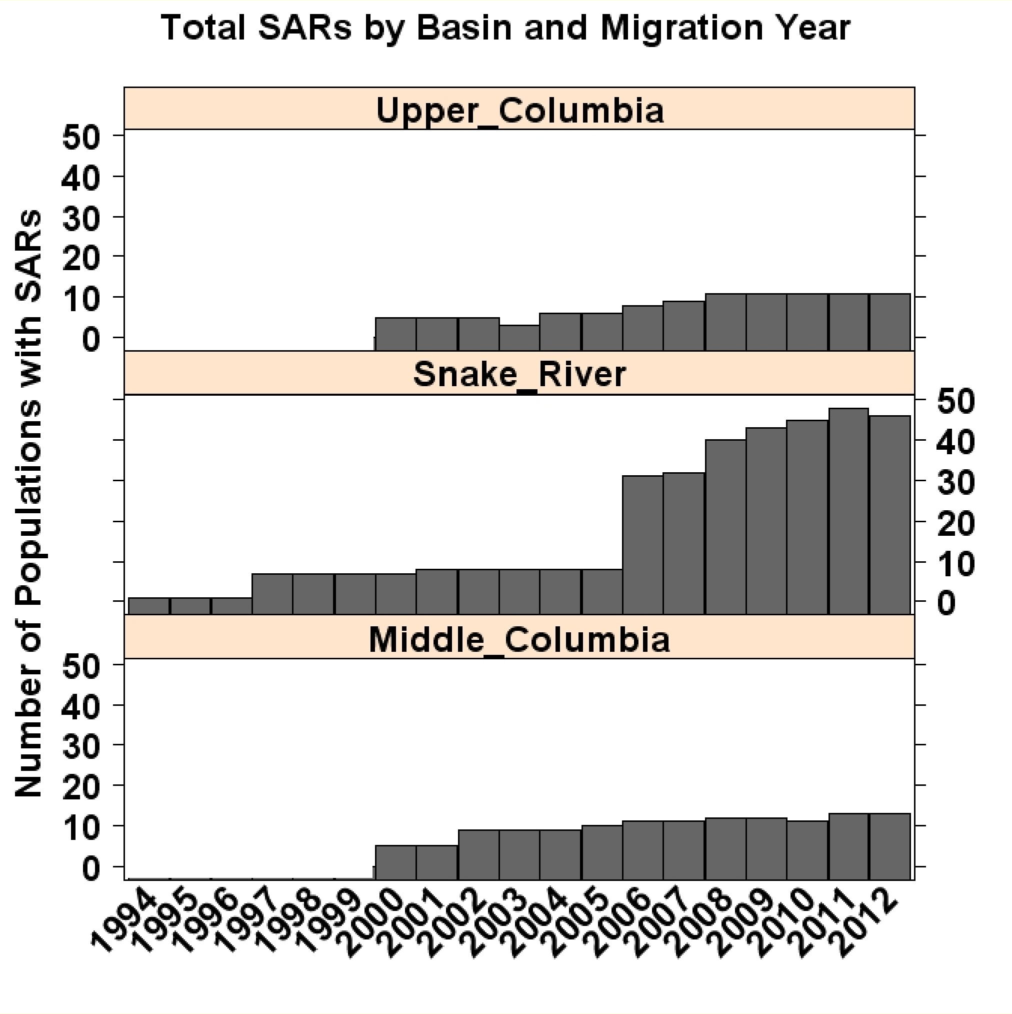
- Draft on BPA & FPC websites
- Regional Public Review: ISAB, ISRP, FPAC, NMFS, etc.

FINAL REPORT

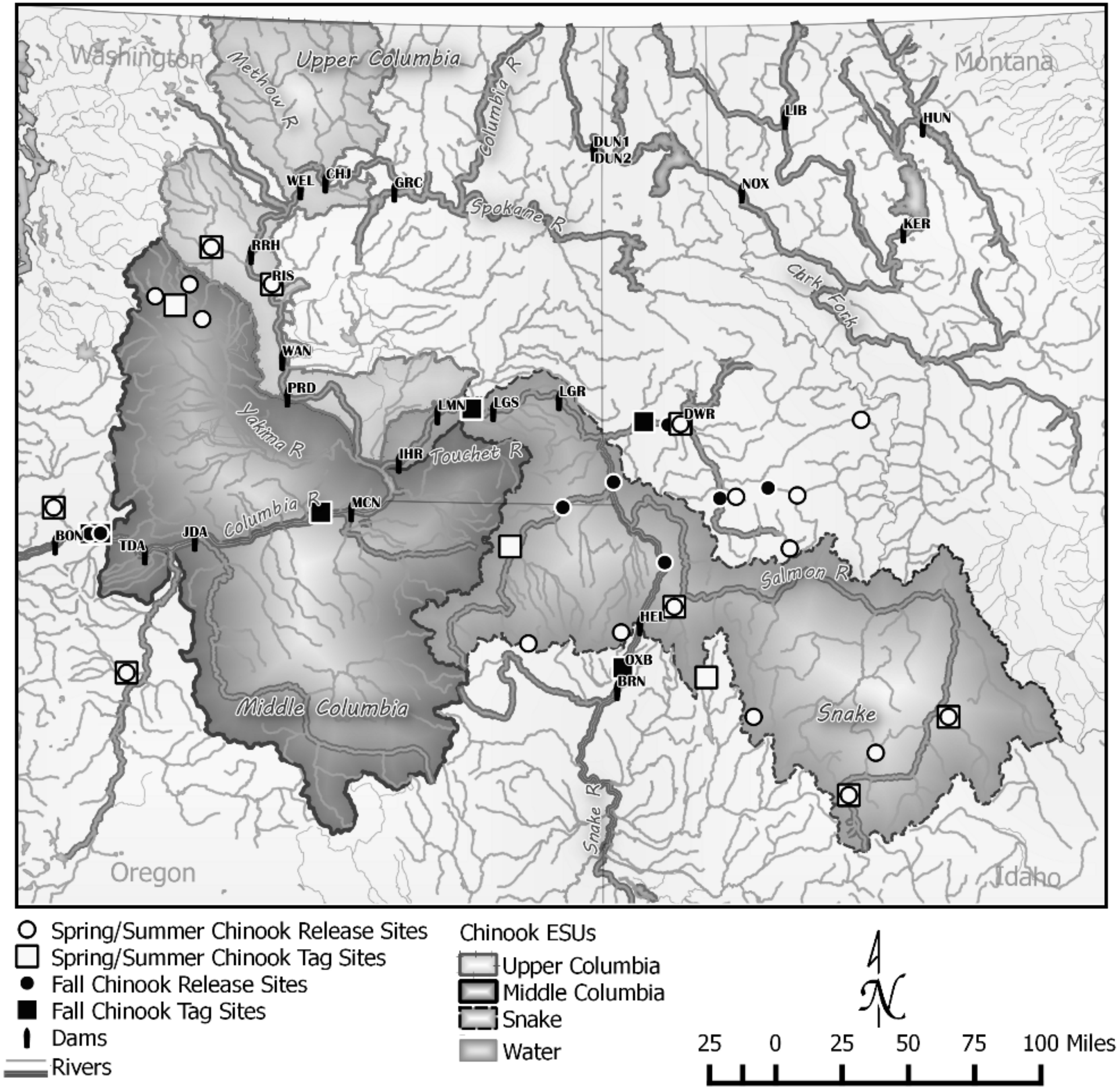
- Posted on BPA & FPC websites

CSS COVERAGE

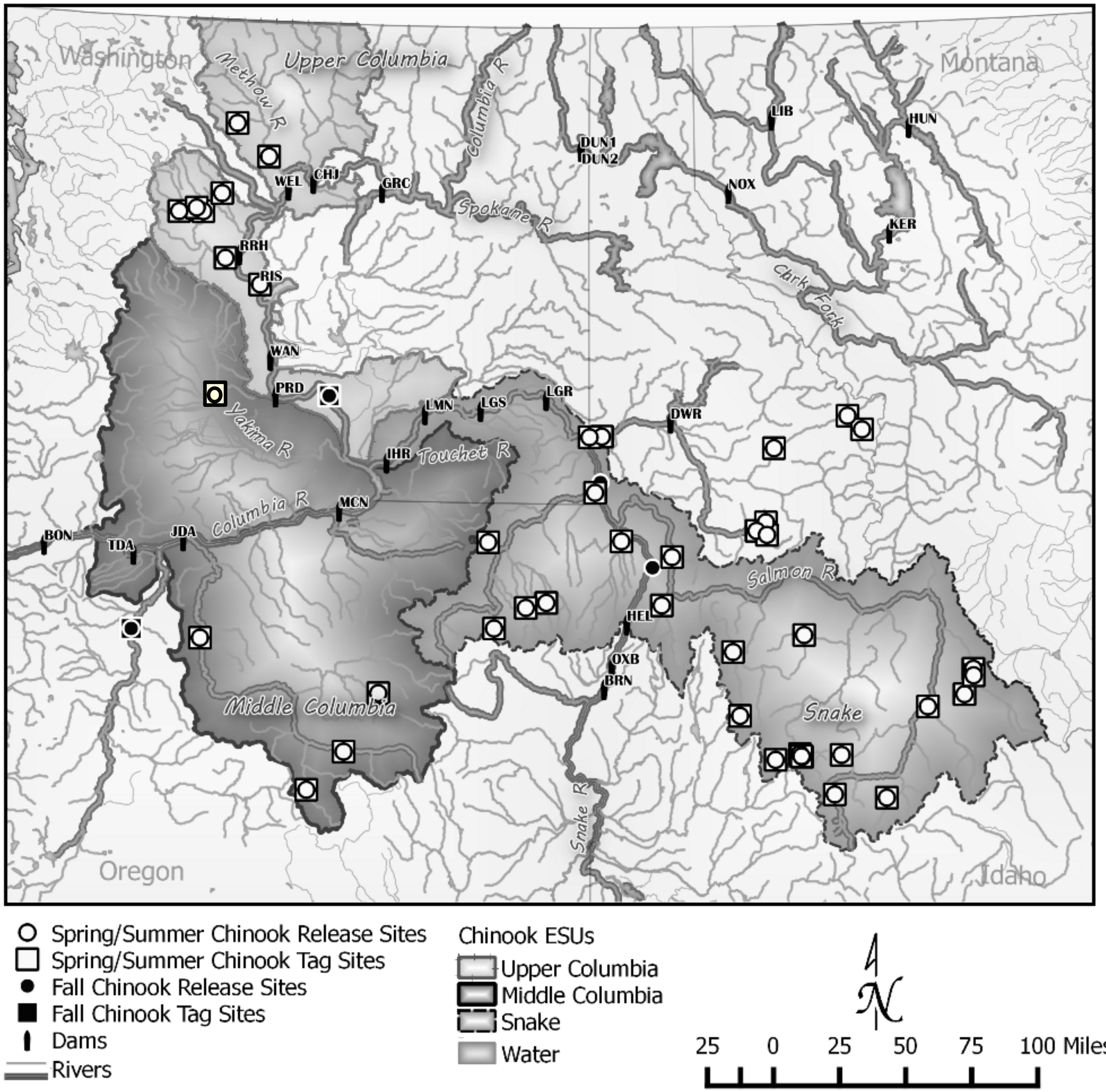
- **Upper Columbia River**
  - Begins in 2000 [Adult detects at BON]
  - ~10 tag groups
- **Snake River**
  - Longer Time Series
  - More groups developed
    - ~40 different tag groups in recent years
    - sp/su Chinook, fall Chinook, steelhead, sockeye
- **Middle Columbia River**
  - Begins in 2000 [Adult detects at BON]
  - ~10 tag groups



CSS PIT-Tag & Release Sites 2014
Hatchery Chinook

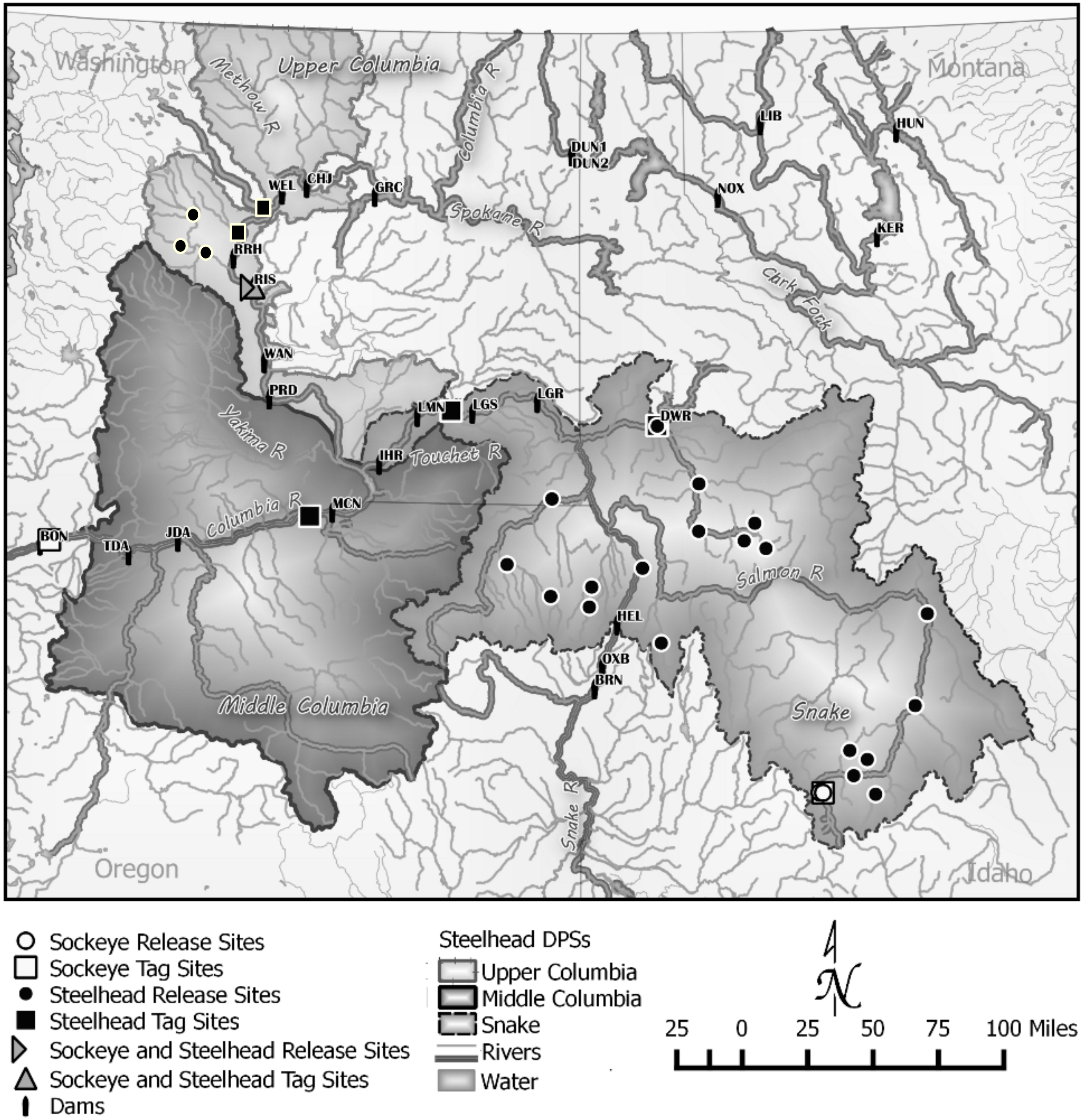


CSS PIT-Tag & Release Sites 2014
Wild Chinook

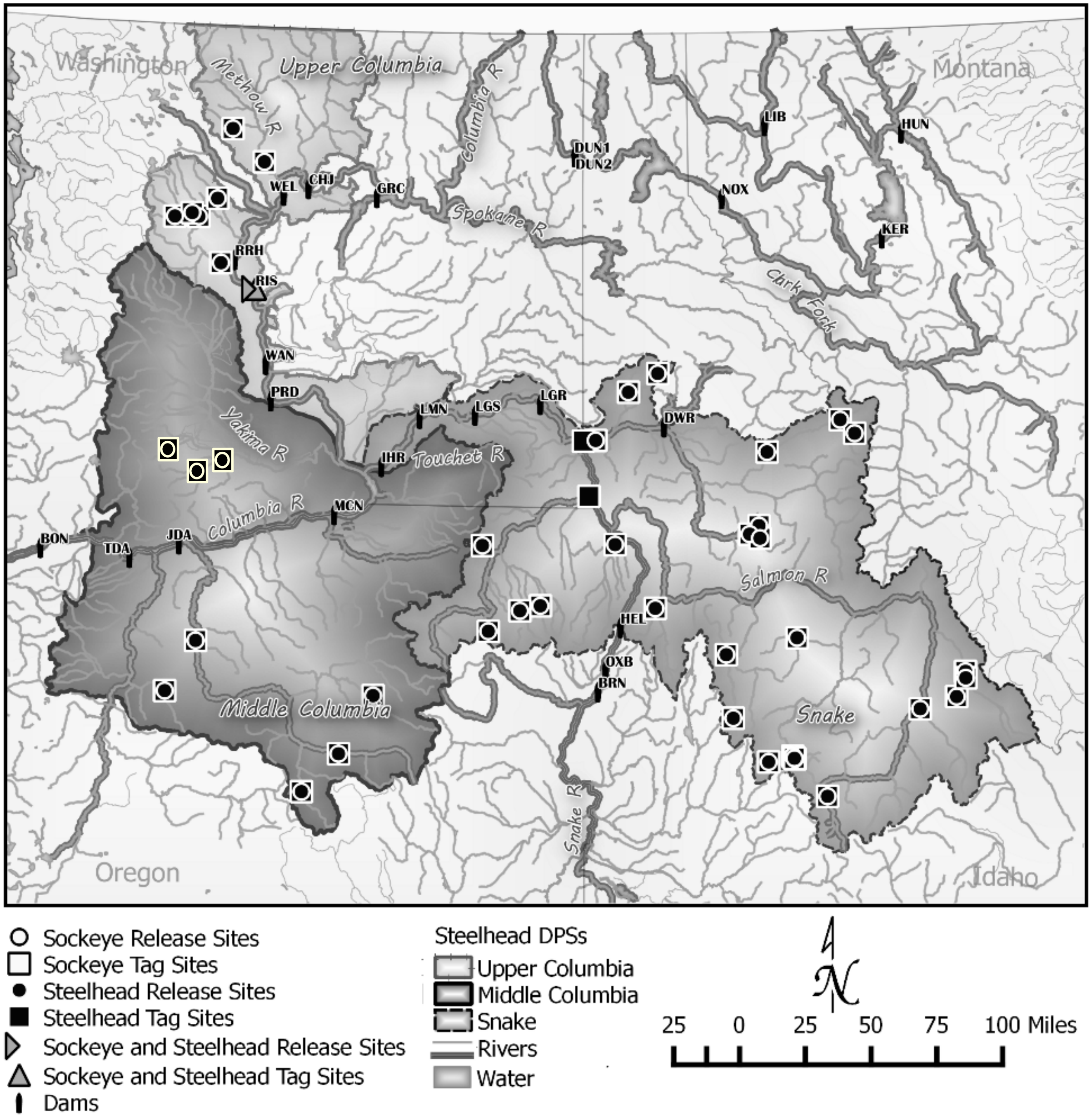


CSS PIT-Tag & Release Sites 2014

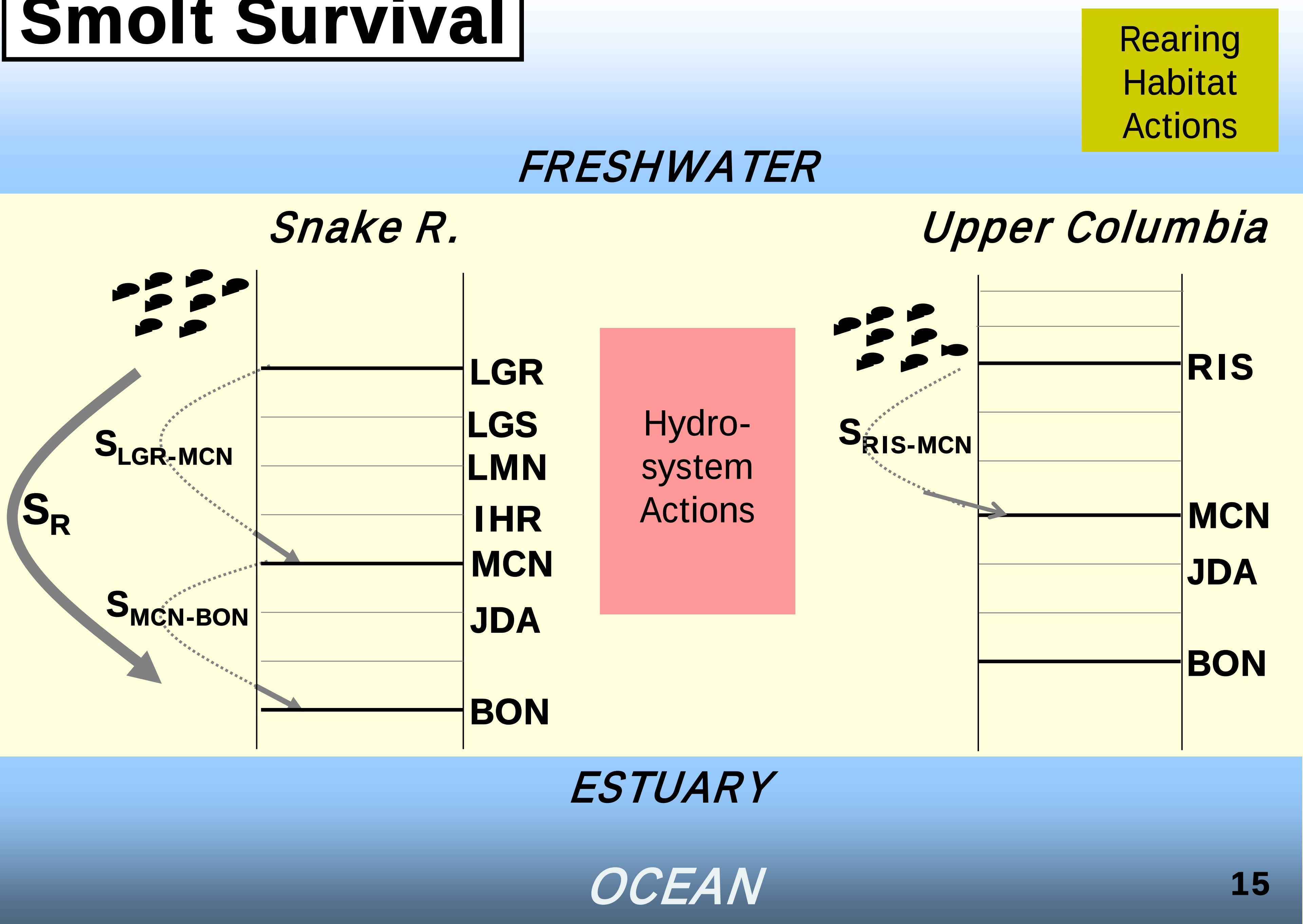
Hatchery Steelhead & Hatchery Sockeye



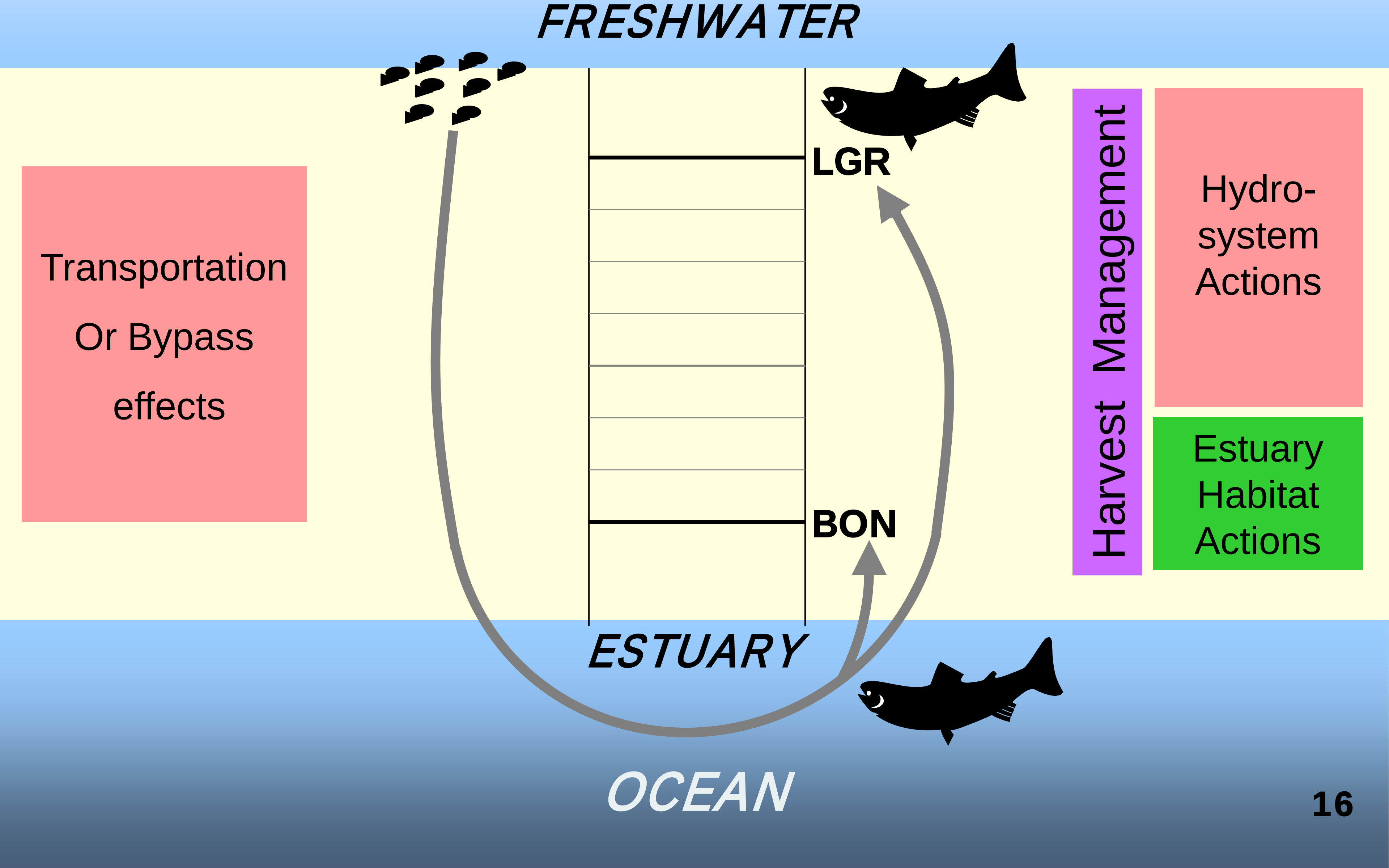
CSS PIT-Tag & Release Sites 2014
Wild Steelhead & Wild Sockeye



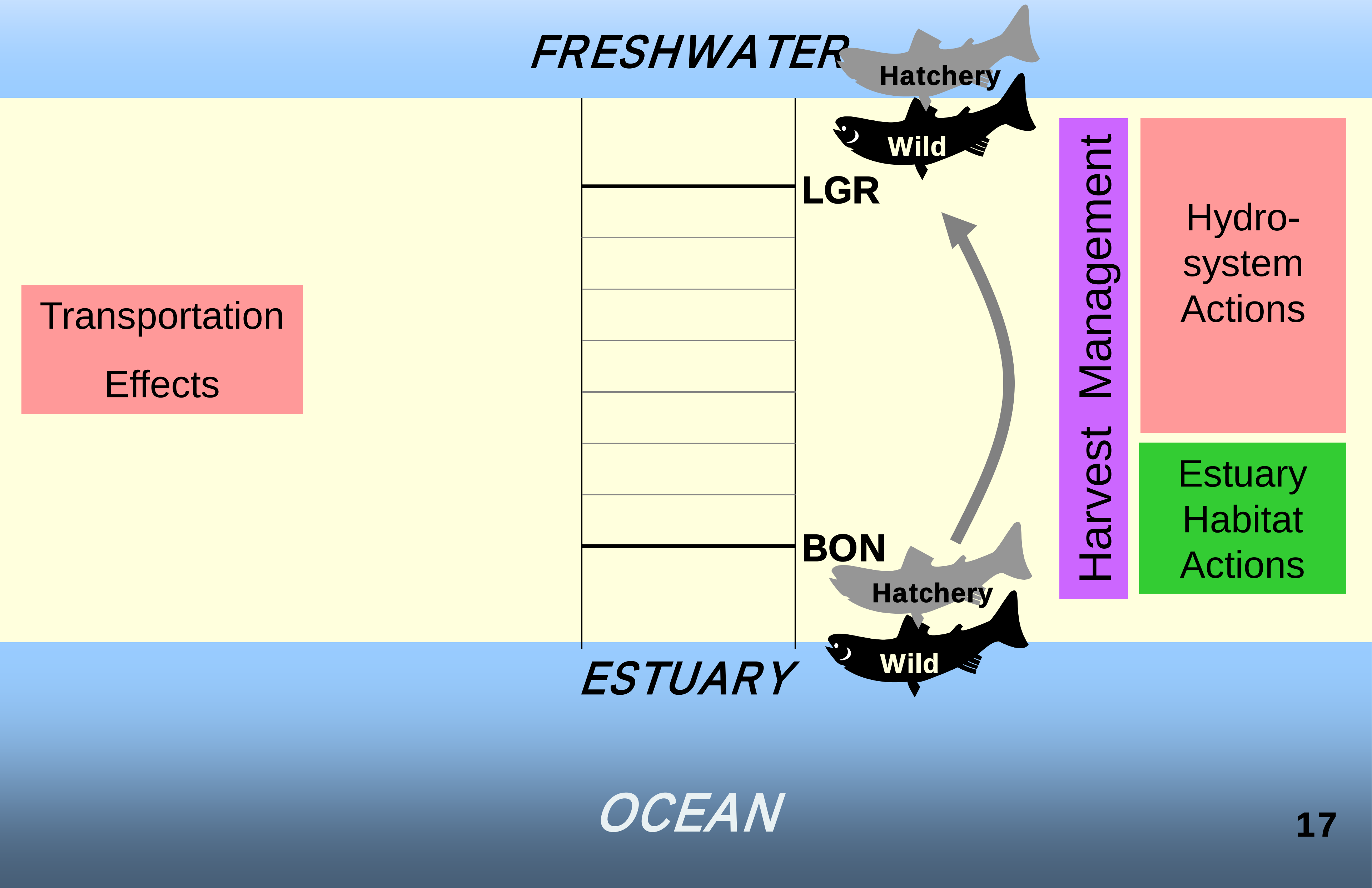
Smolt Survival



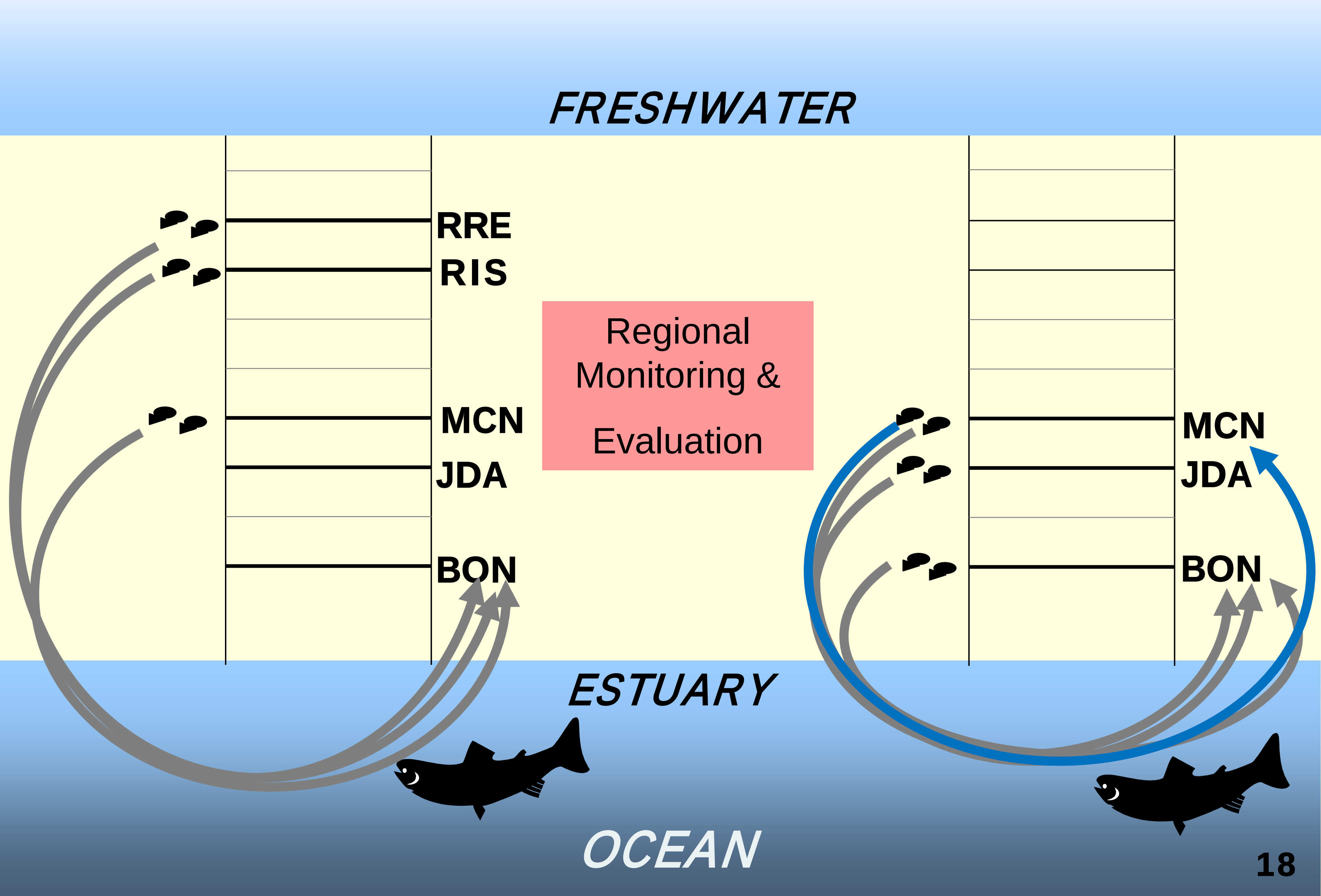
SNAKE RIVER SARS



Adult Success

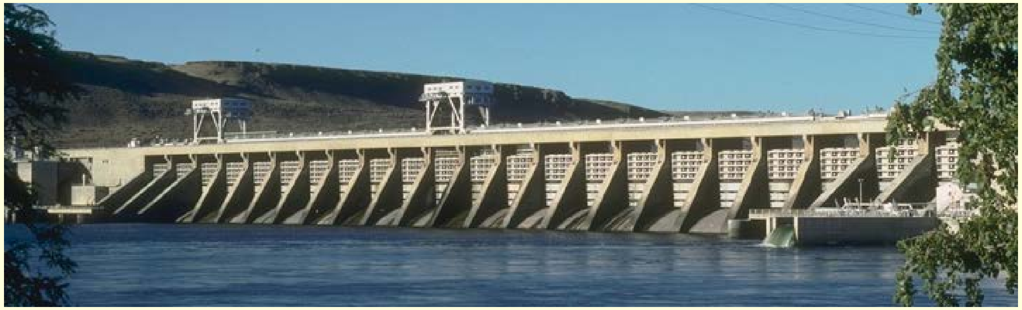


Mid and Upper Columbia R. SARS



What does CSS provide for the region?

- **Long term consistent information collaboratively designed and implemented**
- **Information easily accessible and transparent**
  - CSS PIT-tags accessed by any PTAGIS users, including fisheries managers, researchers, and academics.
- **Long term indices (identify bottlenecks) :**
  - *Travel Times*
  - *In-river Survival Rates*
  - *In-river SARs by route of passage*
  - *Transport SARs*
  - *Adult success, conversion*
- **Comparisons of SARs**
  - *Transport to In-River*
  - *NPCC Regional SAR goal*
  - *By geographic location*
  - *By hatchery group*
  - *Hatchery to Wild*
  - *Chinook to Steelhead*



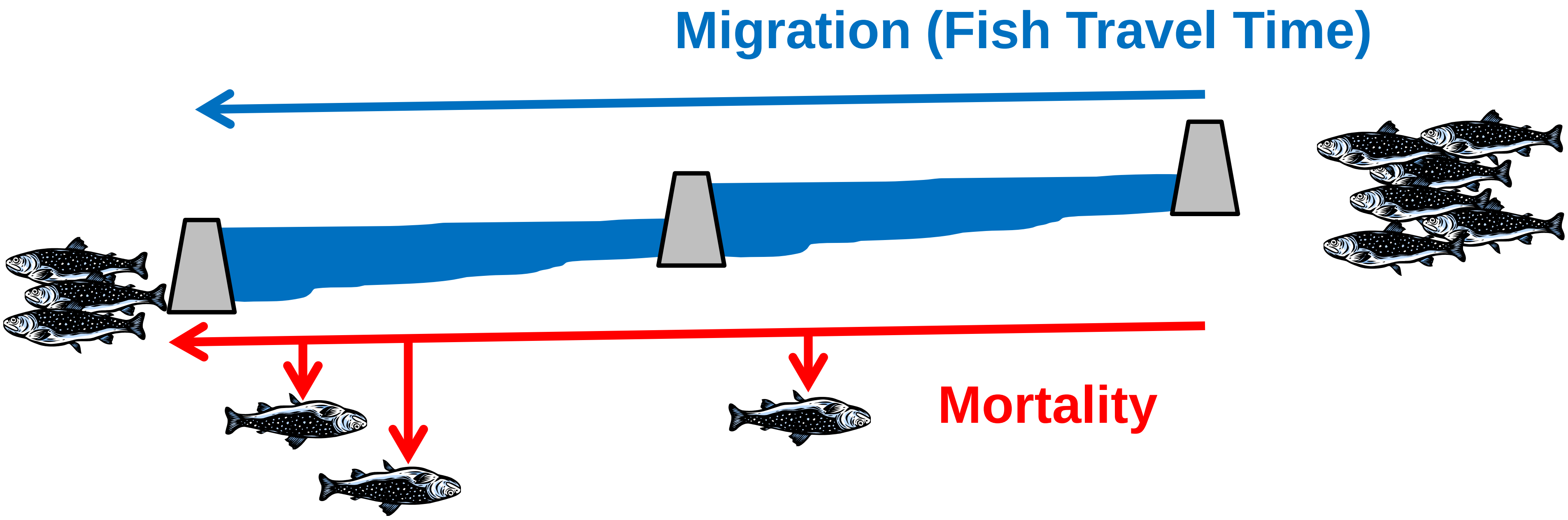
- *<u>Management questions:</u> hydropower operations, hatchery evaluations, habitat evaluations*

Juvenile survival, travel time and the in-river environment

Presenter: Steve Haeseker

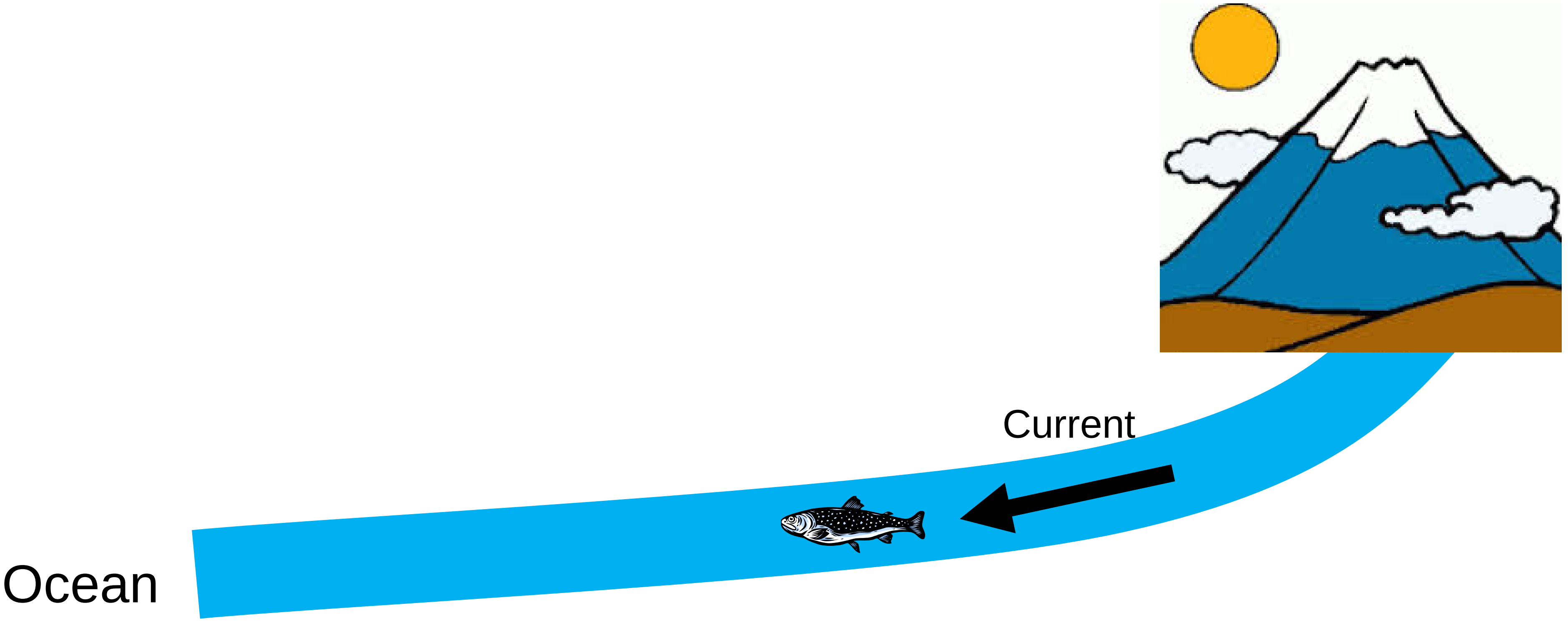
Juvenile migration

- Two simultaneous processes: migration and mortality

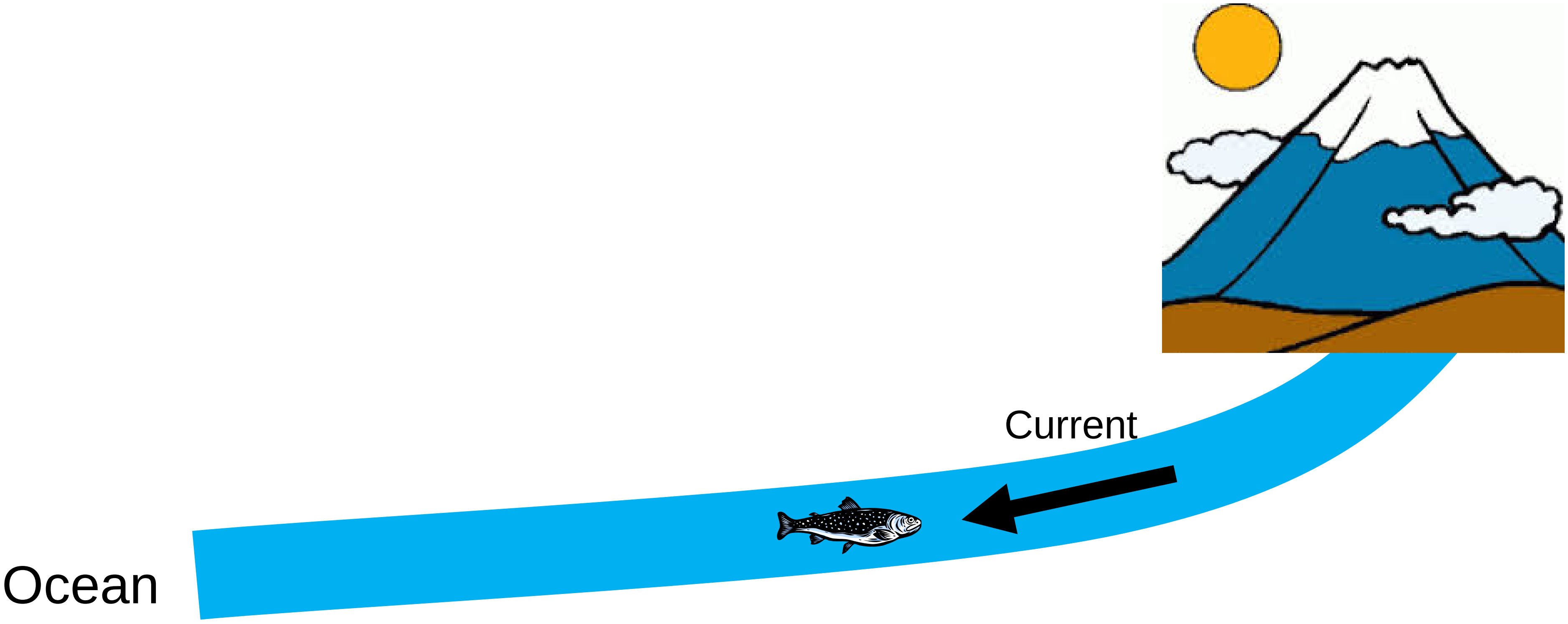


- Migration rates and mortality rates affect survival

Question: Do smolts generally face upstream or downstream as they migrate to sea?

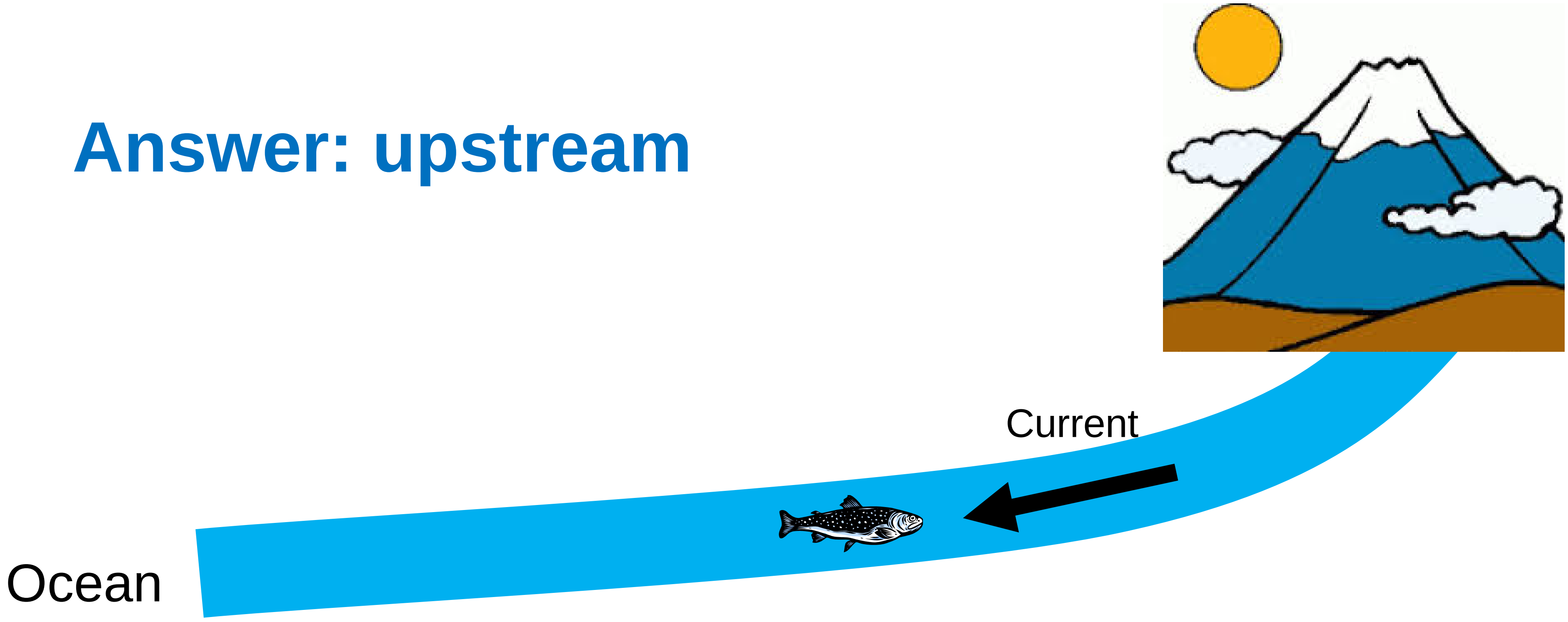


Question: Do smolts generally face upstream or downstream as they migrate to sea?



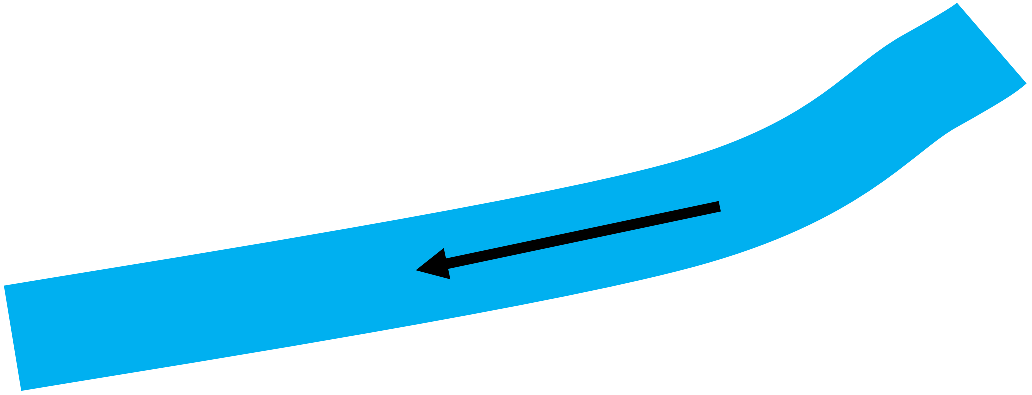
Question: Do smolts generally face upstream or downstream as they migrate to sea?

Answer: upstream

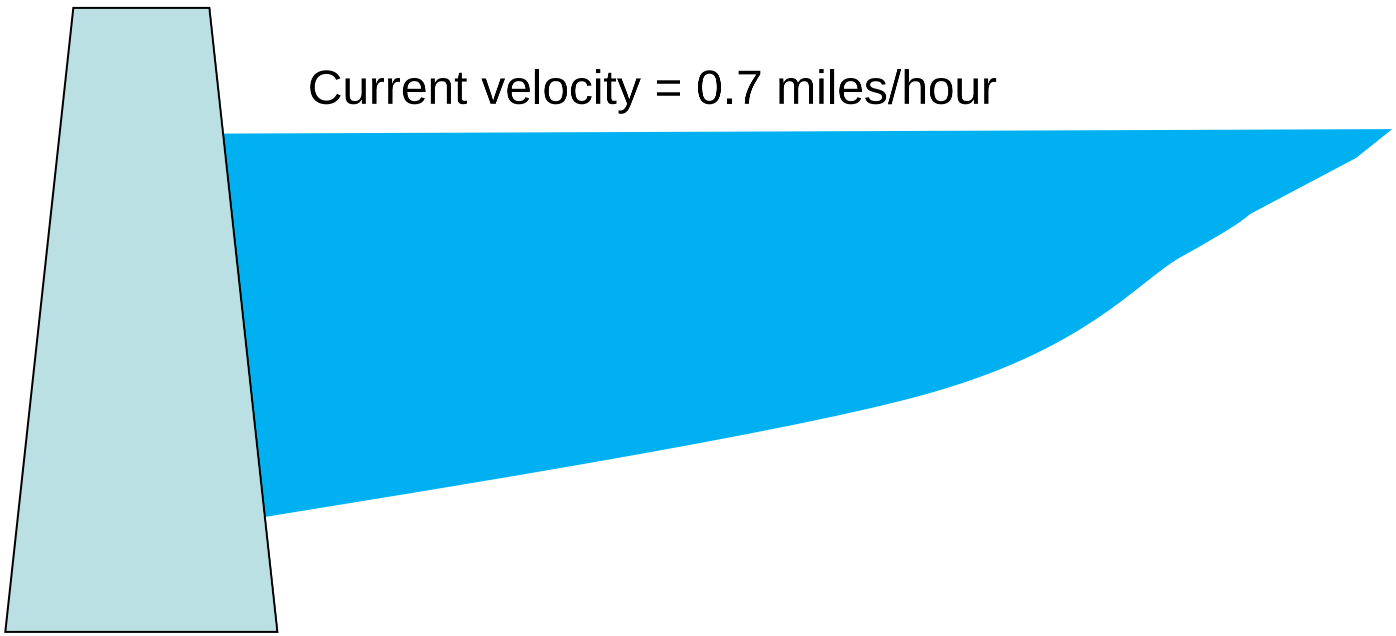


How do reservoirs affect the currents that fish rely on?

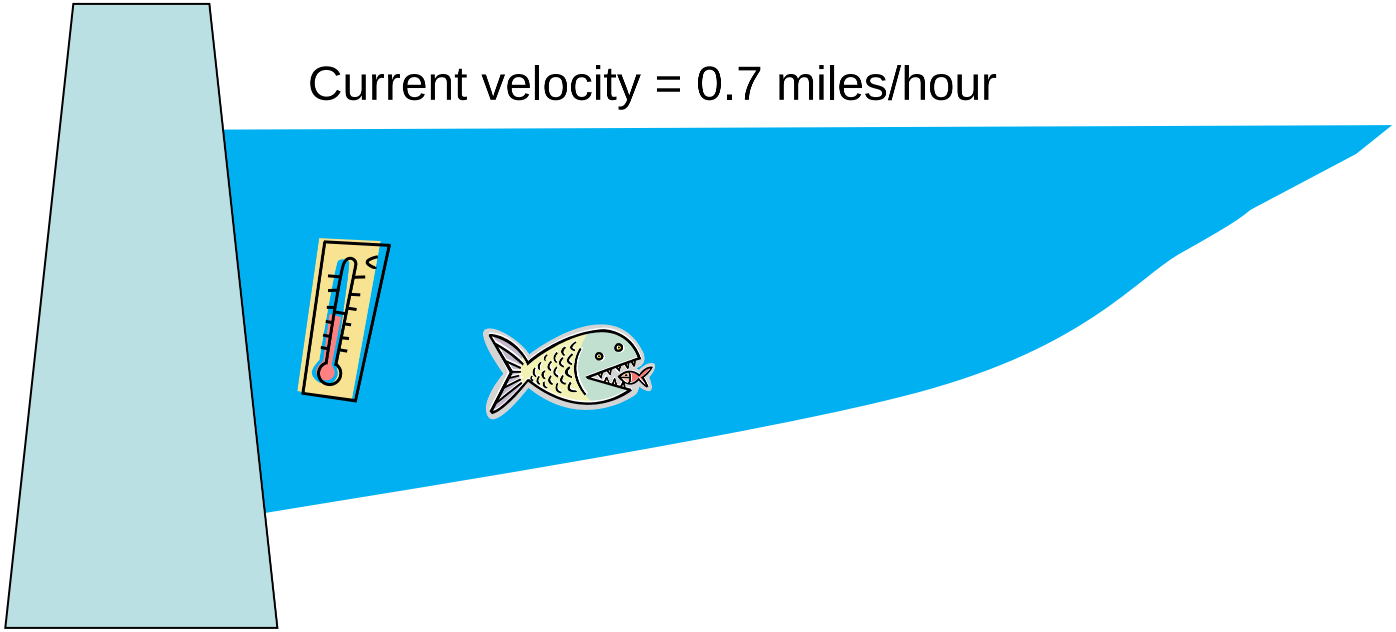
Current velocity = 7 miles/hour



How do reservoirs affect the currents that fish rely on?

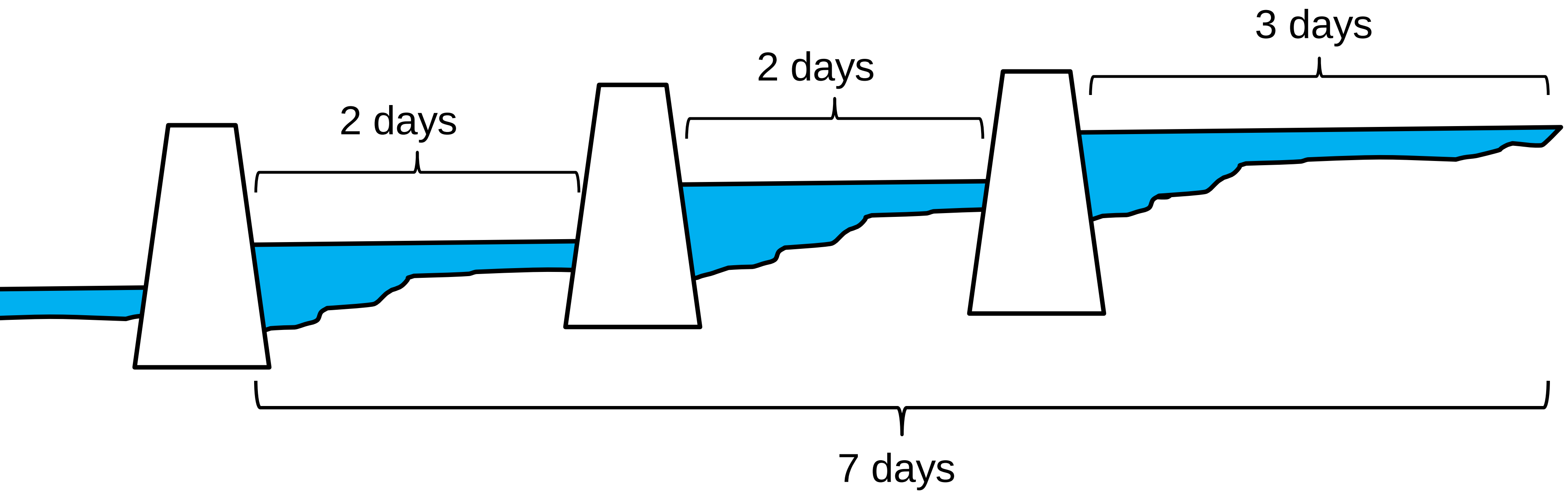


How do reservoirs affect the currents that fish rely on?

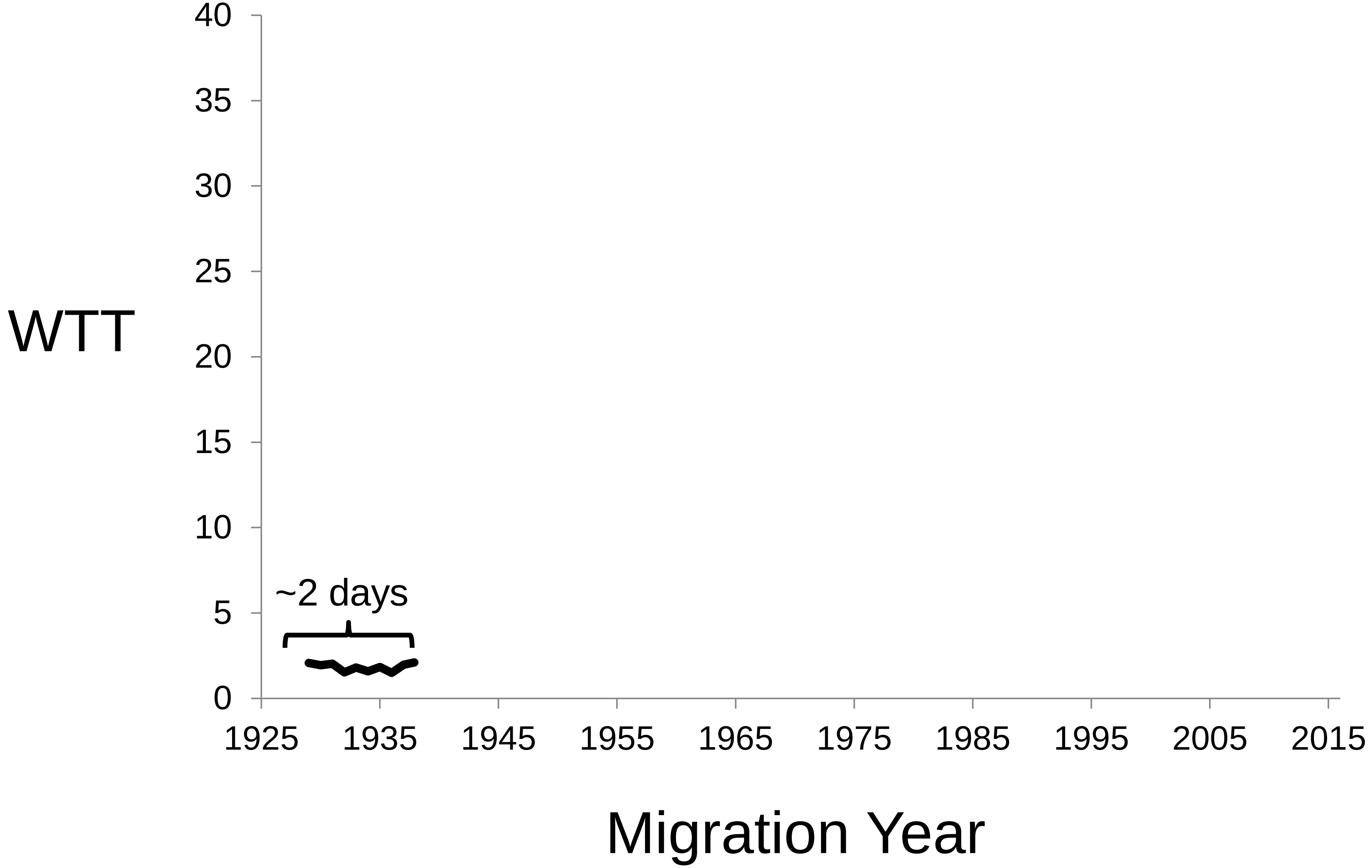


Water Transit Time (WTT)

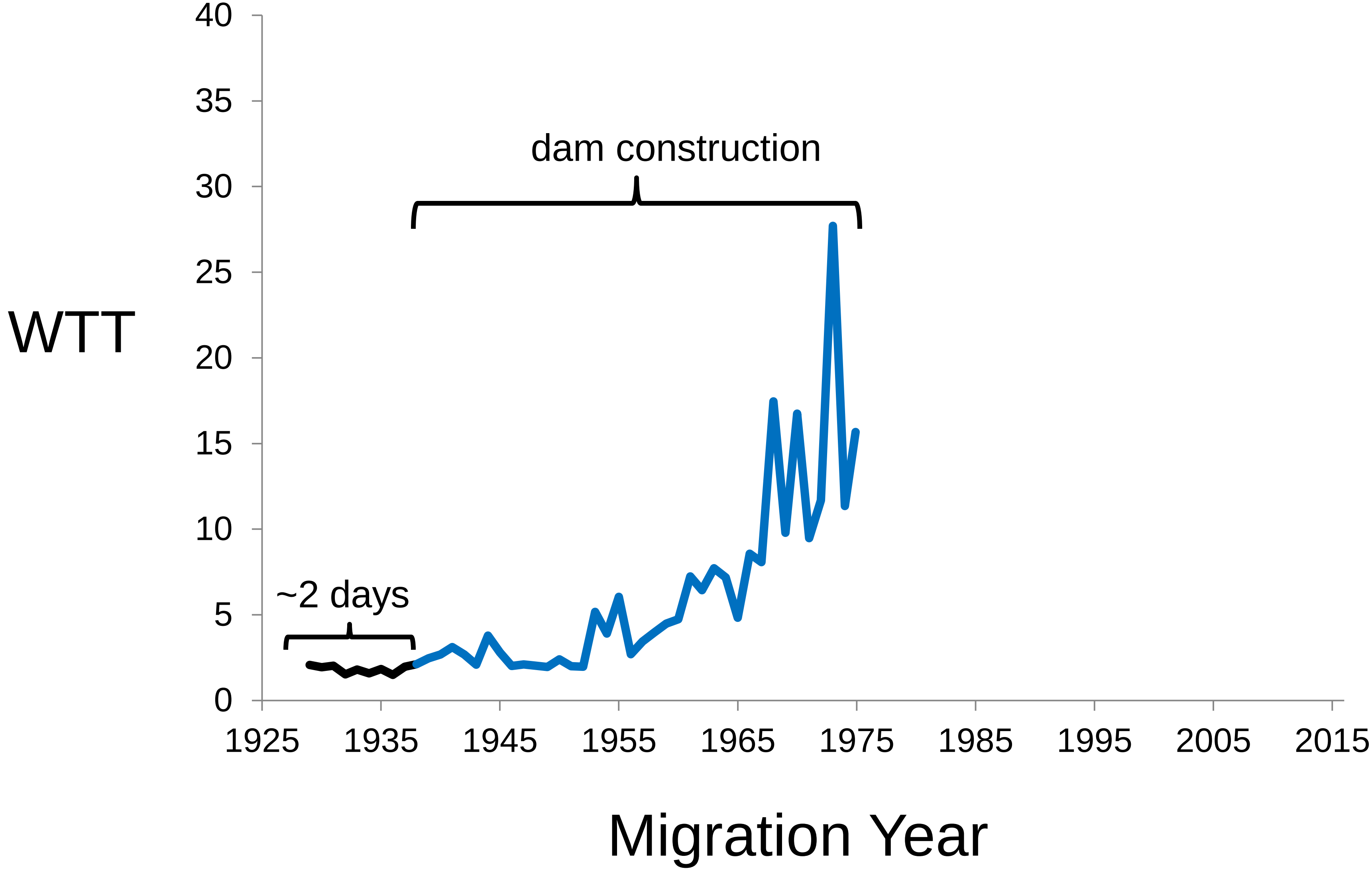
Estimate of the number of days required for average water particle to transit a reservoir (volume/flow)



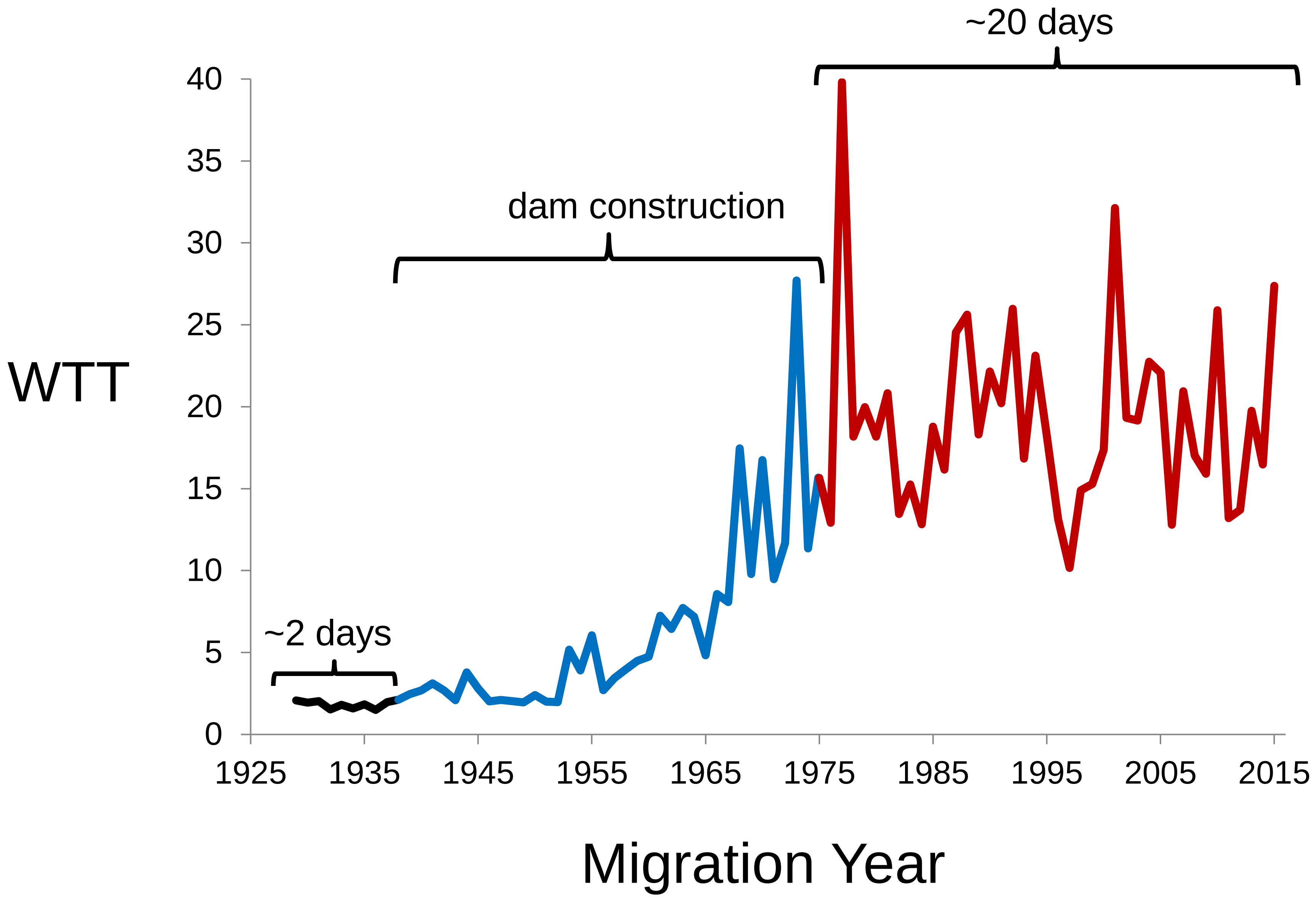
Long-term changes in Lewiston-BON WTT



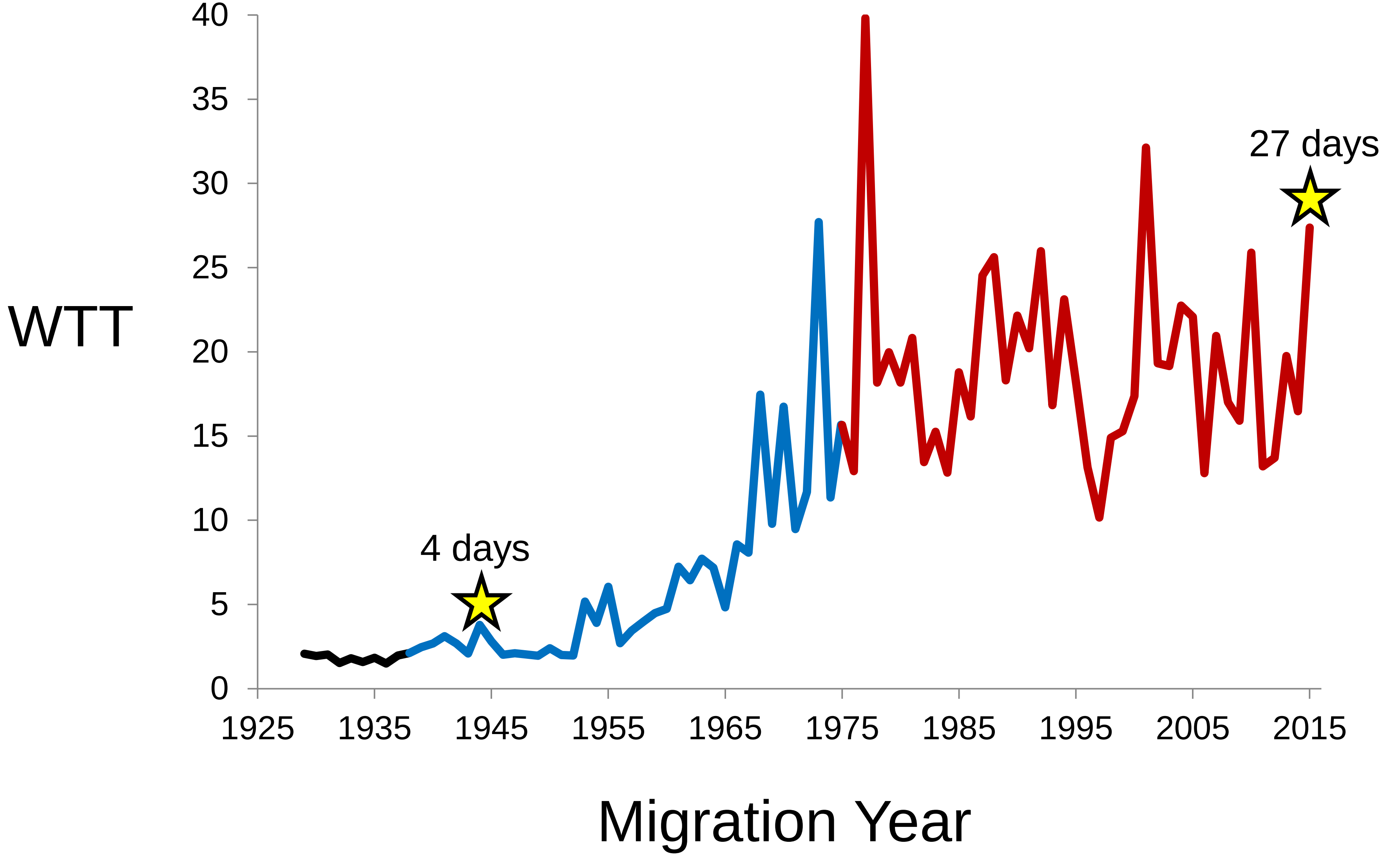
Long-term changes in Lewiston-BON WTT



Long-term changes in Lewiston-BON WTT



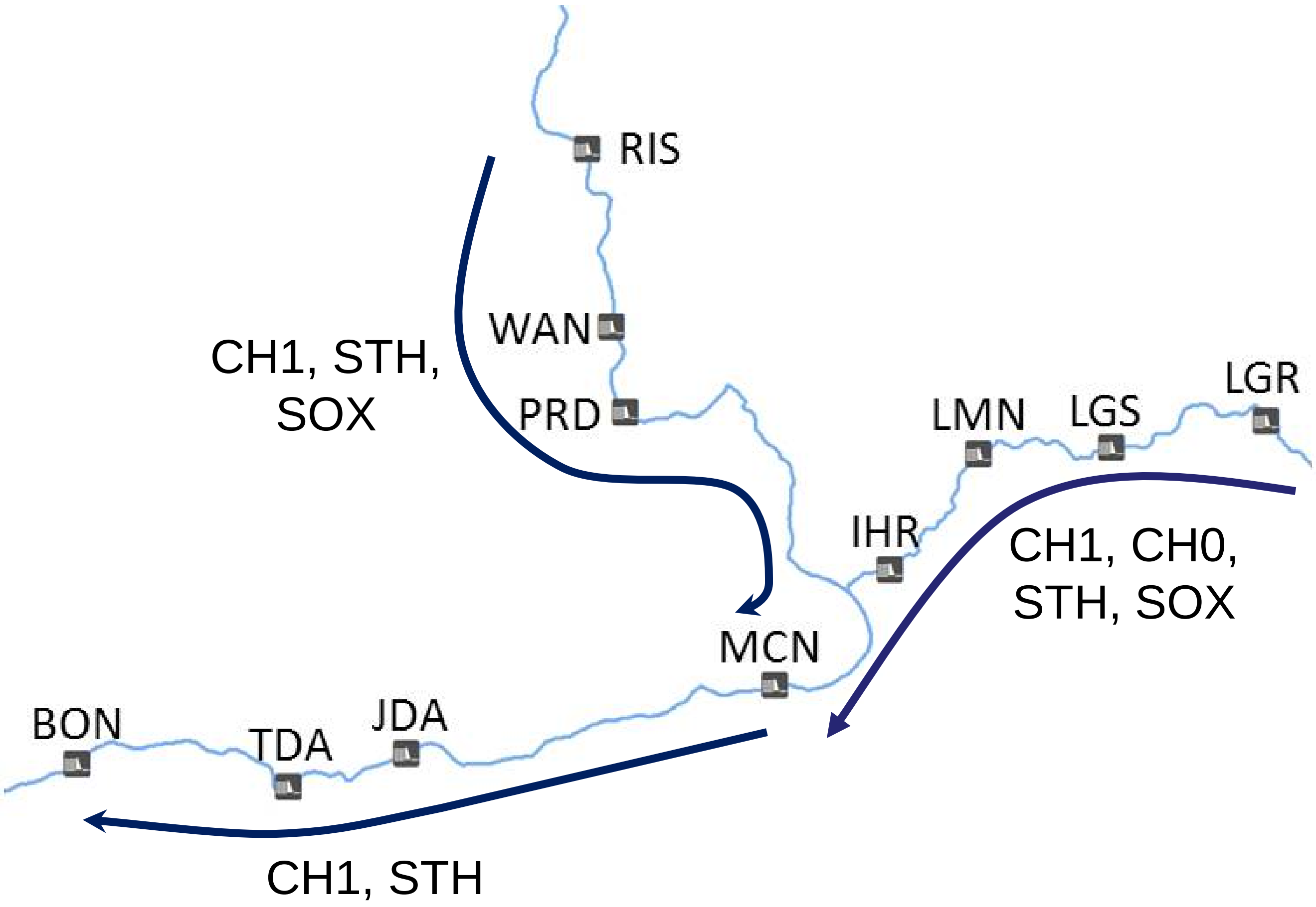
Long-term changes in Lewiston-BON WTT



Objectives:

- Measure and monitor juvenile Chinook, steelhead, and sockeye travel time and mortality rates through the hydrosystem
- Examine associations between environmental factors and travel time and mortality rates
- Develop models that explain variation in travel time and mortality rates through the hydrosystem

Monitoring methods:



Monitoring methods (1998-2014):

- Weekly/two-week release cohorts of PIT-tagged fish
- Estimated mean fish travel times (FTT), survival probabilities, and mortality rates

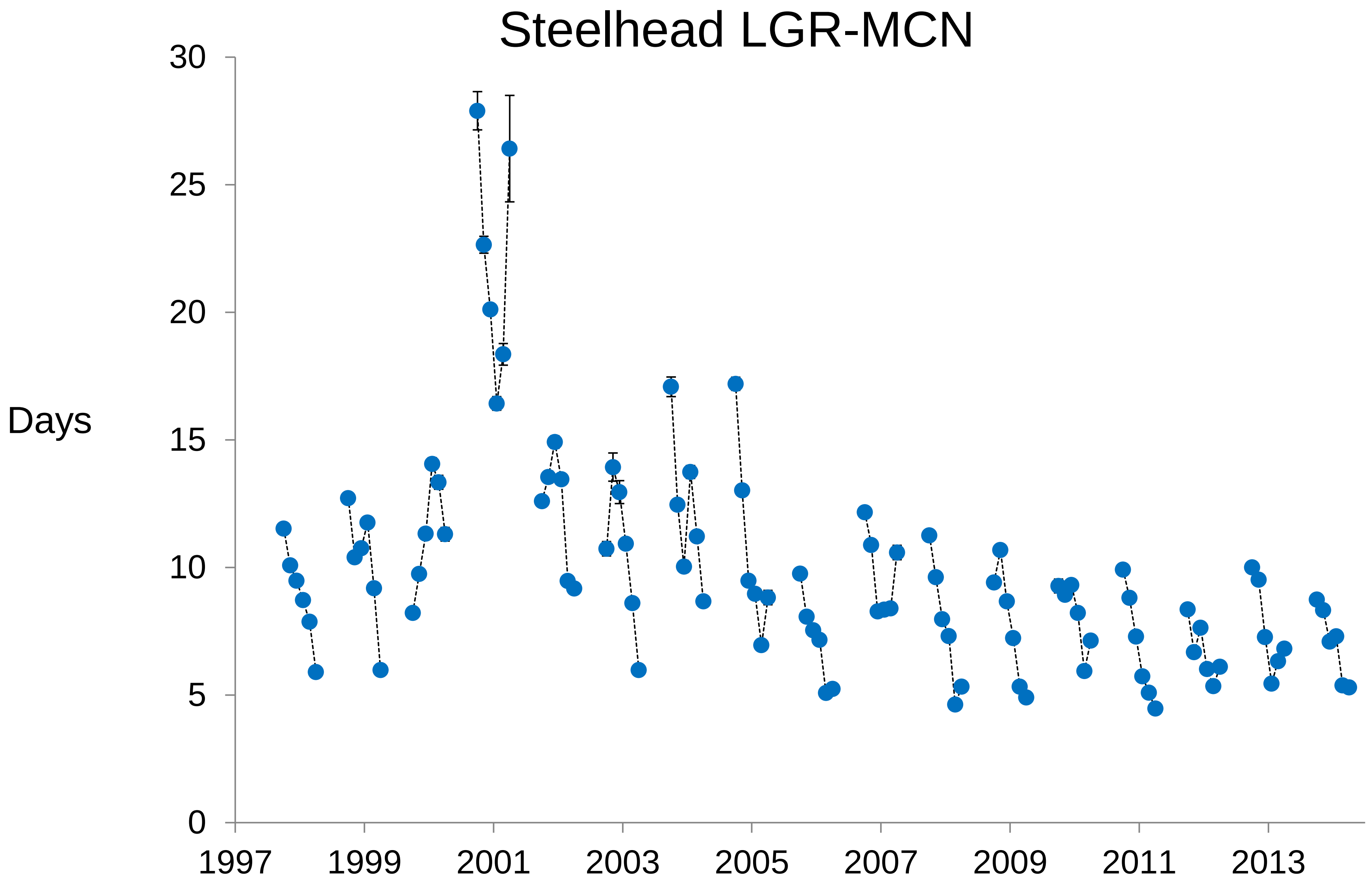
Environmental and Management Factors:

- Seasonality (Julian Day)
- Temperature
- Average percent spill
- Surface passage structures (TSW, RSW)
- Water transit time (WTT, days)

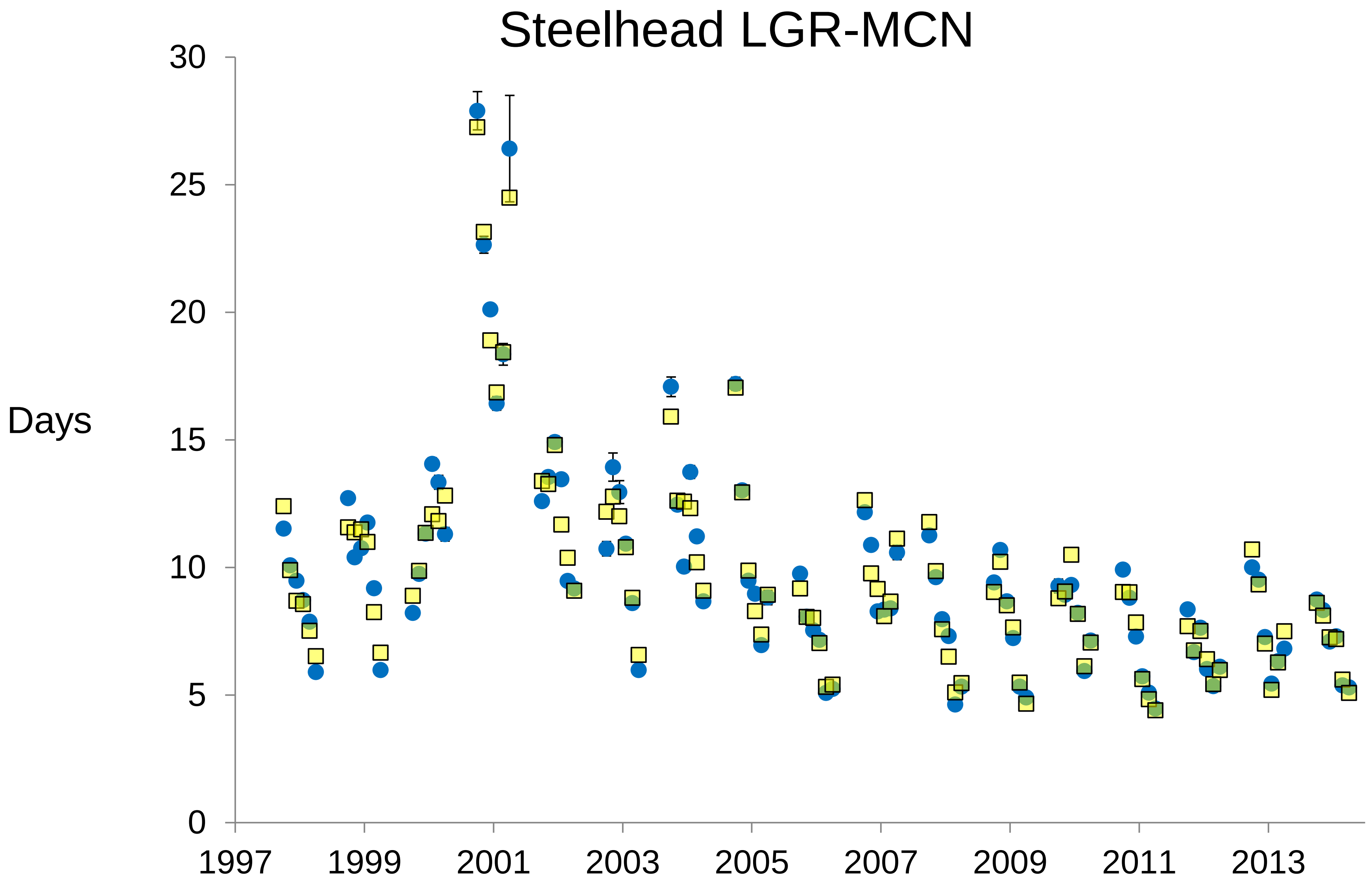
Regression with multi-model inference:

- Both standard and mixed-effects models were evaluated
- All combinations of variables
- Relative variable importance
- Model-averaged coefficients and predictions

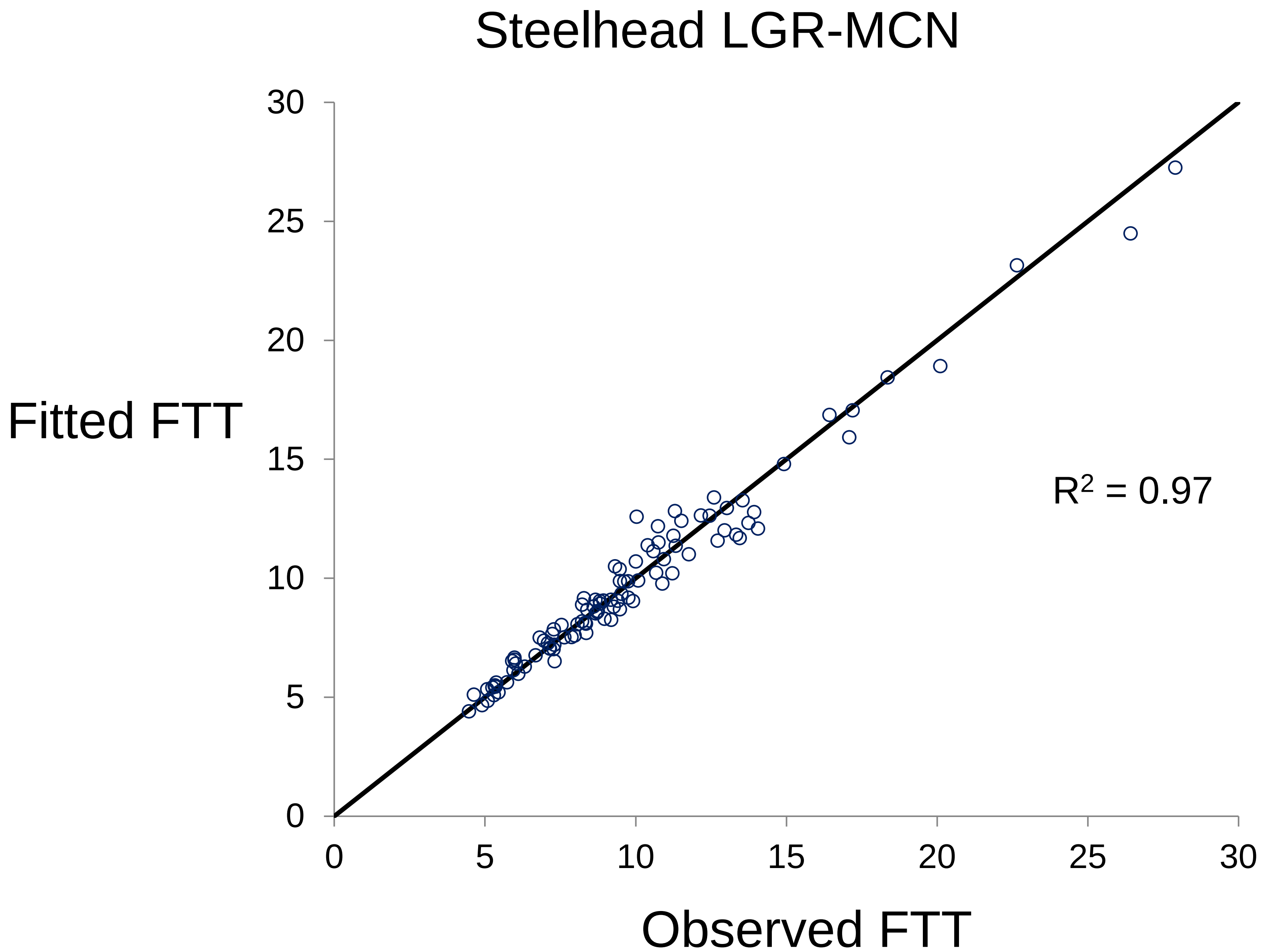
Fish Travel Times



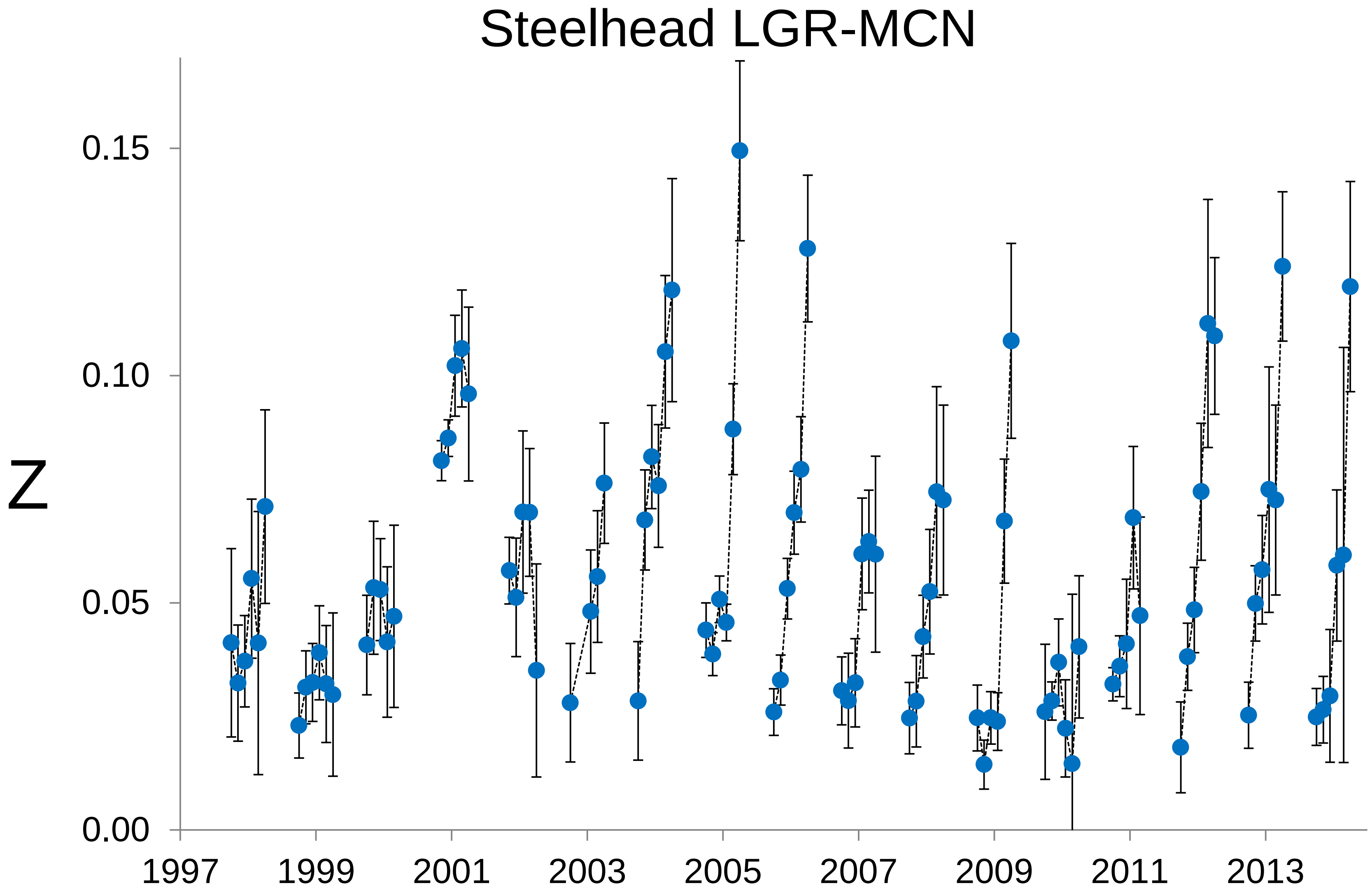
Fish Travel Times



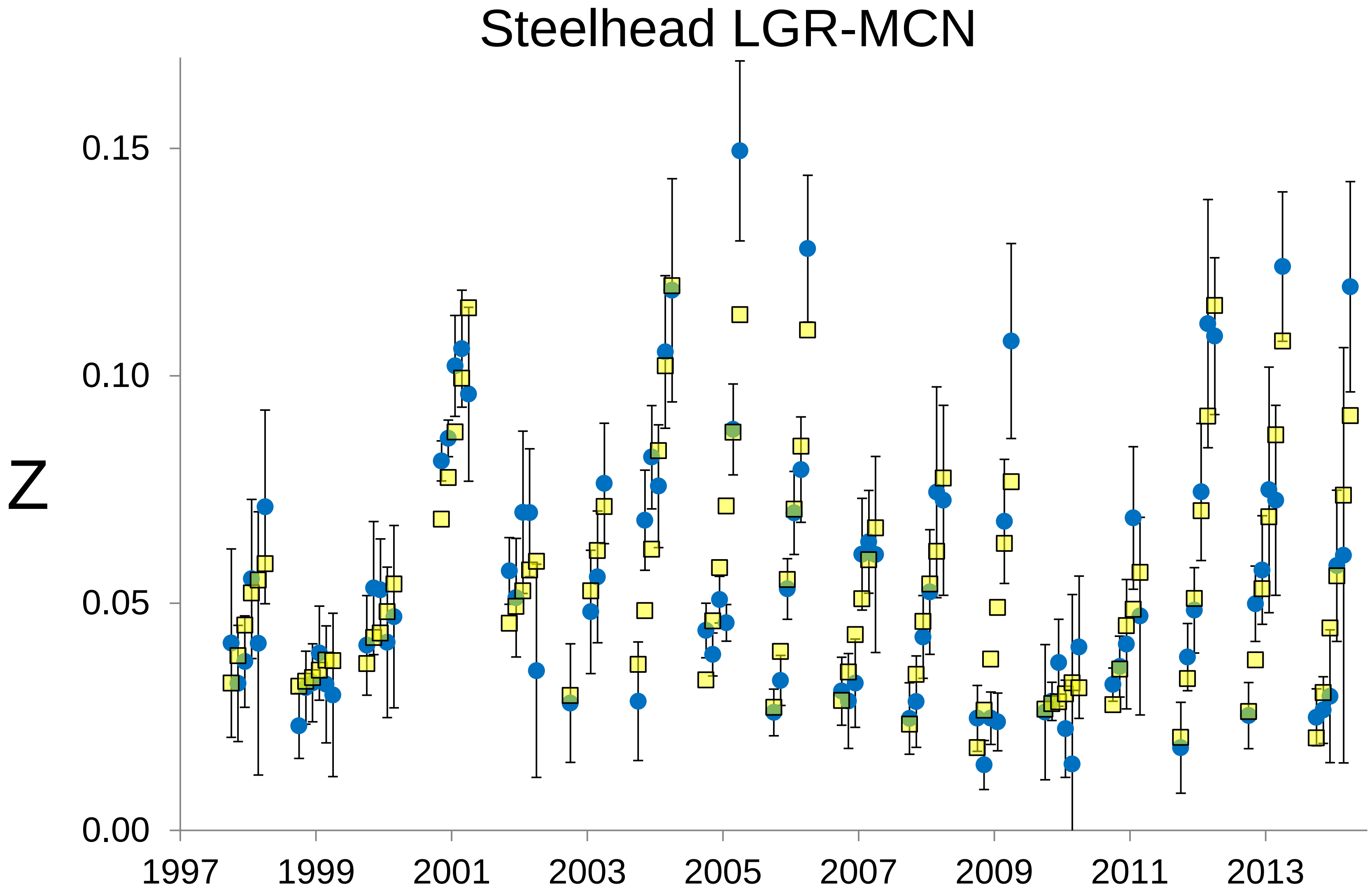
Fish Travel Times



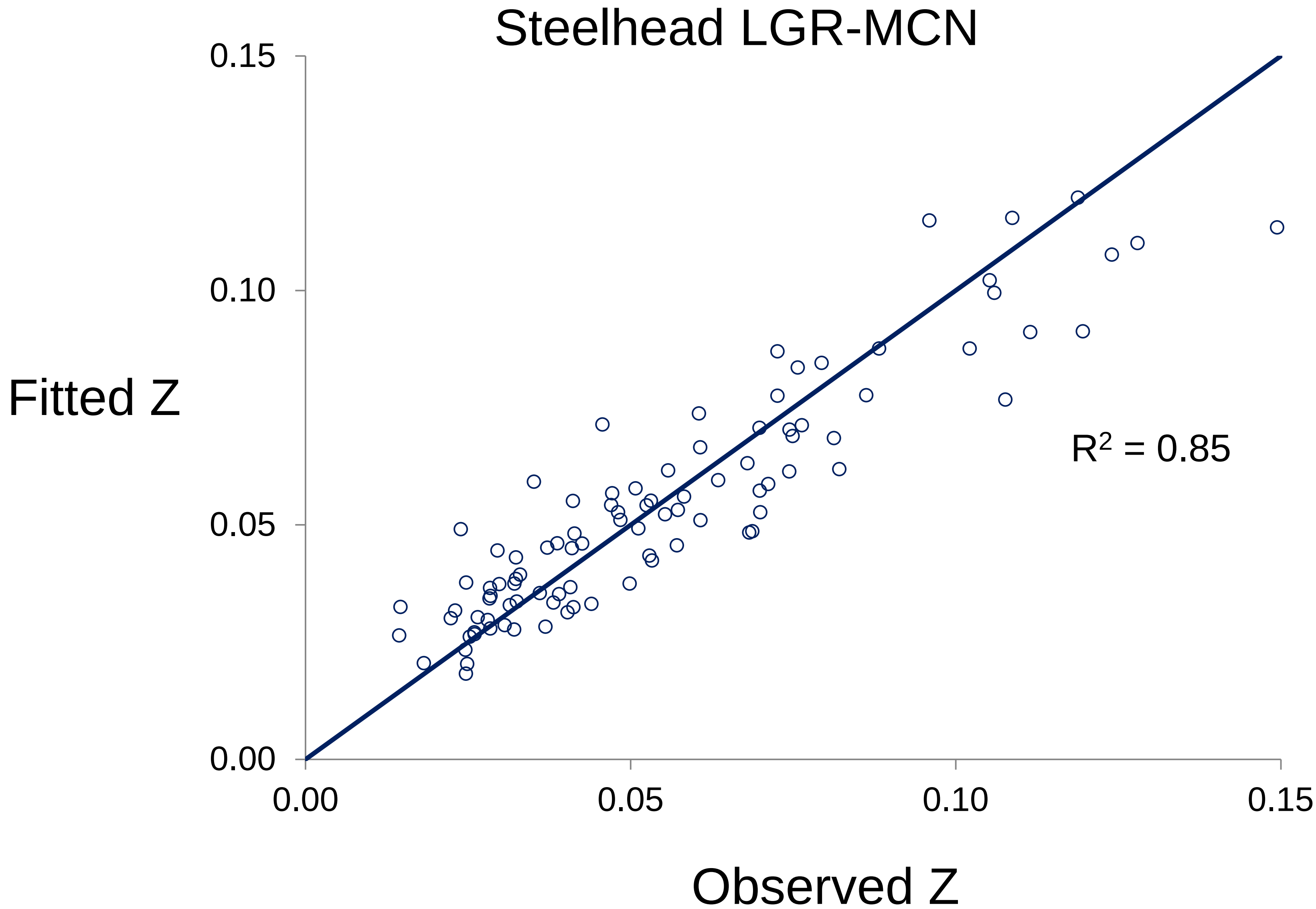
Mortality Rates



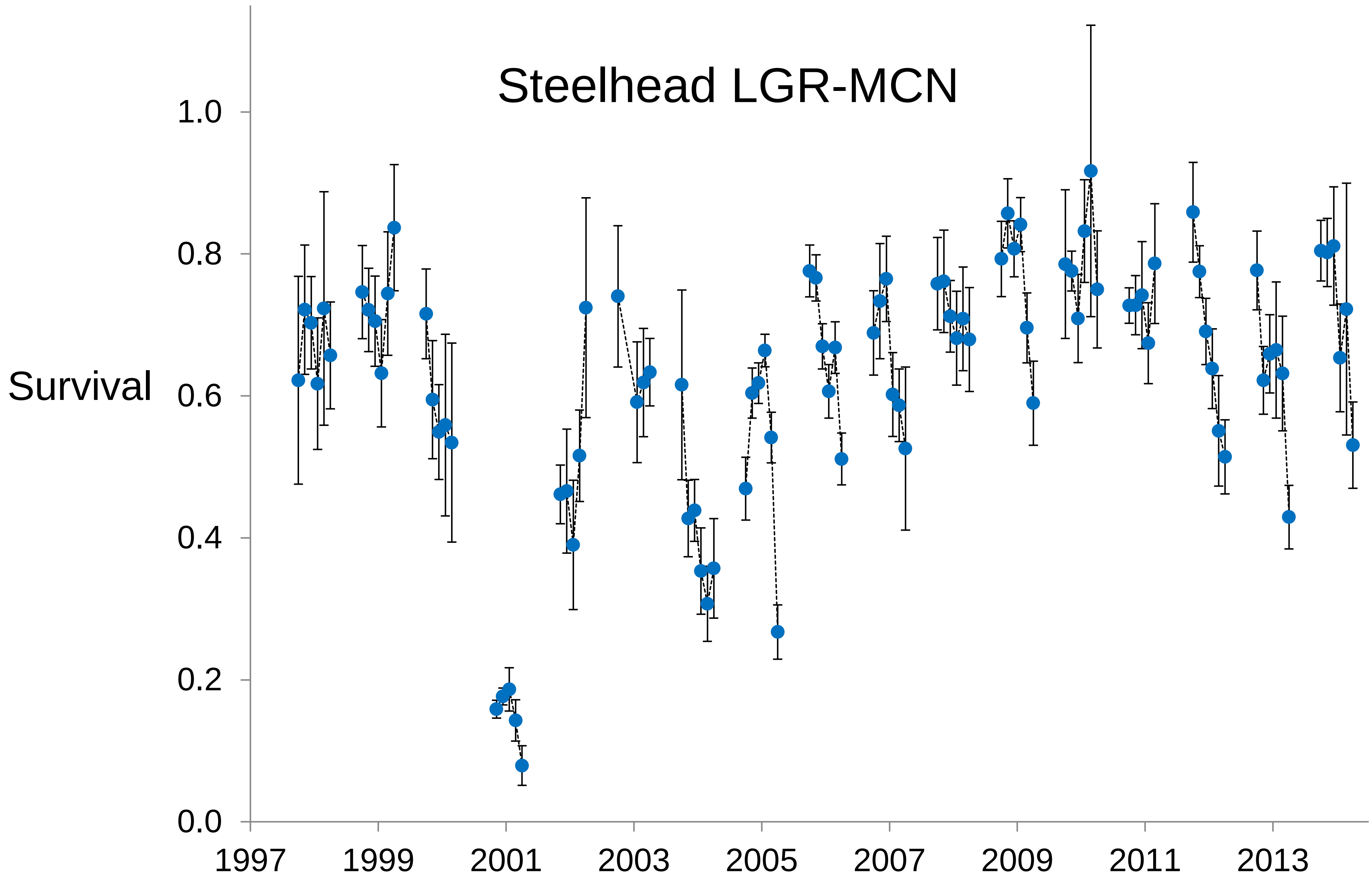
Mortality Rates



Mortality Rates

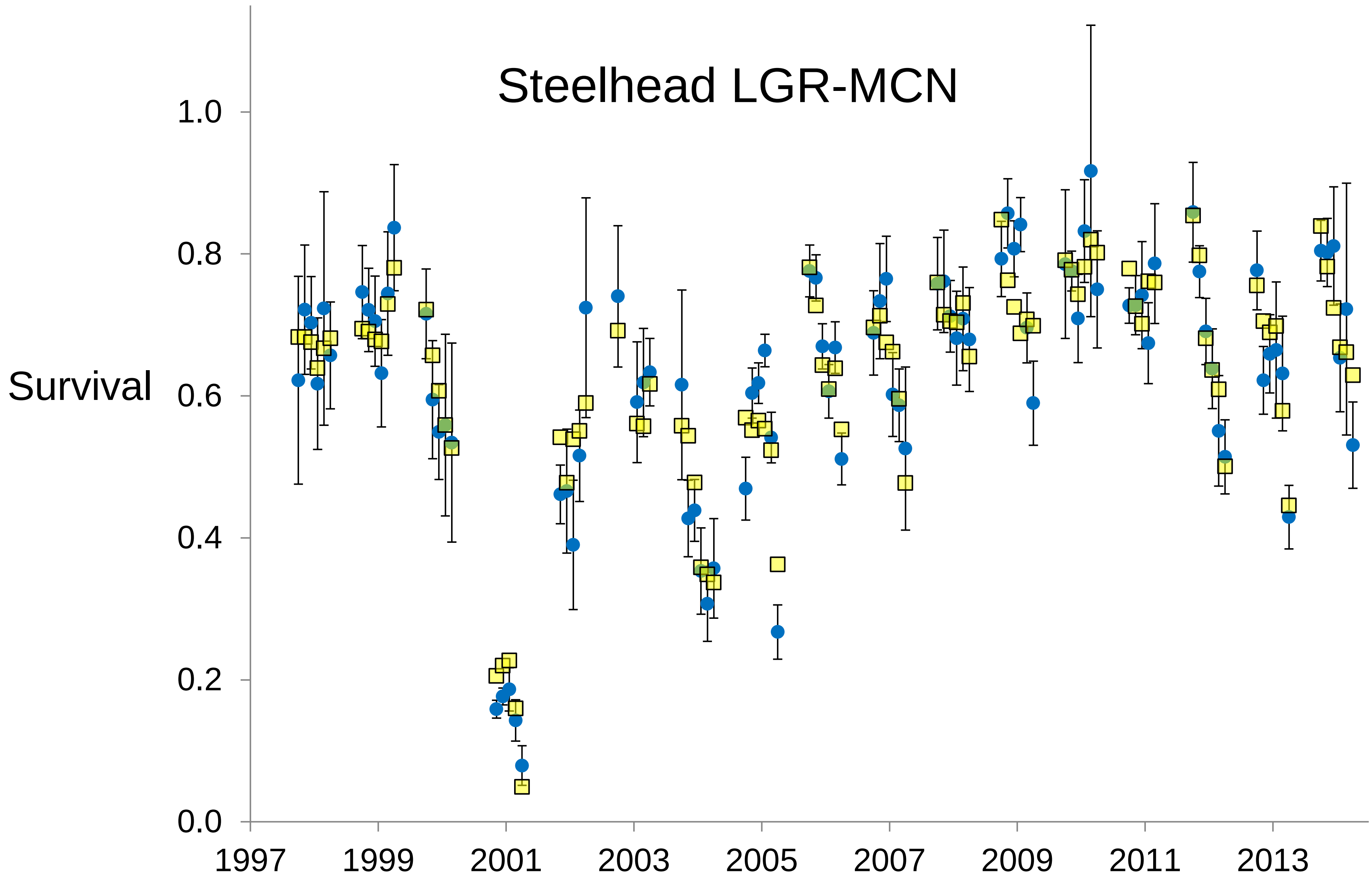


Survival



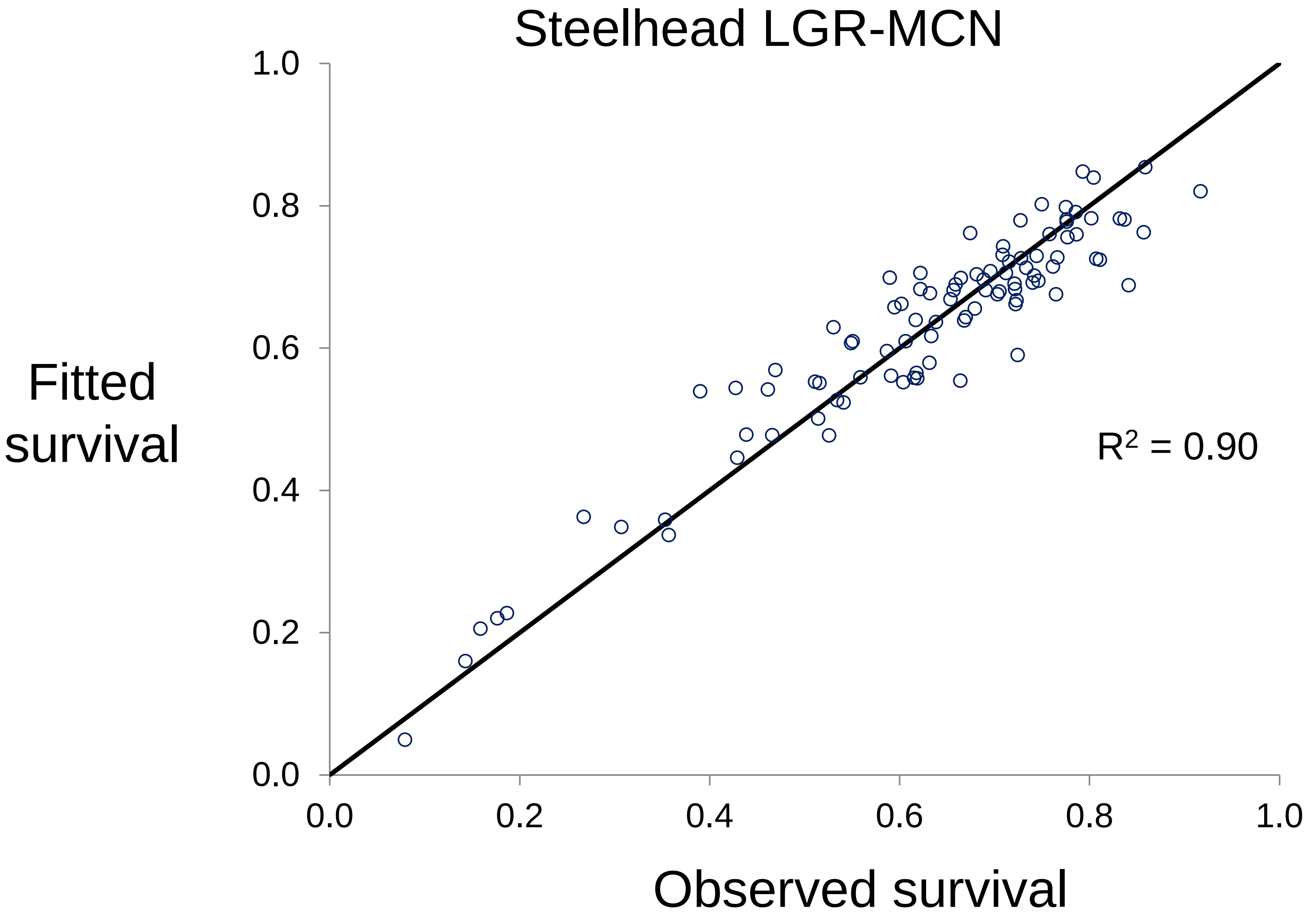
Steelhead LGR-MCN
Survival
1.0
0.8
0.6
0.4
0.2
0.0
1997
1999
2001
2003
2005
2007
2009
2011
2013

Survival

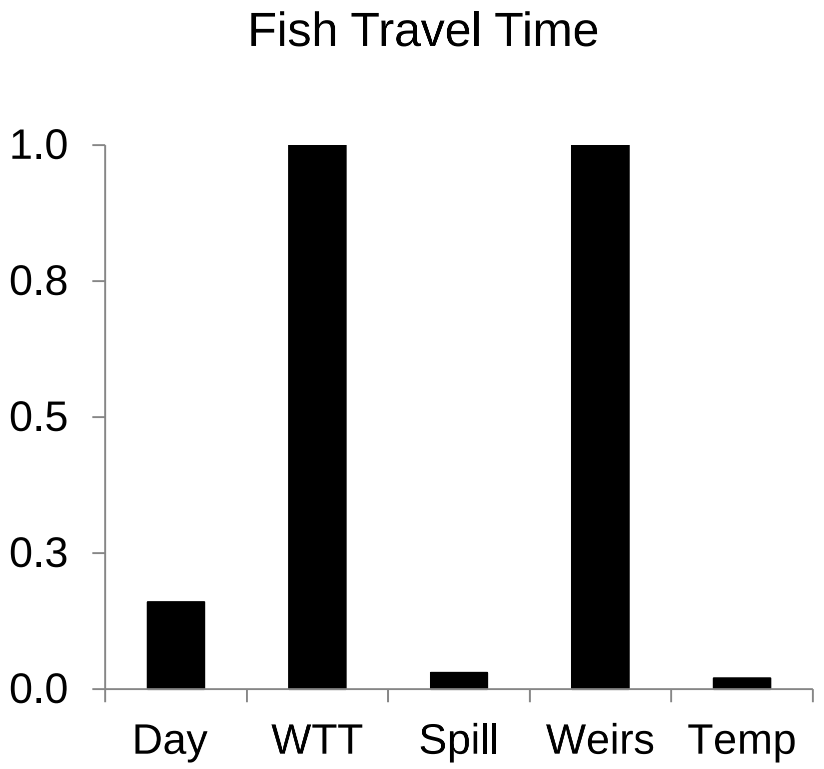


Steelhead LGR-MCN
Survival
1.0
0.8
0.6
0.4
0.2
0.0
1997
1999
2001
2003
2005
2007
2009
2011
2013

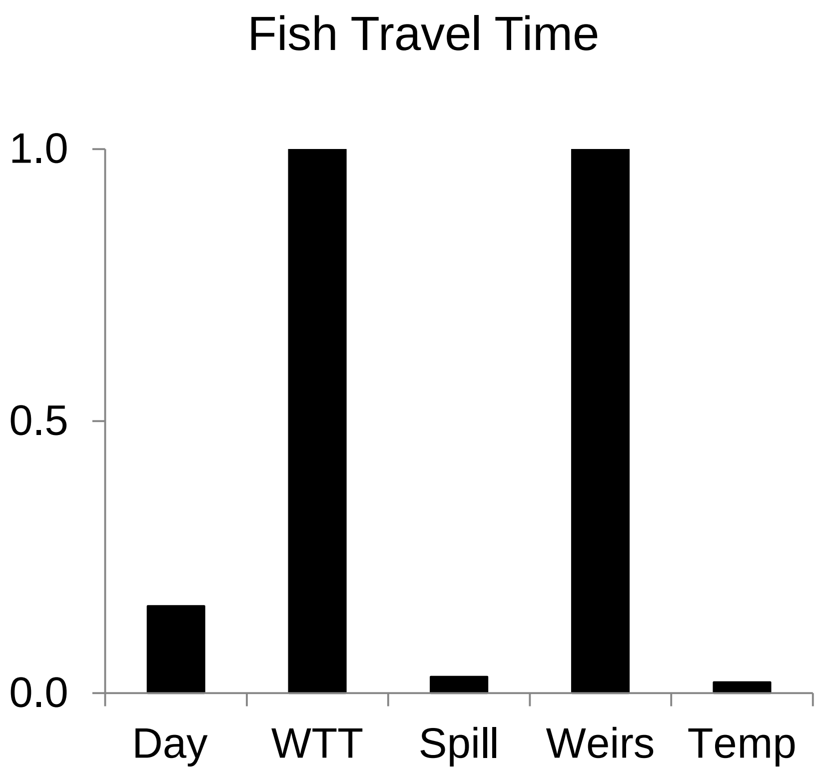
Survival

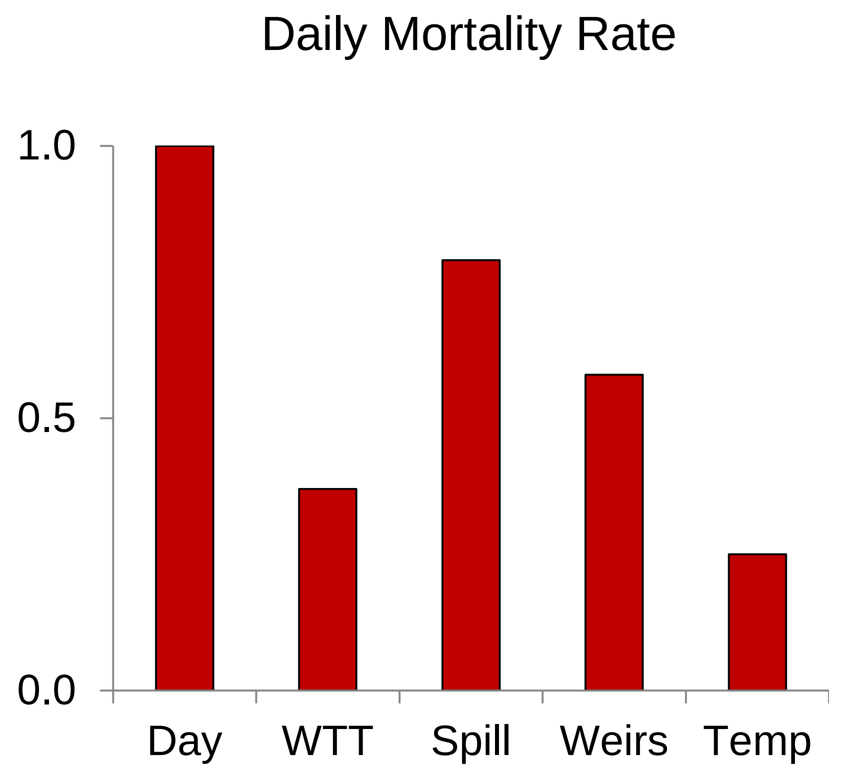

Steelhead LGR-MCN
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Fitted survival
Observed survival
R2 = 0.90

Relative Variable Importance (steelhead)

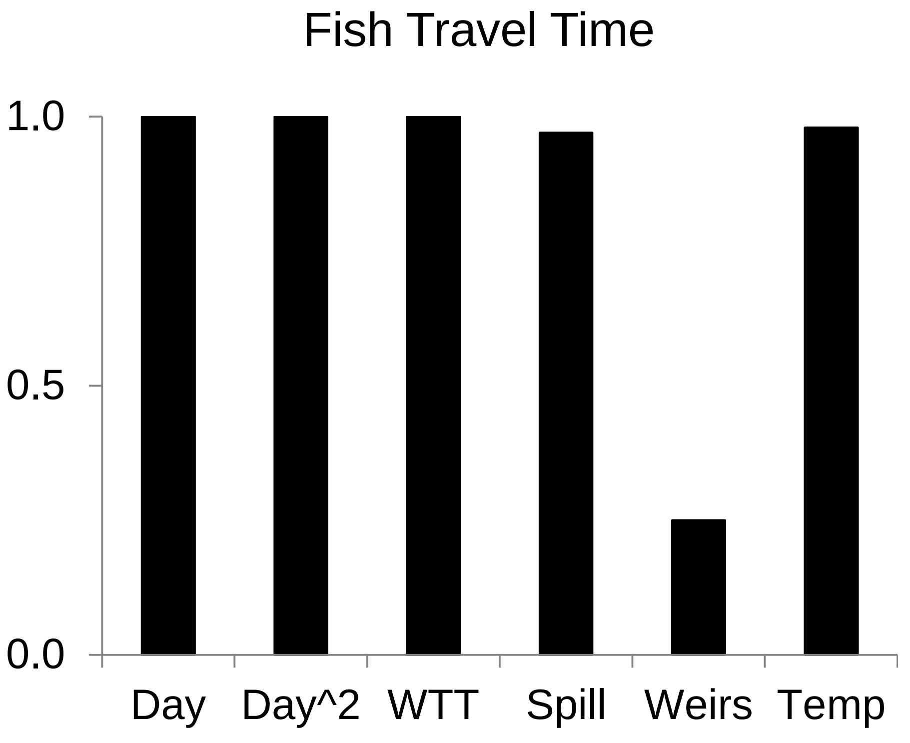


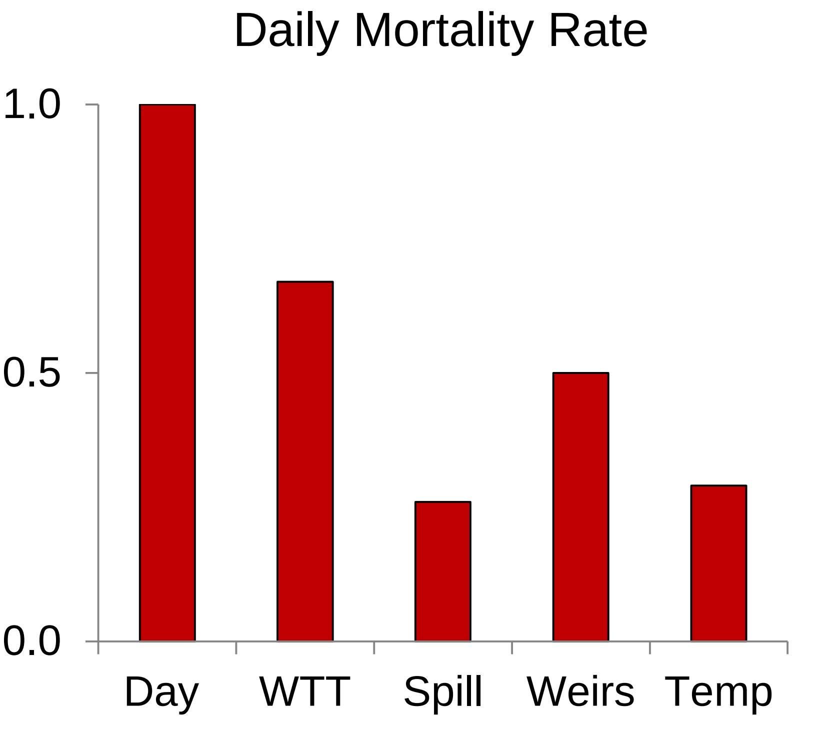
Relative Variable Importance (steelhead)



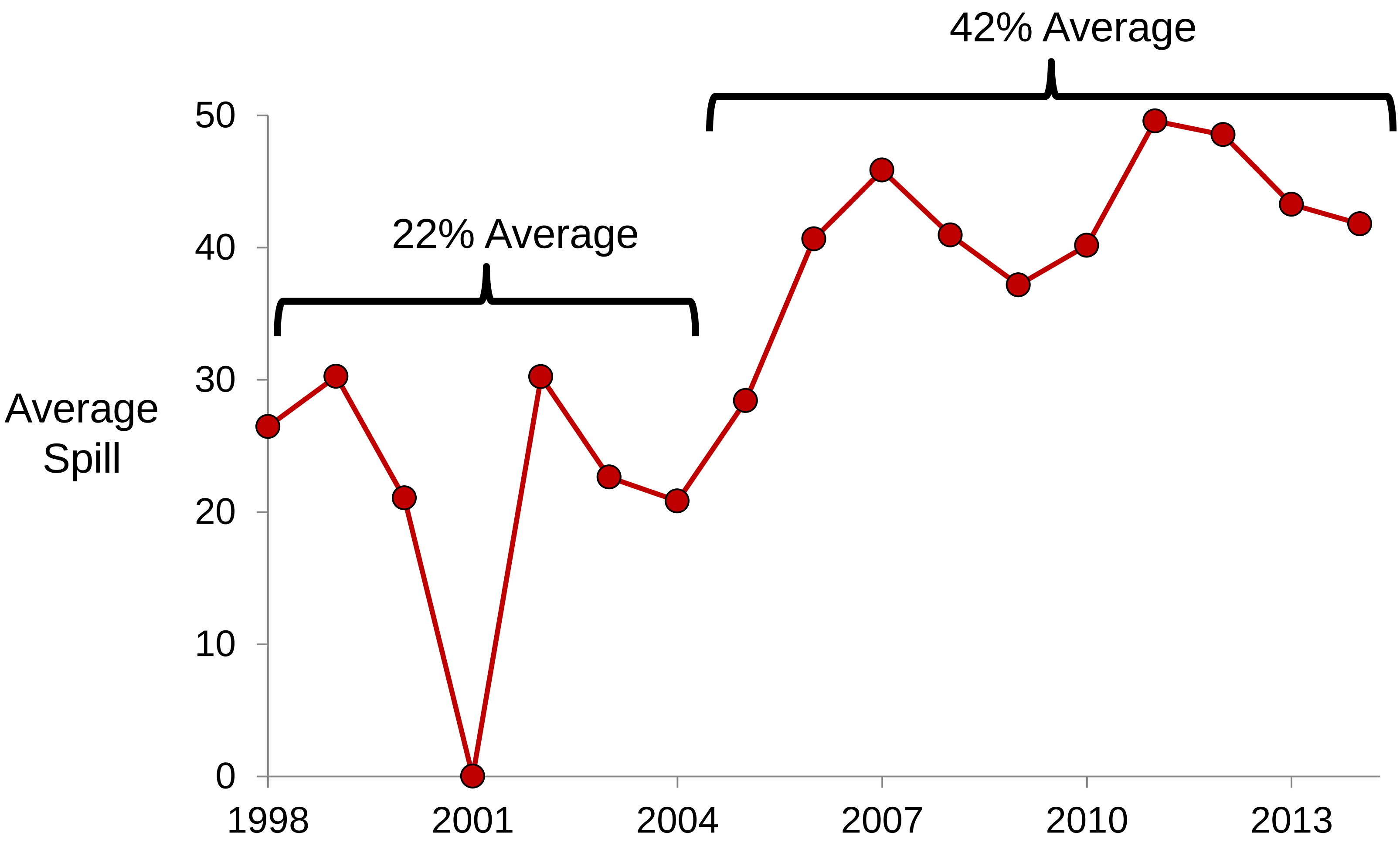


Relative Variable Importance (wild Chinook)

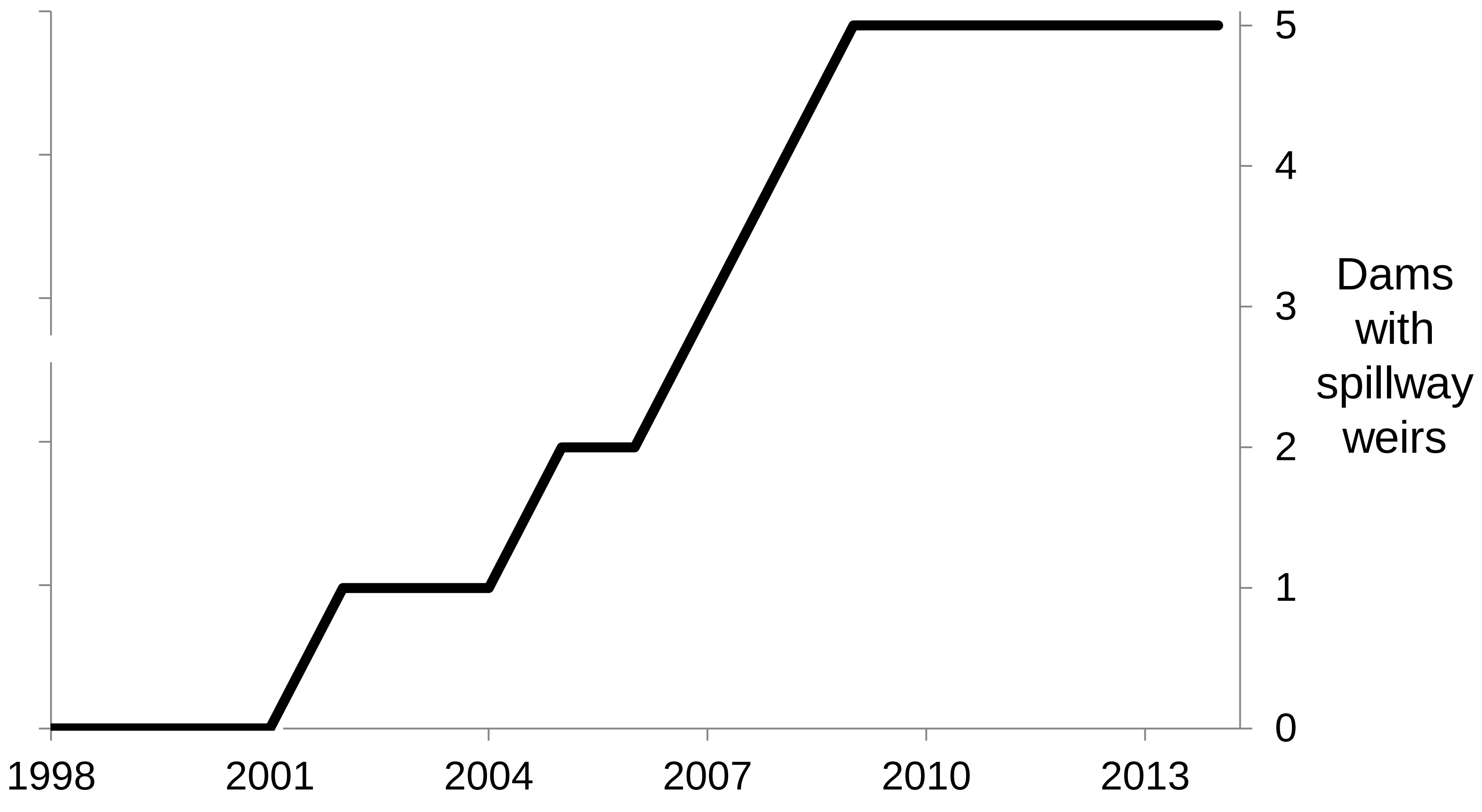




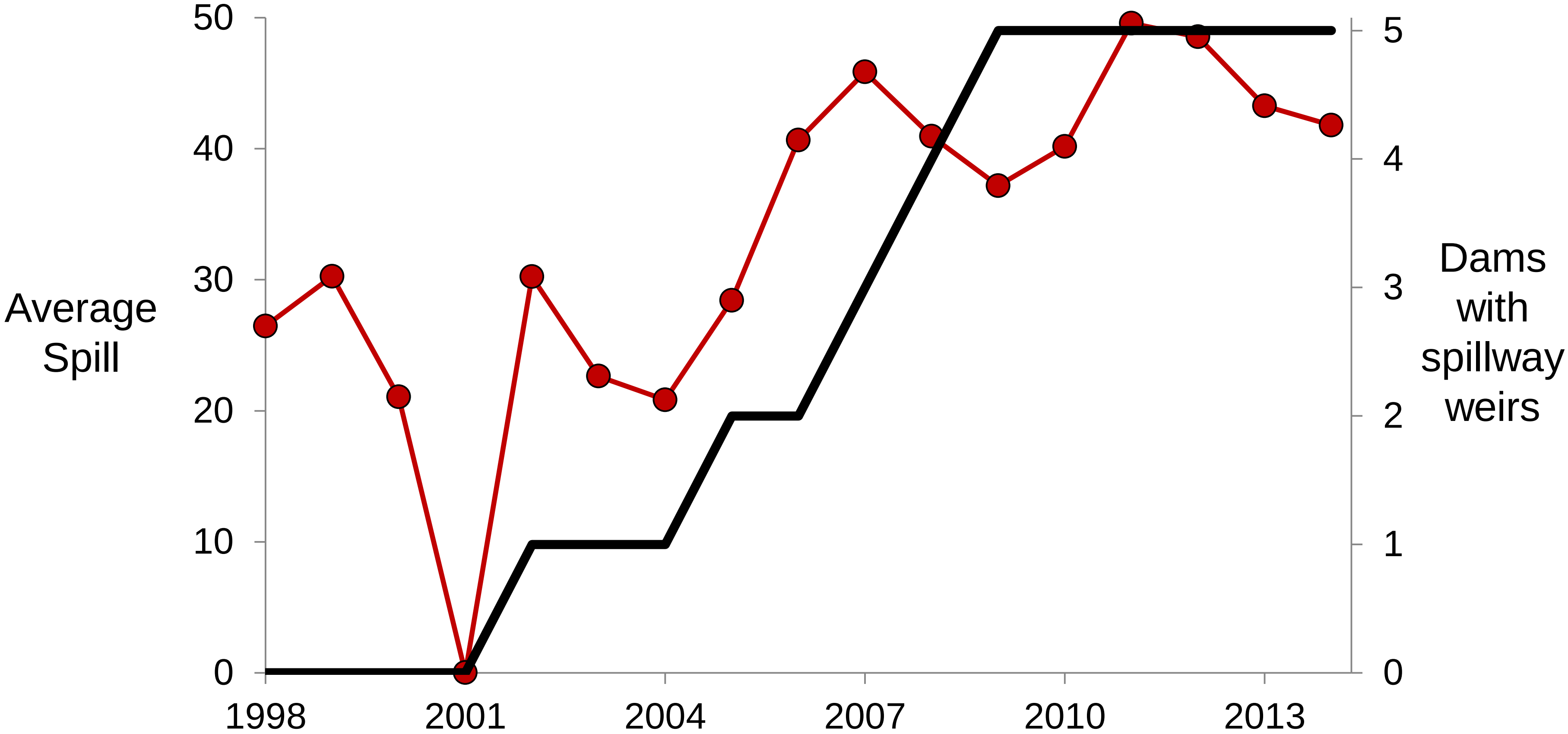
Passive Adaptive Management Experiments: Fall (subyearling) Chinook salmon



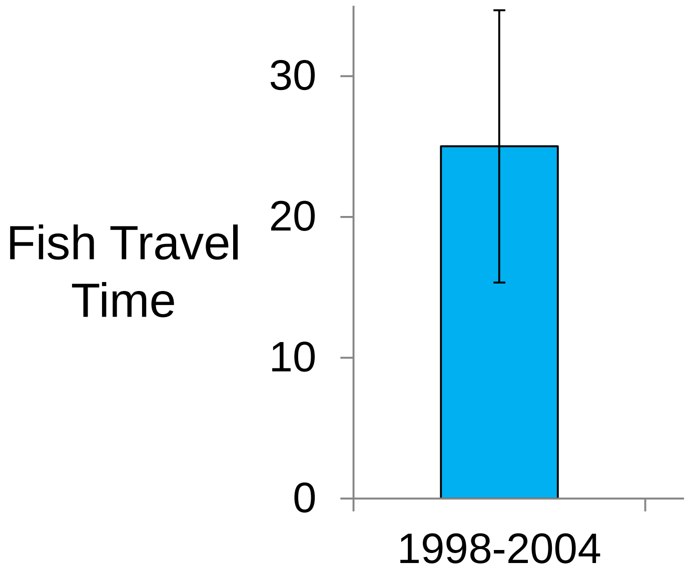
Passive Adaptive Management Experiments: Fall (subyearling) Chinook salmon

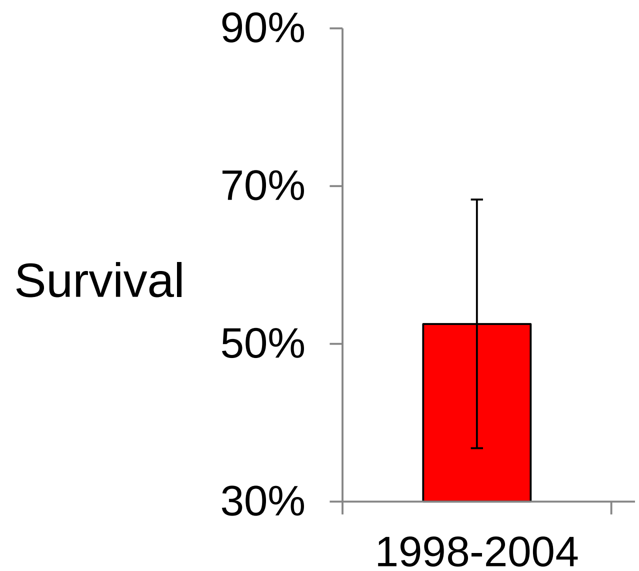


Passive Adaptive Management Experiments: Fall (subyearling) Chinook salmon

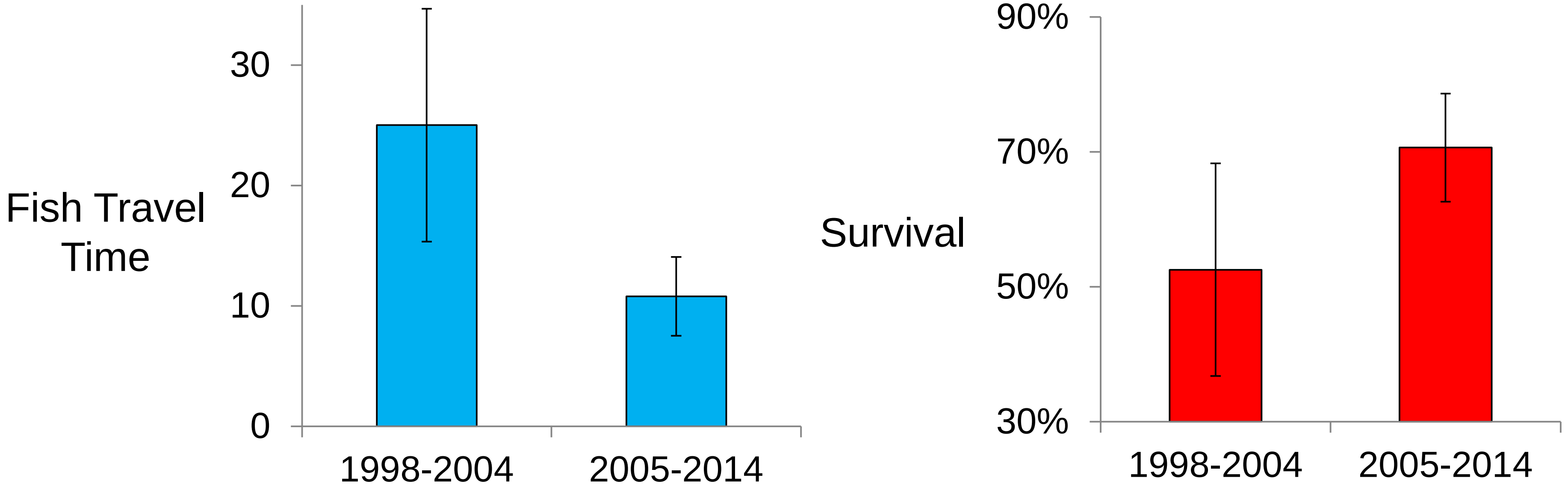


Monitoring Adaptive Management Experiments – Fall (subyearling) Chinook salmon





Monitoring Adaptive Management Experiments – Fall (subyearling) Chinook salmon



Conclusions

- Assembled comprehensive data set across the basin and across species

- Employed consistent analytical framework

- Combinations of managed (WTT, spill) and environmental (seasonal, temperature) factors influence demographic rates

- Models provide testable hypotheses for evaluating effects of future management actions

PITPH (Powerhouse passage rate derived from PIT-tag data)

Presenter: Steve Haeseker

2011 CSS Workshop (Marmorek et al. 2011)

Recommendations:

1) Develop new measures of spill effects (powerhouse passage)

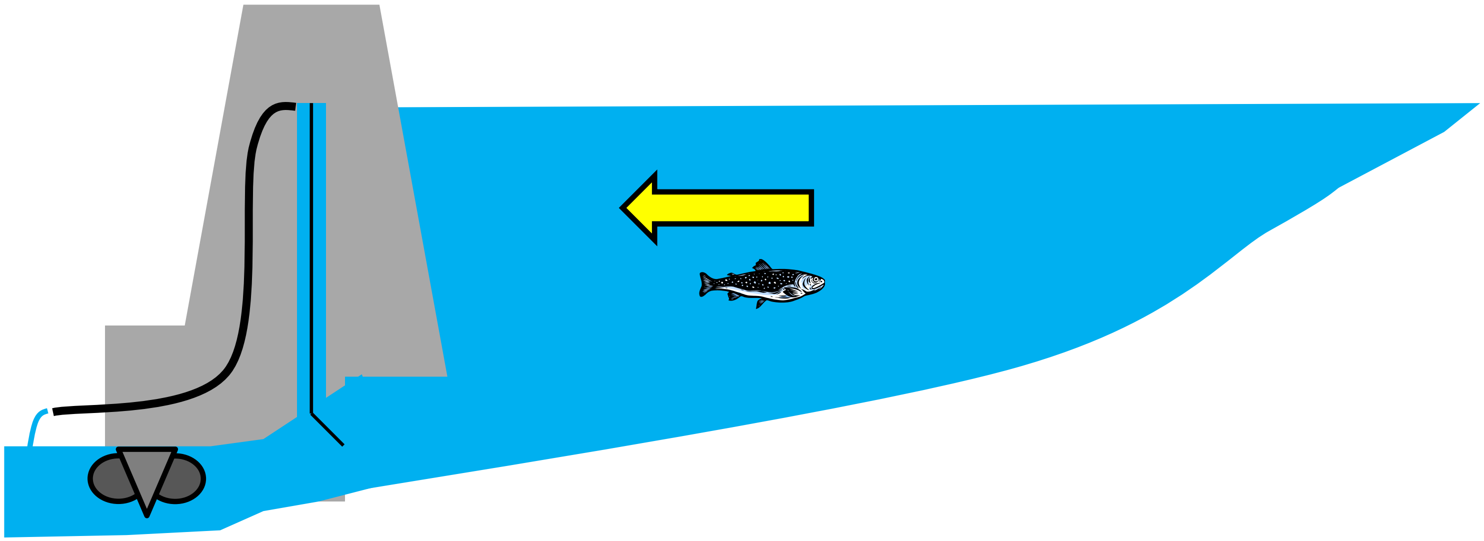
2) Account for the effects of spillway weirs

3) Determine the effectiveness of spill by project


Powerhouse
Spillways

Powerhouse passage routes

- Collection/bypass system
- Turbines



Effects of powerhouse passage

Lowest direct survival through turbines

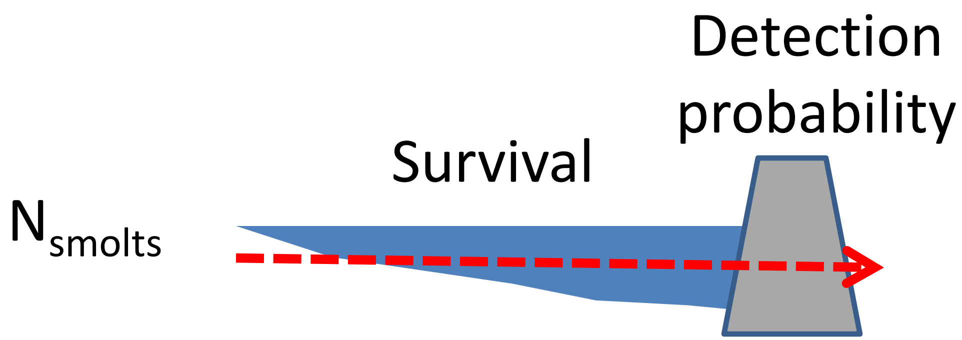
Bypass system effects on survival and delay

(Budy et al. 2002, Tuomikoski et al. 2010, McMichael et al. 2010, Buchanan et al. 2011)

➡ Minimize powerhouse passage to reduce delay and increase survival

How do flow, spill, and weirs affect powerhouse passage rates?

Cormack-Jolly-Seber survival model



Summarize detection probabilities and associated flow, spill, and weir data

Develop models of flow, spill, weirs, and detection probability

Fish Guidance Efficiency (FGE):

Proportion of total powerhouse passage in bypass systems

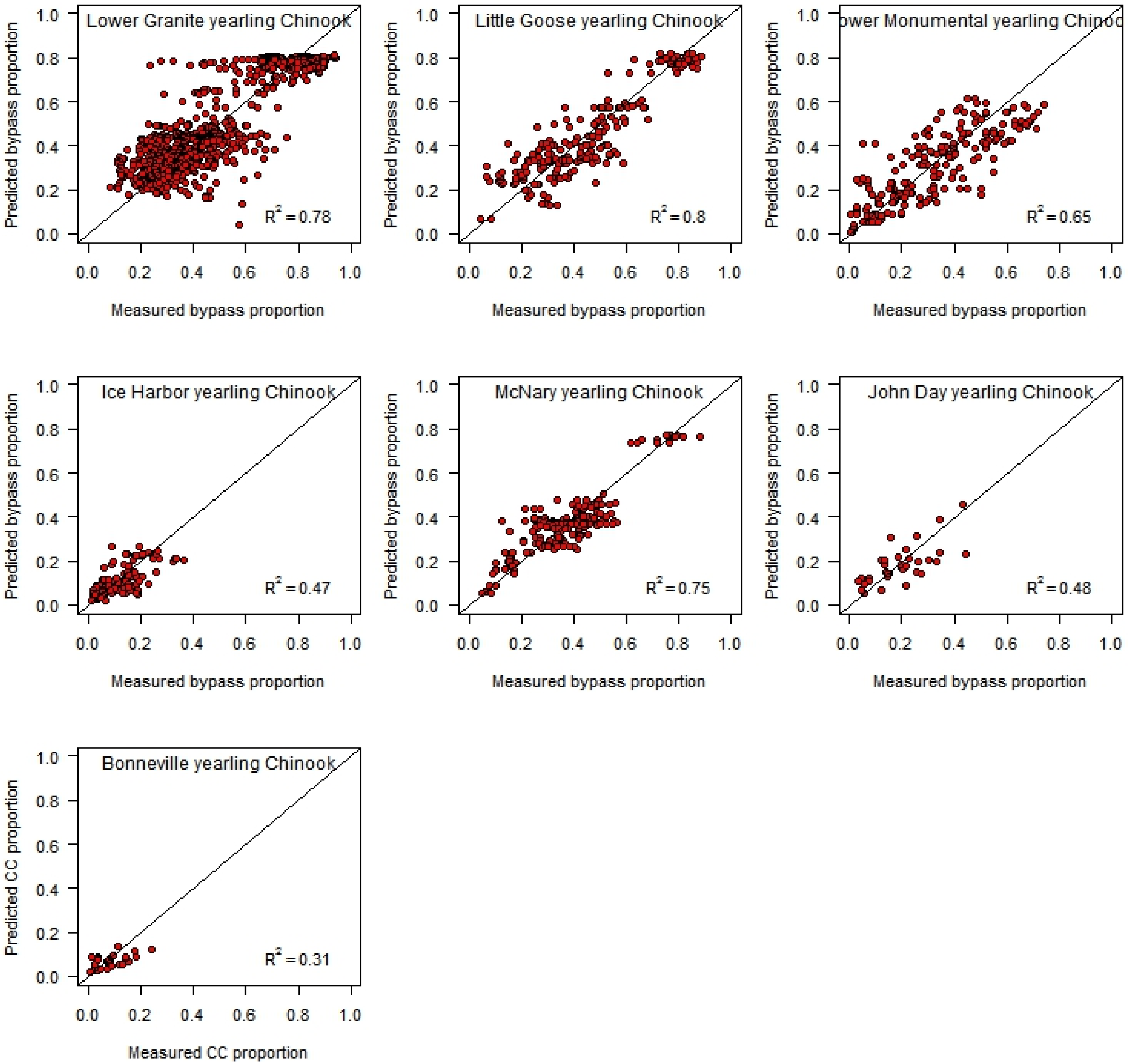
$$\text{FGE} = \frac{\text{Bypass (flow, spill, weirs)}}{\text{Total Powerhouse}}$$

Studies show that FGE is relatively constant at each dam

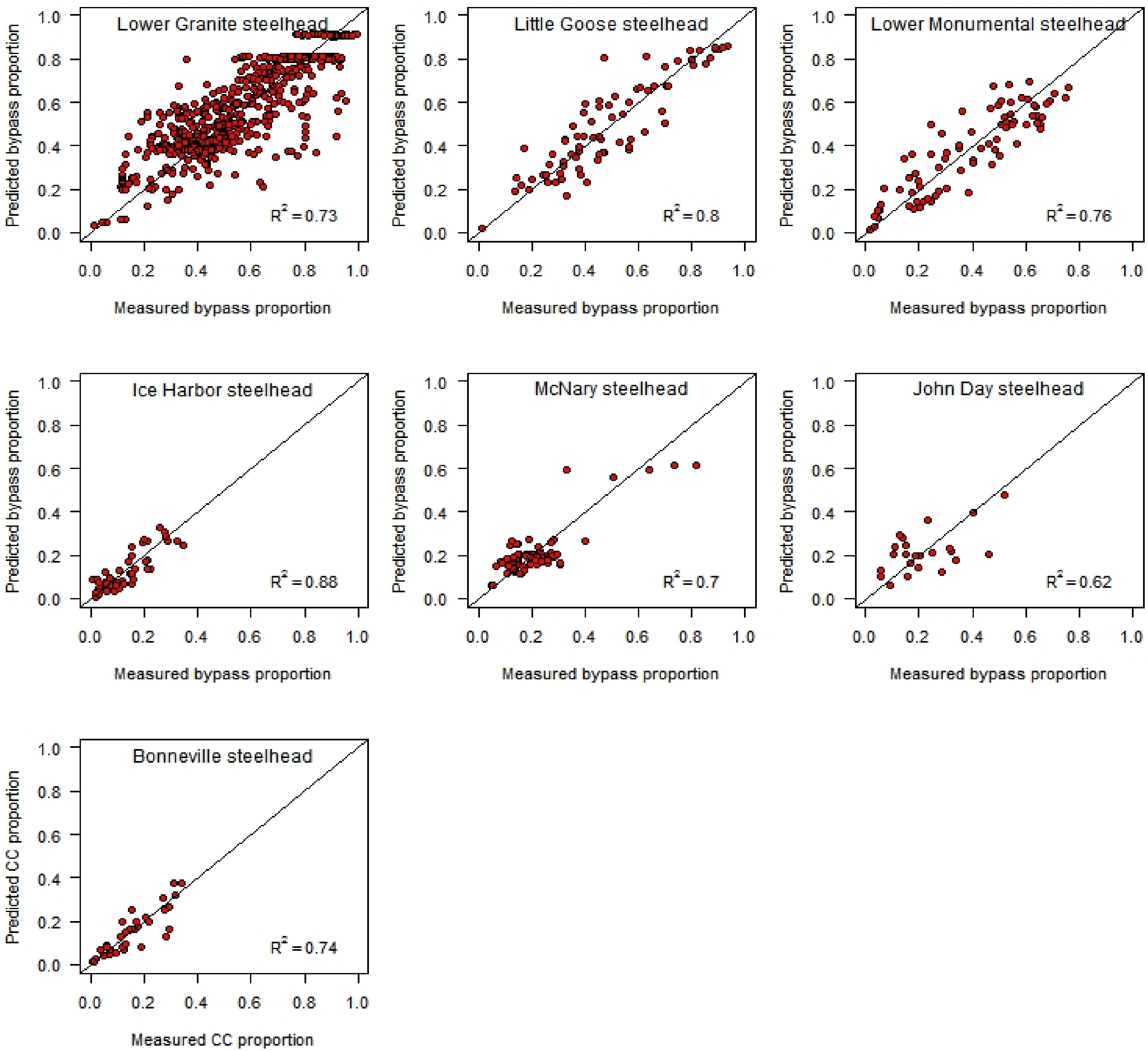
$$\text{Total Powerhouse} = \frac{\text{Bypass (flow, spill, weirs)}}{\text{FGE}}$$

$$\text{Spillway} = 1 - \text{Total Powerhouse}$$

Yearling Chinook salmon



Steelhead



Lower Granite steelhead
R² = 0.73
Little Goose steelhead
R² = 0.8
Lower Monumental steelhead
R² = 0.76
Ice Harbor steelhead
R² = 0.88
McNary steelhead
R² = 0.7
John Day steelhead
R² = 0.62
Bonneville steelhead
R² = 0.74
Predicted bypass proportion
Measured bypass proportion
Predicted CC proportion
Measured CC proportion
0.0
0.2
0.4
0.6
0.8
1.0

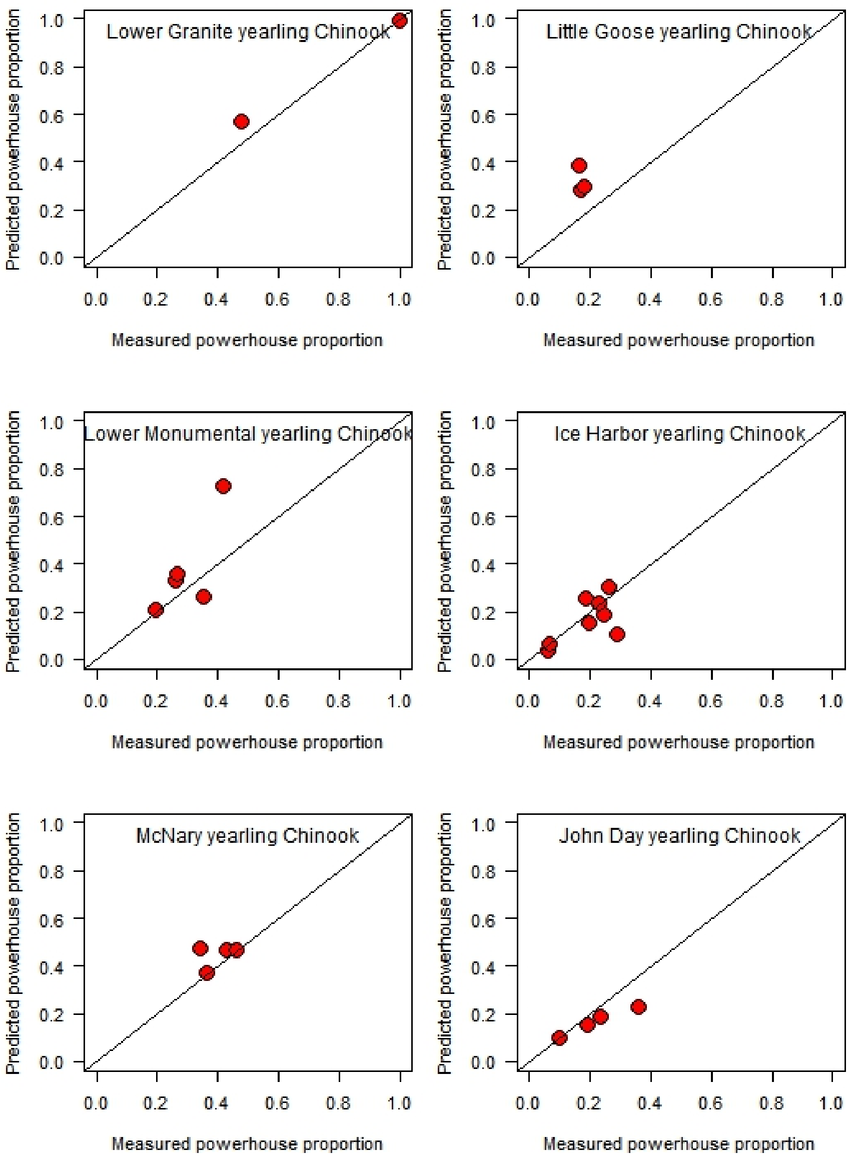
Yearling Chinook

Project	Intercept	Flow	PropSpill	Flow*PropSpill	Weir
Lower Granite	1.5651	-0.0055	-7.5713	0.0237	
Little Goose	0.8561	0.0071	-8.8597	0.0185	
Lower Monumental	-0.6181	0.0107	-7.3790	0.0176	-0.2556
Ice Harbor	-1.2703	0.0158	-5.0724		
McNary	0.8503	0.0028	-2.8578	-0.0092	
John Day	-0.9628	0.0062	-7.1784		-0.4641

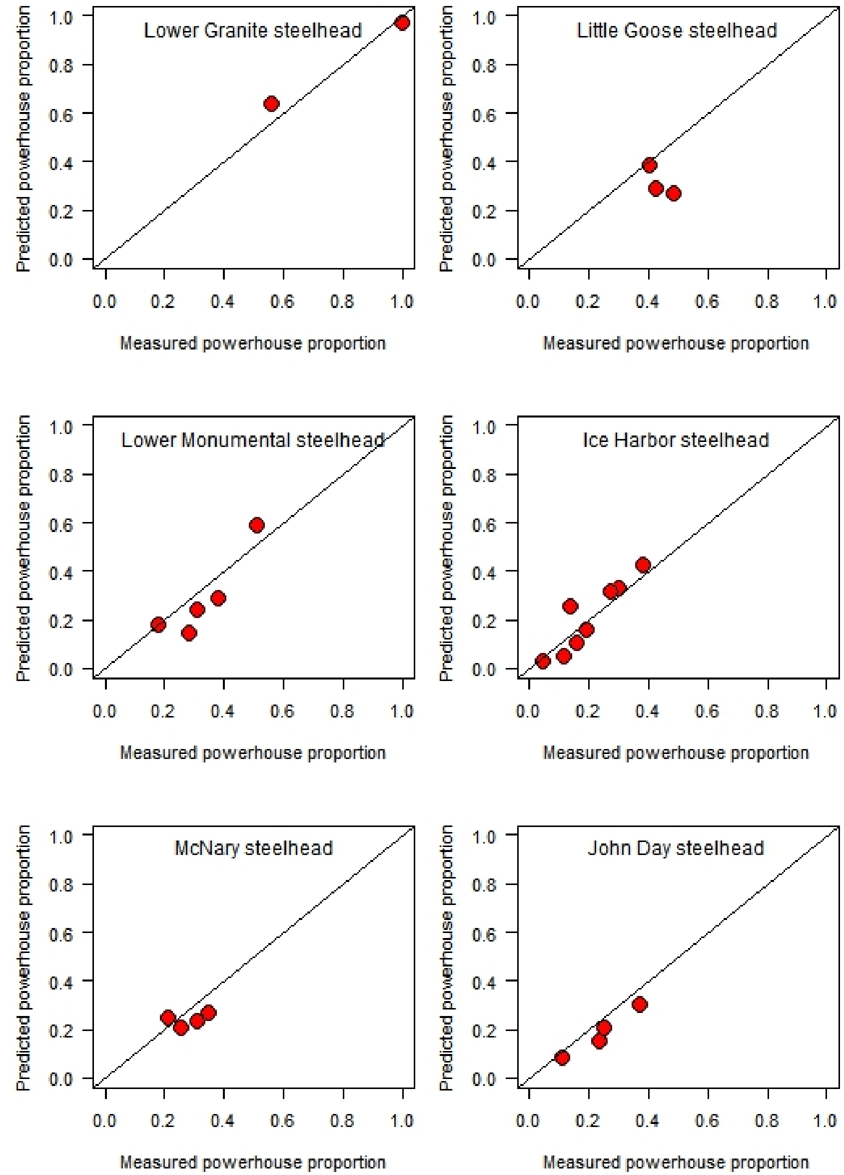
Steelhead

Project	Intercept	Flow	PropSpill	Flow*PropSpill	Weir
Lower Granite	2.4229	-0.0024	-7.5950	0.0249	-0.8620
Little Goose	0.4188	0.0160	-7.8669		
Lower Monumental	-0.8413	0.0161	-4.9650		-0.6506
Ice Harbor	-0.5026	0.0188	-7.0273		
McNary	-0.5389	0.0078	-5.1579	-0.0067	-0.1700
John Day	-1.3532	0.0096	-8.2799		-0.2759

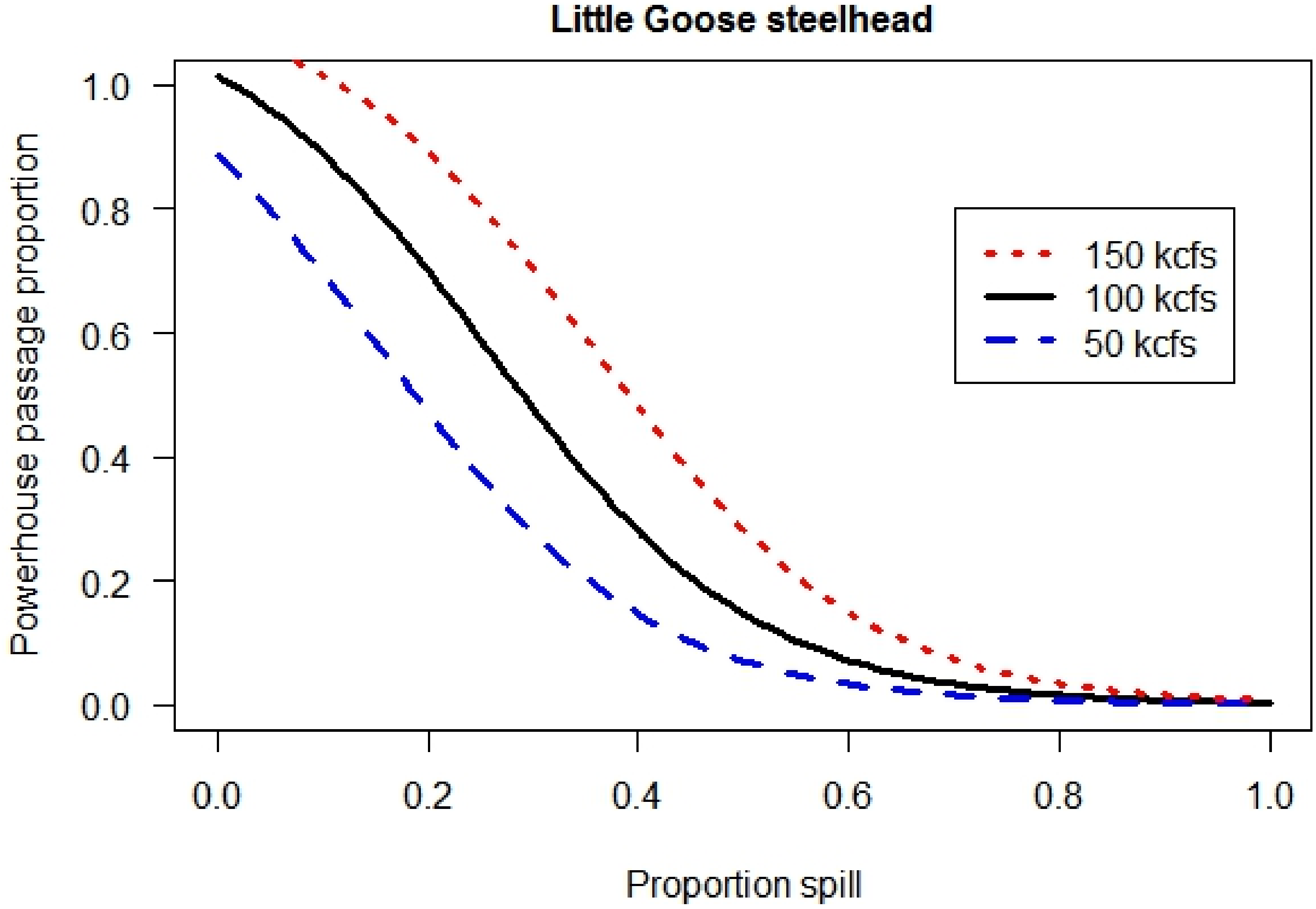
Yearling Chinook salmon



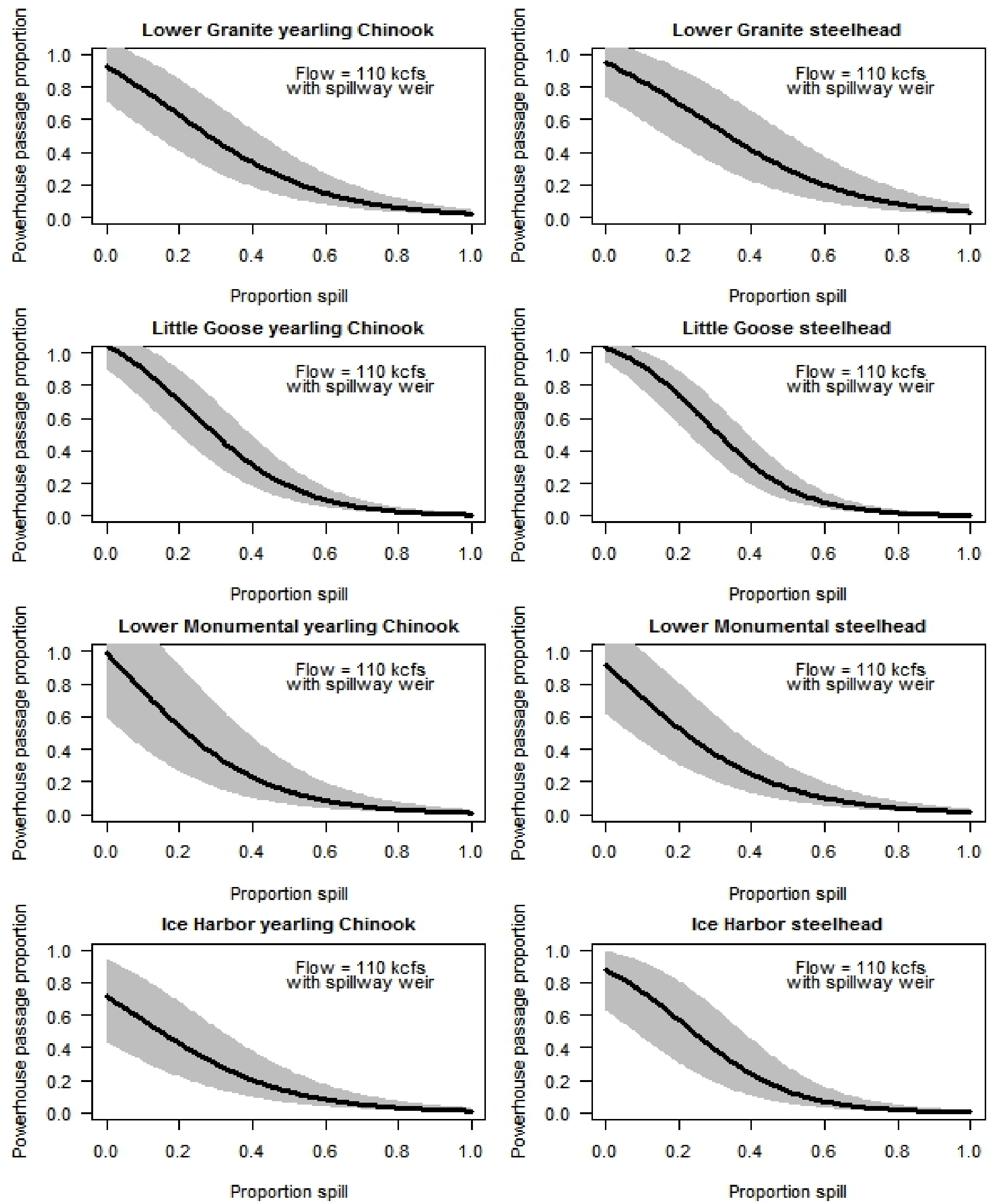
Steelhead



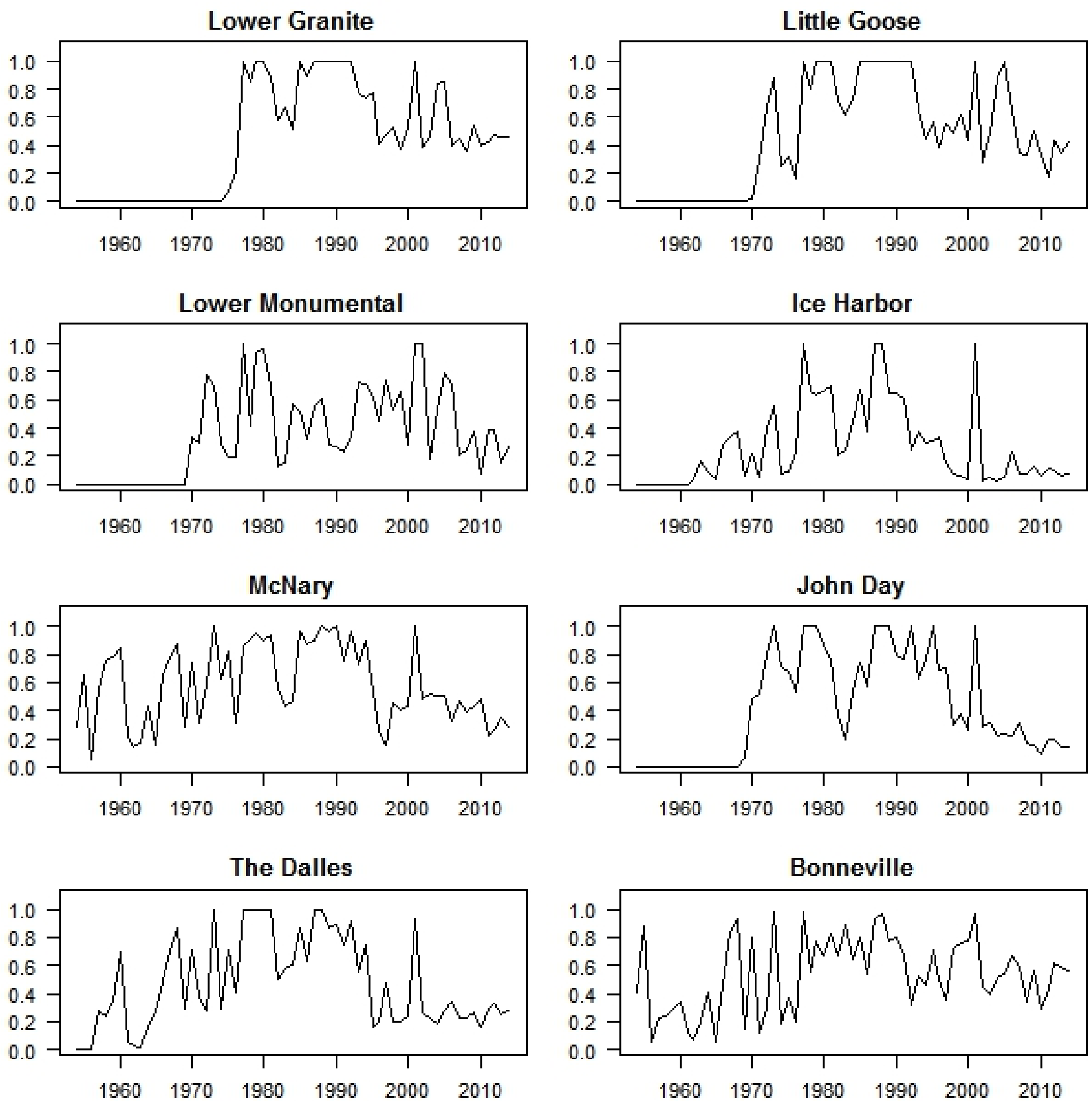
Effects of flow on powerhouse passage



Effects of spill proportions across dams



Powerhouse passage over time



Conclusions

CSS has responded to regional requests to develop improved measures of spill effects

Independent telemetry data validate powerhouse passage predictions

Spill, flow, and weirs affect powerhouse passage

Methodology provides useful index for contemporary and historical powerhouse passage rates

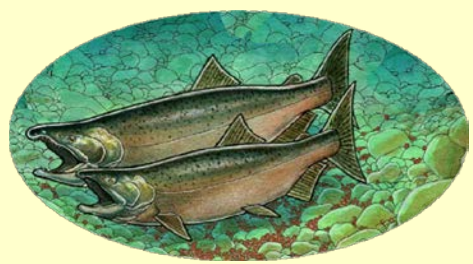
Comparative Survival Study

SAR Patterns: Snake and Mid-Columbia

Charlie Petrosky, Idaho Department of Fish and Game

2016 Annual Meeting

April 20,2016



Smolt-to-Adult Survival Rate (SAR) Patterns

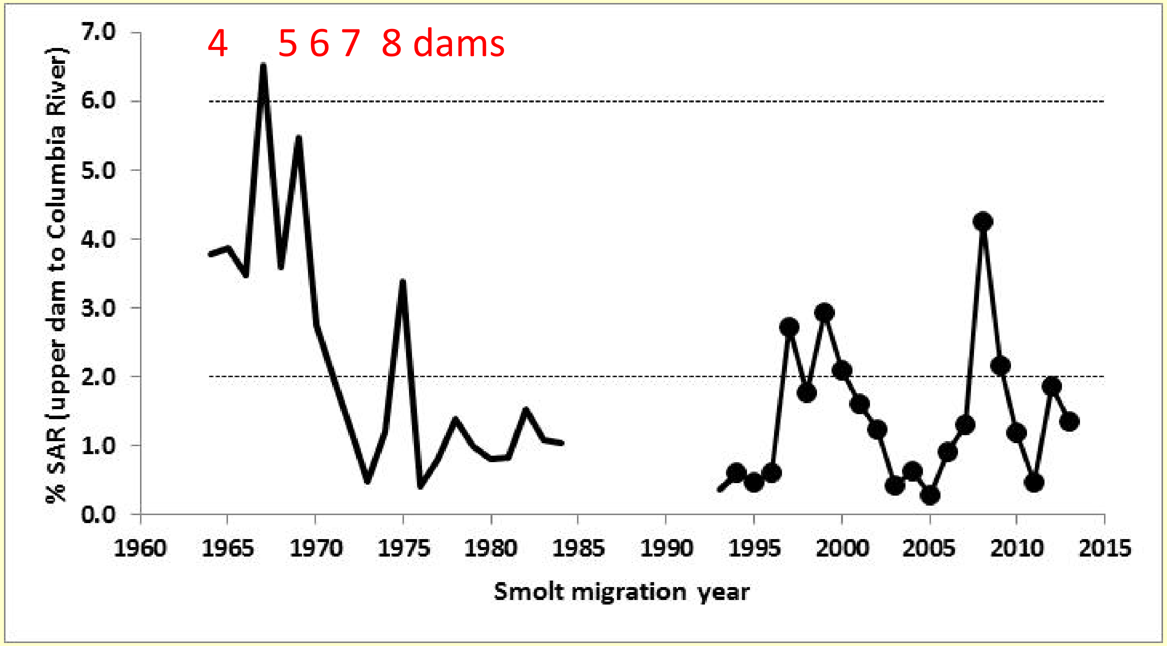
1. Snake River spring/summer Chinook, Steelhead and Sockeye:
   a. Annual SAR patterns
   b. SARs vs. NPCC 2%-6% SAR goals
   c. Transport vs. In-river SARs
2. Mid-Columbia spring Chinook and steelhead
   a. Annual SAR patterns
   b. SARs vs. NPCC 2%-6% SAR goals

Snake River Chinook & Steelhead SARs

Historic declines associated with FCRPS development in 60s and 70s

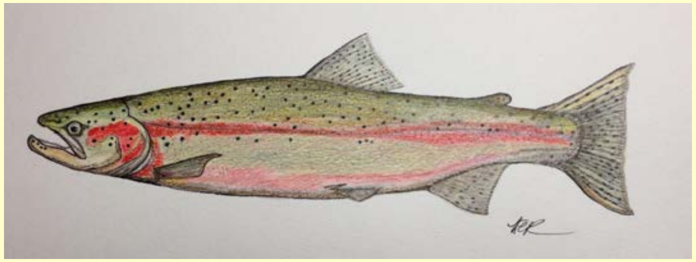
Marine conditions also varied

NPCC (2014) goal 2%-6% SAR, 4% ave.



NPCC strategy:

- identify effects of ocean conditions
- evaluate & adjust inland actions



Snake River Spring/Summer Chinook (8 dams)

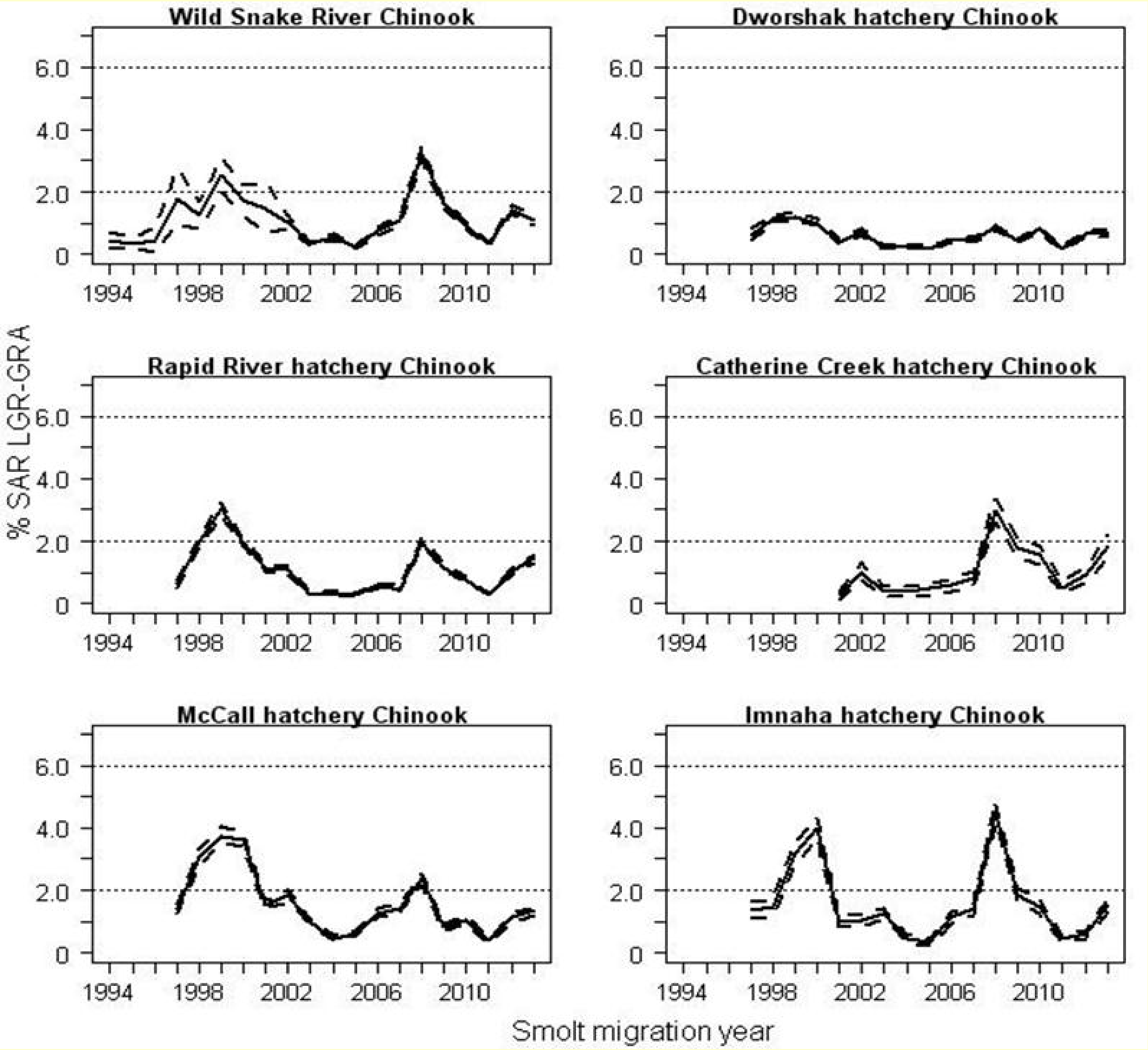
Wild & Hatchery SARs highly correlated (r ~ 0.8)

Wild SARs « NPCC goals of 2%-6% (4% average)

Wild SARs averaged 0.89% (1994-2013)

Wild SARs:

- > 2% in 2/20 years
- < 2% in 15/20 years ($p<0.05$)



Snake River Wild Chinook MPGs

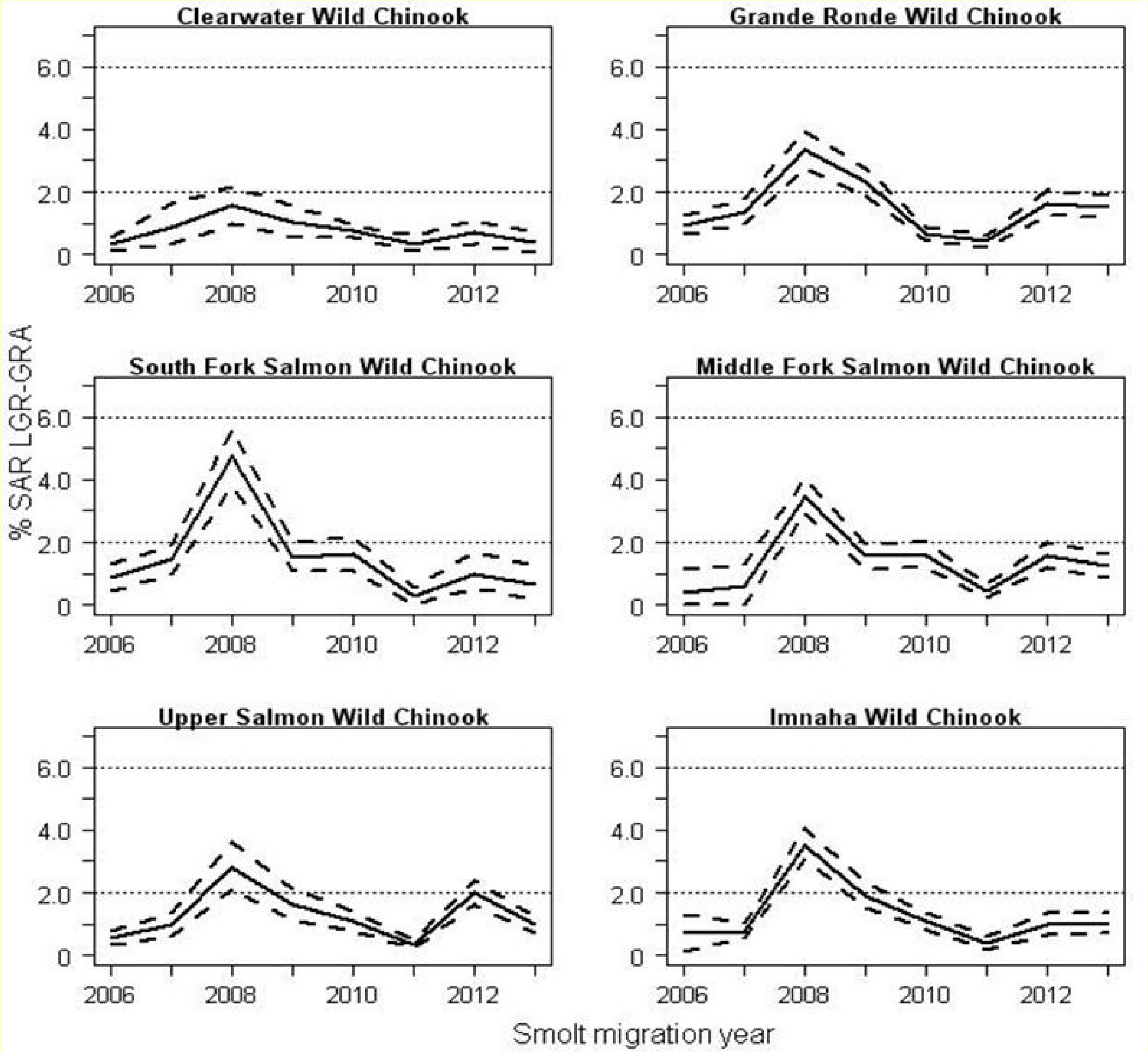
Major Population Group-specific wild SARs since 2006

Similar patterns:

- highest in 2008; low in 2010 and 2011

Generally similar magnitude:

- Clearwater MPG tended to be lower



Snake River Steelhead

Wild & Hatchery SARs moderately correlated

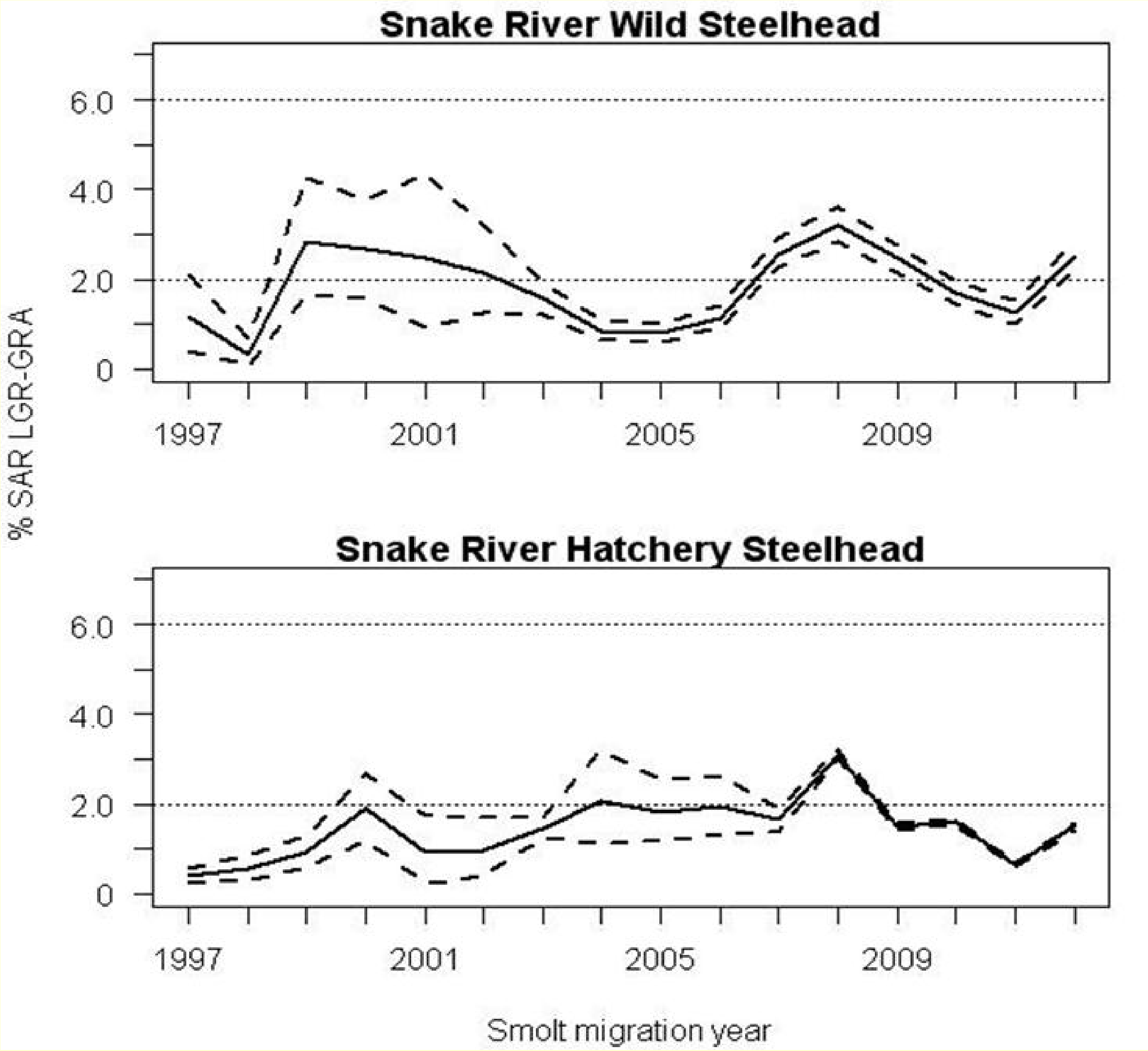
- Opportunistic hatchery group before 2008

Wild SARs << NPCC goals of 2%-6% (4% average)

Wild SARs averaged 1.6% (1997-2012)

Wild SARs:

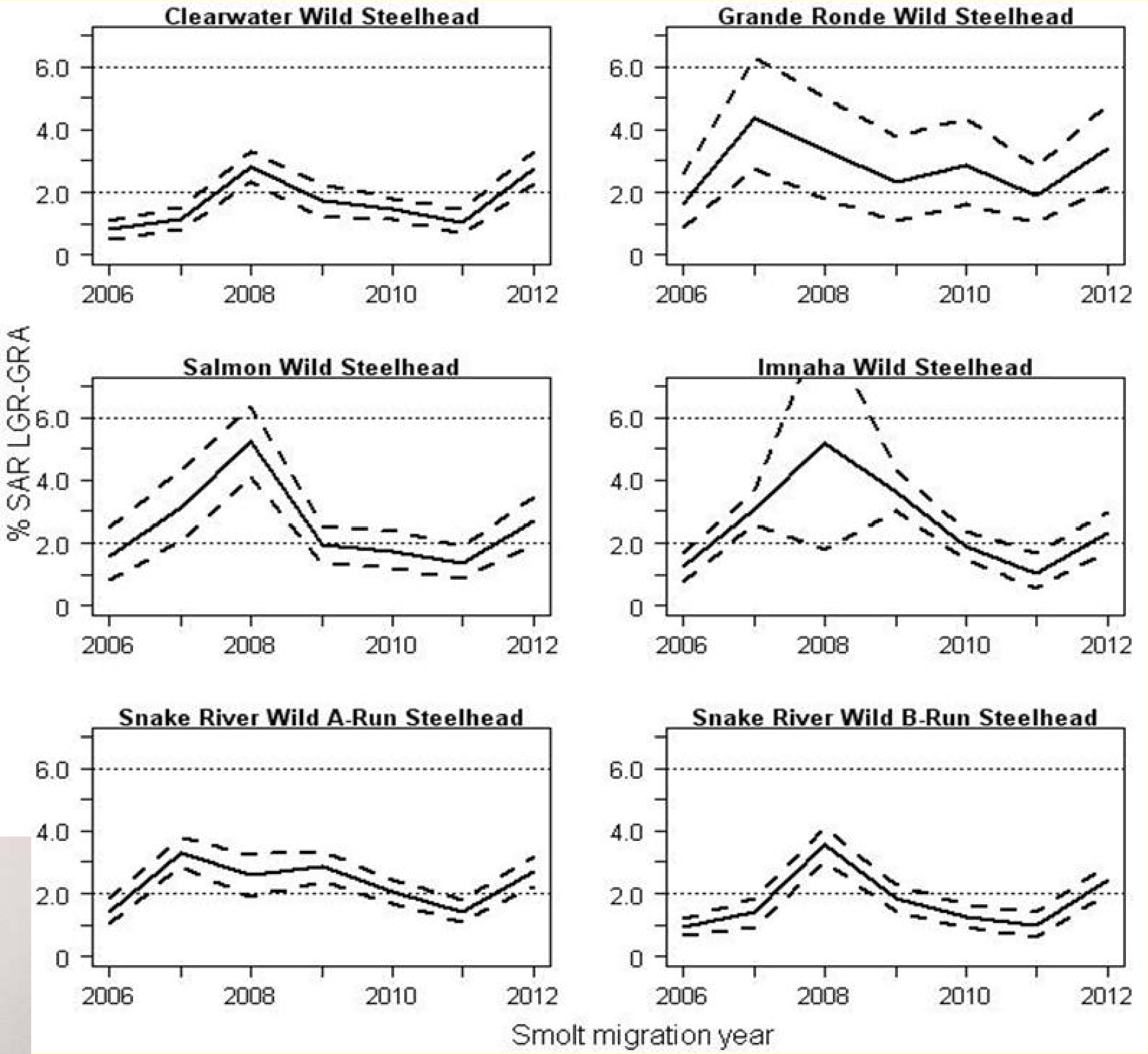
- > 2% in 4/16 years
- < 2% in 7/16 years ($p<0.05$)

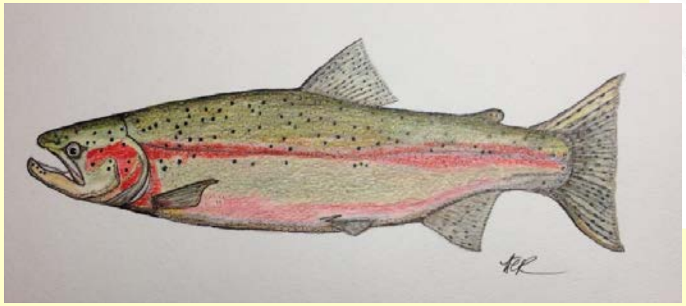


SR Wild Steelhead MPGs

MPG-specific and aggregate A-run & B-run SARs since 2006

Smaller sample sizes and less clear SAR patterns than for Chinook





Snake River Sockeye SARs

Extremely low natural sockeye abundance

- limited SAR data

Hatchery Sockeye SARs, 2009 & 2011-2013

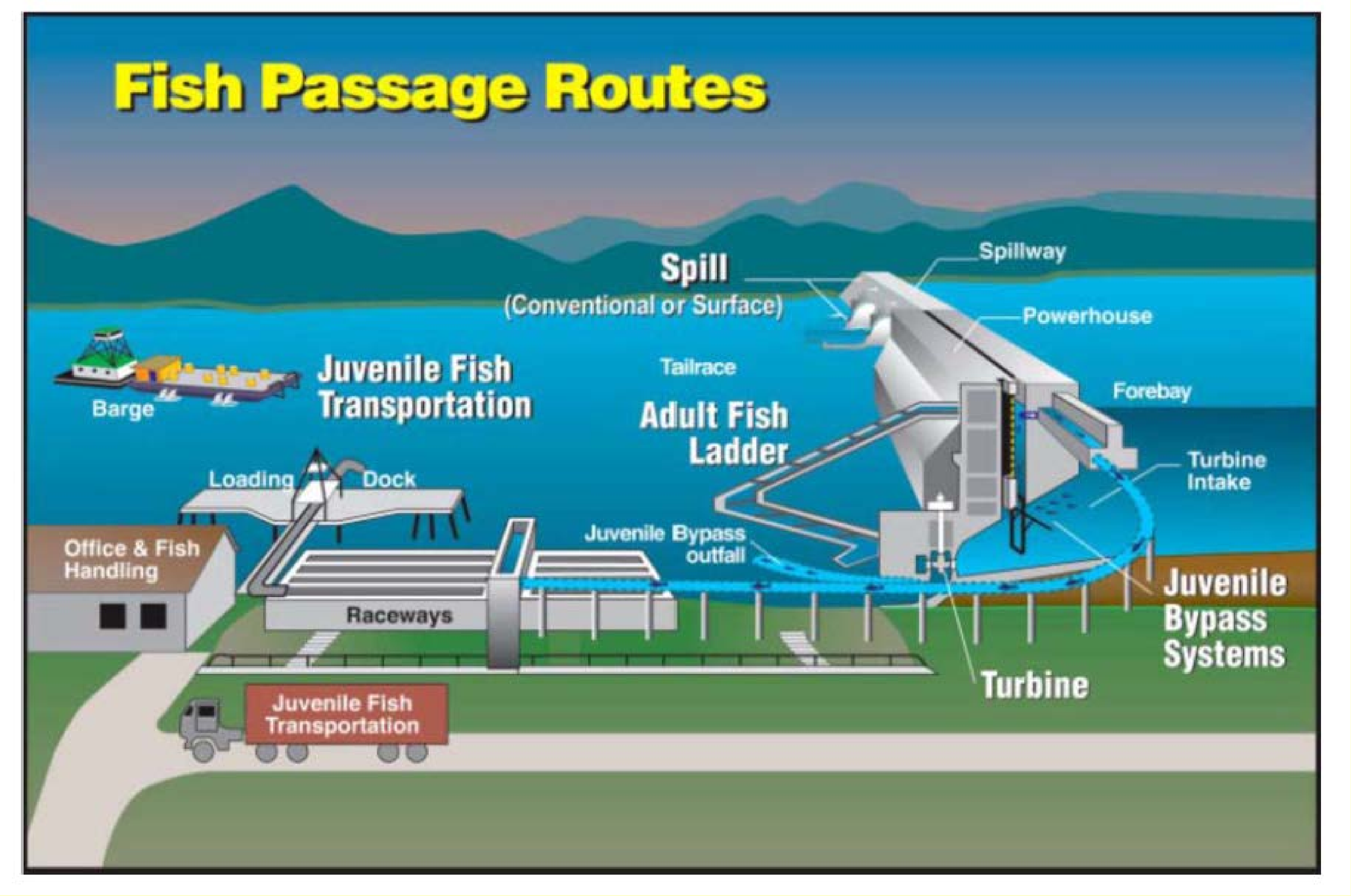
- Sawtooth and Oxbow hatcheries
- SARs ranged from 0.1% to 2.3%
- Oxbow SAR > Sawtooth SAR

Ongoing monitoring

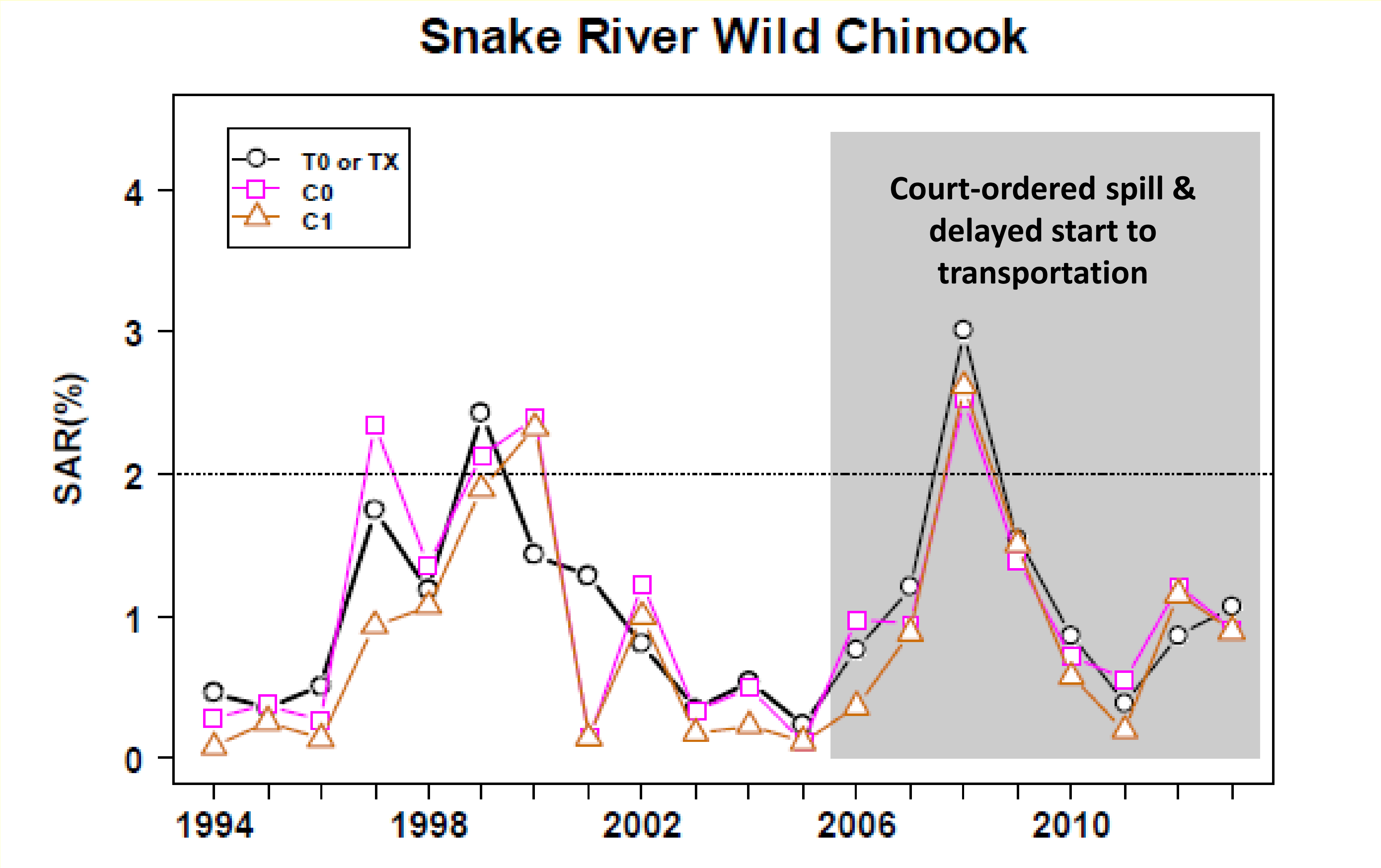
- Springfield Hatchery startup in 2015

SARs by Passage Route

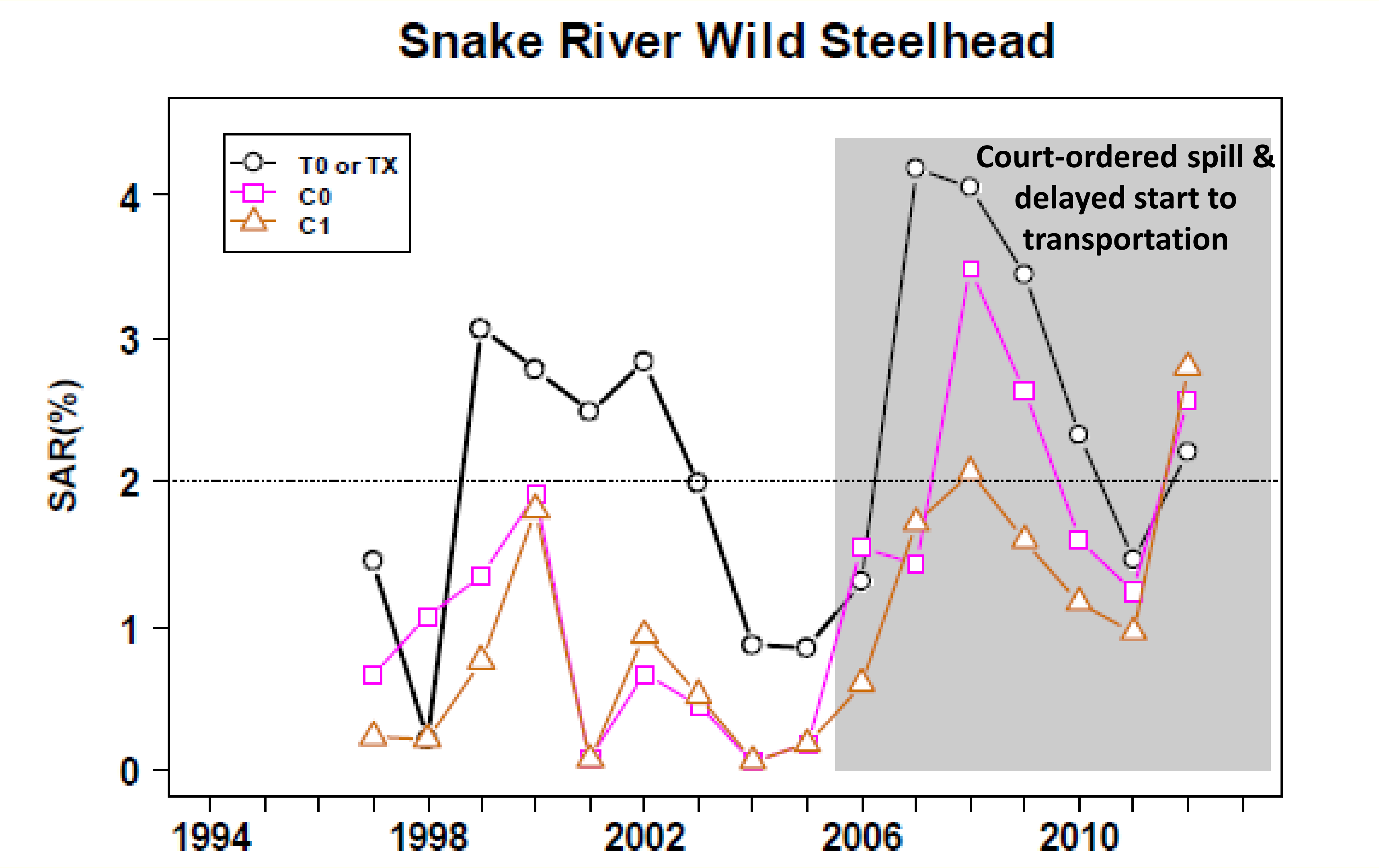
T = transported from LGR, LGS, LMN
C_0 = not collected or bypassed at LGR, LGS, LMN
C_1 = collected and bypassed at LGR, LGS, LMN



None of passage routes have been meeting NPCC 2%-6% SAR goals



None of passage routes have been meeting NPCC 2%-6% SAR goals

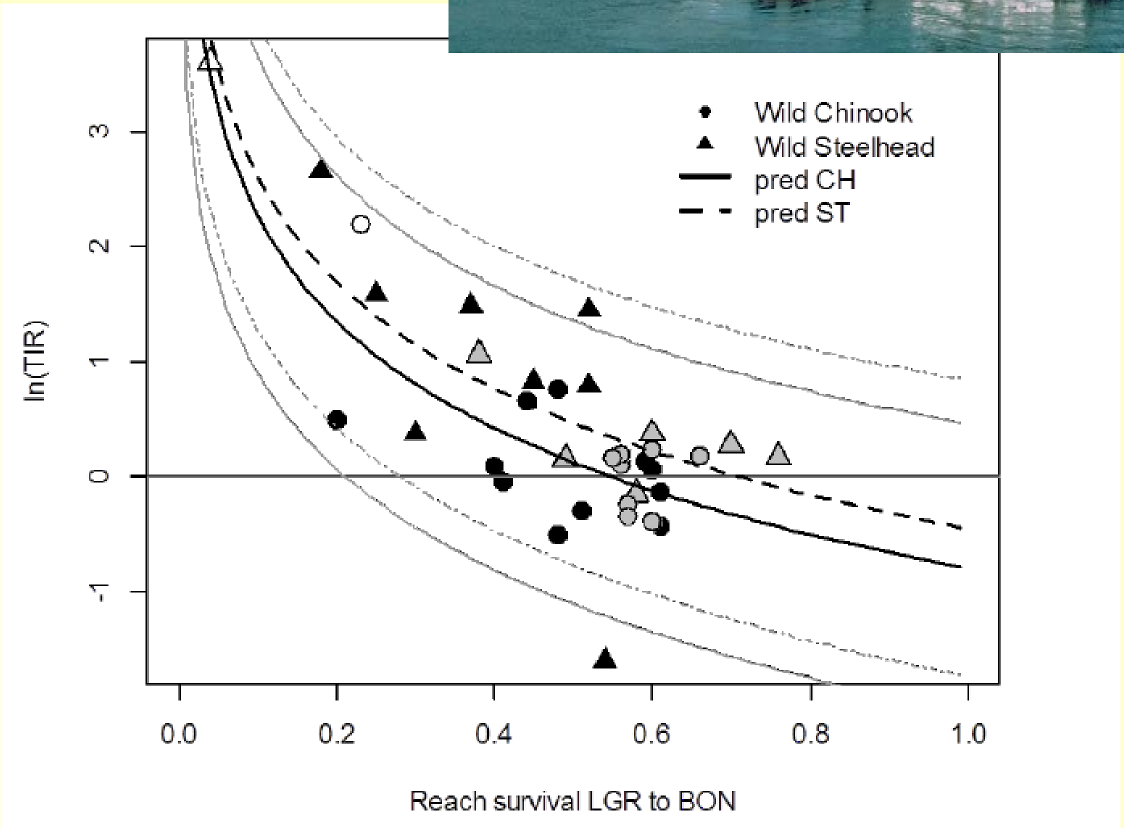


Relative Effectiveness of Transportation

Ratio of Transport SARs to In-river SAR (TIR) decreases with improved in-river conditions and juvenile survival

At S_R~0.6-0.7, relative "benefit" of transport becomes "detriment"

Potential to further improve in-river conditions and S_R



Mid-Columbia Spring Chinook (1-4 dams)

Mid-C wild & hatchery SARs highly correlated (r ~ 0.7)

Mid-C wild SARs 2.4–3.4 X Snake SARs; highly correlated with Snake (r ~ 0.7)

Mid-C wild SARs generally in range of NPCC goals (2000-13):

JDA averaged 3.9% SAR

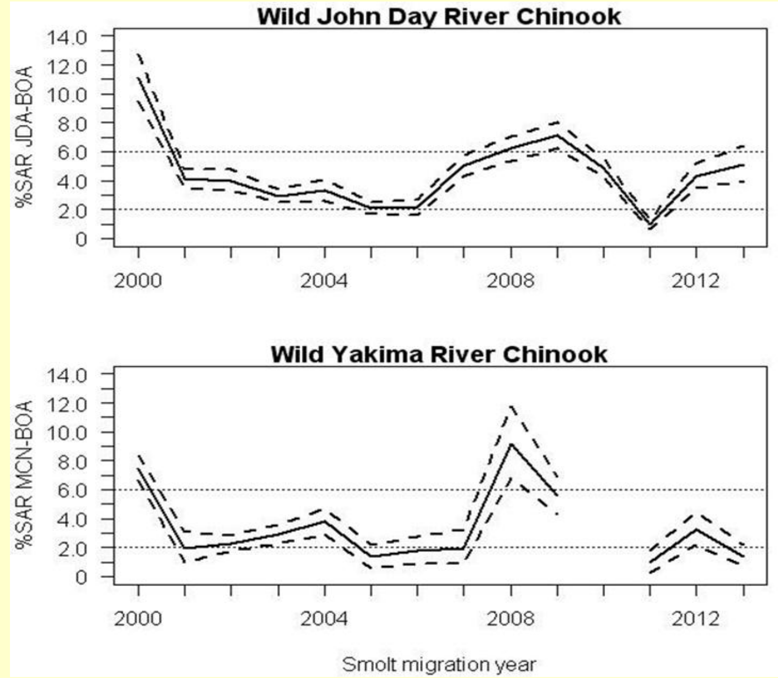
YAK averaged 2.7% SAR

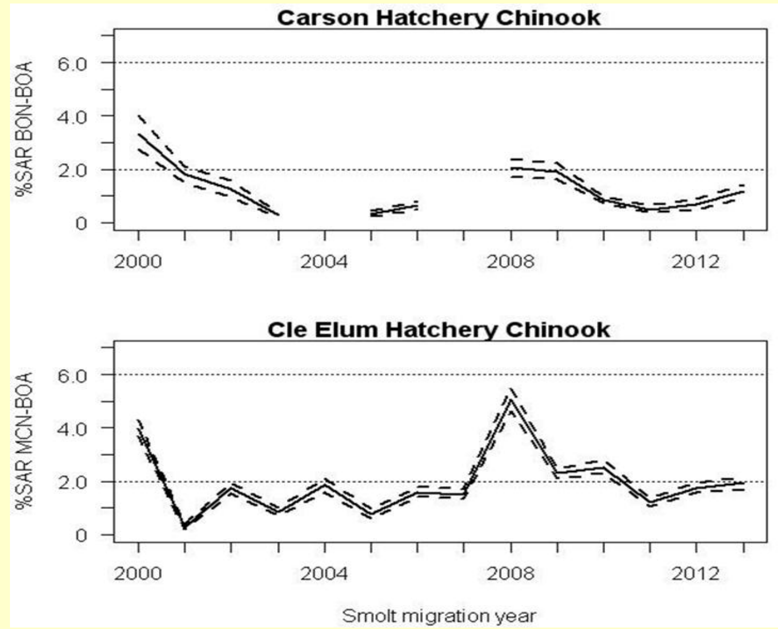
Wild SARs:

> 2% in 17/27 year-populations

< 2% in 2/27 year-populations

($p<0.05$)





Mid-Columbia Steelhead

Mid-C wild SARs 2.3 X Snake SARs; highly correlated with Snake (r ~ 0.7)

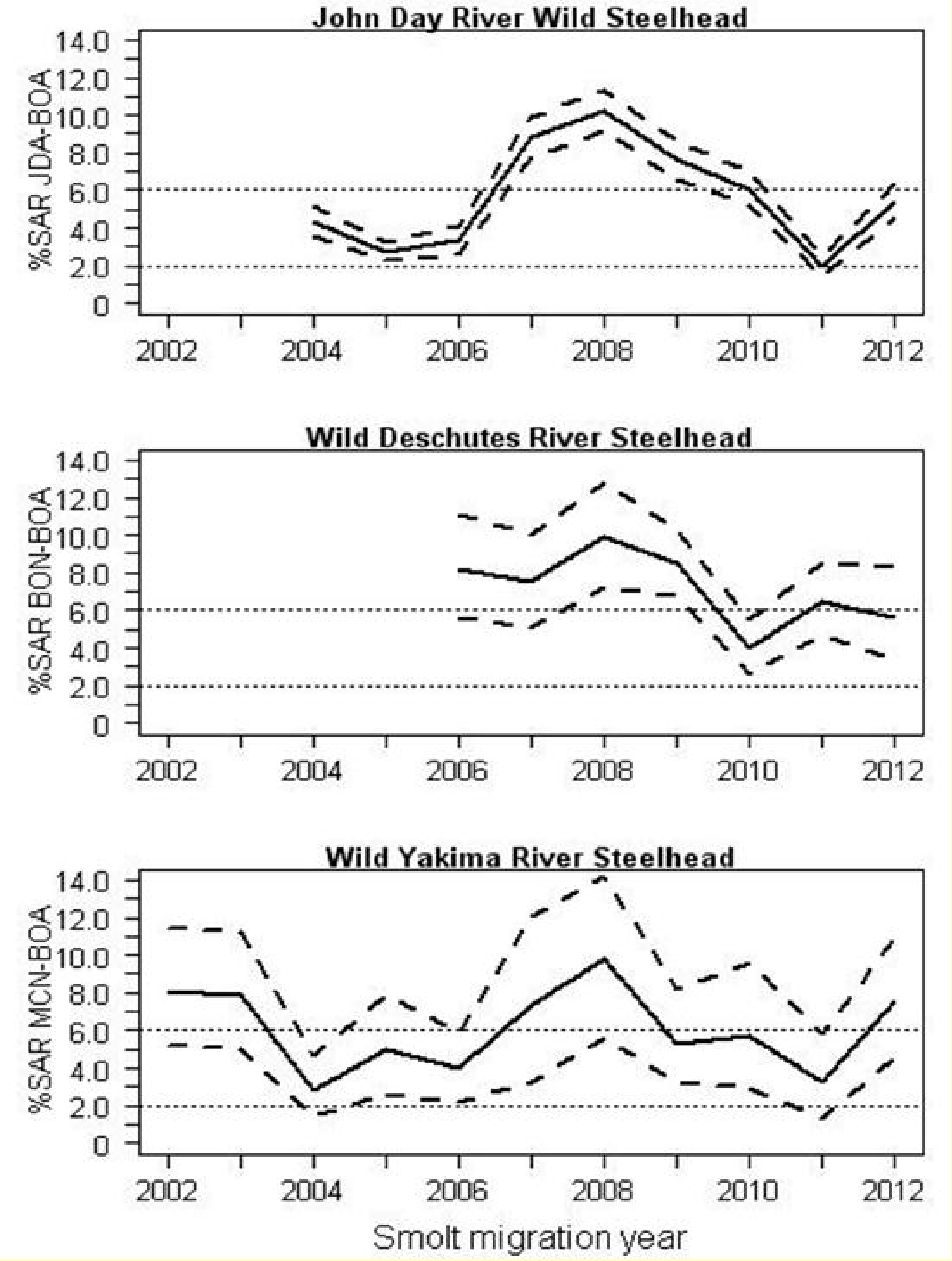
No Mid-C hatchery PIT tag groups

Mid-C wild SARs met or exceeded NPCC goals (2002-2012):

- JDA averaged 5.0% SAR
- DES averaged 6.9% SAR
- YAK averaged 4.7% SAR

Wild SARs:

- > 2% in 23/27 year-populations
- < 2% in 0/27 year-populations (p<0.05)



Summary

- Overall SARs of Snake River wild spring/summer Chinook and steelhead << NPCC 2%-6% SAR goals

- SR hatchery & wild Chinook SARs highly correlated; hatchery & wild steelhead SARs moderately correlated

- Relative efficacy of transport decreases with improved in-river conditions and juvenile survival
    - Potential to improve in-river conditions (e.g., spill, WTT)

Summary

- Mid-C wild spring Chinook and steelhead SARs generally meeting NPCC SAR goals

- Mid-C wild spring Chinook and steelhead SARs
  - 2.3X – 3.4X greater than Snake River wild SARs
  - highly correlated with Snake River wild SARs

- Upper Columbia monitoring poses special challenges:
  - Robin Ehlke – next presentation…

SARs and Juvenile Metrics of Upper Columbia Stocks

Robin Ehlke

CSS Annual Meeting April 20, 2016

CSS Objectives: Upper Columbia

- Establish long term survival estimates over the full life-cycle of upper Columbia stocks
- Develop Smolt to Adult Return rates (SARs) from the upper most dam encountered
- Develop estimates of ocean survival rates
- Use additional mark groups as they become available

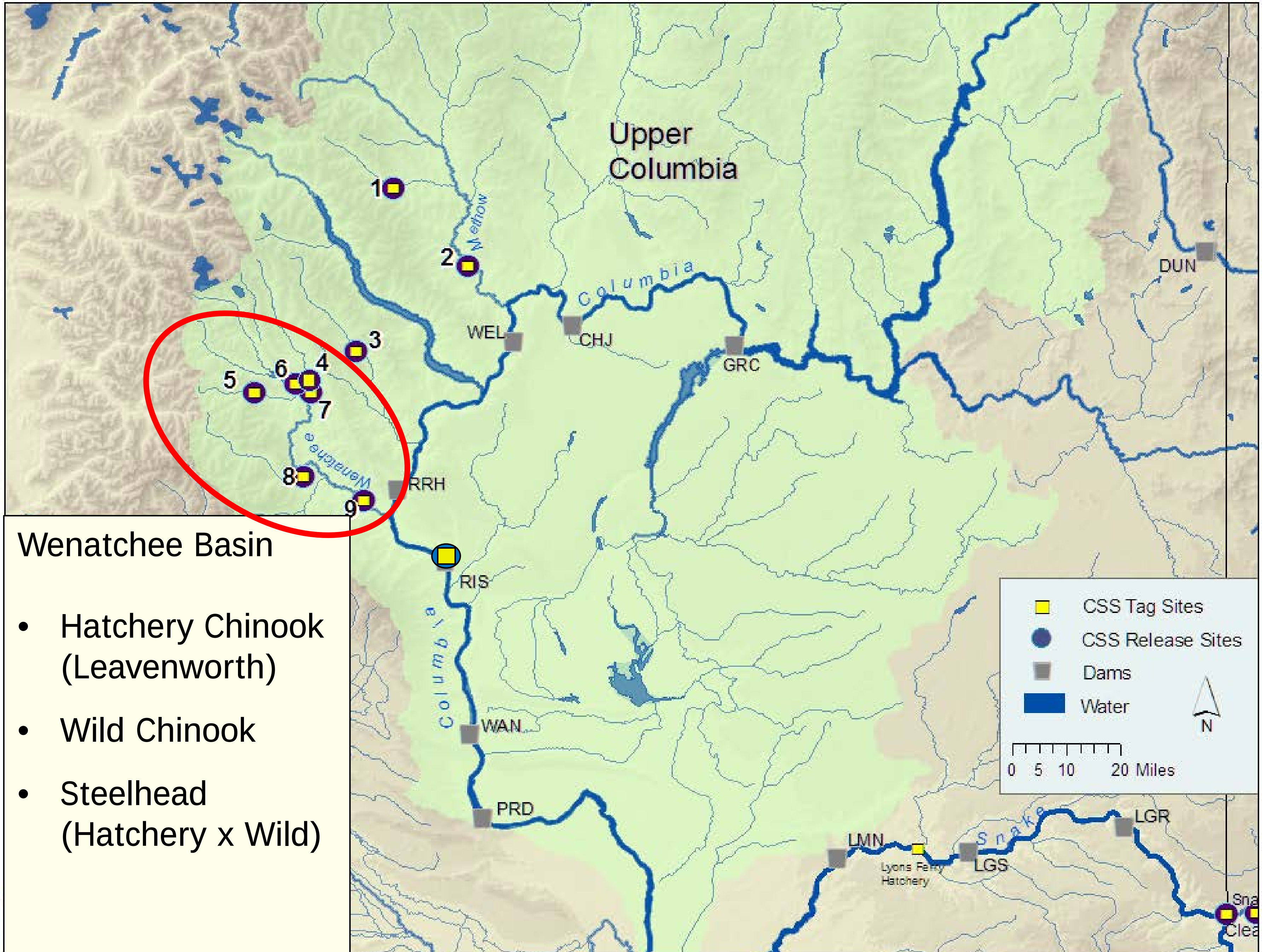
CSS Challenges: Upper Columbia

- Low abundance of smolts makes it difficult to tag enough fish within a specific area
  - Limited hatcheries, traps and weirs
  - Result is aggregate tag groups

- Juvenile detection sites are minimal
  - SARs and survival estimates may not account for full life history

Upper Columbia Mark Groups

- **Five groups – basin and rear-type specific**
  - Wenatchee hatchery spring Chinook (Leavenworth)
  - Wenatchee wild Chinook
  - Wenatchee hatchery/wild cross Steelhead
  - Entiat-Methow aggregate wild Chinook
  - Wenatchee-Entiat-Methow aggregate wild Steelhead
- **Four groups - not basin or rear type specific**
  Tagged at Rock Island Dam; hatchery/wild aggregates
  - Yearling Chinook
  - Subyearling Chinook
  - Steelhead
  - Sockeye (New in 2014)

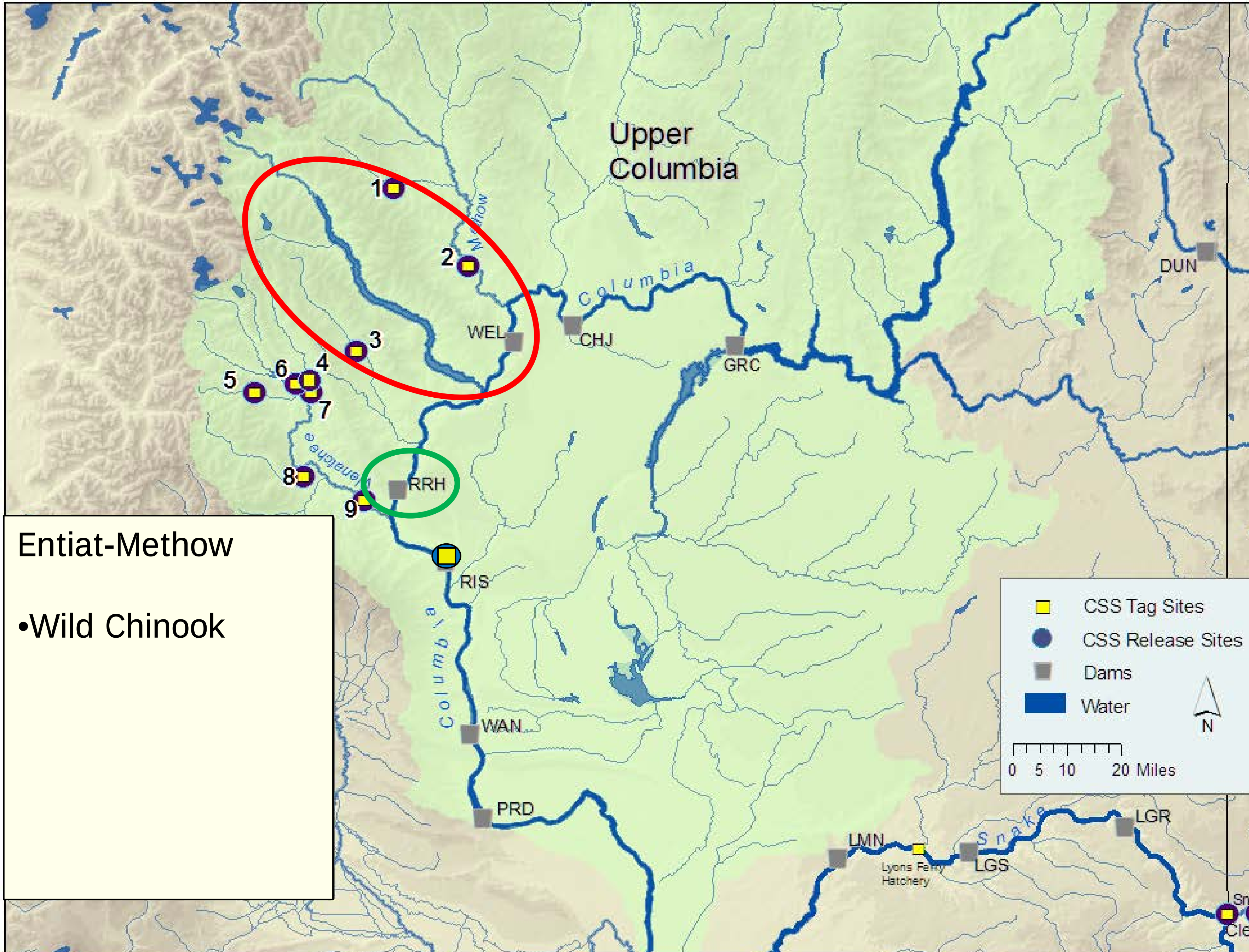


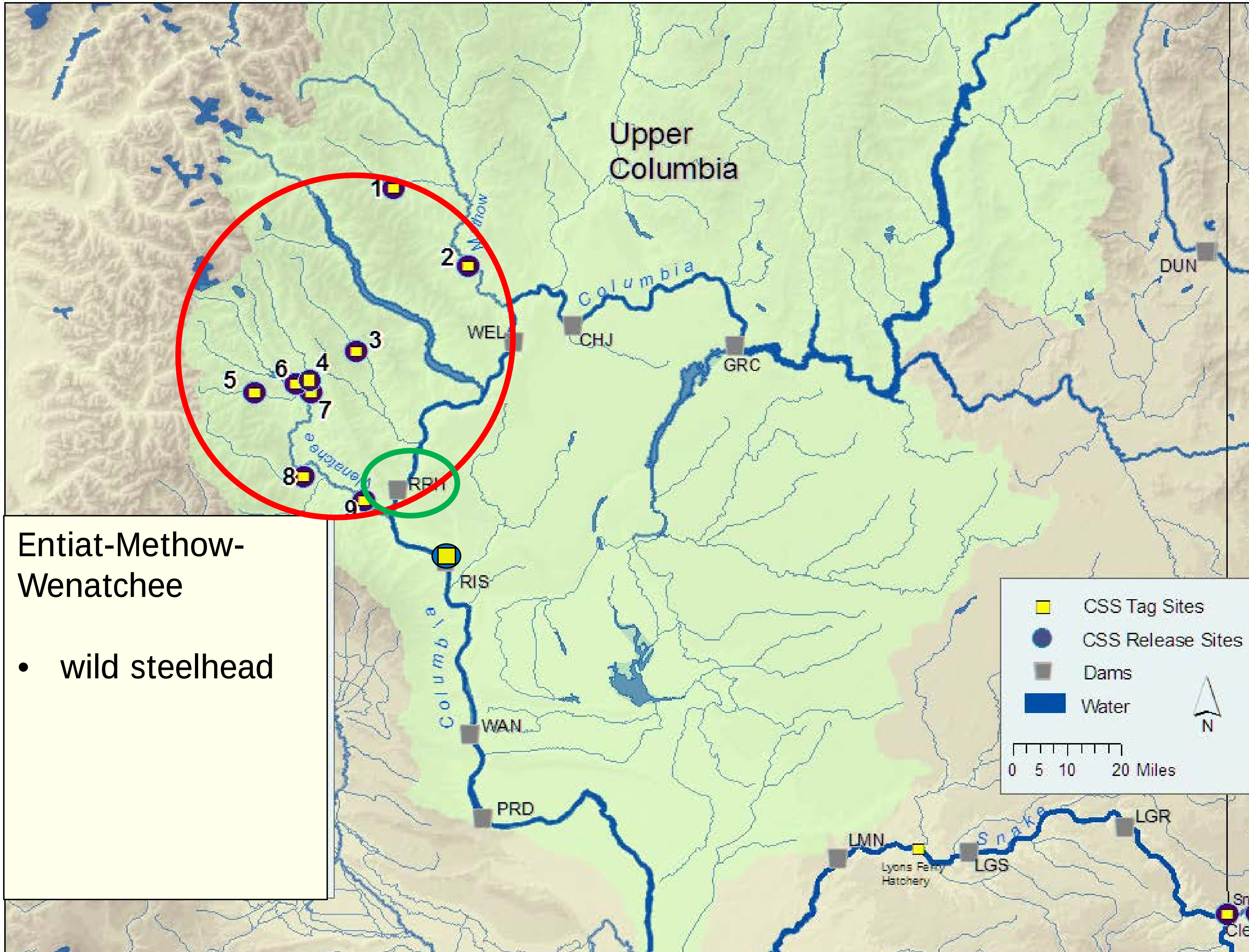
Wenatchee Basin

- Hatchery Chinook (Leavenworth)
- Wild Chinook
- Steelhead (Hatchery x Wild)

Entiat-Methow

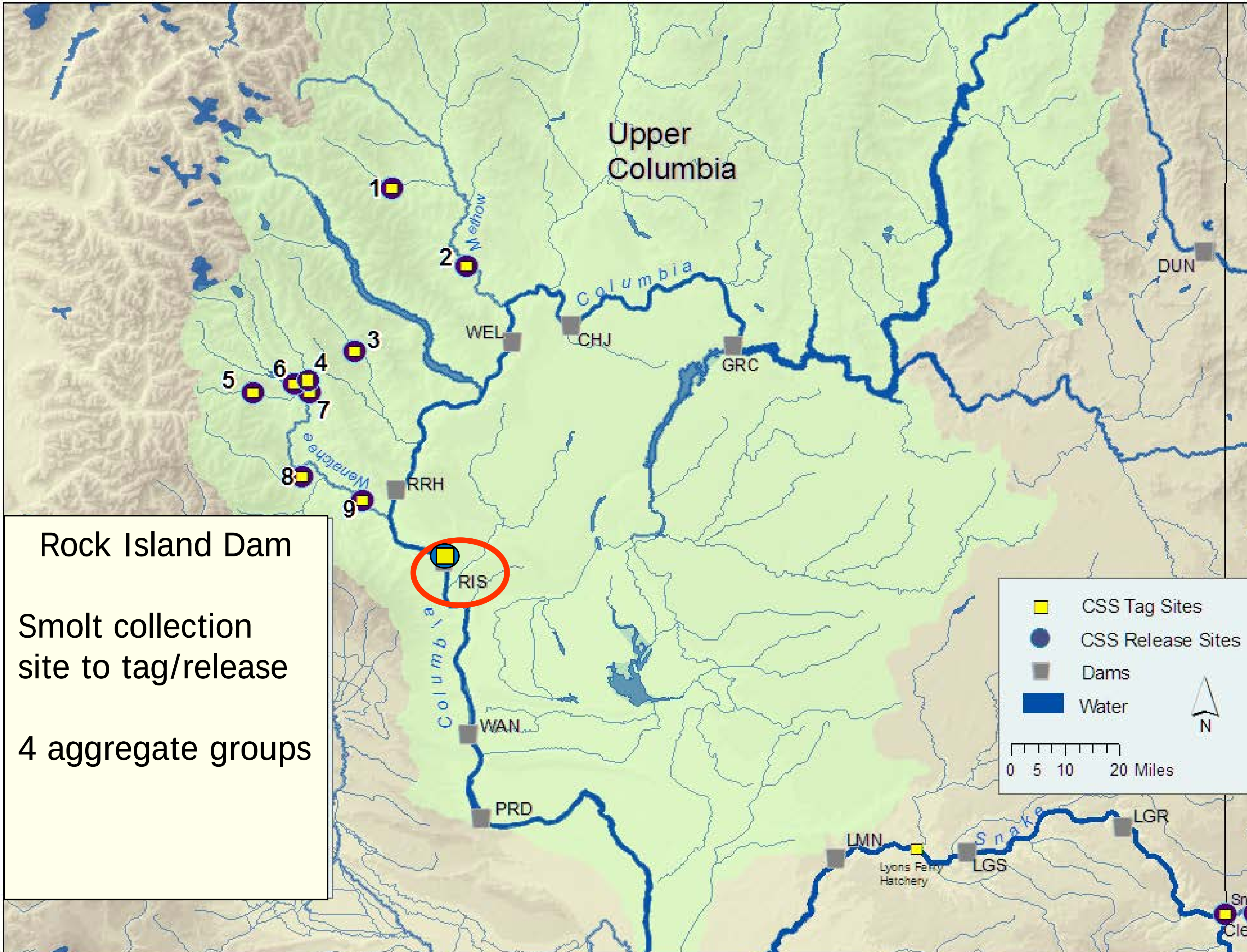
- Wild Chinook





Entiat-Methow-Wenatchee

- wild steelhead



Rock Island Dam
Smolt collection site to tag/release
4 aggregate groups
Upper Columbia
Methow
Columbia
Wenatchee
Snake
1
2
3
4
5
6
7
8
9
WEL
CHJ
GRC
RRH
RIS
WAN
PRD
DUN
LMN
LGS
LGR
Lyons Ferry Hatchery
CSS Tag Sites
CSS Release Sites
Dams
Water
N
0 5 10 20 Miles

Rock Island to McNary Juvenile Metrics:

- RIS – MCN distance is ~150 miles with 2 dams in between

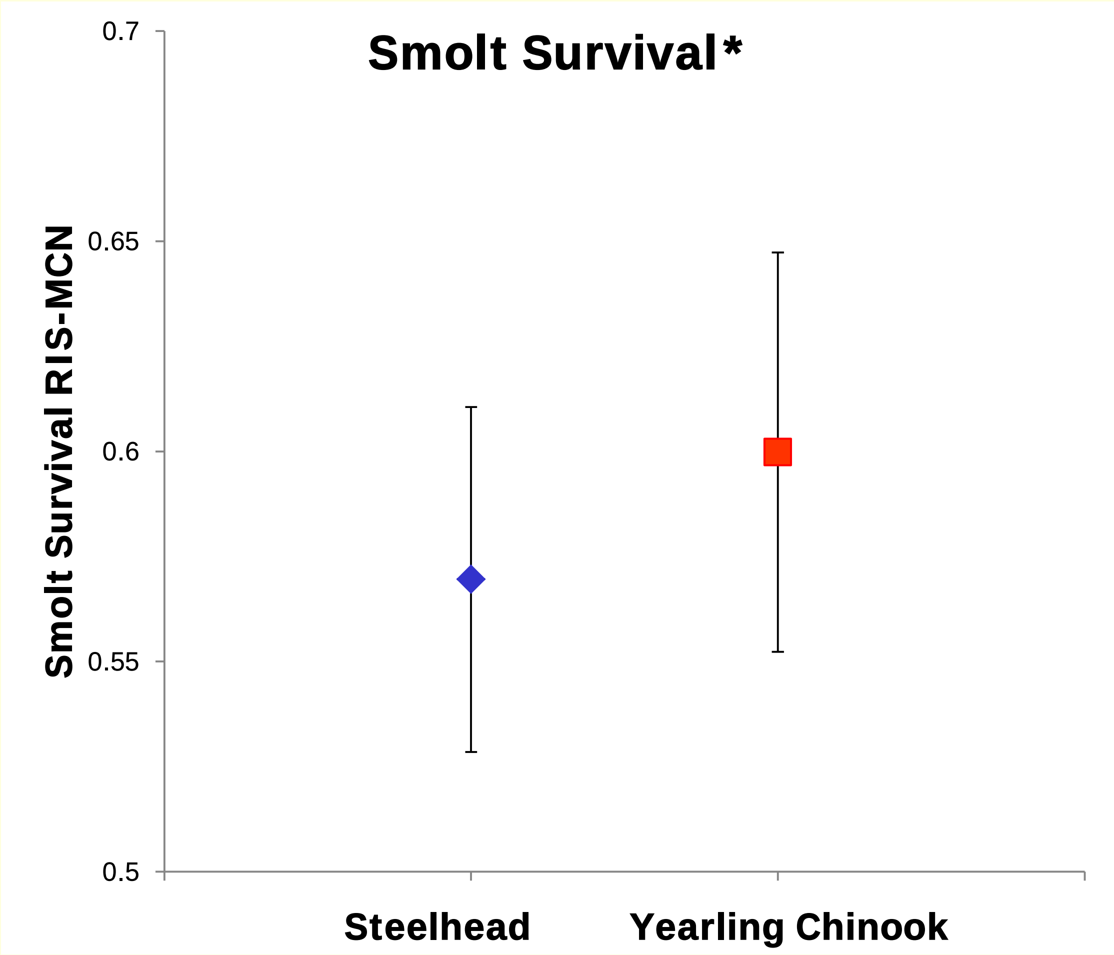
- Juvenile passage metrics
  - Travel time
  - Instantaneous mortality
  - Survival

- Report the analyses of passage metrics relative to environmental variables

Rock Island to McNary:
Juvenile Metrics/Environmental Variables

- Fish Travel Time:
  - Decreased with higher flow and with higher Julian date
- Instantaneous Mortality:
  - Decreased for Chinook as spill levels increased at Wanapum and Priest Rapids
  - Increased for steelhead with increase in Julian date
- Reach Survival:
  - Increased with higher flow and spill

Rock Island to McNary
Juvenile Survival



- Typically both species' survival is less than 60%.
- A large component of life-cycle is not represented in MCN to BON SARs

* Weighted Average of 2004 – 2014 survival estimates with 95% Confidence Intervals

Upper Columbia SARs

MCN to BON (~150 miles; MY 2000)

- Longest time series, shortest juvenile reach
- Basin and rear-type specific

RIS to BON (~300 miles; MY 2000)

- Marked and released at Rock Island Dam
- Not basin or rear-type specific

RRE to BON (~330 miles; MY 2008)

- Shortest time series, longest juvenile reach
- Basin and rear-type specific
- Not applicable for stocks below RRE

McNary to Bonneville SARs

- MCN to BON SARs do not include or account for any juvenile mortality occurring upstream of McNary Dam
- Lack of juvenile detection sites and small tag groups often preclude us from calculating SARs from the uppermost dam
- As an example, the SARs for Wenatchee stocks would be ~ 58% of reported if RIS to MCN juvenile survival were taken into account

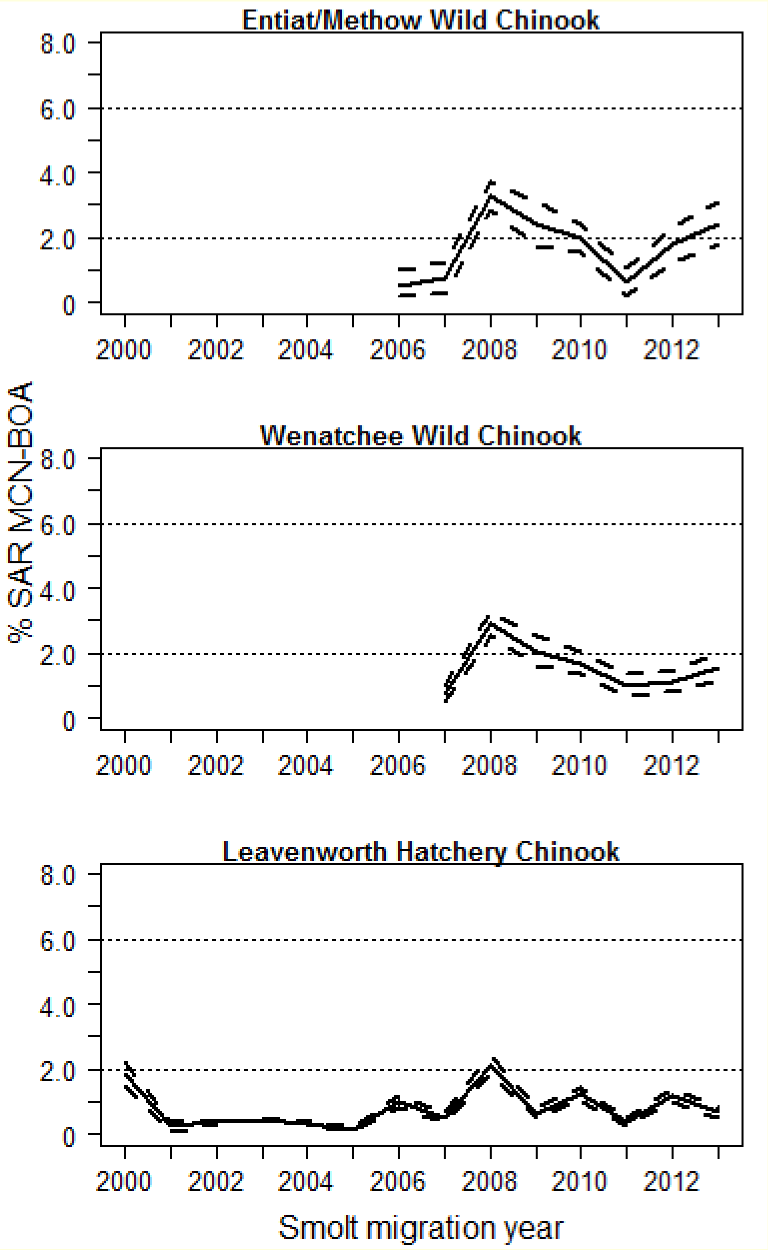
MCN to BON SARs Chinook

Entiat / Methow Wild Chinook
- SARs averaged 1.4% (0.5%-3.2%)
- exceeded 2% in 2008 and 2009

Wenatchee Wild Chinook
- SARs averaged 1.5% (0.8%-2.9%)
- exceeded 2% in 2008 and 2009

Wenatchee Hatchery Chinook
- SARs averaged 0.6 (0.2% - 2.1%)
- exceeded 2% in 2008

All Groups
- Upper reaches not included in SARs
- 2013 data does not include 3-salt fish



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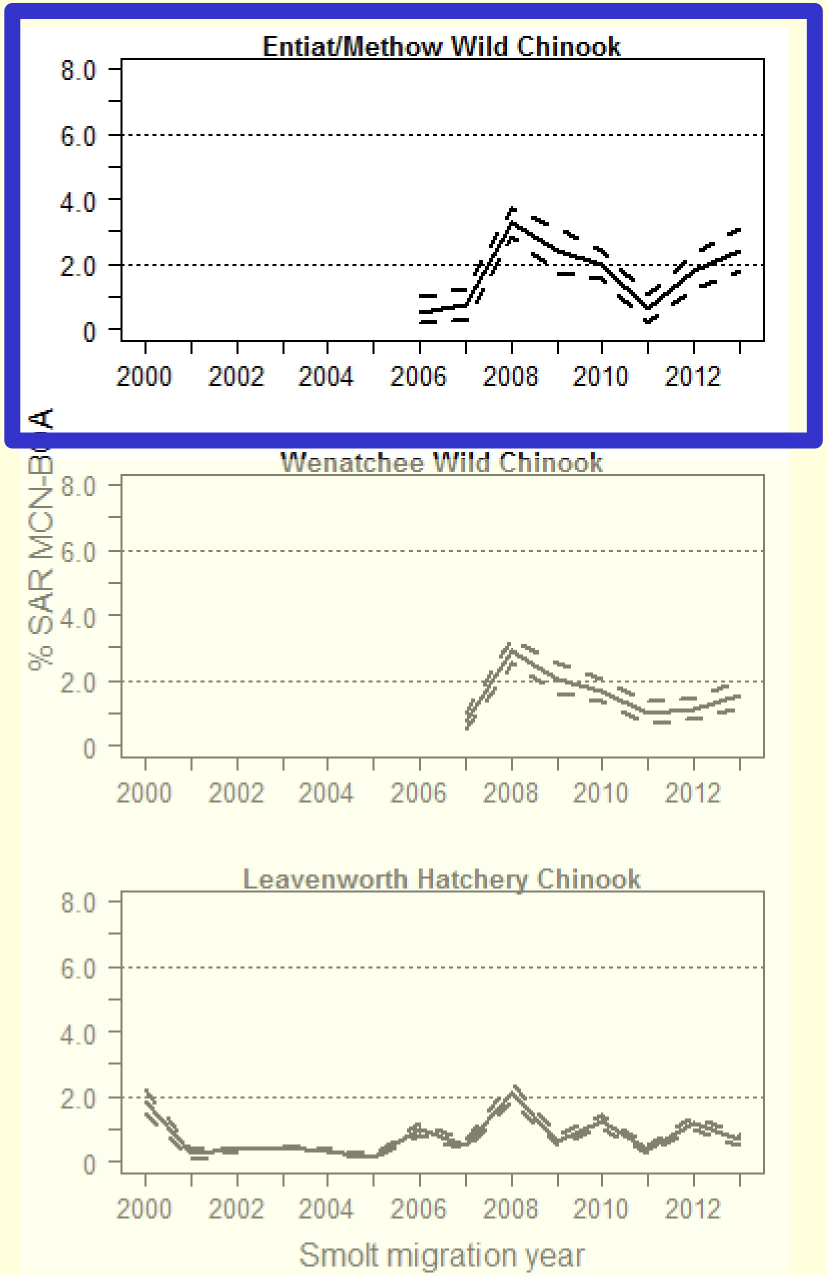
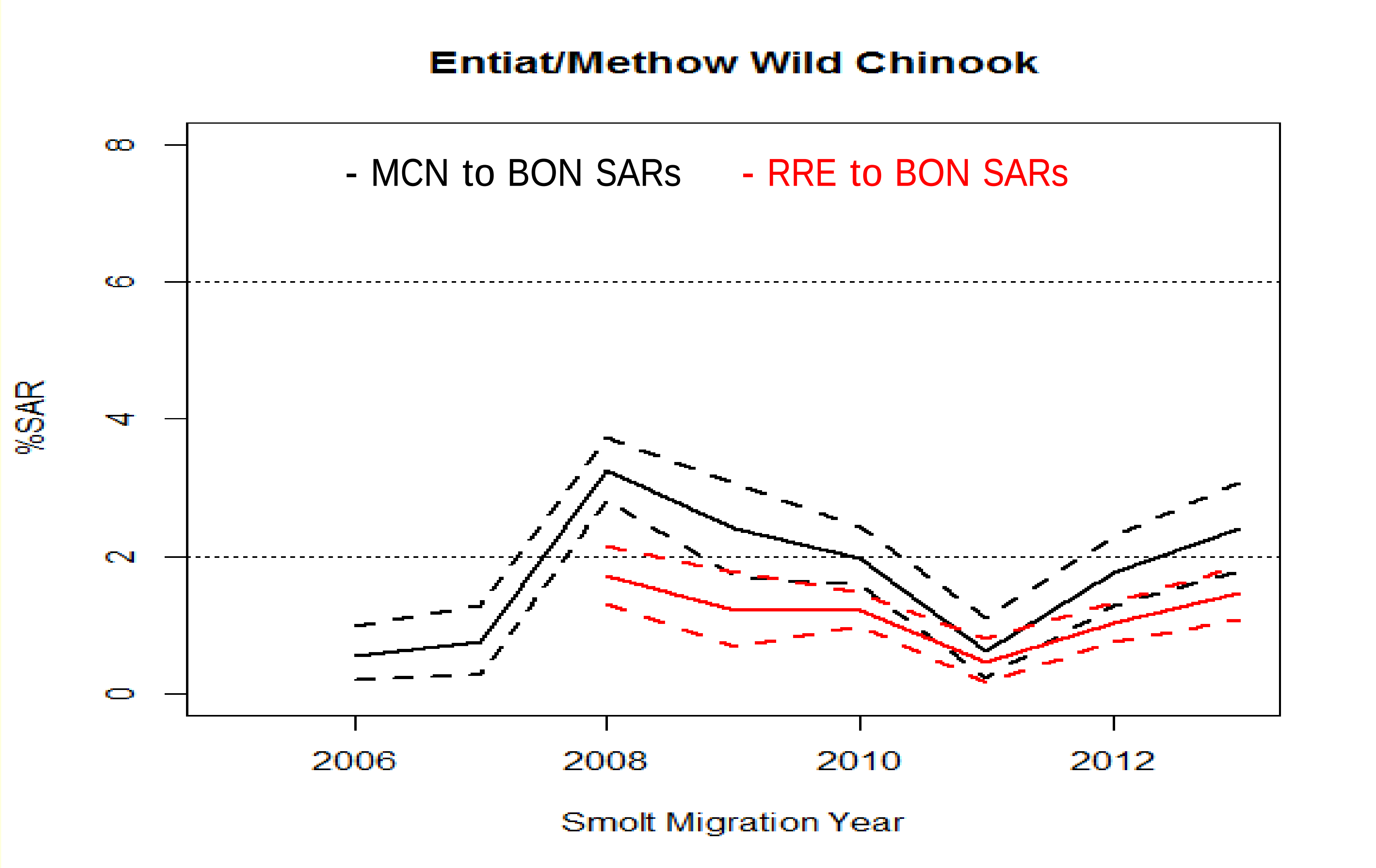




- SARs for RRE to BON are much lower than those calculated for MCN to BON
- SARs developed for the uppermost dam are less than those that start at MCN

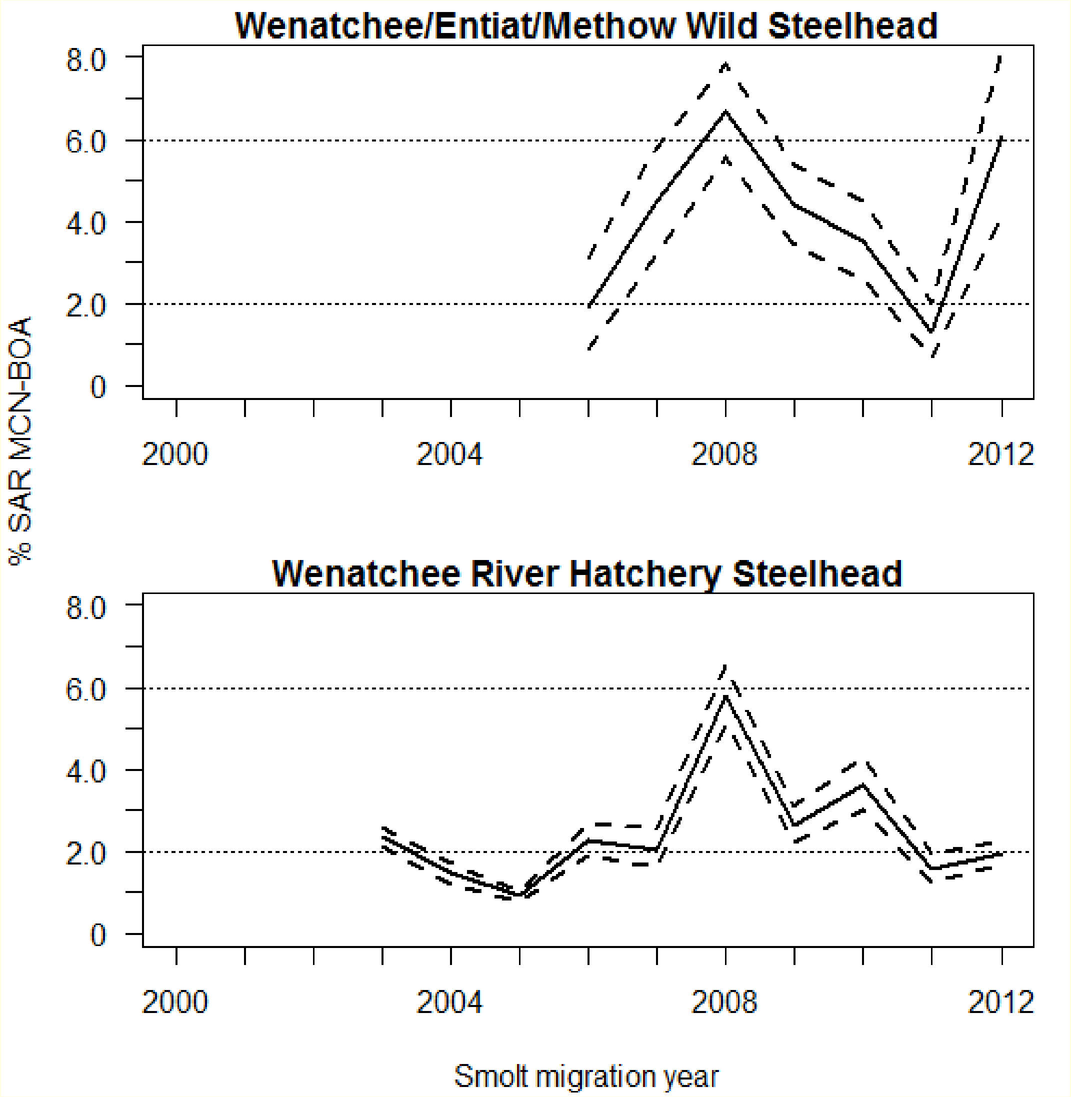
MCN to BON SARs Steelhead

Wild Steelhead

- Aggregate
- Short time series
- SARs averaged 3.5%

Hatchery Steelhead

- Wenatchee River
- Time series a little longer
- SARs averaged 2.2%



MCN to BON SARs Steelhead

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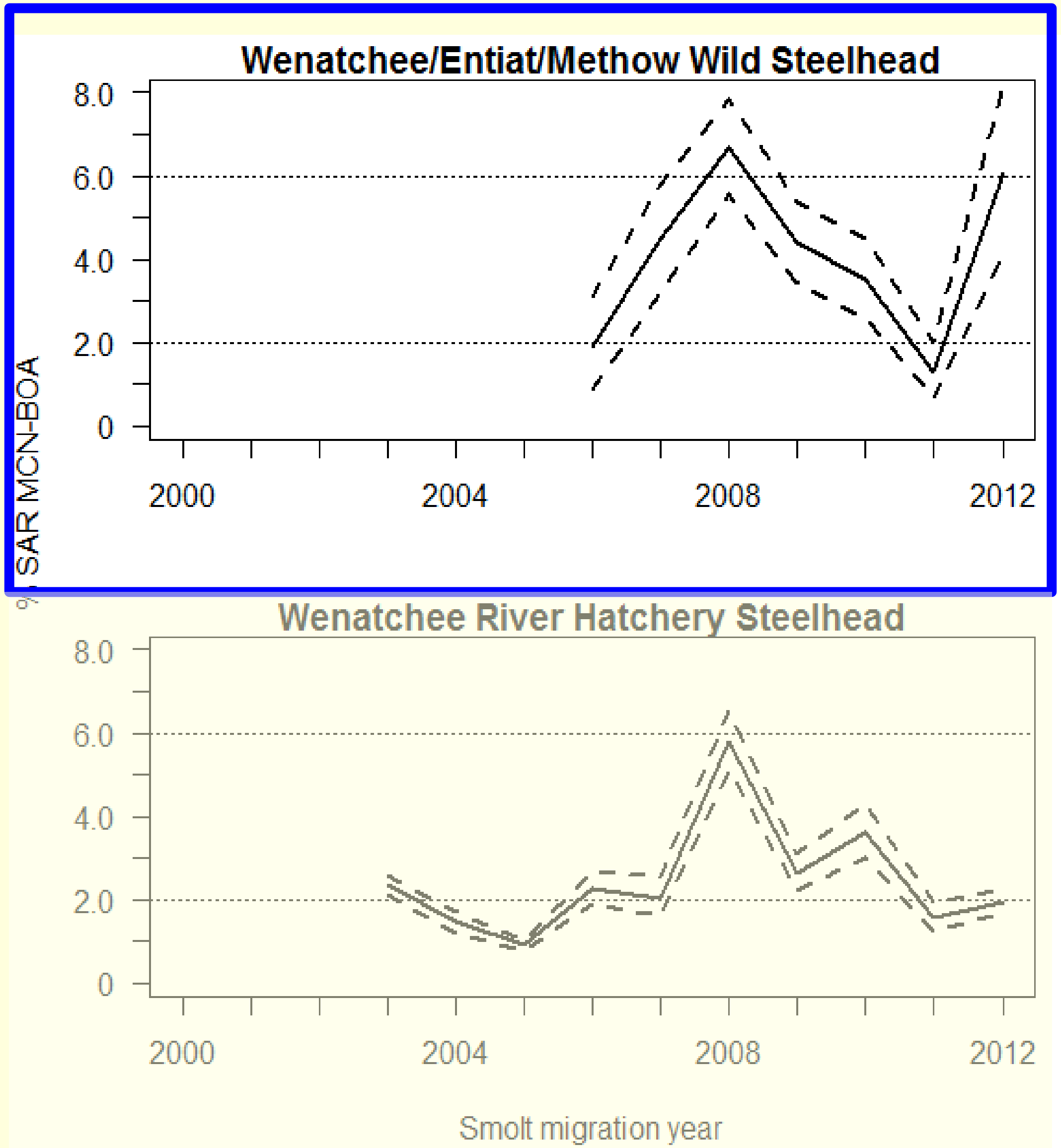
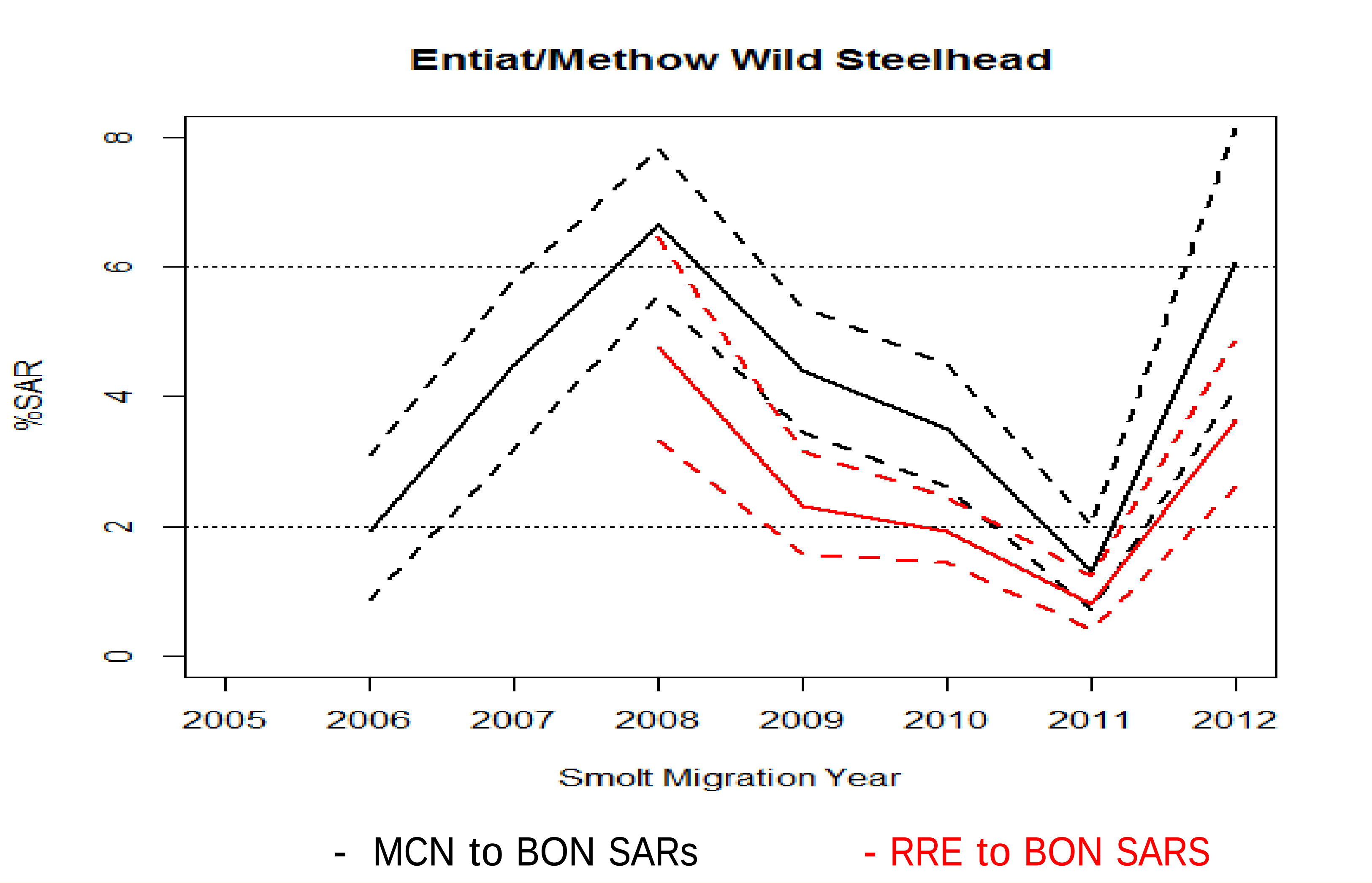


Hatchery Steelhead

- Wenatchee River
- Time series a little longer
- SARs averaged 2.2%



- SARs for RRE to BON are much lower than those for MCN to BON
- SARs for the uppermost dam are less than those that start at MCN, and dip below 2% in 2010 and 2011

RIS to BON SARs Chinook and Steelhead

Yearling Chinook

- Hatchery and wild aggregate
- SARs averaged 0.4%

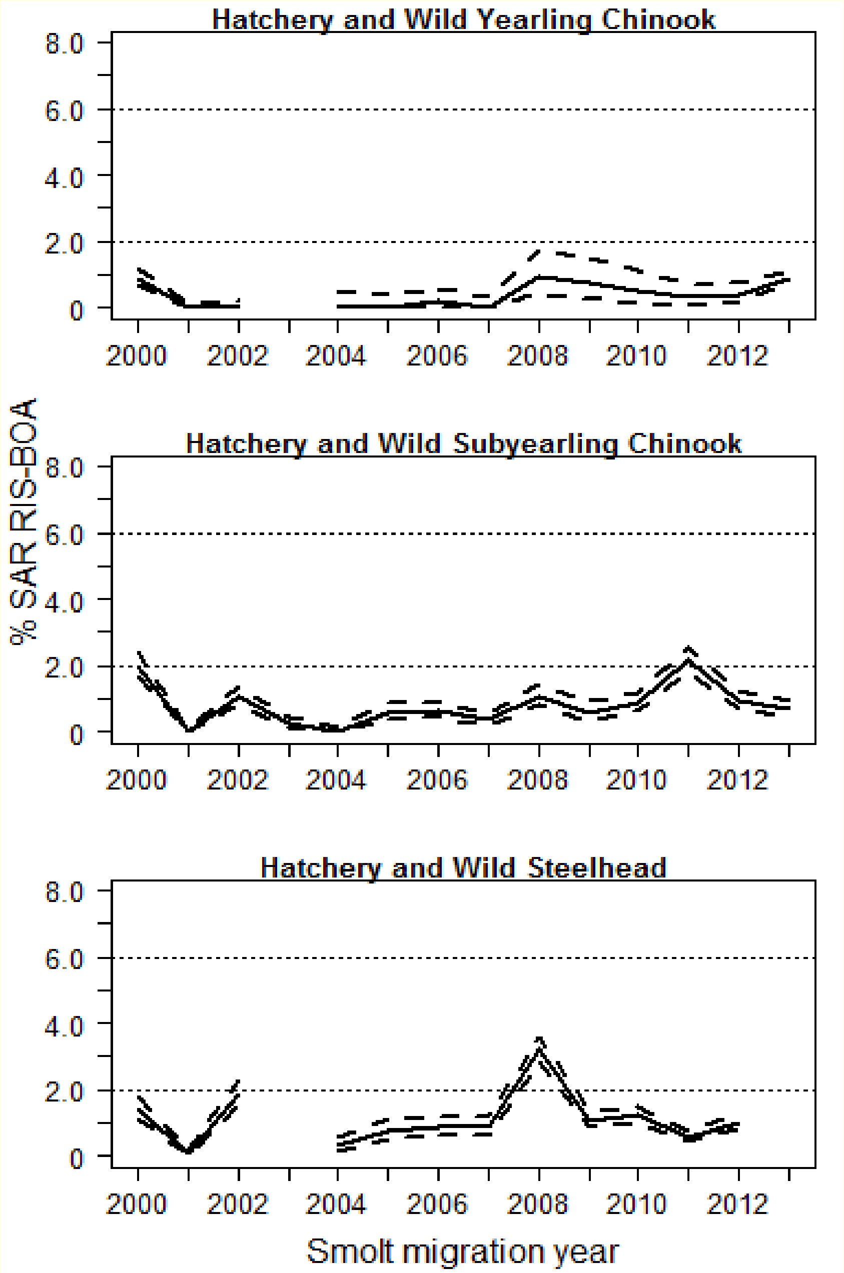
Subyearling Chinook

- Hatchery and wild aggregate
- SARs averaged 0.8%

Steelhead

- Hatchery and wild aggregate
- SARs averaged 1.1%

**Bypass inoperable during spring of 2003 – no data*

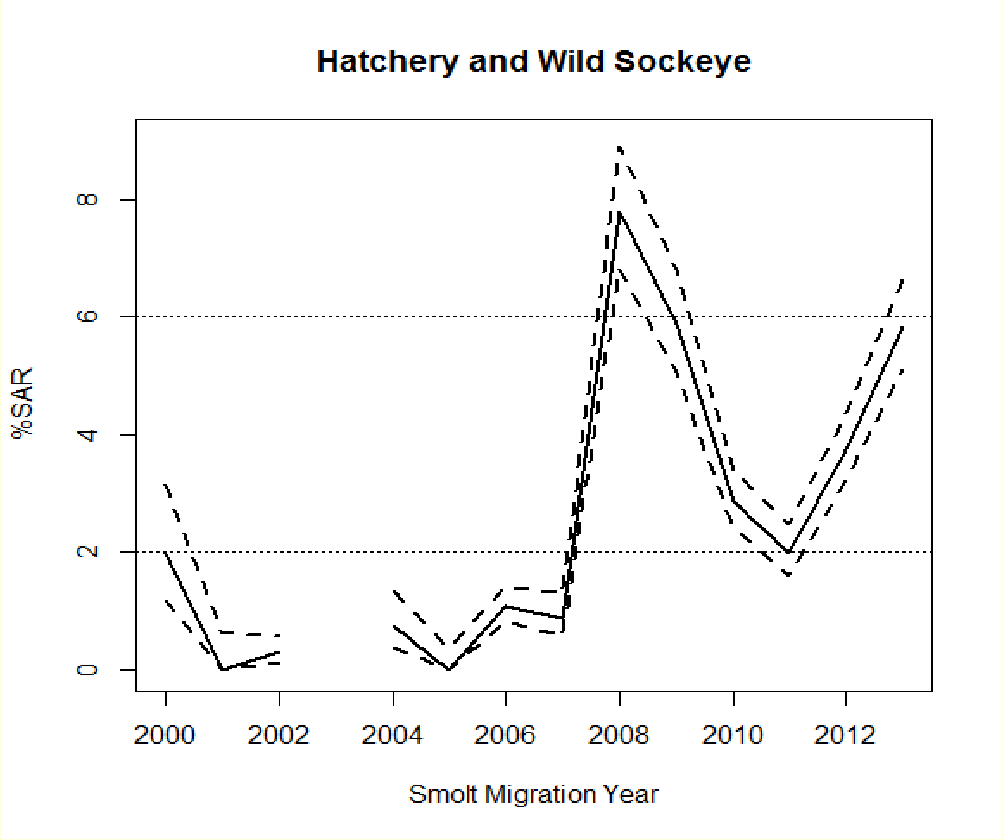


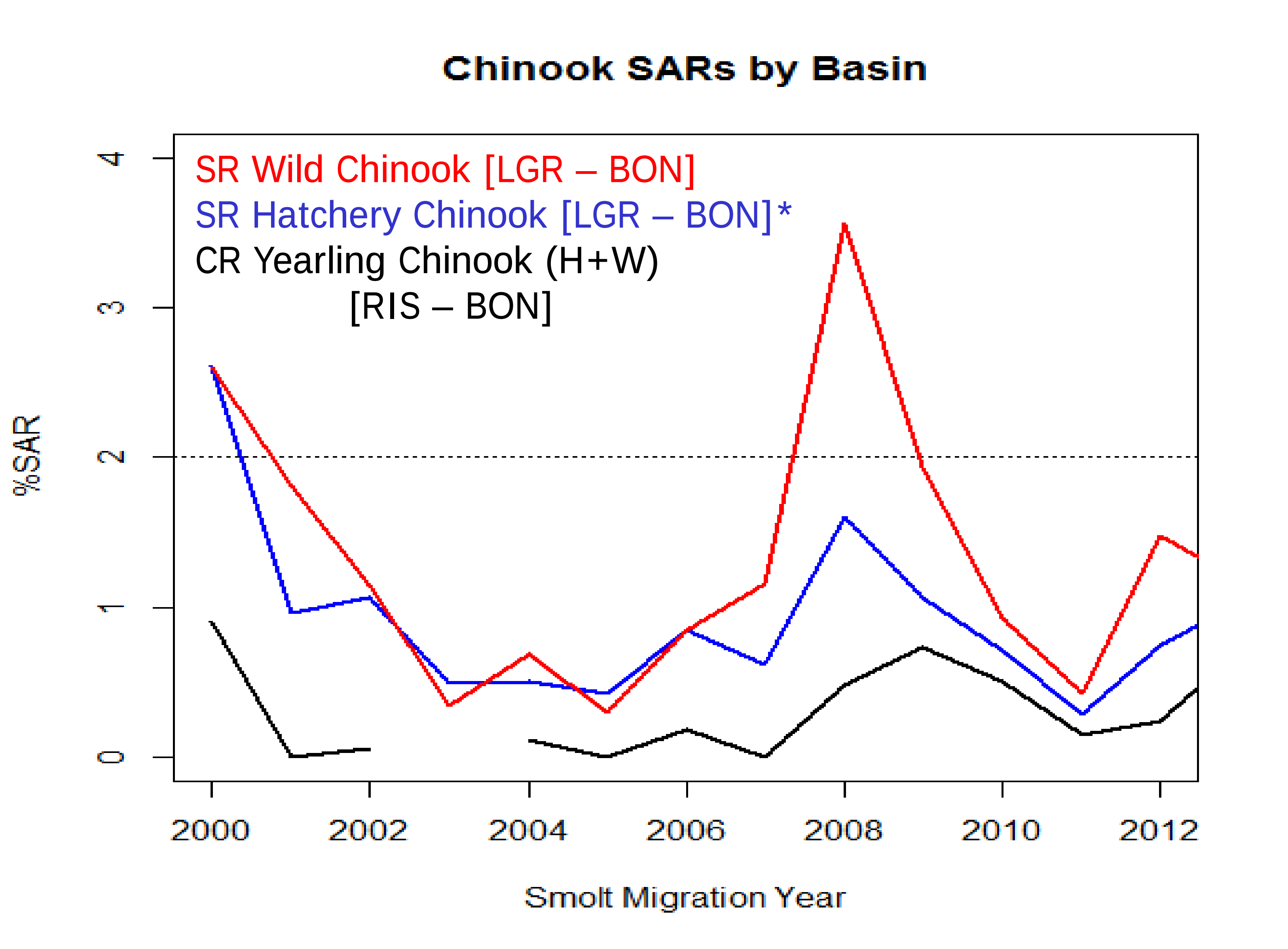
RIS to BON SARs
Sockeye

Sockeye

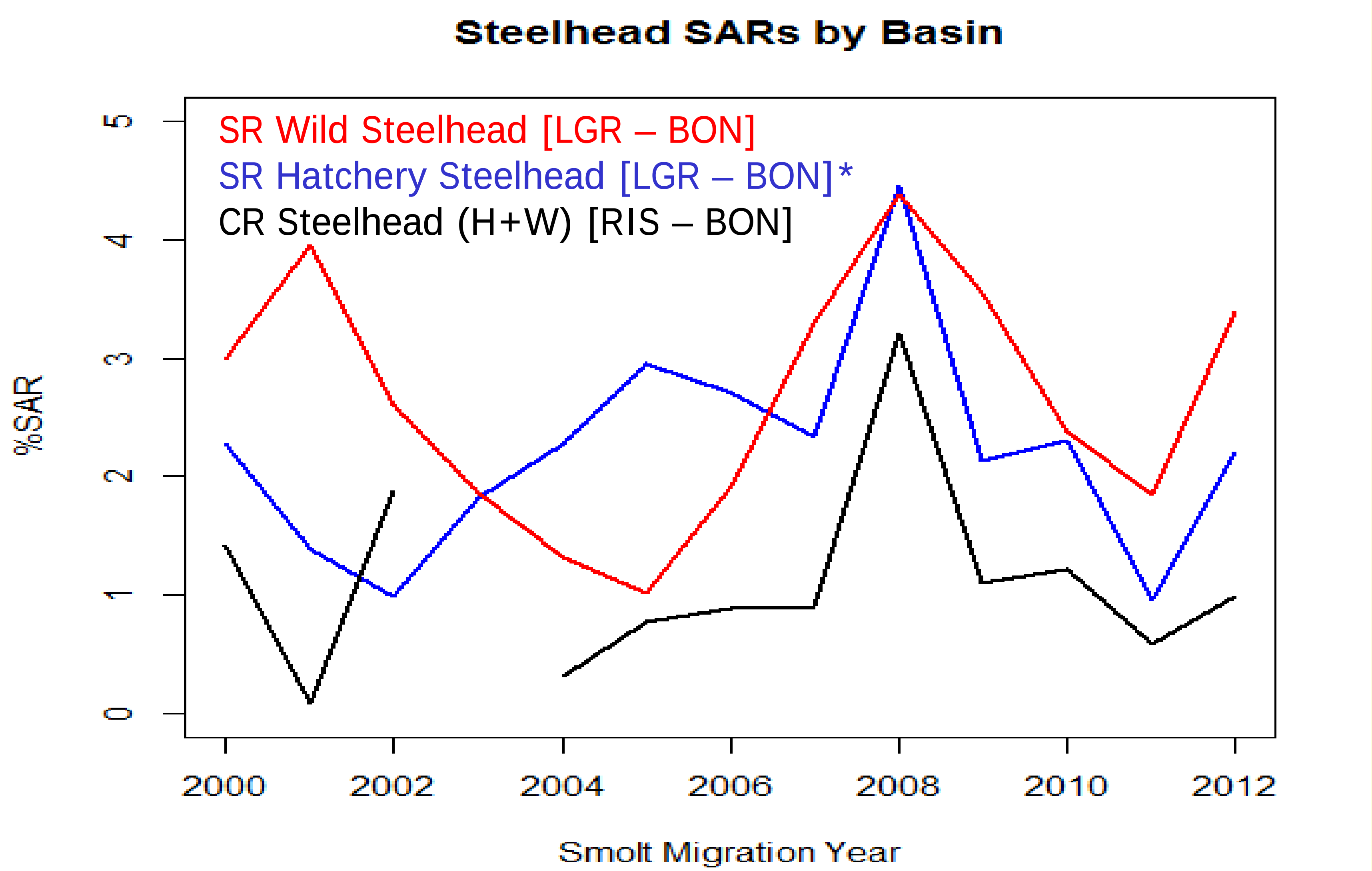
– Hatchery and Wild combined
– SARs averaged 2.6%
– Data part of CSS Report since 2014

**Bypass inoperable during spring of 2003 – no data*





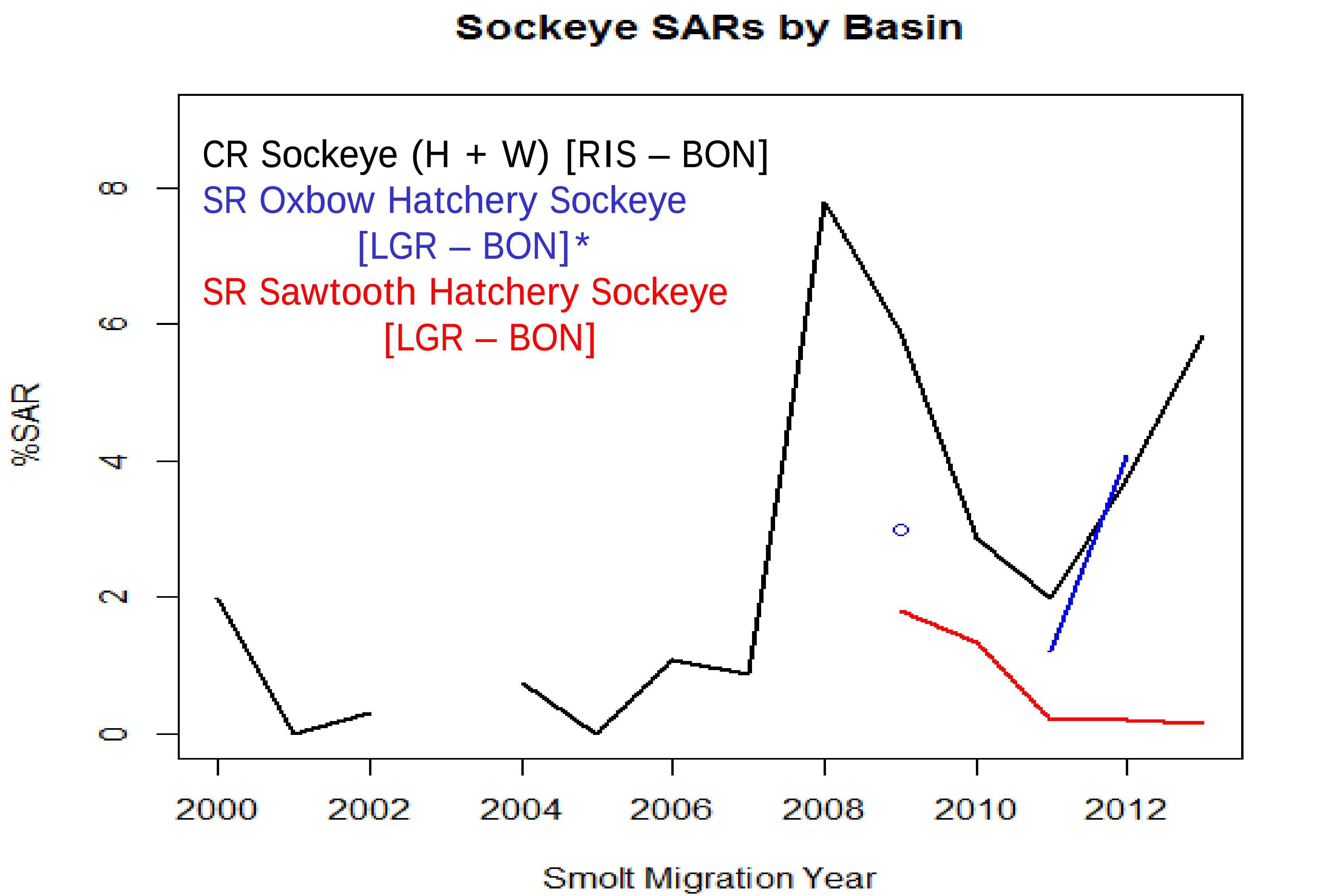
LGR to BON is approximately 286 miles [7 dams]
RIS to BON is approximately 308 miles [6 dams]
*Snake River Hatchery Chinook is an average of annual hatchery specific estimates



LGR to BON is approximately 286 miles [7 dams]

RIS to BON is approximately 308 miles [6 dams]

*Snake River Hatchery Steelhead 2000 – 2012 are averages of annual hatchery specific estimates



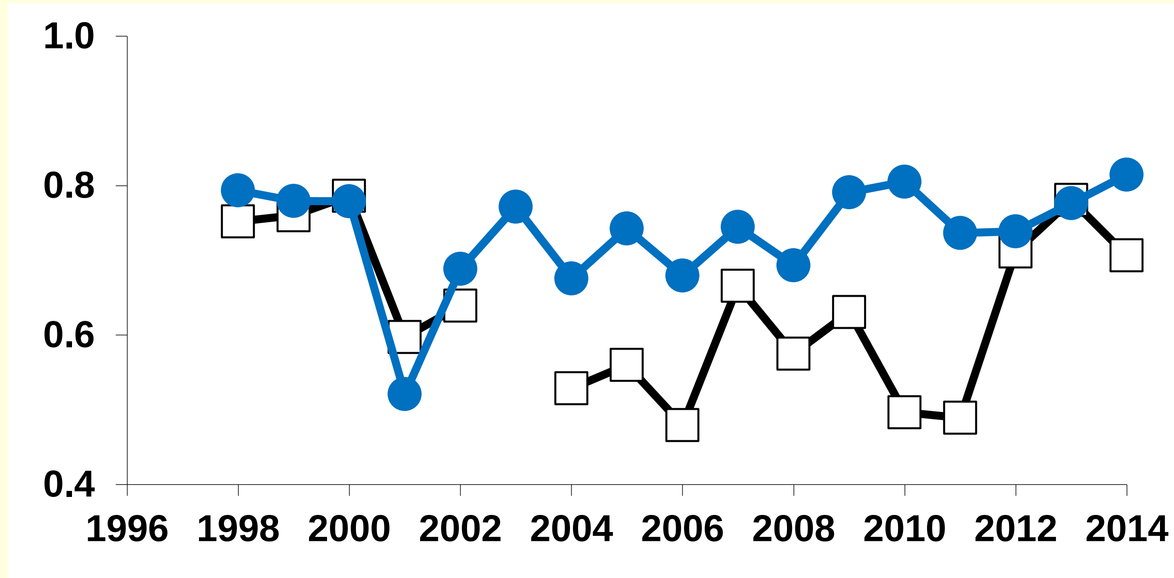
LGR to BON is approximately 286 miles [7 dams]

RIS to BON is approximately 308 miles [6 dams]

*No SARs calculated for Oxbow Hatchery for migration year 2010

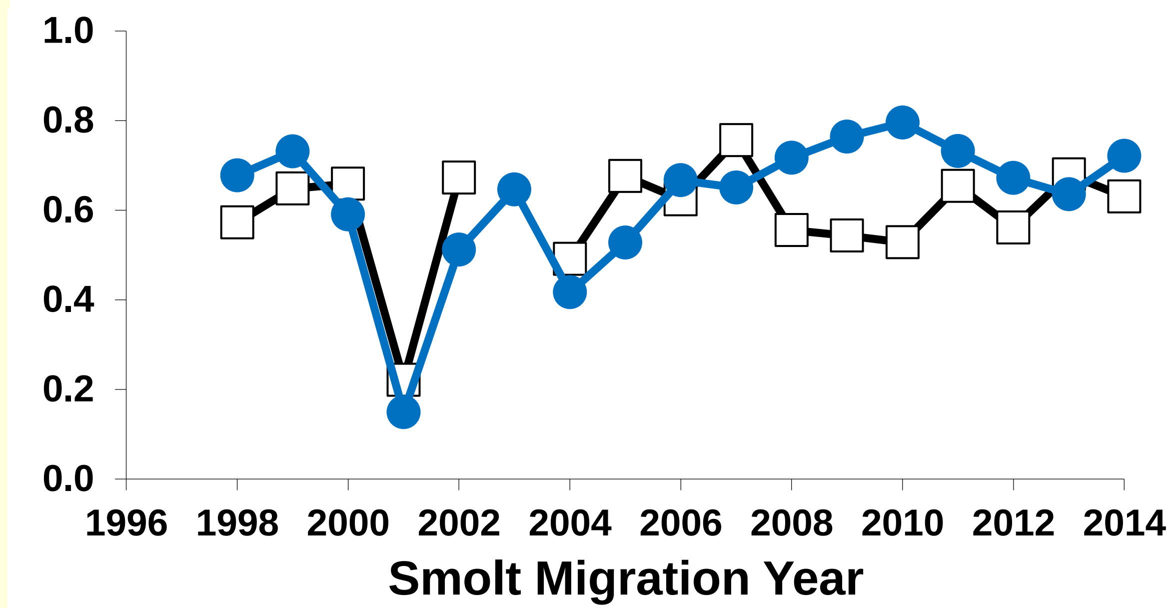
Reach Survival Comparison of Juvenile Salmon: Snake River to Upper Columbia Stocks

Yearling Chinook

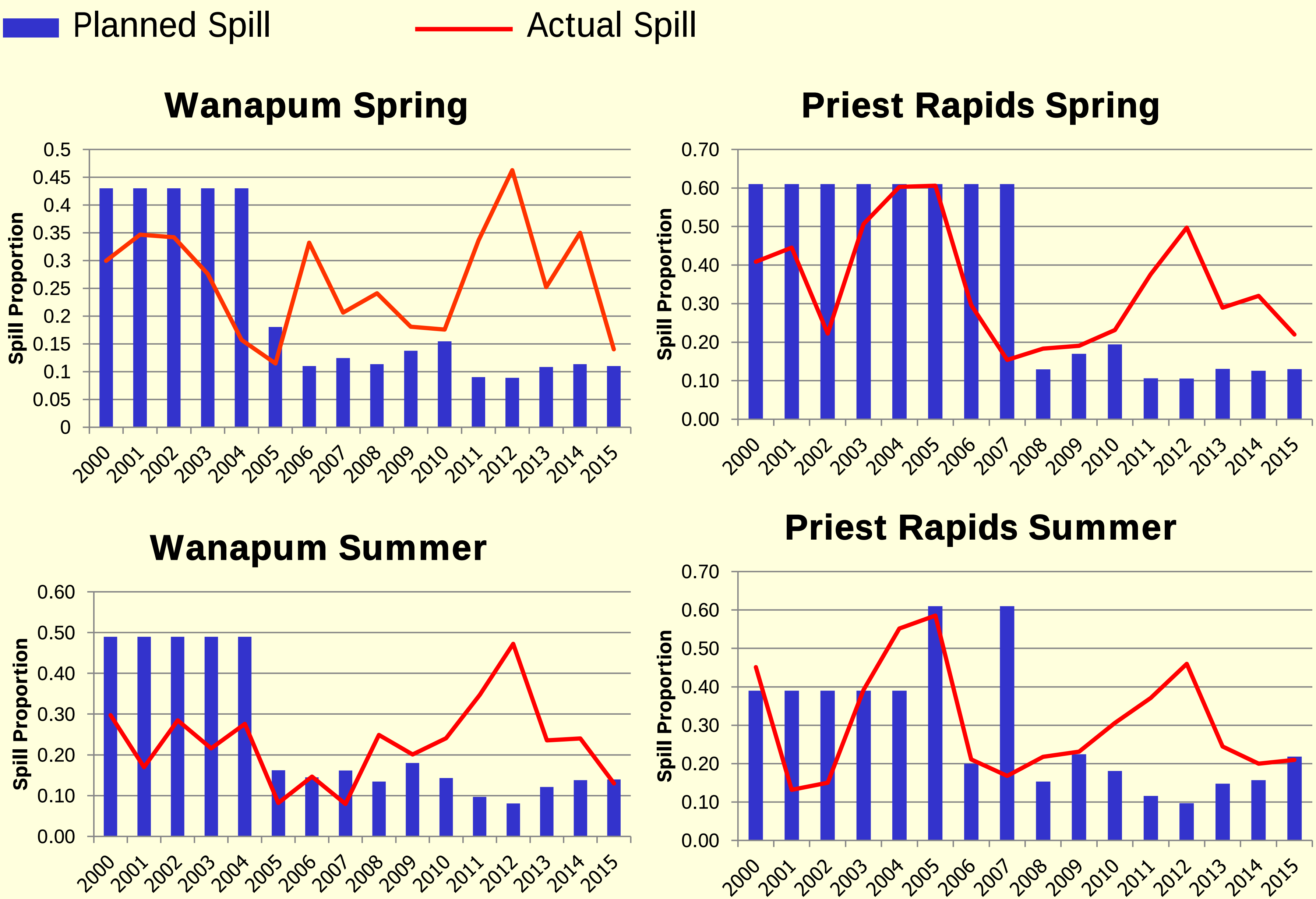


RIS to MCN
LGR to MCN

Steelhead



Average Proportion Spill



Conclusion

- The Upper Columbia SAR (MCN-BON) trends follow the same SAR trends as the Snake River, but are lower
- Upper Columbia stocks show similar patterns of response to environmental variables when compared to the Snake and Middle Columbia stocks
- Comparison of SAR trends of upper Columbia sockeye to Snake River sockeye will become available as the data series builds over time.

Conclusion

- Collaboration and coordination with marking efforts in the Upper Columbia is cost effective and provides a region-wide benefit
- Monitoring the effect of hydro system passage on Upper Columbia groups from existing marking is value added for managers
- An increase in the number of mark groups/tags and the number of detection sites would help strengthen the data

Next Up:

- Break time!
- We will reconvene at 10:30
- Tommy Garrison will give a presentation on Snake River Fall Chinook

Snake River Subyearling Fall Chinook

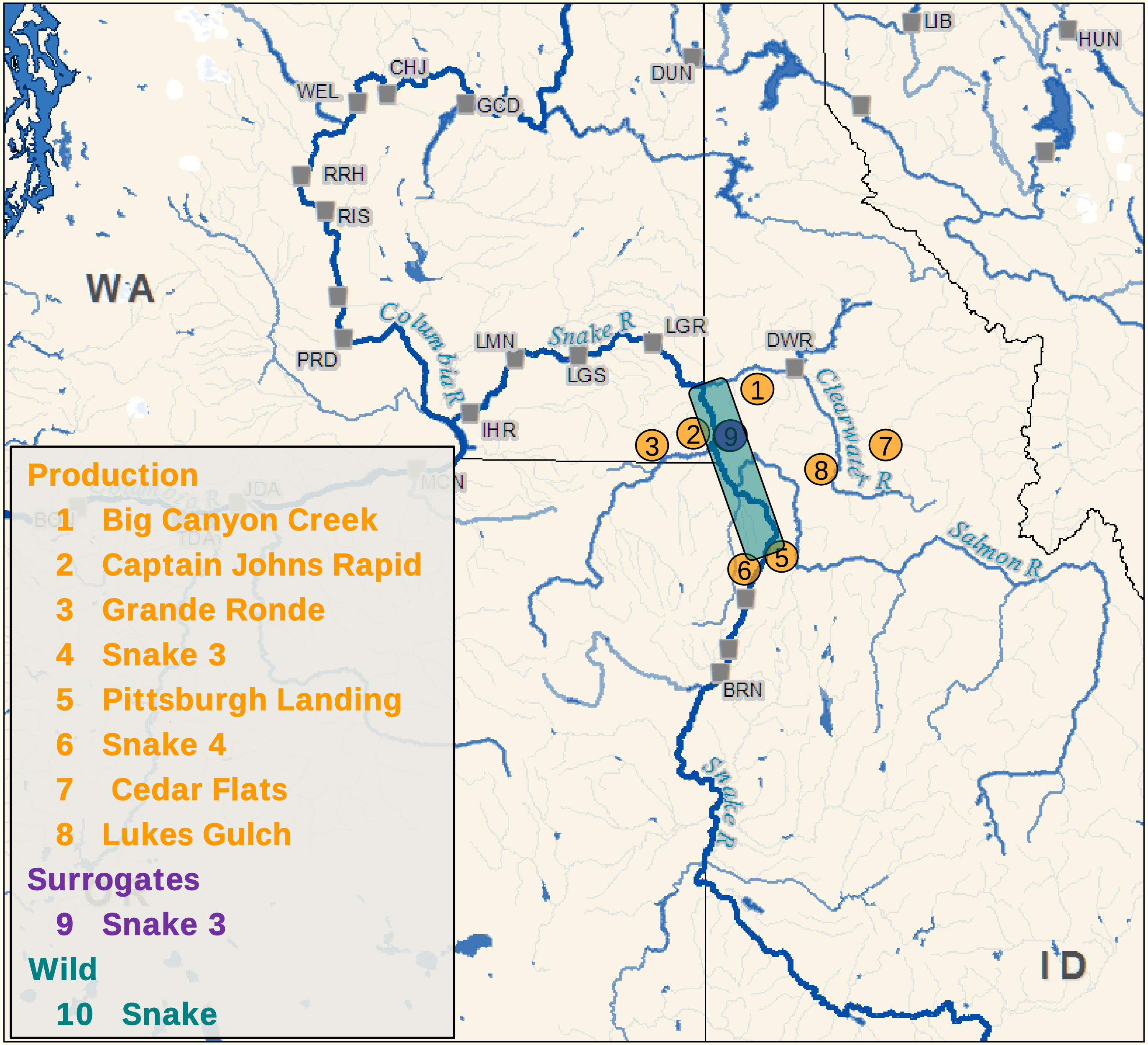
Author: Jerry McCann
Presenter: Tommy Garrison

CSS Annual Meeting
April 20, 2016

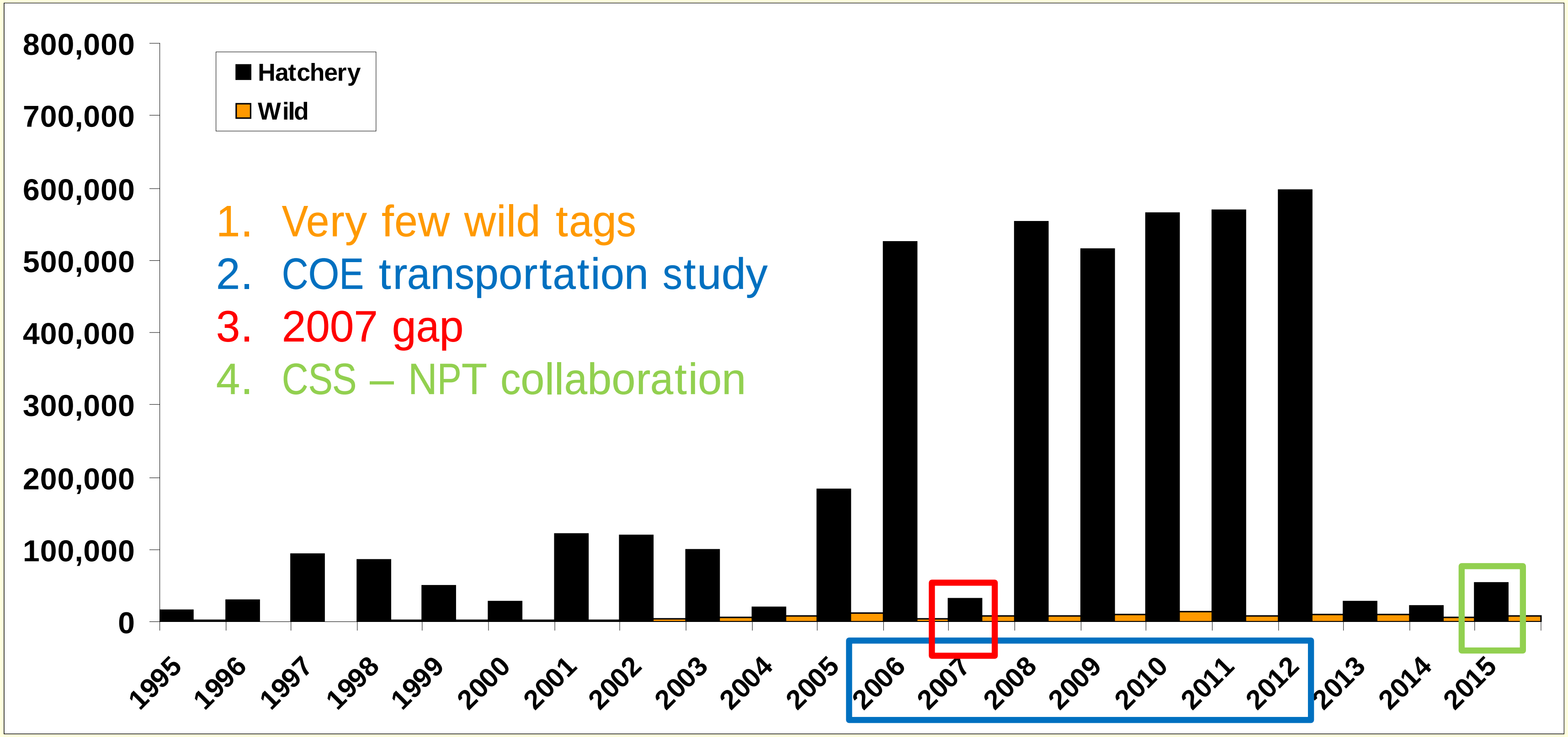
Background

- CSS requested to develop SARs for subyearling fall Chinook
- Use existing methods to compare transport and in-river SARs
- Holdover fish can bias estimates of in-river SARs
  - Few groups had significant holdovers
  - Most subyearling production and wild tag groups were included
- SARs have been developed for migration years 2006 through 2012

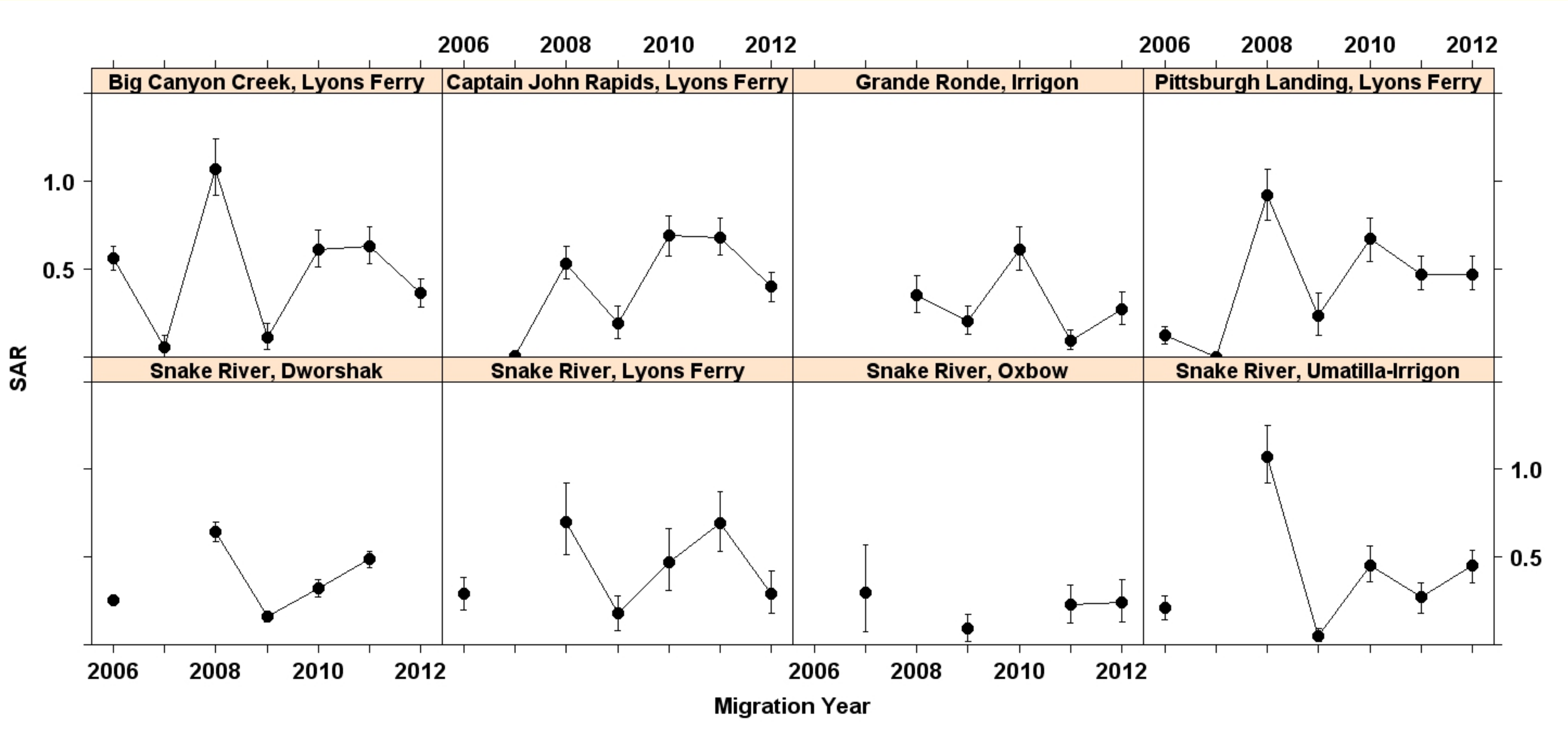
Subyearling Fall Chinook PIT-tag Releases



Tagging above Lower Granite Dam

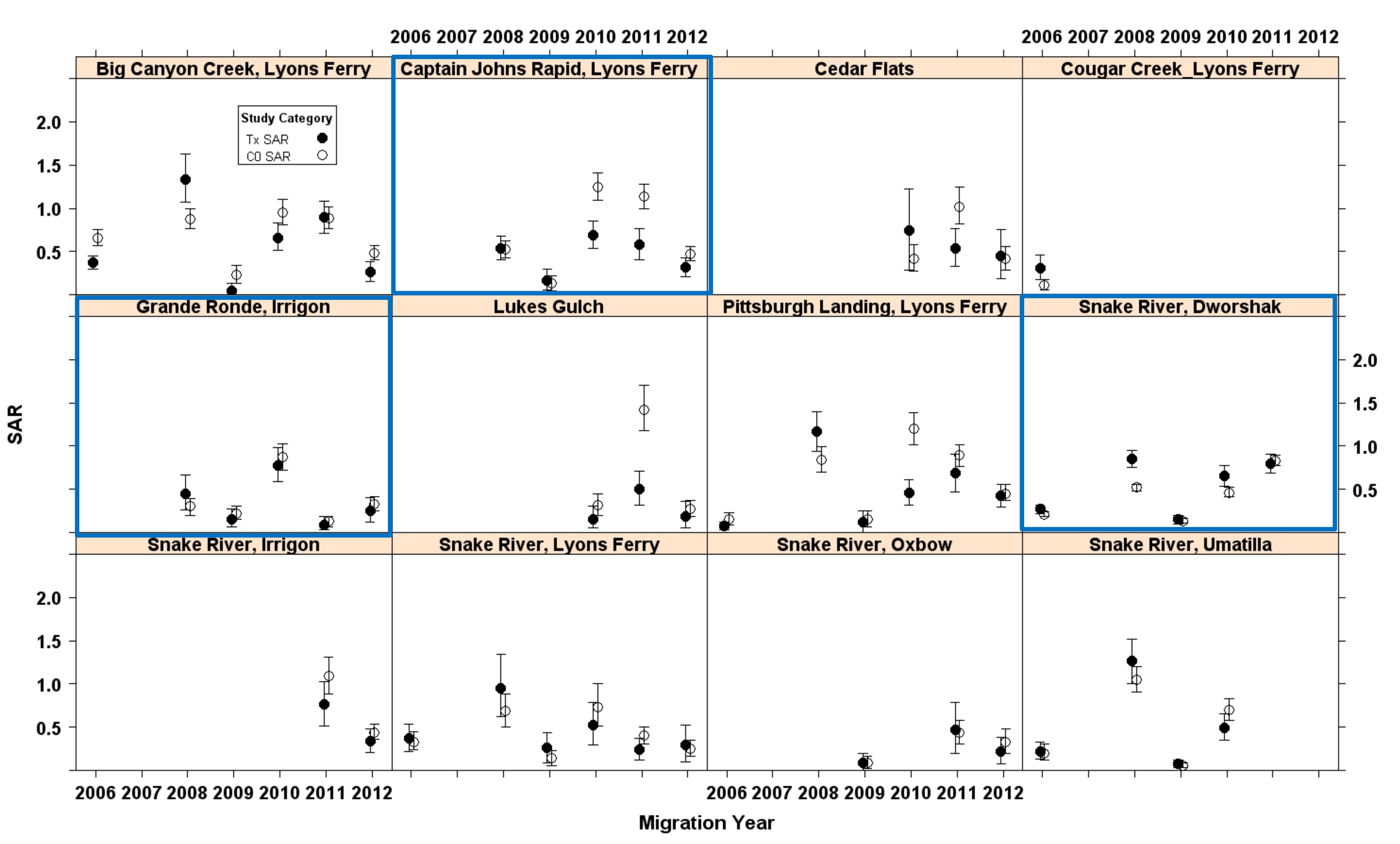


Overall LGR to LGR SARs (Adults)



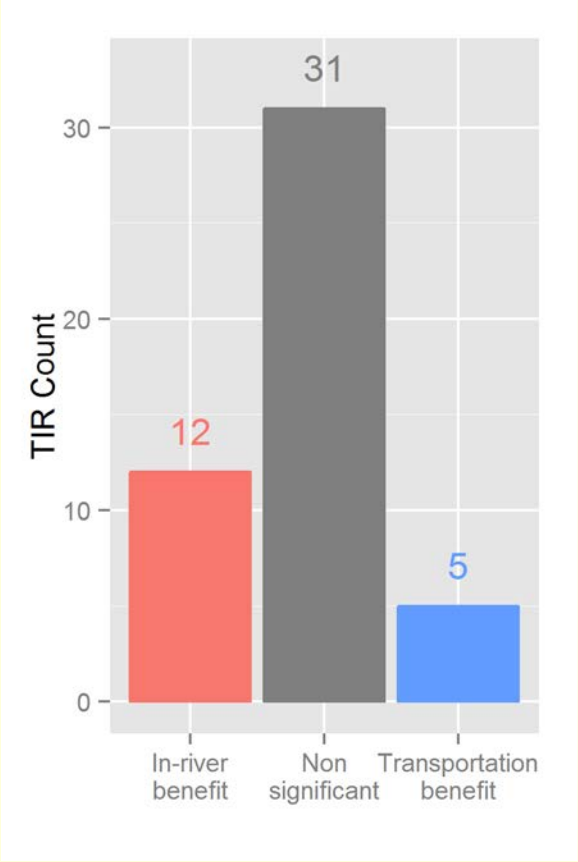
- SARs ranged between 0% and 1%

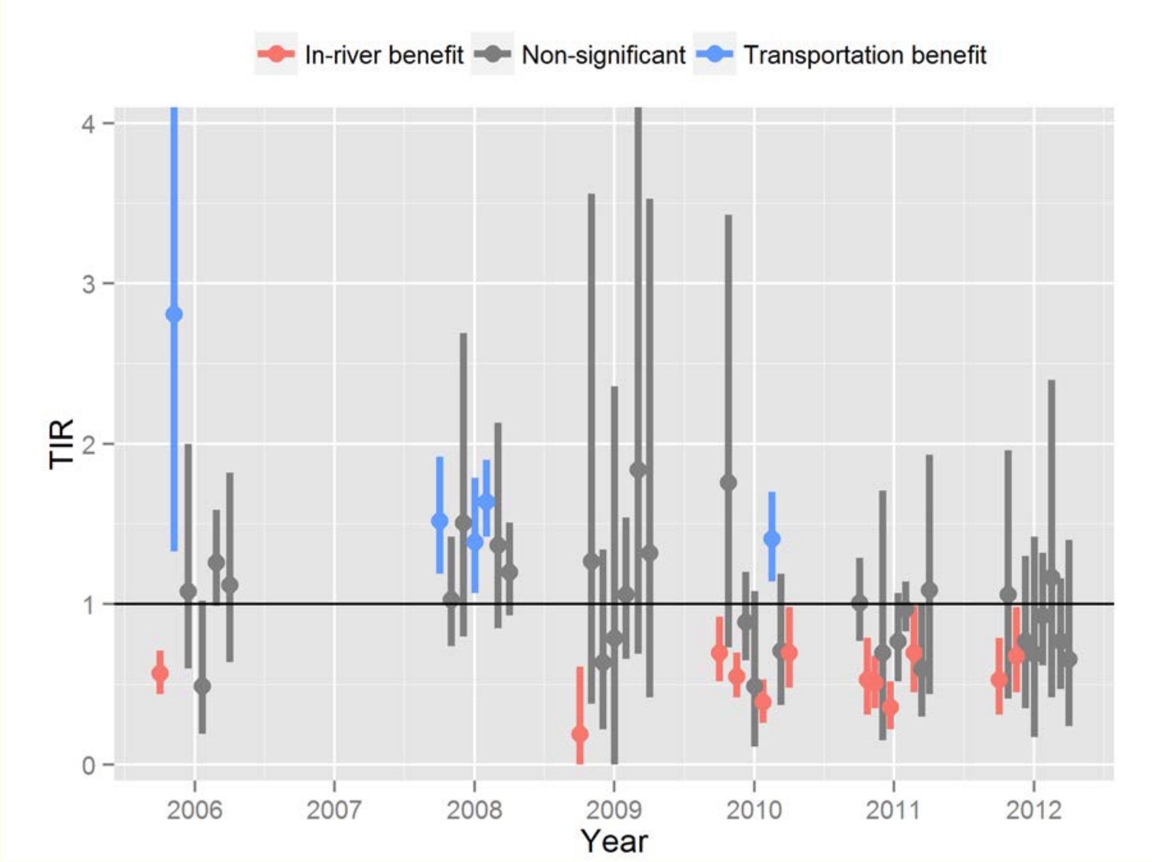
SARs by category LGR to LGR



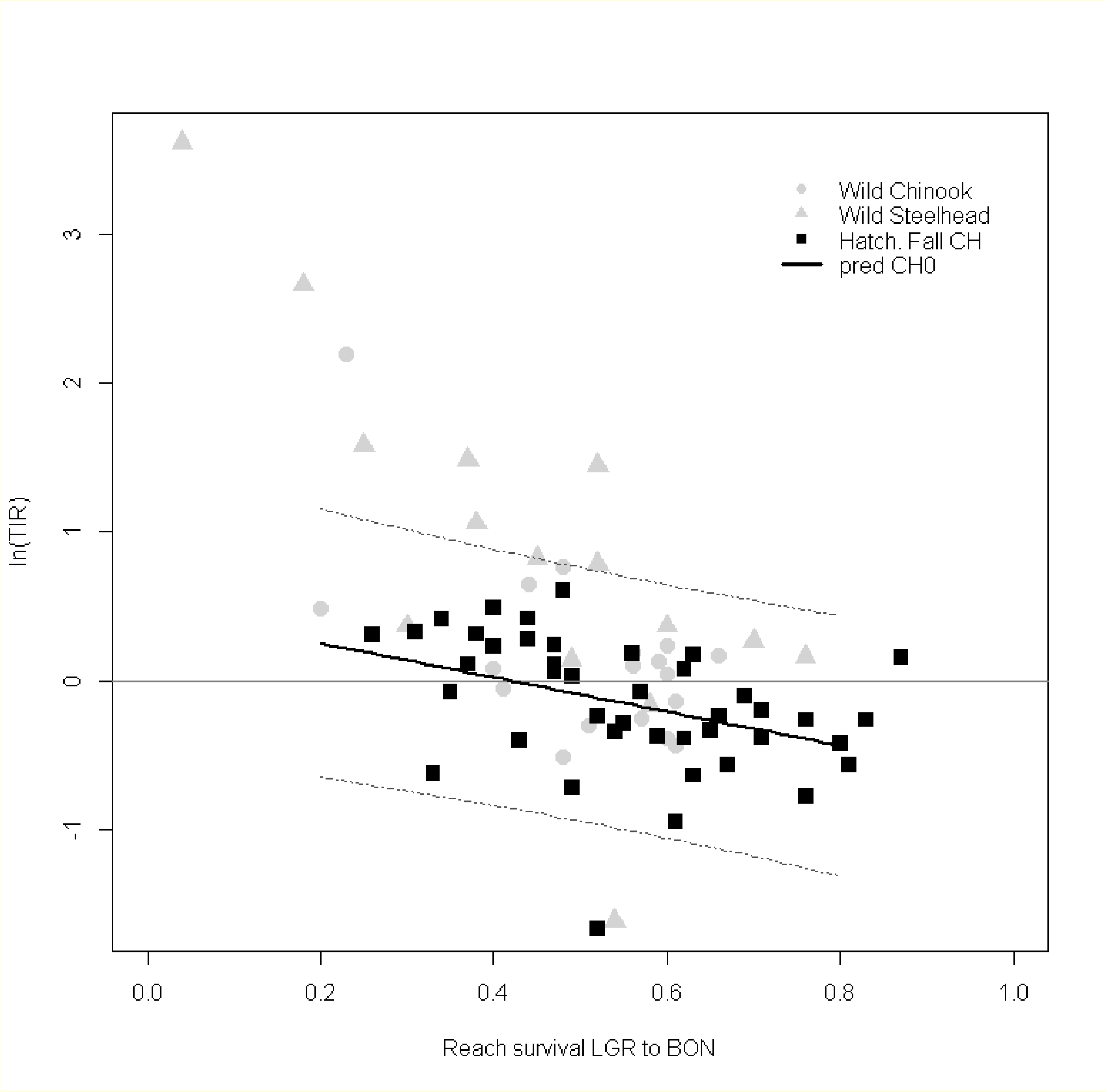
Transport to In-river SAR Ratio

$$TIR = SAR_{Transportation} \ / \ SAR_{In\text{-}river}$$





TIR vs Reach Survival



Conclusions

- CSS successfully used existing methodology to estimate SARs for several groups throughout the Snake River Basin
- SARs ranged from 0% to just over 1%
- Preliminary trend in SARs indicates an in-river benefit
- Transportation may be beneficial only up until a certain point
- In 2015 and 2016 CSS collaborated with NPT to continue tagging Snake River subyearling fall Chinook
- Other groups added to 2015 Annual Report including Hanford Reach, Deschutes River wild, Spring Creek and Little White Salmon NFH groups.

Questions ?

Life cycle modeling: Population recovery of Snake River Spring Chinook

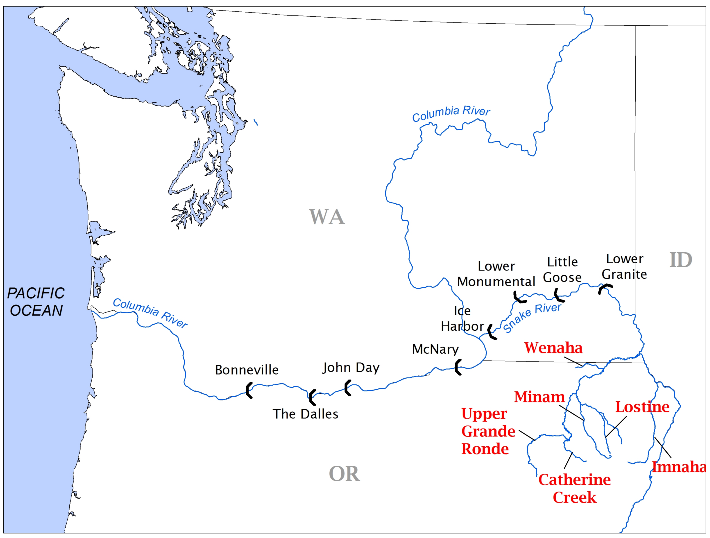
Presenter: Robert B Lessard
CSS annual meeting April 20, 2016

1

Talk synopsis

- Life cycle reconstruction with estimated uncertainty
- Examination of relative benefits
  - Change in tributary productivity
  - Change in tributary capacity
  - Change in hydro operations

2



3

Life stage predictions

- Spawner to smolt (distinct to each population)
- Smolt to early ocean (common to all populations)
  - Transport survival
  - In-river survival
- Ocean survival (depending on route of passage)
- Maturation 1, 2, and 3 salt
- Harvest

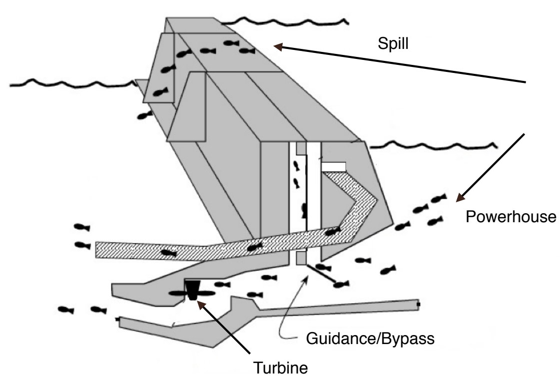
4

Data (1964-2010)

- Age specific adult spawners (All)
- Smolt abundance (CC, GR, LOS, MIN)
- May PDO, April Upwelling
- Water transit time through hydro system
- Route of passage index (PITPH)
- Harvest rates (US v. OR TAC/ODFW)

5

Powerhouse passage (PITPH)



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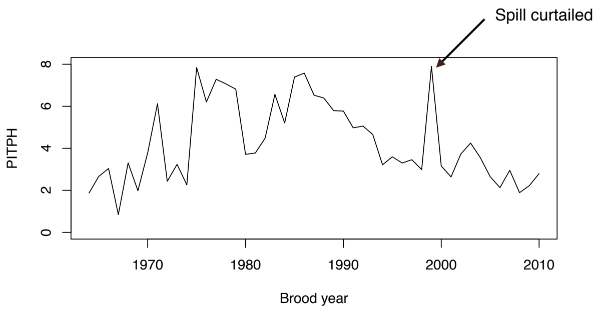
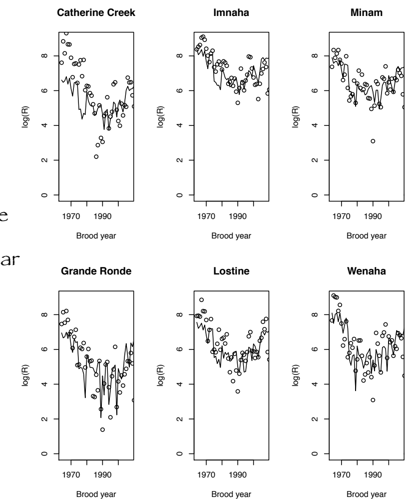
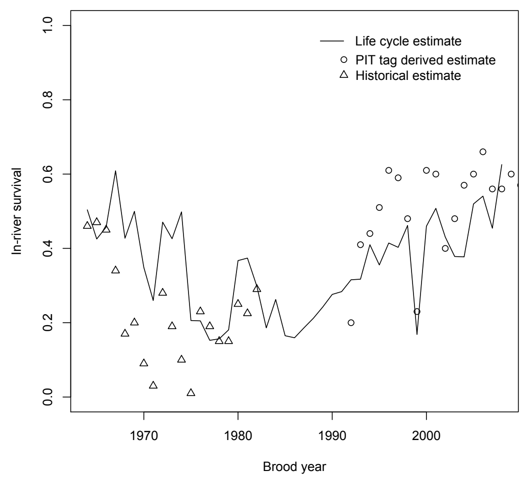
Cumulative across dams



log-scale Adult brood-year returns





Parameter variability

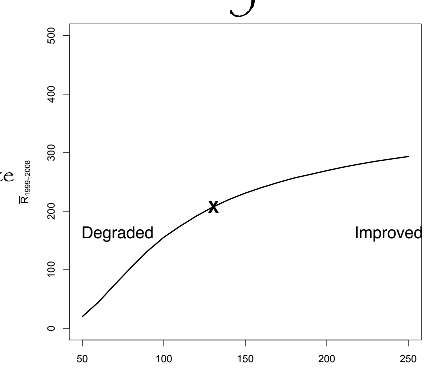
- Productivities and capacities (2 x 6)
- Magnitude of in-river PITPH and WTT effects (2)
- Magnitude of ocean effects of PDO and UPW (2 x 3)
    - Transported survival
    - In-river survival (+ PITPH)

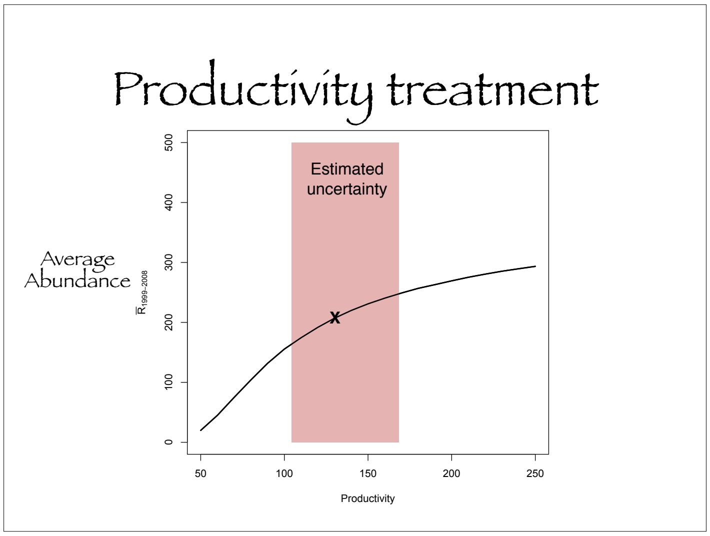
Alternative treatments

- Treat the best fit model as a baseline historical record
- Simulate alternative outcomes 10,000 times randomly from range of variability
    - Fixed tributary productivity levels (50-250)
    - Fixed tributary capacity levels (1K-50K)
    - Fixed hydro-operations (50-100% PITPH)

Productivity treatment

Average Abundance





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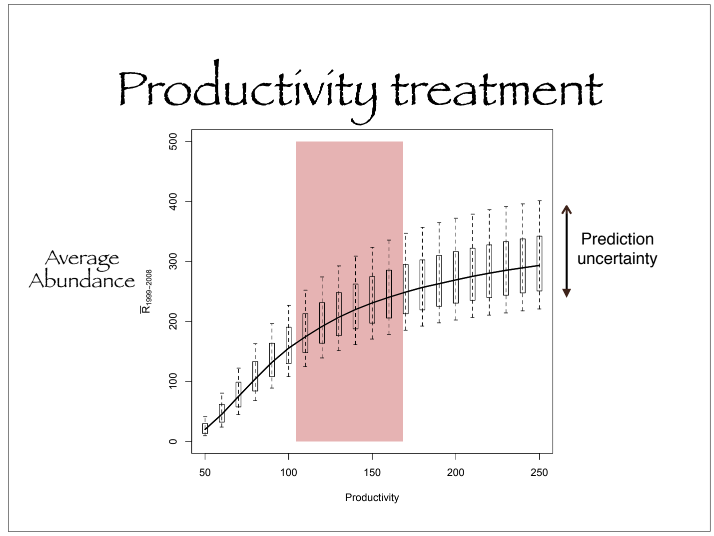

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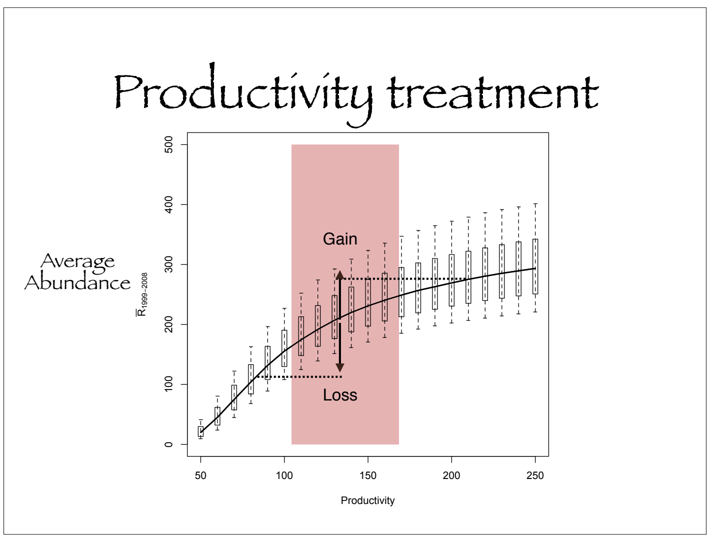

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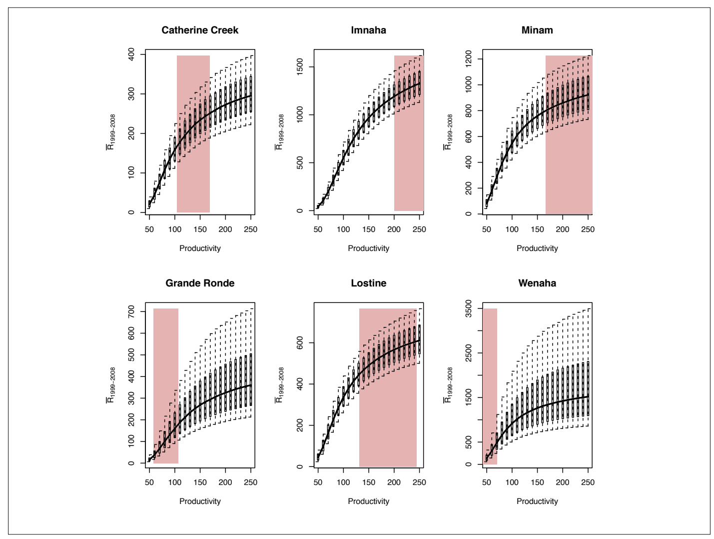

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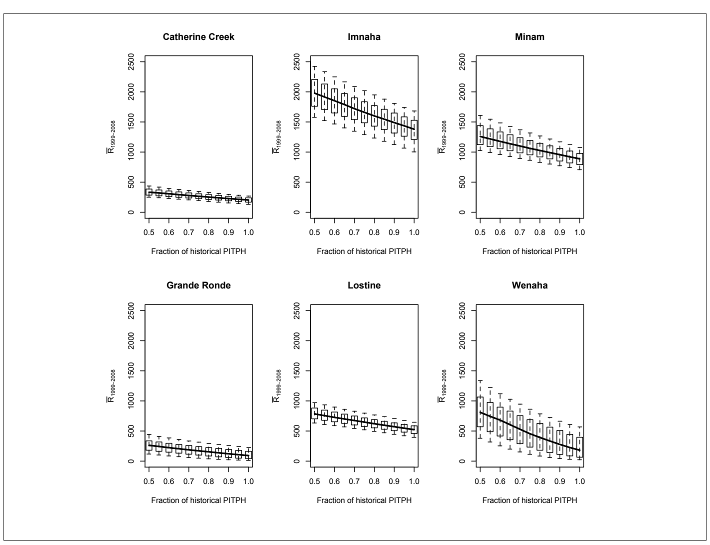

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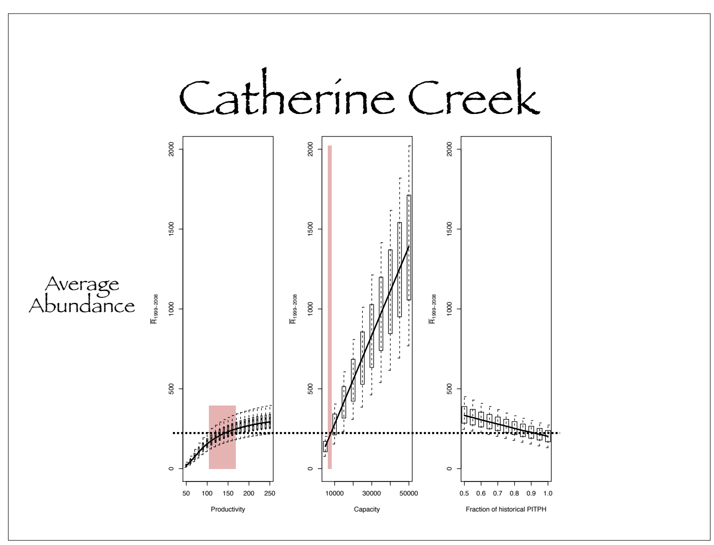

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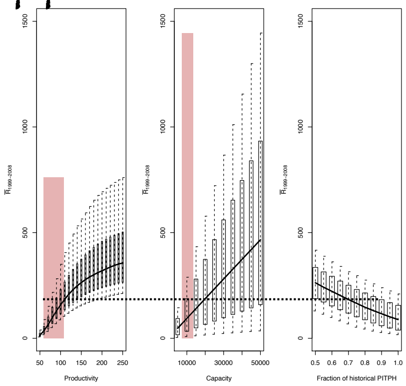
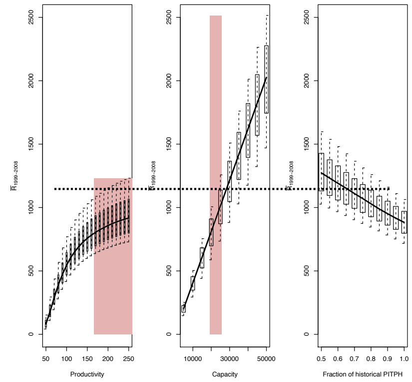
Upper Grande Ronde

Average Abundance



Minam

Average Abundance



Key findings

- Changes to hydro-system operations have the highest immediate benefit to recovery
- Habitat restoration efforts should target productivity and capacity strategically
- Spill predicted to have a higher impact on recovery when habitat improves

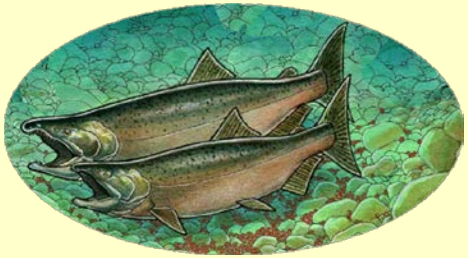
Comparative Survival Study

SARs and Productivity

Charlie Petrosky, Idaho Department of Fish and Game

2015 Annual Meeting

April 20,2016



Smolt to Adult Survival Rate (SAR) Goals

PATH (1998); NMFS 2000 BiOp:

- 2% SAR met interim NMFS survival criteria
- 4% SAR met interim NMFS recovery criteria
  - Snake R. spring/summer Chinook
- Applied to Snake R. steelhead by analogy

NPCC (2004, 2009) F&W Program:

- 2%-6% SAR, average 4% SAR – ESA salmon & steelhead
- Identify effects of ocean conditions; evaluate & adjust inland management actions

2014 F&W Program & ISAB comments:

- Investigate goals, examine applicability & biological basis relative to population viability & rebuilding

SARs & Life Cycle Productivity

Snake River
spring/summer
Chinook

What levels of SAR are associated with:

1) Population replacement at recent spawner abundance

2) Historical (pre-FCRPS) productivity

SR Chinook Life Cycle Productivity

1) Viability criteria to achieve low or very low risk of population extinction (ESA recovery or delisting; ICTRT 2007):

- Abundance must exceed Minimum Abundance Threshold (MAT)
- Intrinsic productivity must be adequate to maintain population at or above MAT
  - Post-harvest recruits to spawning grounds

2) "Broad scale recovery" goals (e.g., States, Tribes, Subbasin Plans) are higher than simple ESA delisting (e.g., sustainable fisheries)

- Pre-harvest recruits

SR Chinook Life Cycle Productivity

<u>Viability Criteria:</u>

Recent abundance

- Spawner abundance as % Minimum Abundance Threshold (1992-2008 brood years)

- Middle Fork Salmon MPG ~ 31% MAT
- Grande Ronde/Imnaha MPG ~ 29% MAT

ICTRT 2007 "Survival Gap"

- Life cycle survival multiplier to meet TRT viability criteria (1979-2001 brood years; 5% extinction risk)

- Middle Fork Salmon MPG ~ 1.7 - 2.7X
- Grande Ronde/Imnaha MPG ~ 1.7 - 3.8X

Post-harvest recruits to spawning grounds --> viability

Hypothetically, life cycle survival improvement could be in egg-smolt survival rates and/or SARs

Little room to increase egg-smolt survival in good habitats (e.g., Middle Fork Salmon MPG)

Egg-smolt survival could be increased in degraded habitats (e.g., some Grande Ronde populations) – Lessard presentation

SR spring/summer Chinook life-cycle productivity has been inadequate to maintain spawner abundance at MAT

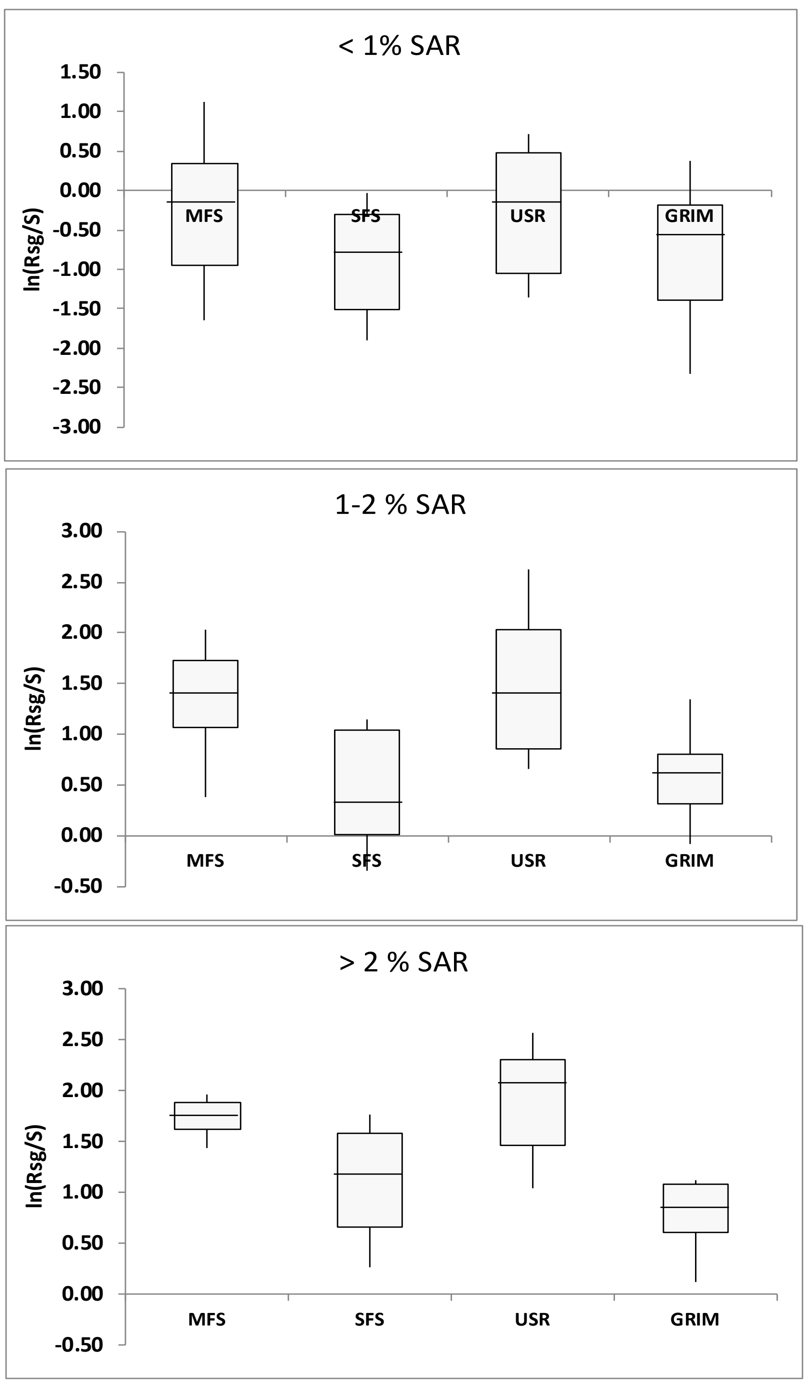
Low SARs → low productivity

(1992-2006 BYs, Snake River MPGs)

Observations to date are relevant to & support NPCC SAR objectives

- SARs < 2% → inhibit rebuilding to MAT
- SARs < 1% → major population declines

- Future CSS work
  - Explore steelhead population replacement vs. SARs:
  - Fish Creek (Lochsa), Rapid River (Lower Salmon), others



SARs & Life Cycle Productivity

Snake River
spring/summer
Chinook

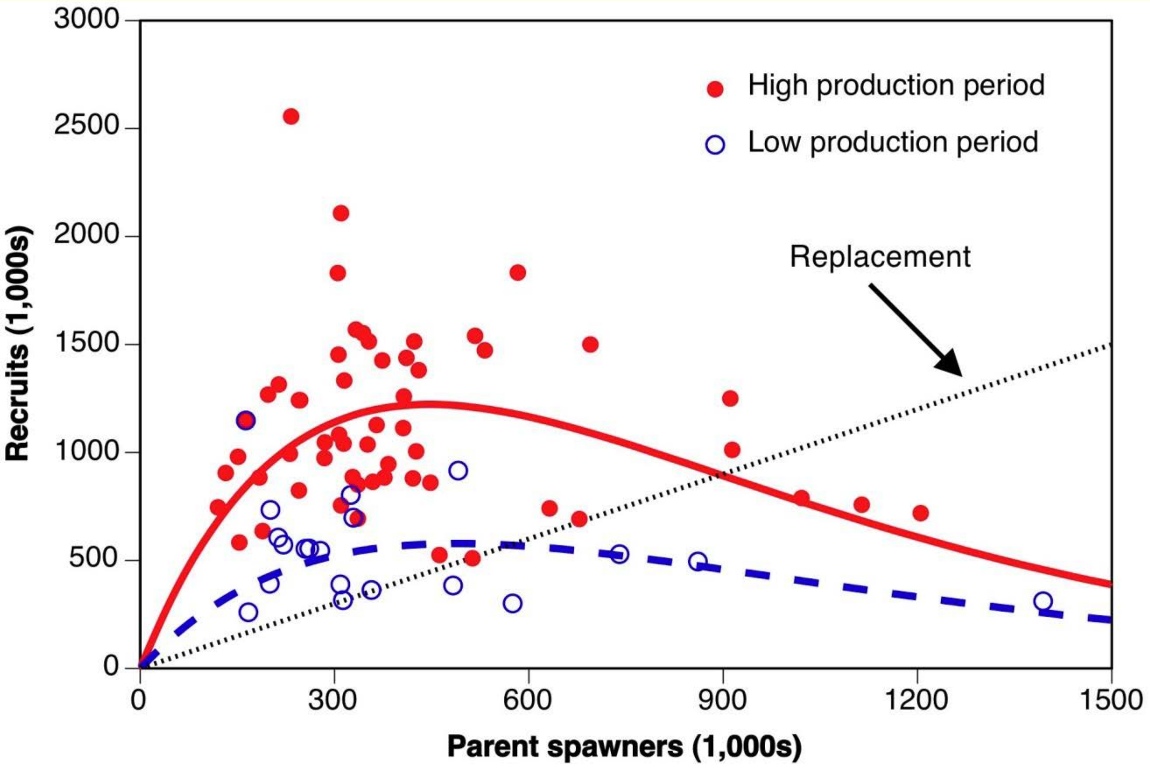
What levels of SAR are associated with:

1) Population replacement at recent spawner abundance

2) Historical (pre-FCRPS) productivity
   - Account for density dependence & changing environmental conditions
   - Pre-harvest recruits

Chinook Life Cycle Productivity

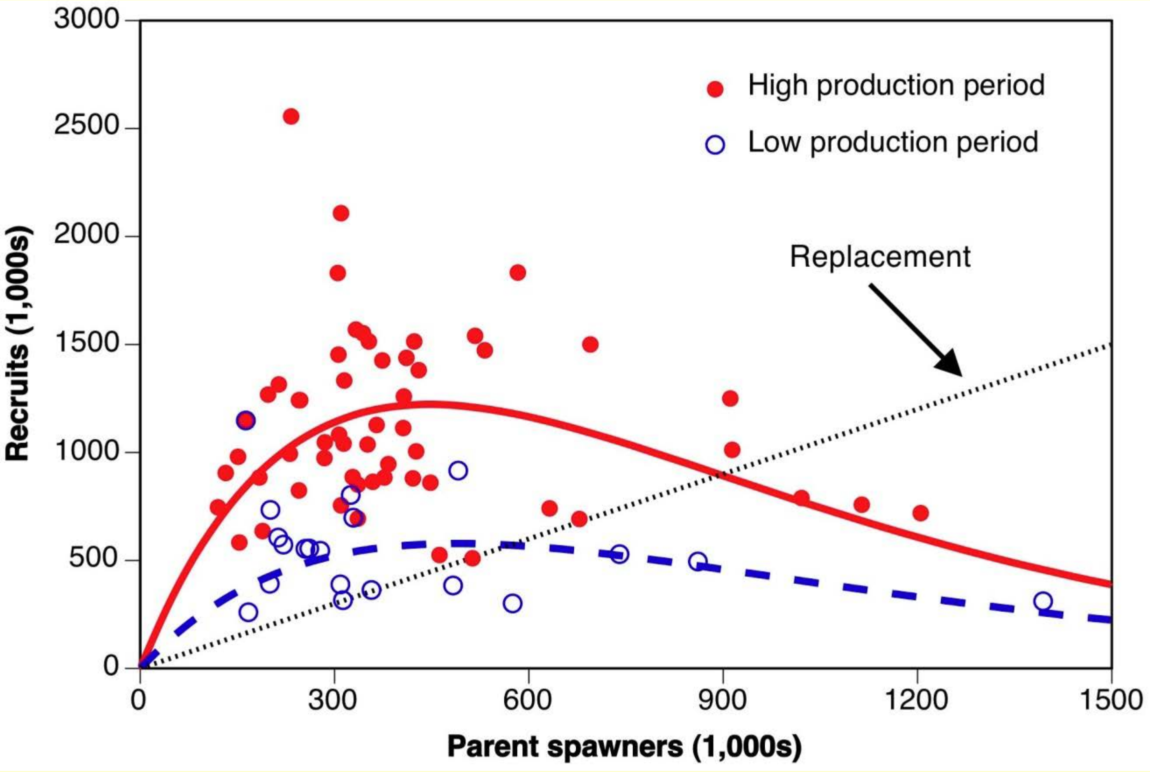
Accounting for density dependence and changing environmental conditions



e.g., Chignik Lake, Alaska sockeye recruitment functions – from ISAB 2015-1

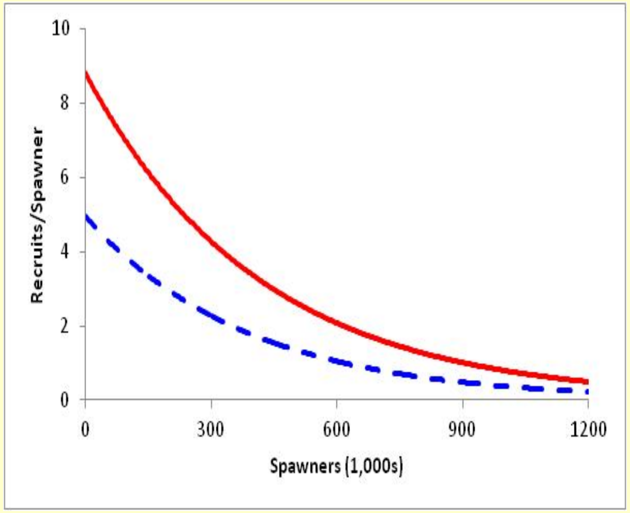
Chinook Life Cycle Productivity

Accounting for density dependence and changing environmental conditions



e.g., Chignik Lake, Alaska sockeye recruitment functions – from ISAB 2015-1

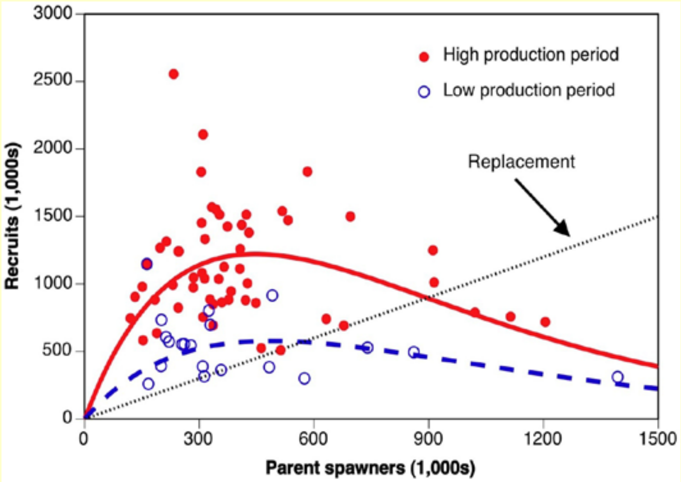
R/S decreases as S increases



Chinook Life Cycle Productivity

Accounting for density dependence and changing environmental conditions – <u>Interior Columbia populations</u>:

- Ricker function with period effect, pre & post FCRPS completion (Schaller et al. 1999, 2014 - CJFAS)
- 18 Snake River populations, 4 MPGs, 1950s – 2004 brood years
- 3 John Day River populations, 1 MPG, 1950s – 2004 brood years
- Tested for changes in productivity & capacity
- Pre-harvest recruits to Columbia River (to account for changing harvest patterns)



Chinook Life Cycle Productivity

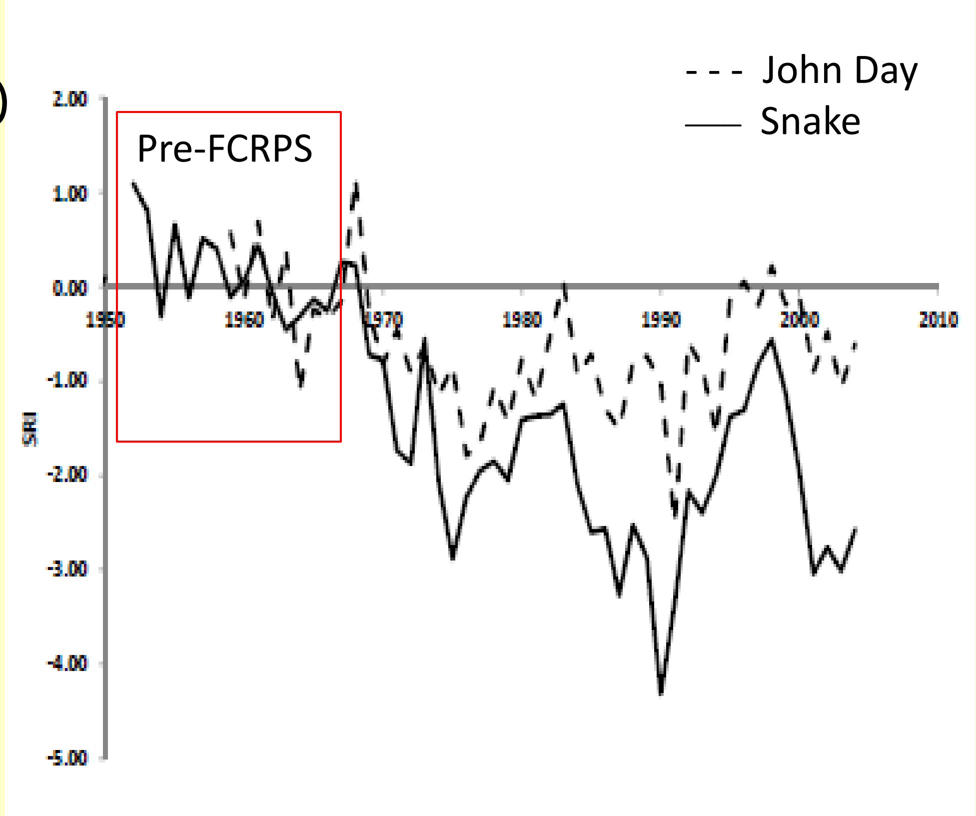
Accounting for density dependence and changing environmental conditions - Interior Columbia populations:

SRI, Survival Rate Index

- Observed ln(R/S) – Expected ln(R/S)

where, expected productivity is defined for the period before FCRPS completion (pre-1970)

  - SRI = 0, survival = 100% of expected productivity
  - Strong evidence for increase in density independent mortality (reduced productivity); less evidence for change in capacity
  - SRIs vary with ocean conditions and declined with FCRPS development

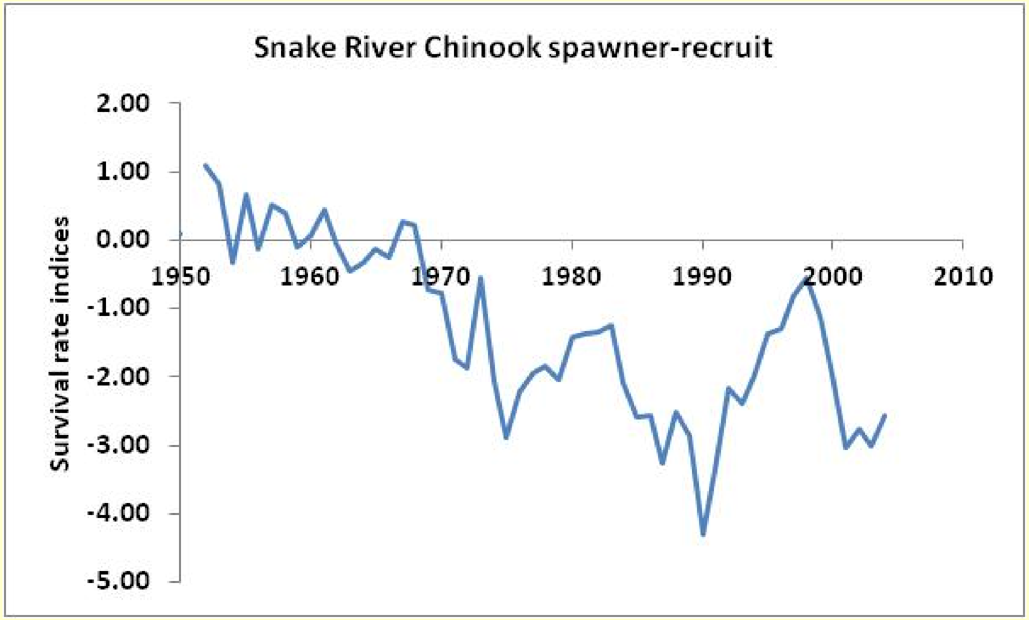


Schaller, Petrosky & Tinus 2014 CJFAS

Snake R Chinook Life Cycle Productivity & SARs

Life cycle survival rates declined to about 12% of Pre-FCRPS productivity

Post-FCRPS SRIs:
-2.1 average
(-4.3 to -0.6)



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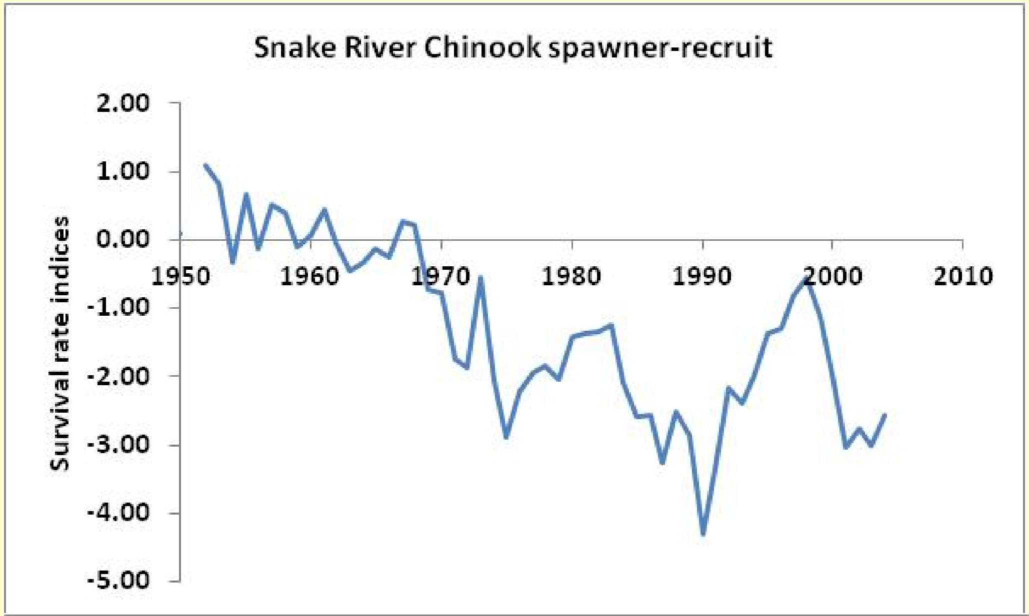
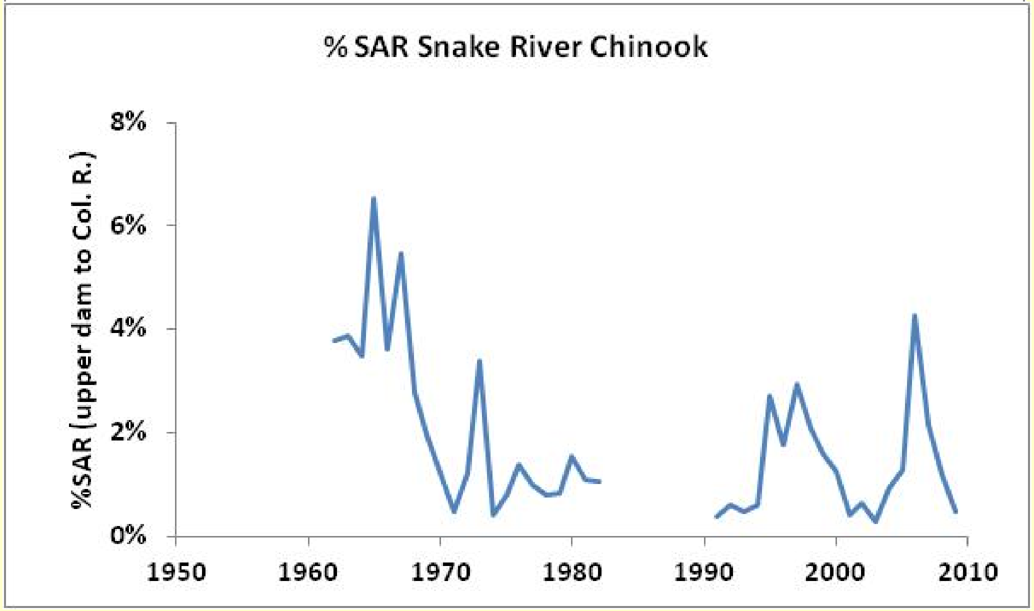
SARs also vary with ocean conditions and declined with FCRPS development





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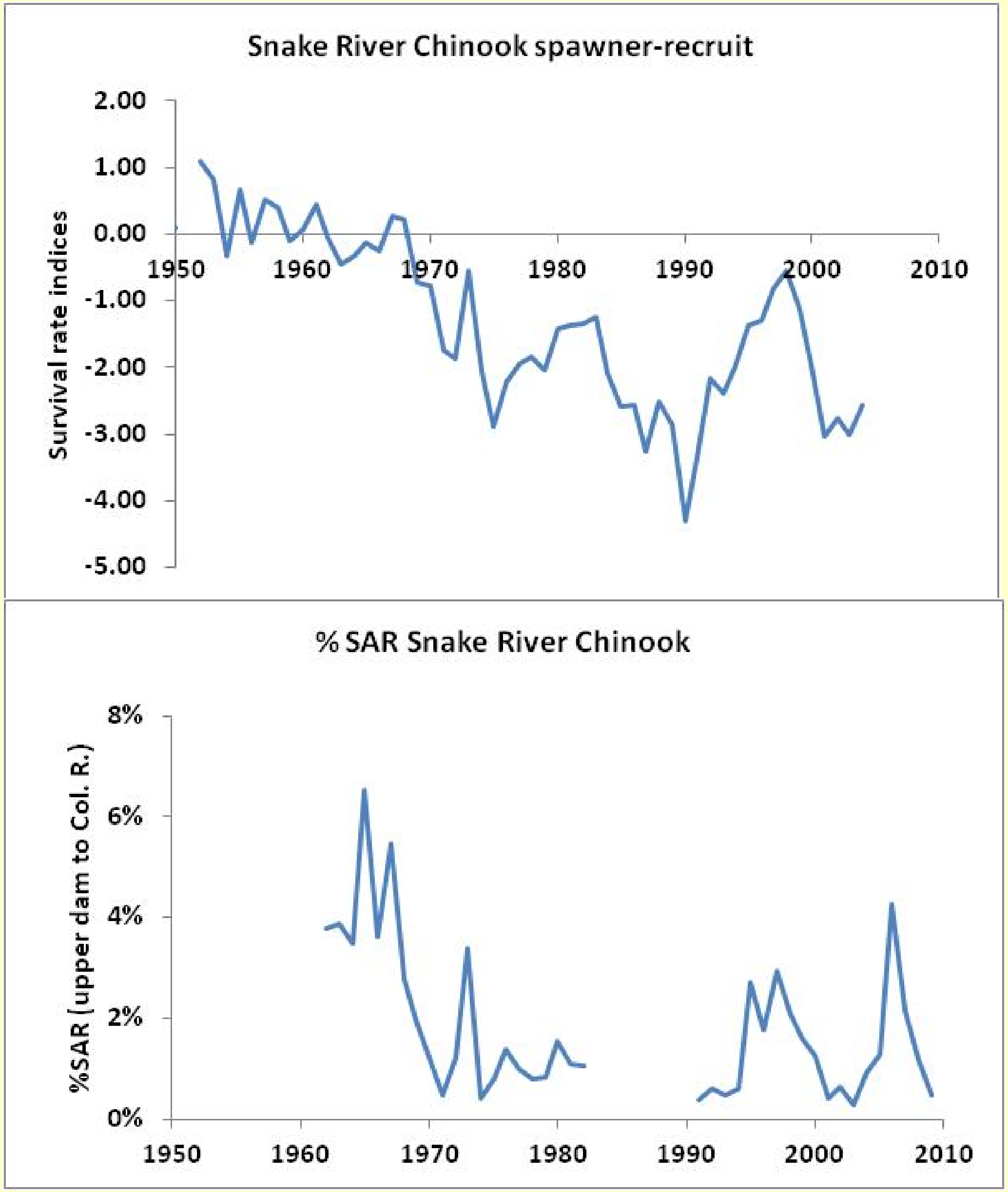
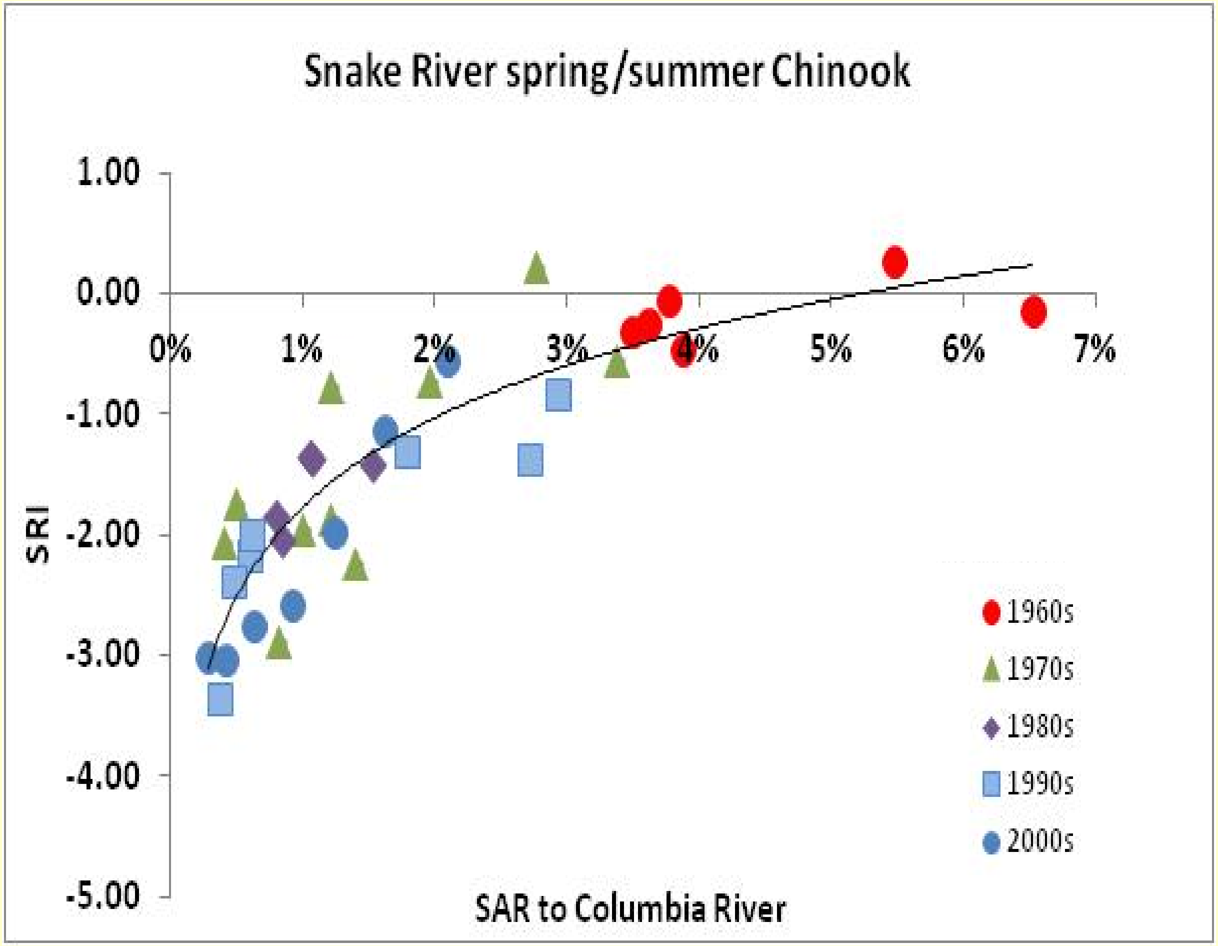
Aligning observed SARs and SRIs…



Snake R Chinook Life Cycle Productivity & SARs

SARs explain majority of variation in life-cycle productivity over this period (1964-2006)



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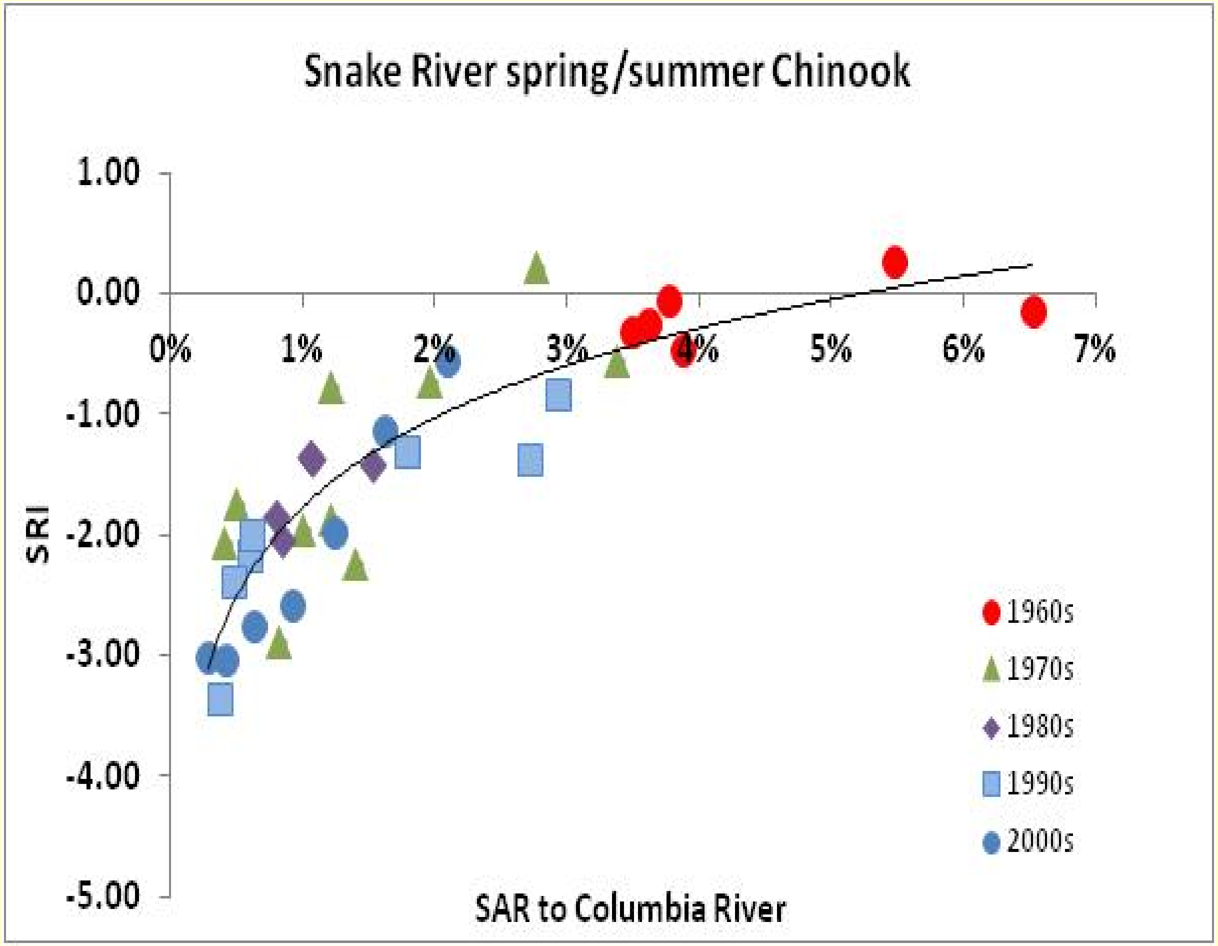
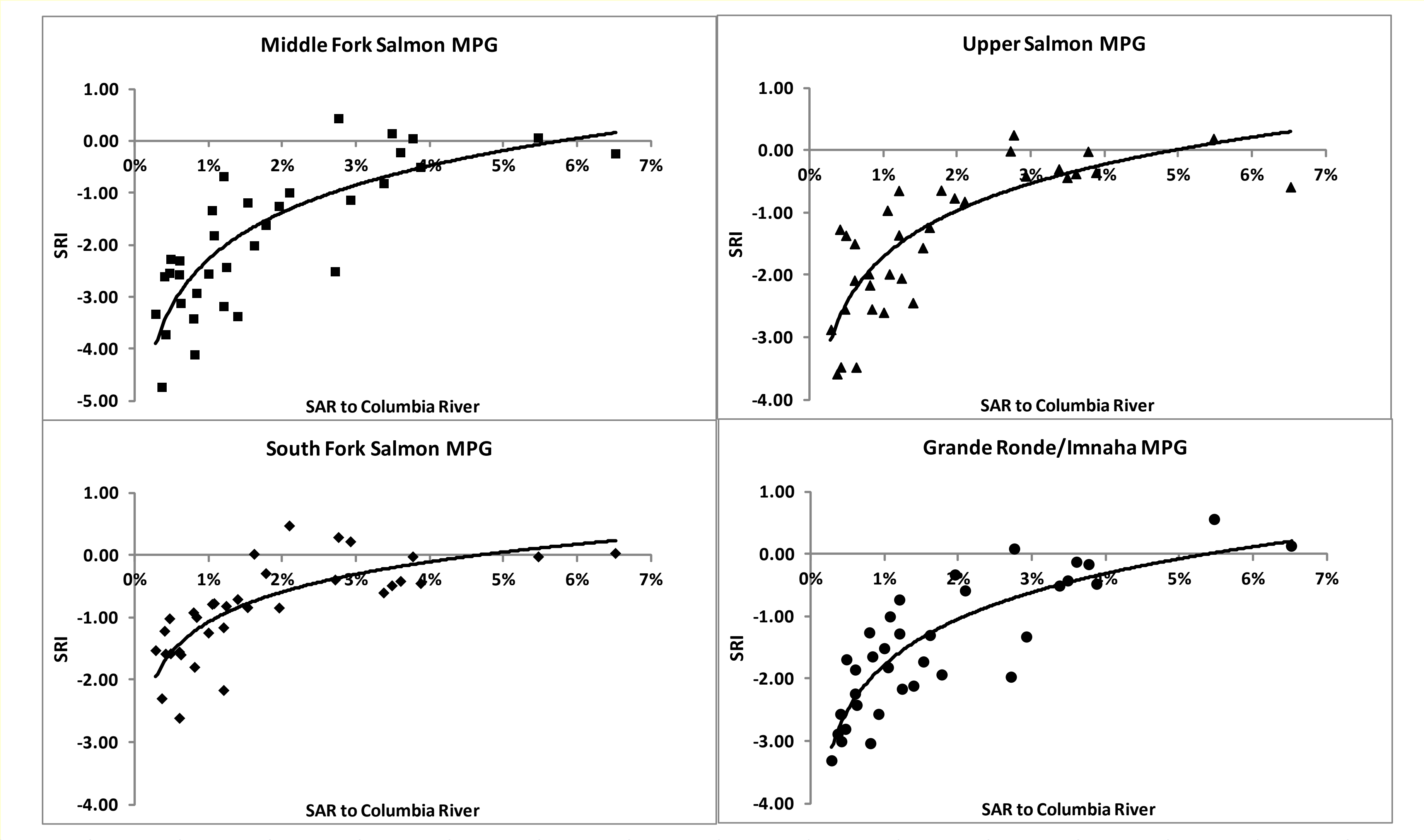


Expected productivity responses to (pre-harvest) SARs:

SAR	% pre-FCRPS
2%	36%
4%	75%
6%	116%

Results generally consistent with NPCC's 2-6% SAR goal

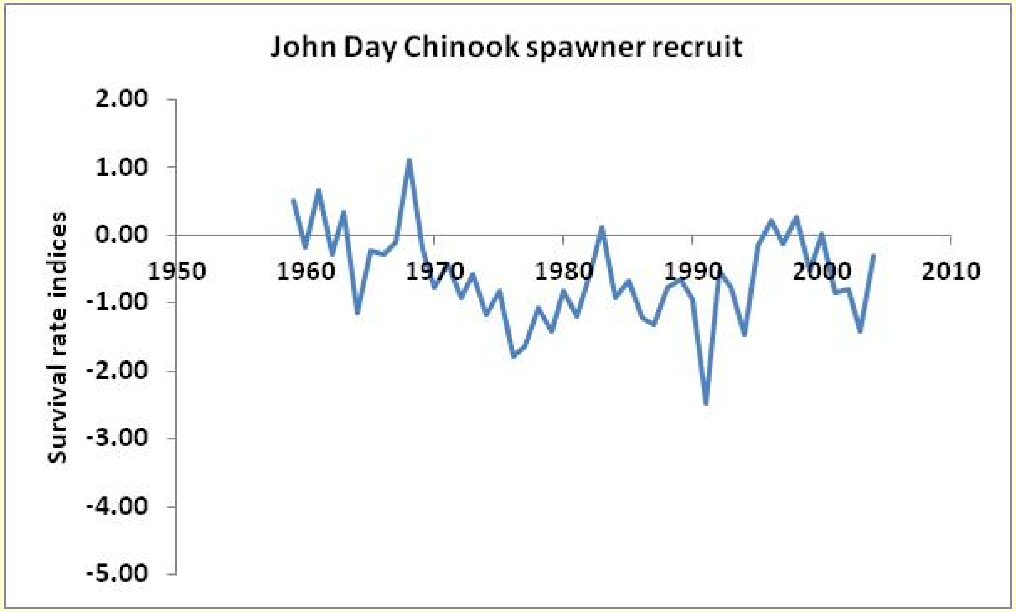
Similarity in responses across Snake River MPGs



John Day R Chinook Life Cycle Productivity & SARs

Life cycle survival rates declined to about 44% of Pre-FCRPS productivity (vs. 12% for Snake)

Post-FCRPS SRIs:
-0.8 average
(-2.5 to 0.3)



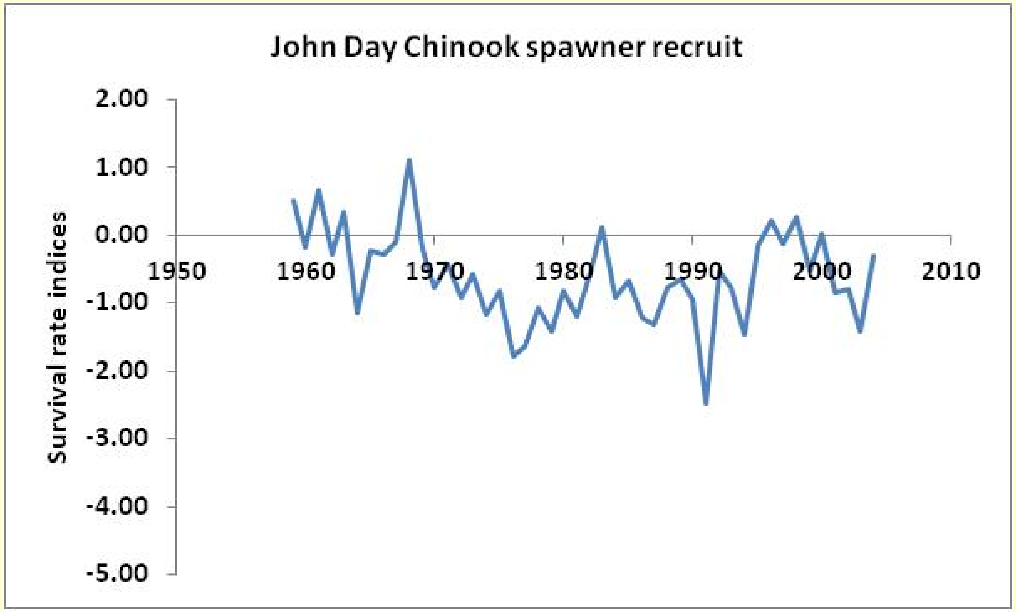
John Day R Chinook Life Cycle Productivity & SARs

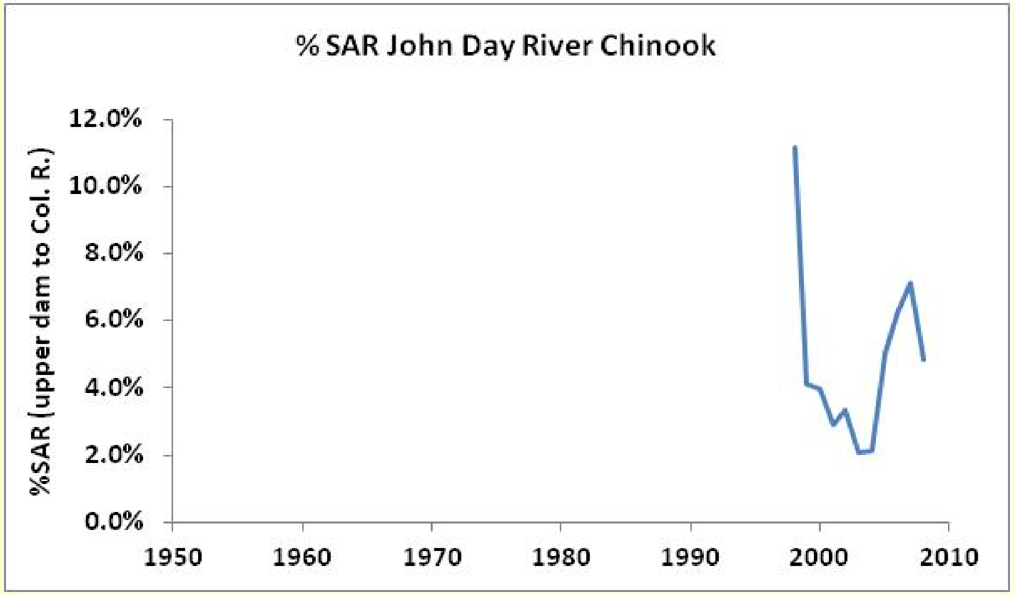
Life cycle survival rates declined to about 44% of Pre-FCRPS productivity (vs. 12% for Snake)

Post-FCRPS SRIs:
-0.8 average
(-2.5 to 0.3)

PIT tag SARs begin in 2000

Aligning observed SARs & SRIs…



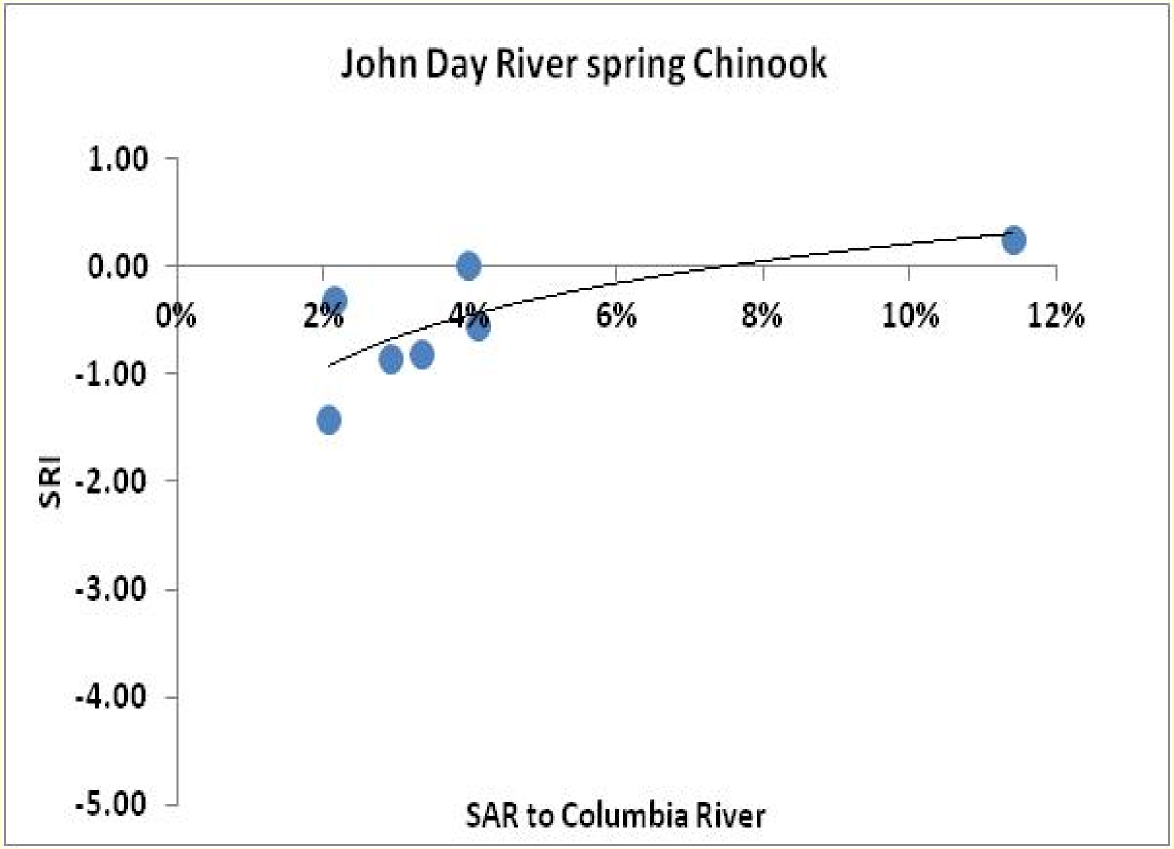


John Day R Chinook Life Cycle Productivity & SARs

Fewer SAR estimates, but…

SARs in 4-7% range associated with historical levels of productivity

Results also generally consistent with NPCC's 2-6% SAR goal



2015 ISAB review:

Comment: "The Discussion provides a good summary of key information, leading to the conclusion that pre-harvest SARs of ~4-7% are needed to improve productivity to pre-1970s levels."

"Is this sufficient to enable a self-sustaining natural population at spawning densities that exceed minimum abundance thresholds?"

2015 ISAB review:

Comment: "The Discussion provides a good summary of key information, leading to the conclusion that pre-harvest SARs of ~4-7% are needed to improve productivity to pre-1970s levels."

"Is this sufficient to enable a self-sustaining natural population at spawning densities that exceed minimum abundance thresholds?"

Response: "Pre-harvest recruits to the Columbia River [associated with 4-7% SARs] ranged from 140% to 900% of the MAT, providing considerable buffer for harvest and upstream passage survival for most populations."

"Key actions to increase SARs include reducing powerhouse passage and increasing water velocity…"

Future Work

- Update spawner-recruit analysis through recent brood years (smolt years 2007-2010)

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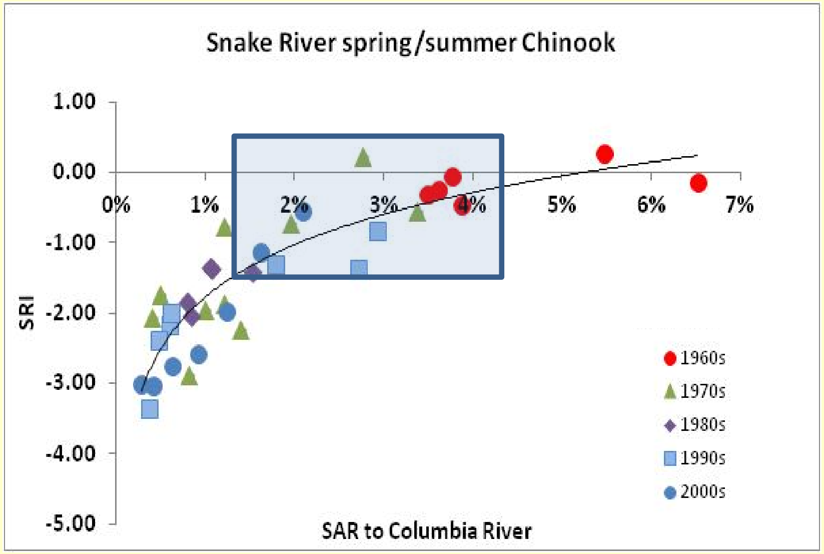
    - Snake: SAR range 1.3% to 4.3%

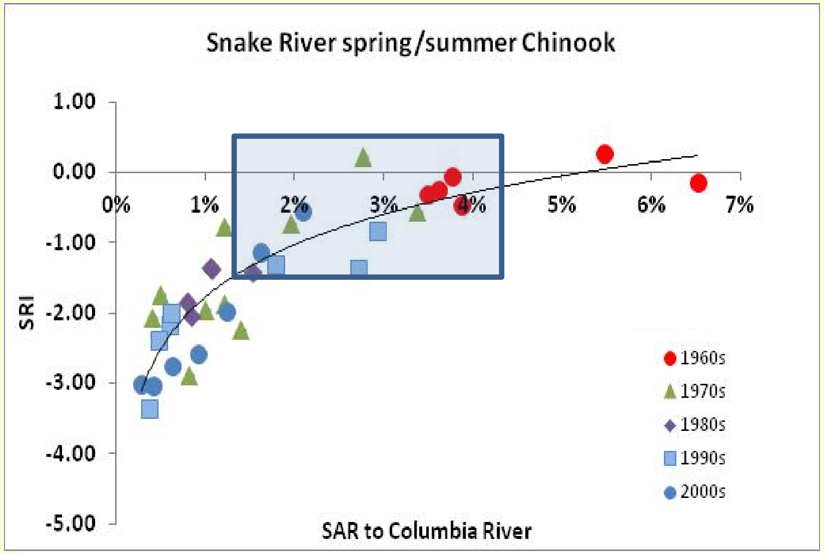


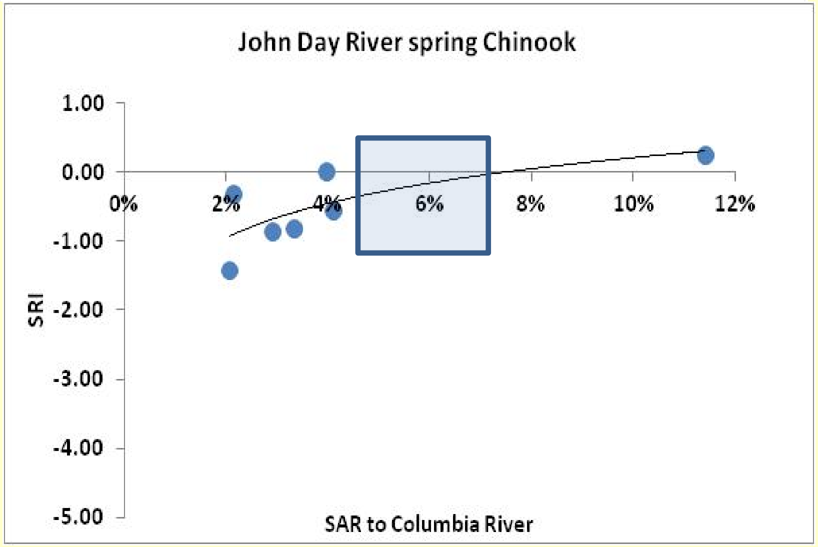
Future Work

- Update spawner-recruit analysis through recent brood years (smolt years 2007-2010)

    - Snake: SAR range 1.3% to 4.3%

    - John Day: SAR range 4.9% to 7.3%





Summary

- Recent SARs of Snake River wild spring/summer Chinook << NPCC 2%-6% SAR goals

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- Recent Snake River Chinook SARs inadequate to achieve population replacement at Minimum Abundance Threshold levels

- Recent SARs (LGR to LGR) and life-cycle productivity (measured at spawning grounds):
    - Low spawner abundance (~30% Minimum Abundance Threshold)
    - SARs < 1% major population declines
    - SARs > 2% allow for population to increase (at recent low abundance)
    - Populations in good habitat: few other options to improve status

Summary

- Density dependence considerations (address ISAB comments on Chapter 4)
  - Historical period with larger escapements and variable harvest rates (1950s to recent)
  - Fitted stock-recruitment functions available for large number of Interior Columbia spring/summer Chinook populations (pre-harvest recruits vs. spawners ~ density dependence)

Summary

- Density dependence considerations (address ISAB comments on Chapter 4)
  - Historical period with larger escapements and variable harvest rates (1950s to recent)
  - Fitted stock-recruitment functions available for large number of Interior Columbia spring/summer Chinook populations (pre-harvest recruits vs. spawners ~ density dependence)

- SARs explain majority of variation in life-cycle productivity for Snake River spring/summer Chinook
  - SARs and life-cycle productivity declined since FCRPS completion
  - Declines associated with FCRPS development; survival varies with ocean conditions
  - SARs in 4-6% range associated with historical (pre-FCRPS) levels of productivity
  - Results generally consistent with NPCC 2-6% SAR goals
  - Unlikely to achieve "broad-scale" recovery without substantial increases in SARs

0:00 ***(Brandon)*** So that concludes this portion of the review with the presentations. We're going to jump into the question/ answer session. So, for our speakers, please come back up to the front so you can be here for that, and I did want to mention one thing which is: all the presentations you saw today will be posted to the Fish Passage Center website hopefully tomorrow if not in the very near future. If you're used to downloading a copy of the CSS Annual Report It's going to be on the same website or link where that is typically posted. So, with that I will open up the question/answer session. And again, if you have a question, don't forget to state your name before the question so we can know who everyone is. So, questions?

2:11 ***(Bob)*** This is Bob Heinith, I work for CRITFC as a consultant. Question for Robin, looking at those 2008 SARs, for the *Upper Columbia stocks,* it seems like that was sort of a high point and I wondered if you had some sort of hypothesis why the SARs for that particular year seemed to be much better than other years?

2:32 ***(Robin)*** I'm not real familiar with the data that we used to build that and I thought that I saw even some of the Snake River and mid-Columbia and there was a high point around that time as well. But, unless somebody else is recognizing some in-river conditions or something like that it looked like 2008 was a consistent high year not just for the Columbia but Snake and Mid as well. I can't explain without getting into the details why that might be-

3:06 ***(Heinith)*** It might have been ocean conditions or something?

3:07 ***(Robin)*** I think it would be an environmental response since we did see it across all basins.

3:12 ***(Bob)*** Thanks.

3:16 ***(Brandon)*** Other questions?

3:27 ***(Al)*** Al Giorgi, consultant to Bonneville and I just wanted to follow up on that 60% value as a break point for transport efficacy, whether you decide to transport or not and whether there were more specific species estimates and how you would use that to manage transport in real time on an annual basis. Do you guys have any clarity on that one?

4:06 ***(Charlie P.)*** This gets back to what you asked earlier on 60% and all of that. In Appendix A of our annual report if you look at the details of this the black line is the predicted line for Chinook, the dashed for Steelhead. We actually looked at a variety of models, one whether Chinook and Steelhead had separate curves, whether they shared intercept, whether they shared a slope, or whether they were different on both counts. I think if I remember right there was no more evidence to say they're different lines than they are to say that they share the same intercept with different slopes or they share the same slope with different intercepts. So, there's quite a bit of noise right around this threshold value, at

least, on the annual basis. But, the point remains, that there is a crossover and we see it in Fall Chinook and basically, if in-river conditions, if survival can be pushed into this region, we could make some pretty good gains overall. Steve, do you want to address the temporal part of management?

5:56 ***(Al)*** How do you use this information on an annual basis to tailor your transport program for the upcoming year?

6:05 ***(Tommy)*** As far as I'm aware there's no forecasting that's currently going on for in-river survival so, if somebody was out there that did some modeling and said "Okay we're expecting this kind of water year with these expected spill proportions based on where these certain reservoirs are at in terms of their water capacity..." look at all the factors that are affecting in-river survival like Steve presented and came up with the forecast model. That would be the only way that I can see using a predicted in-river survival, in-season, to guide transportation strategies, but, I don't think there's a lot of forecasting of that.

6:59 ***(Steve)*** I just have a couple thoughts on this. First, I think it's important to consider that these are annual estimates of transport versus in-river. So those data are not really looking at within-season temporal patterns. Within-season temporal patterns are very difficult to get at because you don't know the timing of the true in-river fish. You don't detect them at the transportation projects. You get an index by fish that are bypassed, so, it's difficult for that kind of purpose. One of the points that I think is important is: rather than think about optimal timing of transport, you have to look at the SARs for transported fish, and they're not really where they need to be. Even if you were to optimize the timing of transport they're still not getting you the SARs that we need. So I think the more important question is: what needs to be done to optimize in-river survival so that you don't really need to transport. We haven't even mentioned that there are some unanticipated detrimental consequences to transportation, namely strain, to out-of-basin populations. That's a particular problem from Steelhead from the Snake River and the strain to the John Day, and transport fish are more likely to stray than fish that are migrating in-river. So I think, at least from my perspective, it's not so much trying to optimize the timing of transportation as to what needs to be done to provide consistently good in-river conditions and good in-river survival rates such that transportation really isn't necessary anymore.

9:07 ***(Brandon?)*** Other questions for the speakers?

9:25 ***(Doug)*** Doug Olson, Fish and Wildlife Service. This is a question for the life cycle model. I was wondering if you've seen any movement or discussion with managers of interest of using that life using that life cycle modeling to guide my management actions?

9:46 ***(Bob)*** The answer is "no". But, I can't speak to why. I just know that we've been developing this because it seems like an obvious door is open to look at relevant benefits. But no, I haven't been involved in any conversations with managers.

10:29 ***(Ed)*** Ed Bowles, Oregon (DFW), and, following up on that as a manager, I'm real intrigued with anything that allows me to turn dials and look at outcomes and so I appreciate the life cycle modeling. I wanted to just pursue, I asked a clarifying question earlier relative to the capacity and whether or not that was bounded in reality based on the geomorphology of the basins. I'd like to just follow-up with this whole idea. As a manager, I think, best scenario is a portfolio approach re-optimizing powerhouse, minimizing powerhouse passage, improving capacity where you can, improving productivity where you can. But I'd like, Bob, for you to speak to, assuming I can't make those all happen as a manager, assuming that SARs are static we can't turn that dial, because of political or economic or other things, can we habitat our way out of this dilemma from you standpoint with these models? This is why this issue of the feasibility of capacity building is an important one. Are we realistic in applying a habitat solution to an SAR problem, fundamentally? If you could just speak to that, and then I have a follow-up.

12:12 ***(Bob)*** I think my answer is going to reflect how I wasn't able to answer your previous question to your satisfaction. Because it's the "Bounded in reality" part of things. So to go back to your first question, no, those were not bounded in reality; they were bounded in theory, and loosely in visual evidence from what the modeling results were showing. I put a wall around what I saw and then just, assumed that if something could be done, what would it look like? That's all. Given that, if you're saying there's nothing we can do about improving return abundances with hydro-actions, then I would assume that this whole PIT PH remains at 100% of historical. So then it becomes, you know, we can't do anything *(too fast)* (to develop?) in these areas. They're not any loss of production they're climate based, or down river. I've been to a few of them and I'm the modeler not the field biologist. I've seen a few of these systems and I recognize that the limitations in some of them is not productivity and in others is not capacity. And in some cases, it is definitively both. Having seen firsthand in Catherine Creek in the Upper Grande Ronde I can see that they're different. I don't know whether there's enough money or political will or logistic nightmares, etcetera to change the habitat significantly. But if you look at what the return abundances were, clearly the habitat once was improved and it's better than it is now. I don't know, your question is definitely for somebody more well versed in what it takes to implement sufficient measures to achieve the kind of increments that I'm pointing to in the theory and model reconstruction. I'm not sure.

14:45 ***(Ed)*** I appreciate the attempt, Bob. I've got to ask, again though, I don't want to put you on the spot, this could be for anybody there, but, maybe in more simplistic terms: If we improve, let's use Catherine Creek as an example or Upper Grande Ronde, compared to mine or more some of the more wilderness areas. If you prove all the habitat parameters allowed the watershed time to heal but don't change SARs, can you expect those systems that you improve to perform better than the current wilderness systems are performing now? Which is, not meeting our targets.

15:47 ***(Bob)*** We could use the Minam as that comparison, specifically there was a reason I put it up there, because it's not degraded. If you could achieve all of your goals, and let's assume that you did, and let's assume we're talking about Catherine Creek, I think you would find yourself approaching what the Minam is currently doing. And I wouldn't expect any better than that.

16:17 ***(Ed)*** Okay.

16:18 ***(Bob)*** I would expect that whatever caused the Minam to fall below its historical levels is mostly unrelated to anything occurring in that area and more to do with, let's just say the smolt production itself.

16:39 ***(Ed)*** Okay, thanks. The last follow up on that line-

16:44 ***(Howard)*** Can I just respond, one thing to the last piece? I think CSS developed these tools for a number of reasons. One is to explore, like you say, "how would you turn these dials" and "how are some of the streams, particularly the ones in wilderness areas going to perform relative to some of the degraded streams?" and looking at this tradeoff between capacity, productivity and improvements and hydro system improvements. So, tools develop to help explore those kinds of things but like we showed with some of the work Charlie did is try to ground some of those pieces in observational information. Ultimately, trying to look at the modelling work- help sort of calibrate or validate the modelling work- but the other challenge we have, and I think the big issue that's here is there's things, like Bob said, we could do in the short term because of the ability to change things and things we can do in the longer term, but, during that period of time we're seeing shifts in things like climate change and shifts in corresponding ocean conditions. So it seems like these tools will not only help explore what dials to turn but it's also going to help with longer-term strategies because probably, like we've all discussed over the years, going to have to look at all of these things. Because the whole environment's shifting and it's not just hydrosystem changes, and it's not just freshwater habitat changes, but it appears the capabilities we're going to have to overcome these other challenges, is trying to look at the combination of those things and how you're going to stage that so you can have some immediate changes that give you the potential to realize these future habitat changes. In the future, changes from freshwater habitat or because, like we said, it takes a very long time to forward those freshwater systems to recover. So I think the combination of the empirical work and the modeling work, we're staging this and we're trying,I hope, from this feedback, this evolves to try to help with those answers. I think that's really the approach.

19:42 ***(Bob Lessard)*** I would add that I don't think it's reasonable to tackle the problem by working on only one thing. I think, if there's more than one problem you need to tackle more than one thing.

20:01 ***(Ed)*** The other point I bring up that I didn't hear come out too much- has to do with the dial turning- is turning the dial relative to resources and other things for tributary habitat is obviously not common to other tributary habitats or other major population groupings; whereas the migration corridor, powerhouse exposure is common, I'm assuming, to all these population groupings at least within a particular run timing or immigration timing. So the benefits relative to turning a dial, you turn it once it's helping the entire suite of population in that context, correct?

20:50 ***(Bob Lessard)*** That is correct. The assumption was, that, in terms of looking at safe population together, that particular aspect was in common.

21:12 ***(Alec)*** I'm Alec Maule with the ISAB and ISRP. I just wanted something to give us an update as to what's going on with the Carson tag effects study? The future of that study?

21:25 ***(Steve)*** Yes, that was initiated with smolt migration year 2011. We have three groups of tagged fish there: there's a coded wire tag-only, a pit-only, and a dual tagged pit plus coded wire. The study design was laid out such there would be four brood-years and so 2014 is the final juvenile migration year, and so that's occurred. We're expecting the four-year-olds from that to come back this year and all the returns will have been completed by 2017, it'll take some time to process the coded wire tag and the PIT tags that return through those times. So I expect that study will have a final report sometime in 2018.

22:36 ***(Brandon)*** Other questions?

22:42 ***(Dave)*** Dave Statler, Nez Perce Tribe. I'd really feel cheated if I didn't have some way to interject something about Pacific lamprey**,** in this conversation.

22:56 ***(???)*** The only reason we bring him.

22:58 ***(Dave)*** But, what I'm going to say here, relates to Ed Bowles comments about limitations of habitat due to geology and soils and stuff like that in areas like, I don't know, that one. It also relates, I believe, potentially to modeling efforts? It's obviously true that the inherent fertility of places like the **(**Location**)** with its geology is inherently not productive or unproductive or relatively speaking not as productive. What's happened to these area's like that due to the lack of anadromous fish, anadromous salmonids, and Pacific lamprey is that the influx of marine-derived nutrients are no longer near what they were in historical times so that, to me, is a cause for the current capacity to be reduced. So, what we would need ultimately in those systems is to restore the salmon and the Pacific lamprey. We really an ecosystem restoration-kind of thing and so even though in-wilderness areas may appear outwardly to be, 'pristine', those ecosystems are not functioning as natural ecosystems due to the lack of the marine-derived nutrients. So we've got ourselves into a box here and it's going to take some work and some smart people to get us out of that so that we can have these areas, provided we can get fish up to them with increased SARs. Increase the SARs, they can actually realize the production more approaching what the historical production was. So that means getting the marine-derived nutrients from the salmon and Pacific lamprey back into the system so we can have that type of ecosystem restoration that can support what we need to be supported in terms of anadromous fish, and also to take full advantage of whatever hydrosystem improvements are made to increase the SARs. Thank you.

25:35 ***(Bob Lessard)*** I don't think there was a question there. But, I'd like to say something about that anyway. You more or less described one potential mechanism for capacity being a transient value versus a fixed value. It's also relevant to population recovery and density limits. You could easily notice that a population building up with what appear to be reaching some sort of a density limit, and if marine-dried nutrients contributes significantly to capacity and more productivity, it may look like you're beginning to

reach a limit. Whereas because the abundance has been so low for so long, that system actually needs to build up to regain some of its former potential. I don't know how significant that is, but that's the way I see it.

26:41 ***(Dave)*** So then, one of my questions would be, are you going to think about any way, including that type of marine-derived nutrient pumped into modeling efforts?

26:59 ***(Bob)*** I'm not sure where to get the data to quantify that in the system. Clearly the Columbia has been at pretty low abundances for a long time. It's hard to see where we could get, in light of that fact that other things have changed as well and climate factors considered. I'm unsure how long it would take to so see something measurable that would show that effect. But, it's interesting and I agree with you, we don't know, and there is a potential benefit that's unrealized until we so those kind of *(unintelligible) abundances?*

27:48 ***(Brandon)*** Any more?

28:03 ***(Charlie Morrill)*** Ed asked a question about having buttons to turn the dials to adjust, and I think I'll ask the group, maybe Charlie in particular, You've been working with following SARs for years. We still see some very significant differences among the different reaches of the system. What would your perspective be and what would you share with the group what you think we need to work most? What dials, what *(unintelligible/noise)* transportation versus in-river spill? If you were to suggest these dials that we think we need to focus our efforts on, where would they be?

28:45 ***(Bob?)*** This graph kind of- this graph and the graph that led up to it basically pushing in-river survival, if you look back at- it's really clear on the Snake River wild chinook- we need to be operating in this range upward and none of these routes are really getting there. There's more potential for the in-river route. We've tweaked transportation; we've been working with transportation for before you started working here. It predated me, but-we've made some improvements, we've delayed the start, we've done all of that. But, until we get, until we start to see some in-river survivals we're capping what the in-river fish can do, and so I'll just leave it at that.

30:07 ***(Ed?)*** Charlie was getting at one of the questions I was going to ask relative to that: We're seeing this powerhouse piece that you kind of treat a little differently than reach survival correct? Yet the two seem to be coming, more and more, perhaps, an important kind of Index of Performance of Health for the in-river migrants: one having a stronger bearing, I think, on SARs, the powerhouse passage, perhaps more so than on reach but I just-. My first question relative to those two becoming more important metrics for managers relative to be judging the health of the in-river experience. Do you have some ideas on how CSS can help refine those tools as, I hate to use the word 'standard', but at least metric for us to be using more carefully in our management?

31:19 ***(Steve)*** That's exactly the direction we're trying to move forward in future reports. It seems to be a better standard and better measure and better metric than 'percent spill' and 'number of dams with

spill'. It's a way to-kind of- more mechanistically quantify the effects of dam passage routes. That's exactly where we're trying to move in the future and trying to look at what are appropriate goals in terms of number of powerhouse passages that would be necessary to achieve in-river survival targets or smolt-to-adult return targets. And so that's exactly where we're trying to move things.

32:13 ***(Ed)*** My last comment and question is: I've been at this a long time as a manager tracking CSS, and there's been, I'll call it a "trajectory of knowledge" that is accumulated as a result of this really unprecedented sort of time series of collaboration and effort. To me, and obviously I'm speaking from a perspective of Oregon I guess, but, it's really coming together into a compelling story with this trajectory of knowledge. I guess I'd ask: is there anything new or thing that's given pause in that trajectory that you're aware of as we progress? Anything that we- you spoke to this Steve, right here, on perhaps, powerhouse, reservoir reaches, as something to explore more, but anything in that trajectory that you're now learning that we need more emphasis? And then, as managers, are you getting the resources you need, to continue this trajectory because I'm not aware of other time series like this that have been so fruitful relative putting the pieces of the puzzle together.

33:44 ***(Steve)*** On the second question I would say that I think we are, for the most part, getting the resources that we need because we're relying on both the CSS itself for buying some of the pit tags but also the region in general and all the collaborate efforts that are going on out there to release these tagged fish which have given us such amazing information that is not only useful when a assessing environmental conditions on survival or measuring SARs but also using up and showing up in harvest management and all these other age maturity issues, so, as long as those collaborations and tags are released and I think that we could continue this fruitful effort and provide relevant, important management knowledge to the region. There are some places that could use improvement, and it's basically kind of related to the availability of pit tags and the information that we can get to them particularly the upper-Columbia. There's, as Robin mentioned, there's less pit tagging effort up there, there's less availability of smolt for pit tagging and, a big issue is the lack of detection at some of those upper-Columbia dams and so that kind of impairs our ability to do some of the assessments to some degree. To the degree we can improve tagging levels up in the upper-Columbia I think that would be helpful, improved detection capabilities in the upper-Columbia I think that would be helpful as well. Does that answer your question?

35:30 ***(Ed)*** Yes, thanks.

35:32 ***(Brandon)*** I think one other group that we could continue to build on is the Snake river fall Chinook groups that Tommy had mentioned, the CSS stated collaborating with the Nez Perce to add some tags, or bring tags back, to two of the production groups in 2015 and increase those a little bit for 2016, but the desire would be bring in-the transportation study had several production groups that were getting substantial pit tag groups in 2015 and 2016 we've only been able to incorporate two of those production groups and the desire would be to bring back most of the other ones if not all of other ones that you saw in Jerry's or Tommy's presentation.

36:24 ***<u>(Brandon)</u>*** Any other questions for the group? Thank you guys for coming, see you next year.

APPENDIX J

RESPONSE TO COMMENTS ON DRAFT CSS REPORT

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Review of the Comparative Survival Study Draft 2016 Annual Report

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ISAB 2016-2
October 21, 2016

Review of the Comparative Survival Study (CSS) 2016 Draft Annual Report

Contents

Review of the Comparative Survival Study (CSS) 2016 Draft Annual Report

I. Background

The Northwest Power and Conservation Council's 2009 amendments to the Columbia River Basin Fish and Wildlife Program called for a regular system of independent and timely science reviews of the Fish Passage Center's (FPC) analytical products. The 2014 Program's Appendix H maintains this review function. These reviews include evaluations of the Comparative Survival Study's draft annual reports. The ISAB has reviewed these reports annually beginning six years ago with the evaluation of the CSS's draft 2010 Annual Report and most recently the draft 2015 Annual Report (ISAB 2010-5, ISAB 2011-5, ISAB 2012-7, ISAB 2013-4, ISAB 2014-5, and ISAB 2015-2). This ISAB review of the draft 2016 CSS Annual Report is the ISAB's seventh review of CSS annual reports in response to the Council's Program language.

II. Summary

This ISAB review begins with an overview of the latest report (this section). It then moves on to suggesting topics for further CSS review (Section III), general comments on each chapter of the 2016 CSS Annual Report (Section IV), and ends with specific queries and suggestions (Section V).

The annual CSS report is a mature product, typically including only updates with the latest year of data and expansion of analyses as more data are acquired. Many of the methods have been reviewed in previous ISAB reports and so now receive only a cursory examination. As more data are acquired, new patterns and questions arise on the interpretation of the results—this is now the primary focus of our reviews. The ISAB appreciates the CSS's detailed response to suggestions provided in previous reviews, and we do not expect the CSS to necessarily respond immediately to new requests for further analyses.

Chapter 1 is similar to previous years with the 2015 results added. Two new fish populations have been added. In the 2016 report, the size of the PIT tags used is reported as being 11 to 12 mm instead of the 9 to 12 mm in previous reports. If this is a real change, the rationale for the change is needed along with a discussion of potential impacts on the fish (e.g., are larger fish now tagged to accommodate the larger tags?).

In Chapter 2, the existing life cycle model was used in a prospective analysis to simulate the relative benefits of flow/spill modifications to habitat. While the approach is generally well implemented, the ISAB has some concerns about specific aspects of the simulation study that suggest the outcomes may not be as clear cut as indicated in the report. For example, what is the justification of choosing particular years as "representative" of low/medium/high flow conditions? Some variables that could vary are held constant—e.g., powerhouse contact rate derived from PIT tag data (PITPH) and water travel time (WTT)—and so the simulation results may underreport the variability in the response.

Chapter 3 is mainly an update with the latest information on in-river effects on juvenile travel time, instantaneous mortality, and survival. A key finding is that there is large variation in the results among years and among cohorts. The variation among years is understandable; the variation within a year less so. Many figures (e.g., Figure 3.2) show a consistent pattern in fish travel time and survival over cohorts as the year progresses. Mortality tends to increase over the migration season and with water temperature (except for sockeye). The report lists four potential mechanisms: (1) declining smolt energy reserves or physiological condition over the migration season and with water temperature, (2) increasing predation rates on smolts over the migration season and with increased water temperature, (3) increases in disease susceptibility or disease-related mortality over the migration season and with increased water temperature, or (4) some combination of these often interrelated mechanisms. Is there an attempt to test these hypotheses using other approaches, either within CSS or by other investigators? Answers to these questions might lead to improvements in survival. We agree that the apparent contradictory response of sockeye warrants further investigation.

Chapter 4 described overall annual SARs and was updated with new data; details are presented in appendices. In addition, an analysis of relationship between the ratio of transport to in-river survival (TIR; transport effect) and in-river survival is now included. It is not surprising that the transport TIR is inversely correlated with in-river survival (Lower Granite Dam [LGR] to Bonneville Dam [BON]). This new analysis identified the value for in-river survival when the benefits of transportation appear to disappear. The CSS also reported on the relatively large absolute difference in SAR based on PIT-tags versus run reconstruction (the values are highly correlated, however). As in previous reports, this report listed various hypotheses. A study is underway to further evaluate PIT-tag effects on salmon survival, but these results will not be ready until after summer 2017 when tagged age-5 Chinook will have returned. Potential bias in survival caused by tagging methodology (or in the run reconstruction methodology) is an important issue to resolve, and the ISAB looks forward to the results of this study.

CSS Response: The results of the PIT-tag effects study should be available for the 2017 report. And will be provided then.

The material in Chapter 5 was combined with other chapters in previous reports and has now been split out. This is an update with an additional year of data. Chapter 5 continues the examination of the relationships between life cycle productivity and SARs, including the level of SARs needed to reach or exceed population replacement. The findings suggest that pre-harvest SARs of 4%-6% are associated with pre-1970 levels of productivity for Snake River spring/summer Chinook; SARs are much lower in subsequent decades. How might these early SARs (~4-6%) compare with SARs from viable wild Chinook populations in other regions? To what extent might improvements in hydrosystem management, predator control, and estuarine habitat lead to SARs of 4%-6%?

Chapter 6 is mostly an update on Snake River subyearling fall Chinook.

Chapter 7 is a repeat of an analysis done in 2010 with additional years of data. A logistic regression analysis was used to investigate the impact of year, bypass effects, and rearing type on subsequent survival and return as an adult. Estimates (Table 7.4) appear to be on a "per bypass" basis. What is the average number of bypasses encountered by a fish? Wouldn't that be a more accurate reflection of the impact of bypass on an outgoing smolt?

Chapter 8 examined differences in the mean age of maturity among different stocks, years, and fish type (wild or hatchery) using regression methods. While the analysis mostly seems appropriate, the ISAB has numerous suggestions on improving the presentation of the results.

Appendices A and B are updated with an additional year of data. The ISAB is pleased that electronic versions of many of these tables are now available at the FPC website.

Appendix C reports on the development of a weighted bootstrap procedure to deal with a stratified sampling and tagging of smolts that is not proportional to abundance. The authors describe a bootstrap procedure for estimating parameters, but the ISAB suggests that a stratified approach be incorporated directly into the analysis routines currently used to allow for future expansion of stratified-tagging studies.

III. Suggested Topics for Further Review

In 2013, we recommended these topics (ISAB 2013-4, Page 1):

1. *Hypotheses on mechanisms regulating smolt-to-adult survival rates (SARs)*
2. *Life-cycle modeling questions and Fish and Wildlife Program SAR objectives*
3. *Data gaps*
4. *Rationalization of CSS's Passive Integrated Transponder (PIT)-tagging, and*
5. *Publication of a synthesis and critical review of CSS results*

In 2014, we recommended these topics (ISAB 2014-5, pages 2-3):

1. *Hypotheses on mechanisms regulating smolt-to-adult return rates (SARs) [update from 2013 review]*
2. *Life-cycle modeling questions and Fish and Wildlife Program SAR objectives [update from 2013 review]*
3. *New PIT/CWT study to further investigate differential survival among these tag types*

In 2015, we recommended these topics (ISAB 2015-2, pages 4-5):

1. *Use SAR data to examine both intra- and interspecific density dependence during the smolt out migration and early marine periods*
2. *Propose actions to improve SARs to pre-1970s levels*
3. *Explore additional potential relations between SARs and climate and ocean conditions*
4. *Consider ways to explore the variability of inter-cohort response*

The CSS group has incorporated many of our suggestions into the current document. For example, the current report has a substantial discussion of correlations among SARs from different regions or effects of transport on SARs (#1 in 2013; #1 in 2014). The life cycle modeling now allows for variation in stream productivity and hydrosystem survival and simulates the correlative impacts of these changes on predicted future population abundances (#2 in 2013; #2 in 2014; #2, #3 in 2015). The ISAB appreciates the CSS efforts to respond to our queries which in turn lead to further questions.

Some of the recommendations from the ISAB appear to be beyond the scope of the CSS but will become increasing important in the future. For example, is there evidence of density dependence during the smolt out-migration and early marine periods (2015 #1)? Could the CSS estimate total smolt abundance of each species, say at Bonneville Dam? Is this a potential

mechanism to explain the inter-cohort variation in responses (2015 #4)? This is reflected in our recommendations for future work below.

In 2016, we recommend the following four topics for future reports:

1. *Use more realistic and more variable future flow conditions for the study on the impact of flow/spill modifications under future climate change. Simulating only low flows or high flows for decades may not be a realistic scenario. What is the impact of a correlation between Pacific Decadal Oscillations (PDOs) and flows that has not been considered in the simulations presented in the 2016 report?*

CSS Response: We will take this into consideration in future reports.

2. *What is the impact of the new restricted tag sizes? Are there fish that were previously marked and are now not marked (e.g. smaller fish) due to the larger PIT tags being used? Similarly, conclusions from studies of compensatory mortality (e.g. in relation to predator control) may be affected by the choice of fish that are tagged. A brief review of the PIT tag procedures should be undertaken so that users of the CSS data are fully aware of any limitations in the conclusions of other studies that are related to types/sizes of fish tagged.*

CSS Response: We have corrected the text to say that tag sizes range from 9 to 12 mm. So restricted tag size is not an issue.

3. *There has been a great deal of interest in the impact of predator control programs on salmon returns, especially northern pikeminnow and birds. A life-cycle model is the natural way to study these impacts, but the current version of the life-cycle model appears to incorporate density dependence only at the spawner-to-smolt stage. The ISAB recommends that consideration be given to modifying the life-cycle model to allow a range of compensatory responses ranging from complete additivity (as now is the case) to plausible compensatory mortality effects related to density dependence and predator selectivity (see ISAB 2016-1). This continues our previous recommendation (#1 in 2015) to investigate impacts of density dependence on subsequent return.*

4. *Both the CSS and NOAA provide estimates for in-river survival. How do these estimates compare to each other? If there are consistent differences in the estimates, can these be explained?*

CSS Response: The CSS uses a different approach to survival estimation from LGR to BON than NOAA. The CSS estimates are calculated for each release group above Lower Granite Dam, and as such are often limited in sample size, especially when estimating survival to Bonneville Dam. The CSS uses per mile expansions when estimates are not calculable for all reaches. Estimation of S_R with fewer than six individual independent estimates was calculated as follows: first, the product of the survival estimates over the longest reach possible was converted to survival per mile, and then this was expanded to the number of miles between LGR and BON. However, because survival per mile rates thus generated were generally lower for the Snake River (LGR to MCN) than for the Columbia River (MCN to BON), direct estimates of in-river survival over the longest reach possible were preferable.

5. *What factors have led to declining proportions of four and five-year olds and increases in three-year olds in spring/summer Chinook? Models that include ocean factors associated with salmon growth and climate change, differences in hatchery practices, or freshwater environments (tributary temps, or annual differences in migration corridor) may be of interest.*

IV. Comments on New or Updated Analyses in the draft CSS 2016 Annual Report by Chapter

IV.1. Chapter 1. Overview

Chapter 1 is similar to previous years, providing a summary of other chapters and what is new in this year's report. Last year's report was updated with 2015 results. In addition, two new fish populations have been added: natural-origin Okanogan River sockeye and natural-origin summer Chinook from above Wells Dam.

According to the 2016 report, the size of PIT tags is now 11 to 12 mm (p.13, l. 26) instead of the 9 to 12 mm reported in previous reports. Is this an actual change in the size of the PIT tags or just a typo? If this is a real change, the rationale for the change needs to be given and a

discussion of potential impacts is needed (e.g., are larger fish now tagged to accommodate the larger tags?).

CSS Response: We have corrected the text to say that tag sizes range from 9 to 12 mm. So restricted tag size is not an issue.

This year's report has three new topics: 1) statistical relationships among total annual flow and salmon population parameters such as survival, smolt-to-adult-return rate (SAR), and other response variables in the life cycle model; 2) impact of the juvenile bypass system on delayed mortality as measured by SARs; and 3) average age of maturity across stocks and years. Additionally, Appendix C presents preliminary results on using a weighted bootstrap procedure to account for a stratified random sampling of fish from certain populations.

CSS Response: We have moved weighted bootstrap procedure description to Appendix H for the Final Report.

IV.2. Chapter 2. Life cycle modeling of alternative spill experiment scenarios

This chapter continues the development of the life-cycle model. No new features were added to the life-cycle model in 2016. However, they used the life-cycle model to evaluate the impact of alternative spill/flow levels on SARS and long-term abundance of spring/summer Chinook to 2050.

The new work uses the 2015 model and investigates the impacts of flow/spill prospectively by applying simulated future environmental conditions to mimic current conditions or preliminarily investigate climate change conditions.

They also investigate the relative benefit of improvement in juvenile passage vs. improvements in spawning productivity and capacity.

They conclude that:

- *greatest benefits to SARS occur at highest spill and lowest flow*
- *relative return abundance appears to be mostly limited by capacity of the habitat to support the fish.*

CSS General Response: Several comments seem to focus on the fact that the analysis of alternative spill scenarios held certain aspects of the simulations fixed, rather than allow them to vary. While it's true that some things were held constant, the goal was not to quantify uncertainty in predicted outcomes when variability is introduced everywhere. The goal was to contrast alternative spill scenarios at different underlying conditions (eg: high, average and low flow years). The variability in the simulated outcomes was driven largely by uncertainty in parameter estimates and simulated variation in ocean conditions. The simulation results present ranges of predicted long-term average abundances and SARs for each of four spill scenarios at three flow levels. It is the overall pattern of relative behavior across flow levels and spill scenarios that is of interest, rather than a comparison of simulated results at each random draw.

While the approach is generally well implemented, the ISAB has some concerns about specific aspects of the simulation study that suggest the outcomes may not be as clear cut as indicated in the report. For example, in Figure 2.9 (and similar figures), the box plots and whiskers show the variation in the $\overline{R}$*(the average abundance in the last 10 years of a simulated population trajectory over simulated future flow conditions) over the different simulation scenarios. However, when discussing differences in outcomes among scenarios, it is differences in the average of the* $\overline{R}$ *(*$\overline{\overline{R}}$*, the average of the average abundances) that is of interest and no information on the uncertainty of* $\overline{\overline{R}}$*is shown. Presumably the uncertainty in* $\overline{\overline{R}}$ *is very small because it is based on 10,000 simulations. These figures would be improved by adding a "typical" measure of uncertainty for* $\overline{\overline{R}}$ *to the plots. Otherwise the unwary reader may conclude that because the box-plot overlap considerably, there is no evidence of a difference in the* $\overline{\overline{R}}$ *among scenarios.*

CSS Response: $\overline{R}$ for one scenario is the average abundance predicted by using PITPH and WTT for that scenario, using a draw from the posterior parameter estimates. Figure 2.9 (and other similar figures) shows the variability in the $\overline{R}$, with the boxes showing medians and ranges of uncertainty. A different scenario uses the same posterior draw, but different PITPH and WTT. All of the variability comes from the variability in the posterior draws, and from the simulated ocean variability, harvest, and conversion rates, but all of those are consistent across all scenarios. In other words, each simulated comparison between $\overline{R}$from different scenarios will follow the same pattern as the medians in the box-whisker plots.

Similarly, there are no measures of uncertainty shown in Figure 2.12/2.13. The text implies that such a measure could be inferred (page p.48, l.31) but it was not clear how this is done. Measures of uncertainty should be added to the graphs by the CSS team rather than forcing the reader to try and impute them.

CSS Response: Figures 2.12 and 2.13 show the relative median predictions. The 12 scenarios all predict a range of outcomes depending on the posterior draw, but all 12 are predicted 10,000 from a common draw 10,000 times. A figure comparing individual ratios is included for evaluation of uncertainty in Figure 2.12 ratios.

What was the justification for using 2010 as a typical low-flow year, 2009 as an average year, and 2011 as a high-flow year? Did the team do a frequency analysis to choose these years, and if so, what were the exceedance probabilities for these years? If not, was it just by looking at a plot of annual and seasonal flows and deciding that these particular years seemed to appear low, average, or high flow? If the latter, it might be helpful to refer to Figure 1.6, middle panel. By choosing only one year's conditions to represent low, average, and high flow conditions, the simulation will have reduced future variability (see next point as well).

CSS Response: 2009, 2010, and 2011 are fairly representative of low, average, and high flow years, and for which known WTT data can be used in conjunction with PITPH calculated at a known flows. PITPH was calculated with spill caps applied to the hourly flow data at all eight projects from April 1 through August 31. These three years represent a range of flow conditions relative to the historic data (1929 to 2012). The three years also represent operations representing the most recent configuration and operation of the FCRPS. While 2010 was not a low flow year when the whole spring and summer period is considered, the flows that took place during the spring period being modeled were considerably less than other years. This analysis was performed not to evaluate precisely what in-river survivals would be at a the most average, high, or low of all possible flow profiles, but rather to predict in a relative sense what the population response would be to a reasonable contrast in flow conditions. 2009, 2010, and 2011 provided what appeared to be a reasonable contrast of high, average and low flow years.

The range of observed variation in the long-term results may be understated because variation in all variables was not considered. For example, PITPH and WTT were fixed at certain values for each scenario and not allowed to vary (e.g. p.38, l.38).

CSS Response: PITPH and WTT are held constant in order to provide a relative perspective on how spill alternatives will affect survival at different flow levels. PITPH changes as a result of the spill occurring at each scenario. If PITPH were not held constant, a comparison across spill scenarios would not be possible.

Harvest doesn't appear to have any variation at different levels of abundance.

CSS Response: Harvest increases with abundance. See page 36 line 11-12. "We modeled the harvest rate to increase asymptotically to 40%, and to reach 20% at an aggregate run abundance of 5000 for all populations."

The ISAB assumes that stochastic variability in harvest has been applied; i.e., a 50% harvest probability does not always lead to exactly 50% of fish being harvested, but this should be clarified in the document. Only one flow "year" was considered for "low", "average" and "high" flows (see above), and this single flow year was repeated for the future population projection. This may be unrealistic to assume that there is little future variation in flows. The report was not clear if demographic stochasticity was applied in the forward projections. For example, was there random variation in the number of recruits produced for a given set of productivity and capacity parameter values? Was there random variation in the number of fish surviving given a particular survival parameter value?

CSS Response: PITPH and WTT are held constant in order to provide a relative perspective on how spill alternatives will affect survival at different flow levels. PITPH changes as a result of the spill occurring at each scenario. If PITPH were not held constant, a comparison across spill scenarios would not be possible.

The Pacific Decadal Oscillation (PDO) was simulated independently of flow conditions. There are studies that have indicated that PDO is correlated with stream flow—e.g., refer to the NOAA fisheries website where it states that stream flow is correlated with the PDO. Will the simulation of PDO and flow as independent variables lead to unrealistic outcomes?

CSS Response: Figure 2.2 shows that there is a modest amount of correlation between PDO and stream flow, but model fitting results indicate a better fit if WTT and PDO are both included.

There is some confusion in the text that makes it hard to evaluate some of the results. For example, when evaluating impacts of changes in productivity, the text indicates (p. 39, l.9) that evaluations were made for average flow conditions, but it then continues to read that results

are only shown at low flows. The text is also confusing on how to evaluate the impacts at the other flow conditions (p. 39, l.16); this needs some reworking and perhaps an example.

CSS Response: Clarified that it is only at average flows.

There has been a great deal of interest in the impact of predator control programs on salmon returns, especially the northern pikeminnow and bird programs. A life-cycle model is the natural way to study these impacts, but the current version of the life-cycle model appears to incorporate density dependence only at the spawner-to-smolt stage. The ISAB recommends that consideration be given to modifying the life-cycle model to allow a range of compensatory responses ranging from complete additivity (as now is the case) to a range of plausible compensatory mortality effects related to density dependence and predator selectivity. This revised life-cycle model could then serve as a planning tool for the impacts of predator control. Note that we are not suggesting that compensatory response be estimated from any data, but only to modify the code to allow for prospective exploration of a range of impacts.

CSS Response: We will take this into consideration in future reports. The life cycle model does, in fact, currently have density dependence in the estuary/early-ocean stage, but in the statistical validation of the model with empirical data, the CSS was unable to detect density dependence for that stage (AIC results rejected inclusion of density dependent parameter, i.e., infinite capacity). The model can in fact be used to evaluate compensatory vs additive response for evaluation of predator control. It would require assuming a non-infinite value for the density dependent parameter.

IV.3. Chapter 3. Effects of the in-river environment on juvenile travel time, instantaneous mortality rates and survival

This is an update based on another year of data. The methodology has not changed from previous years. We have a few questions and comments.

Both the CSS and NOAA provide survival estimates for in-river survival. How do these estimates compare to each other? If there are consistent differences in the estimates, can these be explained?

CSS Response: While a formal comparison has not been done, the estimates are comparable. Both the CSS and NOAA use the Cormack-Jolly-Seber model to estimate in-river survival. Any minor differences in the estimates are likely due to the exact set of PIT tagged fish that are

analyzed. For example, the NOAA estimates typically include fish that were tagged at Lower Granite Dam, while the CSS does not include these fish. The CSS reports seasonal estimates of survival in Chapter 3, while the NOAA estimates are typically for the whole season.

Do fish tagged and released at LGR have lower survival below LGR than fish tagged and released at hatcheries and from the upstream fish traps, as might be expected from near term tag-related mortality?

CSS Response: There are some indications in the data that fish tagged and released at Lower Granite Dam have lower survival than fish tagged and released at hatcheries and from upstream fish traps. A formal analysis of the magnitude of this difference has not been conducted. The data reported in the CSS does not include those fish that were tagged and released at Lower Granite Dam.

Mortality tends to increase over the migration season and with water temperature (except for sockeye). The report lists four potential mechanisms: (1) declining smolt energy reserves or physiological condition over the migration season and with water temperature, (2) increasing predation rates on smolts over the migration season and with water temperature, (3) increases in disease susceptibility or disease-related mortality over the migration season and with water temperature, or (4) some combination of these often interrelated mechanisms. Is there an attempt by CSS or other investigators to test these hypotheses using other approaches? Answers to these questions may lead to additional improvements in salmonid survival. We agree that the apparent contradictory response of sockeye warrants further investigation.

CSS Response: It would be difficult for the CSS or other investigators to conclusively separate and identify the proximate cause of the observed trend of increasing mortality rates over the season because these mechanisms are so interrelated.

The ISAB recently released a report on density dependence in the Columbia Basin (ISAB 2015-1) and a report on how to measure the effects of predator control at various points in the life cycle (ISAB 2016-1). Is it possible to estimate the fraction of hatchery versus wild salmon and total abundances of each group by species and race? Has CSS tested whether total salmonid abundance or abundance of each species within a migration cohort affects survival? Could this type of an approach shed light on potential depensatory mortality caused by predators? To what extent might salmonid size and condition relate to survival? This latter question cannot be investigated with the current cohort model, but there are statistical models based on individual tags that allow for covariates (such as body mass). What are the limitations to doing such an

analysis, i.e., is body mass/size at time of tagging collected for all fish? How far back do these data go?

CSS Response: The CSS has not attempted to estimate the total abundance of smolts and has not tested whether smolt abundance within a migration cohort affects survival, but this may be a task and topic to consider in a future annual report. There are substantial limitations in the data that inhibit efforts to use individual covariates in modeling survival such as long lag times between tagging and migration, difficulties in properly accounting for environmental effects (e.g., spill, flow, and seasonality) on survival, and difficulties in separating the individual versus environmental effects on detection probability. Chapter 7 provides a discussion of these limitations.

The ISAB appreciates the excellent discussion. Approaches for improving precision of survival estimates seem worthwhile, especially for enhancing detection through spillways. The ISAB encourages the CSS to continue its investigation to improve precision in the MCN-BON and RIS-MCN reaches via improved spillway detection or by increasing the number of tagged fish.

IV.4. Chapter 4. Patterns in annual overall SARs

This is an update to the previous report with the recent set of data. In addition, an analysis of SARs vs productivity in 2015 was replaced with an analysis of the relationship between TIR (transport effect) and in-river survival. It is not surprising that the transport TIR is inversely correlated with in-river survival (LGR to BON). This new analysis identified the value for in-river survival when the potential benefits of transportation appear to disappear.

Geometric mean survival of juvenile spring Chinook salmon and steelhead is only ~0.6 when migrating from Rock Island Dam (RIS) to McNary Dam (MCN). It would be interesting to know more about the various factors contributing to the high mortality, such as dam passage and predation.

CSS response: This is actually a comment on results from Chapter 3. Chapter 3 provides analyses of juvenile survival for spring Chinook and steelhead in the RIS to MCN reach as well as in the LGR-MCN and MCN-BON reaches. Model-averaged coefficients and relative variable importance indicated that Julian date, water transit time, spill, and the number of dams with spillway passage structures frequently were important variables for describing variability in FTT.

The CSS reported on the relatively large absolute difference in SAR based on PIT-tags versus run reconstruction (the values are highly correlated, however). As in previous reports, this report listed various hypotheses. An email from the FPC's Michele Dehart to the ISAB indicated that a study is underway to further evaluate PIT-tag effects on salmon survival, but that results will not be ready until after summer 2017 when tagged age-5 Chinook will have returned. Potential bias in survival caused by tagging methodology (or in the run reconstruction methodology) is an important issue to resolve.

CSS Response: We agree.

IV.5. Chapter 5. SARs and productivity

Chapter 5 continues the examination of the relationships between life cycle productivity and SARs, including the level of SARs needed to reach or exceed population replacement. How were hatchery-origin Chinook adults on the spawning grounds identified and excluded from the productivity estimates of the natural-origin population? For steelhead, the text indicates a weir was used to identify natural origin adult returns and was used to exclude hatchery fish.

CSS response: Hatchery-origin Chinook adults on the spawning grounds have been identified by adipose (or other) fin clips since the mid-1990s. In prior years, discriminant scale analysis was used. Hatchery-origin adults are counted as spawners, and are excluded from recruit estimates using the estimated fraction of hatchery-origin fish on the spawning grounds. (See Schaller et al. (2014) for details of Columbia River recruit calculations).

The findings suggest that pre-harvest SARs of 4%-6% are associated with pre-1970 levels of productivity for Snake River spring/summer Chinook. How do these SARs compare with SARs from viable wild Chinook populations in other regions? To what extent might improvements in hydrosystem management, predator control, and estuarine habitat lead to SARs of 4%-6%?

CSS response: SARs in the range of 2-6% have been achieved by wild, unlisted spring Chinook from the mid-Columbia region in recent years. Specifically, John Day River spring Chinook SARs (JDA-BOA) ranged from 0.9% to 11.1%, with a geometric mean of 3.85% during smolt migration years 2000-2014 (Table B.70). Yakima River spring Chinook SARs (MCN-BOA) ranged from 1.0% to 9.2% with a geometric mean of 2.7% during this same period (Table B.71). Mid-Columbia Chinook have similar life history with regard to smolt emigration and adult return timing, face similar levels of predators in the mainstem, estuary and early ocean environments, but have a different hydrosystem experience than spring/summer Chinook from the Snake River. In addition, wild steelhead from the mid-Columbia region (John Day, Deschutes and Yakima rivers)

have recently experienced geometric mean SARs above 5% (Tables B.77-B.79), also well above those from the Snake River region.

We are not aware of measures of SAR for stream-type Chinook from regions outside the Columbia that are directly comparable to those from the Snake River. CSS estimates SARs for Snake and Columbia populations from smolts at the uppermost dam with juvenile detection capability to adult returns at Bonneville Dam and the uppermost dam with adult detection capability. Studies in regions outside the Columbia may monitor smolt abundance at a convenient freshwater location, which may or may not be consistent methodologically with CSS smolt abundance monitoring at the uppermost dam. One would also need to ensure consistency in accounting for fisheries impacts on adult returns in these comparisons. We agree, however that this would be an interesting subject to explore.

Improvements to hydrosystem management will be essential to increase Snake River spring Chinook SARs into the 2%-6% range through actions that reduce WTT and/or increase spill. There are two means to reduce WTT with the current FCRPS: reducing reservoir elevations and/or increasing flow rates. Currently only the Lower Snake reservoirs are maintained near their minimum operation elevations during the fish migration season; reductions in WTT (with all dams in place) could be achieved in the MCN-BON reach by managing pool elevations to lower levels. Improvements in SARs could also be achieved through increased spill at dams. A potential spill management experiment was investigated in the CSS 2013 workshop (Hall and Marmorek 2013), which showed promise in terms of both conservation benefits (e.g., increased average SARs, reduced risk of very low SARs) and the potential for learning. Potential improvements in SAR from predator control and estuarine habitat actions appear relatively less promising in the near term (10-20 years) and more uncertain than hydrosystem actions for Snake River spring/summer Chinook and steelhead.

From the results in Chapter 4, it seems major improvements would be needed to reach the desired SAR range given recent ocean conditions which lead to low SARs.

CSS response: We agree.

IV.6. Chapter 6. Estimation of SARS, TIRS and D for Snake River Subyearling Fall Chinook

This chapter contains updates from previous years on SARs by route of passage and TIR for 2006 to 2012. There are some minor changes in how results are reported. The ISAB has no major comments other than the editorial notes below.

IV.7. Chapter 7. Effects of juvenile bypass systems on smolt to adult return rates

This is a repeat of an analysis done in 2010 using similar methodology. As before, only smolts that are detected at BON are used in the analysis. A logistic regression analysis was used to investigate the impact of year, bypass effects, and rearing type on subsequent survival and return as an adult.

Estimates (Table 7.4) appear to be on a "per bypass" basis. What is the average number of bypasses encountered by a fish? Wouldn't that be a more accurate reflection of the impact of bypass on an outgoing smolt?

CSS Response: The reported values are per bypass event and we have used model averaging to estimate the effect of each bypass event at each dam. These estimates reflect the impact of experiencing a bypass event at a particular dam on the post-Bonneville smolt-to-adult return rate. To address the question on how many bypasses are encountered by smolts that were detected at Bonneville Dam, we have added a figure that presents the average number of bypass events and the proportion of smolts with at least one bypass event by year, species, and rear-type.

The results in Figure 7.1 for steelhead appear to show that for all of the hatchery versus wild comparisons by year the 95% confidence intervals overlap. Wouldn't that indicate that there is no evidence of an effect of rearing type? Wouldn't a set of models without the effect of rearing type also be of interest?

CSS Response: The data for steelhead supported an effect of rearing type. Models without rearing type had AIC scores that were approximately 6 points higher compared to models with rearing type, effectively indicating no support for models without rearing type.

IV.8. Chapter 8. Patterns of variation in age-at-maturity for PIT-tagged spring/summer Chinook salmon in the Columbia River Basin

This chapter examined the mean age of maturity among different stocks, years, and fish type (wild or hatchery) using regression methods.

We have many editorial comments on this chapter (see comments below) in how the models are described and in reporting the results.

An analysis was conducted on the proportion of age-3, age-4, and age-5 fish using standard regression methods. Usually, proportions are analyzed in regression contexts using variants of logistic regression. Alternatively, standard regression could still be used with the empirical logit of the proportions as the response variable as outlined in Warton (2011).

A large portion of the discussion (e.g., p. 165, p. 166) deals with models that essentially have no weight in the AIC framework with delta AIC > 100! Why are results from such models even reported? The authors should conduct model averaging and only discuss the model averaged results.

One consideration for the future work is looking for factors that have led to the shift to declining proportions of four and five-year olds and increases in three-year olds such as ocean factors associated with growth and climate change, differences in hatchery practices, or freshwater environments (tributary temps, or annual differences in migration corridor).

IV.9. Appendix A: Survivals (SR), SAR, TIR, and D for Snake River Hatchery and Wild Spring/Summer Chinook Salmon, Steelhead, and Sockeye

The ISAB found the figures to be well done and informative.

IV.10. Appendix B: Supporting tables on Chapter 4 - Overall SARs

The ISAB has no comments on this chapter (other than some editorial notes, see below) as it is an update of previous reports. This is an excellent set of data tables, and the ISAB anticipates these will be updated in future years. These data may be useful in future years to investigate possible density dependent effects on in-river survival.

IV.11. Appendix C: Development of a weighted bootstrap for unequally represented hatchery PIT-tag groups

Appendix C describes a weighted bootstrap procedure to estimate SARS for PIT-tag groups that are not sampled proportional to run size. For example, if the first half of the run has 90% of the

PIT tags applied, the appendix describes how to weight the tags from the early and late parts of the run to get an overall value for the entire run.

This procedure appears to be satisfactory under conditions that the actual sampling weights are known with little or small error (e.g., see Table C.1). If the sampling weights have to be estimated because the actual sampling fractions are estimated, then this will introduce additional steps in the bootstrap procedure.

The half-step method is a fast way to select samples after the cumulative sampling weights are found. This is one of the methods discussed in Brewer and Hanif (1983).

The authors describe a weighted bootstrap method to estimate the parameters. This is likely to be infeasible in more complex model structures such as the life-cycle model. A likelihood approach based on a stratified sample, followed by deriving weighted averages of the parameters from each stratum, will be computationally more feasible rather than using the average of the bootstrap values (Hogg, McKearn, Craig 2005). A stratified bootstrap procedure could then be used to estimate the uncertainty in the estimates in the usual fashion.

One area of concern is a key assumption that every fish has independent fates. This may not be true; i.e., fish travel together and can share fates, and this may result in over-dispersed estimates. Has this been investigated?

CSS Response: We responded to a similar comment on the 2014 CSS Report. Our response now is the same, that we see no evidence of over-dispersion. We did run a quick simulation to compare a stratified bootstrap procedure to the normal procedure that assumes independent random sampling for a binomial distributed random variable (x (# Adults) ~ Binomial(N (# Juveniles), p (SAR)) from 3 sub-populations with unequal sample sizes and SAR rates. Coverage determined by the 90% confidence interval for the two procedures were nearly identical.

V. Specific editorial comments and requests for clarification on each chapter

This section contains editorial suggestions, requests for small clarifications, and the like.

Front matter

p.v, Figures 2.2. and 2.5. Typo in "Coreelations"

CSS Response: Fixed.

Chapter 1

p.5, Figure 1.4. Figure is out of place and needs definitions of abbreviations as in Figure 1.1.

CSS Response: Moved figures to below where they are referred to in the text. Definitions are embedded in graphs. Not sure what definitions and abbreviations you are referring to?

p.12, l.31: typo on "reflects" (missing the "r")

CSS Response: Fixed.

p.12, l.32-33: Suggest wording "but included for review" more clearly. We believe that this means that it's included in Appendix C for review by ISAB?

CSS Response: Fixed.

p.12, l.42: typo on "implemented"

CSS Response: Fixed.

p.15, l.27-33: There are some grammatical or punctuation errors in this new paragraph.

CSS Response: Rewrote paragraph.

p.16. Table 1.1. Header needed for 4th column of table (currently says "25"?)

CSS Response: Fixed. Column 4 should have read "CSS".

*p.17, Table 1.3: The note at the bottom of the table says "** Pre-assigned by NPT" but this notation is not in the table. Should there be a "**" somewhere?*

CSS Response: Fixed. Notation should have been "2" superscript.

p.19, Figure 1.6. Why was the proportion transported estimated in 2015 rather than known?

CSS Response: The transport proportion is estimated in every year based on CJS methods. The caption was referring to the fact that despite no SARs being reported for migration year 2015, the juvenile population proportions were presented in the report.

p.20, l.11: Typo on "three" (missing the "t")

CSS Response: Fixed.

p.20, l.15-21: Suggest that the preliminary nature of the results be indicated here.

CSS Response: Added a sentence indicating the preliminary nature of results and the also indicated the relative value of SARs reported.

p.20, l.23: Change "effects" to "relationship"

CSS Response: Fixed.

p.20, l.24: Change "seasonality on" to "seasonality to"

CSS Response: Fixed.

p.20, l.36-38: This sentence is confusing. If the correlation is between SARS and wild and hatchery populations, then it doesn't seem like common environmental factors were included in the correlations and the second part of the sentence should say something more like "suggesting that common environmental factors could be influencing survival rates." If common environmental factors were included in the analysis (which it appears it was), then the sentence should be reworded to make that clear, perhaps "… and common environmental factors were significantly related to survival rates from outmigration to the estuary and ocean environments."

CSS Response: Sentence was edited as follows: SARs of wild and hatchery populations were highly correlated within and among regions, suggesting that common environmental factors were influencing survival rates." While CSS has included environmental factors in analyses of wild and hatchery population survival rates within and among regions (e.g., Chapter 3), this was not the focus of Chapter 4.

Chapter 2

CSS Response: Where pointed out the CSS has made editorial changes as suggested for Chapter 2. In some cases, where the CSS either disagreed or decided further comment was necessary, responses to those comments are included below.

p. 24, l.19: What does "TAC" stand for?

CSS Response: US v. Oregon Technical Advisory Committee. Added to Glossary of Terms section of final report.

p.28, l.3-6. Correlations are among the log(R/S) for each population and the environmental covariates. Reword these sentences to improve readability.

CSS Response: Petrosky and Schaller (2010) showed correlation between the powerhouse index and SARs, so the text is correct. Figure 2.2 of this analysis displays log(R/S) correlations with environmental indices, but the statement about Petrosky and Schaller (2010) remains true.

p.28, l.23 "is" should be "are"

p.28, l.24 "know" should be "known"

p.28, l.37 and onwards. Some symbols are not directly defined anywhere?

CSS Response: Table 2.1 describes all variables and parameters used in Equations 2.1-2.12

p.31, l.5 "Bonnevile Dam" should be "Bonneville Dam." Check rest of chapter as well for such usage.

p.33. Table 2.1 Move definitions of terms before the equations for the model.

p.34, l.24. Uninformative priors do have an impact on parameter estimates. For example, a U[0.1] commonly used as an uninformative prior for a proportion, pulls the estimated proportions towards 0.5. "Uninformative priors" still provide information.

CSS Response: Amended state to say that limits of distribution set by uninformative prior, but shape determined by data.

p.36, l.15: "it's" should be "its"

p.36, l.23. Don't understand why ε_t *is multiplied by 0.7? The series is normalized later to match the range of the observed variation so this seems to be redundant?*

CSS Response: The autoregressive formula employed produced the most PDO-like sequences. Normalizing is possibly redundant, but ensures that the sequences are similar in magnitude.

p.37, l.35. "… saving the better combinations (accepting) and not saving (rejecting) worse combinations …" The MCMC Metropolis-Hastings algorithms accepts/rejects MOVES from the current parameter values but does not say that a MOVE is a better or worse parameter combination in any absolute sense. Similarly, the wording in the whole paragraph needs some tightening up to make it more technically accurate.

CSS Response: Wording changed to reflect the fact that MCMC jumps are not absolute, but merely probabilistic relative to ratio of likelihood.

p.38, l.19 "the the" needs to be fixed.

p.39, l.15. We didn't understand this explanation. Please provide additional details.

p.43, Figure 2.6. "Triangles" should be defined in upper plot.

p.44, l.26. Reword to "an increase in the AVERAGE total number of returning spawners." Make similar changes everywhere in this chapter when discussing the results of the simulations.

p.44, l.38. Reword to "Figure 2.10 shows the predicted AVERAGE SARS" and make similar changes throughout this chapter.

p.47, Figure 2.9. The figure indicates that average log-abundance is plotted. But the earlier explanation of the simulation indicated that the average abundance was collected. So perhaps this should be the log(average abundance)? The flow conditions are ordered High, Average, Low; why was this order of flow conditions used rather than Low, Average, and High which would be ordered "numerically." As the plot now stands, average total returns tend to increase in each cluster as you read from left to right which corresponds to DECREASING flows—this is sure to trap the unwary reader. Y-axis label doesn't note that results are on log-scale. As noted previously, the ISRP is concerned that not all sources of variation have been captured in the simulation, and so the box plots may underreport the actual variation in average total returns.

CSS Response: The order was made High, Average, Low because it maintains a left to right increase, which is less confusing. Scale of axis is log-scaled, and clarified text in caption.

p.48, l.14. "You can see it the mouth…" Not clear what is meant here. Do you mean "Bonneville"? Reword.

p.48, l.16. Not clear how the relative average abundance to that of BiOp was computed? Is this the simple ratio of the average of the average abundances? To avoid the influence of outliers, perhaps the ratio of the median of the average abundance should be shown. Measures of variation need to be added to the plots (and discussion).

CSS Response: The relative measure is the ratio of the median of one level to another. This was clarified in the text.

p.48, l.20. "significant." How do you know without measures of uncertainty? In general, how do you know if the effects actually vary across treatments without measures of uncertainty?

CSS Response: Uncertainty is shown in Figure 2.9, which shows the median value with a range of uncertainty in predicted average abundance in the 10,000 random simulations. The relative measures are ratios of medians of the random simulations, so it's not possible to build a distribution of ratios that do not come from the same random draws. It's unlikely that comparing from the same random draw would produce a relative perspective that is any different than the ratio of medians.

p.48, l.30. Now to switch to comparing the MEDIAN long-term averages. Why the switch from the average of the averages?

p.48, l.31. Reviewers didn't understand how the uncertainty corresponded to crossing the shaded area. Further explanation is needed.

CSS Response: Shaded area represents the uncertainty in the productivity parameter estimate.

p.48, l.39. Reword to "predicted increase in AVERAGE."

p.49, Figure 2.10. Similar comments about ordering flow levels. Y-axis label should be labeled as average SAR (similar to Figure 2.9 labeled as average return). Similar comment about not capturing all variation in results.

p.50. Figure 2.11. Similar comments about ordering flow levels. Y-axis should be labeled as average SAR. What is meant by "mouth" – Bonneville?

p.51, Figure 2.12. Not clear how these were computed (see earlier comments). Measures of uncertainty need to be presented for each ratio. Legend needs reword to "when compared to expected long-term average abundance at BiOp …"

CSS Response: Presenting the ratio of the medians helps demonstrate the trend in the relative difference in predicted return abundances. We provide an additional figure to demonstrate the uncertainty in the ratios. The pattern in the medians of the ratios shows the same pattern as the ratios of the medians.

p.52, Figure 2.13. Similar comments to Figure 2.12.

p.53, Figure 2.14. Check Y-axis label. Are these really in 1000's of fish?

p.54, l.27. Is this 28% of 42% or 28 percentage points (i.e. by 0.28)? Best to express survivals as proportions rather than percentages to avoid these confusions, i.e. in-river survival of 0.42 rather than 42%.

p.54, l.32. Similarly, is this 10% or 10 percentage points?

p.55, Figure 2.15. Similar comments to Figure 2.14.

p.56, l.15, Reword to "increasing AVERAGE abundance and AVERAGE SARS" here and elsewhere in the discussion, e.g. p.56, l.25;

p.56, l.8: The table number is missing (should it be Table 2.3?).

p.57. Table 2.3. Without measures of uncertainty how do you know these rankings? Is it possible to show the value of the metrics you used to rank the scenarios in the table (reviewers guess these would be SAR or Rbar)?

p.57, l.2. Reword to "highest AVERAGE SAR"

p.57, l.8. Missing Table number. The wording here is very confusing. It appears to be arguing to remove the highest ranked result (high spill at low flow), and there is a justification for that in the wording. Is it important to have a spill scenario for each flow, if the high spill at low flow is removed?

CSS Response: We removed the table and text that speculates how the spill scenarios might be prioritized on the basis of the analysis. We leave it to the reader to interpret the relative performance measures presented and gauge how relative predicted increases in abundance might be weighed against implications of increased spill at flow levels.

p. 57, l. 12-27: Be careful of wording about model results. Lines 14-15 say that these precise in-river survivals will happen, but as pointed out in this paragraph, there is uncertainty in the models. The argument about the 20% transportation fraction is a bit confounding as it is being

used as a rationale for why model results are giving high predicted SARs, yet the next sentence argues that it's a reasonable number.

CSS Response: We note that 2007-2012 migration year SARs averaged 37%, and therefore 20% transportation should predict considerably higher SARs.

p.57, l.22. "five less powerhouses" than which population?

p. 57, l.28 to p. 58, l.8: The method described here was not clear in the methods section. Over how much time were the fixed levels held? The simulations are a good first step, but just to give preliminary insights into relationships. The variability of flow may not have a predictable effect on model outcomes based on the static conditions simulated.

CSS Response: See following response.

p. 58, l. 9-10: The model results show that increased abundance can be related to alternative treatments, but they are not showing they are a result of alternative treatments. The results are showing which items have strong relationships, but also because they are so preliminary, the strength of these relationships may change if assumptions are changed (for example, if non-static flows were simulated).

CSS Response: The static flow assumption is necessary to evaluate relative performance. Simulating non-static flows would merely predict average abundances and SARs that fall somewhere in the middle of the high, average, and low flow predictions. The sensitivity to how large the relative impacts at different flows would be difficult to discern in a variable flow scenario, and it would not be evident that there might be some flexibility in how much benefit additional spill provides at different flow levels.

p.58 l.12 Insert AVERAGE before all SARS.

p.58, l.17. Always report in-river survival as a proportion. Don't switch to %.

p. 58, l. 31-40: Reviewers suggest emphasizing the preliminary nature of these results.

The section on the simulation study needed editorial work to make it flow better: remove colloquialisms "e.g. you can see" and be consistent in the presentation (e.g. always express survival in proportions).

Chapter 3

p.66, l.33. We don't particularly like sqrt(Z) transforms except if the random variable is a count. We would always use log(Z) based on theoretical considerations that effects are multiplicative. The results should be similar under the two transformations.

CSS Response: Box-Cox power transformation analyses indicated that a square-root transformation was most appropriate for the data, and therefore we retained that transformation. We agree that the results will be similar under the two transformations.

Chapter 4

P.98. Table 4.1. AIC column needs 1 decimal place.

CSS Response: Fixed.

p.98, l.7. "Model of the form ln(TIR) = ln(SR) + species." Reword, either use a proper model notation with proper coefficients associated with each term or go to a short hand R-like notation, but don't do something in between. Also, traditionally models are written with intercept terms first.

CSS Response: Fixed.

p.98. l.15. "… estimated significance for the species specific intercept at alpha 0.09." Don't mix paradigms—AIC methods avoid p-values and only use model weights to decide among models.

CSS Response: Fixed.

p.98, l.20. If using AIC, don't report an overall p-value.

p.99, Table 4.2 What does the coefficient associated with "species" represent? This appears to be just the difference in the intercepts for the two species, but why not just present the intercept for the two species instead. Report fewer decimal places for the estimate and SE. Do not report t-values and p-values when using AIC.

CSS Response: Fixed. Species represents the effect of steelhead additional to Chinook. Added notation to clarify this.

p.99. The authors used AIC and found multiple models with similar weight. Yet they didn't model average. Why not? Rather than just using the best model to predict at which point transportation benefits disappear, model average first, and use the model averaged coefficients to make the prediction.

CSS Response: We reran the model for the final report with additional data from years up to 2015 migration. These were newly available for the final report. Model averaging is not useful in the this context. We are exploring the relationship between TIR and Sr and wanting to determine the most appropriate way to characterize the relationship. The analysis seeks to determine whether each species should be plotted with a separate curve or would single curve be appropriate. We used AIC to make the selection. Model averaging would not provide meaningful results since in some models have two intercepts, two slopes, and thus two curves, while other models present one intercept, one slope and possibly only one curve.

p.100, Figure 4.10. Report survival rates when benefits of transportation cease as a proportion rather than a % to match the graph and text.

CSS Response: Fixed.

p.112, l.36 "survival rates." Not rates, just probabilities. Reword consistently here.

CSS Response: We retained the term "survival rates" and clarified in the methods section that, in this chapter, the term refers to survival through a fixed life-stage. Our usage of the term survival rates is consistent with other literature (see following response).

p.113. Label on Y-axis is "survival rate." These are not rates (are they on an annual basis?), but simply probabilities. Reword the axis.

CSS Response: We think that our use of the term "survival rate", reflecting the survival over a fixed life stage, is appropriate and consistent with other Pacific salmon literature. For example, Peterman et al. (1998) uses the term "survival rates" for spawner-to-adult recruits, as well as for freshwater and marine life stages, none of which are on an annual basis. CSS co-authors have also used the term "survival rates" to describe survival over the life cycle and for a fixed life stage (e.g., Petrosky and Schaller 2010, Schaller et al. 1999, 2014, Schaller and Petrosky 2007). We added a sentence in the methods clarifying our use of the term.

Peterman, R.M., B.J. Pyper, M.F. Lapointe, M.D. Adkison and C.J. Walters. 1998. Patterns in covariation in survival rates of British Columbian and Alaskan sockeye salmon (Oncorhynchus nerka) stocks. Can. J. Fish. Aquat. Sci. 55: 2503–2517.

p.115, l.42 "survival rates." Remove "rates" here as they are not an annual basis. Go through entire discussion and fix usage of "rates" where it appears.

CSS Response: See above response.

Chapter 5

p.121, l.40. Model notation is awkward. The index j is used as brood years, but each brood year also belongs to different periods. The current notation also uses j as an index to year. Perhaps consider a different notation. It is not clear what is a "period." There also doesn't appear to be any results from fitting this model? Was it used in this chapter?

CSS Response: Analyses for this chapter simply contrasted the spawner-recruit residuals calculated by and published in Schaller et al. (2014) with CSS estimates of Columbia River SARs. For complete documentation of spawner-recruit methods and results, please refer to Schaller et al. (2104).

The notation is the same as in the cited paper, where a specific brood year, *j*, belongs to only one time period, *i*. The notation is consistent with the statistical package (SAS 2002) used in the spawner-recruit analysis.

SAS Institute, Inc. 2002. SAS/STAT users guide, version 9.1. SAS Institute, Cary, N.C.

We added the following description of time periods, citing Schaller et al. (2014).

> "Schaller et al. (2014) classified SR data into two primary periods defined by FCRPS development and operations affecting the threatened Snake River populations. The first period, pre-1970 brood years, was before completion of the final two Snake River dams. The second period, post-1974 brood years (1975–2004), was characterized by completion of the full eight dam complex, collection and transportation of smolts around dams in barges and trucks, turbine screening programs, and other management actions to improve passage at the dams (Budy et al. 2002). The 1970–1974 period was excluded from fitting of the recruitment functions because it was a period of construction and of changing operations in the Snake River that caused extremely high levels of atmospheric gas supersaturation in high-flow years (Raymond1979) before mass transportation of smolts had begun."

Model fitting was performed for and reported in Table 2 of Schaller et al. (2014) (reproduced below).

Table 2. Analysis of covariance results for Ricker recruitment functions (eq. 2) that used period (treatment) and spawners (covariate) for stream-type Chinook salmon major population groups (MPG) and populations from the Snake River and John Day River regions, brood years 1954–2004.

Region, MPG	Population	Fraction of hatchery spawners (post-1974)	Intercept: T1 + a pre-1970	Intercept: T2 + a post-1974	Intercept: T1 − T2	Intercept H0: T1 = T2, *P*	Slope (−*B*)	H0: −*B* < 0, *P*	R^2
Snake River									
Middle Fork Salmon (MFS)	**Bear Valley**	0.00	3.9995	1.0326	2.9668	<0.0001	−0.00168	0.0001	0.40
	Marsh	0.00	3.8725	0.6973	3.1753	<0.0001	−0.00224	0.0002	0.46
	Sulphur	0.00	3.5699	0.5576	3.0123	<0.0001	−0.00401	0.0002	0.46
	Big	0.00	2.6974	0.9454	1.7520	0.0011	−0.00236	0.0006	0.28
South Fork Salmon (SFS)	**Mainstem**	0.23	1.7163	0.6976	1.0187	0.0029	−0.00038	0.0024	0.25
	East Fork South Fork	0.04	2.5528	0.9608	1.5920	<0.0001	−0.00267	0.0000	0.53
	Secesh	0.02	1.6764	1.1836	0.4928	0.0679	−0.00156	0.0001	0.31
Upper Salmon (USR)	Lemhi	0.00	2.5395	0.4166	2.1229	0.0006	−0.00084	0.0086	0.27
	Upper Salmon	0.15	3.4158	1.1485	2.2673	<0.0001	−0.00100	0.0002	0.37
	East Fork	0.11	3.2066	1.0852	2.1215	0.0005	−0.00124	0.0003	0.30
	Valley	0.00	2.9375	0.8419	2.0956	0.0003	−0.00252	0.0002	0.34
Grande Ronde/Imnaha (GRIM)	**Imnaha**	0.29	2.4367	0.6950	1.7416	<0.0001	−0.00061	0.0000	0.55
	Big Sheep	0.26	1.7178	−0.7791	2.4968	0.0819	−0.00098	0.2972	0.23
	Wenaha	0.21	2.5661	0.4025	2.1636	<0.0001	−0.00082	0.0133	0.41
	Lostine	0.21	3.7156	1.1477	2.5680	<0.0001	−0.00234	0.0000	0.65
	Minam	0.15	2.5039	0.7222	1.7817	<0.0001	−0.00112	0.0000	0.47
	Catherine	0.27	2.7399	0.0640	2.6759	<0.0001	−0.00091	0.0018	0.45
	Upper Grande Ronde	0.24	3.2572	0.4797	2.7775	<0.0001	−0.00330	0.0000	0.56
Snake River mean		0.12	—	—	2.1568	—	—	—	—
John Day River									
John Day (JDA)	Upper Mainstem	0.02	1.9346	1.2056	0.7289	0.0102	−0.00136	0.0004	0.47
	Middle Fork	0.02	1.8733	1.2855	0.5878	0.0964	−0.00158	0.0003	0.46
	North Fork	0.02	2.6916	1.4550	1.2366	<0.0001	−0.00072	0.0001	0.63
John Day mean		0.02	—	—	0.8511	—	—	—	—

Note: Historic index populations are bolded.

p.121, l.40. Are spawner numbers estimated here? If so, and if the uncertainty in the spawner numbers is appreciable, you have an error-in-variables problem as well which requires a different fitting approach.

CSS Response: Spawner (and recruit) numbers are estimated. The general approach used in Schaller et al. (2014) to retrospectively fit recruitment curves to estimated spawners and recruits is widely used and accepted in Pacific salmon research, literature and management (e.g., Hilborn and Walters 1992 , PFMC 1997, Pyper et al. 2001). Here we were reporting on a published retrospective analysis, but recognize that other approaches may also be appropriate.

Note also that Deriso et al. (2001) investigated possible use of spawner measurement error in 37 alternative Ricker models, using the same spawner-recruit data as Schaller et al. (1999) (a precursor to Schaller et al. 2014). Stock–recruit models that best fit the spawner–recruit data included a common year-effect, excluded spawner measurement error, and included varying parameterizations of Ricker "a" and total dam passage mortality (direct mortality below John Day Dam and differential mortality between Snake and mid-Columbia regions).

Deriso, R.B., Marmorek, D.R., and Parnell, I.J. 2001. Retrospective patterns of differential mortality and common year effects experienced by spring chinook of the Columbia River. Canadian Journal of Fisheries and Aquatic Science 58(12):2419–2430.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York.

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Pyper, B. J., F. J. Mueter, R. M. Peterman, D. J. Blackbourn, and C. Wood. 2001. Spatial covariation in survival rates of Northeast Pacific pink salmon (Oncorhynchus gorbuscha). Canadian Journal of Fisheries and Aquatic Sciences 58:1501–1515.

p.122, l.19. "survival rate." This is not a rate (per year?) but rather just a survival probability.

CSS Response: The phrase was edited to read "survival ~~rates~~ of adults returning through the lower river fisheries".

p.130, Figure 5.6. Too many decimal places are reported.

CSS Response: Edits made.

p.130. Figure 5.7. Plot all figures on the same scales to make it easier to compare results. Different symbols are used, but these appear to be related to the different locations and not the different brood years as in Figure 5.6. Make the two sets of figures consistent.

CSS Response: Edits made.

p.131. Figure 5.8. Use same symbol color and shape as in Figure 5.6.

CSS Response: Edits made.

Chapter 6

p.148, Table 6.11. Don't bold the confidence interval bounds as this is not sensible. Because these are 90% confidence intervals, the formal test has an alpha of 0.10 rather than the usual 0.05.

CSS Response: We recognize that the test would have an alpha of 0.10 given the 90% confidence intervals, however, with think that is appropriate given the nature of these data.

p.149, Table 6.12. Similar comments to Table 6.11.

CSS Response: We recognize that the test would have an alpha of 0.10 given the 90% confidence intervals, however, with think that is appropriate given the nature of these data.

p. 151. Figure 6.5. Because prediction intervals were plotted, it is impossible to get some idea of the uncertainty in the estimated survival at which ln(TIR)=0. Include the confidence interval for the mean response and the end points where the confidence interval also intersects 0 as this will provide a measure of uncertainty on the estimated survival where ln(TIR)=0.

CSS Response: We provided a prediction interval around the estimated ln(TIR) at 0 (-0.71, 0.71) which was reflected by the figure. We did not predict the reach survival so providing confidence intervals around would be problematic.

Chapter 7

p.155, Table 7.1 Do these returning adults include harvest?

CSS Response: The returning adults experienced some level of harvest below Bonneville Dam, which is the location where adults were detected. Because PIT-tags are not monitored in the harvest sampling program below Bonneville Dam, it is not possible to make adjustments for harvest.

p.155, l.7. Rather than using a binomial with an index of 1, just use a Bernoulli distribution.

CSS Response: Text was changed to a Bernoulli distribution.

P.155, l.10. Rearing variable never defined.

CSS Response: Text was added to define the rearing variable (i.e., hatchery or wild).

p.156, Table 7.2. There is no definition of "Bypass Location," which we assume is Snake vs. Columbia river dams.

CSS Response: We have added text to better define what is represented by each model. In the case of the "Bypass Location" models, individual bypass effects are estimated for each individual dam. Ultimately, model averaging is used to estimate the magnitude of the bypass effects at each dam across all the models that were fit.

p.157, l.14. Model averaging ignored models where the bypass effects were forced to be zero (models 1 and 5) why? There are several schools of thought if such models need to be included when estimating the effect of regression variables (see Burnham and Anderson, 2002), but because the interest lies in bypass effects (and a 0 bypass effect is a possibility), these models should be included in the model averaging. This comment is somewhat moot given the near zero model weight placed on these models.

CSS Response: Methods and text were changed to clarify that bypass effects were averaged across all models, including those models where bypass effects were forced to be zero (models 1 and 5). The resulting estimates did not change because there was essentially zero weight for these models.

p.157, Table 7.3. Fish are not tagged independently of each other, and so there is a possibility of overdispersion. Model diagnostics need to be done on the best fitting model to see if adjustments for overdispersion are needed.

CSS Response: For Bernoulli random variables, overdispersion cannot be measured or modeled (McCullagh and Nelder 1989). Therefore no adjustments for overdispersion are necessary.

p.158, Figure 1. But these are model averaged estimates and because the best fitting model for steelhead had no interaction, a consistent difference on the logit scale is enforced by the model and not by the raw data. A better plot would be of the raw SAR values to see if parallelism is evident.

CSS Response: The AIC scores reflect the degree of fit between the models and the raw data. The model averaging accounts for the degree of fit across the models considered and because the additive model had the lowest AIC score, the additive pattern is most apparent on the figure. There are no “raw SAR values” as the data are Bernoulli random variables that can only take on the values 0 (no adult return) and 1 (an adult return). A plot of this type (0’s and 1’s) would be impossible to interpret and compare.

p.160, l.6. The reported values are per bypass are they not? So, on average how many bypasses are encountered by an outgoing smolt?

CSS Response: The reported values are per bypass event and we have used model averaging to estimate the effect of each bypass event at each dam. To address the question on how many bypasses are encountered by smolts that were detected at Bonneville Dam, we have added a figure that presents the average number of bypass events and the proportion of smolts with at least one bypass event by year, species, and rear-type.

p.160, Table 7.4. If you adopt the AIC paradigm, there is no need to report p-values. Just report estimates and confidence intervals. Table legend needs fixing for reference to “Table 2.” These appear to be estimates from each model, so what are “adjusted standard errors.”

CSS Response: We have eliminated the p-values that were reported in the draft and now only report the estimates and their standard errors. The table legend has been revised and we report the standard errors.

p.161.Table 5. Needs to be re-numbered to Table 7.5? Fix reference to Table 2. Do not report p-values. Check estimates for Chinook as model with different bypass effects by system has important weight.

CSS Response: We have re-numbered the tables, revised the table legend, and eliminated the reporting of p-values. The estimates for both species have been verified.

Chapter 8

p.164, l.8. How was harvest dealt with?

p.164, l.25. The model needs a term for tau to be multiplied against (e.g. an indicator variable for hatchery vs wild). The model assumes equal variance, but the mean age of maturity will be based on different sample sizes and so will have a different variance. It may turn out that the process error is much larger than this sampling error, but this needs to be investigated.

p.164, l.32. If the proportion age 3, age 4 or age 5 is used as the response variable, then this is now a logistic regression exercise. Or following the advice of Warton (2011), use the empirical logit of the proportions as the response variable.

p.164, l.39. This model needs fixing because none of the parameters are multiplied against any design variables!

p.165, l.3 If using AIC, what is the set of models being compared? If using AIC, don't report p-values etc. Later on, we see that Table 8.2 has the model set, but this is never referenced directly.

p.165, l.24. Are these model averaged estimates or model specific estimates? These appear to be specific from model 2, but according to Table 8.2, this model essentially has NO weight with delta AIC more than 100 units away. So why are results from a model with such low weight being reported? Report only the model-averaged estimates.

p.166, l.1. Again, why are models with such low weights being discussed at all? Don't mix AIC with hypothesis testing (i.e. no p-values). The whole discussion about model effects changing delta AIC should be struck and just report model averaged estimates.

p.166. Similar comments about models for proportion of age 3, age 4, or age 5. Only report and interpret model averaged estimates. No p-values if using AIC.

p.167, l.28. "… variability in mean age is a direct result in variation in proportions within each age class." Yes, this is true without needing any statistics to prove it. Again, how was harvest accounted for?

p.169, Figure 8.1 How were the mean ages for a stock averaged across brood years? A simple average? Weighted by the number of adults?

p.172. Figure 8.2, 8.3, 8.4. How was the mean proportion of age 3, 4, 5 averaged across brood years? Was it a simple average? Was it weighted by the number of adults? What is the purpose of the different colors across the three plots? The bars in a different order in each year, so it makes it difficult to compare across plots. Perhaps a combined plot with lines for p(age 3), p(age 4), p(age 5) plotted across the stocks would be more useful. We don't think that stacked bar charts would be very helpful.

p.174. Figure 8.5, 8.6, 8.7, 8.8, and 8.9. Not sure how useful these figure are. There appears to be a high correlation among stocks, but can these be sorted in groups by location in the basin, common experiences at sea? The last paragraph in the discussion on page 169 is getting at this, but perhaps more discussion is needed?

p.176, Figure 8.10. Not clear what the reader is to infer from this plot? Perhaps it can be deleted?

p.178, Table 8.2 It is customary to sort model tables by the delta-AIC value. Add the model weights to the table.

p.179. Tables 8.3, 8.4, 8.5. See comments for Table 8.2. As noted earlier, these should be analyzed on the logit-scale.

Chapter 9

Appendix A

Appendix B

Table B.72. These are not survival “rates”. Capitalize “lgr” in table columns headers. Here SAR are presented as proportions, but elsewhere in the report they are reported as a %? Perhaps also report as % here?

CSS Response: Fixed

Appendix C

p. C-7. Table c.2 Improve table headers.

VI. References

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach Springer.

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Warton, H. 2011. The arcsine is asinine: the analysis of proportions in ecology. Ecology 92, 3-10.

To: Michele DeHart
From: NOAA Fisheries Hydropower Branch
Subject: Comments on draft 2016 CSS report
Date: October 19, 2016

Michele,

Thank you for the opportunity to comment on the draft CSS report. Our comments follow.

CSS responses to comments are in plain text following the NOAA comments. The original NOAA comments document is provided in *italicized* font.

Chapter 2.
Providing some empirical data in addition the modeled data would help reconcile some questions I have with the modeled results. For example, Figure 2.1 presents a graph of PIT power house passage (PITPH). The data suggests fish experience between 2 – 6 power houses annually. Is this correct for the years after 2006?

CSS Response: During juvenile migration years 2006-2010, the PITPH estimates ranged from a low of 1.8 in 2010 to a high of 3.6 in 2006. The empirical data and methods that were used to develop the PITPH variable are described in Appendix J of the 2015 CSS Annual Report.

A table or figure demonstrating the percentage of fish that actually pass the hydrosystem annually that were detected from 0 to 6 times would be helpful. We ask this, because both this document as well as the Faulkner et al. juvenile survival papers (2015 – 2016) state the need for higher fish detection rates at the projects. These requests for greater detection ability does not seem consistent with the high PITPH rates reported in this chapter.

CSS Response: Chapter 7 provides a figure with the proportion of smolts that were bypassed (i.e., detected) at least once and the average number of bypasses (detections) for smolts that were detected at Bonneville Dam. Figure 2.1 shows the estimates of the PITPH variable over juvenile migration years 1966-2012 (brood years 1964-2010). PITPH values are not detection rates; they are estimated powerhouse passage rates derived from models that predict detection probabilities as a function of the flow and spill levels that occurred, and whether surface passage structures were in place, at each project. These predicted detection probabilities are then divided by the project-specific estimates of Fish Guidance Efficiency to estimate total powerhouse passage. The methods for deriving PITPH are described in Appendix J of the 2015 CSS Annual Report. Greater detection rates could be achieved by developing spillway detection systems. However, the estimates of powerhouse passage would not change as installing a detection system in the spillway would not alter the proportion of fish passing through the powerhouse or the spillway.

Also, the first paragraph on page 26 states the following: "The time series of environmental conditions is shown in Figure 2.1, where we can see that PITPH appears to generally follow the same trend as the water transit time. This is expected, since slower moving water is consistent with lower spill, and spill is a

major factor in reducing powerhouse contact." This suggests that spill percentage decreases with flow. However, this is not the case at projects where spill is a constant percentage. In the past several years, lower flows have greatly reduced juvenile power house passage and decreased detections. This was observed in 2015, when detections through the system were very low that low flow year.

CSS Response: Original statement misleading. Paragraph was rewritten to include a more comprehensive description of changes that took place in the hydrosystem.

Page 35. The use of 2010 to represent a "low flow" year does not provide much variation between the medium year of 2009 which was 94% of average and ranked 41 out of 57 years and 2010, which was 90% of average and ranked 43 out of 57 years (both as measured at The Dalles). Could a lower flow year than 2010 be used?

CSS Response: These three years represent a range of high (2011), average (2009) and low (2010) flow conditions relative to the historic data (1929 to 2012). It is correct that there is not much variation between the medium and low flow year when the entire year's runoff is considered. However, 2010 cool spring weather pattern resulted in a delayed freshet and lower than average flows in the Snake and Lower Columbia rivers during April and May. It wasn't until early June when a strong Pacific jet stream brought storms with heavy precipitation to the Northwest that high flows occurred. Since the focus of the analysis was to predict in-river survival in relation to spill operations, using estimates of passage from recent years better reflects the most recent hydrosystem operations. 2010 is both a recent year, and for reasons described, also a year that reflects low flows.

Page 43 - 44. A more thorough explanation of why the transported fish first year ocean survival was so much lower than that of in-river fish would be helpful.

CSS Response: Total age class returns, in-river survival, and SARs influence the likelihood, leaving the distinction of transportation entirely to the inter-annual variation in the proportion transport. As this analysis is evolving, the CSS will include a transport to in-river ratio term to the likelihood. Currently, the SAR is insensitive to the ratio of transported and in-river survivals in the ocean. It's possible that survival is lower for in-river migrants and higher for transported fish, but since they are not measured quantities, the predictions can fit the data equally well as long as the total returns and SARs match empirical data.

The lifecycle model outputs in Figures 2.10 and 2.11 are unclear as they seem to predict an average SAR of approximately 5% under the BiOp spill regime. Please clarify if this is a correct interpretation of the Y-axis or modify the figures as necessary to make them clearer.

CSS Response: Median SARs at average flow and BiOp spill are predicted to be approximately 0.025-0.03 when simulated at 20% transport and the sliding scale harvest described. Higher transport rates would predict lower SARs since ocean survival of transported fish is predicted to be lower than that of in-river migrants. The model prediction of SARs is biased high in recent years (see Figure 2.6), so the long-term average predicted SARs at BiOp spill levels may also be high. The simulation analysis of SARs was intended to provide a gauge of the relative expected difference in predicted SARs under different spill alternatives, and should therefore not be interpreted as absolute measurements of SARs, but rather as relative predicted SARs. A bias correction may be required to scale predictions to absolute values.

Page 78. Several statements are made regarding management actions that could be taken to reduce travel time through the FCRPS. The text reads: "These results indicate that improvements to fish travel time, mortality rates and survival may be possible through management actions that reduce WTT and increase spill percentages. There are only two means for reducing WTT: reducing reservoir elevations and/or increasing flow rates. The data also indicate that there is an opportunity to reduce fish travel time and increase survival throughout the FCRPS through increases in spill levels up to the tailrace dissolved gas limits". This chapter described the development of models which allowed the effects of the actions of spill and travel time to be estimated. Since these tools exist, the chapter would benefit from an estimate of how much the actions of lower reservoir elevations and increased spill would affect travel time over a range of flow. This would give the reader a better estimate of the effectiveness of these actions and put it in the perspective of whether the change would be hours or days. A graphic may best describe the effect of these actions and effects.

CSS Response: If defined actions are proposed, such as lowering reservoir elevations or increasing spill levels, the CSS models are available tools that can be applied to estimate the effects of those proposed actions on travel time and survival. However, we are not aware of specific proposals for lowering reservoir elevations or what elevations may be considered. As actions are proposed, the CSS is willing to provide estimates of the expected effects of those proposed actions.

An effect that is not considered in this section is that if the Columbia River pools were operated at lower elevations a great deal more bird habitat – particularly tern nesting habitat - would be created (Evans et al 2015). A complete appraisal of the effects of lower reservoir elevations would include an analysis of potential predation effects that would result from the action of creating additional habitat for predators.

CSS Response: It would be reasonable to expect that increased water velocity associated with lower reservoir elevations would reduce the amount of avian or piscine predation on smolts. However, these issues have not been evaluated to date by the CSS or Evans et al. (2015). There are additional issues to consider, such as the degree of compensation and uncertainties about the magnitude of avian versus piscine predation rates.

Page 105. Maintaining a consistent reporting system for SAR from McN to McN or to Rocky Reach (RRE) for the upper Columbia stocks would be preferred than the use of McN to BON. This is especially the case when the 2% - 6% values are superimposed on the graphics.

CSS Response: The use of McNary as an adult return site is under investigation by CSS. We have developed SARs to McNary for Yakima River groups since that is the upper most dam prior to return to that sub-basin. But even then, adult salmon face further low head dams in the Yakima River too. For other groups we will investigate SARs to dams further upstream of McNary.

Page 118. If the document chooses to use the 2% - 6% SAR as a reporting criteria, I suggest stating the performance of the upper Columbia stocks relative to this criteria in terms of McN to McN.

CSS Response: The use of McNary to McNary SARs would not always be equivalent to SARs for the 2% to 6% criteria.

Page 119. This page provides discussion of the 2% - 6% SAR objective. What is not discussed is where it was meant to measured. Was it to the river mouth to allow harvest, at Bonneville, or at the last dam upstream? The document uses various measures at various times, such as LGR to LGR and McN to BON.

If the document chooses to use the 2% - 6% origin to origin criteria, it would be best to have it standardized, such as the point of first detection in the hydrosystem as juveniles to the last point of detection as adults.

CSS Response: The use of these criteria is discussed in detail in Chapter 4 paragraphs two to eight. We suggest that the commenters review the introductory paragraphs beginning on page 80 line 35 (in the draft) and continuing through line 25 on page 81. Essentially, what the authors wrote was that the SAR objective was measured to the uppermost dam FCRPS dam with juvenile detection capability and adults to the uppermost dam with adult detection capability. The ISAB criteria were not specific. The reason CSS provides SARs to various locations is to provide managers with different measures depending on the life stage of interest for management.

Page 134. The introduction to this chapter states the objective of this chapter was: "to provide data and analyses to the Fall Chinook Planning Team. In 2007, the U.S. v. Oregon parties approved a consensus proposal entitled Evaluating the Responses of Snake River and Columbia River basin fall Chinook Salmon to Dam Passage Strategies and Experiences. The intent of the parties agreeing to the consensus proposal is for the salmon managers to work together with the U.S. Army Corps of Engineers (USACE) on collaborative analyses that include methods consistent with the CSS". The original intent was to have a single analysis. At this point there are two analysis with two somewhat different conclusions. The CSS chose to perform a "seasonal analysis" on discrete release groups, while the NOAA analysis has included an "in season" analysis that sought to determine whether there was a "transportation window" during which transport may or may not be beneficial. For the two years that NOAA has analyzed, there was indeed a time during which transport provided no benefit and a time when transport provided a benefit (Smith 2014). The CSS report should include a similar "in season" analyses or reference the NOAA findings, to make this a more complete discussion of the subject and present managers with the full range of considerations when making decisions on this issue.

CSS Response: The CSS disagrees with the methods used by NOAA to develop seasonal analyses. We have provided reviews of those methods previously. However, we encourage others to compare both methods. We anticipate that seasonal SARs will be estimable when spillway PIT-detectors are available at the dams. The seasonal SAR comparison would be implementable if the detector at Lower Granite Dam becomes available as proposed by NOAA.

Page 158. As I understand it, Figure 7.1 is a graphic of SARs for fish that had no detections prior to being detected at the Bonneville Bypass or corner collector. Since these fish were detected at Bonneville they had one encounter. It would be informative to know the estimated population or percentages of the annual smolt migration that had zero, one, and incrementally as many as 6 bypass encounters since 2006.

CSS Response: To address the question on how many bypasses are encountered by smolts that were detected at Bonneville Dam, we have added a figure that presents the average number of bypass events and the proportion of smolts with at least one bypass event by year, species, and rear-type.

The discussion section would benefit by including references and consideration that bypass structures may select for fish that are smaller or less fit than non-detected fish and have lower SARs as a result of differences in condition (ISAB 2014, Hostetter et al 2015, Williams et al 2005).

CSS Response: Both NOAA and Bonneville Power Administration commented on bypass selectivity. In response to the NOAA recommendation, a discussion has been added to the Chapter that addresses the issue of bypass selectivity in the discussion section. The references identified in the NOAA comments as well as others are addressed in the discussion section.

It would also be informative to explain why the SAR data presented in Table A.8 does not always follow the rule that each encounter with a bypass decrements the SAR by 13%. The table indicates that in many years after 2006 the SAR of the C_1 fish is close to or higher than the C_0 fish.

CSS Response: The vast majority of the estimates presented in Table A.8, as well as the vast majority of the estimates presented in Tables A.9-A.27, show that the SARs of C_0 smolts are higher than SARs of C_1 smolts. These results are consistent with those results reported by Sandford and Smith (2002). It is important to recognize that the Chapter 7 analyses are focused on evaluating smolts detected at Bonneville Dam, while the C_0 and C_1 smolts are evaluating smolts arriving at Lower Granite Dam.

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General Comments on the 2016 CSS Report

CSS responses to comments are in plain text following the BPA comments. The original BPA comments are provided in *italicized* font.

- *Has FPC/CSS made any progress on separating PIT tag effects from non-tag related in river mortality? This is of particular concern because of increased marking of natural origin fish, which additionally tend to have higher SARs than hatchery fish. The 2015 CSS report cited the tag effects study by Knudsen et al. (2009) which reported sizable PIT tag effects and we're curious if there has been further progress on this question since you last reported on your efforts.*

CSS Response: The CSS will provide further results in the 2017 Annual Report.

- *Many of the 2015 CSS report results are consistent with relevant NOAA or University of Washington results, and some are not. The region could benefit from an open discussion on points of agreement and disagreement.*

CSS Response: The CSS have made data used in our analyses available to anyone who wished to view or review or reanalyze them. Data are made available through the report but also are made available via web query. We encourage an open discussion/comparison of these CSS data as well as other available data.

- *Virtually every resource management program in the United States includes discussion of climate change implications in their reports and CSS should consider including this topic as well.*

CSS Response: The CSS recognizes the importance of climate change in considering future management of Columbia Basin salmonids. The CSS primarily relies on monitoring data to develop analyses. We are unaware of a useful dataset that could be used to predict the impacts of climate change on future populations of salmon. When regional managers develop a model of future climate change that can be converted to metrics suitable for modeling the CSS will explore incorporating that into CSS products.

Chapter Specific Comments on the 2016 CSS Report

[Chapter 2]

The rationale for the high survival predicted at the 120% and 125% TDG scenarios could use additional explanation. Mesa et al (2000) conducted lab studies of TDG effects on juvenile Chinook and steelhead. They found that at levels of 120-130% saturation, even short term exposure was lethal. The magnitude of the effect is associated with the dose level and duration of exposure. Given fish travel time indices (or associated WTT predictions), juveniles will be exposed to elevated TDG conditions for longer periods

under the high TDG/spill scenarios. Based on findings from Mesa et al. (2000) high smolt mortality could be expected at the high TDG scenarios. It is not clear if the CSS model captures these gas effects. If it does not reflect gas effects, the report should explain why it is not of concern.

CSS Response: Mesa et al. (2000) is one study based on a series of experiments during the second half of the 1990's. Many more studies were conducted over the past two decades. The Columbia River Research Laboratory of the USGS conducted research on the monitoring of gas bubble trauma (GBT) in migrating juvenile salmonids in the Snake and Columbia rivers to quantify and describe the severity of GBT signs observed in fish, and to relate the signs to the potential for mortality in fish. To do this a series of laboratory studies were conducted where they assessed the prevalence, progression and severity of signs of GBT in juvenile salmonids exposed to different levels of total dissolved gas (TDG) and temperatures and related them to the "likelihood of mortality" using a series of data collected from laboratory experiments. These studies were all conducted in very shallow water (23 cm) to induce the development of signs in a "worst case" scenario.

It is important to note the differences between shallow water laboratory experiments and riverine conditions. For each incremental increase in depth of about one meter the actual TDG level expressed as percent of saturation decreases by about 10%. Thus, 120% TDG level at surface pressure is only 110% of saturation at a depth of one meter and only 100% at two meters deep. Therefore, the tendency for the dissolved air to come out of solution decreases with depth until there is no tendency to leave solution at two meters deep. If the dissolved gas does not come out of solution, then there are no impacts to fish.

There have been a number of studies that have looked at the response of migrating salmonids relative to migration depth and TDG exposure. Beeman and Maule (2006) looked at the migration patterns of juvenile salmonids in the Snake and Columbia rivers. The tailrace TDG levels were as high as 133% during the course of their study. They did not observe signs of gas bubble trauma or mortalities at the levels they would have predicted based on the shallow water experiments of Mesa et al. (2000). Beeman and Maule concluded that: "In our study, conservative estimates indicate that hydrostatic compensation was sufficient to reduce the effects of the ambient TDG to levels below those generally shown to result in signs or mortality from GBD at the exposure times of fish in the four study areas."

> John W. Beeman & Alec G. Maule (2006) Migration Depths of Juvenile Chinook Salmon and Steelhead Relative to Total Dissolved Gas Supersaturation in a Columbia River Reservoir, Transactions of the American Fisheries Society, 135:3, 584-594, DOI: 10.1577/T05-193.1

Backman et al. (2002) found that Gas Bubble Trauma was not detected in most of in-river migrants sampled in the Columbia River from 1996-1999. This included fish sampled during two very high flow years where spill was at uncontrolled levels through the Federal Columbia River Power System.

> Backman, T.W.H., A.F. Evans, and M.S. Robertson. 2002. Symptoms of gas bubble trauma induced in salmon (Onchorhynchus spp.) by total dissolved gas supersaturation of the Snake and Columbia Rivers, USA. North American Journal of Fisheries Management. 22:965-972.

The CSS models are based on empirical data for smolt to adult survival rates (SARs). These data have only shown a positive relation between SARs and spill. Gas effects are negligible within the range of TDG observed in the hydrosystem among several years when depth compensation is taken into consideration.

Pg. 32- WTT and PITPH are strongly correlated (0.67) because low flows are associated with low spill volumes. Thus, WTT and PITPH should have a similar influence in the model. Is it justified to use both as the primary freshwater variables? Both eqn. 2.9 and 2.10 contain PITPH, and when they are combined, this appears to double the effect of PITPH.

CSS Response: Both are included because it improves the fit to do so. While they are correlated, there is still some variation not common to both. The estimated effect only captures variation in one that is not explained by the other.

Pg. 32- It is stated that "PITPH is implemented in such a way as to allow the parameter estimation to predict if it is significant in both in-river and early ocean survivals." Yet, in-river and early ocean survivals are combined in eq. 2.2. Do you intend to partition in-river and ocean effects in this model? Can you do this while retaining eq. 2.2?

CSS Response: In-river and ocean survivals are not combined in Equation 2.2. They are grouped together for each route of passage (transported vs in-river), but they are distinct rates that are dependent on different independent variables, and they have separate parameters.

Pg. 32- How do you estimate the parameters delt.PH and gamma.PH? The values are unconstrained and can range to infinity.

CSS Response: Estimates are in logit space, and the parameters are scaled for sensitivity within the optimization search algorithm. The likelihood is very sensitive to small changes at low values of the parameters, but very insensitive to changes at high values.

The model's fit might be driven by the PDO variable. Because spill volumes were relatively low over most of the time series, the effect of PITPH should have a minor effect in most years of the observations. A graph of the sensitivity of SAR with spill that indicates the range of spill for calibration would help us understand whether the model projects beyond the data. If the model has value and the effects are as strong as the model predicts, it should also predict seasonal changes in SAR and D.

CSS Response: Figure 2.5 shows the sensitivity of predicted SAR to PITPH and other environmental variables, as well as the sensitivity of in-river and transported survivals.

Pg. 36- Table 2.2 shows that PITPH decreases with higher spill %/volume, and increases with higher flow levels. An additional graph or table would be helpful, showing the assumed spill percentages/volumes corresponding to the BiOp, 115%/120%, 120%, and 125% TDG levels. The study infers that both higher flows and higher spill volumes are associated with higher SARs. It would be helpful to further explain the

apparently contrasting effects on PITPH… does the PITPH variable have a different level of influence at low, medium, and high flow levels, perhaps requiring a separate estimate of delt.PH at each flow range?

CSS Response: The following table shows the spill volumes used for each scenario where PITPH was estimated. The spill volumes were taken from a spill priority list developed by the US Army Corps of Engineers (COE) for the distribution of additional uncontrolled spill above the BiOp levels. The list is based on the COE's SYSTDG model runs. (The only modification to the COE list was to implement the uniform spill pattern at Lower Monumental at all flows greater than 65 Kcfs). The spill caps were applied to the flow data at all eight projects from 2009, 2010 and 2011 for April 1 through August 31. These three years represent a range of high (2011), medium (2009), and low (2010) flow conditions relative to the historic data (1929 to 2012). While 2010 was not a low flow year when the whole spring and summer period is considered, the flows that took place during the spring period being modeled were considerably less than other years.

Project	Scenario 1 BIOP	Scenario 2 115/120% (Kcfs)	Scenario 3 120% (Kcfs)	Scenario 4 125% (Kcfs)
Lower Granite	20 Kcfs	41	45	63
Little Goose	30% of Instantaneous Flow	40	52	70
Lower Monumental	30 Kcfs	30	44	80
Ice Harbor	30%/30% vs 45 Gas Cap	92	75	110
McNary	40% of Instantaneous Flow	150	140	230
John Day	30% of Instantaneous Flow	146	146	190
The Dalles	40% of Instantaneous Flow	140	135	269
Bonneville	100 Kcfs	100	100	215

Note: There will be some discrepancies observed in the spill proportions between the spill to 115/120% and the spill to 120%. It can be observed from the table that at some projects there is less spill at 120% tailrace than at 115/120%. This is because as spill caps at the upper projects are increased, spill caps at the lower projects may actually have to decrease to accommodate the incoming total dissolved gas levels.

When developing estimates for PITPH, the fixed spill volume under each scenario result in a greater proportion of flow being spill at lower flows than at higher flows. This is why PITPH generally increases as flow levels increase.

Does the current evaluation of “BiOp” operations assume full powerhouse capacity? Or does the model account for any additional spill associated with reduced powerhouse capacity spill based on either the lack of turbine availability or lack of power market spill? Incorporation of those sources of additional spill would likely reduce the predicted differences between BiOp operations and the higher modeled spill scenarios such as 115%/120%.

CSS Response: For modeling purposes, the hydraulic capacity at each project was determined using the 2012 Fish Passage Plan, based on all units in operation at the upper end of the 1% efficiency range. Turbine availability is not predictable and may vary over the time period. Without a way to predict the change among years, the hydraulic capacity was held constant. Excess generation spill was not included in this modeling exercise. Excess generation spill occurs when flow is greater than the hydraulic capacity plus the planned spill level. In this situation, actual spill exceeds the planned spill levels, since there is no market available for the energy that would have been produced if the water was put through turbine units. Excess generation spill is episodic and dependent on the real-time power markets, and therefore could not be included in this analysis. Excess generation spill will, however, affect the cost. Since most excess generation spill occurs during the spring, the cost of implementing the spill levels above the Biological Opinion levels would be less. That is to say, the energy foregone was not always marketable during this time frame. In addition to the hydraulic capacity, minimum generation and miscellaneous flow requirements at each project were considered.

Pg. 39- I t looks as though the base case (current conditions) of smolts per spawner is set at 50, and that the MCMC will draw from a future range of 50-250 smolts/spawner. Average LGR-LGR SARs have averaged ~1% recently. A SAR of 1% x 50 smolts = 0.5 adult recruits / spawner, which would force each population into a rapid decline. With fixed second and third year ocean survival parameters of 0.6, and 0.7 (.6x.7=.42), in order to approach the observed 1% SARs, the first year outmigration + ocean survival would need to be ~ 2.3% (or smolt output might need to be revised upwards). Could the base case data reflect an underestimation of smolt emigration, perhaps caused by overestimation of trap efficiency?

CSS Response: Figure 2.8 shows the predicted smolt relationship not to be biased. The actual estimates of productivity in smolts per spawner differed among populations and vary from as low as 80 to as high as around 200. A range of 50-250 was examined to look at relative predicted average returns if each population had a productivity different from the estimated historical value, but 50 was not a base case for any of the populations. The lowest estimated productivity would equate to approximately 80 smolts per spawner (the Grande Ronde), which would require a 1.25% SAR for replacement. The geometric mean SAR from 2006-2014 migration years was 1.19% (Appendix B,Table B.5, this report), which is in line with the productivity estimate assuming a stable population.

[Chapter 6]

Previous chapters dealing with spring migrating species provide population trend data extending back decades, which is helpful to establish the status and trend of the populations in question. However, these data are missing for Fall Chinook in Chapter 6. Given the increase in abundance for the ESU in recent decades, developing longer term trend estimates would be useful.

CSS Response: We will explore adding these data in future reports. We are uncertain whether reliable data are available for historic trends, however.

[Chapter 7]

Previous studies have found evidence that juvenile salmon length or size influences smolt-to adult survival (Zabel et al. 2005) to a varying extent for hatchery and wild origin steelhead and yearling Chinook. Likewise, there is evidence that smolts on the smaller side of the size distribution have a higher probability of using the bypass or powerhouse routes through the dam (Congleton et al. 2005). Therefore, size-selective bypass passage has the potential for explaining different patterns of SAR for categories of juveniles passing through spillway, turbine, and bypass routes.

CSS Response: Both NOAA and Bonneville Power Administration commented on bypass selectivity. In response to these comments and recommendations, a discussion has been added to the Chapter that addresses the issue of bypass selectivity in the discussion section. The references identified in the BPA comments as well as others are addressed in the discussion section.

The eight models evaluate the effects of year, rear type, total bypasses, and bypass location. In future analyses, we encourage you to incorporate juvenile length as a factor in your logistic regression model. Juvenile length was recorded and is available for most of the categories of Chinook and steelhead used in the Chapter 7 model, with sample sizes being smallest for wild steelhead. While Congleton et al. (2005) did not find strong evidence for bypass selectivity among wild Chinook, there are indications that length at tagging could be an important covariate for hatchery origin Chinook and steelhead.

CSS Response: There are substantial limitations in the data that inhibit efforts to use individual covariates in modeling survival such as long lag times between tagging and migration, difficulties in properly accounting for environmental effects (e.g., spill, flow, and seasonality) on individual survival, and difficulties in separating the individual versus environmental effects on detection probability. Chapter 7 provides a discussion of these limitations.

Literature Cited:

Knudsen, C. M., Johnston, M. V., Schroder, S. L., Bosch, W. J., Fast, D. E., & Strom, C. R. (2009). Effects of passive integrated transponder tags on smolt-to-adult recruit survival, growth, and behavior of hatchery spring Chinook salmon. North American Journal of Fisheries Management, 29(3), 658-669.

Mesa, M., et al. 2000. Progression and severity of gas bubble trauma in juvenile salmonids. TAFS 129: 174-185.

Zabel, R W., et al. "Survival and selection of migrating salmon from capture–recapture models with individual traits." Ecological Applications 15.4 (2005): 1427-1439.